Status and Trends of Seagrass Habitats in the Great Barrier Reef World Heritage Area

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1. Purpose of this Report

The Department of Primary Industries and Fisheries of Queensland (DPI&F) has supported research, monitoring, and mapping of seagrass habitats since 1985, when the strong links between seagrasses and fisheries in Queensland waters were first published (Coles and Lee Long 1985; Staples *et al*. 1985). Initially this program mapped the seagrass resources of the Queensland coast at a broad scale. The mapping program has continued albeit splitting into several themes driven in part by improvements in modern position fixing and modelling techniques. This has included broad-scale mapping of deepwater seagrasses (>15 m deep), and high resolution remapping of coastal and estuarine areas of importance and areas of perceived high risk of loss due to anthropogenic impact. And in several locations long-term (circa10 years) high resolution data sets have been accumulated tracking change at seasonal and annual time scales and relating these changes to potential anthropogenic impacts.

A need to be alerted to changes in seagrass populations at large spatial scales was recognised in 1993 in reviewing the loss of seagrass in Hervey Bay, southern Queensland (Preen *et al.* 1995) which impacted heavily on the population numbers of the marine mammal, the dugong (*Dugong dugon*). In response, the Seagrass-Watch program was established in 1998 to include community volunteers collecting data quarterly in widely dispersed locations using standardized monitoring protocols. This program has been refined in subsequent years to include collection of an extensive range of biophysical data and has expanded to include data from all of Australia and other countries (McKenzie *et al.* 2006a; b).

The DPI&F has also addressed specific research issues with publications on the distribution and value of seagrasses to fisheries, the factors involved in recovery from disturbance, the role of nutrients, light, temperature, flowering and seasonality and reviewed methods and management approaches.

In recognition of the importance of seagrass meadows in the Great Barrier Reef World Heritage Area (GBRWHA), the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) developed a seagrass research program with the DPI&F. The program continues the cost effective monitoring and assessment of the status of coastal seagrasses in the GBRWHA. The project uses community, industry resources and co-investment to enhance and broaden the scope of the monitoring and assessment and builds on the existing seagrass monitoring programs established by DPI&F.

An enormous amount of information has been gathered in the twenty-two years of the program. The nature of the time scales and the differing purposes for which data has been collected make it difficult to access this data in a cohesive way. The DPI&F as part of the MTSRF Annual Research Plan agreed to summarise the seagrass research and monitoring program that has been conducted in the GBRWHA, north-eastern Australia in a Status and Trends report.

This report is designed to provide a summary of the state of this knowledge and to emphasise the gaps in knowledge that still remain and issues confronting the management agencies responsible for protection and development of coastal waters. We have chosen to stratify the information by the six Natural Resource Management Regions in the GBRWHA: Cape York, Wet Tropics, Burdekin, Mackay-Whitsundays, Fitzroy and the Burnett/Mary. Where data is available, we have reported separately on estuaries, coasts, reef and deepwater seagrass habitats.

2. Introduction

Seagrasses are specialised marine flowering plants that grow in the nearshore environment of most of the world's continents. Most are entirely marine although some species (such as *Enhalus acoroides*) cannot reproduce unless emergent at low tide. Surviving in a range of conditions; from upper estuarine to marine, there are relatively few species globally (about 60) and these are grouped into just 13 Genera and 5 Families.

Seagrasses support food webs by virtue of their physical structure and primary production and are breeding grounds and nurseries for important crustacean, finfish and shellfish populations. Providing food for green sea turtles, nearly 100 fish species, waterfowl and for the marine mammal the dugong; which is on the IUCN red list as vulnerable to extinction (IUCN 2000); seagrasses are also the basis of a detrital food chain. These plants filter nutrients and contaminants from the water, stabilise sediments and act as dampeners to wave action. Seagrasses rank with coral reefs and mangroves as productive coastal habitats and strong linkages among these habitats make the loss of seagrasses a contributing factor in the degradation of the world's oceans.

There is now a broad understanding of the range of species and seagrass habitats around the world (Green and Short 2003) although shallow sub-tidal and intertidal species distributions are better recorded than seagrasses in water greater than 10 m below Mean Sea Level (MSL). Surveying deeper water seagrass is time consuming and expensive. Further areas of deepwater seagrass are likely to be located (Lee Long *et al.* 1996a). It is important to document seagrass species diversity and distribution and the contribution seagrass species and seagrass meadows make to broader ecosystem services. This information is essential in order to identify those areas requiring conservation measures.

Destruction or loss of seagrasses has been reported from most parts of the world (Short and Wyllie-Echeverria 1996; Larkum *et al.* 2006), often from natural causes (den Hartog 1987) or storms (Poiner *et al.* 1989). However, destruction commonly has resulted from human activities, e.g. as a consequence of eutrophication, or land reclamation and changes in land use (Cambridge and McComb 1984; Coles *et al.* 2003b). Increases in dredging, development of the shoreline, damage associated with overexploitation of coastal resources, and recreational boating activities along with nutrient and sediment loading has dramatically reduced seagrass distribution in some parts of the world (Short and Wyllie-Echeverria 1996).

Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease seagrass functions and values, including their contribution to fisheries (Walker *et al.* 1989; Green and Short 2003). Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world through transplantation, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitats through law and environmental policy.

A number of general parameters determine whether seagrass will occur along any coastline. These include the biophysical parameters that regulate the physiological activity of seagrasses (such as temperature, salinity, waves, currents, depth, substrate, day length, light, nutrients, water currents, wave action, epiphytes and diseases), the availability of propagules and anthropogenic inputs that inhibit available plant resources (such nutrient and sediment loading). Combinations of these parameters will permit, encourage or eliminate seagrass from a specific location.

The depth range of seagrass is likely to be controlled at its deepest edge by the availability of light for photosynthesis. At the shallow edge exposure (with associated high temperatures and drying at low tide), wave action and associated turbidity and low salinity from fresh water inflow determine seagrass species survival. Seagrasses survive in the inter-tidal zone especially in sites sheltered from wave action or where there is entrapment of water at low tide, (e.g. reef platforms and tide pools), protecting the seagrasses from exposure.

Regular reporting on the distribution, status and ecosystem role of seagrasses at a global scale is now possible with electronic communication and dedicated monitoring programs such as Seagrass-Watch and SeagrassNet. This information is available for use by coastal zone managers to aid planning and development decisions.

Tropical Seagrasses

Seagrasses of the Indo Pacific

The Indo-Pacific region has the largest number of seagrass species worldwide, with approximately 24 species and vast meadows (Short *et al.* 2001; Waycott *et al.* 2004). In the western Pacific there are 16 species recorded from the Philippines, 13 from Papua New Guinea, and 16 from northern Australia. Moving east, there are 9 species in Micronesia New Caledonia and Vanuatu and 1 species in French Polynesia

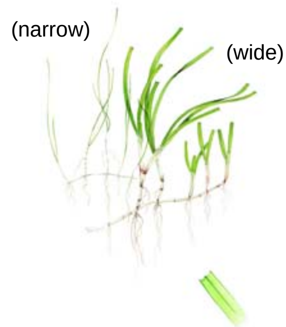
Indo-Pacific seagrasses include species not found in colder parts of the world. Species such as *Enhalus acoroides* which has flowers that are fertilized on the water surface by windblown distribution of male flowers are common in shallow water in estuaries and bays and on reef platforms. Seagrasses are often found near fringing mangroves. *Thalassia hemprichii,* an Indo-Pacific species, is mostly associated with coral reefs and is common on reef platforms where it may form dense meadows. It can also be found colonizing muddy substrates, particularly where water pools at low tide. Both species can be found in inter-tidal regions where tolerance to 40°C temperatures and low salinity allow these species to colonize.

Other common species such as *Syringodium isoetifolium* and *Cymodocea serrulata* are usually found in subtidal waters but may at times also be found associated with reefs inter reef lagoons, and reef platforms. *Thalassodendron ciliatum* is an unusual tropical seagrass in being restricted almost exclusively to rocky or reef substrates. It is often found on reef edges exposed to wave action, protected from damage by its flexible, woody stem and strong root system. Some species such as *Halophila ovalis* and *Halodule univervis* are essential food for the marine mammal, *Dugong dugon*, while the green sea turtle, *Chelonia mydas* feeds on a broad range of seagrass species. Indo-Pacific seagrasses are habitat for many species of fish (Klumpp *et al.* 1989; Coles *et al.* 1993) and are essential in supporting subsistence fishing throughout the region.

Seagrasses of the Great Barrier Reef World Heritage Area

There are 15 species of seagrass in the GBRWHA (Table 1). The high diversity of seagrass reflects the variety of habitats provided by extensive bays, estuaries, rivers and the 2600 km of Great Barrier Reef with its reef platforms and inshore lagoon. Seagrasses can be found on sand or muddy beaches, on reef platforms and in reef lagoons, and on sandy and muddy bottoms down to 60 m or more below MSL. More than 5,000m km^2 of coastal seagrass meadows in eastern Queensland waters are shallower than 15 m and it is expected that approximately $40{,}000km^2$ of the seafloor in the GBRWHA deeper than 15 m has some seagrass (Coles *et al.* 2003a). This represents about 36% of the total recorded area of seagrass in Australia.

Table 1. Seagrass species of the Great Barrier Reef World Heritage Area (illustrations by Ruth Berry).

Family	Species			
CYMODOCEACEAE Taylor	*Cymodocea serrulata* (R.Br.) Aschers and Magnus		*Cymodocea rotundata* Ehrenb. et Hempr. ex Aschers	
	*Halodule pinifolia** (Miki) den Hartog		*Halodule uninervis* (wide and narrow leaf morphology) (Forsk.) Aschers. in Boissier	
	Syringodium isoetifolium (Ashcers.) Dandy		*Thalassodendron ciliatum* (Forsk.) den Hartog	
ZOSTERACEAE Drummortier	*Zostera capricorni** Aschers.			

Family	Species			
HYDROCHARITACEAE Jussieu	*Enhalus acoroides* (L.F.) Royle		*Halophila capricorni* Larkum	
	Halophila decipiens Ostenfield		*Halophila ovalis* (R. Br.) Hook. F.	
	*Halophila minor** (Zollinger) den Hartog		*Halophila spinulosa* (R. Br.) Aschers. in Neumayer	
	Halophila tricostata Greenway		*Thalassia hemprichii* (Ehrenb.) Aschers. in Petermann	

* Ongoing taxonomic revisions occurring for these species. Some names may change and not all species are currently recognised. *Ruppia maritima* can be considered a seagrass but is generally only found in freshwater in Queensland and does not form part of this report.

Seagrasses in the GBRWHA can be split into four major habitat types: estuary/inlet, coastal, reef and deepwater (Carruthers *et al.* 2002) (Figure 1). All but the outer reef habitats are significantly influenced by seasonal and episodic pulses of sediment-laden, nutrient-rich river flows, resulting from high volume summer rainfall. Cyclones, severe storms, wind and waves as well as macro grazers (fish, dugongs and turtles) influence all habitats in this region to varying degrees. The result is a series of dynamic, spatially and temporally variable seagrass meadows.

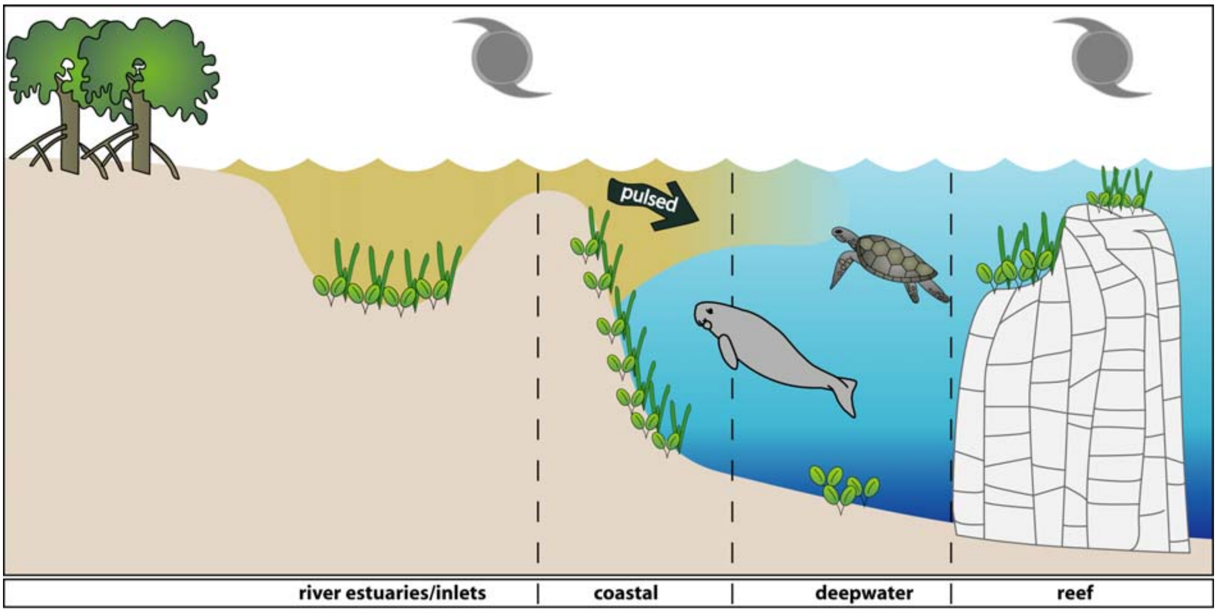


Figure 1. General conceptual model of seagrass habitats in north east Australia (*from Carruthers et al. 2002*).

The species composition, growth and distribution of estuary/inlet seagrass meadows are influenced by terrigenous runoff, temperature and salinity fluctuations. Increased river flows in summer cause higher sediment loads and reduced light, creating potential light limitation for seagrass (McKenzie 1994). Associated erosion and unstable sediments make river and inlet habitats a seasonally stressful environment for seagrass growth. These meadows often have high shoot densities but low species diversity (Lee Long *et al.* 1993). Differences in life history strategies and resilience to habitat variability and the physical characteristics of the inlet control the species assemblages in different river and inlet systems. Estuary/inlet systems are mostly inter-tidal but sub-tidal meadows may occur.

Coastal seagrass habitats also have extensive inter-tidal and sub-tidal seagrasses. Inter-tidal environments are impacted by sediment deposition, erosion, tidal fluctuations, desiccation, fluctuating and sometimes very high temperature, variable salinity resulting from rainfall and impacts from strong winds and storms. Tidal range can be in excess of six metres. These communities are affected rapidly by increased runoff with heavy rain or cyclone events (Preen *et al.* 1995), A large and variable seed bank can facilitate recovery following disturbance (Inglis 2000b). Inshore seagrass communities are found in varying quantity all along the eastern Queensland coastline where these are protected to some extent from the prevalent south east winds by the Great Barrier Reef. Along the southern coast of the GBRWHA, the Great Barrier Reef offers little protection and coastal seagrass meadows are restricted to sheltered bays, behind headlands and in the lee of islands. Extensive coastal seagrass meadows occur in north-facing bays such as Bathurst Bay, Bowling Green Bay and Shoalwater Bay.

Reef platform seagrass communities support a high biodiversity and can be extensive and highly productive. Shallow unstable sediment and fluctuating temperature characterise these habitats. Low nutrient availability is a feature of reef habitats as seagrasses are nitrogen limited in carbonate sediments (Udy *et al.* 1999). Seagrasses are more likely to be present on reefs with vegetated cays than on reefs with highly mobile sand. Intermittent sources of nutrients come with seasonal runoff reaching the reef. In some localised areas, particularly coral cays, seabirds can add high amounts of phosphorus to reef environments. The more successful seagrass species in reef habitats of the Great Barrier Reef include *Thalassia hemprichii, Cymodocea rotundata, Syringodium isoetifolium,* the colonising species *Halophila ovalis,* and species of the genus *Halodule*.

Increasing distance from the coast decreases the impacts from pulsed terrigenous runoff and clear inter-reef water at depth (>15m) allows for deepwater seagrass growth. Deepwater seagrass areas are dominated by species of *Halophila* (Coles *et al.* 2000, Lee Long *et al.* 1996a). Large monospecific meadows of seagrass occur in this habitat comprised mainly of *Halophila decipiens* or *Halophila spinulosa*. *Halophila spp.* display morphological, physiological and life history adaptations to survival in low light environments (Josselyn *et al.* 1986). *Halophila* species can be annuals in the Great Barrier Reef region, have rapid growth rates, and are considered as pioneering species. An important characteristic of this strategy is high seed production and rapid clonal reproduction through horizontal rhizome extension. Rates of 70 000 seeds m^2 per year have been estimated from field observations of *Halophila tricostata* (Kuo *et al.* 1993) and horizontal rhizome extension of 574 cm yr^{-1} recorded for *Halophila ovalis* (Duarte 1991).

Distribution of deepwater seagrasses appears to be mainly influenced by water clarity and a combination of propagule dispersal, nutrient supply, bottom type and current stress. High-density deepwater seagrasses occur mostly on the inner shelf in the central narrow-shelf section of the east coast which experiences a moderate tidal range and is adjacent to high-rainfall rainforest catchments. Where there are large tidal ranges near Shoalwater Bay to the south of Mackay, no major deepwater seagrass areas exist, but some meadows occur further south where tide ranges moderate again (Coles *et al.* 2000). Deepwater seagrasses are also less common north of Princess Charlotte Bay.

Tropical Seagrass Biology

Growth

Seagrass meadows consist of a nested structure of clones, possibly fragmented into individual plants, each supporting a number of shoots. Meadows may appear static however these are highly dynamic landscapes maintained through the continuous recruitment of new clones to the meadow and the growth and turnover of the shoots that these contain (Duarte *et al.* 2006).

There are two types of seagrass growth strategy: a leaf-replacing form, in which strap-like leaves are continuously generated and lost within a leaf cluster, and a non-leaf-replacing form, in which a fixed number of leaves are generated in independent leaf clusters. These types can also be divided into two groups based on growth pattern; groups with a single (mono-meristematic) or double (di-meristematic) growth pattern (Short and Duarte 2001).

Growth rates of seagrass plants are affected by a range of biophysical variables including light, temperature, pH, salinity, nutrient availability, substrate, herbivory, competition for space, exposure at low tide, current, epiphyte load and the species of seagrass and the age or maturity of the meadow (Short *et al.* 2001).

Biomass records for tropical seagrass range up to 8100 g dw m^2 of leaves (*Thalassia* in Florida reported in Larkum *et al.* 1989) and rhizome elongation rates of 356 cm y^{-1} (*Halophila ovalis* reported in Duarte *et al.* 2006). Tropical Queensland meadows typically have much lower biomass values than this. Moderately dense inter-tidal *Thalassia* meadows in the Torres Strait had only 31.8 g dw m^2 and subtidal meadows 13.1 g dw m^{-2} (Rasheed *et al.* 2007b). Inter-tidal *Zostera* meadows in Cairns Harbour reached 243.14 g dw m^{-2} (McKenzie 1994) and dense *Enhalus acoroides* meadows in the Torres Straits up to 175.9 g dw m^{-2} (Rasheed *et al*. 2003a). Subtidal measurements in the GBRWHA typically range from 1.0 to 45 g dw m^{-2} these measurements reflecting the smaller structure of the most common tropical Queensland species (Coles *et al.* 2000). Leaf turnover times can be a short as 8.5 days in the tropics (Rasheed *et al.* 2007b) at the very low end of recorded values in the literature (Larkum *et al*. 1989). Comparative growth and biomass measurements however are difficult to interpret as there is little standardization in the method of collection and there is enormous variability in approach.

Reproduction

All seagrass species are capable of asexual reproduction, through horizontal rhizome growth. Seagrasses are also capable of sexual reproduction through the production of fruits, seeds or viviparous seedlings (Short *et al.* 2001). Seagrasses can exhibit separate male and female plants (dioecious), or have both sexes on the same plant (monoecious). For example, the Hydrocharitaceae and Zosteraceae have both monoecious and dioecious species and the Cymodoceaceae are exclusively dioecious. Overall, about 75% of all seagrass species are dioecious (Waycott and Les 1996).

Seagrasses can live and, with the exception of the Genus *Enhalus*, reproduce submerged. Studies of seagrass reproduction and flowering help determine the contribution of reproduction to the population dynamics of different seagrasses (Walker *et al.* 2001). Determining flowering frequency, sex ratios and reproductive success also allows the "mating" system of plants to be understood (Waycott and Sampson 1997), enhancing our understanding of their genetic structure. Reproductive biology may also be critical in the re-establishment of declining seagrass populations. (Orth *et al.* 1994).

Some species of seagrass are capable of producing long lived seeds which may form a "seed bank" (McMillan 1983). Seeds for most seagrass species are poorly adapted for dispersal (den Hartog 1970, Orth *et al.* 1994). A reproductive strategy involving clonal growth and production of long-lived, locally dispersed seeds may provide an evolutionary advantage to plants growing in environments subject to temporally unpredictable major disturbances (Rasheed 2004). Some meadows may be completely reliant on asexual reproduction as these meadows have been established by a single plant and have no capacity for sexual reproduction (Rasheed 2000). Knowledge of plant reproductive strategies is becoming increasingly important as research examines the dynamics of recovery and loss of seagrass communities and management options for restoration are explored.

There have been very few studies directly reporting on flowering and sexual reproduction for Queensland waters with the exception of Kuo *et al.* (1991 and 1993), Rasheed (1999 and 2004), Inglis (2000a) and a review by Inglis and Waycott (2001).

Seasonality

Seagrass biomass, meadow area, leaf emergence rates, flowering and asexual shoot production all have seasonal species and location specific variations in north Queensland. Broad scale seasonal patterns are most likely the result of seasonality in light and temperature (Duarte *et al* 2006). Seasonal variation generally decreases towards the equator (Duarte et al 2006) but some tropical species are annuals.

Many studies have reported seasonal trends on GBRWHA seagrass meadows (Mellors *et al.* 1993; McKenzie 1994; Lanyon and Marsh 1995; Rasheed 1999; Inglis 2000a; Mellors 2003; McKenzie *et al.* 2006b). Temporal studies of meadows with structurally large species (*Zostera capricorni, Halodule uninervis – wide morph, Cymodocea serrulata)* found abundance peaks late in the dry-season (October - November), decline through the wet-season (Rasheed 2000) with a minima in the early dry season (south-easterly season (June-August) (Mellors *et al.* 1993, McKenzie 1994; Rasheed 1999). This pattern is considered typical for seagrass species in tropical north Queensland (Coles *et al.* 2001; McKenzie *et al.* 1998; Rasheed 2000). There is some evidence that seagrass seasonality may differ between the east coast of Cape York and the Gulf of Carpentaria and Torres Strait, with seagrass peaking in biomass in March/April rather than later in the year (Rasheed *et al.* 2001; 2007b).

Growth has also been shown to be more rapid during the warmer months with significant increases in all growth parameters: shoot production, rhizome extension and the number of new meristems (Figure 2; Udy 1999, Mellors 2003). Differences in light availability and temperature were attributed as the primary drivers for this seasonality.

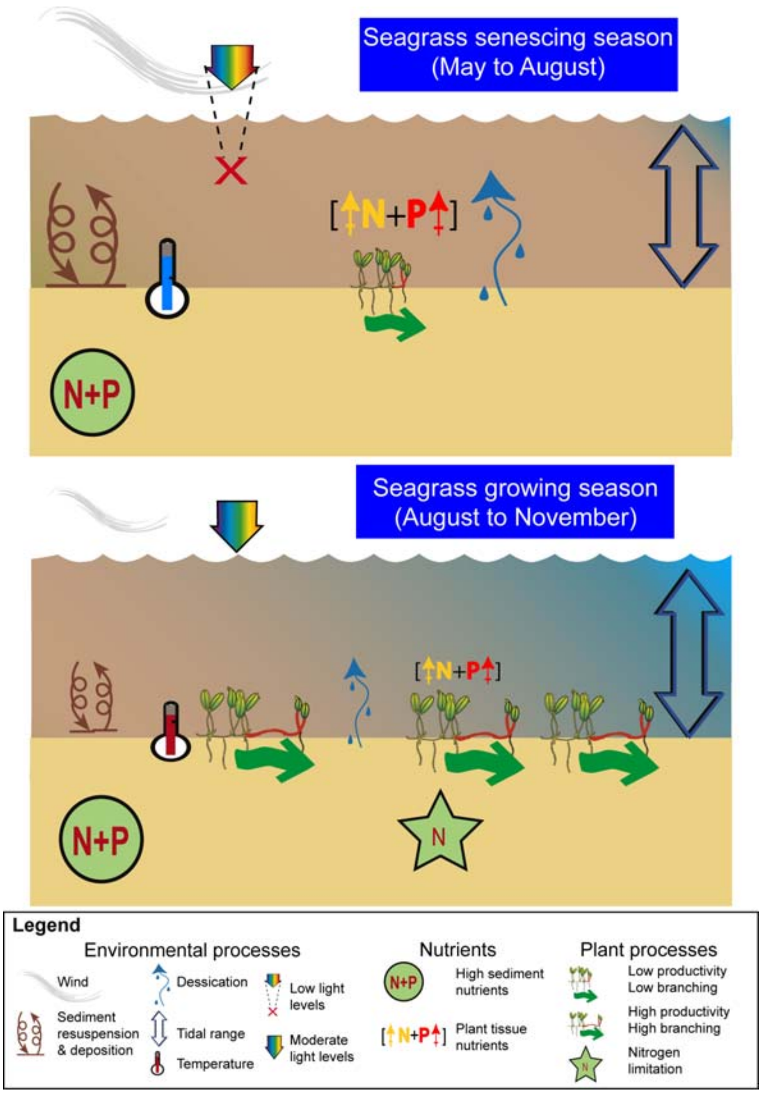


Figure 2. Conceptual diagram of controls and key processes limiting growth between seasons of intertidal *Halophila ovalis* (from Mellors 2003).

Halophila tricostata (a structural small deepwater seagrass) is an annual in the GBRWHA and changes in its area and biomass between summer and winter seasons can be dramatic. *H. tricostata* can form extensive sub-tidal meadows but is absent in autumn and winter months and re-establishes from its seed bank when sea temperatures rise to 26-28°C (Kuo *et al.* 1993). *Halophila ovalis* abundance and distribution peaks late in the dry-season (October - November) and declines through the wet-season (Rasheed 2000). Like *Halophila tricostata*, *Halophila ovalis* is capable of producing large quantities of seed and is a vigorous sexual coloniser (Rasheed 2000).

Seagrass meadows in other Queensland locations, such as in Mourilyan Harbour (McKenzie *et al*. 1998), Cairns Harbour (McKenzie 1994; Rasheed 1999) and at Green Island (Mellors *et al*. 1993; Rasheed 2000), show large seasonal trends in biomass but not necessarily changes in meadow area. The extent and intensity of these localized changes on an intra-annual scale will vary between seasons, with light availability and turbidity driven by seasonal wind regimes (Figure 2). Inter-annual differences in the disturbance regime of a seagrass meadow will also vary depending on the prevailing climatic conditions. Over longer temporal scales, large scale short duration but intense disturbances, such as cyclones, affect seagrasses either directly by removal through substrate scouring or indirectly through extended periods of high turbidity and changes in light regime disrupting physiological processes. Inter-annual variability tends to be greatest in meadows growing in deeper water or at the limit of their environmental tolerances.

Fisheries

The trophic and nursery importance of seagrass meadows for fish and larger invertebrates confirm seagrass' role as a vital component of coastal ecosystems. Seagrass material may be directly consumed by grazing animals or indirectly consumed as detritus by numerous species, including crabs, prawns and fishes. Seagrasses also provide shelter for small animals from larger fish predators, thereby increasing the diversity of coastal waters and providing a nursery habitat for commercially-important species (Coles *et al.* 1993). Seagrass leaves when dead and washed up on the beach as litter play a role for fisheries by contributing to carbon sources in the environment, by supporting a detrital food chain, and by providing food for a wide range of invertebrates (Koch *et al* 2006)

Information on the ecosystem functions of seagrasses for fish, dugong, green turtles, and invertebrates is critical for coastal zone management. There are few global generalisations that have emerged on the importance of seagrasses for marine animal species. Seagrasses provide a major nursery habitat for commercial species in some areas but not in others, depending on local species composition and local conditions (Edgar *et al*. 2001) which greatly influence the contribution of seagrasses to fisheries productivity.

Detailed studies of the value to fisheries of tropical seagrasses in the GBRWHA have shown a close link between penaeid prawn fisheries and inter-tidal and shallow sub–tidal seagrasses (Coles and Lee Long 1985; Coles *et al.* 1987a) with Cairns Harbour seagrasses valued at $1.2M per year in 1992 Australian dollars (Watson *et al.* 1993). Cairns Harbour foreshore seagrasses had 134 taxa of fish and 20 species of penaeid prawn, mostly juveniles at a density of nearly 9000 fish per hectare (Coles *et al*. 1993). Seagrass meadows of the central Queensland coastline were also found to support large numbers of fish and prawn (Coles *et al.* 1992).

Various studies in Queensland waters have demonstrated that loss of seagrass meadows reduces fisheries productivity (Poiner *et al*. 1989; Pitcher 1994: Connolly *et al.* 1999) although none of these studies are within the GBRWHA. At a global scale the relationships between fisheries and seagrass are complex as changes in seagrass may result in changes in fish assemblages rather than a loss of numbers and a decadal temporal scale may be required to discriminate between site to site and yearly natural variations (Gillanders 2006).

Ecosystem Values

Seagrasses provide a diversity of ecosystem services (Kenworthy *et al.* 2006). These coastal habitats are a favoured gathering, hunting and fishing site for coastal people throughout the world. Their rich diversity of plants and resident and transitory birds, fish, invertebrates, and other micro-organisms attest to their importance in the overall harmony of global ecosystems (Green and Short 2003).

The benefit coastal systems derive from seagrasses has been summarised as six axioms by Larkum *et al.* (1989): stability of structure, provision of food and shelter for many organisms, high productivity, recycling of nutrients, stabilising effects on shorelines, and a provision of nursery grounds for fish.

The most difficult ecosystem services to quantify are the intrinsic values of natural systems such as the sheer beauty of a lush seagrass meadow, and the structure and functions that do not have obvious immediate value to society (Kenworthy *et al*. 2006). Some services are deeply rooted in Aboriginal and Islander cultural values ranging from traditional hunting for food to ceremonial attributes, (particularly associated with dugong and green turtle) that are an essential part of daily life. Historical and cultural attributes provide an alternative way of assigning conservation and ecosystem values to seagrass systems previously not emphasized in legal, managerial and judicial processes.

Attempts have been made to place economic values on seagrasses. The average global value of seagrasses for their nutrient cycling services and the raw product they provide has been estimated at 1994 US$ 19,004 ha^{-1} yr^{-1} (Costanza *et al.* 1997). Seagrass/algae beds have been rated the third most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. This value would be significantly higher if the habitat/refugia and food production services of seagrasses were included. In seagrasses meadows of western Cairns Harbour for example, the estimated landed value of the three major commercial penaeid prawns (*Penaeus esculentus, P. semisulcatus* and *Metapenaeus endeavouri*) was (in 1992 dollars) AUS$3,687 ha^{-1} yr^{-1} (Watson *et al.* 1993).

Key Elements of the Biophysical Setting

Light and Depth

Seagrasses in the GBRWHA are found in a depth range from nearly 2 m above Mean Sea Level (Lee Long *et al.* 1993) to approximately 60 m below (Coles *et al.* 2000). In shallow waters and the intertidal zone, seagrass photosynthesis and production are inhibited by exposure to high light conditions and desiccation. Photo-inhibition due to high light levels can prevent the proliferation of some species and result in a distribution that favours more high light tolerant species (Short *et al.* 2001).

The maximum depth limit for seagrasses is determined largely by the depth to which sufficient light intensity for sustaining plant growth reaches the bottom (Short *et al.* 2001). Other factors resulting from water column height may also play a role in determining the maximum depth limit of seagrass growth, including water colour (particularly in locations influenced by river discharges and other areas of increased humic acid release), and decreased duration of the light period at the bottom. The minimum light requirement for seagrasses is 10-20% of surface light (Carruthers *et al.* 2001), higher than other marine plants, presumably because of the high photosynthetic demand to survive rooted in anoxic sediments and the proportion of non-photosynthetic material. Different species of seagrass have varying light requirements. Variation in light reaching the substrate may vary seagrass species composition by enhancing growth of species having lower or higher light requirements or may reduce depth of distribution.

Greater water depth not only reduces light and attenuates some light frequencies, but also increases the hydrostatic pressure on seagrass plants. Inhibition of photosynthesis in deepwater can result from excessive hydrostatic pressure (Short *et al.* 2001).

Temperature

Temperature is a driving factor in seagrasses growth and may influence seasonal and inter-annual changes directly through changes in productivity and indirectly through changes in flowering and seed germination. All species have an optimum temperature for photosynthesis and growth. Above the optimum, plants experience thermal stress that can be detrimental and result in plant mortality. In the tropical habitats of the GBRWHA water temperatures fluctuate from 19.8 to 41°C (Campbell *et al.* 2006). Seagrasses exposed to temperatures of 40-45°C, even for short periods equivalent to a tidal cycle exposure, are irreversibly damaged (Campbell *et al.* 2006). The effect of prolonged exposure to temperatures at the lower end of this temperature range is uncertain for tropical species. A difference in response to temperature among seagrass species establishes a species tolerance range and influences survival and distribution.

Tide and Water Movement

Tides restrict the depth to which seagrass can grow by influencing available light. Tidal range also determines the amount of inter-tidal exposure seagrass experience at low tide. The shallow edge of an inter-tidal bed is limited by plant stress due to prolonged exposure at low tide. Water motion, including current velocity, circulation flow patterns, and flow duration, all affect seagrass plants and habitat structure. Water movement is necessary for pollination (Ackerman 1986). At low velocities, increasing water motion reduces the diffusion boundary layer and has been shown to increase photosynthesis (Koch 1994).

Seagrasses can tolerate a wide range of water motion conditions from stagnant to relatively high velocity flows. Tidal channels erode seagrass beds in some areas favouring species with greater anchoring ability. While some genera are adapted for growth in soft mud and sand, others thrive in much higher energy areas. For example *Thalassodendron cilliatum* anchors to rock and reef material in wave and surge areas where little sediment is available. The direct impacts of storm activity on seagrass distribution result from erosion by wave action and water movement or from resulting physical changes to a shore or embayment topography from extreme wave or current action.

Nutrients

Nutrient fluxes are essential components of the energy flow that sustains seagrass ecosystems. Low nutrient availability may explain some of the large spatial North - South discontinuities in seagrass presence in the GBRWHA with areas north of Princess Charlotte Bay supporting only sparse off shore meadows due to a lack of runoff from pristine coastal catchments (Coles *et al.* 2000).

An increase in nutrient concentrations, either in the water column or in sediment pore water, initiates a sequence of events with an increase in plant uptake or followed by higher nutrient assimilation rates and other effects in the plant itself (Romero *et al.* 2006). Nutrients may increase recruitment and investment in sexual reproduction but may also lead to mortality due to competition for light. At a community ecosystem level the diversity of mechanisms affected by nutrient supply is huge. The most commonly invoked outcome of an increase in nutrients is a reduction in light from phytoplankton blooms or epiphyte and macro-algae overgrowth and subsequent seagrass decline or changes in species composition (Romero *et al.* 2006). In real world experience complex community level interactions and sediment composition and microtopography at a location scale may greatly influence the outcome of changes in nutrient flows.

Nutrient levels within seagrass meadows of GBRWHA are relatively low on a global comparison for porewater concentrations (Mellors *et al.* 2005, McKenzie *et al.* 2006b); are comparatively high levels for adsorbed N and low for adsorbed PO_4^{3-} (Udy and Dennison 1997a; b; Udy *et al.* 1999). These observations, combined with the low suspended and particulate nutrients recorded for this coastline (Furnas 2003), suggest that the nutrients in the coastal shallow seagrass environments are bound up in the sediments and biome rather than free in the water column.

Excess nutrients have not had a negative effect on seagrass growth and distribution in the GBRWHA (Waycott *et al.* 2005). Conversely seagrass growth may be limited by nitrogen availability in parts of the region (Udy *et al.* 1999, Mellors 2003). Udy and Mellors assessed the response of seagrass to enhanced nutrient levels and reported an increase in biomass associated with increases in N and P with N being the primary limiting nutrient during periods of optimal growth. This would indicate that seagrasses, within this region, have the capacity to absorb additional nutrients, either by increasing in biomass or by storing nutrients until conditions are optimal for increased growth.

Salinity

Salinity may limit both the reproduction and distribution of seagrass species and changing salinity can facilitate replacement by a more or less salt-tolerant seagrass or by other macrophytes. Additionally, the effects of salinity on seagrasses create osmotic stress and alter the plants' susceptibility to disease. Some seagrasses may tolerate a range of salinities. The Genera, *Ruppia*, has species found from fresh water to sea water and even in hypersaline environments.

Resilience

Resilience is a systems adaptive capacity to maintain structure and function in the face of stress and disturbance (Harris and Hobbs 2001). The resilience of seagrass meadows is likely to be a result of a complex interaction of many factors including carbohydrate reserves, ability of photosystems to recover, luxury uptake, vegetative propagation, seed bank occurrence and disturbance regime. Within the GBRWHA region some inter-tidal seagrass meadows are referred to as being ephemeral (Mellors *et al.* 2003, Waycott, *et al.* 2005) when these meadows are better described as resilient: demonstrating an ability to recover after a disturbance.

For those species that have been tested, seagrasses in this region are able to recover from a few weeks of reduced light caused by elevated turbidity, but beyond this resilience threshold these suffer potentially irreversible damage (Longstaff and Dennison 1999, Longstaff *et al.* 1999). This is also true for pulsed events of pollutants such as herbicides and nutrients (Schafelke *et al.* 2005) and temperature (Campbell *et al.* 2006). There is evidence of recovery after physical damage (Rasheed 1999; 2004), but even small scale disturbances can lead to long term (>3 years) changes to seagrass meadows (Rasheed 2004). While these processes have been studied at a small scale, at the seagrass meadow scale resilience in the GBWHA is poorly understood (Waycott *et al.* 2005).

Anthropogenic Impacts

Worldwide human use of the coastal zone is intense and humans negatively impact nearshore and coastal waters via both land and water-based activities. Impacts can occur from direct effects, such as land reclamation, dredging or propeller scarring, or from indirect effect such as increased sediment or pollution. Large scale seagrass losses in Queensland have so far been mostly associated with natural catastrophic events such as tropical storms and flood water run off and recovery has occurred within a time scale of several years (Lee Long *et al.* 2000).

Sediment and nutrient loads associated with agricultural land use may have exacerbated the impact on seagrass of a flooding event in Hervey Bay leading to the loss of 1000 km^2 of seagrass (Preen *et al.* 1995). However it is difficult to know whether catchment impacts in Queensland have led to overall increases in seagrass growth, or amplified natural losses through increased soil erosion, caused sub-lethal stresses, and slowed the recovery of seagrasses after loss (Lee Long *et al.* 2000).

Pesticides can be found in seagrass meadows in the GBRWHA but not at levels that appear to have had any major effect although at levels where there is potential for a reduction in photosynthetic activity (Haynes *et al.* 2000; Scheflke *et al.* 2005; McKenzie *et al.* 2006b).

Seagrasses are common in Queensland’s sheltered inlets and bays which are targets for coastal development, e.g. commercial ports, where industrial and urban runoff, dredging, reclamation and other habitat modification are likely to occur. Direct impacts do occur through processes such as dredging, clamations and the establishment of new infrastructure but the more indirect impacts such as turbidity from maintenance dredging are often difficult to separate from natural variability. Introduction of marine pests such as sea urchins and invasive algae species through shipping activity has the potential to impact seagrass communities by displacement, herbivory or smothering of seagrass meadows (Lee Long *et al.* 2000)

Global climate change is likely to lead to an alteration of seagrass habitats. Increased temperatures can alter seagrass growth rates and other physiological functions. The distribution of seagrasses is likely to shift as a result of increased temperature stress to existing plant populations and changes in the patterns of sexual reproduction (Short *et al.* 2001).

Global climate change affects sea level, increasing water depths, changing tidal variation, altering water movement, and increasing seawater intrusion into estuaries and rivers. Climate change will result in greater storm frequency and intensity. A major impact of all these changes on seagrasses will be a redistribution of existing habitats. The impact of increases in CO_2 will vary between species and environmental circumstances, but could affect seagrasses by altering the competition among species as well as between seagrass and algal populations. Increases in UV-B radiation resulting from climate change may inhibit photosynthetic activity, and add to the increased metabolic cost of producing UV-B blocking compounds within plant tissue. The effects of UV-B radiation will likely be strongest in the tropics and in southern oceans (Short *et al.* 2001).

Management Framework for the Protection of Seagrasses

Many management actions to protect seagrasses have arisen from the need to protect wider ecological systems and their economic values or have been designed to protect the overall biodiversity of the marine environment. The need to manage fisheries in a sustainable way has itself become a motivating factor for the protection of seagrasses.

Australia has developed historically as Federation of States with the result that coastal issues can fall under State or Federal legislation depending on the issue, its origin or extent. There may also be local, regional or port management plans with responsibility and actions for environment protection and management. International treaties, such as the RAMSAR Convention, Convention on Migratory Species of Wild Animals, and the Convention on Biodiversity, may also influence the level and management of protection.

There are close to fifty pieces of legislation listed for Queensland that could have some bearing on coastal management and protection (McGrath 2003). In addition, numerous non-prescriptive documents such as industry codes of practice and farm management plans may have a downstream positive influence on seagrass protection and management. Protection may also be reactive as in the case of oil spill protection plans or as environmental management systems designed to reduce the impact of coastal developments.

Legislation may provide direct protection as in requiring a permit or notification before disturbing seagrass meadows or indirect protection through limiting activities in a Marine Protected Area or through temporal or spatial restrictions such as seasonal or permanent closures to fishing. Some level of protection may also be afforded by a system of restoration or offsetting. Key legislative instruments in the GBRWHA are the Commonwealth Great *Barrier Reef Marine Parks Act 1975*, the *Environment Protection and Biodiversity Conservation Act 1999*, and the Queensland *Fisheries Act 1994*. Other legal instrument are reviewed by McGrath (2003) and analysed in a global context by Coles and Fortes (2001).

The Great Barrier Reef Marine Park Zoning plan affords eight different levels of protection for the park through a multi use approach (GBRMP Zoning Plan 2003). Of these zones, Buffer, Scientific, Marine National Park and Preservation afford the highest levels of protection. The zones are matched by Queensland legislation where the Park adjoins Queensland waters and the areas are not excluded by other zoning such as for port limits.

Queensland fisheries legislation (Queensland *Fisheries Act 1994*) also affords protection through a more focused aim to protect from habitat disturbance areas of the coast identified as important habitats for fisheries. This legislation protects seagrass meadows from all direct physical disturbances by human activity. At the present time for seagrasses in water shallower than 15 m there is an estimated 1900 km^2 of seagrass in a GBRMP zone of greater protection than General Use and 250 km^2 protected in declared Fish Habitat Areas. There are additional seagrasses in waters deeper than 15 m. As maps for these areas are based on modeled information and estimated areas may not be a complete representation, these have not been included in this analysis.

3. Seagrass Status and Trends in the GBRWHA

Monitoring Strategy

Seagrass Habitats

The assessment of status and trend of seagrasses in the GBRWHA in this document is based on results of the DPI&F / MTSRF seagrass monitoring program. The DPI&F program consists of four ongoing components which work together as an integrated approach to seagrass assessment and monitoring for the region.

1. **Broad scale mapping**
   This fills information gaps in the GBRWHA seagrass baseline information. The broad scale mapping program covers large regions of the coast at relatively low resolution and provides much of the baseline information for planning processes such as declared Fish Habitat and Dugong Protection Areas and input into marine park zoning. However the broad resolution of this mapping is not suited for assessing changes to seagrass at a local level.

2. **Fine scale assessment and monitoring in key risk areas**
   This detailed intensive monitoring focuses on seagrass areas at greatest risk. This component includes detailed regular annual monitoring of intertidal and subtidal seagrass meadows at key sites where there is a high risk of impacts from human activity. These surveys produce detailed information on changes to the area, composition, and biomass of seagrass meadows and relate them to natural and anthropogenic influences in the area. The methodology used is standardised across locations and examines a sub-set of representative seagrass meadow types following initial fine scale baseline surveys (Rasheed *et al.* 1996; 2003b). The unit of measure is based on a seagrass meadow with power analysis used to determine appropriate within meadow site replication to determine change. The method allows for sampling of subtidal seagrasses and other meadow types not easily accessed using Seagrass-Watch volunteers.

3. **Seagrass-Watch**
   This approach involves supervised monitoring at predominately intertidal sites (including sites monitored for the Reef Plan MMP). Survey methodology follows Seagrass-Watch standard methodology (www.seagrasswatch.org, McKenzie *et al.* 2006b). This program provides information on a range of seagrass variables at a large number of locations throughout the GBRWHA. At each sampling location, sampling includes two or more sites nested in location and three 50m transects nested in each site. A site is defined as a 50m x 50m area within a relatively homogenous section of a representative seagrass community/meadow (McKenzie *et al.* 2000). Sites are monitored for seagrass cover and species composition. Additional information is collected on canopy height, algae cover, epiphyte cover, seagrass reproductive health (*Halodule uninervis* seed bank) and associated macrofaunal abundance. The methods simplicity and relatively low cost allows for sampling to occur more frequently and across a large range of locations, helping to complete the regional picture of trends in seagrass change.

4. **Modelled seagrass distributions**
   Deepwater seagrass data was collected by DPI&F in the 1990s and is being analysed and compared with recent data from the Cooperative Research Centre for the GBRWHA seabed biodiversity project (2003-2006) using statistical models. This data is point source data and cannot be mapped in a comparative way with shallow sub-tidal and inter-tidal seagrass data.

Assessing Seagrasses at Risk for Priority Monitoring

A key goal of the seagrass program is to ensure that monitoring covers seagrass areas that are most “at risk” from the various direct and non-point source threats in the GBRWHA. There are limitations to the information in some locations due to the monitoring strategy of using community volunteers and industry funds to enable GBRWHA wide seagrass monitoring (Rasheed *et al.* 2007c). In order to identify and prioritise high risk areas to target for monitoring a review was conducted as part of the program (see Rasheed *et al.* 2007c).

Nineteen regions of the GBRWHA coast were identified where seagrasses are at heightened risk (Map 1). Those regions are further divided into three threat level categories, very high, high and moderate according to the severity of threats faced (Table 1). The established seagrass program addresses many of these risk areas, particularly areas that are in the highest threat category. However there are several areas where information is not available or could be improved.

While it is important to assess high risk areas and to target these for monitoring in the GBRWHA, there is merit in monitoring some seagrass areas that do not face high levels of anthropogenic threat. Monitoring in these areas would provide “reference regions” to put changes observed in highly threatened areas into context. The program does examine some of these areas, for example Rodds Bay south of Gladstone. Collecting more information on other key representative seagrass areas in the GBRWHA at low risk would be desirable.

Map 1. Coastal seagrass regions and location of high risk areas (from Rasheed *et al.* 2007c) and the six NRM regions within the Great Barrier Reef World Heritage Area.

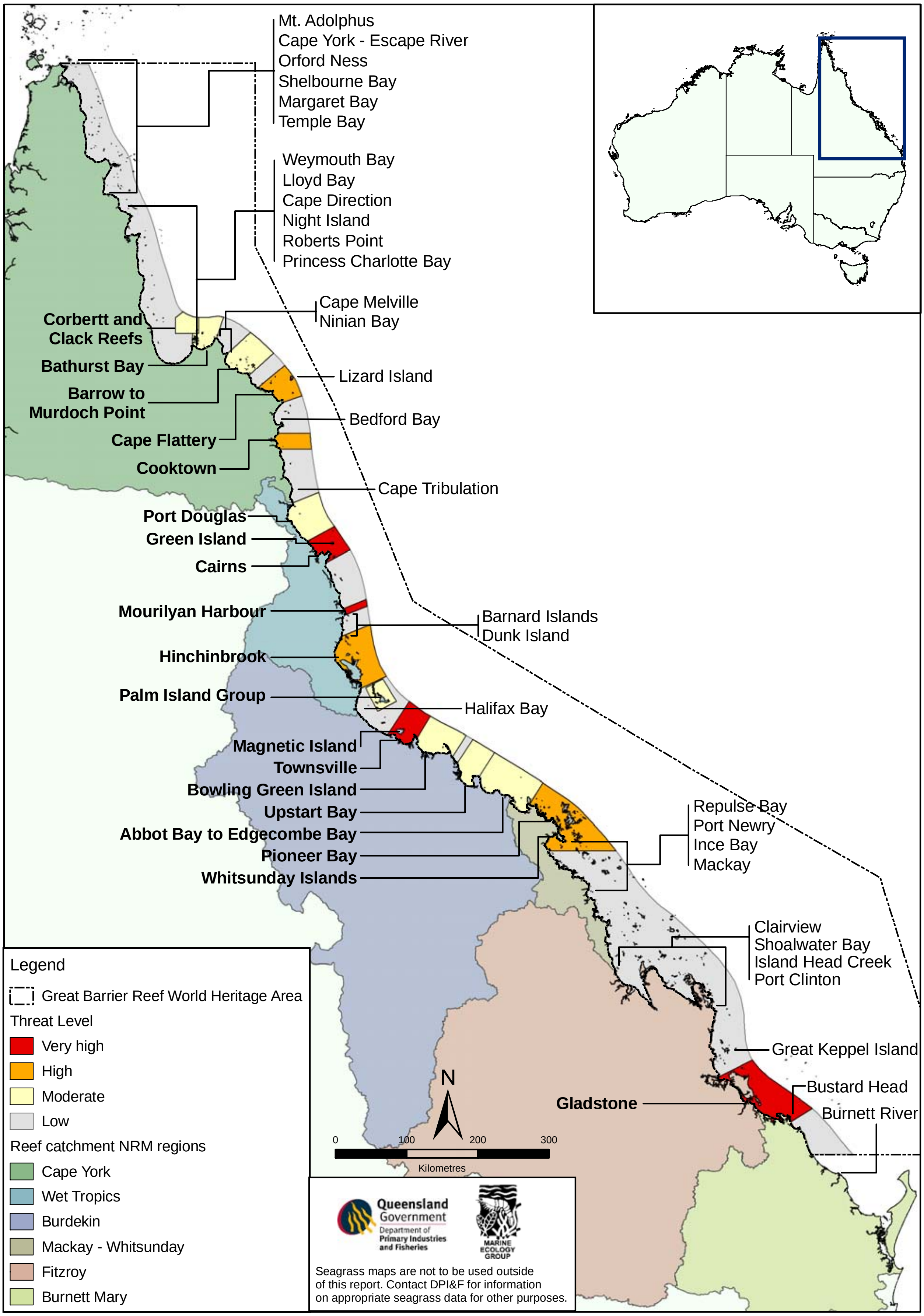


Table 1. Categories of threats and threat level for identified high risk seagrass target areas in the GBRWHA. L = low level; M = medium level; H = High level. Red shading indicates the key threats for a location (from Rasheed *et al.* 2007c).

Region *(See Map 1)*	**Threat Category**						
	Threat Score	**Coastal development** (eg. marinas, boat ramps, reclamations, aquaculture)	**Port Activities** (e.g. dredging)	**Urban and Industrial runoff**	**Agricultural Runoff** (includes river/ flood inputs)	**Oil/ chemical spills** (proximity to high risk areas of shipping lanes)	**Localised physical disturbances** (eg anchoring, bait worming)
Gladstone (Narrows - Rodds Bay)	10	H	H	H	H	H	L
Cairns (Double Island - Cape Grafton)	10	H	H	H	H/M	H/M	L/M
Townsville (Cape Pallarenda - Cleveland Bay)	10	H	H	H	M/L	H	L
Mourilyan Harbour	10	H	H	L	H	M	L
Whitsunday Islands (including mainland coast)	7.5	H	L	M	L	H	H
Hinchinbrook (Family Islands – Lucinda)	7.5	L	L	L	H	L/M	L
Pioneer Bay	7.5	H	-	M/H	L	M	L/M
Cape Flattery (Starke River - Cape Flattery)	7.5	L	M	M	L	H	L
Cooktown (Indian Head - Walker Bay)	7.5	M	M	L/M	L	L	L
Abbot Bay - Edgecombe Bay	7.5	M	M	M	L	M/H	L
Corbett Reef/Clack Reef	5	L	L	L	L/M	H	L
Bathurst Bay	5	L	L	L	L/M	H	L
Barrow-Murdoch Point	5	L	L	L	L	H	L
Upstart Bay	5	L	L	L	H	L	M
Green Island	5	L	M	L	M	L	M/H
Bowling Green Bay	5	L	L	L	H	L	L
Palm Island Group	5	M	L	L	M	L	L/M
Magnetic Island	5	H	L	L	M/L	L	L
Port Douglas (Daintree to Double Island)	5	H	M	L	M/L	L/M	L

Climate

Climate observations were drawn from permanent weather stations closest to monitoring locations, provided courtesy of Commonwealth Bureau of Meteorology. Within canopy temperature was measured at many locations using discrete iButton® temperature data recorders. Loggers were attached to permanent markers within the seagrass canopy at the sediment surface. Temperature data (±0.5°C) is logged every 90 minutes. Tidal information used was for the nearest tidal recording station and was provided by Maritime Safety Queensland. Daytime tidal exposure was determined by calculating when intertidal banks in the region became exposed at low-tide. For the purpose of this report, this was assumed to be at a tide height of 0.8m below mean sea level for most locations. River flow information was provided courtesy of the Queensland Department of Natural Resources and Water

Associated Macrofauna

Although associated macrofauna were examined at all Seagrass-Watch locations, only locations which were representative for each habitat type and where scientific supervision was present were chosen. Macrofauna were separated into four categories: decapods, molluscs, holothurians and others. Decapods were only identified to broad categories (including crabs, hermit crabs, prawns, shrimps and soldier crabs). Mollusc identification was often to taxonomic level of class (including bivalves gastropods and cephalopods) however for many sites it was to family level (e.g. Cerithiidae, Conidae, Littorinidae, Naticidae, Nassariidae, Potamididae and Trochidae). Others included various crustaceans (amphipods isopods, stomatopods and yabbies), echinoderms (urchins, sand dollars and starfish), polychaetes (including tube and free-living), fish (e.g. mud skippers and Sygnathidae), acorn worms (enteropneusts), anemones, ascidians, brachiopods, forams, hydroids, jelly fish and sponges. Bioturbation was recorded by the number of burrows (e.g. holes made by crabs, worms, yabbies or unidentified macrofauna). Bird feeding marks were common at some sites (particularly Pioneer Bay in the Mackay Whitsundays) but these were excluded from bioturbation estimates. Similarly, other miscellaneous fauna such as gastropod egg sacks were excluded from abundance estimates. Presence and absence of dugong grazing tails were recorded.

Fisheries Data

The fisheries data used in this report is derived from the CFISH commercial fishing data base compiled by the Department of Primary Industries and Fisheries. It is separated into Natural Resource Management (NRM) regions based on the coastal and outer reef location of the boundaries of each region. Data is for the last five years and is complete up to the 2006 calendar year. Data is provided on the main species present in the data base and that may have some dependence on seagrass meadows for shelter as juveniles or for food or are coastal species that may prey on seagrass dependent species. Recreational fishing data and data collected by traditional fishers are difficult to relate to Natural Resource Management regions and are not used in this report.

Reporting Approach

We have chosen to separate the analysis and discussion of seagrass status and trends into the NRM Regions identified in the GBRWHA area. These discrete regions have been used for stratifying issues of land and catchment based resource management and used to report downstream impacts on the reef environment such as from the affect of water quality. There are fifty-six NRM regions identified in Australia, fifteen are in Queensland and six are part of the coastal processes of the GBRWHA.

These regions are mostly based on catchments or bioregions using assessments from the National Land and Water Resources Audit. Regional investment plans have been developed for each of these, setting out the means for identifying and achieving natural resource management targets and detailing catchment-wide activities addressing natural resource management issues including land and water management, biodiversity and agricultural practices. Seagrass habitat data forms part of these targets and activities.

Within each region we also report separately on estuaries/inlets, coasts, reef platform and deepwater seagrasses. Estuarine and coastal habitat boundaries were delineated based on the Queensland coastal waterways geomorphic habitat mapping, Version 2 (1:100 000 scale digital data) (Heap *et al.* 2001). Reef habitat boundaries were determined using the AUSLIG (now the National Mapping Division of Geosciences Australia) geodata topographic basemap (1:100 000 scale digital data) and the deepwater boundary was seabed >15m bMSL.

Conceptual diagrams have been used to illustrate the general seagrass habitats type in each region. Symbols/icons have been used in the conceptual diagrams to illustrate major controls, processes and threats/impacts (Figure 3).

Figure 3. Key to symbols used for conceptual diagrams.

Cape York

Background

Cape York Peninsula is considered an area of exceptional conservation value and supports an adventure tourist industry and commercial and non commercial fisheries. The marine coast has social value as sea country to Aboriginal people, and fish turtle and dugong are staple foods (NRM 2007b). Along the nearly 800 km of coastline there are only three small towns Cooktown, Hopevale and Lockhart River and virtually no industrial development. There are several large rivers, but catchment development is limited to low intensity grazing and agriculture. Riparian vegetation is generally in good condition and with the exception of the Annan River near Cooktown; the rivers are unmodified by dams and weirs.

The region has a monsoonal climate with distinct wet and dry seasons with mean annual rainfall ranging from 1715 mm (Starke region) to 2159mm (Lockhart River airport). Most rain falls between December and April. Mean daily temperatures in the area range from 19.2 – 32.1°C. The prevailing winds are from the SE and persist throughout the year (Cape York Peninsula NRM 2007b).

Extensive seagrass beds occur in the shallow waters of the Starke region, and in Bathurst, Princess Charlotte, Shelburne and Margaret Bays. Thirteen species of seagrass were identified from this region (Coles *et al.* 1987a; Rasheed *et al.* 2005b*)*. Seagrass meadows have been found from intertidal regions to depths of 58m near Lizard Islands (Coles *et al.* 2001). These meadows were characterized by high diversity and relatively small total biomass (Lee Long *et al.* 1993, Rasheed *et al.* 2005b). Monospecific seagrass meadows were uncommon.

Halodule uninervis and *Halophila ovalis* were the most common species in coastal intertidal areas. *Cymodocea serrulata* and *Syringodium isoetifolium* were found in shallow subtidal areas that are sheltered from the south-east winds. Subtidal meadows of *Halophila ovalis* and *Halophila spinulosa* were also quite extensive (Lee Long *et al.* 1993). Species common on coral reef platforms such as *Cymodocea rotundata* and *Thalassia hemprichii* were less common around islands and in coastal regions (Rasheed *et al.* 2005b). *Enhalus acoroides* was found as small isolated patches in sheltered embayments. *Enhalus acoroides* and *Thalassia hemprichii* are often dominant species in the tropics (Womersley 1981; Coles *et al.* 2003a). Their position in the seagrass community in Cape York was occupied by *Cymodocea serrulata* which formed dense stands in a variety of habitats including estuaries and muddy bays and reef tops (Coles *et al.* 1987a, Lee Long *et al.* 1993, Rasheed *et al.* 2005b). Sites that have been revisited since the broadscale surveys in 1983 show that seagrasses generally occurred in similar areas but when surveyed at a finer scale were more extensive (Rasheed *et al.* 2005b; Ayling *et al.*1997). As the majority of information for Cape York comes from the broadscale surveys, the area of recorded coastal seagrass for the region is likely to be an underestimate.

Initial mapping results from the east coast were first published in 1985. This data was re entered and validated in 2001 and is available in GIS formats (Coles *et al.* 2001) Since then DPI&F has conducted finer scale surveys of Shelburne, Margaret and Indian Bay region (Rasheed *et al.* 2005b). Fine scale mapping of coastal seagrass meadows between Walsh Bay and Lookout Point and around reefs in the Cooktown area has been conducted by the Cape York Marine Advisory Group (Howley 2006). The only regular monitoring of seagrass meadows in this region occurs at a single location using Seagrass-Watch protocols.

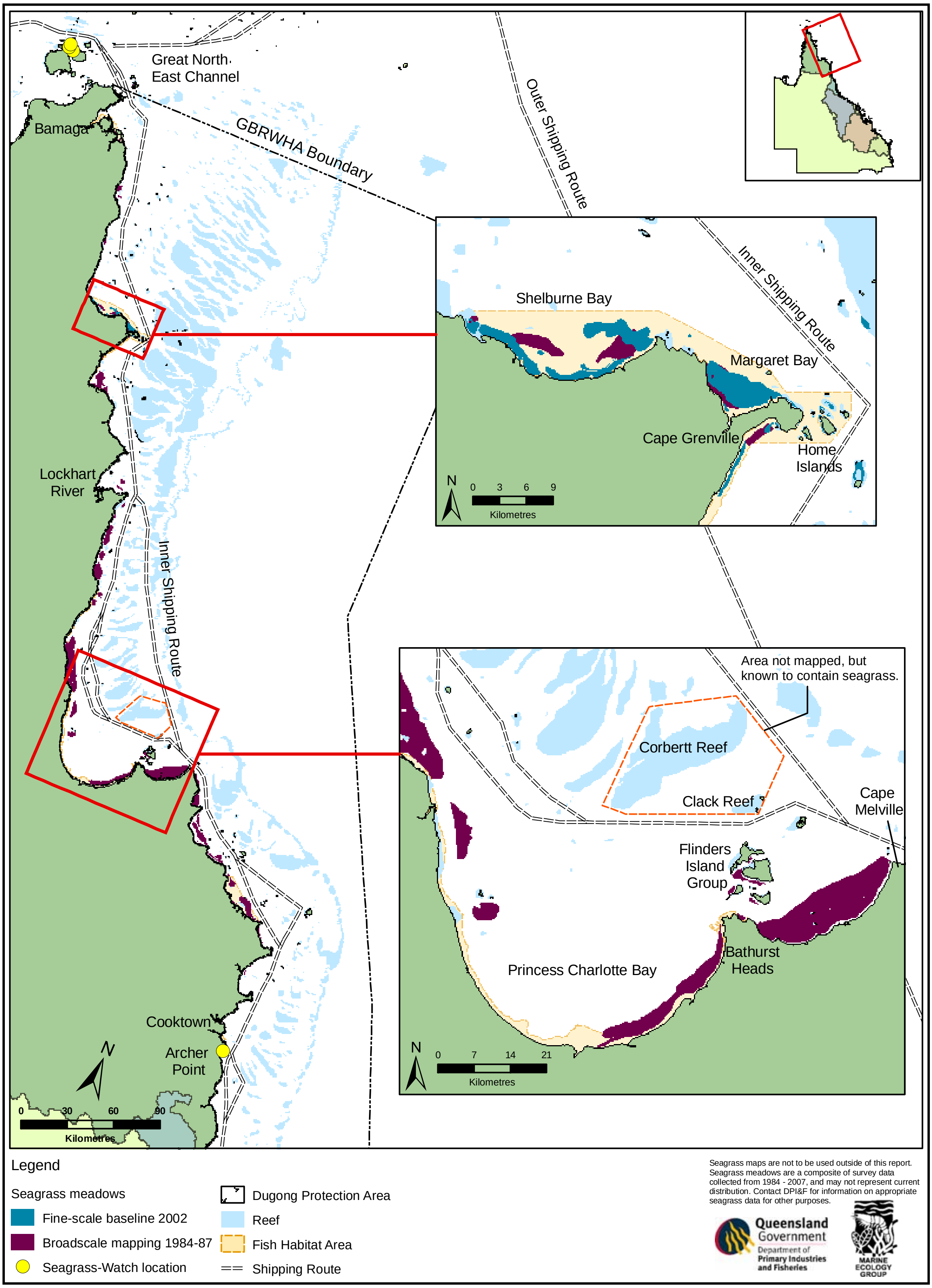
Mining, agriculture, shipping tourism and commercial and recreational fishing are the major economic activities. All have potential to expand in this region. The Cape York Peninsular community perceive the greatest threats to their seagrass meadows to be from sedimentation from shipping traffic and erosion in river catchments, disturbance from trawling and oil or chemical spills (Cape York Peninsula NRM Plan, 2005). Oil spillage from large vessels represents the single biggest point source pollution threat to the Great Barrier Reef in this region (Haynes *et al.* 2001)

Based on the mapped seagrass areas, the majority of meadows in the Cape York region are within coastal habitats (Table 2). Of these, 49% are protected within declared Fish Habitat Areas. Approximately 33% of seagrass meadows (excluding deepwater) covered by the highest levels of protection zones of the GBRWHA.

Table 2. Area (km^2) of seagrass within each habitat type, port area and marine protected zone in Cape York. Shaded areas afford highest levels of protection for seagrass (cells are not additive as there is overlap among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	6.13	0.00	0.00	2.44	1.39	0.03	0.00	1.61	0.00	0.15	3.75	**9.50**
Coast	49.04	0.02	28.24	267.88	329.60	1.95	0.00	252.45	57.51	0.01	0.00	**937.89**
Reef	3.76	0.00	0.00	8.21	10.94	0.00	0.00	8.26	0.00	0.00	0.00	**27.42**

Map 2. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Cape York NRM region.



Conceptual Summary

Each of the four generalised seagrass habitats occur within the Cape York region.

Estuarine

Less than one percent of the seagrasses mapped in the Cape York region are within estuaries/inlets (Table 2). Estuarine habitats in the Cape York can be subtidal or intertidal, contain only a few seagrass species, and are possibly highly productive (Coles *et al*. 1985). These habitats are closely associated with mangrove forests, characterised by fine sediments and prone to high sedimentation and anoxic conditions (Figure 4). The dominant influence of estuary habitats is terrigenous runoff from seasonal rains.

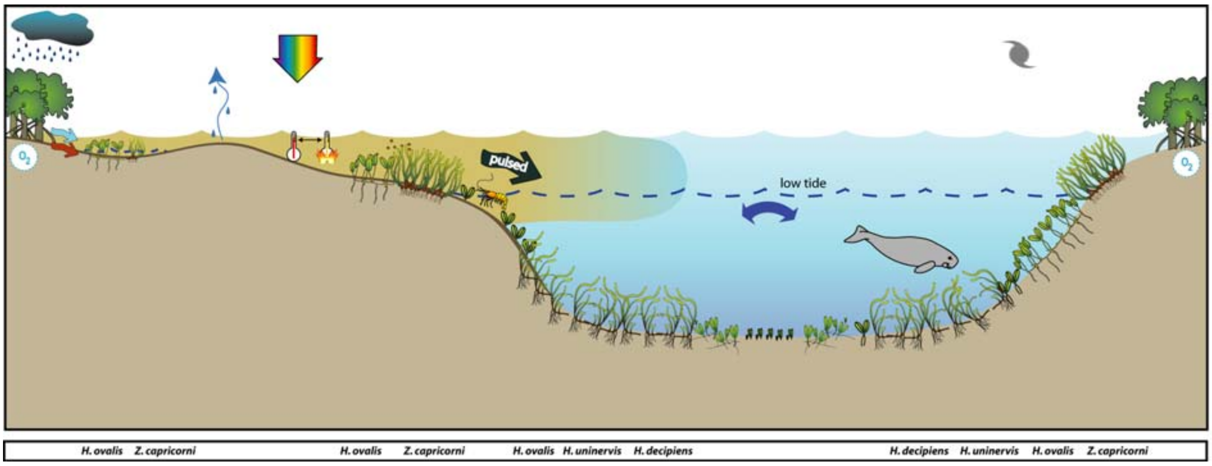


Figure 4. Conceptual diagram of estuary habitat in the Cape York region – major control is pulsed terrigenous runoff and exposure (temperature and desiccation): general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*

Coastal

Most seagrass meadows (~96%) are within coastal habitats in the Cape York region. The majority of these meadows are in the shallow subtidal waters of large bays sheltered from the prevailing SE trade winds. In the Cape York region there is little land-based influence with few major rivers. These seagrass meadows are also highly productive and provide important nursery grounds for fisheries (Coles *et al.* 1985). The meadows are also of important to the large dugong population within the region (Marsh and Lawler 2002).

A dominant influence on coastal habitats although small, is terrigenous runoff from seasonal rains, similar to the adjacent estuary habitats (Figure 5). Episodic terrigenous runoff events result in pulses of increased turbidity, nutrients and a zone of reduced salinity in nearshore waters. The inter-tidal upper reaches of the meadows are limited by elevated temperatures and desiccation. The region also has a busy shipping lane immediately adjacent to the coast, where the passage of large ships during low tides can resuspend sediment plumes in their wakes (NRM 2007b). Shipping also has the added risk of accidents and oil spills (QT and GBRMPA 2000).

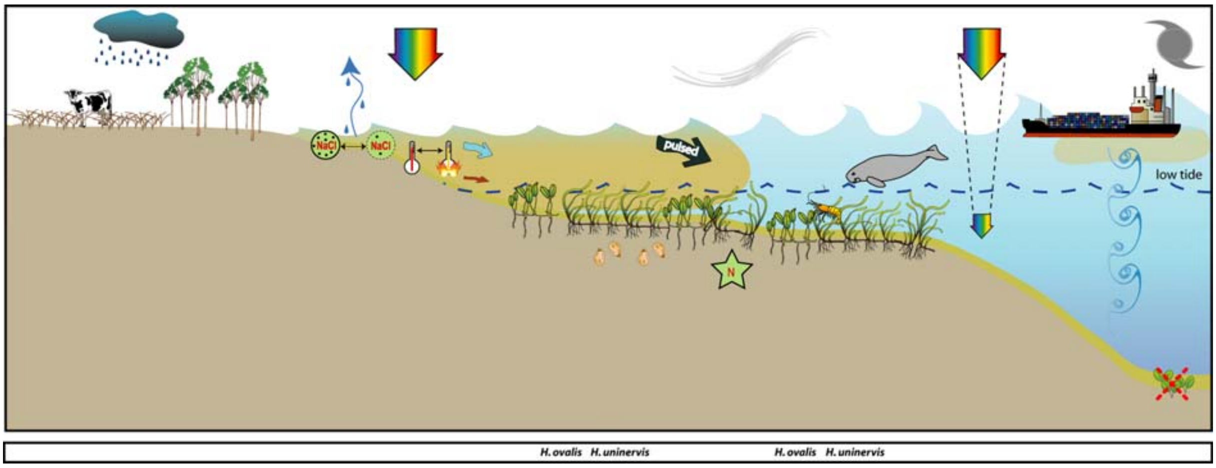


Figure 5. Conceptual diagram of coastal habitat (<15m) in the Cape York region – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Reef

Reef-platform habitats are both subtidal and intertidal and support diverse seagrass assemblages. Approximately 3% of all mapped seagrass meadows in the Cape York region are located on fringing-reefs (Table 2). Meadows are known to be found on mid shelf sand reefs (e.g. Corbett Reef (DPI&F Unpublished Data)) and smaller vegetated cays (e.g. Turtle Island Group), however no detailed mapping has been conducted. On fringing-reefs, physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats (Figure 6). Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Sediment movement due to bioturbation and prevalent wave exposure creates an unstable environment where it is difficult for seagrass seedlings to establish or persist.

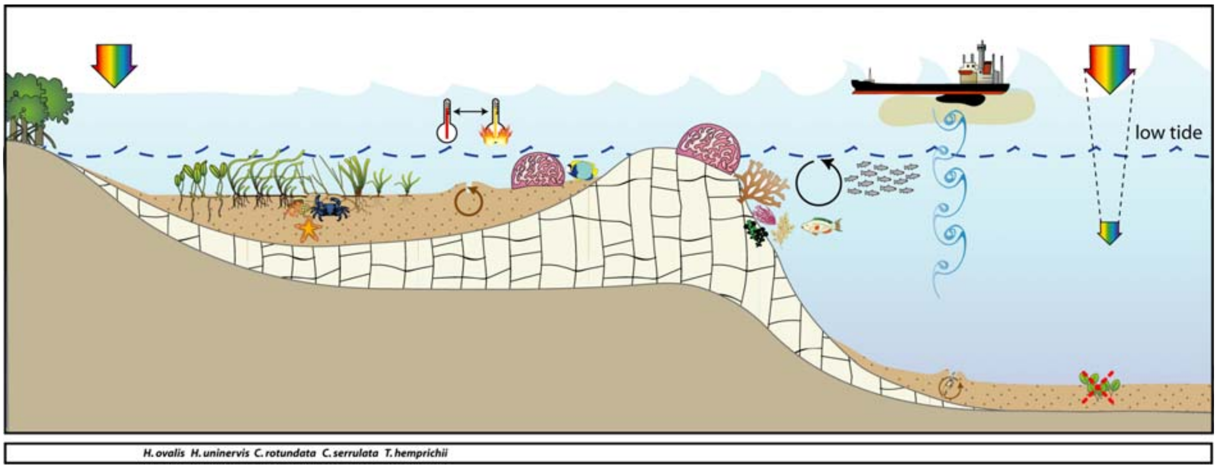


Figure 6. Conceptual diagram of reef habitat (<15m) in the Cape York region – major control is pulsed physical disturbance, salinity and temperature extremes: general habitat and seagrass meadow processes *(See Figure 5 for icon explanation)*.

Deepwater (>15m)

In the Cape York region there is little coastal influence with few major rivers and little coastal development, muddy sediments extend down only to 25m. Seagrasses extend from 15m down to 58m. Light is limiting only at the deep edge and even there maximum depths are much less than those found at other locations – topography is the limiting factor (Figure 7). Seagrass distribution in this region is patchy and most likely limited by the availability of nutrients. There may also be little availability of seeds as the area receives offshore water that sweeps west and north, from just north of 18°S (Church 1987) with little chance of picking up replenishing seeds or plant material. Bottom trawling for Tiger, Endeavour, and Red Spot King prawns (*Peneaus esculentus, Metapenaeus endeavouri, and Melicertus longistylus*) occur through 9 months of the year outside of Marine Park 'no take' zones. Dugong and turtle populations graze on seagrass in this region but this does not appear to strongly influence seagrass distribution. Shallow seagrasses are found well out onto the shelf and dugong can feed away from the coast in this region. Seagrasses are under little threat in this zone and management requirements are restricted to monitoring coastal development and changes in light penetration.

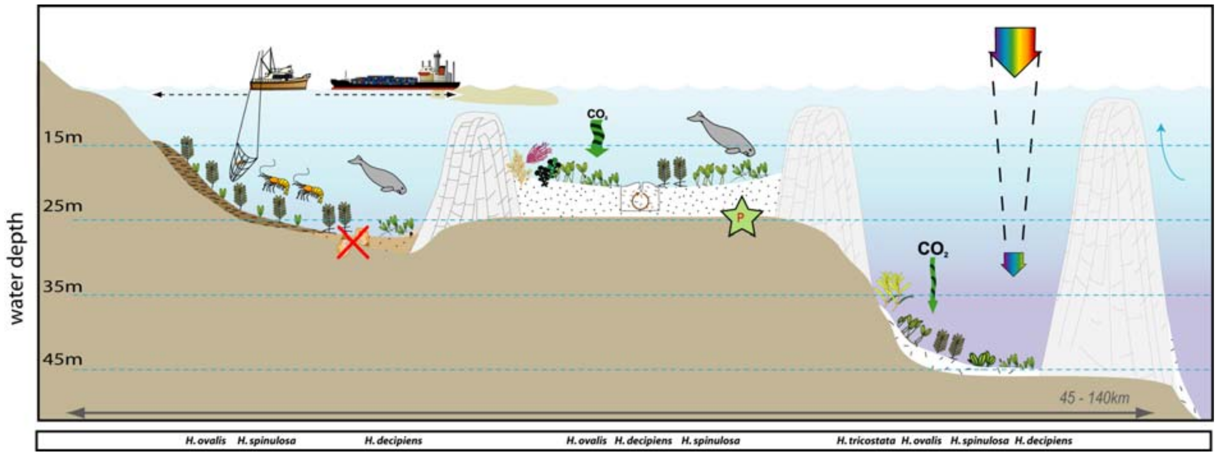


Figure 7. Conceptual diagram of deepwater habitat (>15m) in the Cape York region – major control is light: general habitat, seagrass meadow processes and threats/impacts (See Figure 3 for icon explanation).

Summary of Monitoring Data

In the Cape York region, the only location monitored in the region is a fringing reef platform in a protected section of the bay adjacent to Archer Point, fringed by mangroves, approximately 15km south of Cooktown.

Reef

The seagrasses monitored were dominated by *Halodule uninervis* and *Halophila ovalis* and seagrass cover was between 20% in winter and 35% in spring (Figure 8). Monitoring was established in late 2003. Species composition remained relatively stable over the monitoring period. Seagrass cover over the past 12-24 months (2005-07) appeared to follow a seasonal trend with higher abundance in late spring/early summer.

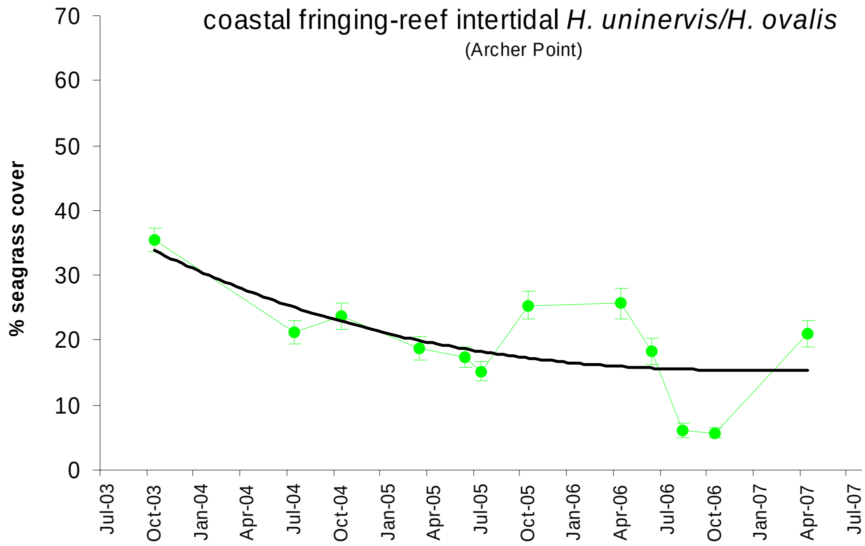


Figure 8. Seagrass abundance (% cover) at coastal intertidal fringing-reef habitat over the monitoring period.

Deepwater

Seagrasses in deep water (>15m) have been sampled twice, once between 1994 and 1999 and again between 2003 and 2006. The modelled distribution of seagrass species for both time periods shows spatial discontinuities in deep water seagrass meadows along the north-south axis with a low probability of seagrass being present north of Princess Charlotte Bay and extensive seagrass areas in the south of the region extending out from the coast in the Lizard Island region. *Halophila ovalis, Halophila spinulosa, Halophila tricostata, Halophila decipiens* and *Halophila capricorni* dominated the meadows in both surveys. The deep water comparisons are not true monitoring as they compare modelled distribution rather than actual meadow locations with the potential for unestimated error at small spatial scales. The comparisons for deep water are summarised and discussed in a separate report (De'ath *et al.* 2007).

Climate

Climate information collected from Cooktown shows that during the period of seagrass monitoring (2003 onwards) there have been two major rainfall events in early 2004 and 2006, with other years relatively dry (Figure 9). Maximum temperatures tended to be higher from 2002 to 2005.

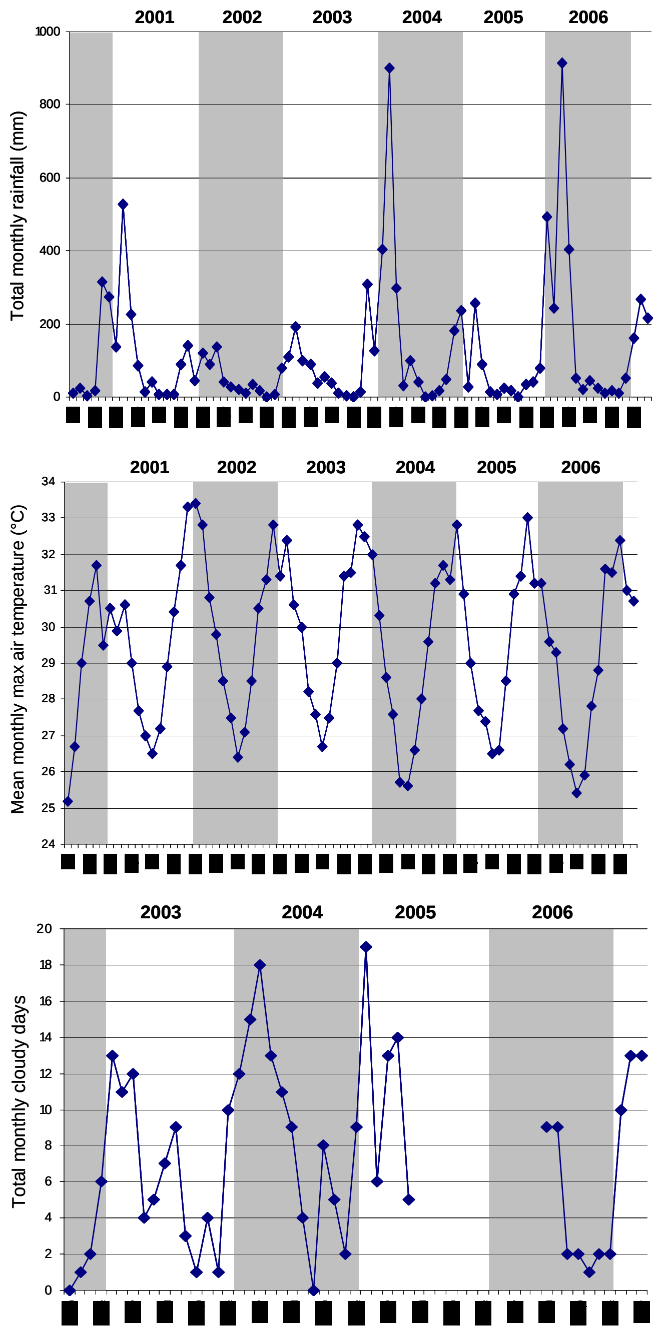


Figure 9. Cloudy days mean monthly maximum temperature and mean monthly rainfall for Cooktown in the Cape York NRM 2001-2006.

Associated Macro-fauna

The fringing reef platform seagrass habitat was dominated by molluscs, particularly grazers, which appeared to increase during the winter months (Figure 10). Bioturbation, particularly crab burrows, varied over the monitoring period.

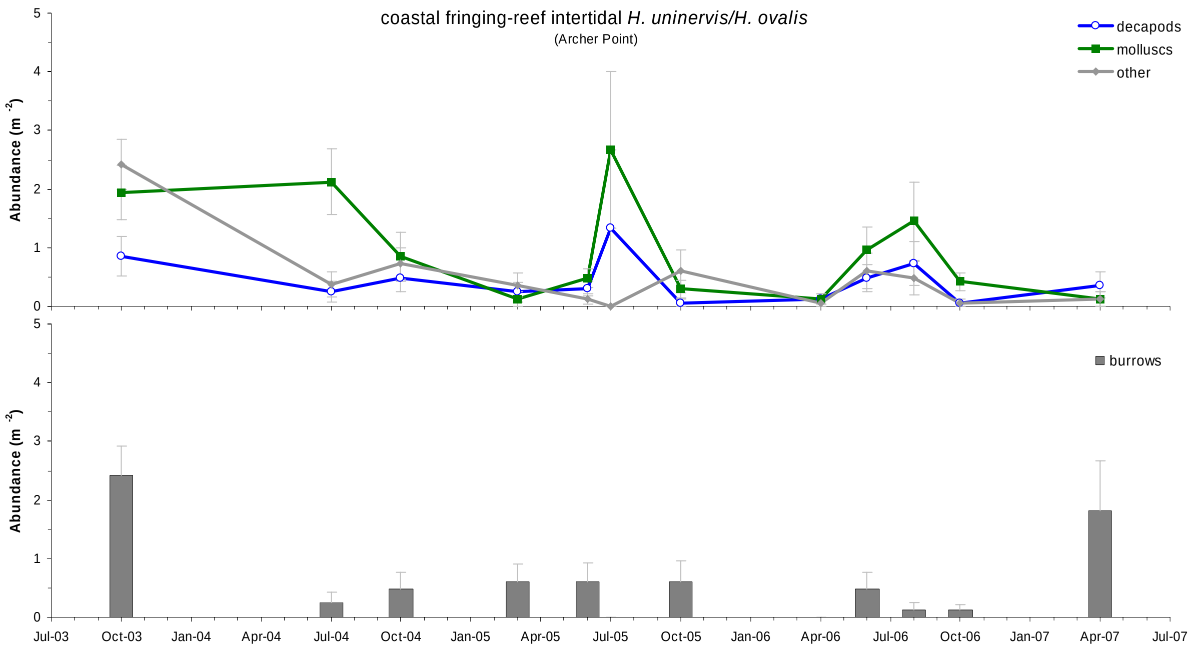


Figure 10. Abundance of associated benthic macro-fauna and bioturbation at a coastal fringing reef *H. uninervis/H. ovalis* meadow over the monitoring period.

Fisheries

There is little information on recreational and traditional fish catch in the Cape York region but $5.3M (mean value of catch between 2002 and 2006) of commercial fish are reported from the inshore fin fish fishery which includes species found in seagrass meadows as juveniles.

The otter trawl fishery for penaeid prawns is the major fishery in the Cape York region with major fishing grounds in Princess Charlotte Bay and the coastal strip immediately to the north. Five species of juvenile prawn (*Penaeus esculentus, Penaeus semisulcatus, Melicertus latisulcatus, Melicertus longistylus* and *Metapenaeus endeavouri*) have been collected from seagrass meadows in the Cape York region (Coles *et al.* 1985). The prawn fishery in the region operated between 2002 and 2006 for an average catch of 2231 tonnes per day, with an average gross value of product over that time of approximately $30.3M per year.

There is a small mud crab fishery along the east coast of Cape York mainly in Princess Charlotte Bay with mean catch of 45 tonnes of crabs for 2002-2006 worth an average of $0.47M per year. Mud crabs (*Scylla serrata*) depend on seagrass material for food (Waltham and Connolly 2006) and may shelter in seagrasses as juveniles. There has been a small increase in the average daily catch per boat of tiger prawns, tropical rock lobster and mud crabs with no clear trends for other species (Figure 11, Figure 12).

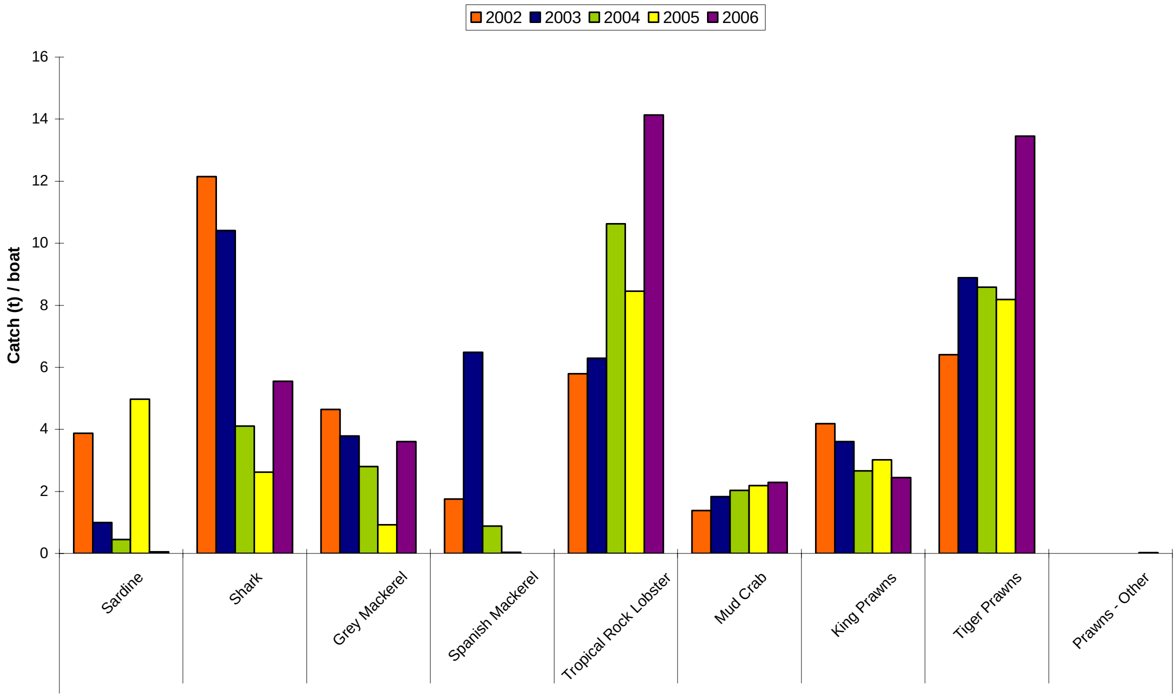


Figure 11. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Cape York NRM region between 2002 and 2006.

Regional Summary

The only regular monitoring of seagrasses in the area comes from Archer Point, where seagrass cover (percentage cover estimate) has remained relatively constant since 2004. Due to the lack of monitoring in the region it is difficult to determine how seagrasses are trending. Of the few sites that have been revisited since broadscale mapping in the 1980's (e.g. Margaret and Shelbourne Bays) most appear to have maintained at least a similar distribution indicating that seagrasses in the region may be relatively healthy (Rasheed *et al.* 2005b and 2006). Seagrasses in the region also generally face low threat levels from chronic anthropogenic impacts when compared to other regions in the GBRWHA (Rasheed *et al.* 2007c). While there are high risks associated with shipping accidents and oil spills in the region, none of the ship grounding or collision events in recent times has resulted in major oil-spills (QT & GBRMPA 2000).

Information Gaps

- Very little seagrass monitoring information is collected in this region, with the majority of seagrass habitat types unrepresented in the current program.
- The large reef-top seagrass areas of Corbett and Clack Reefs have not been mapped in any detail and no monitoring is currently conducted. These meadows are highly important for Dugong.
- No subtidal coastal or estuary seagrass habitats are monitored in this region.

Wet Tropics

Background

The Wet Tropics catchment region covers 22,000 km^2 and supports a population of 200,000 people, with 90 per cent residing in the Cairns area (NRM 2007e). Land use practices include land-based primary production such as cane and banana farming, dairying, beef, cropping and tropical horticulture. Others uses within the region include fisheries, mining, tourism and World Heritage areas. Average annual rainfall is between 800 and 2000 mm, with the majority falling during the wet season from December to March (BOM 2007). Declining water quality, due to sedimentation combined with other forms of pollutants, the disturbance of acid sulfate soils, and point source pollution have been identified as major concerns to the health of coastal estuary and marine ecosystems of which seagrass meadows are a major component (FNQ NRM Ltd and Rainforest CRC 2004).

Thirteen seagrass species have been recognised for this region (Lee Long *et al.* 1993). The most extensive areas of seagrass meadows in this region occur around Low Isles, Cairns Harbour, Green Island, Mourilyan Harbour and the Hinchinbrook Island area (between Dunk Island and Lucinda). Intertidal seagrass meadows are situated along nearshore sand and mud banks and mostly consist of *Halodule* and *Halophila* dominated meadows in the northern and southern areas. Intertidal meadows in Cairns Harbour and southern Hinchinbrook channel are dominated by *Zostera capricorni*. Shallow subtidal coastal meadows consist of *Halodule uninervis* and *Halophila* communities mostly found along sheltered coasts and harbours (e.g. Cairns Harbour and Mourilyan Harbour). *Cymodocea* spp., *Thalassia* and a suite of *Halophila* species tend to dominate island habitats in the region (e.g. Dunk Island and northern Hinchinbrook Island).

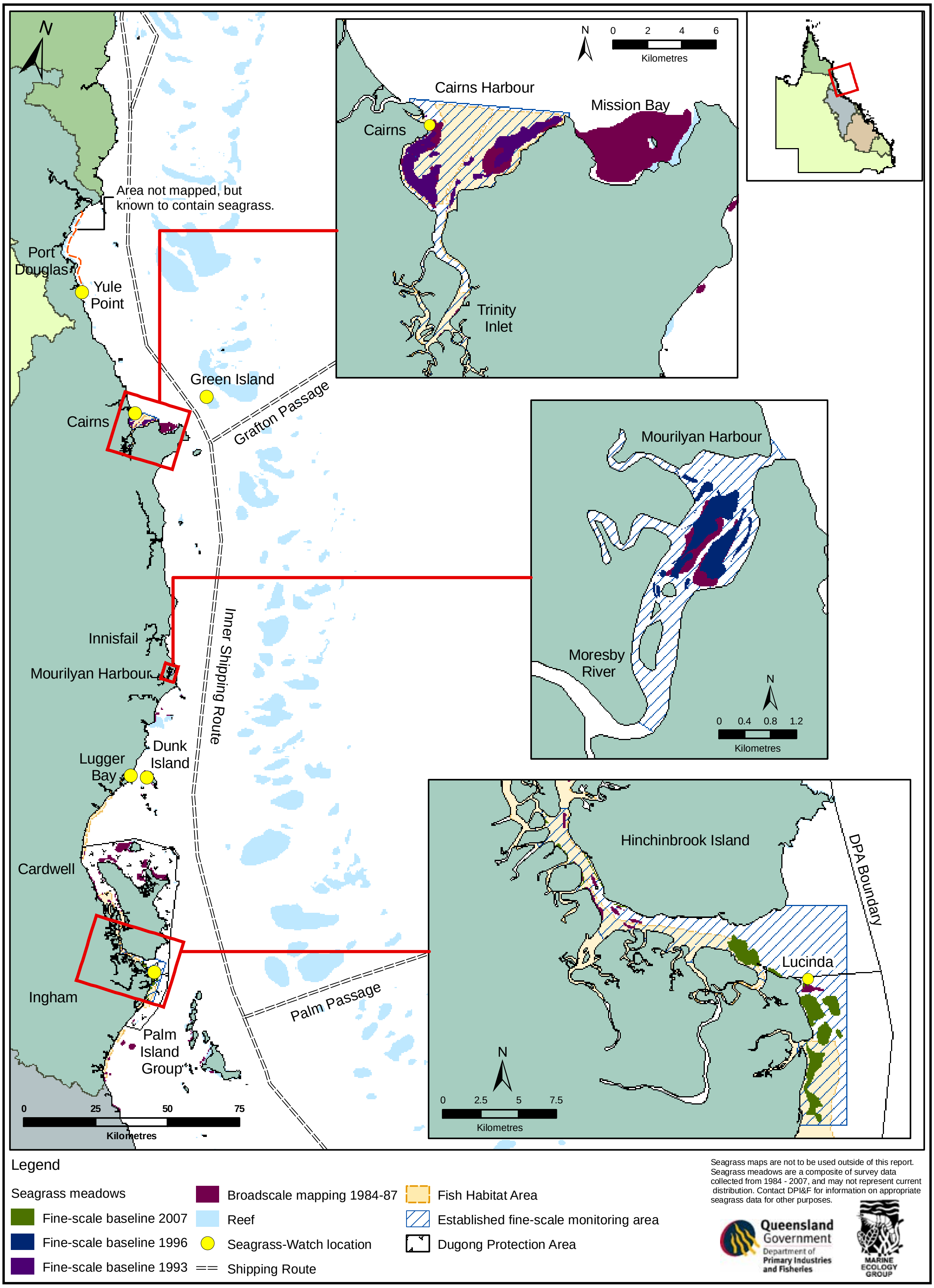
Based on the mapped seagrass areas, the majority of seagrass meadows in the Wet Tropics region are within coastal and estuary habitats (Table 3). Of these, 27% are protected within Fish Habitat Areas and 40% are located within port boundaries. Approximately 20% of seagrass meadows (excluding deepwater) are covered by the highest levels of protection zones of the GBRWHA.

Table 3. Area (km^2) of seagrass within each habitat type, port area and marine protected zone of the Wet Tropics. Shaded areas afford highest levels of protection for seagrass (cells are not additive as overlap occurs among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	14.34	25.82	1.61	21.33	25.11	0.00	0.00	0.24	0.00	4.29	0.00	**52.79**
Coast	18.02	22.59	5.45	6.96	85.06	0.00	0.00	26.04	0.00	9.98	0.00	**66.54**
Reef	0.00	0.01	0.01	4.56	6.00	0.00	0.99	0.00	0.00	0.00	0.00	**13.31**

The Wet Tropics region has a good coverage of seagrass monitoring and assessment sites for the major seagrass habitats (Map 3). Good baseline information on seagrass distribution also exists for the majority of this region with the exception of the northernmost section (north of Cairns Harbour) where seagrass is known to occur but has not been mapped in any detail.

Map 3. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Wet Tropics NRM region.



Conceptual Summary

Each of the four generalised seagrass habitats are represented within the Wet Tropics region.

Estuarine

Fifty three percent of seagrass meadows in the Wet Tropics region are located within estuaries/inlets (Table 3). Estuarine habitats in the Wet Tropics include both subtidal and intertidal meadows, contain relatively few seagrass species, and are highly productive. In the Wet Tropics, these habitats are closely associated with mangrove forests, characterised by fine sediments and prone to high sedimentation and anoxic conditions (Figure 12). The physical and biological connectivity between these habitats is of high importance to support the detrital food chains and the productive faunal communities. The dominant influence of estuary habitats is terrigenous runoff from seasonal rains. Increased river/creek flow results in higher sediment loads which combine with reduced light to create potential light limitation for seagrass (McKenzie 1994). Estuary habitats also have higher loadings of micro and macro-algal epiphytes than those in other seagrass habitats. Salinity fluctuations and scouring make estuary and inlet habitats a seasonally extreme environment for seagrass growth. Estuary habitats also include the ports and shipping activities (including dredging).

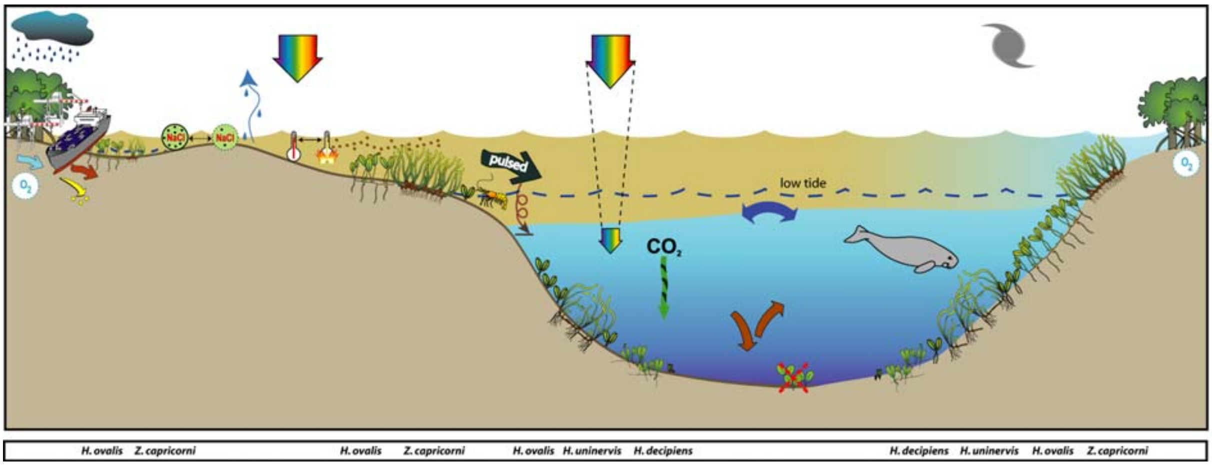


Figure 12. Conceptual diagram of estuary habitats in the Wet Tropics region – major control is pulsed terrigenous runoff: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Coastal

Coastal habitats in the Wet Tropics are both subtidal and intertidal. These seagrass meadows are also highly productive and provide important nursery grounds for fisheries. The sediments in these locations are relatively unstable at the seaward edge restricting seagrass growth and distribution in some localities. A dominant influence of coastal habitats is terrigenous runoff from seasonal rains, similar to that for the adjacent estuary habitats (Figure 13). The Daintree, Barron, Russel-Mulgrave, Tully and Herbert Rivers are major sources of pulsed sediment and nutrient input.

Episodic terrigenous runoff events result in pulses of increased turbidity, nutrients and a zone of reduced salinity in nearshore waters. Seagrasses, especially structurally large species such as *Zostera*, benefit coastal water quality by absorbing nutrients and trapping sediments acting as a buffer between catchment inputs and reef communities. Seagrasses have the ability to act as a bio-sink for nutrients, sometimes absorbing and retaining high levels of tissue nitrogen and phosphorous.

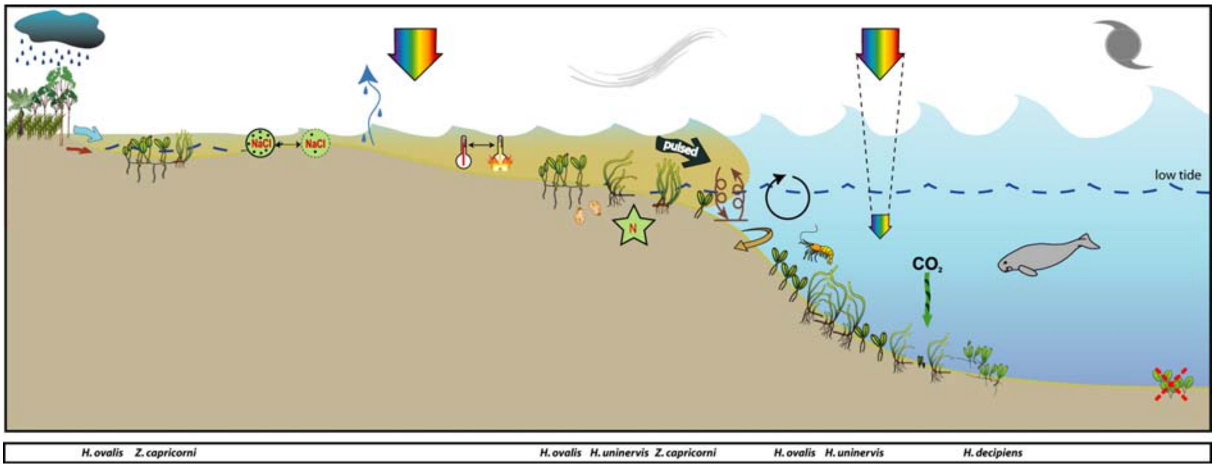


Figure 13. Conceptual diagram of coastal habitats (<15m) in the Wet Tropics region – major control is pulsed terrigenous runoff, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts (See Figure 3 for icon explanation).

Reef

Reef-platform habitats are both subtidal and intertidal and support diverse seagrass assemblages. Physical disturbance from waves, swell, and associated sediment movement primarily control seagrass growing in these habitats (Figure 14). Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Nutrient concentrations are generally low in reef habitats. The primary limiting nutrient for seagrass growth in carbonate sediments is generally phosphate (Short *et al.* 1990; Fourqurean *et al.* 1992; Erftemeijer & Middelburg 1993). However, in the Wet Tropics, seagrass meadows on reef-platforms have been shown to be nitrogen limited (Udy *et al.* 1999). Tight nutrient recycling strategies of *Thalassia hemprichii* (e.g. the location of nitrogen in the rhizomes) aids in survival in the nutrient-poor reef habitat when leaves are shed due to desiccation stress (Stapel *et al.* 1997).

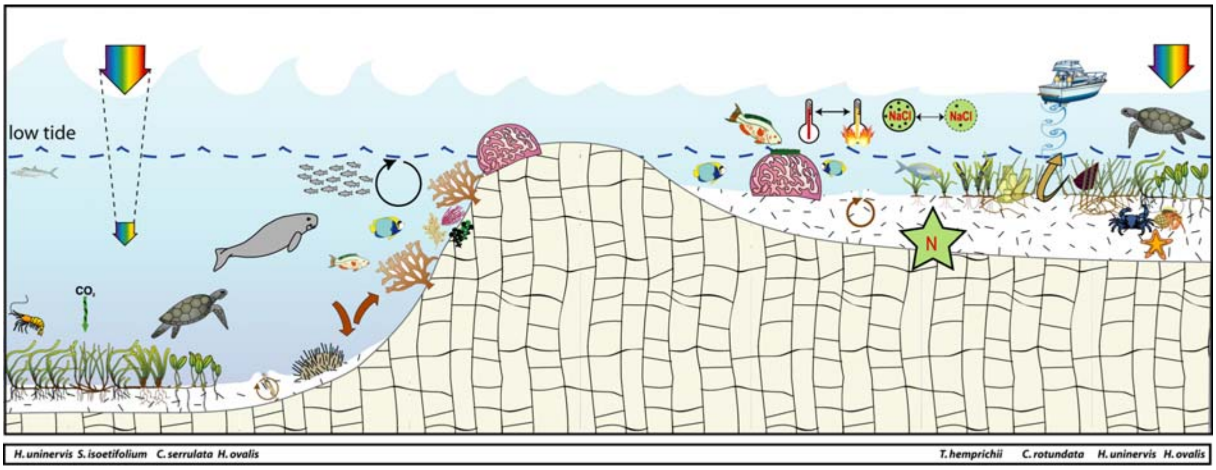


Figure 14. Conceptual diagram of reef habitats (<15m) in the Wet Tropics region – major control is nutrient limitation, temperature extremes, light and grazing: general habitat, seagrass meadow processes and threats/impacts (See Figure 3 for icon explanation).

Sediment movement due to bioturbation and prevalent wave exposure creates an unstable environment where it is difficult for seagrass seedlings to establish or persist. Succession or recolonization after extreme loss has been suggested to be directional and modified by small-scale perturbations, resulting in patchiness in seagrass distributions (Birch and Birch 1984). The end result of this successional process, however, varies with geographic location.

Reef seagrass communities also have unique faunal interactions. Bioturbation by shrimps can be so prevalent in some reef environments as to prevent seagrass growth (Ogden & Ogden 1982). A region of bare sand often separates coral heads from seagrass meadows, previous research suggests this is maintained by parrotfish and surgeonfish associated with the coral (Randall 1965). Reef seagrass habitats in the Wet Tropics are often adjacent to areas of high tourism use and boating activity where propeller and anchor scarring are major impacts.

Deepwater

The Wet Tropics is a region with extensive deep water meadows from 15m down to the deepest meadows found at 60m. Muddy sediments extend down to 30m. There is a highly productive inshore region with vast seagrass meadows and valuable fishing grounds. Dugong are able to use these seagrasses for food. Offshore the depth of the seagrass and sand shell bottom suggest little coastal influence (Figure 15). The extent of coastal sediment and nutrient plumes during the wet season and evidence of agricultural chemicals in coastal environments have been recognised as potential threats and are being monitored (Haynes *et al.* 2005).

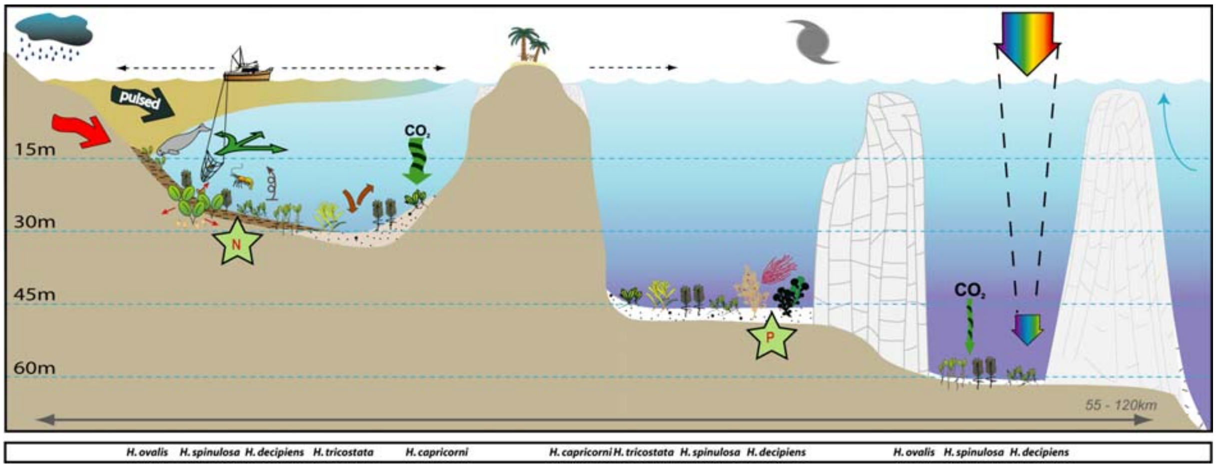


Figure 15. Conceptual diagram of deepwater habitats in the Wet Tropics region – major control light limitation, pulsed turbidity events and nutrients: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Summary of Monitoring Data

Estuarine

Monitoring of estuarine seagrass habitats currently occurs at two locations in the Wet Tropics: Trinity Inlet (Cairns) and Mourilyan Harbour. Annual monitoring of seagrass above ground biomass, species composition and area is conducted for meadows (five in Mourilyan and three in Trinity Inlet) representing the range of seagrass community types found in each estuary. A new baseline survey of estuarine seagrasses at the Herbert River mouth (southern Hinchinbrook) was conducted in March 2007 (see Map 4) and compared to a previous baseline conducted in 1996.

The seagrasses in Mourilyan Harbour are within a relatively enclosed estuary and are highly susceptible to runoff from the Moresby River catchment. A substantial proportion of the catchment is dedicated to intensive cropping such as sugar cane with associated non point source inputs of nutrients, sediments and herbicides. The area also contains an active commercial port that is undergoing expansion and has six aquaculture facilities. The seagrass meadows monitored include a large subtidal *Halodule/Halophila* meadow, two intertidal *Zostera capricorni* meadows and two intertidal *Halophila/Halodule* meadows. Established in 1993, monitoring occurred biannually (July and November) between 1993 and 1997 (McKenzie *et al.* 1998) and annually (December) since 2000 in partnership with the Ports Corporation of Queensland (Thomas & Rasheed 2001; McKenna *et al.* 2007).

The seagrasses of Trinity Inlet estuary are within the southern reaches of Cairns Harbour and annual monitoring (December) has been conducted since 2001 in partnership with the Cairns Port Authority. Two subtidal *Halophila* meadows and a small intertidal *Zostera capricorni* meadow are monitored. The monitoring in Trinity Inlet occurs as part of a broader program that also includes the coastal meadows of Cairns Harbour (Rasheed *et al.* 2007a; McKenna *et al.* 2007).

Intertidal *Zostera* meadows in the Wet Tropics region generally increased in above-ground biomass from 2001 to 2004, while total area of the monitoring meadow remained relatively stable. Since 2004 these meadows show a declining trend in both biomass and area (Figure 16). Intertidal *Halophila* meadows were highly variable in biomass and area between years, but generally declined over the period of monitoring particularly in recent years (Figure 16).

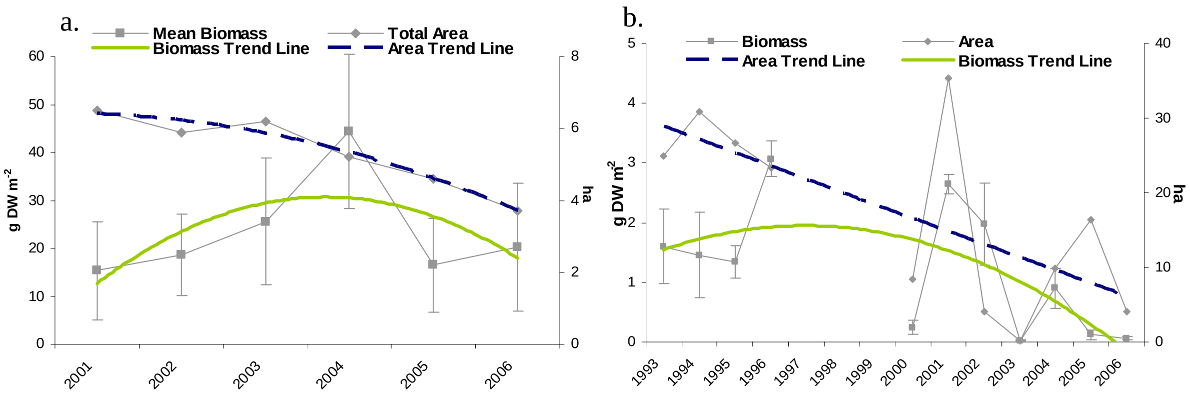


Figure 16. Changes in above-ground biomass and distribution of estuarine intertidal *Zostera* (a) and *Halophila* (a) meadows monitored in the Wet Tropics region from 2001 to 2006.

Above-ground biomass and area of subtidal *Halophila* dominated meadows remained low, but area increased briefly from 2001 to 2003 before declining over the last three years (Figure 17). The subtidal estuarine *Halodule* meadow (Mourilyan Harbour only) was highly variable in biomass and area between 1993 and 1996, and was absent in 2000 when monitoring recommenced after a three year hiatus (Figure 17). From 2000 to 2006 this meadow increased both in biomass and area, but the increase from 2005 to 2006 was accompanied by a major shift in species composition (Figure 18).

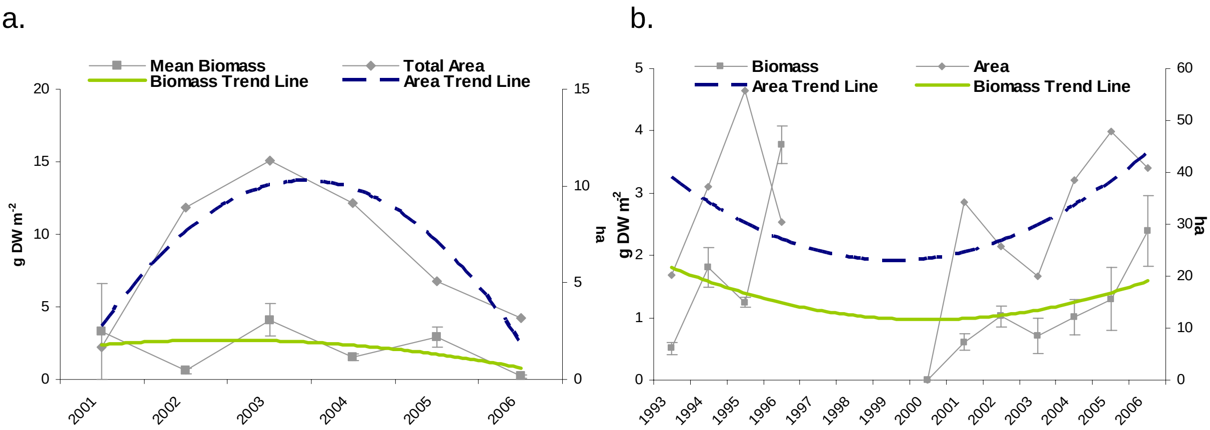


Figure 17. Changes in above-ground biomass and distribution of estuarine subtidal Halophila (a) and Halodule (b) meadows monitored in the Wet Tropics region from 1993 to 2006.

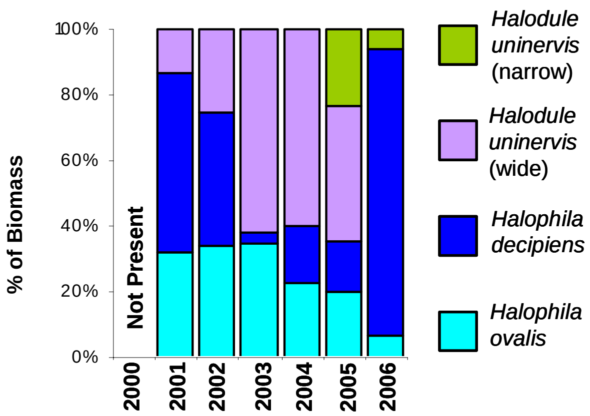


Figure 18. Changes in species composition for the subtidal *Halodule* meadow in Mourilyan Harbour between 2001 and 2006.

In the southern Hinchinbrook/Herbert River estuary, the total area of intertidal seagrass meadows increased between 1996 and 2007, while area of subtidal meadows decreased (Figure 19).

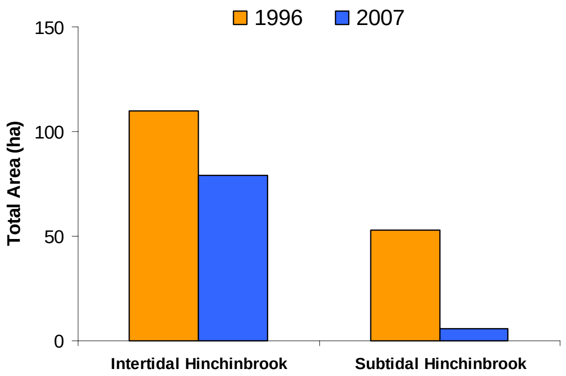
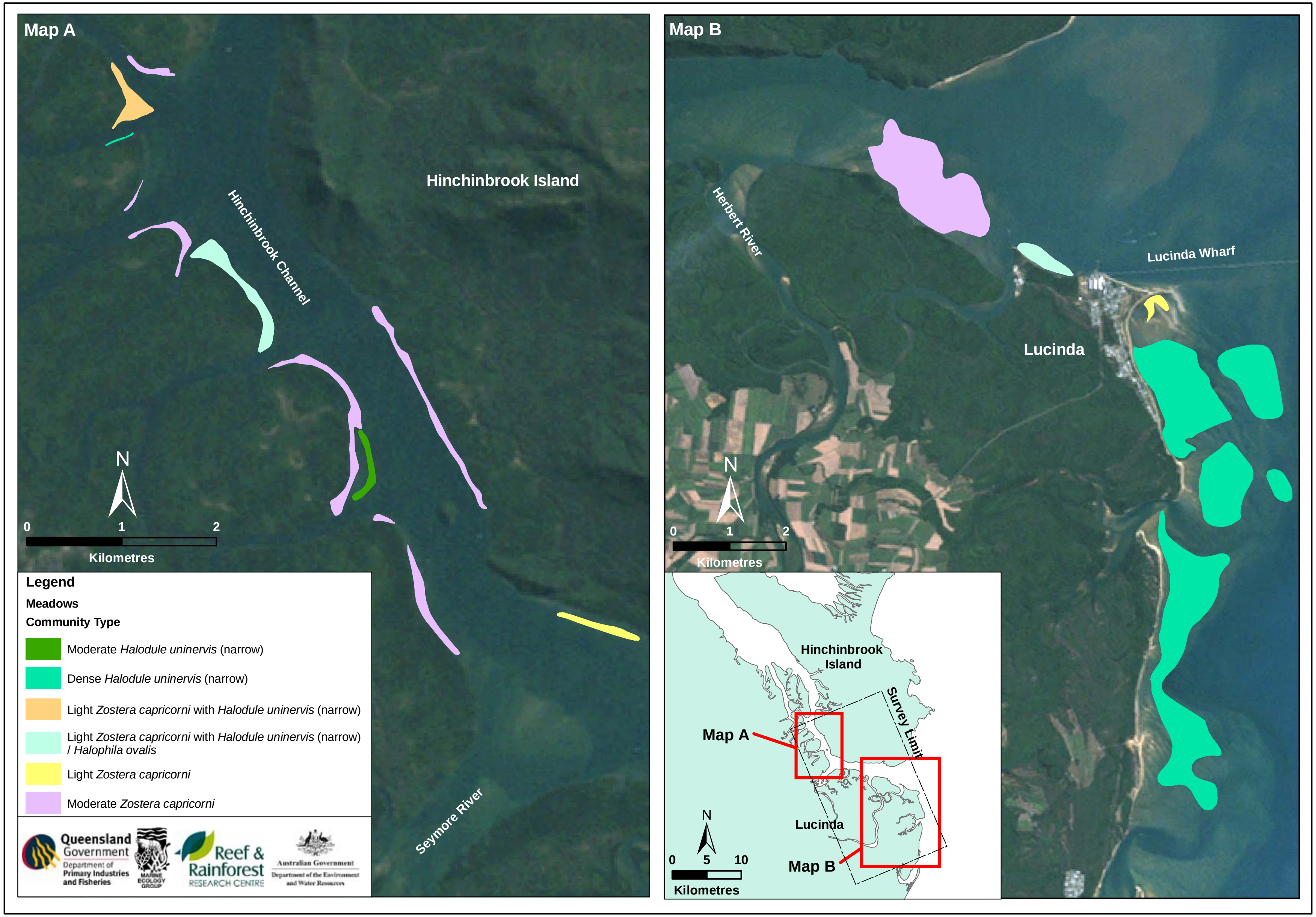


Figure 19. Changes in area of intertidal and subtidal seagrasses between the 1996 and 2007 baseline surveys of the southern Hinchinbrook/ Herbert River mouth region.

Map 4. Seagrass distribution and seagrass community type between Herbert River mouth and Lucinda, southern Hinchinbrook, March 2007.



Coastal

Monitoring of coastal seagrass habitats occurs at four locations in the wet tropics: Yule Point, Cairns Harbour, Lugger Bay and Lucinda. Coastal *Halodule uninervis* meadows are monitored quarterly at Yule Point, between Cairns and Port Douglas (established 2001) and Lugger Bay (Mission Beach) (established in mid-2005) as part of Seagrass-Watch. In Cairns Harbour, annual (December) monitoring has been conducted since 2001 for a large intertidal *Zostera capricorni* meadow and a predominately subtidal *Halodule uninervis* (narrow leaf morphology) meadow. A site (Seagrass-Watch) in the intertidal *Zostera capricorni* meadow at Ellie Point (Cairns) was assessed quarterly from 2001 until 2004 when increased security at Cairns Airport restricted access (McKenzie *et al.* 2006b). In addition, a new baseline survey of coastal intertidal and subtidal seagrasses at Lucinda was conducted in March 2007 (see Map 4) and compared to previous baseline from 1996.

Coastal seagrass meadows at Yule Point and Lugger Bay are located on naturally dynamic intertidal sand banks, protected by fringing reefs. These meadows are dominated by *Halodule uninervis* with some *Halophila ovalis* and are often exposed to regular periods of disturbance from wave action and consequent sediment movement. Abundance at Yule Point appears to follow a typical season pattern (higher in summer than winter) and overall appears relatively stable for the monitoring period (Figure 20).

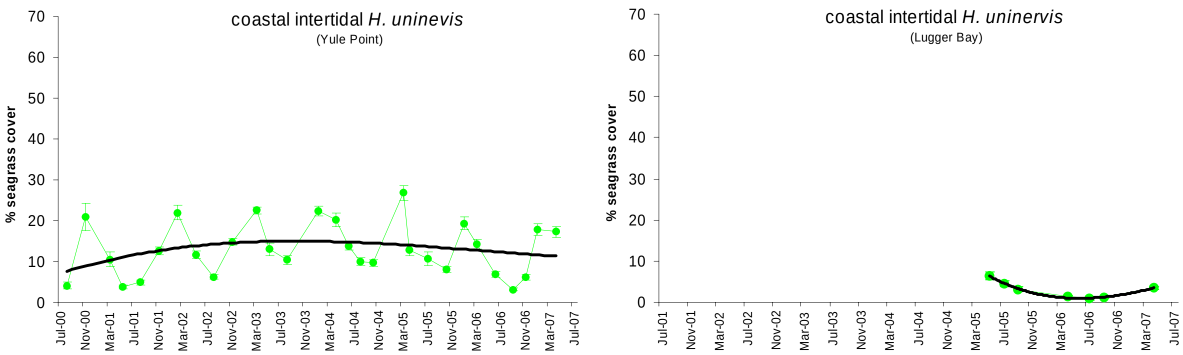


Figure 20. Changes in seagrass abundance (% cover) of coastal intertidal *Halodule uninervis* meadows monitored in the Wet Tropics region from 2000 to 2007.

The large coastal intertidal *Zostera capricorni* meadow on the western side of Cairns Harbour is the only one of its type in the Wet Tropics region. Although area and biomass have fluctuated over the past five years, the overall trend is an increase (Figure 21).

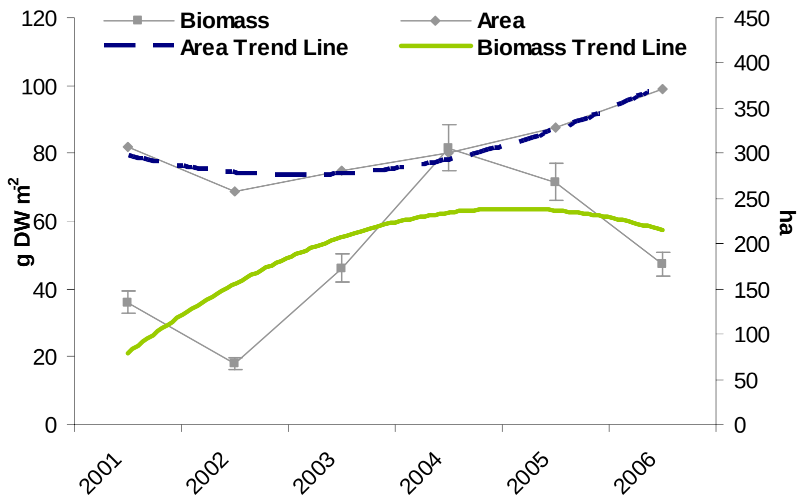


Figure 21. Changes in above-ground biomass and distribution of coastal intertidal *Zostera capricorni* meadows monitored in the Wet Tropics region from 2001 to 2006.

The large subtidal *Halodule uninervis* (narrow leaved) meadow monitored in Cairns Harbour has been increasing in both biomass and area since 2001 (Figure 22). A large increase in the area of the intertidal *Halodule uninervis* (narrow) meadows near Lucinda occurred between the 2007 and 1996 baseline surveys (Figure 23).

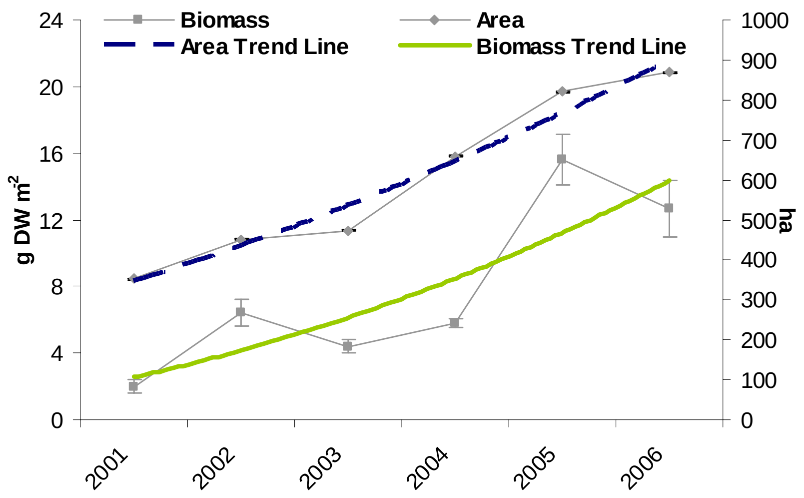


Figure 22. Changes in biomass and distribution of coastal subtidal *Halodule uninervis* (narrow) meadows monitored in the Wet Tropics region from 2001 to 2006.

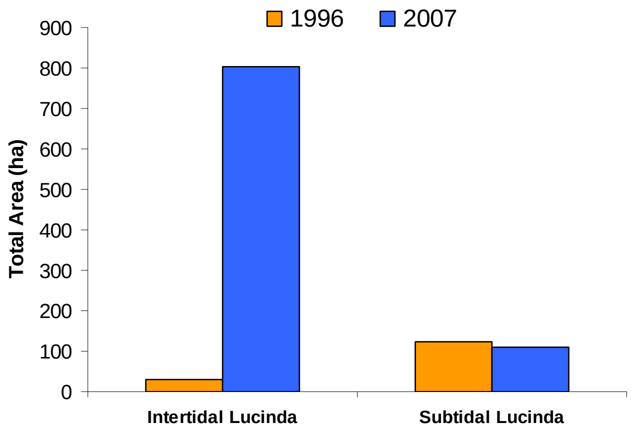


Figure 23. Changes in area of intertidal and subtidal seagrasses between the 1996 and 2007 baseline surveys of the southern Hinchinbrook/ Herbert River mouth region.

Reef

Quarterly monitoring of reef habitats occurs at Green Island, and a new location has been established at Dunk Island (April 2007). Monitoring at Green Island occurs on the large intertidal reef-platform south west of the cay. The meadow is dominated by *Cymodocea rotundata* and *Thalassia hemprichii* with some *Halodule uninervis* and *Halophila ovalis*. The seagrass abundance appears to follow a seasonal pattern, with high cover in the summer and low cover in winter (Figure 24), and no significant changes in species composition were observed.

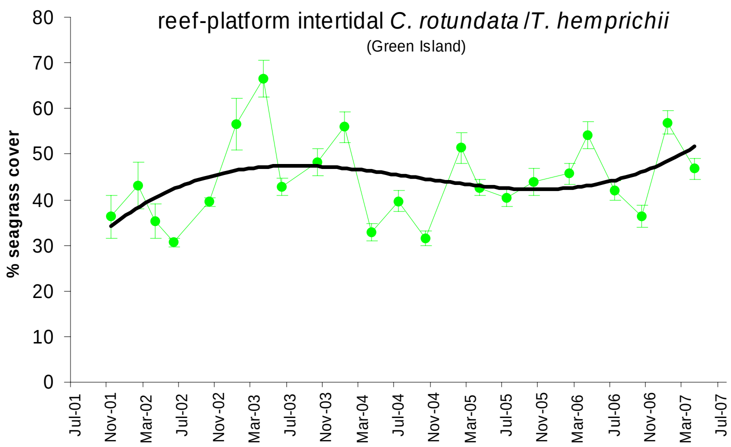


Figure 24. Changes in seagrass abundance (% cover) of intertidal reef-platform *C. rotundata/Thalassia. hemprichii* meadow monitored in the Wet Tropics region from 2001 to 2007.

Deepwater

There is no ongoing seagrass monitoring comparable to the inshore/shallow water programs occurring in deepwater (>15m) in this region. Seagrasses in deep water have been sampled twice, once between 1994 and 1999 and again between 2003 and 2006. The modelled distribution of seagrass species for both time periods shows seagrasses are common in the inter-reef water of the wet tropics (De'ath *et al.* 2007). *Halophila tricostata, Halophila decipiens Halophila ovalis, Halophila spinulosa,* and *Halophila capricorni* were present in both surveys. The annual species *Halophila tricostata* and *Halophila decipiens* are both common in this region and can form extensive meadows. The comparisons for deep water are summarised and discussed in a separate report (De'ath *et al.* 2007).

Climate and Seagrass Change

Climate appears to be one of the major drivers for changes in seagrass abundance, species composition and distribution in the Wet Tropics region. In estuarine habitats, subtidal seagrasses generally expanded into deeper areas during the dry "drought" years of 2002 and 2003 and began to decline in area in subsequent wetter years from 2004 on. The subtidal *Halodule* meadow in Mourilyan Harbour was an exception, but this meadow was already in a process of recovery from its complete flood related loss in 2001 (Thomas and Rasheed 2002). While this meadow had not declined in biomass there had been a shift in species composition to the low-light tolerant species *Halophila decipiens* in 2006. These changes suggest that the distribution of subtidal seagrasses in estuarine areas is being heavily driven by rainfall related turbidity events. Subtidal seagrasses in coastal areas were not affected in the same manner. Their coastal location would generally shield from the majority of direct catchment related runoff or at least expose these more regularly to the influence of relatively clean oceanic water.

In contrast intertidal meadows in coastal areas declined in the hotter and drier drought years of 2002 and 2003 when these meadows were exposed to higher temperatures and solar irradiance during low tide exposure (Figure 25). Unlike subtidal meadows these seagrass areas are particularly vulnerable to thermal stress and desiccation when exposed at low tide. Temperature measurements in the shallow intertidal pools formed at low-tide have confirmed that seagrasses in these areas are experiencing temperatures that are known to be detrimental to seagrass photosystems (Campbell *et al.* 2006). Desiccation and "burning" of intertidal seagrasses leaves at low tide were also observed during seagrass monitoring surveys conducted during the drought years.

Several of the estuarine monitoring meadows in the region (Mourilyan Harbour) were exposed to the effects of category four Tropical Cyclone *Larry* in March 2006. It was likely the acute impacts (wave action, sediment load, and freshwater inputs) of this storm combined with the low resilience of meadows were responsible for a substantial decline of some intertidal seagrasses areas (McKenna *et al.* 2007).

Within canopy temperature was monitored at two locations in the region. Mean temperatures were generally within the 23-30°C range, with highest mean temperatures in the December to February period. Extreme temperatures (41°C) were recorded in January and February, 2004 and 2005 respectively (Figure 26). The maximum temperatures were also recorded in October-November 2005 and 2006, and March-April 2006 and 2007. Temperatures at the coastal and reef-platform locations generally follow a similar pattern.

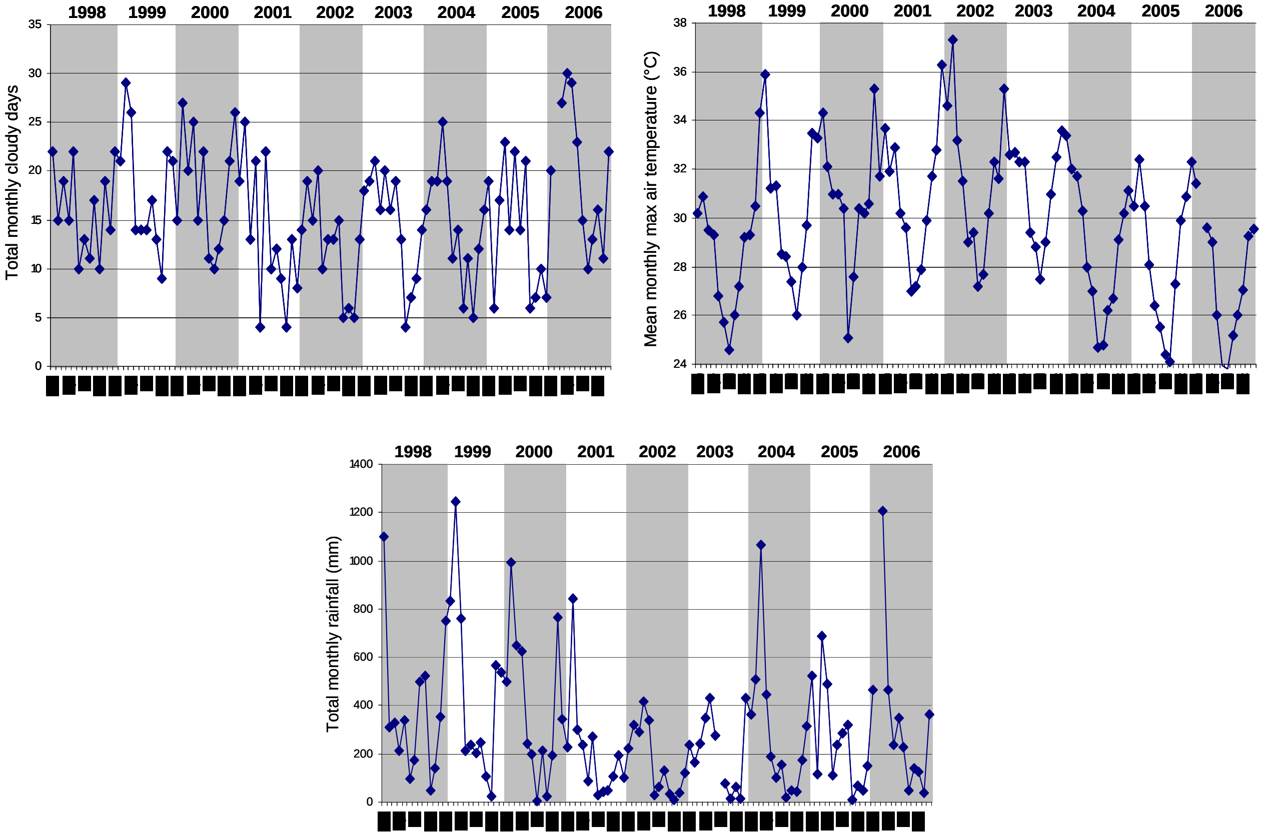


Figure 25. Cloudy days mean monthly maximum temperature and mean monthly rainfall for Mourilyan Harbour in the Wet Tropics NRM 1998-2006.

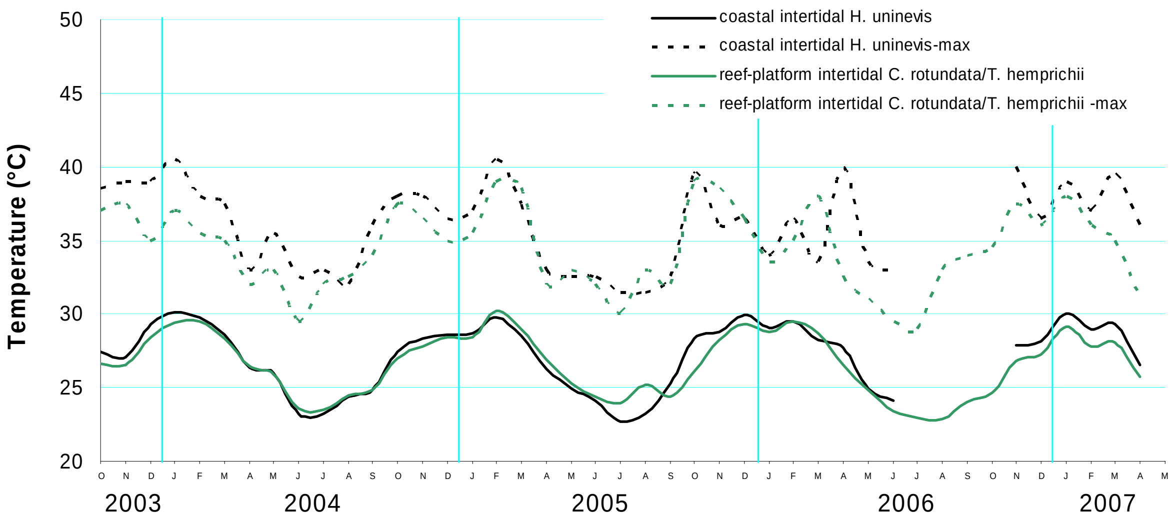


Figure 26. Within seagrass canopy temperature (°C) at intertidal meadows in a coastal and a fringing-reef habitat within the Wet Tropics region.

Associated Macro-fauna

Abundance of associated benthic macro-fauna was examined only at intertidal coastal and reef locations. Benthic macro-faunal abundance is generally low and no seasonal patterns are apparent. There were however, large changes between years (Figure 27). Coastal seagrass habitats were composed of mainly sandy sediments with significant abundances of unidentified gastropods (predominately Trochidae and bivalves), and other macrofauna dominated by predatory starfish (e.g. *Luidia* sp.). Unidentified crabs dominated the decapod fauna, which were also the greater contributors to bioturbation (i.e. crab holes), until mid 2005 when there was an increase in the abundance of acorn worms (Enteropneusta).

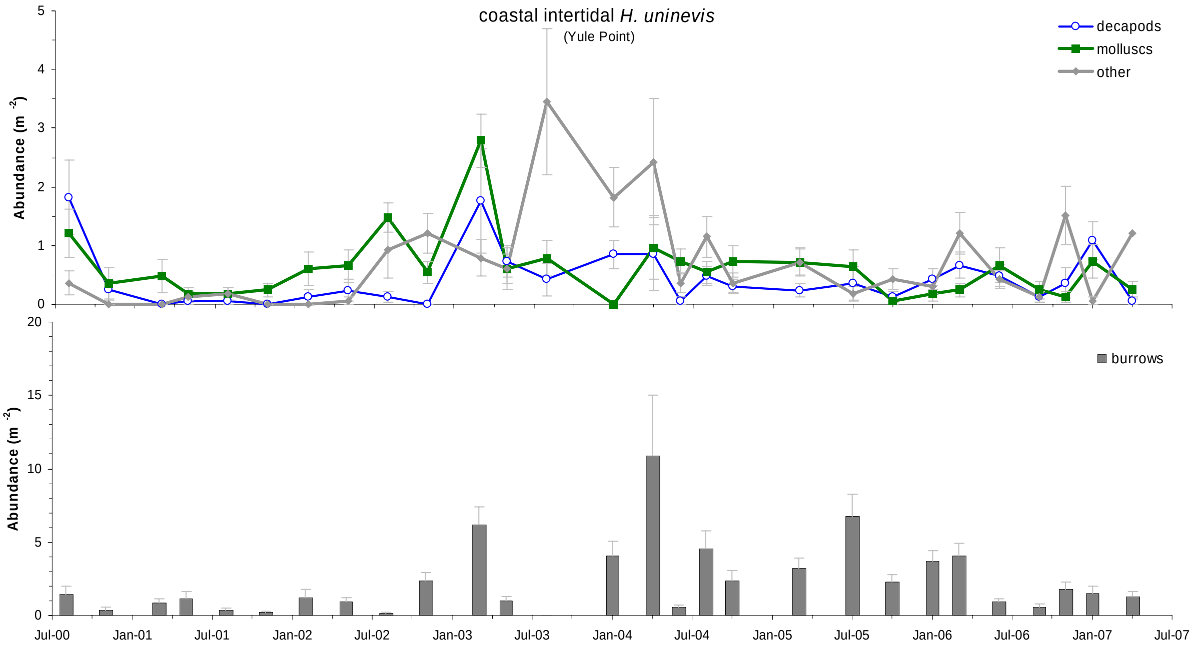


Figure 27. Abundance of associated benthic macro-fauna and bioturbation at the coastal intertidal H. uninervis meadows over the monitoring period.

Reef platform seagrass habitats on Green Island contained large numbers of ascidians which dominated the "other" macrofauna (Figure 28). The holothurian, *Holothuria atra,* was common, and the numbers of burrows (mainly from crabs) varied over the monitoring period.

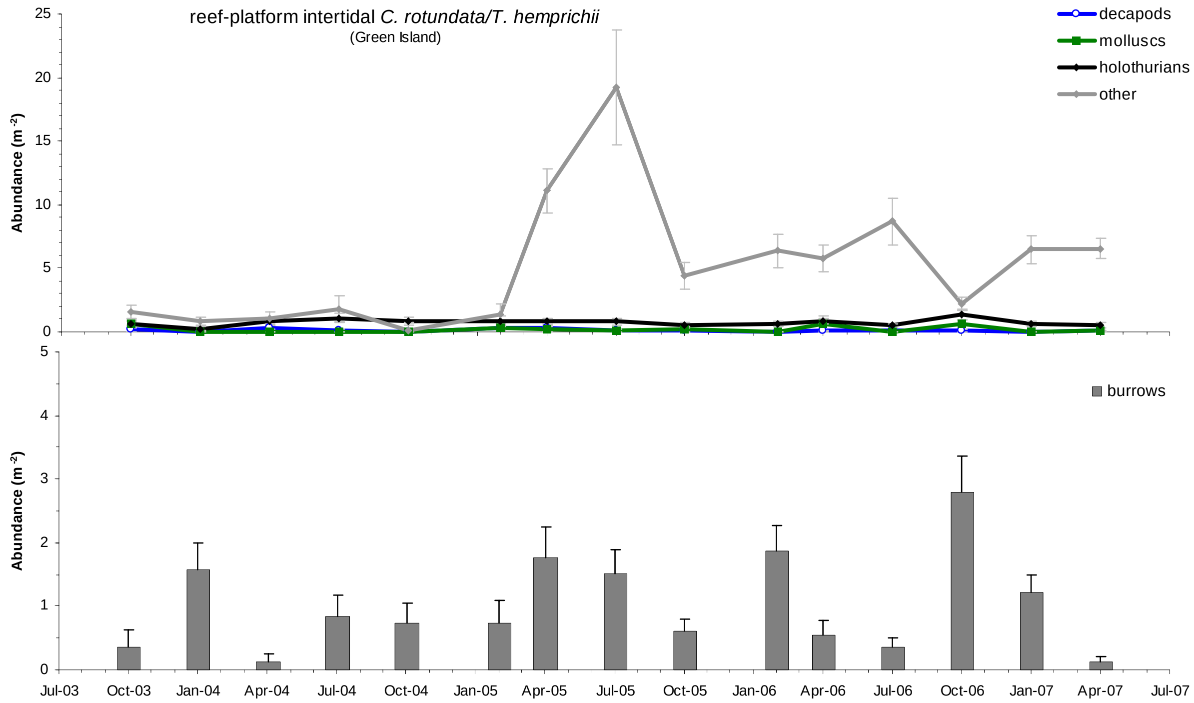


Figure 28. Abundance of associated benthic macro-fauna and bioperturbation at the intertidal reef-platform C. rotundata/Thalassia hemprichii meadow over the monitoring period.

Fisheries

This region includes the fishing ports of Port Douglas and Cairns Harbour and includes inshore reefs as well as estuary regions such as Hinchinbrook Channel that are targeted by recreational fishers. There is a guided fishing tourist industry based in Cairns. Largest commercial catches are from the penaeid prawn fishery, (mostly *Penaeus esculentus, Penaeus semisulcatus, Melicertus latisulcatus,* and *Melicertus longistylus*) with an average value (2002-2006) of $8.0M. Prawn catches in this region have been linked directly to inshore meadow areas (Watson *et al.* 1993). The inshore fin fish fishery reports significant average catches (2002-2006) of 879 tonnes worth an average of $5.3M per year. There is a significant estuarine mud crab fishery of 98 tonnes worth an average of $1.0M per year reflecting the extensive inshore mud banks, seagrass meadows and intact mangrove systems in this region. Trends over the five years are mixed with the increases in tiger prawns, mud crab and some species of fin fish, and a decrease in king prawns (Figure 29).

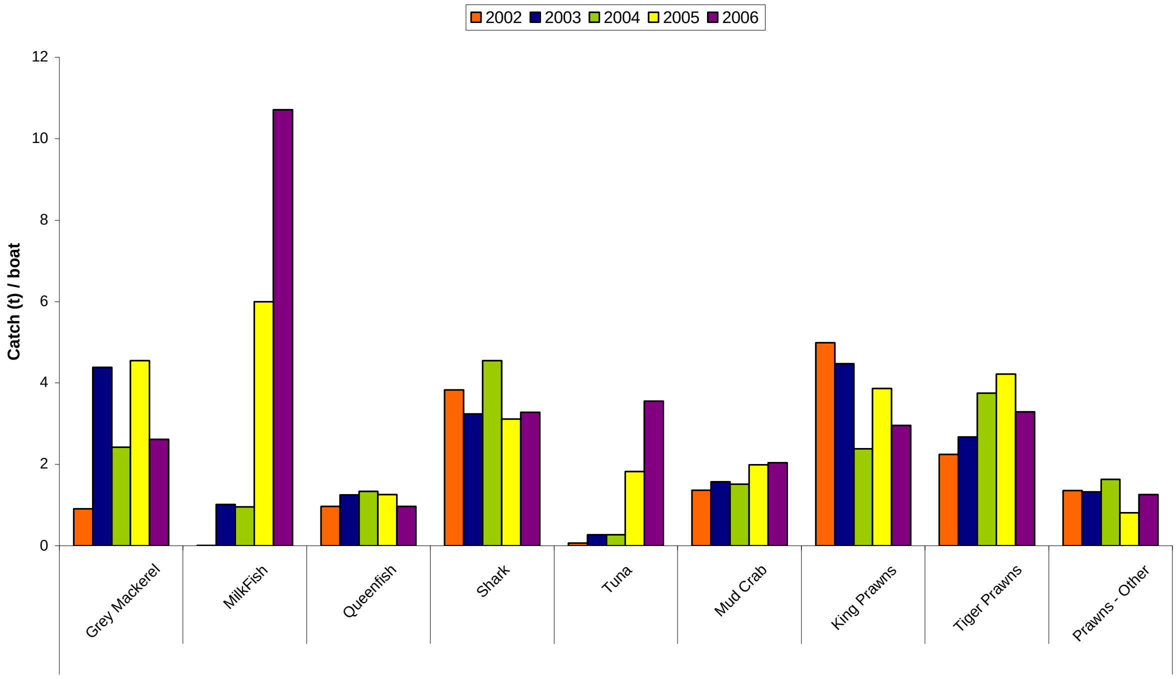


Figure 29. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Wet Tropics NRM region between 2002 and 2006.

Regional Summary

Seagrasses in the Wet Tropics NRM region appeared to be in a relatively healthy state. In 2006 coastal intertidal meadows had generally expanded with *Zostera* meadows at their largest aerial extent and evidence of expansion of intertidal *Halodule uninervis* meadows. Subtidal seagrasses in coastal areas had also expanded in area and biomass in 2006. The major drivers of seagrass changes were likely to be linked to changes in regional and local climate, especially temperature, rainfall and associated turbid catchment runoff and tidal exposure. Differences in seagrass changes were apparent between coastal and estuarine habitats and between intertidal and subtidal seagrasses with the majority explained by the differing effects of the major climate forcing factors in the different habitat types.

The seagrass at Yule Point and Lugger Bay appears to have changed relatively little since 1967, when den Hartog (1970) photographed the area and described the species present and sediment condition. At Lugger Bay however, seagrass cover was generally low (< 10%), which is similar to observations in the early 1990s at this location (Mellors *et al.* 2005). The decline of seagrass at Lugger Bay in 2006 appears a consequence of severe TC Larry, which crossed the coast 50km north of the location on 20 March 2006. No significant changes in species composition were observed at either of the locations (McKenzie *et al.* 2006b).

Despite the severe cyclone in March 2006 seagrasses in Mourilyan Harbour were able to recover to some extent by December 2006. Even a small *Zostera capricorni* meadow that was close to being completely lost had shown the first signs of recovery (McKenna *et al.* 2007). Should climate conditions remain favourable for seagrass growth, these meadows should continue to recover. However, the resilience of meadows to additional stresses in the near future is likely to be low with intertidal seagrasses particularly vulnerable.

Information Gaps

- There is a need for collection of baseline data for seagrasses in the northern section of the Wet Tropics region, north of Yule Point.
- Good baseline information has been collected for seagrasses in the southern section of the region between Hinchinbrook and Lucinda in 2007 but at this stage ongoing long-term monitoring is unfunded.
- There is a need for further research and detailed analysis of the links between climate and seagrass change. While it appears that the key factors of rainfall, temperature, solar irradiance and exposure may be driving the observed seagrass changes, formal analysis of these links is required.

Burdekin Dry Tropics

Background

The Burdekin Dry Tropics region, includes an aggregation of the Black, Ross, Haughton, Burdekin and Don River catchments and includes several smaller coastal catchments, all of which empty into the Great Barrier Reef lagoon (NRM 2007a). Because of its geographical location, rainfall in the region is lower than other regions within tropical Queensland. Annual rainfall averages approximately 1,150 mm from on average 91 rain days. However, there is considerable variation from year-to-year due to the sporadic nature of tropical lows and storms. Approximately 75% of the average annual rainfall is received during December to March (Schletinga and Heydon 2005).

Major threats to seagrass meadows in the region include: coastal development (clamation; changes to hydrology, water quality declines (particularly nutrient enrichment or increased turbidity); downstream effects from agricultural (including sugarcane, horticultural, beef), industrial (including refineries) and urban centres (Scheltinger and Heydon 2005; Haynes *et al.* 2001).

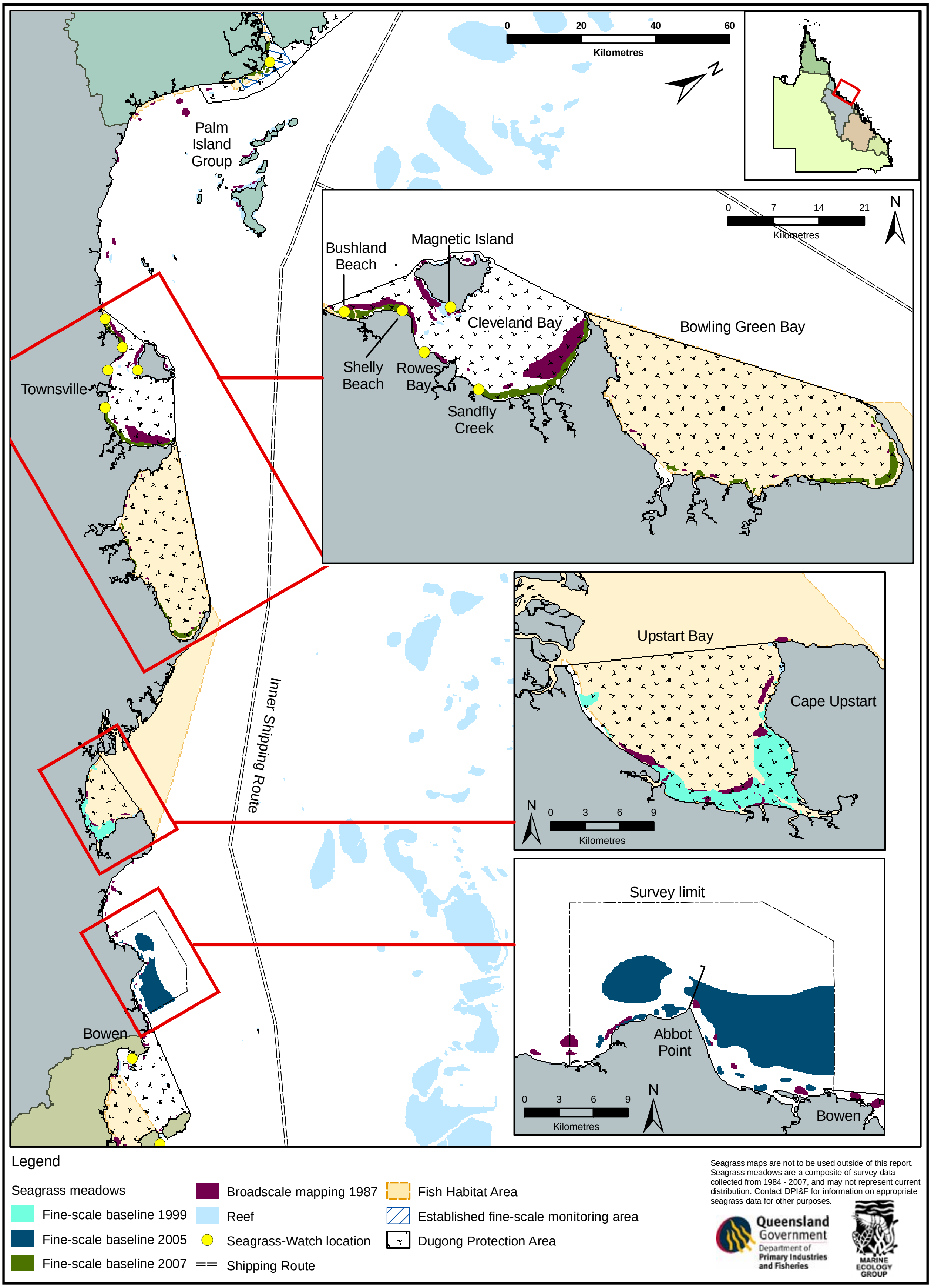
Intertidal seagrasses and shallow subtidal seagrasses predominate in this region and tend to form multi-specific beds that are arranged in mono-specific bands across a depth gradient, with either *Halophila ovalis/minor* or *Halodule uninervis* (narrow leaved)/*Halodule pinifolia* dominating the intertidal reaches. Extensive seagrass meadows occur in Upstart, Cleveland, and Bowling Green Bays and off Magnetic Island. Twelve species have been found within this region (Lee Long *et al*. 1993, 1996a). Deep water seagrasses are found in this region but are not as common or as dense as they are further north (Coles *et al.* 2000). Most fringing reefs associated with continental islands support moderately dense mixed species meadows (especially *Cymodocea serrulata*), which are not restricted to the confines of fringing reefs, but are also found in sheltered bays at continental islands or coastal localities.

Based on the mapped seagrass areas, the majority of seagrass meadows in the Burdekin region are within coastal habitats (Table 4). Of these, 22% are protected within declared Fish Habitat Areas and 8% are located within port boundaries. Only 4% of seagrass meadows (excluding deepwater) covered by the highest levels of protection zones of the GBRWHA

Table 4. Area (km^2) of seagrass within each habitat type, port area and marine protected zone of the Burdekin Dry Tropics region. Deepwater seagrass distribution has been excluded as maps are surface probability models and not comparable to other datasets. Shaded areas afford highest levels of protection for seagrass (cells are not additive due to overlaps among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	11.59	0.00	1.28	4.53	13.22	0.00	0.00	0.00	0.00	0.00	0.00	**19.03**
Coast	46.21	26.89	76.09	20.41	129.85	0.00	0.31	11.56	0.00	0.00	0.00	**265.08**
Reef	0.00	0.00	0.00	0.37	4.92	0.00	0.00	0.08	0.00	0.00	0.00	**5.37**

Map 5. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Burdekin Dry Tropics NRM region.



Conceptual Summary

All four of the generalised seagrass habitats are represented in the Burdekin region. The GBRWHA lagoon of this region is quite wide with the true reef system being quite a distance (approximately 100 km) from the coast

Estuarine

The major estuarine meadows within this region are in open estuaries/inlets and tend to be continuous with the coastal meadows. Both tidal and subtidal distributions are heavily influenced by their proximity to creeks and rivers. Delivery of freshwater and suspended solids, including clays, colloids, fine organic matter, is the major impact to all meadow types in this habitat (Figure 30). This influence extends beyond the estuarine zone during high flow events. Of the total sediment being delivered to the GBRWHA lagoon, the long term average discharge of sediment from this region represents 20%-40% (Burdekin Dry Tropic Board 2005). The major impact of terrestrial run-off on near-shore environments occurs during cyclones or heavy monsoonal rains and is only delivered during infrequent flooding events. Relatively low sediment discharge occurred over the intervening years. During flood events these meadows are subject to scouring, a combination of fast flow and course sediments. The meadows are productive nursery areas, particularly the southern parts of Cleveland and Bowling Green Bay as these are areas targeted by commercial and recreational fishers.

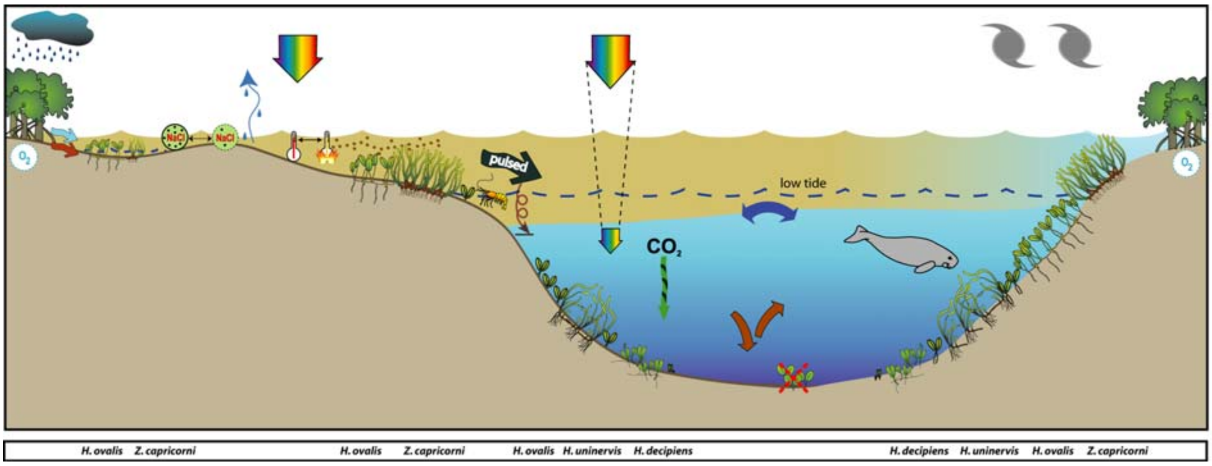


Figure 30. Conceptual diagram of Estuary habitats in the Burdekin Dry Tropics region – major control is pulsed terrigenous runoff: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Coastal

Coastal seagrass habitats in the Burdekin support intertidal and subtidal seagrasses with intertidal coastal meadows representing significant food resources for dugongs and green turtles and nursery grounds for fisheries. The meadows within the Cleveland, Upstart and Edgecumbe Bays support large populations of juvenile commercial prawns (Coles *et al.* 1989). Sediments within this habitat are mud and sand that have been delivered to the coast during the episodic peak flows of the creeks and rivers (notably the Burdekin) in this area. These sediments are trapped in the north-facing embayments which become the long term repositories of terrestrial sediment and contaminants. Whilst episodic riverine delivery of freshwater nutrients and sediment is a medium time scale factor in structuring these coastal seagrass meadows, it is the wind-induced turbidity of the coastal zone that is likely to be a major short term driver (Figure 31). In these shallow coastal areas waves generated by the prevailing SE trade winds are greater than the depth of water, maintaining elevated levels of suspended sediments, limiting the amount of light availability for photosynthesis during the trade season. Intertidal seagrasses can survive this by photosynthesizing during periods of exposure, but must also be able to cope with desiccation.

A significant feature in this region is the intrusion of ground water into marine coastal sediments and its potential to influence seagrass distribution through nutrient supply.

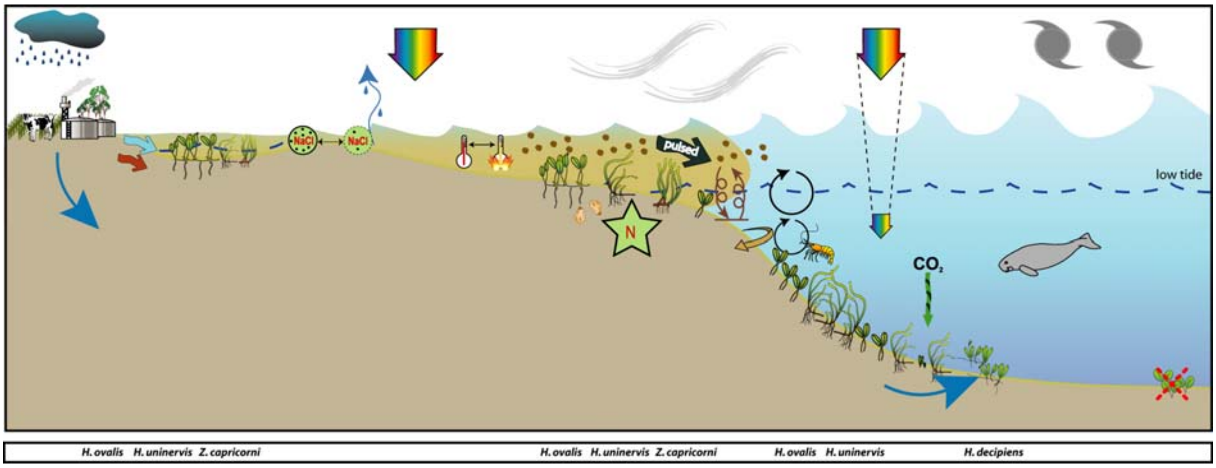


Figure 31. Conceptual diagram of coastal habitat in the Burdekin Dry Tropics region – major control is wind and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Reef

Reef habitats are mainly represented by intertidal and subtidal meadows associated with the fringing reefs on the many continental islands within this area. Seagrass meadows are virtually non-existent on barrier and patch reef platforms, possibly because of the lack of available nutrients being delivered due to their distance from coastal influences. Most fringing reefs however have seagrass meadows growing on their intertidal flats. Nutrient supply to these meadows is by terrestrial inputs via riverine discharge, re-suspension of sediments and groundwater supply (Figure 32). The meadows are typically composed of zones of seagrasses. *Cymodocea serrulata and Thalassia hemprichii* often occupy the lower intertidal/subtidal area, blending with *Halodule uninervis* (wide leaved) in the middle intertidal region. *Halophila ovalis* and *Halodule uninervis* (narrow leaved) inhabit the upper intertidal zone.

Studies from overseas have often implicated phosphate as the nutrient most limiting to reefal seagrasses (Short *et al.* 1990; Fourqurean *et al.* 1992). Experimental studies on reef top seagrasses in this region however, have shown seagrasses to be nitrogen limited primarily with secondary phosphate limitation, once the plants have started to increase in biomass (Mellors 2003). In these fringing reef top environments, fine sediments are easily resuspended by tidal and wind generated currents, making light availability a driver of meadow structure.

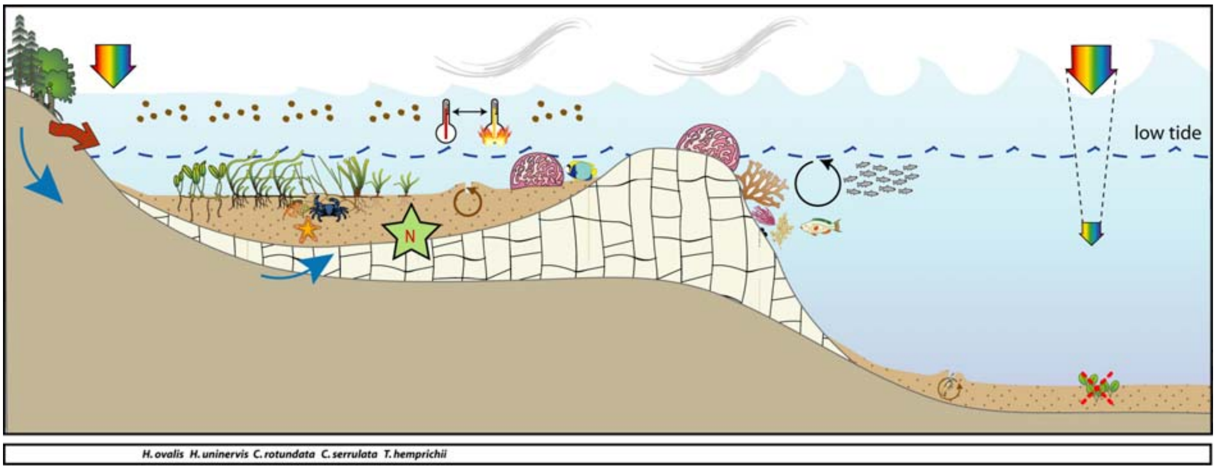


Figure 32. Conceptual diagram of fringing reef habitat in the Burdekin Dry Tropics region – major control is nutrient supply (groundwater), light and shelter: general habitat and seagrass meadow processes (*See Figure 3 for icon explanation*)

Deepwater

The Burdekin deepwater seagrass habitat is similar to the Wet Tropics region with extensive deep water meadows from 15m down to approximately 60m (Figure 33). The Burdekin River is a major source of pulsed sediment and nutrient input. Muddy sediments extend down to 30m. Dugong are able to use these shallow seagrasses for food. Offshore the depth of the seagrass and sand shell bottom suggest little coastal influence.

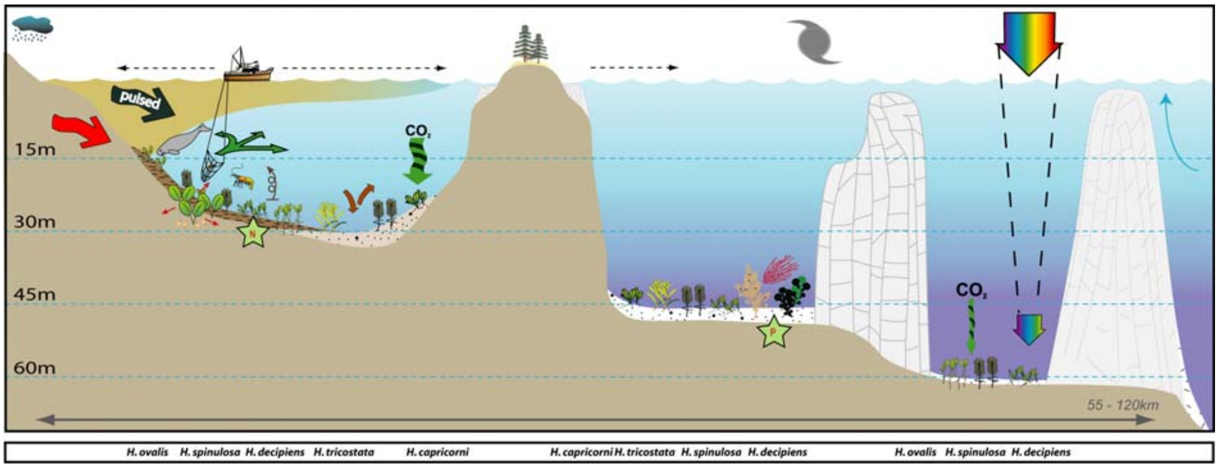
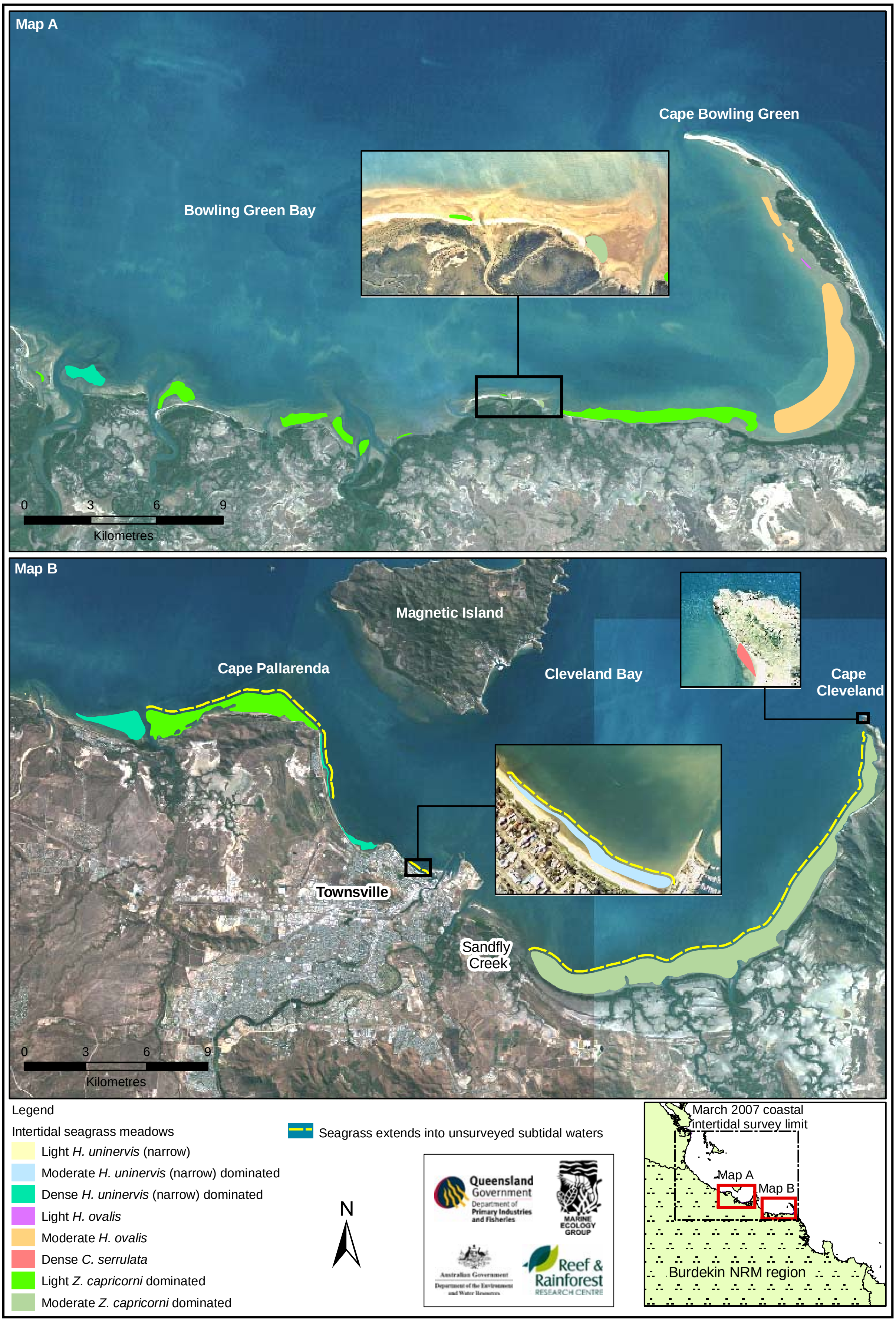


Figure 33. Conceptual diagram of deepwater habitat in the Burdekin Dry Tropics region – major control is light availability (turbidity) and nutrients: general habitat and seagrass meadow processes (*See Figure 3 for icon explanation*).

Summary of Monitoring Data

Monitoring of coastal seagrass habitats with volunteer groups occurs at 11 sites within seven locations of the Burdekin Dry Tropics: Lucinda (1), Bushland Beach (1), Shelley Beach (2), Rowes Bay (2), Magnetic Island (2), Sandfly Creek (2) and Bowen (1). In addition, a new baseline survey of coastal intertidal seagrass meadows for the northern half of this NRM region (Lucinda to Cape Bowling Green) was conducted in March 2007 (Map 6).

Map 6. Intertidal seagrass distribution and seagrass community type between Lucinda and Cape Bowling Green, March 2007.



Estuarine

The only estuarine site monitored in this region was at Sand Fly Creek (Cleveland Bay). Due to the difficulty in accessing this site (boat access required) data available is insufficient to describe long-term trends (McKenzie *et al.* 2006b). Early data collected from this site indicated that the patchy distribution of *Zostera capricorni* abundances showed a typical seasonal pattern (higher in late spring-summer than winter). The recent baseline survey (March 2007) over this site shows the cover of seagrass has increased to a moderate level with the meadow being fringed into subtidal areas by *Halodule univervis* (narrow leaved) (Map 6).

Coastal

The coastal locations monitored in the Burdekin Dry Tropics region were mostly located on the southern shores of Halifax Bay and Cleveland Bay. The most northern location is at Bushland Beach, while the replicate site is located at nearby Shelley Beach (Cape Pallarenda). Additional sites are monitored at Rowes Bay and Port Dennison (Bowen), however monitoring is ad hoc and sites were only recently established. These intertidal meadows are typically dominated by *Halodule uninervis,* with *Halophila ovalis* and intermittent patches of *Zostera capricorni.* Shelley Beach and Bushland Beach are sites that have the longest time series for data sets for this region.

These meadows were first monitored after being decimated by Tropical Cyclone *Tessi* in 2000 (Mellors and Waycott 2000) (Figure 34). Trends of seagrass cover within these meadows show an increase in cover as the meadow recovers after disturbance with a leveling out as the seagrass meadow oscillates around a seasonal pattern (Figure 34). A decline in cover has been recorded for the Shelly Beach site (Figure 34). This decline was likely caused by a shift in sediments and blow outs due to scouring by strong winds and tidal flow displacing the seagrass. Species composition has not changed within the sites, however other seagrass species have started to appear nearby. Notably, within the Shelley Beach sites *Halophila spinulosa* has been observed in tidal pools and more recently *Cymodocea serrulata* has started to colonise.

These sites are located on naturally dynamic intertidal sand flats and are subject to sand waves and erosion blowouts moving through the meadows. The Shelley Beach area is a sediment deposition zone, so the meadow must also cope with incursions of sediment carried by longshore drift. The meadows are frequented by dugongs and turtles as verified from by feeding trials and scars. These meadows are visited regularly by recreational fishers.

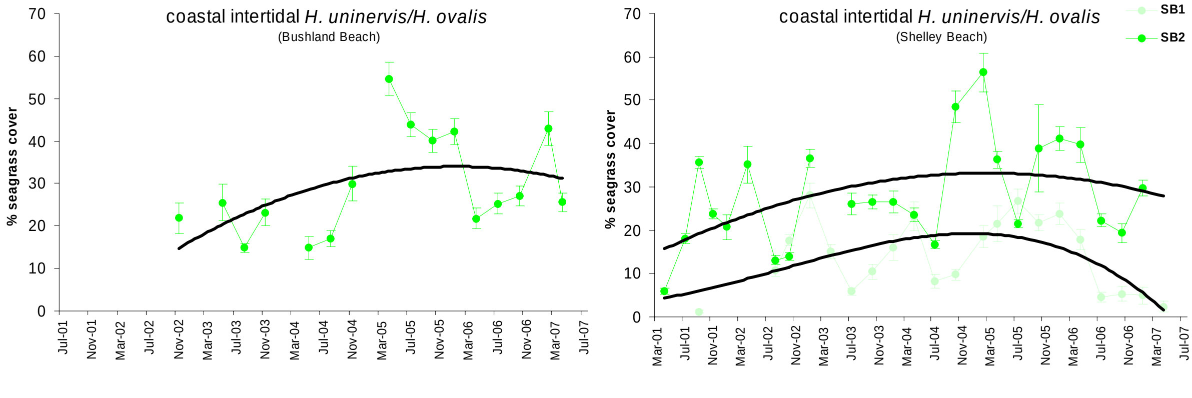


Figure 34. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Burdekin Dry Tropics region.

Reef

Reef habitats are monitored on the fringing reef flats of Magnetic Island. Picnic Bay was dominated by *Halodule uninervis* with *Halophila ovalis*. The adjacent Cockle Bay was dominated by *Halophila ovalis* with *Cymodocea serrulata/ Thalassia hemprichii/ Halodule uninervis* (Figure 35). Due to the paucity of data, it is difficult to describe a seasonal pattern in seagrass cover with sufficient certainty (Figure 35).

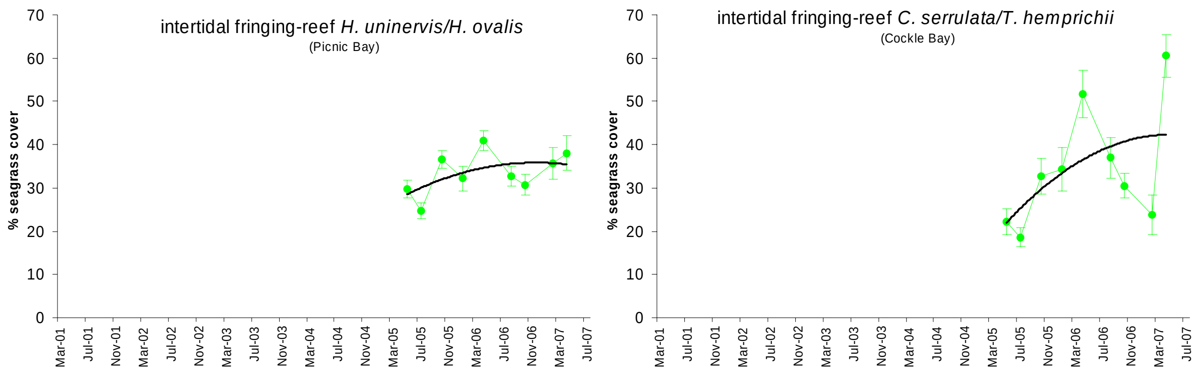


Figure 35. Change in seagrass abundance (percentage cover) at intertidal meadows on fringing reef platforms in the Burdekin Dry Tropics region.

Deepwater

There is no ongoing seagrass monitoring comparable to the inshore/shallow water programs occurring in deepwater (>15m) in this region. Seagrasses in deep water have been sampled twice, once between 1994 and 1999 and again between 2003 and 2006. The modelled distribution of seagrass species for both time periods shows *Halophila spinulosa, Halophila tricostata* and *Halophila ovalis* were common in inter-reef waters with other *Halophila* species also present. The comparisons for deep water are summarised and discussed in a separate report (De'ath *et al.* 2007).

Climate

Climate in the region from 2002 to 2005 was hotter and drier with fewer cloudy days (higher irradiance) than from 1999 to 2001 (Figure 36). In 2006 climate conditions had returned to be similar to those prior to 2002 with cooler air temperatures and an increase in rainfall and cloud cover.

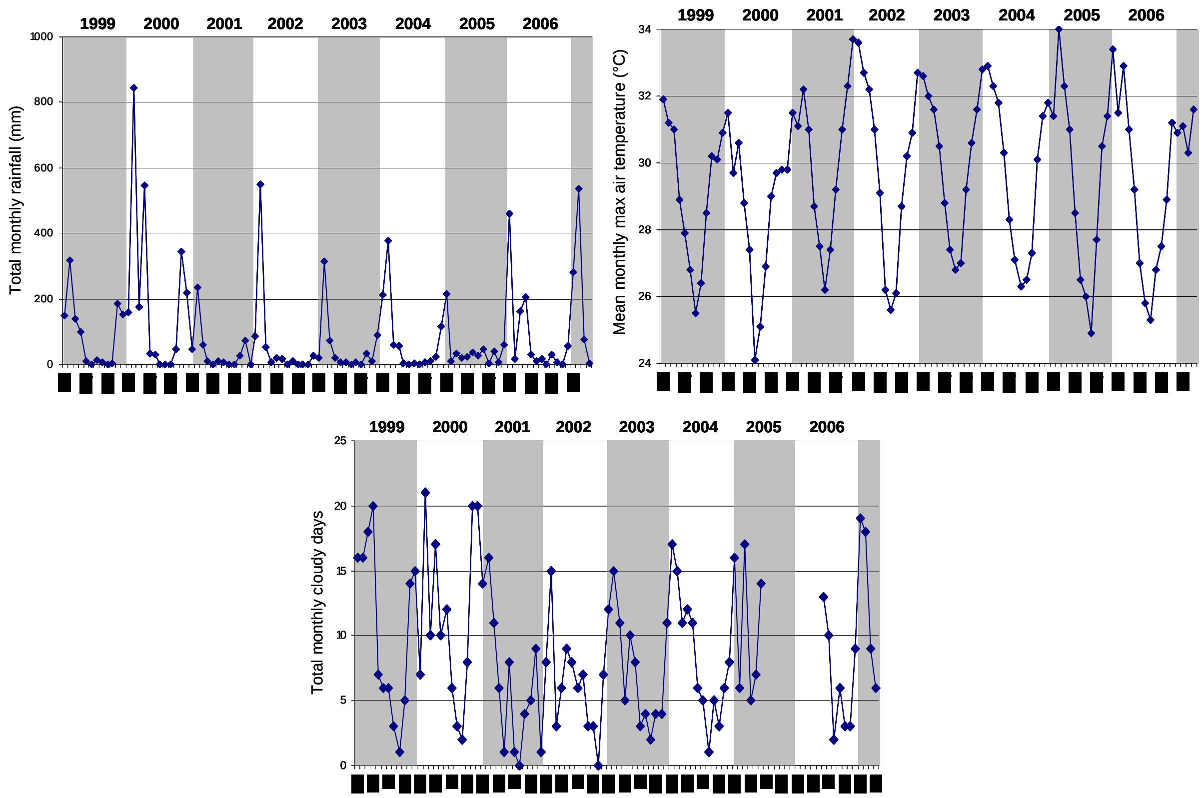


Figure 36. Cloudy days mean monthly maximum temperature and mean monthly rainfall for Townsville in the Burdekin Dry Tropics NRM 1999-2006.

Within canopy temperature was monitored at coastal and reef-platform locations, and generally follow a similar pattern (Figure 37). Mean temperatures were mostly within the 22-30°C range, with highest mean temperatures in the January to March period. Extreme temperatures (41°C) were recorded in February 2004. Maximum temperatures peaked several times throughout the year, generally in February-March, June-July (as a result of exposure at low tide) and October-November.

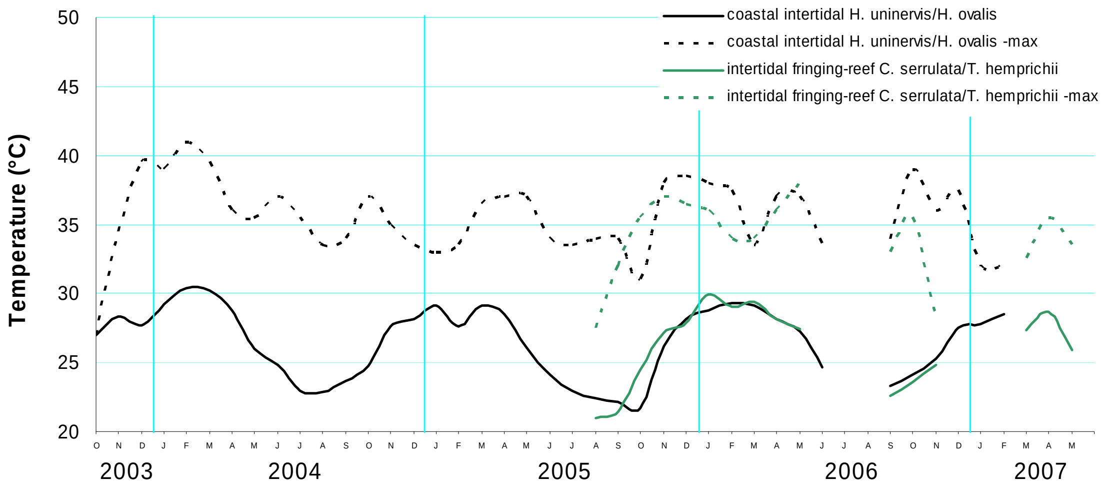


Figure 37. Within seagrass canopy temperature (°C) at intertidal meadows in a coastal and a fringing-reef habitat within the Burdekin Dry Tropics region.

Associated Macro-fauna

Macrofaunal abundance was generally low until early 2005 when the number of crabs increased, resulting in increased bioturbation (crab holes were the major contributor) (Figure 38). Similarly, a slight increase in molluscs (mainly unidentified gastropods) was observed from early 2005, although abundances were variable.

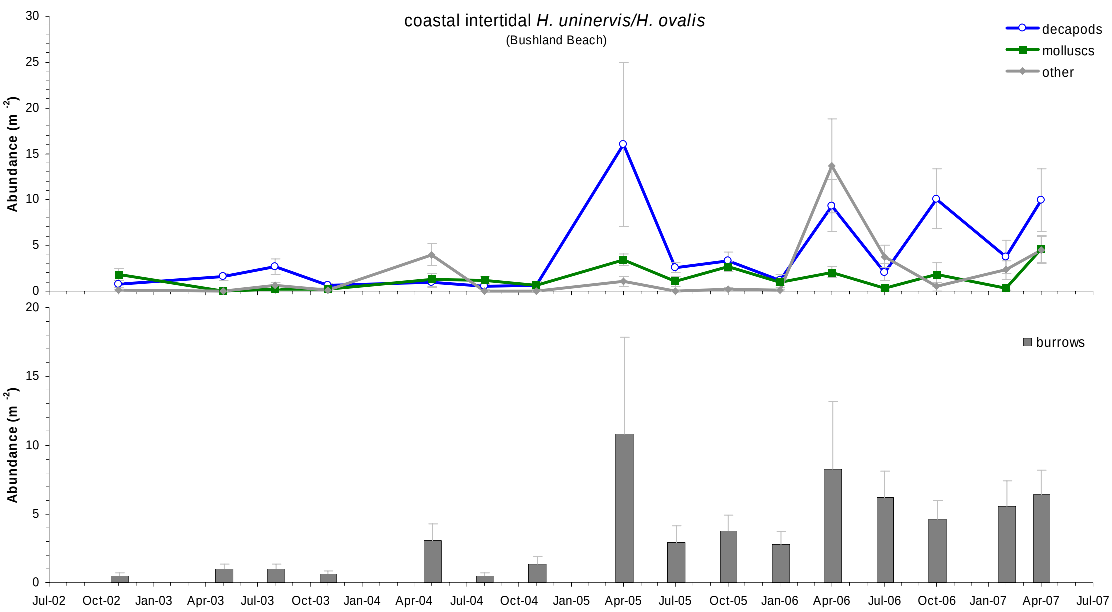


Figure 38. Abundance of associated benthic macro-fauna and bioturbation in a coastal intertidal *Halodule uninervis / Halophila ovalis* habitat over the monitoring period.

The fringing reef-platform seagrass habitats were dominated by unidentified gastropods, which peaked in abundance in early 2006 (Figure 39). The remaining macrofauna were dominated by decapods crabs with few holothurians.

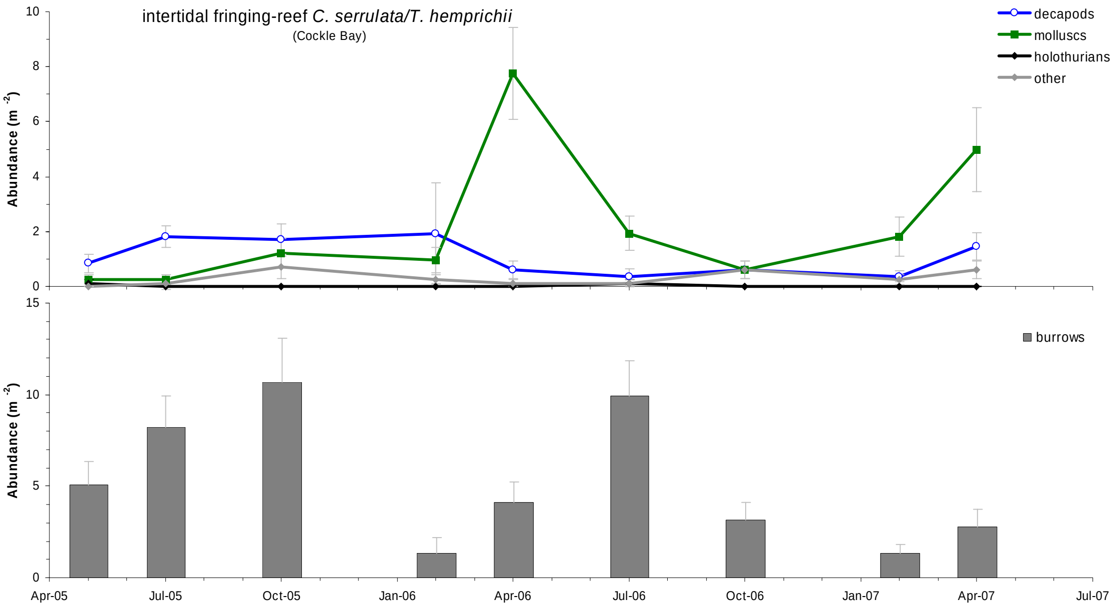


Figure 39. Abundance of associated benthic macro-fauna and bioturbation in an intertidal *Cymodocea serrulata /Thalassia hemprichii* meadow on a fringing reef habitat over the monitoring period.

Fisheries

The region includes the fishing ports of Townsville and Bowen. Average catches per year are 876 tonnes for fish, 351 tonnes for prawns and 68 tonnes for crabs valued at $5.8M, $4.2M and $0.714M respectively. Catch rates have varied over the five years particularly for the larger fishes with no clear trends. Prawn catches in the region are predominately king prawns (*Melicertus latisulcatus, Melicertus longistylus* and *Melicertus plebejus*) reflecting the more southern distribution of prawn species. King prawn catch increased dramatically in 2006, more than doubling that of any other year, while tiger prawn catch decreased to be at its lowest since 2002 (Figure 40).

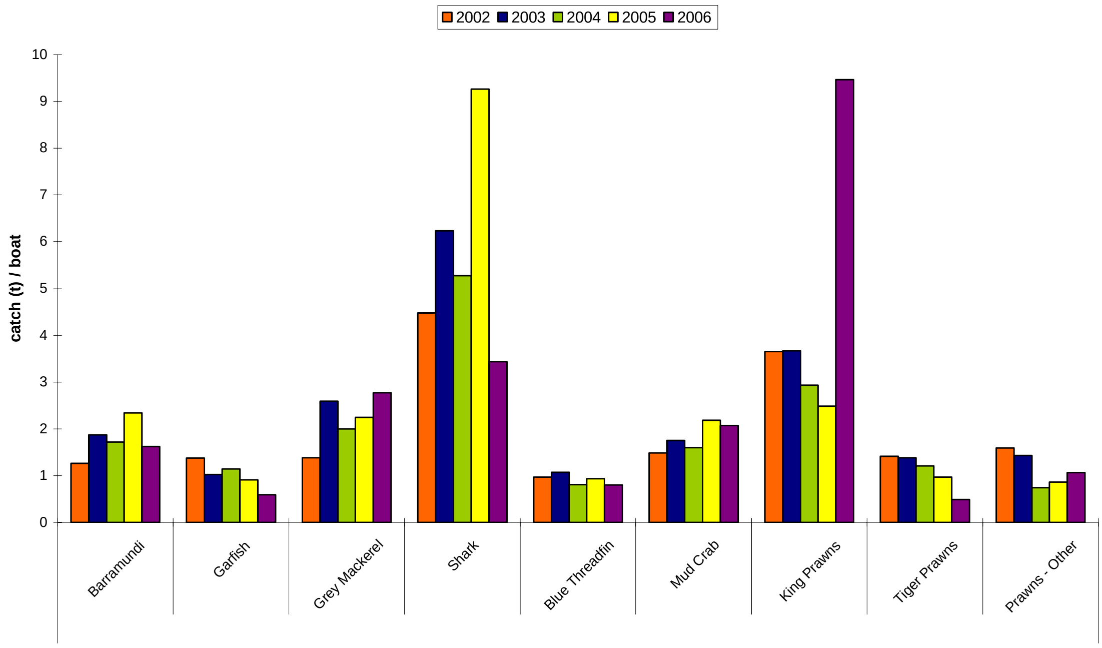


Figure 40. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Burdekin NRM region between 2002 and 2006.

Regional Summary

Seagrasses monitored in the Burdekin NRM region appeared to be in a relatively healthy state in 2006. Intertidal meadows that were affected by Tropical Cyclone *Tessi* in 2000 had recovered within a relatively short period (approximately 18 months). This indicates that intertidal meadows had a good capacity for recovery and resilience to periodic disturbances. Reef top meadows have only been monitored since 2005 but were relatively stable over that time. Accompanied with the recent stability in these meadows, there has been a shift in seagrass species composition consistent with successional change (Birch and Birch 1984).There have been some small and mostly temporary losses of seagrass associated with the Townsville port and esplanade developments.

Broad scale surveys of intertidal seagrasses in 2007 indicated that there has been an increase in the areal extent of these meadows since 1987. Plans for major reclamations and industrial developments in the Townsville region have the potential to impact on seagrasses.

Other threats faced by seagrasses in the region are those associated with flood discharge from the Burdekin River which although only episodic events provide fine sediments which can then be resuspended as wind induced turbidity. Currently there is no regular monitoring of subtidal seagrasses or changes to meadow area and distribution in the region.

Information Gaps

- No regular monitoring information is collected in the region on the status of sub-tidal seagrasses or changes to area of representative seagrass meadows.
- A fine scale monitoring program for meadows in the high risk Townsville/Cleveland Bay area (Rasheed 2007b) would add significantly to our understanding of the status of seagrasses in the region.

Mackay – Whitsunday

Background

The Mackay - Whitsunday region comprises an area of almost 940,000 ha of coastal land. It includes the major population centres of Mackay, Proserpine, Airlie Beach and Sarina, and encompasses the Proserpine, O'Connell, Pioneer and Plane Creek river systems (NRM 2007d). The region's climate is humid and tropical with hot wet summers and cool dry winters. Annual rainfall varies significantly with as much as 3000 mm a year in elevated sections of the coastal ranges. Most (~70%) of the region's rainfall occurs between December and March. Average daily temperatures for Mackay range between 23° and 31°C in January and 11° and 22°C in July. The south-easterly trades are the prevailing winds, with occasional gale force winds occurring during cyclonic and other storm events. (Mackay Whitsunday Natural Resource Management Group Inc. 2005). The tidal range in this region can be more than 6 m exposing intertidal areas for long periods during the tidal cycle. The major industries in the Mackay Whitsunday region are agriculture and grazing, tourism, and fishing and aquaculture.

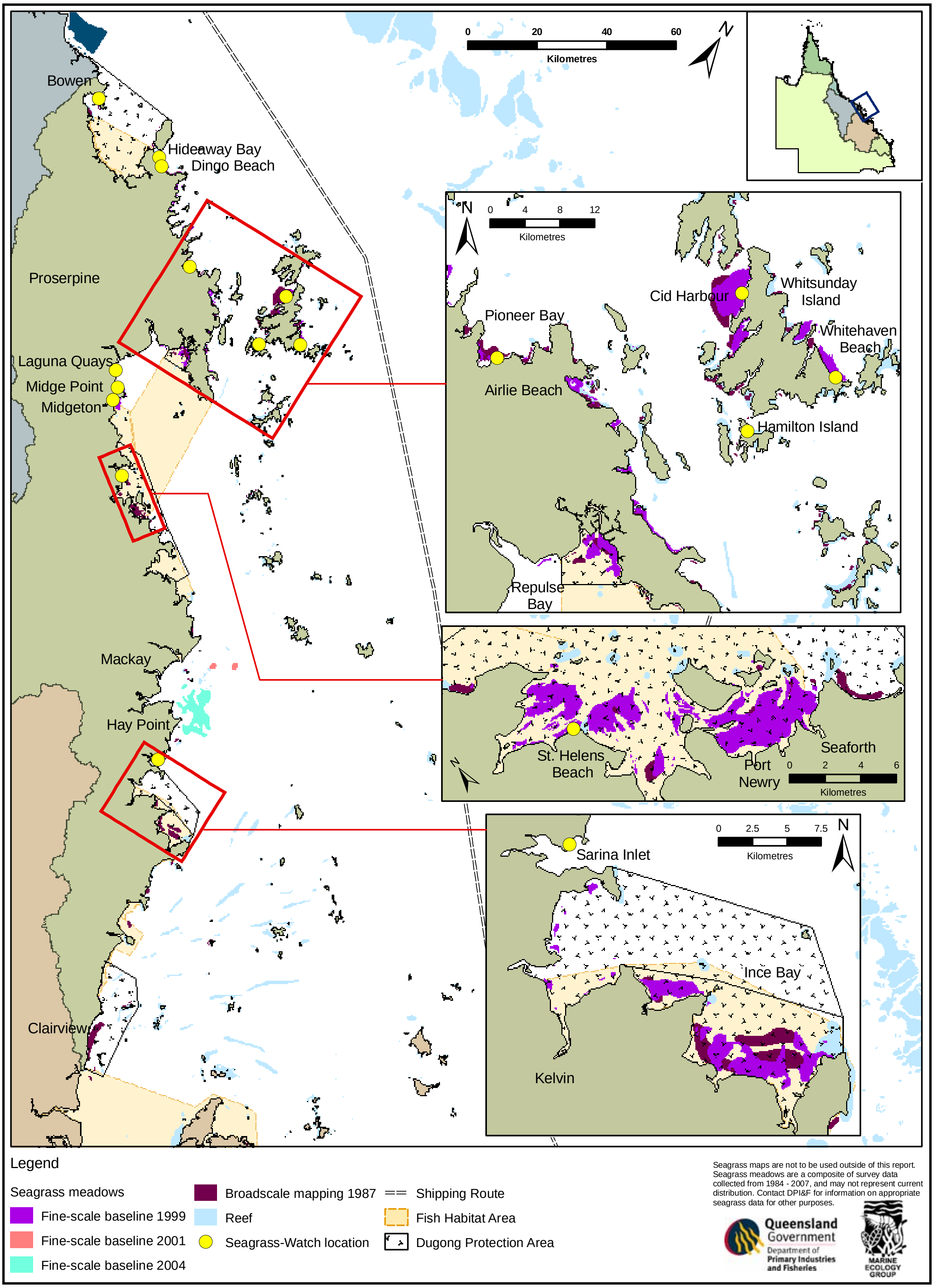
Thirteen species of seagrass have been recorded in this region. A fourteenth species (*Thalassodendron ciliatum*) was recently confirmed from Hamilton Island in the Whitsunday Island group. The majority of the meadows are low to moderate in biomass, and are dominated by *Halophila* and *Halodule* species. Expansive meadows of *Halodule uninervis*/*Halophila ovalis* or *Zostera capricorni* exist on the coastal intertidal flats with reef top seagrass present on the numerous fringing reefs associated with the islands along this coastline. Deepwater seagrasses were generally not found in the central and northern parts of this region, apart from occasional sites in the lee of islands or reefs. These large areas devoid of seagrass are likely to be due to the scouring currents caused by tidal ranges of over six metres.

Based on the mapped seagrass areas, majority of seagrass meadows in the Mackay Whitsunday region are within coastal and estuary habitats (Table 5). Of these, 36% are protected within declared Fish Habitat Areas and 10% are located within port boundaries. Only 5% of seagrass meadows (excluding deepwater) covered by the highest levels of protection zones of the GBRWHA.

Table 5. Area (km^2) of seagrass within each habitat type, port area and marine protected zone of the Mackay – Whitsunday region. Shaded areas afford highest levels of protection for seagrass (cells are not additive as there is overlap among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	29.36	0.00	12.87	16.22	4.30	0.00	0.00	0.25	0.00	0.00	0.00	**33.85**
Coast	39.15	19.42	34.44	43.38	44.17	0.00	0.00	10.09	0.00	0.00	0.00	**154.73**
Reef	0.58	2.26	0.30	8.51	3.06	0.00	0.00	0.35	0.00	0.00	0.00	**14.49**

Map 7. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Mackay Whitsunday NRM region.



Conceptual Summary

Estuarine

Estuarine seagrass habitats in the Mackay Whitsunday region tend to be intertidal on the large sand/mud banks of sheltered estuaries. Run-off through the catchments connected to these estuaries is variable, though the degrees of variability is moderate compared to the high variability of the Burdekin and the low variability of the Tully (Brodie 2004). Seagrass in this habitat must cope with extremes of flow, associated sediment and freshwater loads from December to April when 80% of the annual discharge occurs (Figure 41).

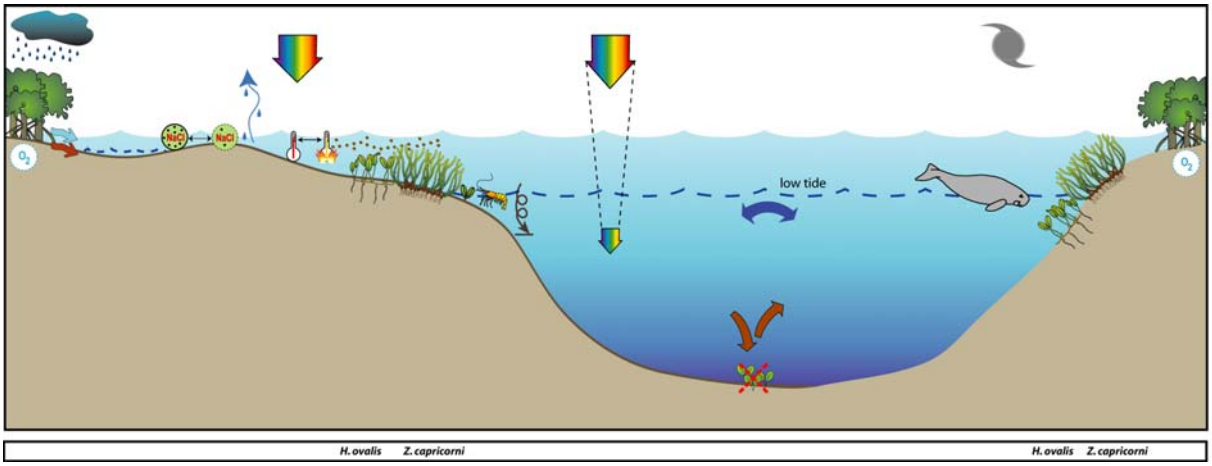


Figure 41. Conceptual diagram of estuary habitat in the Mackay Whitsunday region: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Coastal

Coastal seagrass habitats are found in areas such as the leeward side of inshore continental islands and in north opening bays. These areas offer protection from the south-easterly trades. Potential impacts to these habitats are issues of water quality associated with urban, marina development and agricultural land use (Figure 42).

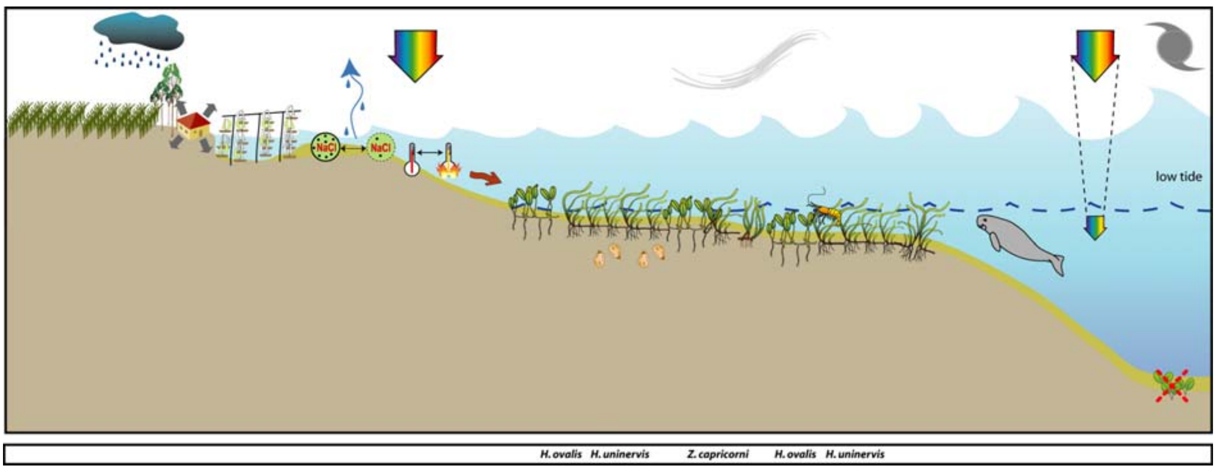


Figure 42. Conceptual diagram of coastal habitat in the Mackay Whitsunday region – major control is shelter and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*

Reef

Reef habitat seagrass meadows are found intertidally on the top of the coastal fringing reefs or fringing reefs associated with the many islands in this region. Subtidal reef associated meadows are found at the base of these fringing reefs on the leeward, protected sides of the continental islands. The drivers of these habitats are exposure and desiccation (intertidal meadows) (Figure 43). Major threats would be increased tourism activities including marina and coastal developments.

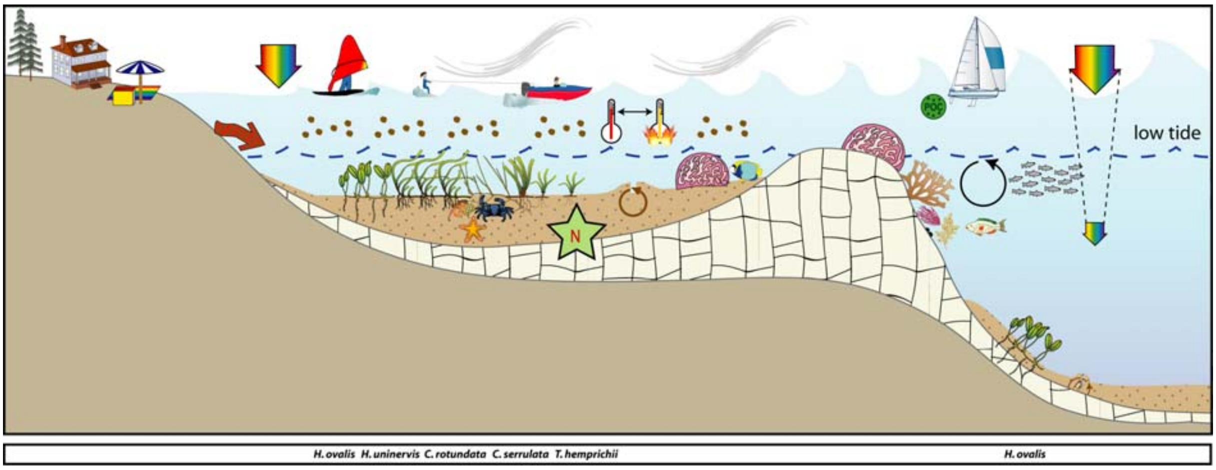


Figure 43. Conceptual diagram of reef habitat in the Mackay Whitsunday region – major control is light and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Deepwater

Deepwater seagrasses are sparse immediately south of Mackay where tidal velocities are high (Coles *et al.* 2000). Mackay is the southern limit for the deepwater seagrass species *Halophila tricostata*. Tidal velocities and ranges creating scouring, turbulence and turbidity limit the distribution of deepwater seagrasses in this region (Figure 44).

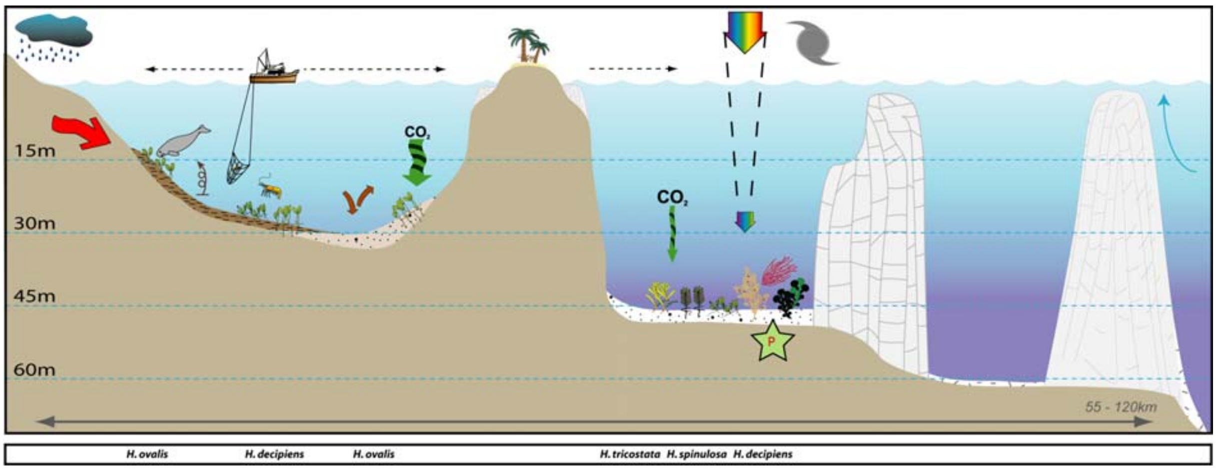


Figure 44. Conceptual diagram of deepwater habitat in the Mackay Whitsunday region – major control is light and nutrient limitation: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*

Summary of Monitoring Data

Estuarine

Sarina Inlet is located on an intertidal sand/mud bank in Sarina Inlet south of Mackay. This site is dominated by *Zostera capricorni* with some *Halophila ovalis*. Seagrass cover in April 2006 was significantly lower than that recorded in September/October 2005 but was similar to cover recorded in April 2005 (Figure 45). As the dataset for this location is limited, it is not possible to determine if this is a natural/seasonal fluctuation in seagrass abundance (Figure 45). Seagrass cover at another estuarine site – Midgeton – has remained stable over the monitoring period. Seagrass at St, Helens was also monitored several times but interest from the local community waned. The meadow here is an extensive *Zostera capricorni* meadow on a very muddy substrate.

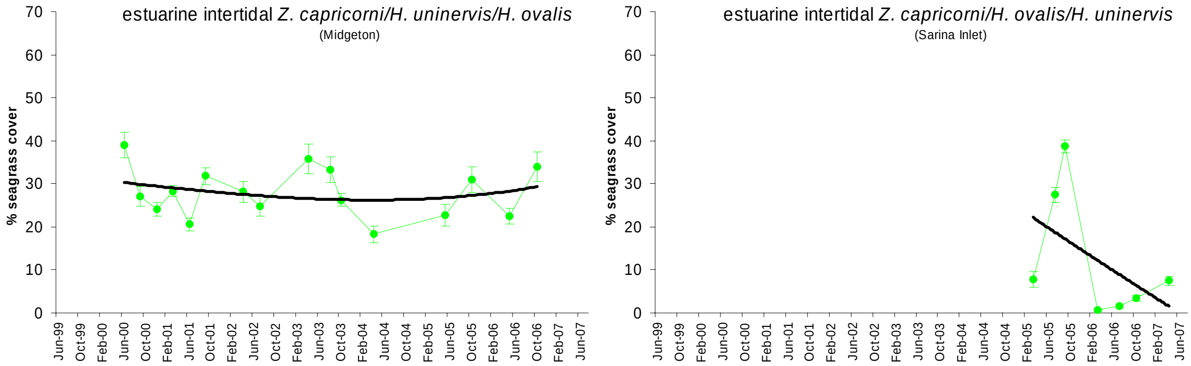


Figure 45. Change in seagrass abundance (percentage cover) at intertidal meadows located in estuaries in the Mackay Whitsunday region.

Coastal

Coastal seagrass habitats were located on intertidal sand/mud flats adjacent to Cannonvale in southern Pioneer Bay. The meadows cover approximately 60ha and were dominated by *Halodule uninervis* and Zostera *capricorni* mixed with *Halophila ovalis*. Species composition remained stable over the monitoring period and total abundance indicated natural seasonal patterns (Figure 46). Percent cover at this location has remained relatively stable (trend line), even though fluctuations are apparent between years indicating disturbance regimes at longer time periods than annually (Figure 46). Dugong feeding trails were abundant at these sites with the highest feeding activity (evidenced by trails) recorded in March and September. Seagrass meadows at Dingo beach and Midge Point have showed relative stability throughout the time monitored.

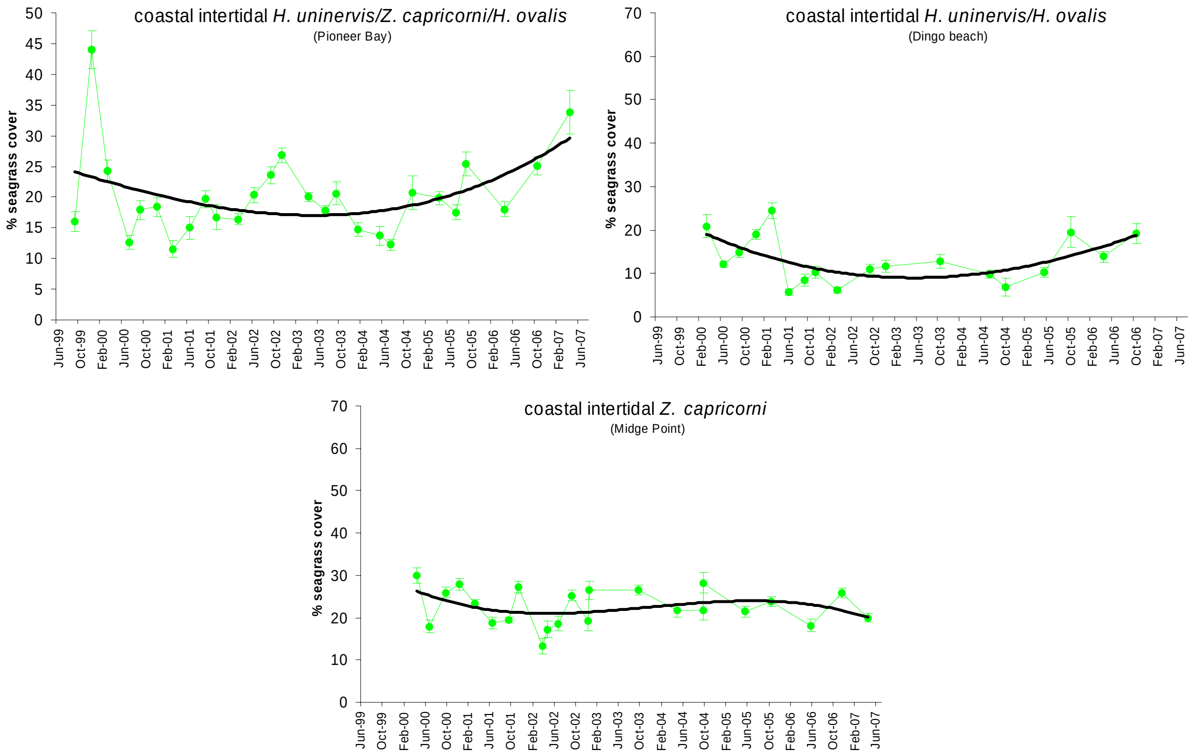


Figure 46. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Mackay Whitsunday region.

Coastal subtidal seagrass meadows in this region have not been monitored since mid 2004, due to the difficulty associated with subtidal monitoring. The trend for both sites that were being monitored has been of decline (Figure 47). This decline is more than 20% of that recorded when monitoring commenced. This may be significant, however with no current information with which to compare, it is difficult to say whether this decline is ecologically significant or whether the meadow has recovered.

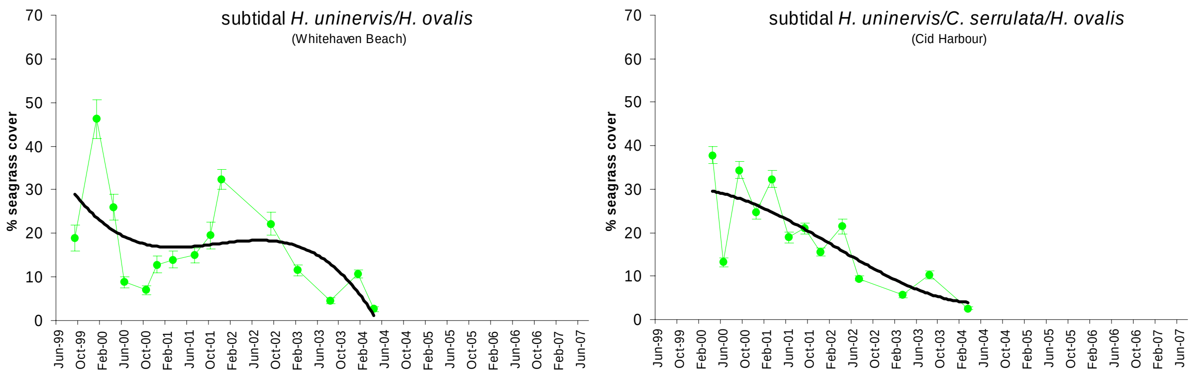


Figure 47. Change in seagrass abundance (percentage cover) at coastal subtidal meadows in the Mackay Whitsunday region.

Reef

Reef top seagrasses are only monitored at Hydeaway Bay. New sites are currently being established on Hamilton Island. Seagrass cover at Hydeaway Bay has remained stable since monitoring began in mid 2000 (Figure 48).

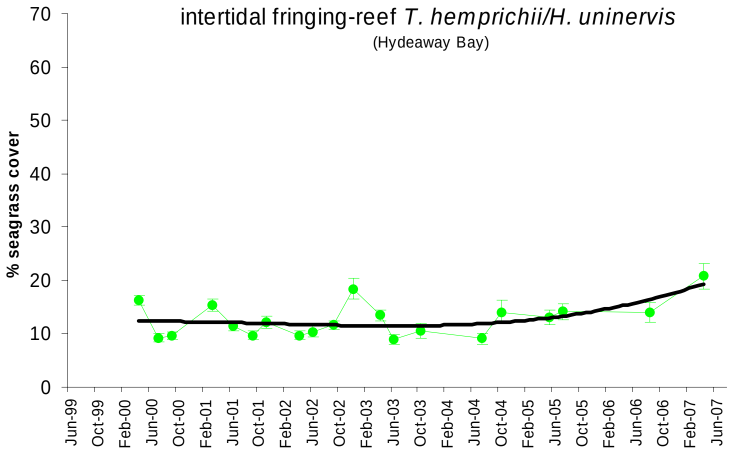


Figure 48. Change in seagrass abundance (percentage cover) at intertidal meadows located on a fringing reef-platform in the Mackay Whitsunday region.

Deepwater

A baseline survey of deepwater seagrasses in the Hay Point area (south of Mackay) was conducted in July 2004 (Rasheed *et al.* 2004). This survey revealed a large area of low cover (typically less than 5%) *Halophila decipiens* and *Halophila spinulosa* covered most of the survey area (6,851.9 ha; Rasheed *et al.* 2004). A program examining the dynamics of deepwater seagrasses and monitoring their response to a major dredging program at Hay Point began in December 2005 and is due to conclude in December 2007. Initial results indicate this seagrass community to be highly dynamic with seagrasses reducing from 6,851.9 ha in July 2004 to a small patch of 338.6 ha in December 2005 and completely lost by March 2006 prior to commencement of dredging.

The 1994-1999 and 2003-2006 modelled distributions in deep water showed patchy *Halophila ovalis, Halophila tricostata* and *Halophila decipiens* in the 1990's with an increase in the presence of *Halophila spinulosa* in 2003-2006. The extent of seagrass presence is less towards the south of the region as the turbid influence of the region of high tidal flows commences. Other than the Hay point monitoring, no ongoing monitoring of deepwater seagrass occurs in this region.

Climate and Seagrass Change

The region has been in an extended dry and hot period from 2001 to 2006 with maximum air temperatures higher than the period from 1999 to 2000 combined with lower cloud cover and rainfall (Figure 49).

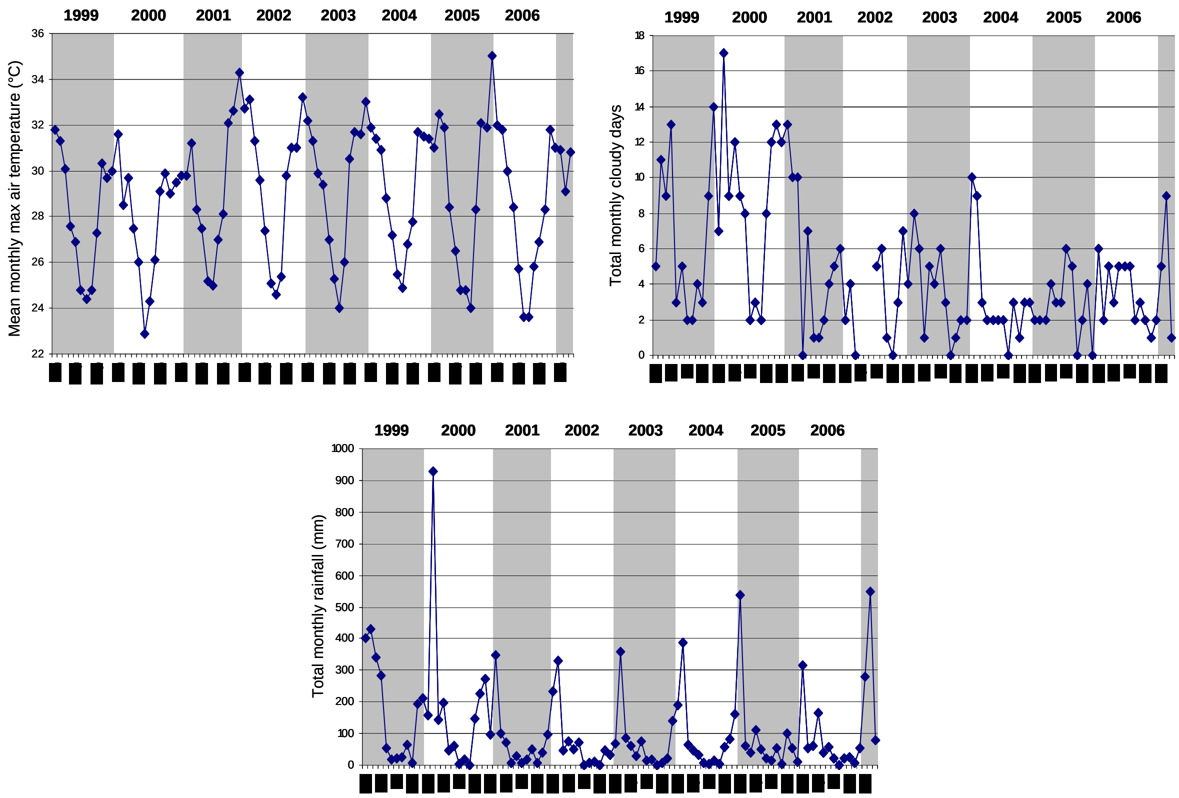


Figure 49. Cloudy days, mean monthly maximum temperature and mean monthly rainfall for Proserpine in the Mackay/Whitsundays NRM 1999-2006.

Within canopy temperature was monitored at coastal and reef-platform locations, and generally follow a similar pattern. Mean temperatures were mostly within the 22-30°C range, with highest mean temperatures in the November and February periods (Figure 50). Extreme temperatures (>40°C) were not recorded in the region. Temperatures peaked in the canopy several times throughout the year, generally in February-March, and October-December.

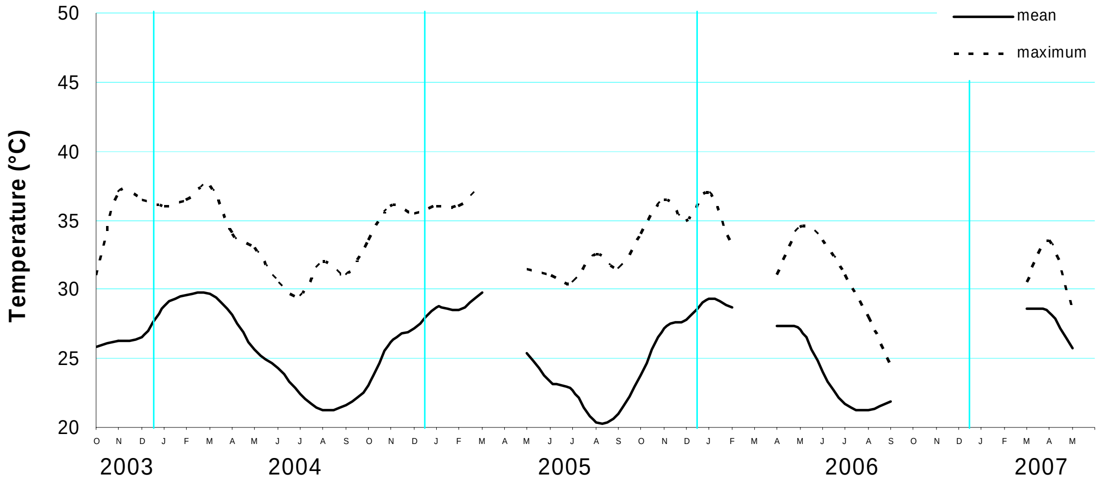


Figure 50. Within seagrass canopy temperature (°C) at intertidal meadows in a coastal habitat within the Mackay Whitsunday region.

Associated Macro-fauna

The estuarine seagrass habitats were dominated mainly by unidentified gastropods and hermit crabs. Bioturbation was generally low, with the exception of mid 2003 when the number crab holes peaked (Figure 51).

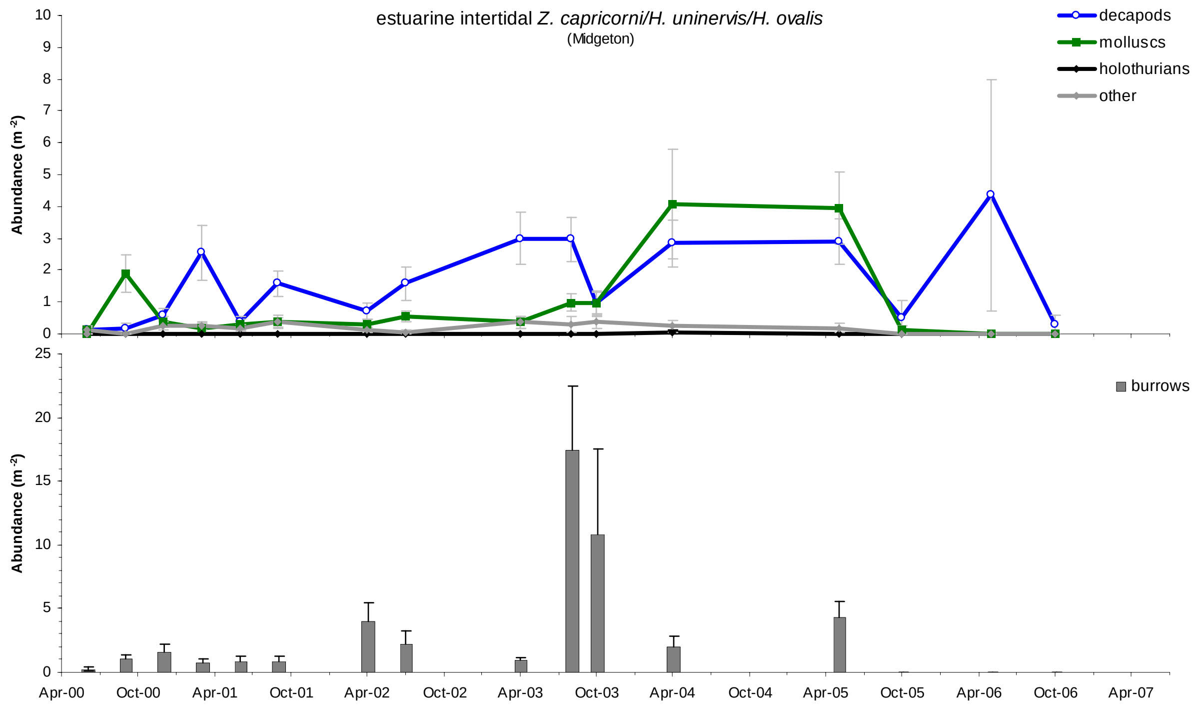


Figure 51. Abundance of associated benthic macro-fauna and bioturbation in an intertidal *Zostera capricorni / Halodule uninervis / Halophila ovalis* meadow in an estuary habitat over the monitoring period.

Decapods (predominately hermit crabs) consistently dominated the macrofauna of the coastal seagrass habitats. Bioturbation was also high due to the number of worm and crab burrows. Abundances of unidentified gastropods varied throughout the monitoring period.

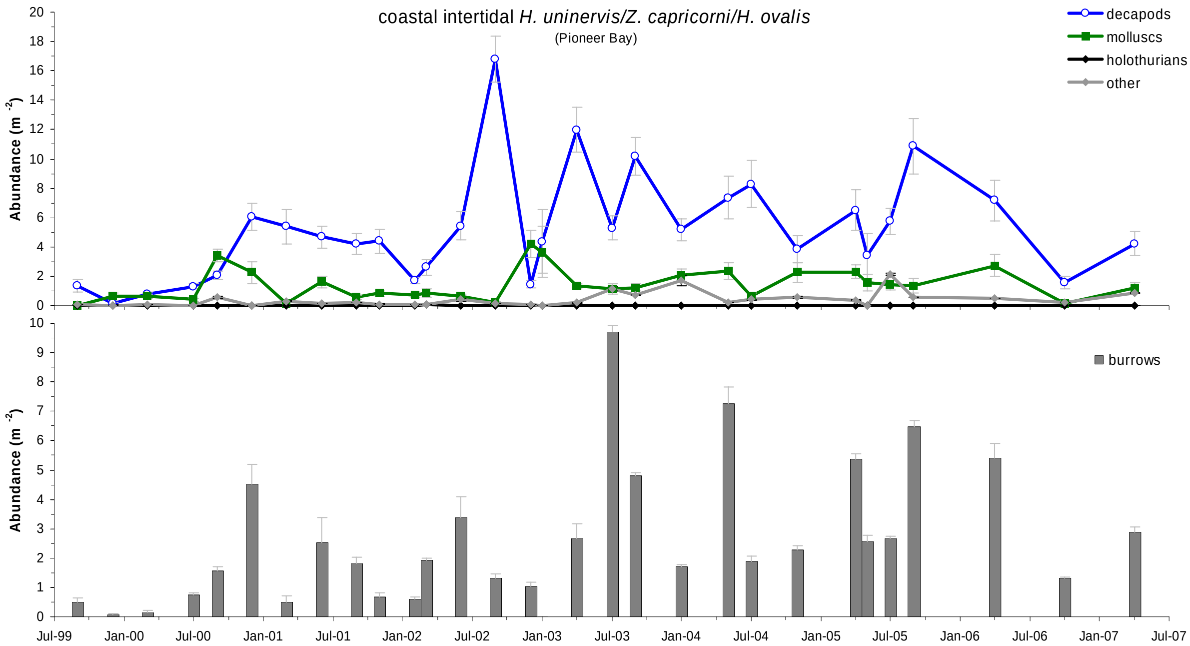


Figure 52. Abundance of associated benthic macro-fauna and bioperturbation in an intertidal *Halodule uninervis / Zostera capricorni / Halophila ovalis* meadow in a coastal habitat over the monitoring period.

Relatively few macrofauna were observed in the subtidal coastal habitat of Whitehaven Beach (Figure 53). Foraminifera dominated with only a few gastropods were observed grazing on the seagrass. Bioturbation was low, as only a few unidentified burrows (not crab) were observed.

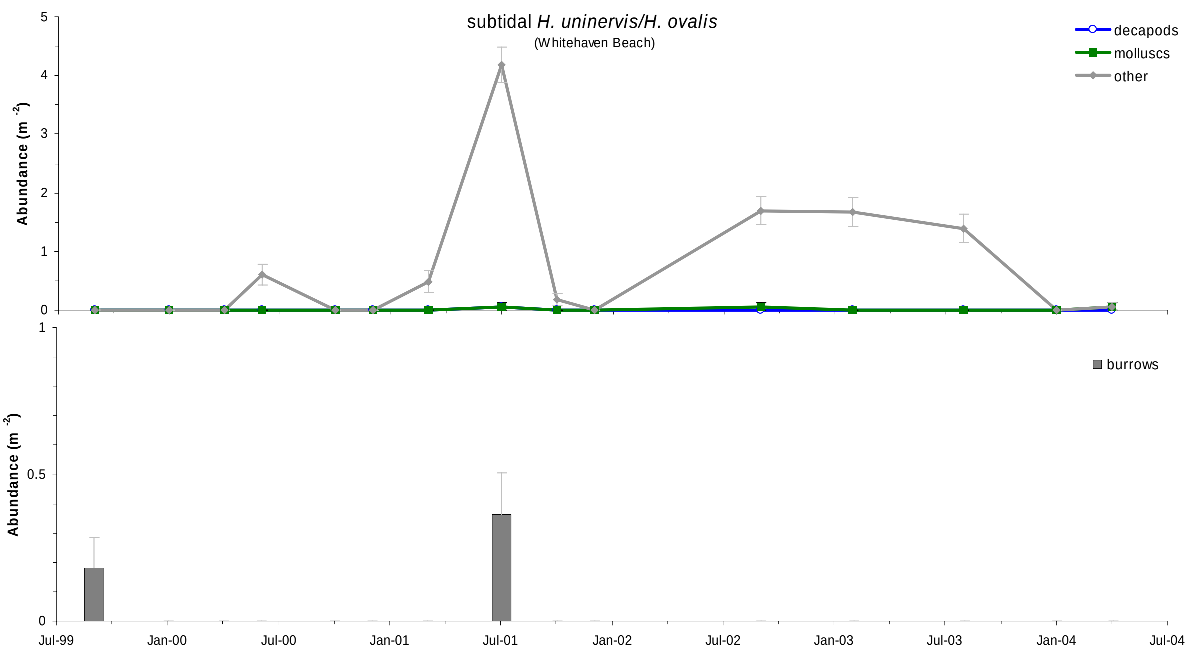


Figure 53. Abundance of associated benthic macro-fauna and bioturbation in a subtidal *Halodule uninervis / Halophila ovalis* meadow in an coastal habitat over the monitoring period.

Cone shells and unidentified gastropods dominated the macrofauna of the fringing reef platform seagrass habitats. Decapods were mainly hermit crabs - abundances were highly variable. Holothurian abundance was relatively high (large species of *Hothuria* sp.), but similarly variable (Figure 54). Bioturbation was also high, due to lots of crab burrows.

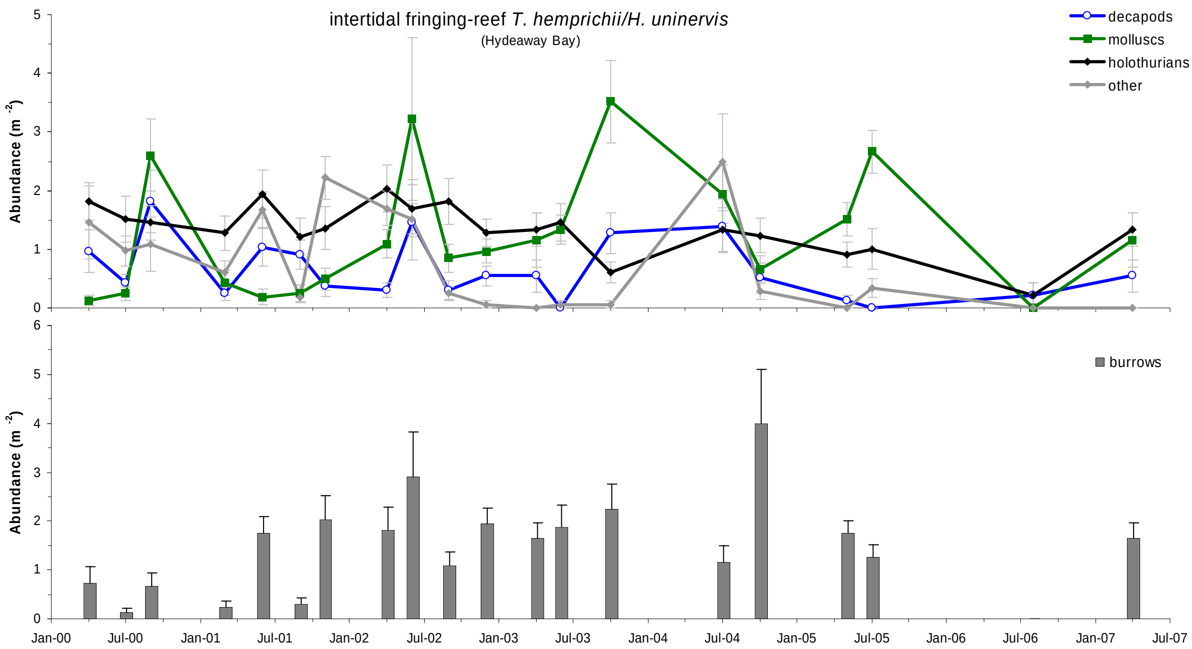


Figure 54. Abundance of associated benthic macro-fauna and bioperturbation in an intertidal *Thalassia hemprichii* / *Halodule uninervis* meadow on a fringing reef platform over the monitoring period.

Fisheries

This area has a relatively short mainland coastline complicated by the many inshore islands of the Whitsunday region and includes numerous declared Fish Habitat Areas. An average of 336 tonnes of prawns per year has been collected from the region with the catch mostly king prawns. The prawn fishery is worth, on average, $4.2M annually. In 2006, king prawn catch almost doubled the catch of the four years prior, whereas catch of tiger prawns decreased in recent years (Figure 55).

An average of 342 tonnes of fish worth $4.4M and 39 tonnes of mud crabs worth $0.4M between 2002 and 2006 have been recorded. Catches are variable but there has been an increasing trend of tonnage caught for fin fish per boat, despite a decline in the tonnage of shark caught in recent years.

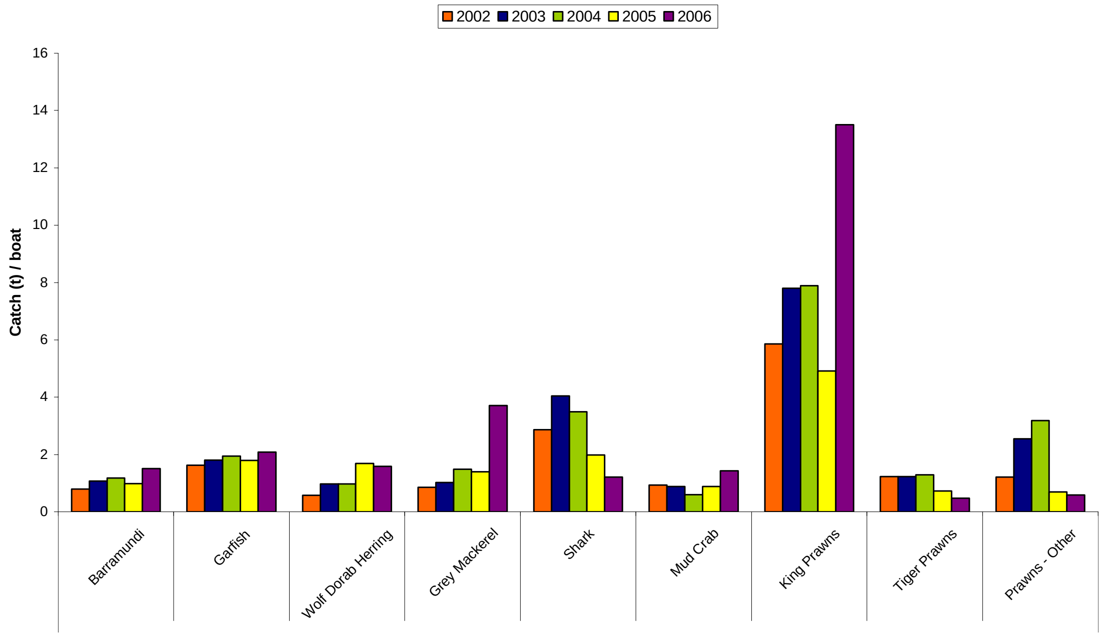


Figure 55. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Mackay - Whitsundays NRM region between 2002 and 2006.

Regional Summary

Intertidal seagrasses monitored in the Mackay Whitsunday NRM region appeared to be in a healthy state in 2006. These meadows have shown a relatively stable trend in abundance since monitoring commenced in 1999. Within this trend of overall stability, at a local level, some meadows have faced short term impacts from which there has been recovery. These impacts include *Lyngbya* outbreaks, sedimentation from marina developments and burning off from temperature stress (Campbell and McKenzie 2001; Campbell *et al.* 2002b). While these meadows have demonstrated resilience to these changes, the region faces continued pressure from coastal and urban development.

As with the Burdekin region, the absence of ongoing monitoring of subtidal meadows has limited our ability to assess seagrass trends in the region. Subtidal meadows are generally the first to respond to declines in water quality that result in a reduction of light. Information collected on subtidal meadow from 1999 to 2004 at Whitehaven Beach also indicated that small scale disturbances from anchoring may have been contributing to a seagrass decline.

While the overall distribution of deepwater seagrasses in the GBRWHA was relatively stable between the 1990's and 2004, results from monitoring at Hay Point indicate that there may be considerable inter- and intra-annual variability at a local level.

Information Gaps

- The majority of information for the region comes from intertidal Seagrass-Watch sites. No regular monitoring information has been collected in the region (since 2004) on the status of sub-tidal seagrasses.
- Changes to area of representative seagrass meadows are also not regularly monitored.

- A monitoring program for sub-tidal meadows in the high risk Whitsunday area (Rasheed 2007a) would add significantly to our understanding of the status of seagrasses in the region.

Fitzroy

Background

The Fitzroy region covers an area of nearly 300,000 km^2 of coastal land. It extends from Nebo in the north to Wandoan in the south, and to the gem fields in the west and encompasses the major systems of the Fitzroy, Boyne, and Calliope rivers as well as the catchments of the smaller coastal streams of the Capricorn and Curtis Coasts (NRM 2007c). The Fitzroy River is the largest river system running to the east coast of Australia. The Boyne and Calliope Rivers drain the southern part of the region, entering the GBRWHA lagoon at Gladstone. The region covers ten percent of Queensland's land area and is home to approximately 200,000 people.

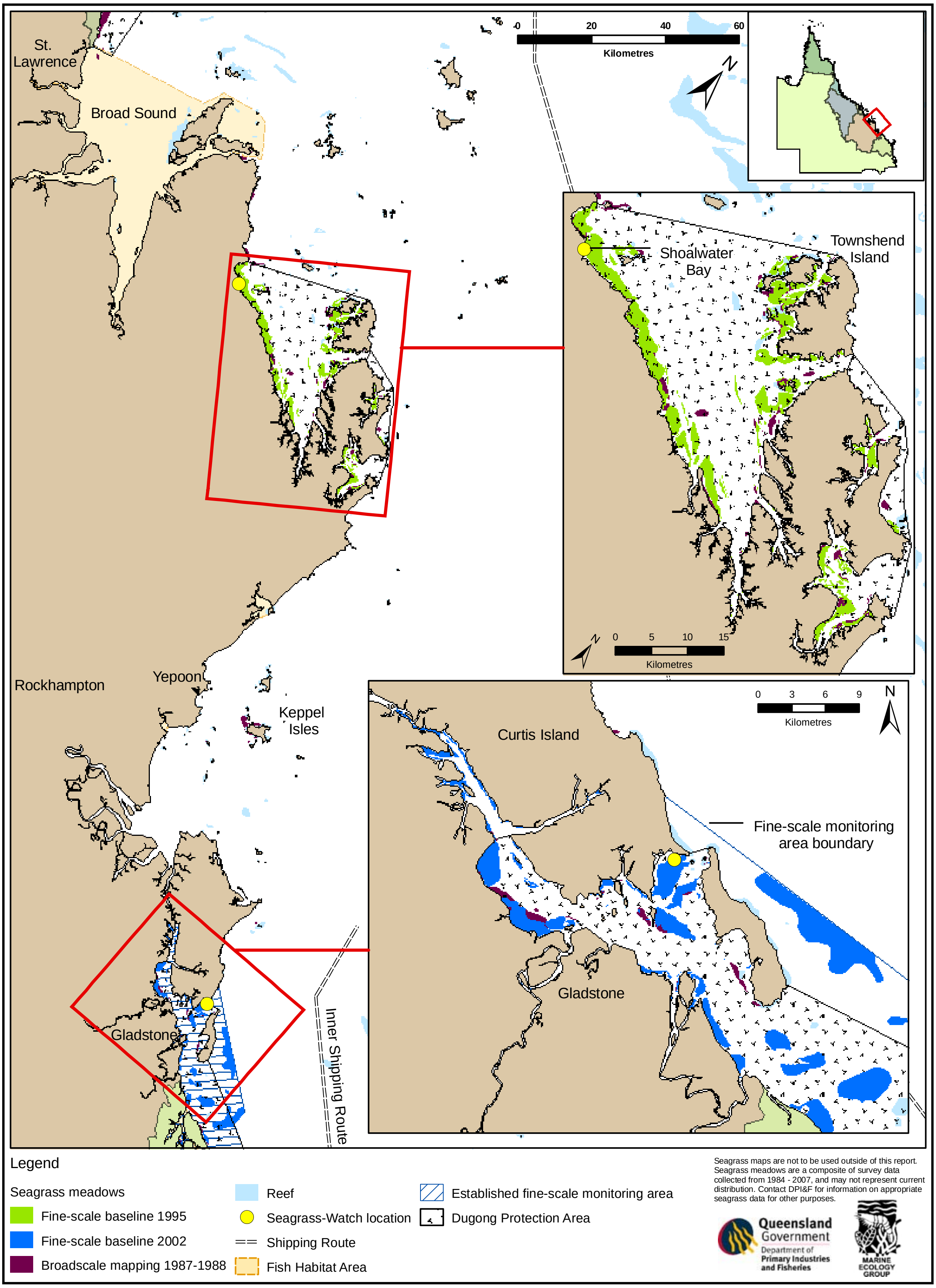
It is one of the richest areas in Queensland in terms of land, mineral and water resources and supports grazing, irrigated and dry land agriculture, mining, forestry and tourism land uses. (Fitzroy Basin Association 2004). Agricultural production constitutes the largest land use in Central Queensland, with nearly 90% of the land under agricultural production. Concomitant with this land use is the usual concern of the quality of the water that is entering the GBRWHA lagoon. While streams further north deliver water to the lagoon every year, about once per decade the Fitzroy floods to an extent that affects the Reef. However, the smaller annual flows deliver sediments and nutrients affecting coastal habitats.

The first broad scale survey of seagrass habitat in this region occurred in 1987 (Coles *et al.* 1987b). Consequent fine scale surveys of Shoalwater Bay (Lee Long 1996b), the Dugong Protection Areas of Llewellyn Bay, Ince Bay and the Clairview Region (Coles *et al.* 2002) and Port Curtis to Rodds Bay (Rasheed *et al.* 2003b) provide more detailed information on the distribution of seagrass within this region (Map 8). Ten species of seagrass have been recorded from this region ranging from the intertidal to a depth of 48m. The majority of seagrass in this region exist on large intertidal flats. Expansive meadows of *Halodule uninervis/Halophila ovalis* or *Zostera capricorni* exist on the coastal intertidal flats of Ince Bay, Clairview, Shoalwater Bay and Rodds Bay. The area of shallow subtidal coastal seagrass habitat in this region is small, as most of the coastline is exposed to south-east winds.

Another factor contributing to the lack of suitable coastal habitat is the scouring tidal currents and associated high water turbidity in this region which limits light penetration and therefore the depth to which seagrasses can grow. Meadows of *Halophila ovalis, Halophila decipiens, Halophila spinulosa* and *Halophila tricostata* were found commonly in the deeper waters of the southern section of this region between the mainland and the Capricorn-Bunker Island group. Less extensive areas of seagrass were also found in the shelter of the Swain Reefs. Deepwater seagrasses were generally not found in the central and northern parts of this region, apart from occasional sites in the lee of islands or reefs.

The Fitzroy NRM region experiences a tropical to subtropical humid to semi arid climate. Annual median rainfall throughout the region is highly variable, ranging from about 600 mm annual at Emerald to more than 800 mm along the coast, and over 1000mm in the north where coastal ranges trap moist on shore airflow. Most rain falls in the summer, with many winters experiencing no rain at all. Because of the tropical influence on rainfall patterns, heavy storms can trigger flash flooding, and occasional cyclones wreak havoc.

Map 8. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Fitzroy NRM region.



Based on the mapped seagrass areas, the majority of seagrass meadows in the Fitzroy region are within coastal and estuary habitats (Table 6). Of these, <1% are protected within declared Fish Habitat Areas and 23% are located within port boundaries. Approximately 57% of seagrass meadows (excluding deepwater) covered by the highest levels of protection zones of the GBRWHA.

Table 6. Area (km^2) of seagrass within each habitat type, port area and marine protected zone of the Fitzroy region. Shaded areas afford highest levels of protection for seagrass (cell are not additive as there is overlap among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	0.80	15.22	6.44	2.38	0.02	0.00	0.00	12.19	0.00	0.00	0.00	**37.02**
Coast	0.00	31.95	7.90	8.23	15.37	0.00	0.00	104.10	0.00	0.00	0.00	**167.56**
Reef	0.00	0.20	0.00	2.02	0.15	0.00	0.00	2.99	0.00	0.00	0.00	**5.36**

Conceptual Summary

No seagrass reef habitats have been mapped within the Fitzroy region.

Estuarine

Estuarine seagrass habitats in the northern Fitzroy region tend to be intertidal on the large sand/mud banks in sheltered areas of the estuaries. Run-off is highly erratic due to variable inter-annual rainfall. A feature of the northern estuaries in this region is the large tidal amplitudes, existing high sediment loads and strong tidal currents. These features of scouring, high turbidity and desiccation linked to this large tide regime, are the main drivers of distribution and composition of seagrass meadows in this area. Estuary habitats in the north (e.g. Port Clinton and Shoalwater Bay) are undeveloped and impacts/threats are few. To the south tidal amplitude is not as great and estuaries that are protected by coastal islands and headlands support meadows of seagrass. These southern estuary seagrasses (Gladstone) face threats from major port, industrial and coastal development (Figure 56). Threats to this habitat type include acid sulfate soils, stormwater run-off from urban, agricultural and industrial development.

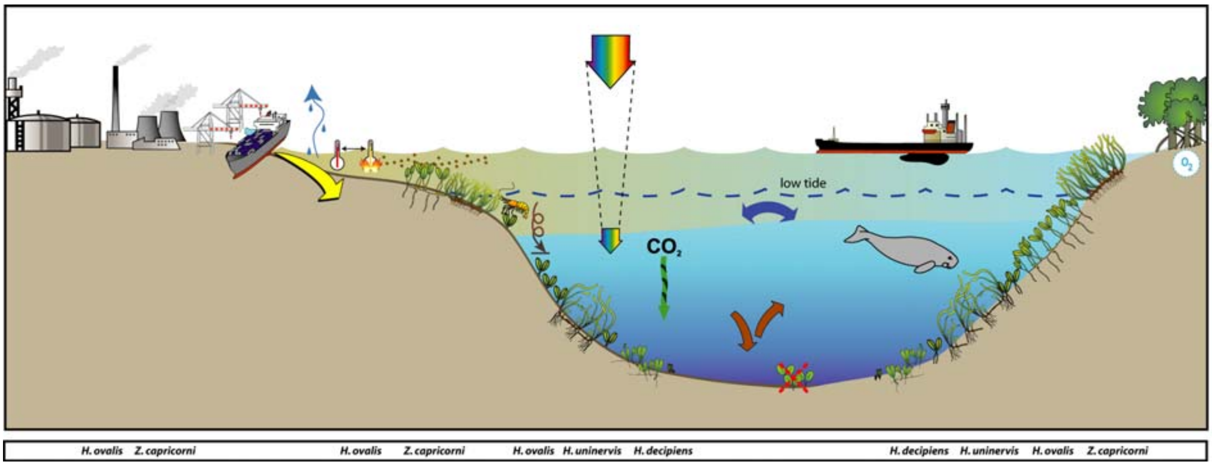


Figure 56. Conceptual diagram of estuary habitat in the Fitzroy region – major control variable rainfall and tidal regime: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Coastal

Coastal meadows in this region have been located along open coastlines sheltered from south-easterly winds and waves by either near-shore islands, or inshore rock reefs (e.g. Clairview) or are found in bays as a continuation of an estuarine meadow afforded protection by headlands. A feature of the region is the large tidal amplitudes and consequent strong tidal currents. As part of this tidal regime large intertidal banks are formed (e.g. Shoalwater Bay) which are left exposed for many hours. Pooling of water in the high intertidal results in small isolated seagrass patches 1-2m about MSL (Figure 57). Threats to these meadows are related to the pulsed events of run-off associated with acid sulfate soils, urban, agricultural and industrial development (Fitzroy Basin Association 2004).

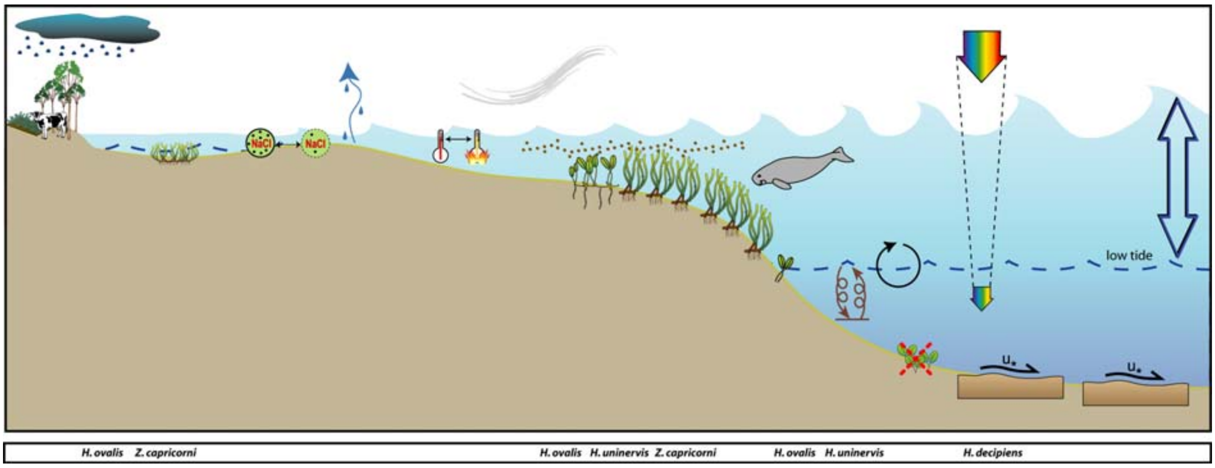


Figure 57. Conceptual diagram of coastal habitat in the Fitzroy region – major control is pulsed light, salinity and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Deepwater

The profile across the reef in the Fitzroy region is noticeable different (Figure 58). The northern section of the region is an area of high tidal velocities and much of the bottom is swept by currents and supports very little seagrass or algae growth (Figure 58). The trawl fishery here targets Tiger and Endeavour (*Penaeus esculentus, Penaeus. semisulcatus* and *Metapenaeus endeavouri*) prawns inshore but with an average depth of trawling of 24m (QDPI&F, compulsory commercial daily logbook data base CFISH) is targeting a band shallower than the seagrasses. Red Spot King prawns (*Penaeus longistylus*) are trawled within the outer reefs of the GBR. Very little of the seagrass below 15m in this region would be in a depth range (down to 33m) used by dugong and these herbivores must use shallow inshore and estuarine seagrasses along this part of the coast. The adjacent coast is relatively undeveloped in the Shoalwater Bay region but has inputs from the Gladstone and Fitzroy River region to the south.

The southern part of the Fitzroy region (Figure 58b) lacks the inshore reef systems of further north and is a region with extensive seagrass meadows and open sandy bottom. Seagrass meadows extend out to 50m depth. Coastal turbidity and pulsed flood events (Preen *et al.* 1995) restrict the deep water seagrass meadows to below 30m and there have been episodes of loss and recovery of seagrass in the past. A trawl fishery for Tiger, Endeavour, prawns and the Saucer Scallop (*Amusium balloti*) operates inshore but probably only interacts with the inner margin of the seagrass as the average trawl depth is 19m and 34m respectively (QDPI&F, compulsory commercial daily logbook data base CFISH). Dugong would only be able to use the inshore edge of the seagrass because of depth and presumably are feeding in the shallow inshore waters not included in this study. Previous research (Preen *et al.* 1995) has identified sediment loads and turbidity from pulsed flood events as a threat to seagrass in this region and coastal management and increased urbanisation with associated nutrient inputs are likely to be management challenges in the future.

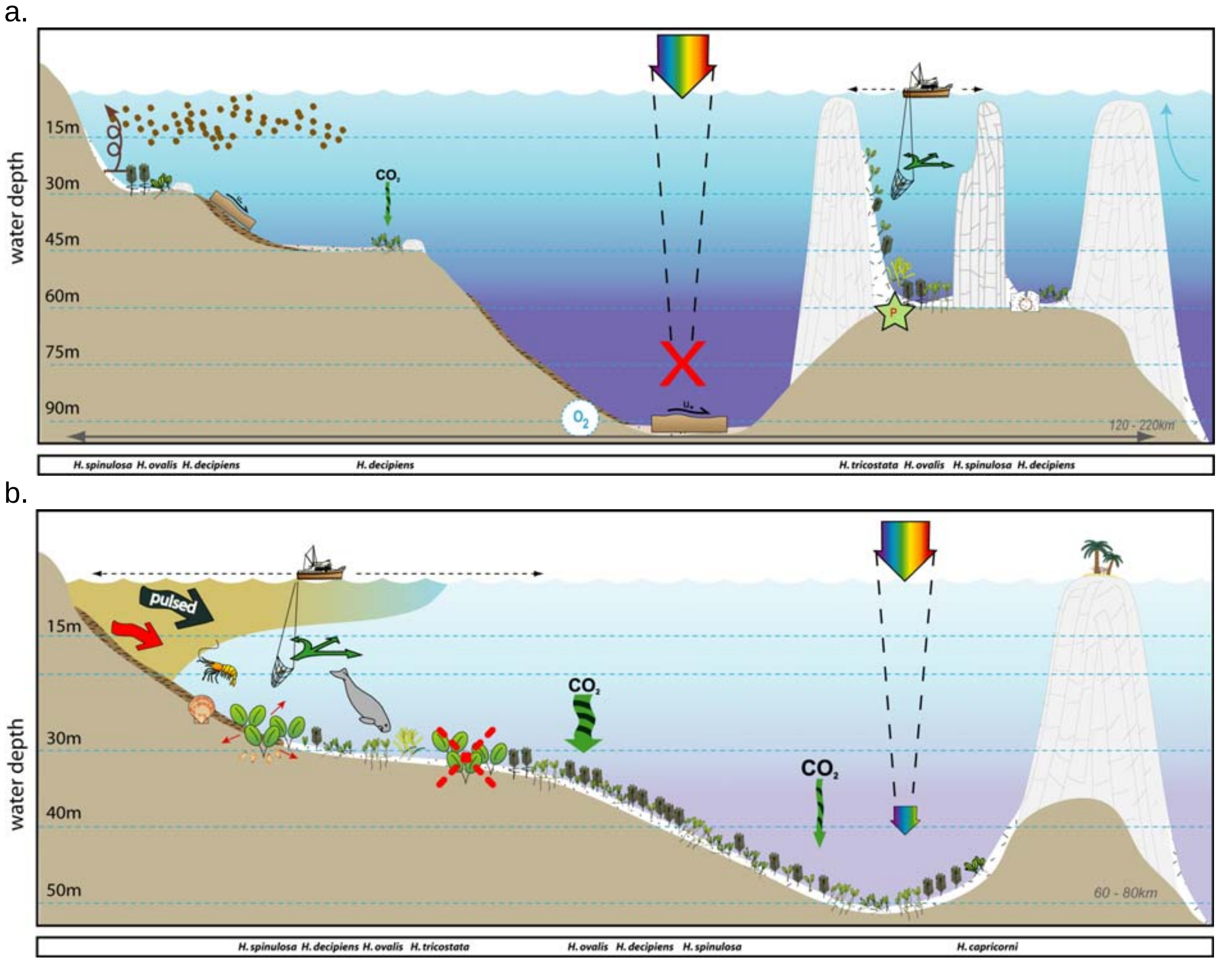


Figure 58. Conceptual diagram of deepwater habitat in the northern (a) and southern (b) Fitzroy region – major control is episodic events (including runoff): general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Summary of Monitoring Data

Estuary

Monitoring of estuarine seagrass habitats in the Fitzroy region currently occurs in the Gladstone area. Annual monitoring of seagrass above ground biomass, species composition and area is conducted in eight meadows representing the range of seagrass community types found in the estuary. The monitoring is part of a broader program that includes seagrass meadows in coastal habitats as well as meadows in Rodds Bay in the Burnett Mary NRM. Monitoring has been conducted each November since 2004 in partnership with the Central Queensland Ports Authority (Taylor *et al.* 2007) following a detailed baseline survey conducted in 2002 (Rasheed *et al.* 2003b).

The Gladstone/Port Curtis area has extensive *Halodule uninervis* and *Zostera capricorni* meadows that support protected species including dugong and green turtles. Seagrasses in the area are highly susceptible to impacts from local industry and inputs from the Calliope River. The Gladstone region is highly industrial with the world's largest alumina refinery, Australia's largest aluminium smelter and Queensland's biggest power station. In addition, Port Curtis is Queensland's largest multi-cargo port with 53M tonnes of cargo passing through the port in 2006.

The meadows monitored included six low biomass intertidal *Zostera/Halophila* meadows and two subtidal *Halophila* meadows located adjacent to the major port and industrial area on the mud banks between Friend and South Trees Points.

The intertidal *Zostera/Halophila* meadows declined in biomass from the baseline survey to 2005, but increased between 2005 and 2006, while total meadow area remained relatively constant (Figure 59a). Area and biomass for the subtidal *Halophila* meadows have been highly variable between years, but generally declined from 2002 to 2005 and increased from 2005 to 2006 (Figure 59b).

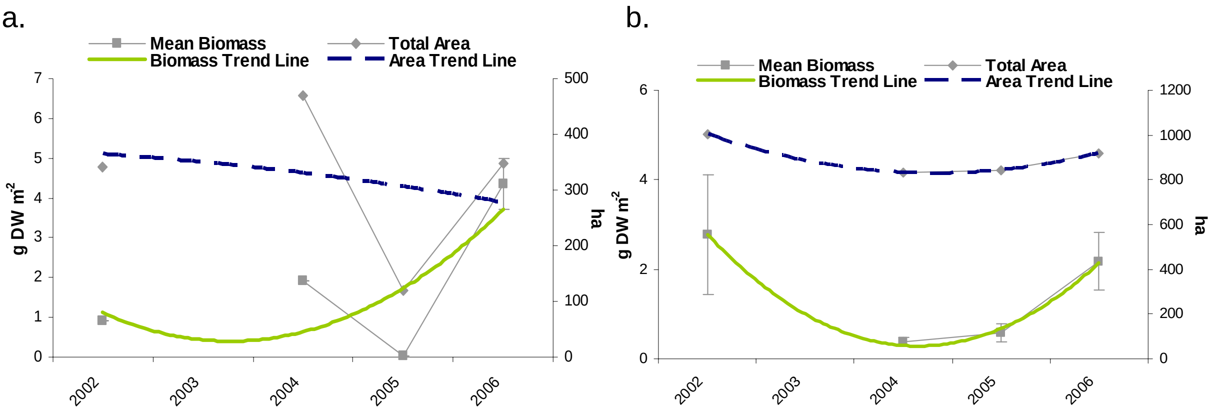


Figure 59. Changes in above-ground biomass and distribution of estuarine intertidal *Zostera/Halophila* (a) and subtidal *Halophila* (b) meadows monitored in the Fitzroy region from 2002 to 2006.

Coastal

Monitoring of coastal seagrass habitats in the Fitzroy region currently occurs at two locations, Gladstone and Shoalwater Bay. Annual monitoring of seagrass above-ground biomass, species composition and area is conducted for a large intertidal *Zostera capricorni* meadow and a subtidal *Halodule uninervis* meadow in Gladstone. Following a baseline in 2002, monitoring has been conducted each November since 2004 (Taylor *et al.* 2007). Seagrass-Watch monitoring occurs biannually in Shoalwater Bay with new sites recently established in Gladstone Harbour.

Coastal intertidal *Zostera capricorni* meadow biomass and area has remained relatively constant between 2002 and 2004 while biomass for the subtidal *Halodule uninervis* meadow has shown a substantial increase in recent years (Figure 60).

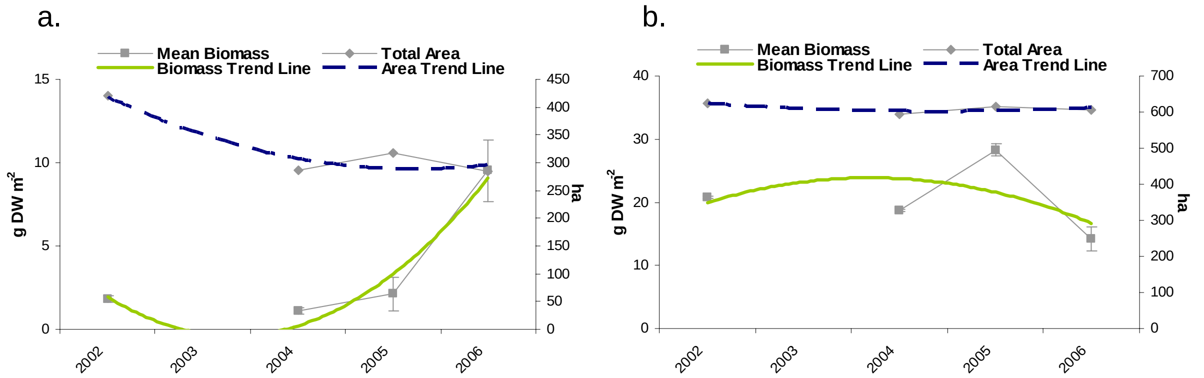


Figure 60. Changes in above-ground biomass and distribution of coastal intertidal *Zostera* (a) and subtidal *Halodule uninervis* (b) meadows monitored in the Fitzroy region from 2002 to 2006.

Sites monitored in Shoalwater Bay, are located on the large intertidal flats of the north western shores of Shoalwater Bay. The remoteness of this area (due to its zoning as a military exclusion zone) represents a near pristine environment, removed form anthropogenic influence. *Zostera capricorni* dominates this meadow with some *Halodule uninervis.* Percent cover appears to be on the increase, driven by a large increase in cover in late 2005. More recent data, though not as high as the 2005 data, still shows seagrass cover to be higher than when monitoring first commenced in early 2002 (Figure 61).

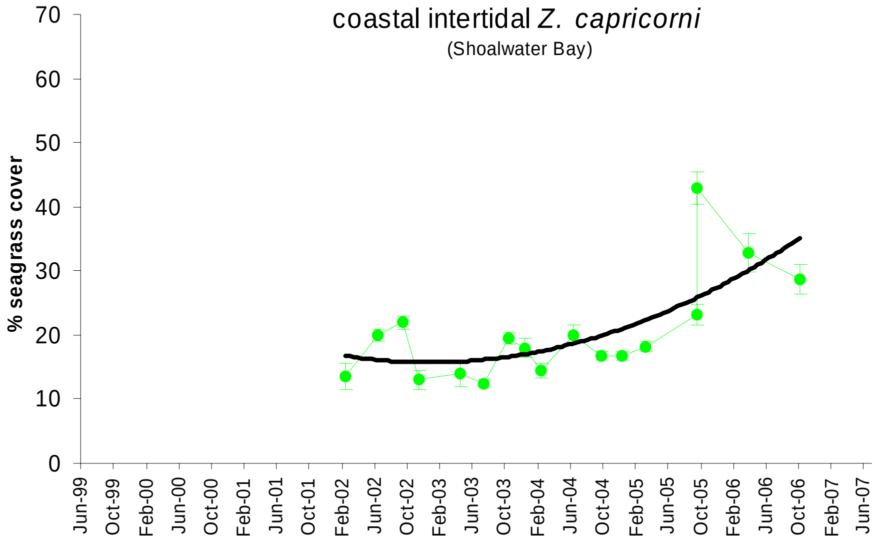


Figure 61. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in Shoalwater Bay (Fitzroy region).

Deepwater

Deepwater seagrasses have been mapped within the Gladstone Port limits and Rodds Bay DPA in a baseline survey conducted in November 2002. Large meadows of typically low cover *Halophila decipiens* and *Halophila spinulosa* were described in waters deeper than 15m below MSL (Rasheed *et al.* 2003b).

The 1994 -1999 and 2003-2006 modelled distributions in deep water showed patchy *Halophila decipiens* offshore from Shoalwater Bay in the 1990’s with an increase in 2003-2006. The mid shelf region adjacent to Shoalwater Bay has almost no other seagrass present. The extent of seagrass presence is greater towards the south of the region as the turbid influence of the region of high tidal flows decreases. The south of the region also has extensive seagrass meadows in shallow water on the outer Swains Reef region (De’ath *et al.* 2007). Other than the Gladstone Port point monitoring, no ongoing monitoring of deepwater seagrass occurs in this region.

Climate and Seagrass Change

The major drivers of seagrass change appear to be strongly linked to climate and tidal exposure. Drought conditions have been prevailing in Gladstone for a number of years, and although they may account for some of the changes, they do not explain all of the fluctuations in seagrass density (Rasheed *et al*. 2006a). The Awoonga Dam was built on the Boyne River in 1984 and changes in fresh water flow may still be influencing seagrass distribution. Declines in intertidal meadows in past surveys may also be linked to changes in daytime exposure of seagrass banks (Taylor *et al*. 2007). This increased exposure combined with the drought conditions of high solar irradiance and temperature were likely to create conditions of increased thermal stress and desiccation on seagrasses when exposed (Rasheed *et al.* 2005a) (Figure 62). In the most recent monitoring in 2006 the number of hours intertidal estuarine meadows were exposed had substantially reduce from the previous two years (Figure 62) and may explain some of the recent recovery.

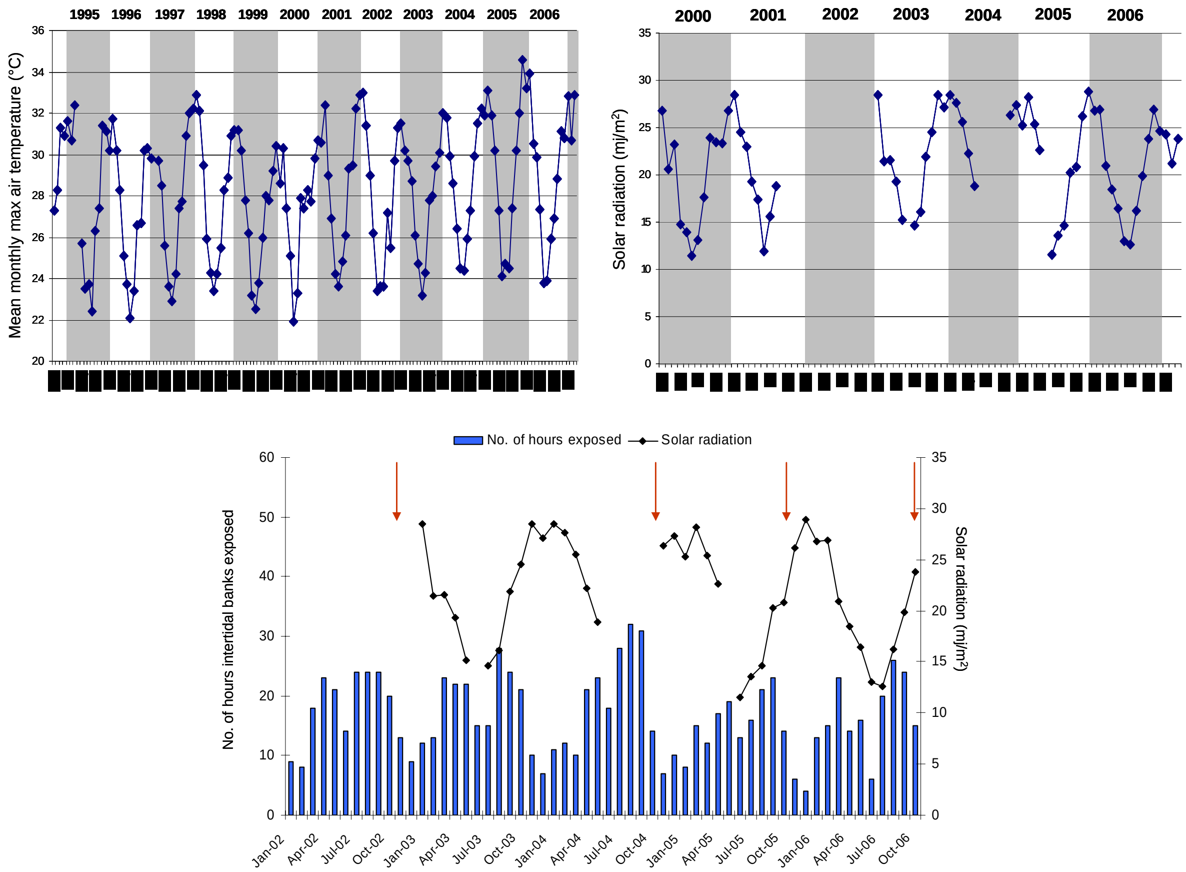


Figure 62. Solar irradiance, daytime exposure of intertidal meadows, mean monthly maximum temperature and mean monthly rainfall for Gladstone in the Fitzroy NRM 1995-2006.

Associated Macro-fauna

Sampling of associated macro-fauna has only been conducted on four occasions, and is insufficient to determine any seasonal or annual changes.

Fisheries

This region includes the massive estuaries of Broadsound and Shoalwater Bay and the fishing port of Yeppoon. Commercial fish catch is predominately King prawns with a total average of 758 tonnes worth $9.1M for the five years. There is a large commercial mud crab fishery and inshore fin fish fishery which operated between 2002 and 2006 for an average catch worth $3.7M (348 t) and $11.3M (1299 t) respectively. The species most caught in the Fitzroy region comprise of mullet, shark, grey mackerel, black jewfish and barramundi. Catches are variable across years with no clear trends for any of these species. Prawn and mud crab catches have remained relatively stable (Figure 63).

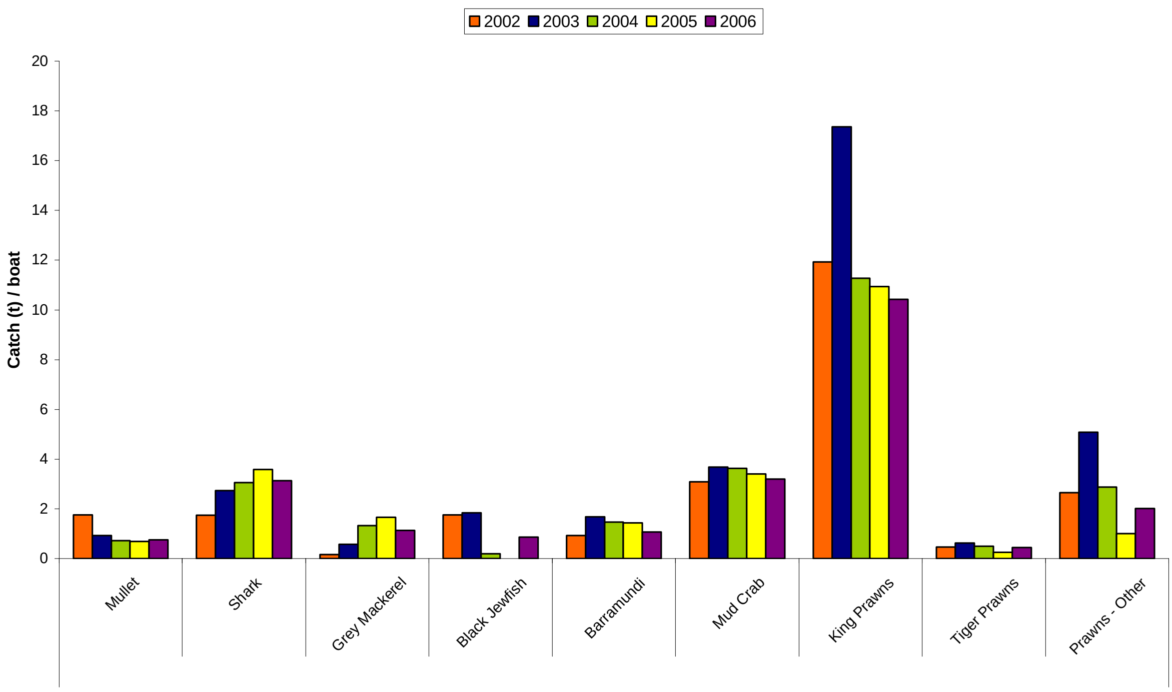


Figure 63. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Fitzroy NRM region between 2002 and 2006.

Regional Summary

Seagrasses in the Fitzroy NRM region appear to be in a relatively healthy state. In 2006 coastal and estuarine meadows generally show increasing trends with subtidal *Halodule* and *Halophila* meadows at the highest biomass we have recorded. The major drivers of seagrass changes were likely to be linked to changes in regional and local climate, and tidal exposure (Taylor *et al.* 2007). Seagrasses within the Port Curtis area also face a high level of anthropogenic threat with major port expansions including reclamations, new facilities and capital dredging planned or underway. The recent collision and fuel oil spill from the “Global Peace” in Port Curtis also highlighted the potential risks to the marine environment from shipping activity in the GBRWHA (Taylor *et al.* 2006). The high biomass may be part of a long term cycle or perhaps a shift to a more marine environment from the influence of the drought and impoundments on the Boyne River.

A major industry funded seagrass assessment and monitoring program is now being conducted in the Port Curtis area with the goal of minimising potential impacts on seagrasses and this program will also provide a long-term data set on meadow variability. The program will come under the umbrella of the Port Curtis Integrated Monitoring Program in 2007 and is set to expand with direct physical and chemical measurements at seagrass monitoring meadows (including temperature, light and contaminants) to assist in determining and formalising the links to drivers of seagrass change.

Information Gaps

Seagrass status and trends are well addressed for the seagrass habitat types found in the Fitzroy NRM region.

Burnett Mary

Background

The Burnett-Mary region covers an area of 88,000 square kilometres and supports a population of over 257,000 people, largely in the main centres of Bundaberg, Maryborough, Gympie and Kingaroy. The region is comprised of a number of catchments including the Baffle Creek, Kolan, Burnett, Burrum and Mary Rivers (Burnett Mary Report card 2004). Only the northern most catchment, the Baffle Basin, is within the GBRWHA. Baffle Basin bounded by the Many Peaks and Bobby Ranges in the west and the Dawes and Watalgan Ranges in the south. The coastal area includes long sandy beaches between Baffle Creek and Bustard Head and tidal mudflats and mangroves in the Rodds Peninsula/Turkey Beach area. It contains examples of riverine and estuarine areas considered 'near pristine' (Geoscience Australia 2005; Burnett Mary Regional Group 2005a) and provides the opportunity to use the area as a benchmark to comparable areas. The eastern coastlines are typically exposed to greater wave action than the regions located further north which are protected by the Great Barrier Reef.

Principal land uses in the area are beef cattle grazing (the largest though currently declining), small crop growers, forestry (including plantations), tourism and fishing (Baffle Creek Catchment Management Group 2007; Burnett Mary Regional Group 2005b). Other significant land uses include conservation, rural and urban residential development. It is anticipated that plantation forestry and tourism will be significant growth areas along with increases in residential development (Prange and Duke 2004).

The majority of coastal habitats within the Baffle region are protected in the Fisheries Habitat Areas, including Rodd's Bay (management A and B), Eurimbula (A) Seventeen Seventy-Round Hill (A and B), Colosseum Inlet (A and B) and Baffle Creek (A) (DPI&F 2007). Rodds Bay is also a Dugong Protection Area (B), reflecting its importance as seagrass habitat worthy of conservation.

The area was first broadly surveyed in 1988 (Lee Long *et al.* 1992) with the section north of Rodds Peninsula resurveyed at a finescale in 2002 (Rasheed *et al.* 2003b) (Map 9). Five seagrass species have been recorded from this region, the least number for any of the regions surveyed in the GBRWHA. This was due to a lack of reef top species being present and the relatively small size of the region that lies within the GBRWHA. Seagrass density within the meadows was low to medium. Meadows were found around Hummock Hill Island, Colosseum Inlet, through Rodds Bay, the inlet to Pancake Creek and on the leeward side of Bustard Heads, areas protected from the south easterly winds and oceanic swell. No seagrass was recorded between on the exposed coastline between Bustard Head to just north of Baffle creek the southern limit of the GBRWHA. No reef top seagrasses are recorded for this area. Large areas of deepwater seagrass were found in the relatively protected waters of Rodds Bay and were dominated by low density *Halophila decipiens* and *Halophila spinulosa* (Rasheed *et al.* 2003b).

Based on the mapped seagrass areas, the majority of seagrass meadows in the Burnett-Mary region are within coastal and estuary habitats (Table 7). Of these, 43% are protected within declared Fish Habitat Areas and 67% are located within port boundaries. Only 1% of seagrass meadows (excluding deepwater) covered by the highest levels of protection zones of the GBRWHA.

Map 9. Seagrass distribution, Seagrass-Watch locations and fine-scale monitoring locations in the Burnett-Mary NRM region.

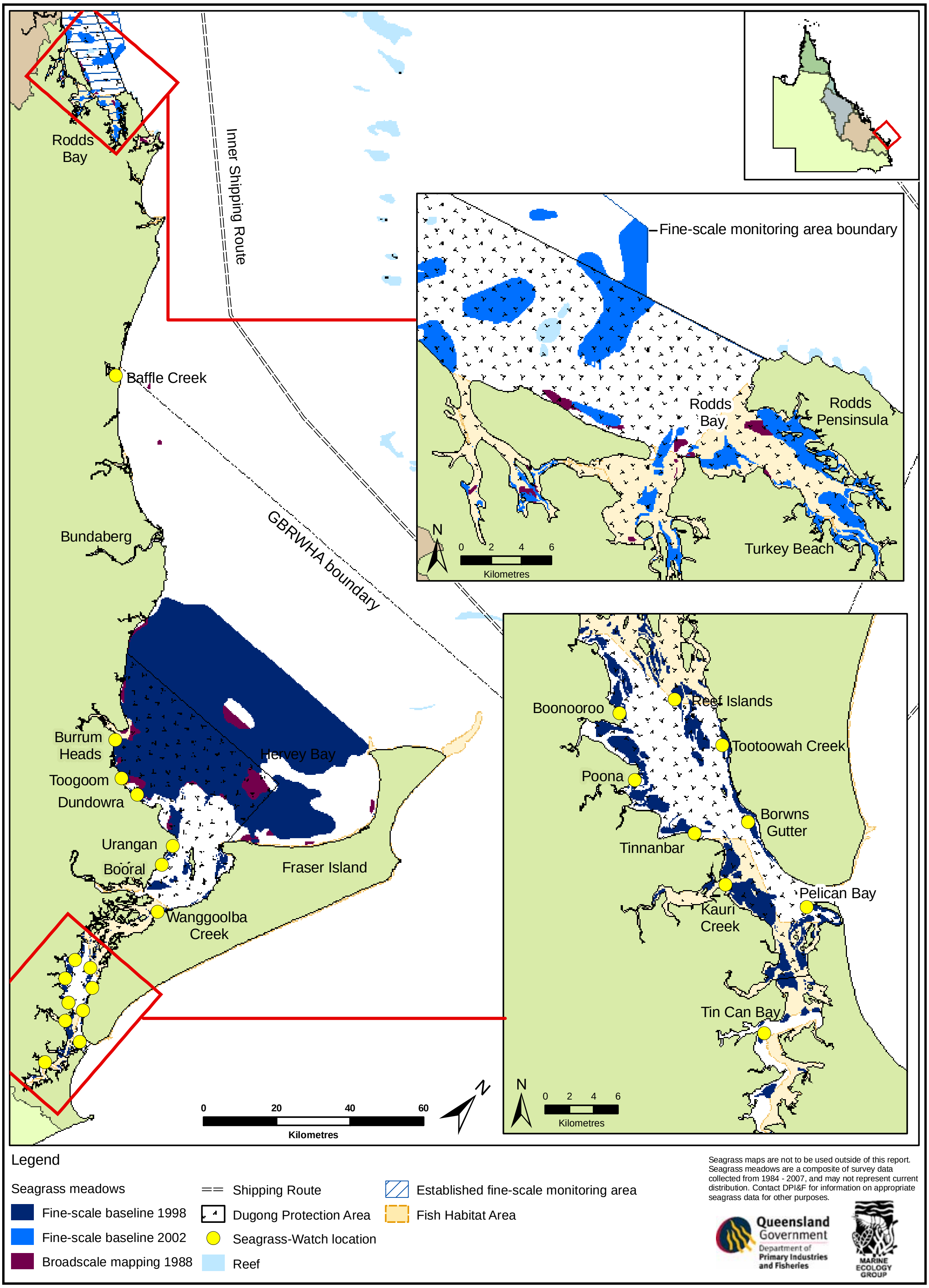


Table 7. Area (km^2) of seagrass within each habitat type, port area and marine protected zone of the Burnett-Mary region. Shaded areas afford highest levels of protection for seagrass (cells are not additive as there is overlap among zones).

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	31.11	32.89	27.26	10.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**37.94**
Coast	0.12	15.26	19.91	0.54	0.00	0.00	0.00	1.06	0.00	0.00	0.00	**34.04**
Reef	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.05**

Conceptual Summary

Estuarine

This the predominant seagrass habitat type for this area as they occur in bays that are protected from the south easterly-winds and consequent wave action. The seagrasses in this area must survive pulsed events of terrestrial run-off, sediment turbidity and drops in salinity (Figure 64). The region is relatively undeveloped so water quality reaching the near shore is relatively clean. Estuary seagrasses in the region are susceptible to temperature related threats and desiccation due to the majority being intertidal.

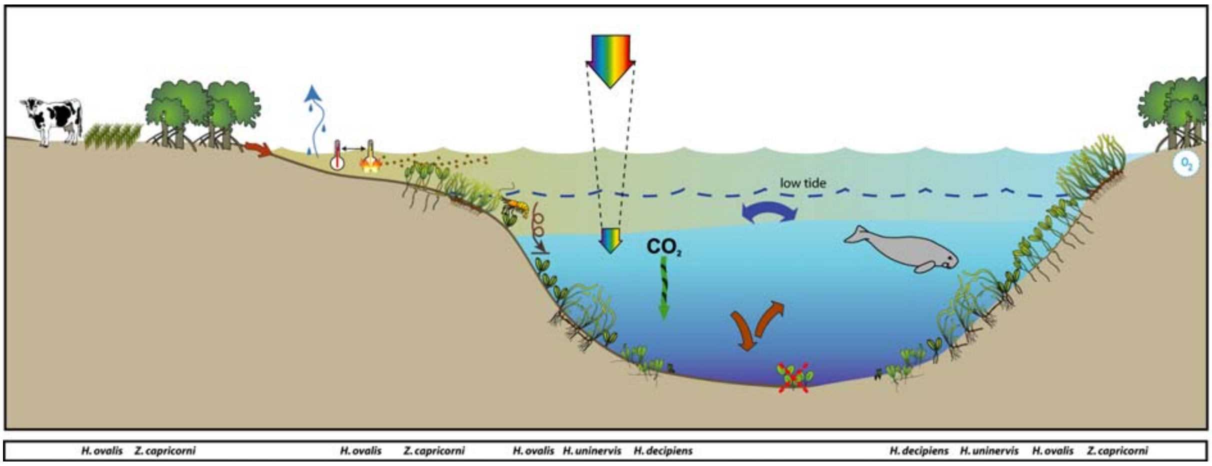


Figure 64. Conceptual diagram of Estuary habitat in the GBRWHA section of the Burnett Mary region – major control is shelter from winds and physical disturbance: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Coastal

Coastal seagrasses in the GBRWHA section of the Burnett Mary region are restricted to the area north of Rodds Peninsula where they are protected from strong south-easterly winds. These meadows occurred on intertidal to shallow sub-tidal sand banks and were dominated by *Halodule uninervis* and *Halophila ovalis*. Turbidity in this area is driven by wind and waves with meadows less exposed to rainfall related pulsed turbidity than for estuary meadows (Figure 65). Meadows in this region were generally not found in the upper-intertidal zone were they would be exposed to wave action. Coastal meadow distribution and species composition are driven primarily by disturbance and exposure at the upper depth limit and turbidity and light at the lower limit.

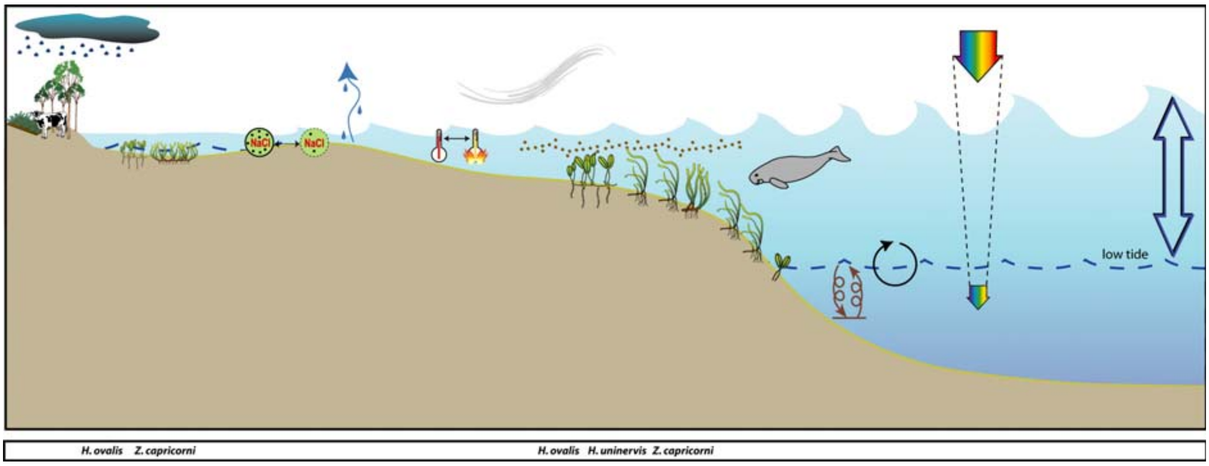


Figure 65. Conceptual diagram of Coastal habitat in the GBRWHA section of the Burnett Mary region – major control is shelter from winds and physical disturbance: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Deepwater

Deepwater seagrass meadows occurred to the north of Rodds Peninsula in the GBRWHA section of the Burnett Mary region. These meadows were typically low percent cover and dominated by *Halophila spinulosa* and *Halophila decipiens*. They occurred on the open sandy bottom areas in the lee of the peninsula. To the south of Rodds Peninsula no deepwater seagrasses have been identified until the sheltered waters of Hervey Bay (outside the GBRWHA). Coastal turbidity and pulsed flood events (Preen *et al*. 1995) restrict the deep water seagrass meadows to below 30m. A trawl fishery for Tiger and Endeavour prawns and the Saucer Scallop (*Amusium balloti*) operates inshore but probably only interacts with the inner margin of the seagrass as the average trawl depth is 19m and 34m respectively (QDPI&F, compulsory commercial daily logbook data base CFISH) (Figure 66). Sediment loads and turbidity from pulsed flood events are a threat to deepwater seagrass in this region (Preen *et al.* 1995).

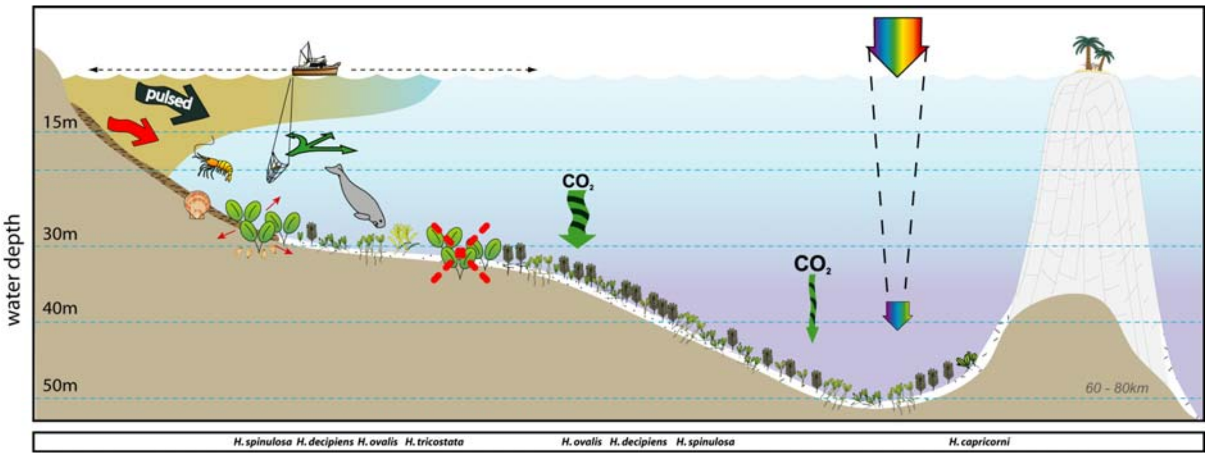


Figure 66. Conceptual diagram of deepwater habitat in the GBRWHA section of the Burnett Mary region – major control is pulsed turbidity from variable rainfall: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

Summary of Monitoring Data

Estuary

Monitoring of estuarine seagrass habitats in the Burnett-Mary region currently occurs in the Rodds Bay area. Annual monitoring of seagrass above ground biomass, species composition and area is conducted in three intertidal *Zostera capricorni* meadows. The monitoring is part of a broader program that includes seagrass meadows in neighbouring Port Curtis in the Fitzroy NRM. Monitoring has been conducted every November since 2004 in partnership with the Central Queensland Ports Authority (Taylor *et al.* 2007) following a detailed baseline survey conducted in 2002 (Rasheed *et al.* 2003b).

The intertidal *Zostera* meadows have maintained a relatively constant area from 2002 to 2006 but had a sharp decline in biomass in 2004 before recovering in 2005 and 2006 (Figure 67).

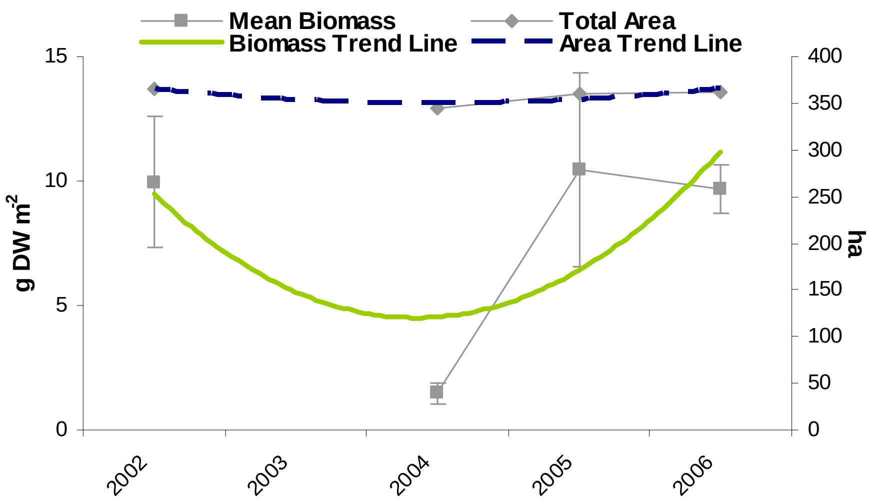


Figure 67. Changes in above-ground biomass and distribution of estuarine intertidal Zostera meadows monitored in the Mary/Burnett region from 2002 to 2006.

Deepwater

There is no ongoing seagrass monitoring comparable to the inshore/shallow water programs occurring in deepwater (>15m) in this region. Seagrasses in deep water have been sampled twice, once between 1994 and 1999 and again between 2003 and 2006. The modelled distribution of seagrass species for both time periods shows seagrasses are common in the inter-reef water of the of the Burnett/Mary region with almost every site sampled having some seagrass (De'ath *et al.* 2007). *Halophila decipiens, Halophila ovalis* and *Halophila spinulosa,* were the most likely to be found in both surveys. These seagrass meadows link with the extensive meadows and dugong feeding areas of Hervey Bay and Great Sandy Strait. The comparisons for deep water are summarised and discussed in a separate report (De'ath *et al.* 2007).

Climate and Seagrass Change

Like the seagrasses in Port Curtis, the major drivers of seagrass change appear to be strongly linked to climate and tidal exposure. The meadows appear to be particularly susceptible to drought like conditions of high solar irradiation and temperature leading to thermal stress and desiccation when meadows are exposed at low tide. Declines in the seagrass meadows in 2004 appear to be linked to daytime exposure of seagrass banks (Taylor *et al*. 2007). During 2004, the intertidal banks were exposed for up to 30 hours a month, almost double the average of other years (Figure 68). This increased exposure combined with the drought conditions of high solar irradiance and temperature was likely to have lead to thermal stress and desiccation of the seagrasses when exposed (Rasheed *et al.* 2005a).

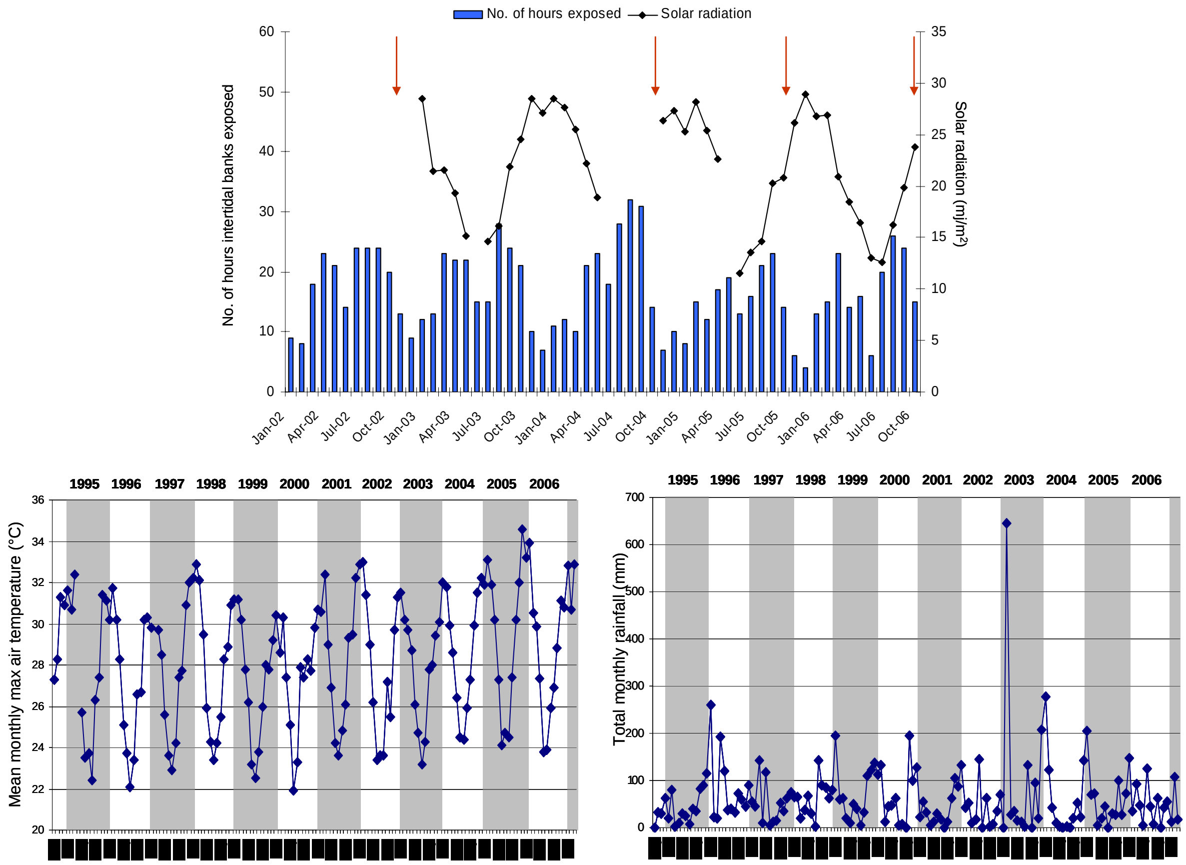


Figure 68. Solar irradiance, monthly hours of intertidal seagrass exposure, mean monthly maximum temperature and mean monthly rainfall for Gladstone north of the Burnett-Mary NRM 1995-2006. (red arrows indicate seagrass monitoring events)

Associated Macro-fauna

No monitoring of benthic macro-fauna is conducted in this region.

Fisheries

This region includes 40,000 square kilometres of marine area and covers five major river basins: Baffle, Kolan, Burnett, Burrum, and Mary and a series of coastal rivers (Isis, Gregory and Elliott). The fishery in this region is dominated by catches of the off shore king prawn fishery (Figure 69) with an average of 576 tonnes of all tiger and king prawns over the five years. The mud crab and fish catches are most likely from outside the GBRWHA as most of this region is to the south of the GBRWHA. They are worth $1.7M and $15.8M respectively making these catches large contributors to the regions fisheries. The inshore fin fish fishery predominantly consists of stout whiting catch which averaged 175 tonnes per boat each year between 2002 and 2006. Generally, fin fish species are variable across years and show no clear trends. Prawns catches have remained relatively stable over the five years.

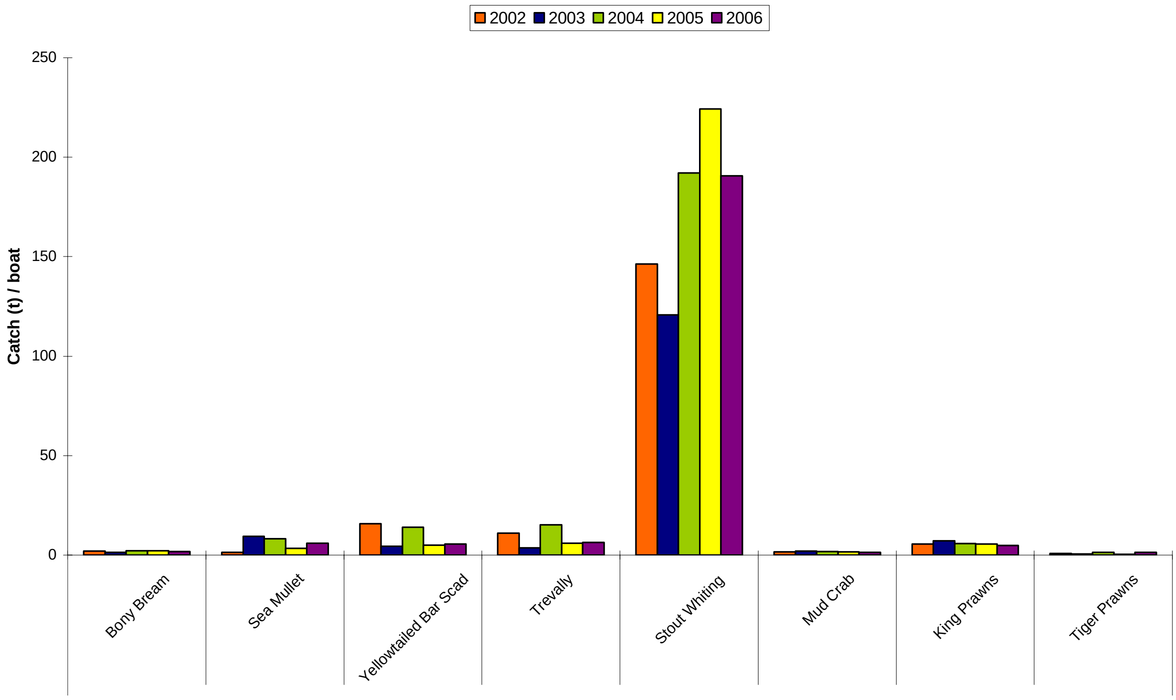


Figure 69. Average catch per boat for dominant commercial inshore fin fish species, mud crab and prawn fisheries in the Burnett Mary NRM region between 2002 and 2005.

Regional Summary

Seagrass habitats in the Burnett-Mary section of the GBRWHA were in a relatively healthy state with monitoring indicating that major changes were likely related to the amount of tidal exposure, temperature and solar irradiance. Major areas of seagrass habitat in the region generally face low levels of anthropogenic threat especially compared with seagrasses to the north in the Fitzroy NRM.

Information Gaps

- None of the coastal *Halodule* meadows important to dugong are monitored in this region. However, these meadows types are monitored just to the north within the Fitzroy NRM region

4. Discussion

General

The intention in developing a status and trend report for the seagrasses of the GBRWHA was always that is would be a snapshot in time, a document on which to build an evolving understanding of the status of seagrasses and the community of species associated with these. It serves a dual role to identify gaps in our knowledge and to assess the performance of our research programs at addressing those gaps.

It is a truism to say that the past does not necessarily predict the future and the trends we identify remain accurate only until the next data point is entered. However with the extensive data coverage we have developed throughout the region, it is likely that only major catastrophic events, massive climate change, a tsunami, intense storms or a disease outbreak would significantly change GBRWHA wide trends. However local distributions may well be seriously impacted by concentrated coastal developments.

Seagrasses are viewed as a habitat type – a seagrass meadow – but the plants belong in three separate taxonomic families and make up 15 separate species. Each of these species fills an individual ecological niche and may use different approaches to colonisation, survival growth and recovery. There are at least four different growth strategies among the species in the GBRWHA. In addition in some locations plants may be sexually reproductive but the same species in another location may grow purely by asexual expansion from a single clone. Each of these strategies and combination of strategies affects the plant and meadow response to natural environmental and anthropogenic influence. The loss of an area of seagrass meadow may be the result of one or more external influences, of a simple plant clone senescing, or a combination of those factors.

Adding to this complexity is the range of habitat types that seagrasses have colonised in the GBRWHA. Different species occur on reef edges exposed to waves, on reef platforms, at 60m deep on coralline sands in the reef lagoon, on sandy coastlines both inter-tidal and sub-tidal, and in estuaries colonising muddy banks and the edges of mangrove-lined creeks. Seagrasses are found from the tip of Cape York more or less continuously to the southern boundary of the GBRWHA a coastal distance of some 2000 kilometres.

Because of this complexity and extended distribution, reviewing the seagrass present in the GBRWHA and changes or trends is scale dependent in time and space. Locations may respond differently to local influences and to seasonal influences in biophysical factors such as temperature and light which influence the extent and biomass of seagrasses through an annual cycle. Different species and species groups may respond differently to these biophysical factors.

Some locations may respond dramatically to a combination of biophysical events. Seagrass exposed at low tide in the tropics can be used as an example. A very low tide in the day time during summer combined with high temperatures and a drying wind can lead to a sudden dying of leaf material and a dramatic temporary loss of biomass in a meadow. The impact of a dugong herd from targeting a specific meadow may also result in a small spatial area suffering a dramatic decline in biomass against a more stable background trend.

DPI&F's monitoring approach addresses this complexity in pressures and scale by taking four approaches:

1. A broad scale (hundreds of kilometres) coastal mapping and monitoring project to provide baseline information for management planning and zoning purposes at a low temporal resolution. Many areas considered to be of low risk have not been remapped in 20 years. This data set could be used at a world heritage area scale to assess global changes such as a response to climate change.
2. Fine scale mapping assessment and monitoring of key meadows with high biological value and in areas such as inlets with urban development considered to be at risk often with a much lower temporal resolution – generally once a year. It includes both intertidal and subtidal meadows. This data set is at a scale of 10s of kilometres, includes detailed area maps, biomass and information on benthic communities and is targeted at areas of risk where change, particularly loss, is likely.
3. A Seagrass-Watch program which has a wide spatial coverage within most of the GBRWHA (monitoring 61 sites) with a high temporal resolution – normally four times per year. This provides an excellent "watch" for changes in percent cover, species composition, local extent and a range of biophysical information. It is focussed on monitoring inter-tidal meadows (including reef platform) and is designed to alert management authorities to changes that may occur in short, less than one year, temporal scales.
4. A project to study and model the extent of seagrass in water deeper than 15m – the GBRWHA inter reef lagoon and infer change in spatial extent.

Combined this approach gives a wide range of spatial and temporal coverages of inter-tidal coastal, estuarine and reef platform seagrass, some targeted sub-tidal seagrass monitoring in coastal and inlet environments, and at least modelled spatial information from deep water regions.

Trends

Results from the DPI&F monitoring programs indicate that at the scale of the GBRWHA, seagrass meadows were in a "healthy" state and have been relatively stable over the past 20 years. However within this overall "stability", seagrasses have fluctuated, most often as a response to climate and at smaller localized scales there have been some acute event related changes. These fluctuations do not appear to represent long term trends in a particular direction - they are simply fluctuations.

Percent cover from the Seagrass-Watch data set when all sites are combined shows since 1998 a flat trend for inter-tidal coastal seagrass at around a 20% cover level, a decline in recent years in estuary inter-tidal and an increase in percent cover for reef platform seagrasses. The changes that have occurred are likely to be related to exposure at low tide and temperature and drying effects and are unlikely to be long term effects. Similarly across locations where fine scale mapping and monitoring is conducted, there have been decreases in intertidal seagrasses and increases in subtidal seagrasses during dry and hot drought years. The reverse occurred during periods of higher rainfall. Within these overall trends there are some location specific exceptions. Whitehaven Beach shows a marked decline related to anchor damage and a *Lyngbya* outbreak. This decline at one of Queensland's premier beaches has been flagged as an issue of concern.

There have also been some gains in area such as at Green Island and Hinchinbrook Island but at least part of that change can be explained by improved technique. In the 20 years we have moved from position fixing errors of nautical miles to GPS fixes of 5-10 m accuracy. There are some notable species changes. *Syringodium isoetifolium* has colonised Green Island near Cairns since the mid 1980s. Pioneer Bay in the Mackay/Whitsunday region is becoming more *Zostera* dominated. But these are likely to be normal succession events.

There have been some losses to clamation projects through the coastal development permit process. Townsville Strand and developments at Airlie Beach are examples. The area lost in these developments is approximately 20 ha. This compares with an estimated area of seagrass of between 5 and 6 thousand square kilometres of coastal seagrass and a vastly greater area of deep water seagrass. It is important however to limit clamation of tidal and sub-tidal habitats for coastal development as this continuing trend is always results in a loss, never again and over long temporal periods the losses are cumulative.

Natural Resource Management Regions

The six regions are set by climate, demographic and catchment groupings are unequal in size and coastline and require some care when making inter-regional comparisons. The types of influences on seagrass differ for these regions. Cape York has almost no seagrass in port limits compared with the Wet Tropics, Fitzroy and Burnett-Mary which have almost half their seagrass in port limits. The Cape York region is also very large and has open sandy beach coastlines in the north, mud, and mangroves in Princess Charlotte Bay and an entirely different rocky coastline to the south. It is not necessarily a coherent region from a seagrass management perspective. For each region we have tried to capture the process that best equate to our understanding but clearly that needs to be tempered by an understanding of regional complexities. In each region we have stratified the information by estuaries, coasts, reef, and deep water, and by depth. The location within these strata is at least as important as region in understanding how a seagrass meadow may respond to external pressures. Our conceptual models synthesise the key driving influences and pressures and conceptual models are a powerful way of visualising how each system works.

Pressures

Pressures on seagrass meadows in the GBRWHA can be divided into three types:

1. *Long temporal scale chronic affects*

   These include the possibility of an effect from low levels of herbicides in coastal waters, increases in turbidity and sediment loads over time, slow climate change, potential for changes in herbivory, and increases in nutrient loads generally over broad spatial scales where the response of meadows is likely to be incremental and difficult to detect.
2. *Long temporal scale acute impacts*

   These include coastal clamation, routine ongoing dredging and disposal for shipping access, and continuous damage from vessels such as propeller scarring generally over smaller spatial scales; and
3. *Short temporal scale acute impacts.*

   Catastrophic events such as oil or other shipping spills, tsunamis, cyclones can have severe short term impacts on seagrass meadows but recovery is generally rapid and successful.

Pressures on seagrass other than from events such as cyclones can be influenced by management approaches, protected areas and changes in land use practices. This has been recognised in the GBRWHA with recent representative area zoning dramatically increasing the areas of seagrass meadow protected from any new direct damage. An ongoing Reef Plan initiative has as its key objective to improve land use practices and the quality of run off water entering the reef lagoon. Clamation of inter-tidal and subtidal habitats remains only a small total effect and routine dredging for shipping occurs with tightly controlled restrictions and monitoring.

Large areas of the GBRWHA lagoon north of Cairns are designated as 'high risk' of shipping accident (QT and GBRMPA 2000). An oil spill has the potential to cause enormous damage to inter-tidal seagrass and the animals that rely on them for food and shelter. While such an oil spill is highly unlikely, some of the meadows near the shipping channel are logistically remote. Protection of these meadows will require urgent response under difficult conditions. The deployment of existing equipment within the framework of the Queensland Coastal Contingency Action Plan may not provide sufficient protection.

Climate change, potential sea level rise, and increased intensity and frequency of tropical storms will all impact on coastal and estuarine seagrass meadows. Opportunities for intervention within the GBRWHA however are limited to ensuring that coastal planning provides for appropriate foreshore and riparian buffers to allow landward movement of the intertidal and subtidal marine plant habitats.

Events associated with climate change combined with the effects of local catchment use may explain some of the seagrass changes observed in coastal waters (Thomas *et al.* 2006). "Drought" years of low rainfall and river flows, high temperatures and high solar irradiance cause declines in inter-tidal seagrasses that become exposed to the higher temperatures and desiccation during daytime low tides. These same conditions may benefit sub-tidal seagrasses that have more available light due to lower turbid river runoff, but are protected from tidal exposure (Thomas *et al.* 2006; McKenna *et al.* 2005, 2007). The reverse may be true of wet years. These processes are complex and poorly understood and will require collection of long term data from a range of sites before a reliable model could be developed.

The pressures are quite different for each of the regions. Anthropogenic affects are far more important in regions such as the Wet Tropics with its port activities and intensive coastal agriculture. This region is well monitored and loss or any long term changes at least in shallow waters would be quickly noticed. North on the Cape such impacts are less frequent and less likely. However changes could occur over time and would not be documented given the lack of monitoring in this region.

Protection

The highest primary level of protection is provided by declared Fish Habitat Area and Preservation Zones within which permits are generally not available for works that disturb seagrass habitats. A secondary level of protection is provided to seagrass by Marine National Park Zoning, Buffer Zones and Scientific Research Zones with a permit required for works that could damage seagrasses. The primary protection is unevenly distributed among regions with Preservation Zones found only in the Cape York Region and little declared Fish Habitat Area protection in the Fitzroy Region (there is a plan to Gazette the Fitzroy – Narrows Fish Habitat Area in 2007/2008). Most seagrass protection is coastal and the only significant protection afforded to reef platform seagrass is in the Cape York region mirroring the extent of seagrass areas to protect. The areas protected from direct disturbance are large with over 700 km^2 of seagrass meadows protected in these six zones alone. Other closure types may also provide some protection. Temporal and spatial closures to bottom trawling reduce any impact fishing may cause to the bottom habitats, and ports, even though excluded from the GBRWHA may have marine park zonings (as in Cairns Harbour) or be subject to detailed port environment management plans and habitat monitoring programs. There are also inshore spatial and temporal closures to fishing practices such as trawling implemented to protect juvenile prawn and fish stocks. These management measures, while primarily for fishing and to protect fisheries resources, have major benefits for seagrass meadows.

While direct protection is high – including approximately 25% of the coastal seagrass, spatial protection does not prevent harm to seagrass meadows from unintended effects of runoff and discharge from land and marine use, shipping accidents, etc. The largest area of seagrass recorded as being damaged in Queensland was a loss that took five years to recover of 1000 km^2 in Hervey Bay just to the south of the GBRWHA. This loss was attributed to loss of light on the bottom due to sediment in the water (Preen *et al.* 1995), a result of consecutive storms exacerbating poor catchment practices. Herbicides have also been recorded in coastal sediments where seagrasses are found (Haynes *et al.* 2000) at levels which laboratory trials indicate do have the potential to reduce photosynthetic activity. Unlike terrestrial environments, the marine seagrass habitat is closely connected to adjacent processes and cannot be adequately quarantined. An approach to protect seagrass is required that includes management of catchment processes outside of the GBRWHA as well as those within.

Gaps in Knowledge

Developing a status and trend report inevitably identifies and emphasises the gaps in knowledge that remain despite seagrass habitats being recognised as essential to the continued productivity of the regions fisheries and as a key food resource for green turtle and dugong. Funding of research by the fishing industry and fisheries management agencies and/or directed only at areas perceived to be at risk of loss directs research to regions where commercial fishing occurs or there is urban or agricultural development. Community based monitoring programs by definition function best where there are strong coastal communities.

In Queensland there are two major regions where little information on seagrass health is being collected. Information on seagrass is not being collected from almost the entire coastal area, estuaries and reef platforms of the Cape York NRM region. Apart from the Cooktown area there are no monitoring locations yet this area supports a major fishery and turtle and dugong populations and contains some of the largest reef platform seagrass meadows in the GBRWHA. Management decisions are presently being based on 20 year old data. Also almost without monitoring programs are all the meadows deeper that 15 m. Some information is being collected from Hay Point near Mackay but this does not represent the vast area of seagrass known to occur. Two deep water surveys have been conducted finishing in 2004 with no plans to continue or repeat this monitoring. It is possible that with climate induced storms and increases in temperature and algae growth light penetration could be reduced and huge areas of seagrass at the deepest edge - 50-60 m lost. An entire habitat type and all the benthic communities it supports could be lost from a region within the GBRWHA and it could pass unnoticed for several years. These events have occurred in Queensland in the past. In 1993 nearly 1000 km^2 of seagrass was lost from meadows in around 20m deep in Hervey Bay and this was not recognised until starving dugong were found washed on the beach. It would be desirable if at least annual monitoring of seagrasses at selected sites in these remote locations was contemplated.

Strong links between seagrass meadows and fisheries have been shown based on location and productivity (Coles *et al.* 1993; Watson *et al.* 1993). This work is limited in extent and inadequate to precisely describe the role of seagrasses in the food chain or its role as shelter for juveniles. The work needs to be repeated for locations other than within estuaries and needs to be updated with modern techniques of tracing carbon pathways and trophic links. Work on carbon production and mapping high starch content seagrass that has been conducted in Queensland waters outside the GBRWHA has not been repeated within the GBRWHA. All seagrasses are not uniformly productive and important for benthic communities and a better understanding is needed if the specific habitat types are to be identified and protected in the future.

The apparent links between climate, exposure and seagrass change identified in this report also need further analysis. DPI&F hold extensive datasets on seagrass change over 10 years and more formal correlative analysis on how these changes are related to climate is to be undertaken in the future.

And finally there is a very poor understanding of meadow resilience. While resilience factors are complex – these may include the previous history of the meadow, species mix, genome types, availability of viable seed banks, reproductive ability, nutrient availability, sediment type and a variety of location specific factors – knowledge of their roles is essential in understanding the “performance” of a meadow under stressful conditions. There are long term data sets that show the range of fluctuations that can occur but the limits to successful recovery and the processes that support recovery are poorly understood or documented. Without this information it is difficult to model scenarios such as the effect of climate change in a meaningful way.

5. Conclusions

Although the seagrass along the east coast of the GBRWHA is in a healthy state, considerable pressures on seagrass meadows remain along the urban coast from river discharge water quality and urban and industrial development. With increasing urban and catchment development further research is will be required to understand the synergistic effects between high nutrient availability and exposure to pollutants, and between water quality parameters and other disturbances or factors that influence health and production of seagrass. However a great proportion of seagrass meadows are remote from these effects and subject only to natural disturbances and fluctuations. There is a potential of loss from catastrophic events such as oil spills but these risks are generally low for most meadows and recovery is generally rapid.

At small spatial scales, bays, estuaries, meadows, there is considerable variability in meadow biomass and percent cover but at a GBRWHA scale there is no evidence of sustained losses or gains where monitoring is occurring. Most changes noted are clearly linked to short term environmental events.

There are information gaps. We poorly understand trophic links and resilience, and our ability to populate scenario models with parameters that reflect the tropical environment is limited. Carbon and nutrient mapping has not been undertaken in the GBRWHA.

The seagrass monitoring program within the GBRWHA has been successful in monitoring seagrass condition at a variety of locations and habitats. It is one of the most comprehensive seagrass programs outside the east coast of North America. Some regions however are less well monitored than others and this needs to be addressed.

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