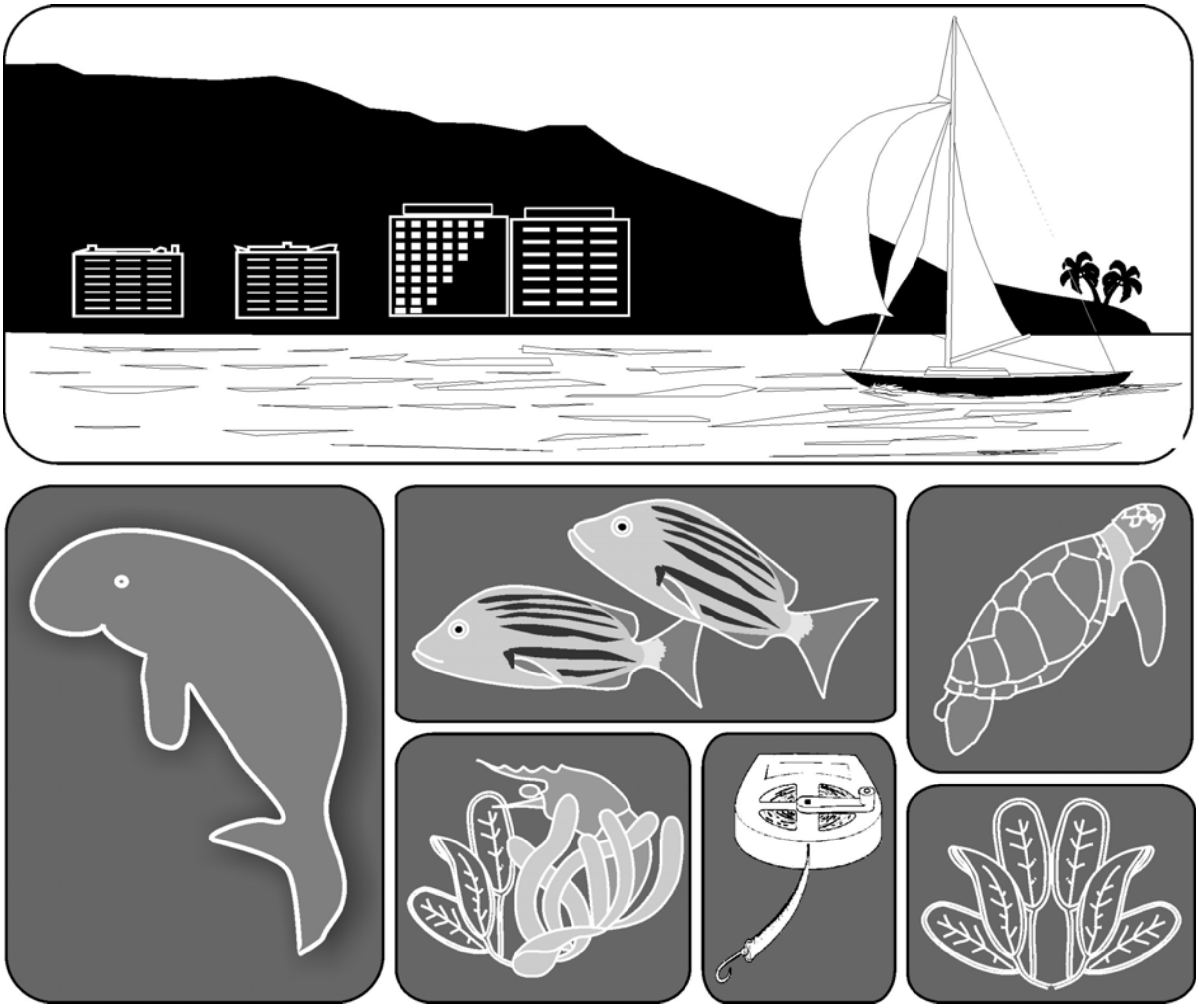
Seagrass-Watch

Proceedings of a Workshop for Monitoring Seagrass Habitats in the Whitsunday Region



QPWS Whitsunday Information Centre, Airlie Beach
14th July 2007

Len McKenzie, Jane Mellors & Rudi Yoshida

Department of Primary Industries & Fisheries, Queensland

Seagrass-Watch

Queensland Government
Department of Primary Industries and Fisheries

Australian Government
Department of the Environment and Water Resources

Reef & Rainforest
RESEARCH CENTRE

First Published 2007

Disclaimer

Information contained in this publication is provided as general advice only. For application to specific circumstances, professional advice should be sought.

Seagrass-Watch HQ has taken all reasonable steps to ensure the information contained in this publication is accurate at the time of the survey. Readers should ensure that they make appropriate enquires to determine whether new information is available on the particular subject matter.

The correct citation of this document is

McKenzie, LJ, Mellors, JE and Yoshida, R (2007). Seagrass-Watch: Proceedings of a workshop for Monitoring Seagrass Habitats in the Whitsunday Region. QPWS Whitsunday Information Centre, Airlie Beach 14th July 2007 (Seagrass-Watch HQ, Cairns). 32pp.

Produced by Seagrass-Watch HQ

Northern Fisheries Centre, Cairns, 2005.

Enquires should be directed to:
Len McKenzie
Northern Fisheries Centre,
PO Box 5396
Cairns, QLD 4870 Australia

Overview

Seagrass-Watch is a global scientific, non-destructive, seagrass assessment and monitoring program.

Often governments are unable to protect and conserve seagrass meadows without the assistance of local stakeholders (e.g., local residents, schools, tertiary institutions, non-government organisations). Seagrass-Watch is a monitoring program that brings citizens and governments together for seagrass conservation. It identifies areas important for seagrass species diversity and conservation. The information collected can be used to assist the management of coastal environments and to prevent significant areas and species being lost.

Monitoring seagrass resources is important for two reasons: it is a valuable tool for improving management practices; and it allows us to know whether resource status and condition is stable, improving or declining. Successful management of coastal environments (including seagrass resources) requires regular monitoring of the status and condition of natural resources.

Early detection of change allows coastal management agencies to adjust their management practices and/or take remedial action sooner for more successful results. Monitoring is important in improving our understanding of seagrass resources and to coastal management agencies for:

- *Exposing coastal environmental problems before they become intractable,*
- *Developing benchmarks against which performance and effectiveness can be measured,*
- *Identifying and prioritising future requirements and initiatives,*
- *Determining the effectiveness of management practices being applied,*
- *Maintaining consistent records so that comparisons can be made over time,*
- *Developing within the community a better understanding of coastal issues,*
- *Developing a better understanding of cause and effect in land/catchment management practices,*
- *Assisting education and training, and helping to develop links between local communities, schools and government agencies, and*
- *Assessing new management practices*

Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assess the human impacts on seagrass meadows, which have the potential to destroy or degrade these coastal ecosystems and decrease their yield of natural resources. Responsive management based on adequate information will help to prevent any further significant areas and species being lost. To protect the valuable seagrass meadows along our coasts, everyone must work together.

The goals of the Seagrass-Watch program are:

- *To educate the wider community on the importance of seagrass resources*
- *To raise awareness of coastal management issues*
- *To build the capacity of local stakeholders in the use of standardised scientific methodologies*
- *To conduct long-term monitoring of seagrass & coastal habitat condition*
- *To provide an early warning system of coastal environment changes for management*
- *To support conservation measures which ensure the long-term resilience of seagrass ecosystems.*

This workshop is hosted by Seagrass-Watch HQ, with local coordination by Margaret Parr and Queensland Parks and Wildlife. It is supported by the Australian Government's Marine and Tropical Sciences Research Facility (Department of the Environment and Water Resources) represented in North Queensland by the Reef and Rainforest Research Centre; the Great Barrier Reef Marine Park Authority (GBRMPA); and the Queensland Department of Primary Industries & Fisheries. As part of this workshop we will

- *learn seagrass taxonomy*
- *discuss the present knowledge of seagrass ecology,*
- *discuss the threats to seagrasses*
- *learn techniques for monitoring seagrass resources*
- *provide examples of how Seagrass-Watch assists with the management of impacts to seagrass resources and provides an understanding of their status and condition.*

The following information is provided as a training guide and a reference for future Seagrass- Watch monitoring activities. For further information, please do not hesitate to contact us at

Seagrass-Watch HQ
Northern Fisheries Centre
Queensland Department of Primary Industries & Fisheries
PO Box 5396
Cairns QLD 4870
AUSTRALIA
Telephone (07) 4057 3731
E-mail hq@seagrasswatch.org

or visit

www.seagrasswatch.org

Workshop leaders

Len McKenzie

Len is a Principal Scientist with the Queensland Department of Primary Industries & Fisheries and Seagrass-Watch Program Leader. He is also chief investigator for the MTSRF task on the condition, trend and risk in coastal seagrass habitats, Task Leader of the RWQPP Marine Monitoring Programme - Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal fisheries habitat. Len has 19 years experience as a research scientist on seagrass ecology, assessment and fisheries habitats. This includes experience within Australia and overseas in seagrass research, resource mapping/ assessment and biodiversity. He has provided information on seagrass communities that has been vital in management of seagrass resources of the Great Barrier Reef and also at the state, national and international levels. He has also advised on fisheries and coastal resource-use issues for managers, fishing organisations, conservation and community groups. Len is also the Secretary of the World Seagrass Association.

Current Projects

- Seagrass-Watch
- Status and mapping of seagrass resources in Queensland
- Assessment of primary and secondary productivity of tropical seagrass ecosystems
- Investigations on the macrofauna associated with seagrass meadows
- Great Barrier Reef Water Quality Protection Plan – marine monitoring program: seagrass

Jane Mellors

Jane is a Fisheries Biologist with the Queensland Department of Primary Industries & Fisheries. Jane has over 20 years experience in seagrass related research and monitoring. She is involved with indigenous participation in marine ecosystem monitoring in the Torres Strait. Jane is a specialist in tropical seagrass eco-physiology, seagrass taxonomy, geochemistry of marine sediments.. In 2003, Jane completed her Doctorate (Dept TESAG, James Cook University) on sediment and nutrient dynamics in coastal intertidal seagrass meadows of north eastern Australia of North Queensland.

Current Projects

- Seagrass-Watch community seagrass monitoring
- NHT & Queensland ED: Education opportunities for indigenous involvement in marine ecosystem monitoring
- Co-author of a guide to tropical seagrasses of the Indo-west Pacific
- Investigations on the effects of nutrients on tropical seagrasses
- Water Quality and Ecosystem Monitoring Programs – Reef Water Quality Protection Plan

Rudi Yoshida

Rudi is a Scientific Assistant with the Queensland Department of Primary Industries & Fisheries. Rudi has over 10 years experience in seagrass related research and monitoring. He is also a core member of Seagrass-Watch HQ, and ensures data submitted is managed and QA/QC protocols applied. He is also responsible for maintenance of the Seagrass-Watch website.

Current Projects

- Seagrass-Watch
- Great Barrier Reef Water Quality Protection Plan – marine monitoring program: seagrass

Agenda

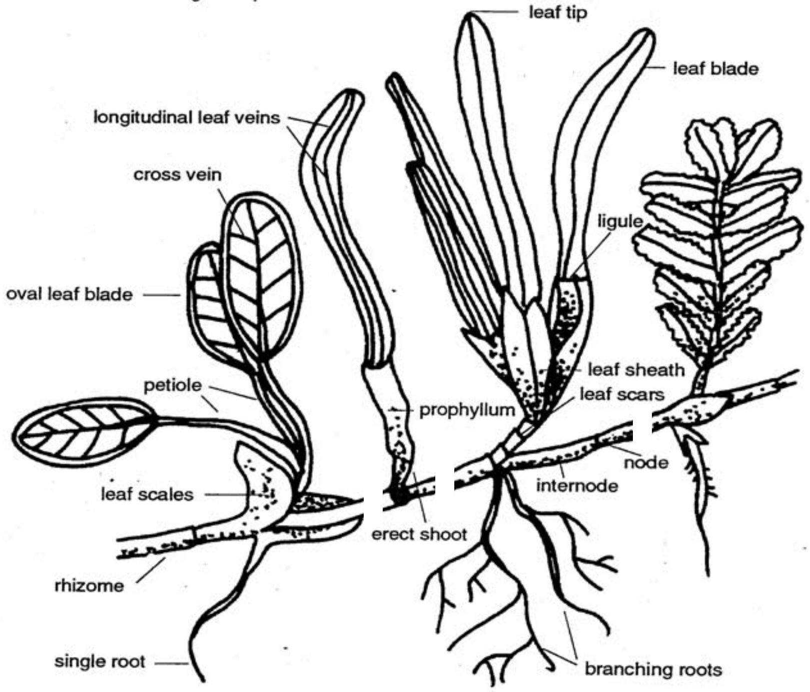
Saturday 14th July 2007

Morning	0830 - 0845	Welcome – *Margaret Parr & Len McKenzie*
	0845 – 0900	Seagrass Biology and Identification – *Len McKenzie*
	0900 – 0945	Laboratory exercise: Seagrass Identification & how to prepare a seagrass press specimen –*Jane Mellors & Rudi Yoshida*
	0945 - 1030	Seagrass Ecology and Threats – *Len McKenzie*
	1030 - 1100	*Morning Tea*
	1100 – 1110	Seagrass monitoring – *Len McKenzie*
	1110 - 1220	Seagrass-Watch - *Len McKenzie & Jane Mellors*
	1220 – 1230	Safety briefing & risk assessment – *Jane Mellors*
Afternoon	1230 – 1330	*Lunch*
	1400 - 1630	**Field exercise** Seagrass-Watch monitoring PI3 – *Len McKenzie, Jane Mellors & Rudi Yoshida* *Where*: At Cannonvale, meet in park *What to bring:* • *hat, sunscreen (Slip! Slop! Slap!)* • *dive booties or old shoes that can get wet* • *drink/refreshments* • *Polaroid sunglasses (not essential)* • *enthusiasm* *We welcome your children, but please keep them under close supervision.* *You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet and muddy!* *Please remember, seagrass meadows are an important resource and are protected by law. We ask that you use discretion when working/walking on them.*
	1700 - 1730	Wrap up *(on foreshore)* • Feedback
	1730 - 1830	Special presentation & refreshments

Low tide: 0.24m at 1619

Background

Seagrasses are specialised marine flowering plants that have adapted to the nearshore environment of most of the world's continents. The majority are entirely marine although some species cannot reproduce unless emergent at low tide. Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline. There are relatively few species globally (about 60) and these are grouped into 13 Genera and 5 Families.



Composite illustration demonstrating morphological features used to distinguish main seagrass taxonomic groups.

from Lanyon (1986)

Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. These names are not consistently applied among countries. Coastal communities would almost certainly recognise the term "turtle grass" as referring to the shallow subtidal and intertidal seagrasses that turtles are associated with.

There is now a broad understanding of the range of species and seagrass habitats. Areas less well known include the southeast Pacific reefs and islands, South America, the southern Atlantic, the Indian Ocean islands, the west African coast, and Antarctica. Shallow sub-tidal and intertidal species distributions are better recorded than seagrasses in water greater than 10 m below MSL. Surveying deeper water (>15m) seagrass is time consuming and expensive and it is likely that areas of deepwater seagrass are still to be located.

Tropical seagrasses occupy a variety of coastal habitats. Tropical seagrass meadows typically occur in most shallow, sheltered soft-bottomed marine coastlines and estuaries. These meadows may be monospecific or may consist of multispecies communities, sometimes with up to 12 species present within one location. The stresses and limitations to seagrasses in the tropics are generally different than in temperate or subarctic regions. Temperature related impacts most often result from high water temperatures or overexposure to warm air; osmotic impacts result from hypersalinity due to evaporation; radiation impacts result from high irradiance and UV exposure.

The depth range of seagrass is most likely to be controlled at its deepest edge by the availability of light for photosynthesis. Exposure at low tide, wave action and associated turbidity and low salinity from fresh water inflow determines seagrass species survival at the shallow edge. Seagrasses survive in the intertidal 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 (to heat, drying or freezing) at low tide.

Tropical seagrasses are important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities (Amesbury and Francis 1988).

Barrier reefs protect coastlines, and the lagoon formed between the reef and the mainland is protected from waves, allowing mangrove and seagrass communities to develop. Seagrasses trap sediment and slow water movement, causing suspended sediment to fall out. This trapping of sediment benefits coral by reducing sediment loads in the water.

Mangroves trap sediment from the land, reducing the chance of seagrasses and corals being smothered. Sediment banks accumulated by seagrasses may eventually form substrate that can be colonized by mangroves. All three communities trap and hold nutrients from being dispersed and lost into the surrounding oceanic waters.

The habitat complexity within seagrass meadows enhances the diversity and abundance of animals. Seagrasses on reef flats and near estuaries are also nutrient sinks, buffering or filtering nutrient and chemical inputs to the marine environment. The high primary production rates of seagrasses are closely linked to the high production rates of associated fisheries. These plants support numerous herbivore- and detritivore-based food chains, and are considered as very productive pastures of the sea. The associated economic values of seagrass meadows are very large, although not always easy to quantify. Seagrass meadows are rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. 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).

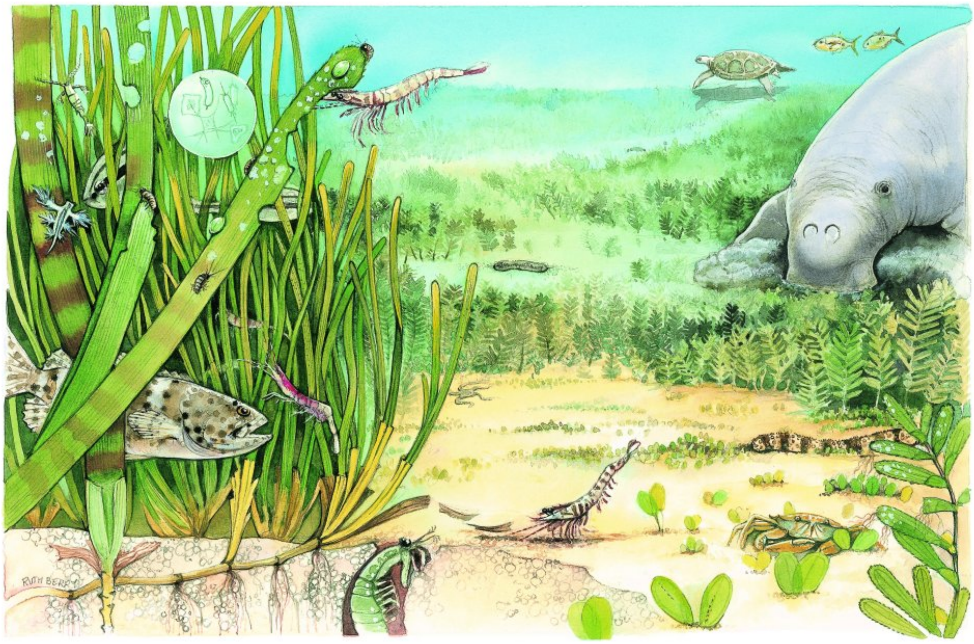
Tropical seagrass meadows vary seasonally and between years, and the potential for widespread seagrass loss has been well documented (Short and Wyllie-Echeverria 1996). The causes of loss can be natural such as cyclones and floods, or due to human influences such as dredging, agricultural runoff, urban runoff and industrial runoff or oil spills.

Loss of seagrasses has been reported from most parts of the world, sometimes from natural causes, e.g., high energy storms, or "wasting disease”. More commonly, loss has resulted from human activities, e.g., as a consequence of eutrophication or land reclamation and changes in land use. Anthropogenic impacts on seagrass meadows are continuing to destroy or degrade these coastal ecosystems and decrease their yield of natural resources.

It is important to document seagrass species diversity and distribution and identify areas requiring conservation measures before significant areas and species are lost. Determining the extent of seagrass areas and the ecosystem values of seagrasses is now possible on a local scale for use by coastal zone managers to aid planning and development decisions. Knowledge of regional and global seagrass distributions are still too limited and general for broad scale protection and management. Such information is needed to minimize future impacts on seagrass habitat worldwide. With global electronic communication it is now possible to begin the process of assembling both formally published and unpublished notes on the distribution of the world's seagrasses with the eventual aim of providing a global "report card" on the distribution and status of seagrass.

With well-recorded events of seagrass loss from many coastal environments it is important to map and record the distribution of not only the location of existing seagrass but also areas of potential seagrass habitat. Such areas are generally shallow, sheltered coastal waters with suitable bottom type and other environmental conditions for seagrass growth. Potential habitat may include areas where seagrass was known to grow at some time in the past but from which it has recently been eliminated.

Spatial and temporal changes in seagrass abundance and species composition must be measured and interpreted with respect to prevailing environmental conditions. These may need to be measured seasonally, monthly, or weekly, depending on the nature of their variability, and the aims of the study. Physical parameters important to seagrass growth and survival include light (turbidity, depth), sediment type and chemistry, and nutrient levels. Detailed studies of changes in community structure of seagrass communities are essential to understand the role of these communities and the effects of disturbance on their composition, structure and rate of recovery.



Notes:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Seagrass in the Whitsundays

The Whitsunday region on the central east Queensland coast extends from Gloucester Island in the north to Midge Point in the south and includes a convoluted coastline and several large continental islands. Seagrasses are a major component of the Whitsunday region marine ecosystems and their contribution to the total primary carbon production is critical to regionally important dugong (Marsh and Lawler 2001) and turtle populations and productive fisheries (Coles *et al*. 2003). Coastal meadows are important nursery habitat to juvenile fish and prawns (Williams 1997; Coles *et al*.1993; Blaber 1980; Beumer *et al*. 1997; Zeller 1998), and provide habitat for migratory wading birds. Extensive seagrass meadows occur both on intertidal mudflats and in nearshore and offshore subtidal areas in the Whitsunday region. In 1999/2000, the region contained 5553 ±1182 hectares of seagrass from Midge Point in the south to Hideaway Bay in the north (Campbell *et al.* 2002). This represented a 40% increase in seagrass habitat compared to 1987, however losses had occurred at specific localities.

Twelve species of seagrass have been recorded in the Whitsundays, representing 80% of the known species found in Queensland waters. The wide range of physical habitats where seagrasses were found undoubtedly contributes to the high species diversity. Habitats include intertidal and subtidal areas of estuary, coastal fringing reef environments and deepwater environments (Figure 1).

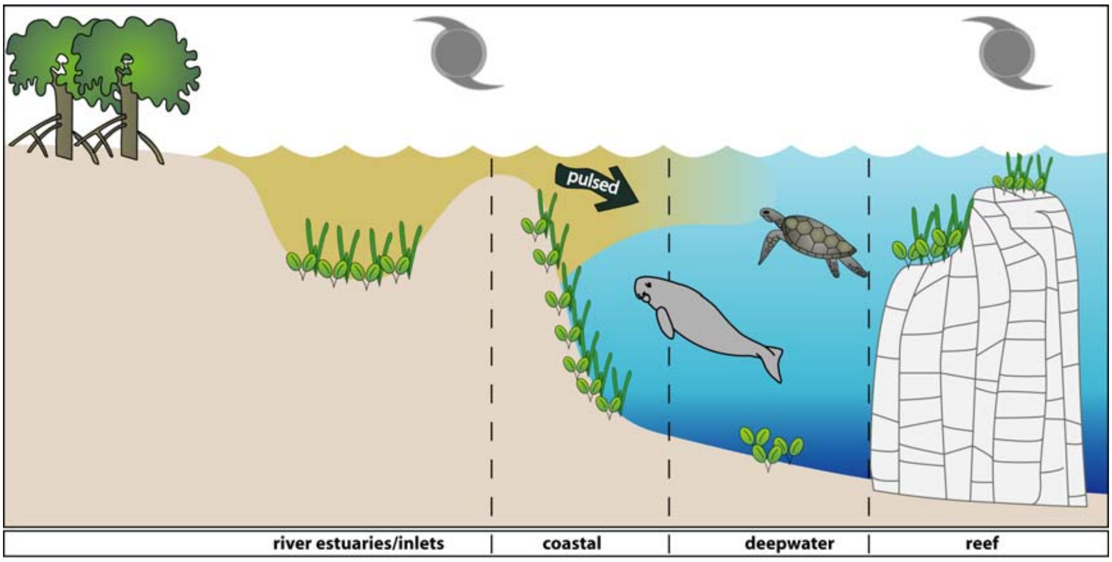


Figure 1. General conceptual model of seagrass habitats in north east Australia (*from Carruthers et al. 2002*)

Based on the mapped seagrass areas, the majority of seagrass meadows in the Mackay Whitsunday NRM region are within coastal and estuary habitats (Table 1; Coles *et al*. 2007). Of these, 36% are protected within declared Fish Habitat Areas and 10% are located within port boundaries. Only 5% of these seagrass meadows (excluding deepwater) are covered by the highest levels of protection within the GBRWHA zoning.

Table 1. Area (km^2) of seagrass within each habitat type, port area and GBR protection zones. Shaded areas afford highest levels of protection for seagrass. From Coles *et al.* 2007. *NB: total seagrass within zones does not add to total area of seagrass, due to many zones having overlapping boundaries.*

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**

Seagrass distribution throughout the region is most likely influenced by shelter, sediment characteristics, water turbidity and tidal exposure. Seagrass meadows are mostly found in the sheltered bays along the mainland coast. The most abundant seagrass areas along the mainland coast are found along the northern mainland coast (863 ha), northern Repulse Bay (822 ha) and southern Repulse Bay (678 ha) (Campbell *et al.* 2002).

The majority of the meadows are low - moderate in abundance, 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 large tides.

Seven locations have been selected for long-term monitoring of seagrasses within the Seagrass-Watch Program. These include intertidal sites at Hideaway Bay, Dingo Beach, Pioneer Bay, Laguna Quays/Midge Point, and Midgeton, and sub-tidal sites at Whitehaven Beach and Cid Harbour. Sites in these locations are representative of the main seagrass habitats (estuarine, coastal and reef) in the region and are used to monitor the condition and trends in seagrass resources.

Estuarine

Estuarine seagrass habitats in the 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 in the north (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 2).

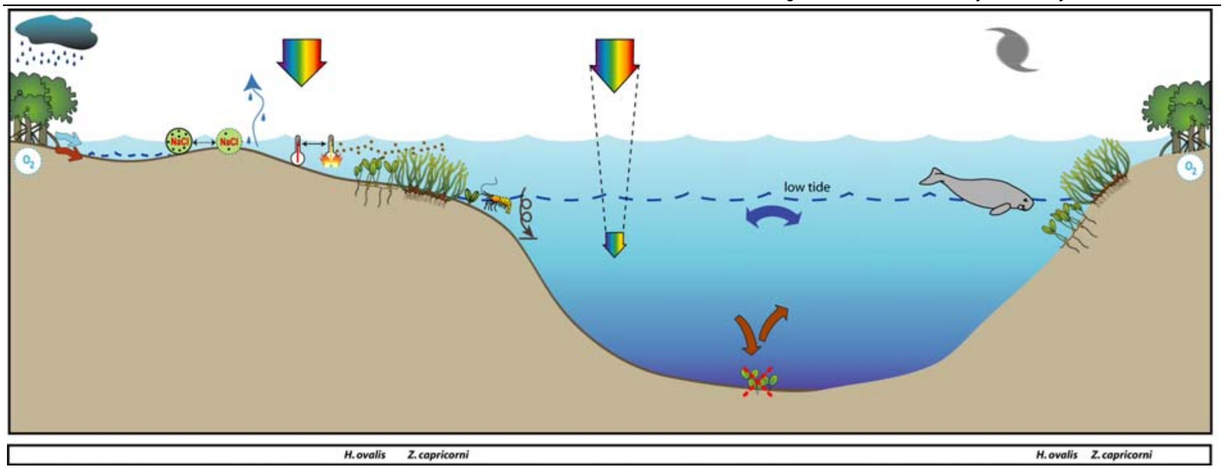


Figure 2. Conceptual diagram of Estuary habitat in the Whitsunday region: general habitat and seagrass meadow processes *(See Figure 3 for icon explanation)*.

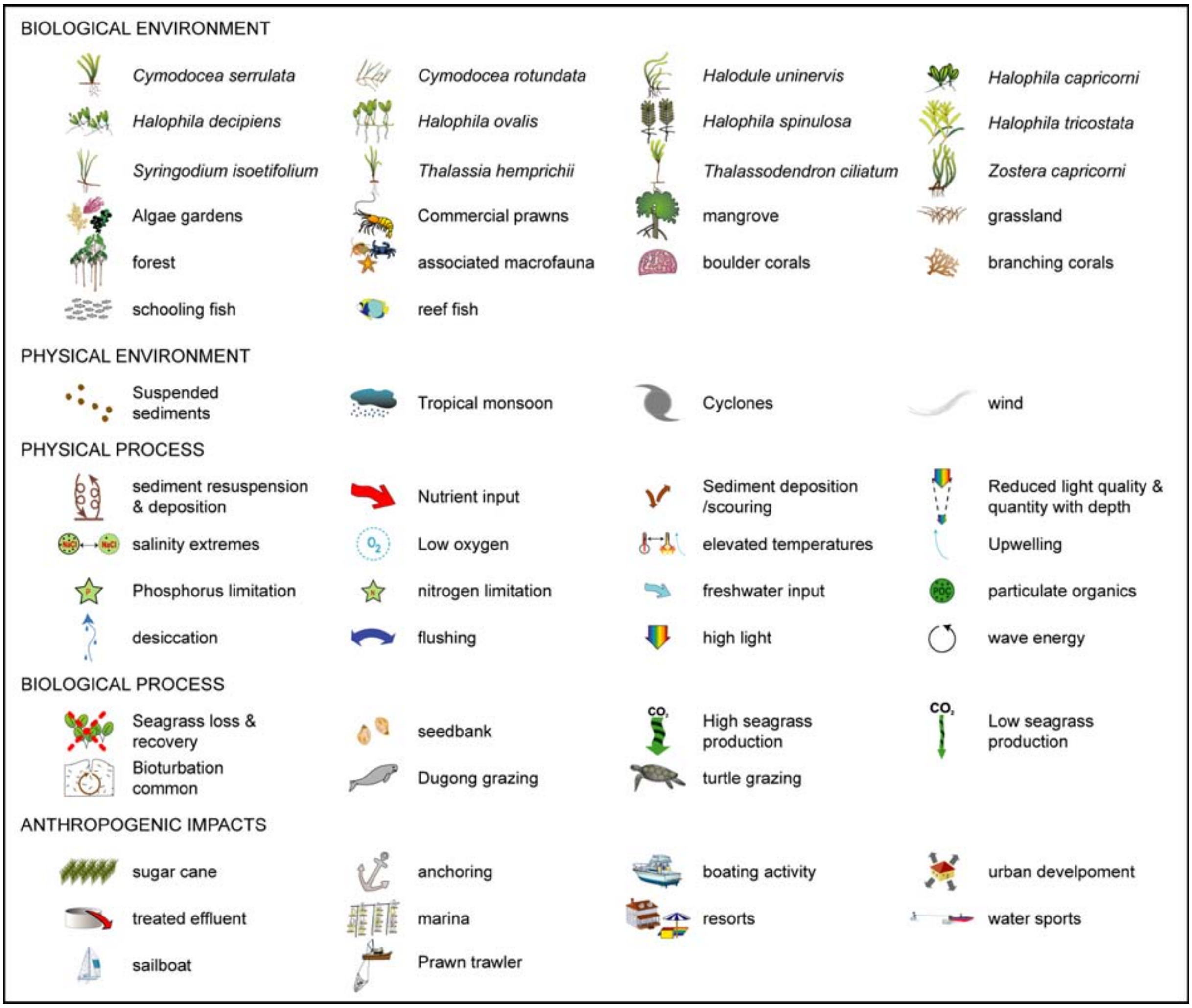


Figure 3. Key to symbols used for conceptual diagrams. Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.

The only estuary habitat monitored in the Whitsunday region is at Midgeton. The two sites are located on an intertidal mud bank, and dominated by *Zostera capricorni/ Halodule uninervis* with some *Halophila ovalis*. Seagrass cover at Midgeton has remained relatively stable over the monitoring period (Figure 4).

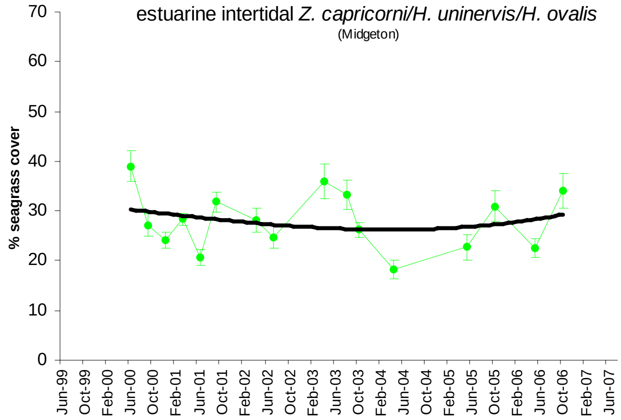


Figure 4. Change in seagrass abundance (percentage cover) in the intertidal estuarine meadows at Midgeton.

The estuarine seagrass habitat at Midegton was 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 5).

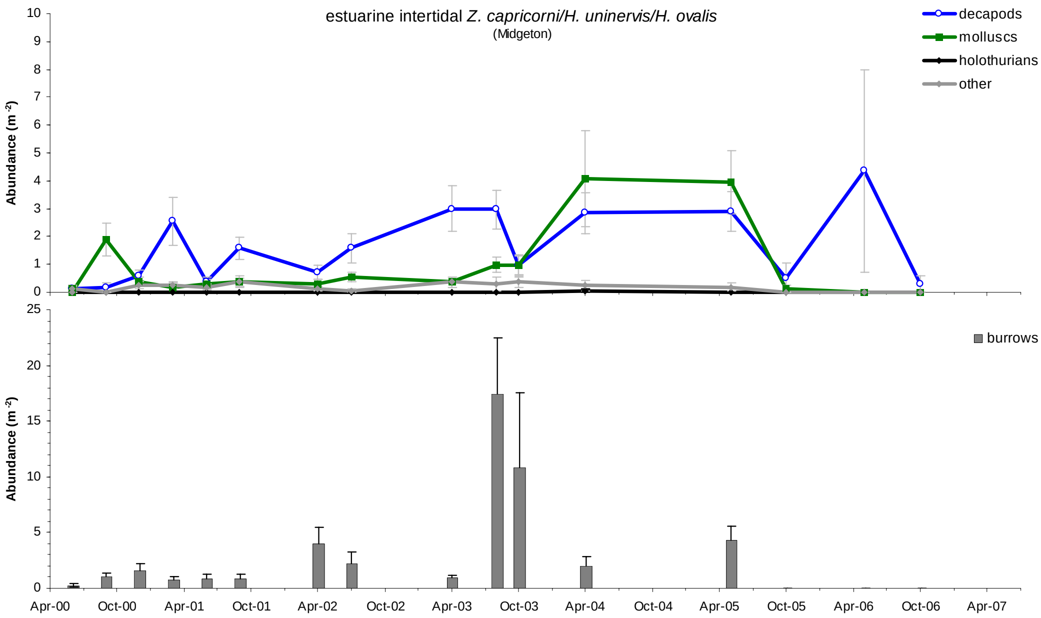


Figure 5. Abundance of associated benthic macro-fauna and bioturbation in an intertidal *Zostera capricorni / Halodule uninervis / Halophila ovalis* meadow in an estuary habitat over the monitoring period.

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 6).

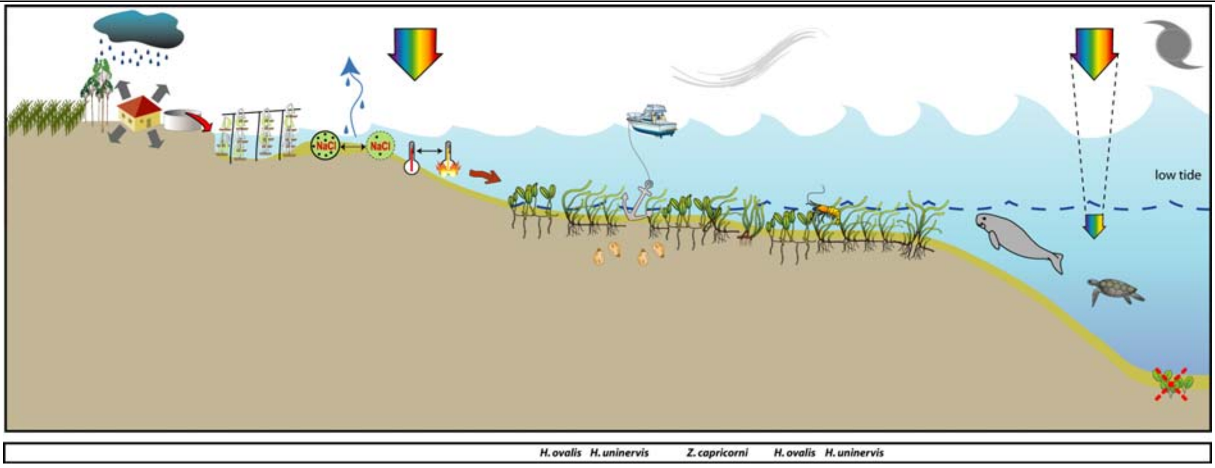


Figure 6. Conceptual diagram of Coastal habitat in the Whitsunday region – major control is shelter and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*

Coastal meadows are important nursery habitat to juvenile fish and prawns, and provide habitat for migratory wading birds. Coastal mainland areas were characterised by meadows of *Halodule uninervis* (wide and narrow leaf form) growing in sheltered intertidal habitats. Intertidal *Zostera capricorni* meadows exist in a few locations along the mainland coast south of Pioneer Bay. This species was mostly present on muddy sediments, where mangroves formed a fringing habitat. Sub-tidal communities of mixed wide-bladed species also occurr in some coastal locations where water clarity and light penetration are sufficient for seagrass growth. Island seagrass communities are mostly sub-tidal meadows of mixed wide-bladed species. The most extensive meadows are dominated by *Halodule uninervis* (wide leaf form) and these are found growing in the less turbid waters of Whitsunday Island along the north-west coast (1431 ha) and Whitehaven Beach (mostly sand/ shell and mud sediments) (Campbell *et al.* 2002).

Monitoring sites of intertidal coastal seagrass habitat are located on the sand/mud flats adjacent to Cannonvale in southern Pioneer Bay. This meadow covers approximately 60ha and is dominated by *Halodule uninervis* and *Zostera capricorni* mixed with *Halophila ovalis*. Species composition has remained stable over the monitoring period and total abundance indicates natural seasonal patterns (Figure 6). 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 7). Dugong feeding trails were abundant at these sites with the highest feeding activity (evidenced by trails) recorded in March and September. Monitoring sites at Dingo Beach and Midge Point have shown relative stability throughout the time that they have been monitored.

The area of seagrass within Pioneer Bay appeared to decline by approximately 74% between 1987 and 1999-2000 (519 ha to 134 ha respectively) (Campbell *et al.* 2002). This apparent decline was due to the contraction of up to 1.3 km in the seaward extent (deep edge) of the meadow mapped in 1987. The inshore meadow edge seemed relatively unchanged. In contrast seagrass meadows in Repulse Bay and the northern mainland coast appeared to have increased in area between 1987 and 1999-2000.

The abundance of filamentous algae commonly found throughout the year at Pioneer Bay is of potential concern to the nutritional requirements of dugong and turtles. Algae may comprise a small percentage (2% volume) of dugong diets (Marsh *et al*. 1982), but dugong have been shown to avoid feeding on seagrass carrying large quantities of epiphytic algae (Preen 1995).

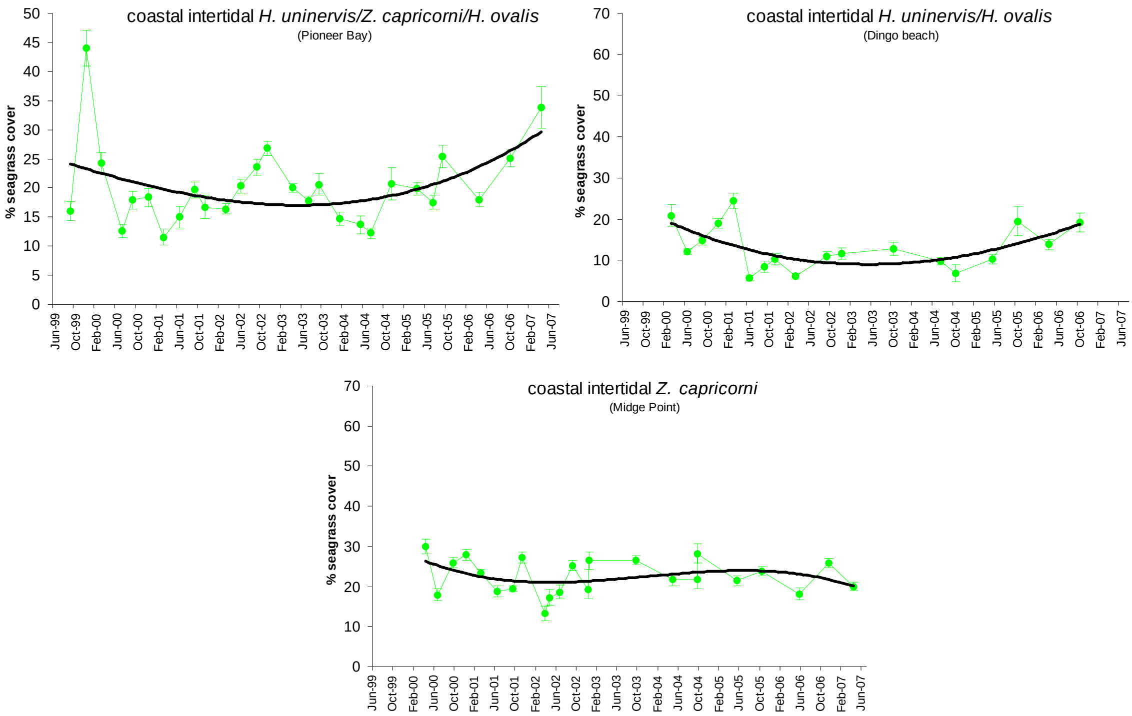


Figure 7. Change in seagrass abundance (percentage cover) at coastal intertidal meadows in the Whitsunday region.

Subtidal seagrass meadows monitored at Whitehaven Beach similarly increased in area between 1987 and 1999-2000, however monitoring was suspended in mid 2004, due to the difficulty associated with subtidal monitoring. The trend for both sites that were being monitored has been of decline. This decline is more than 20% of that recorded when monitoring commenced (Figure 8). 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.

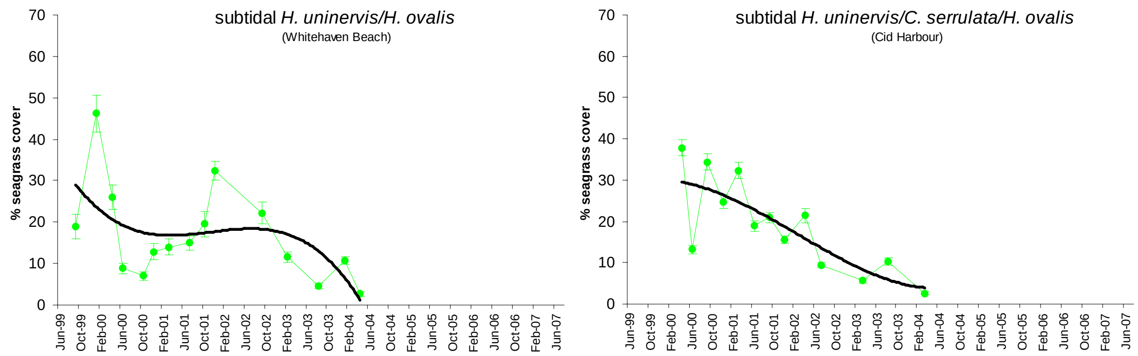


Figure 8. Change in seagrass abundance (percentage cover) at coastal subtidal meadows in the Whitsunday region.

Decapods (predominately hermit crabs) consistently dominated the macrofauna of the coastal seagrass habitats (Figure 9). Bioturbation was also high due to the number of worm and crab burrows. Abundances of unidentified gastropods varied throughout the monitoring period.

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

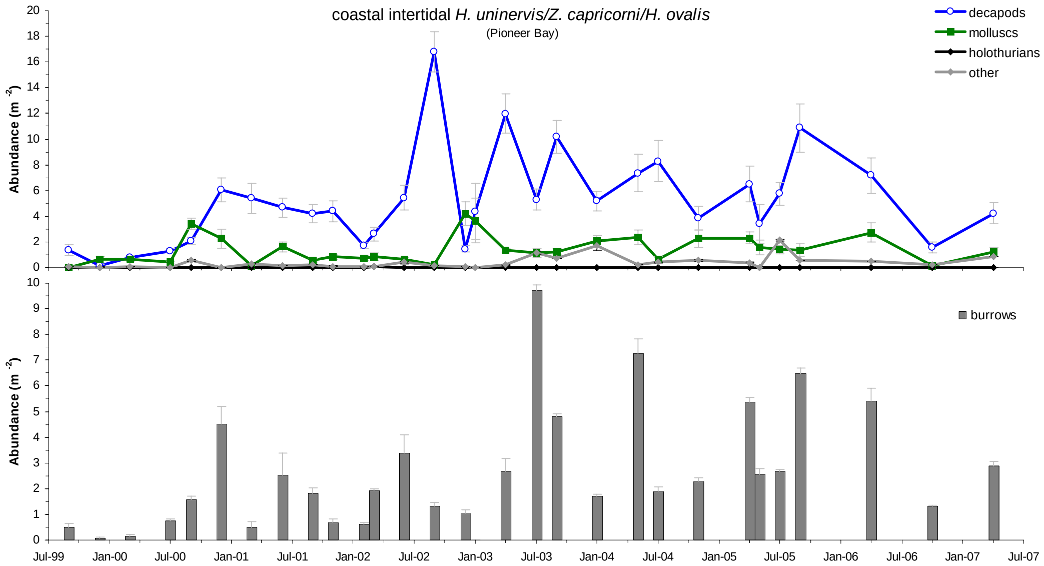


Figure 9. Abundance of associated benthic macro-fauna and bioturbation in an intertidal *Halodule uninervis / Zostera capricorni / Halophila ovalis* meadow in a coastal habitat over the monitoring period.

Relatively few macrofauna were observed in the subtidal coastal habitat of Whitehaven Beach (Figure 10). Foraminifera dominated macrofaunal abundances and only a few gastropods were observed grazing on the seagrass. Bioturbation was low, as only a few unidentified burrows (not crab) were observed.

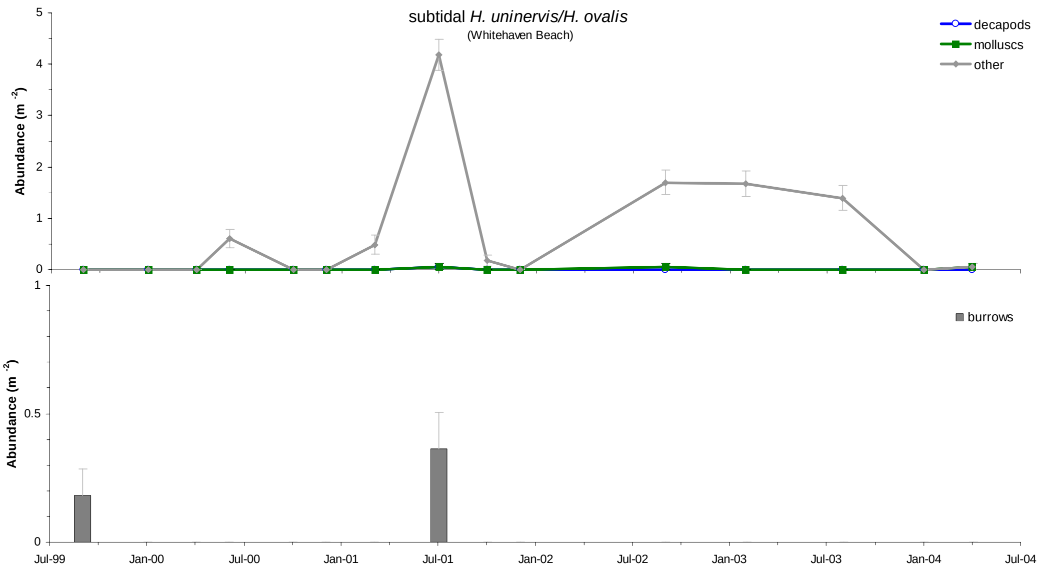


Figure 10. Abundance of associated benthic macro-fauna and bioturbation in a subtidal *Halodule uninervis / Halophila ovalis* meadow in a coastal habitat over the monitoring period.

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 11). Major threats would be increased tourism activities including marina and coastal developments.

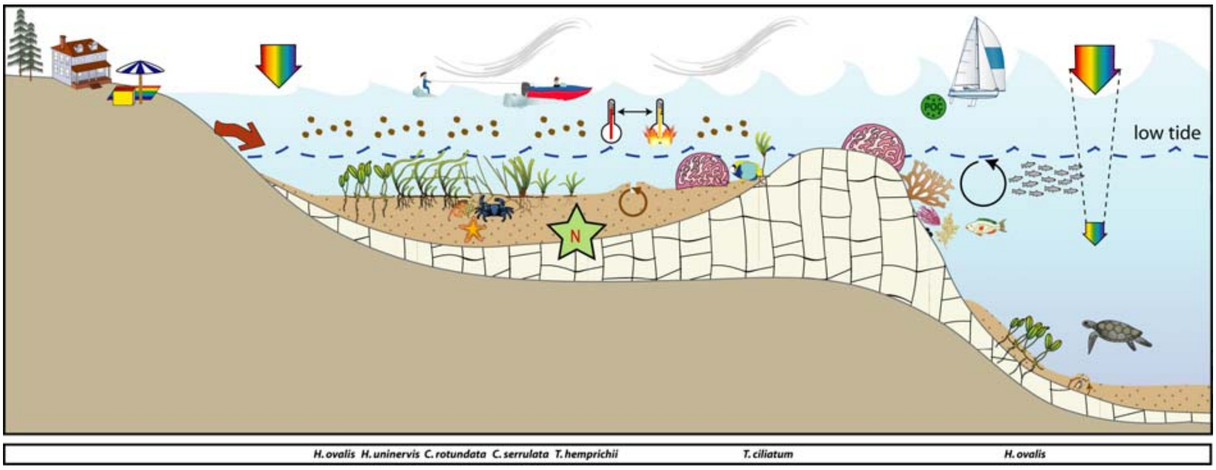


Figure 11. Conceptual diagram of Reef habitat in the Whitsunday region – major control is light and temperature extremes: general habitat, seagrass meadow processes and threats/impacts *(See Figure 3 for icon explanation)*.

Reef top seagrasses are only monitored at Hideaway Bay. New sites are currently being established on Hamilton Island. Seagrass cover at Hideaway Bay has remained stable since monitoring began in mid 2000 (Figure 12).

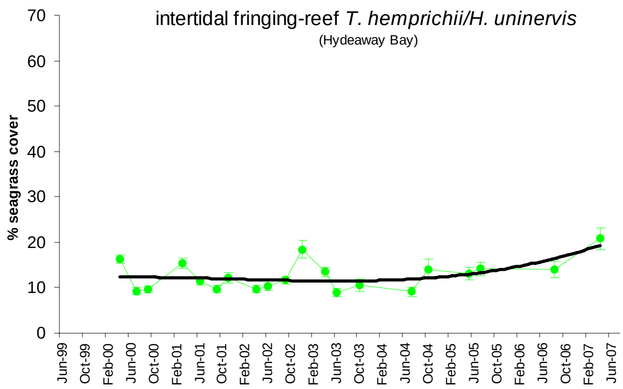


Figure 12. Change in seagrass abundance (percentage cover) at intertidal meadows located on a fringing reef-platform in the Whitsunday region.

The highest diversity of seagrasses in the Whitsunday region occurs between Dingo Beach and Bluff Point, in north facing bays protected from south-easterly winds. Fringing reefs protect many of these bays from northerly winds, providing an ideal sheltered habitat for seagrass to grow. There are no major rivers flowing into this coastal section and a high proportion of the catchment in this region is covered with native terrestrial vegetation.

From Hideaway Bay to George Point seagrass meadows are dominated by meadows consisting of *Thalassia hemprichii, Halodule uninervis* (wide leaf form), *Halophila spinulosa* and *Halophila ovalis*. The abundance of seagrass in the region represents a significant food source and valuable habitat for green sea turtle and dugong moving between Edgecombe Bay and the Whitsundays. Land based development contributing to high sediment runoff poses a threat to seagrass meadows in the region.

Cone shells and unidentified gastropods dominated the macrofauna of the fringing reef platform seagrass habitats. Decapods were mainly hermit crabs - abundances were highly variable (Figure 13). Holothurian abundance was relatively high (large species of

Hothuria sp.), but similarly variable. Bioturbation was also high, due to lots of crab burrows.

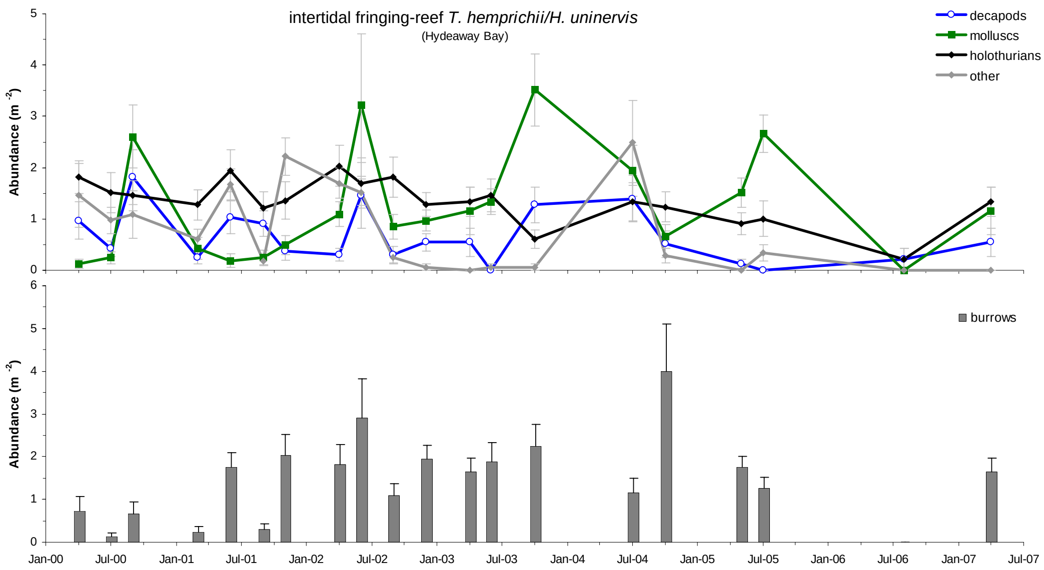


Figure 13. Abundance of associated benthic macro-fauna and bioturbation in an intertidal *Thalassia hemprichii* / *Halodule uninervis* meadow on a fringing reef platform over the monitoring period.

Within canopy temperature monitoring

Within canopy temperature has been monitored at coastal and reef-platform locations, and generally follows a similar pattern. Mean temperatures were generally within the 22 – 30°C range, with highest mean temperatures in the November and February periods. Extreme temperatures (>40°C) were not recorded in the region (Figure 14). Maximum temperatures peaked several times throughout the year, generally in February-March, July-August and October-December.

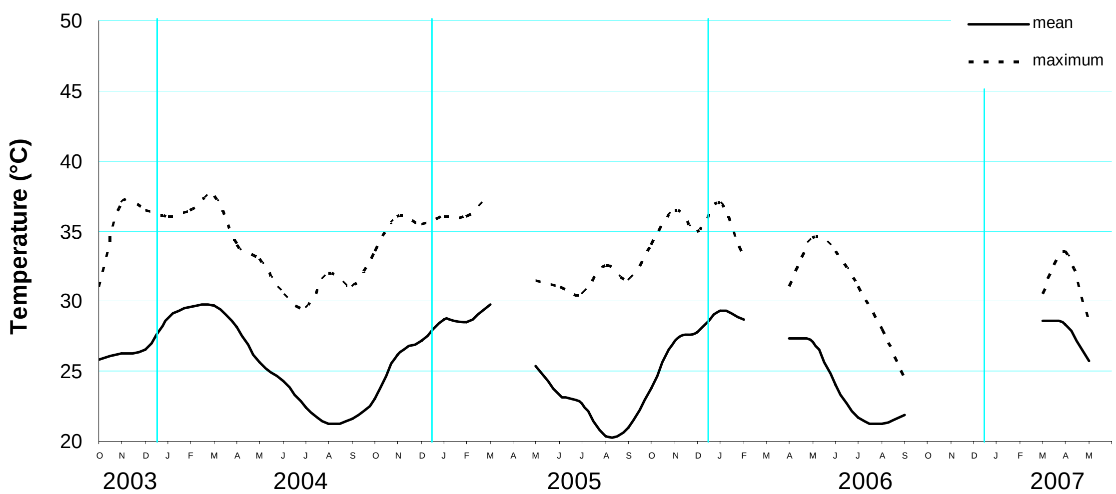
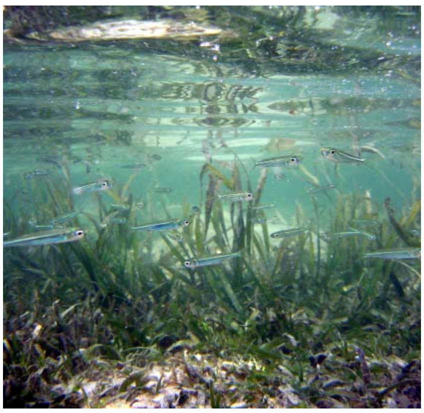


Figure 14. Within seagrass canopy temperature (°C) at intertidal meadows in a coastal habitat (Pioneer Bay) within the Whitsunday region.

Regional report card – Apr07

- Healthy seagrass meadows throughout Whitsunday's support fisheries, turtle and dugong populations
- Seagrass meadows in the Whitsunday region are in a Fair condition, and results of monitoring indicate that seagrasses appear relatively healthy
- 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 they have recovered. These impacts include *Lyngbya* outbreaks, sedimentation from marina developments and burning off from temperature stress (Campbell and McKenzie 2001; Campbell *et al.* 2002). While these meadows have demonstrated resilience to these changes the region faces continued pressure from coastal and urban development.
- The absence of ongoing monitoring of subtidal meadows has limited the ability to assess seagrass trends in the region. 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.
- Seagrass-Watch data provides understanding of seasonal trends and effects of climatic patterns on seagrass meadows
- Seagrass close to urban development is impacted by high algal growth
- Seagrass close to tourism nodes are impacted by anchors and boat traffic
- Management controls depend on public and government support.



A guide to the identification of Queensland's Seagrasses

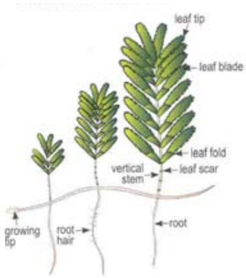
Adapted from *Waycott, M, McMahon, K, Mellors, J., Calladine, A., and Kleine, D (2004) A guide to tropical seagrasses in the Indo-West Pacific. (James Cook University Townsville) 72pp.*

Leaves cylindrical

Syringodium isoetifolium
- Leaf tip pointed
- Leaves contain air cavities
- Inflorescence a "cyme"

Leaves oval to oblong

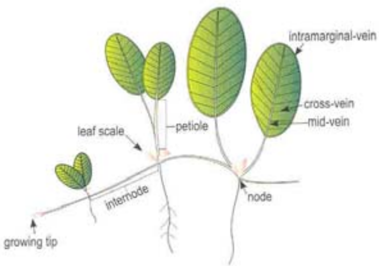
obvious vertical stem with more than 2 leaves



Halophila spinulosa
- leaves arranged opposite in pairs
- leaf margin serrated

Halophila tricostata
- leaves arranged in clusters of 3, at a node on vertical stem
- leaf margin serrated
- leaf clusters do not lie flat

leaves with petioles, in pairs



Halophila ovalis
- cross veins more than 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

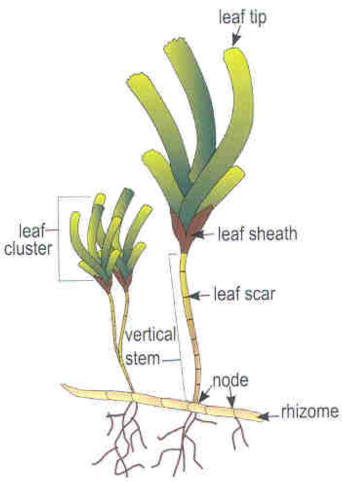
Halophila decipiens
- leaf margins serrated
- fine hairs on both sides of leaf blade
- male & female flowers on same plant

Halophila minor
- Leaf less than 5mm wide
- cross veins up to 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Halophila capricorni
- leaf margins serrated
- fine hairs on one side of leaf blade
- separate male & female plants

Leaves strap-like

Leaves can arise from vertical stem



Thalassia hemprichii

- Leaf with obvious red flecks, 1-2mm long
- Leaf tip rounded may be slightly serrated
- Leaf often distinctly curved
- Distant scars on rhizome

Cymodocea serrulata

- Leaf tip rounded with serrated edge
- Leaf sheath broadly flat and triangular, not fibrous
- Leaf sheath scars not continuous around upright stem

Cymodocea rotundata

- Leaf tip rounded with smooth edge
- Leaf sheath not obviously flattened
- Leaf sheath scars continuous around upright stem

Halodule uninervis

- Leaf tip tri-dentate or pointed, not rounded
- Leaf with 3 distinct parallel- veins, sheaths fibrous
- Rhizome usually white with small black fibres at the nodes

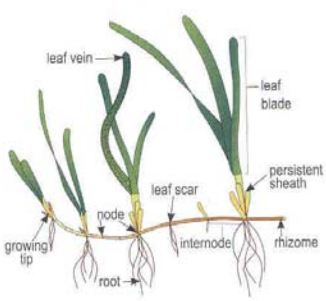
Halodule pinifolia

- Leaf tip rounded
- Leaf with 3 distinct parallel- veins, sheaths fibrous
- Rhizome usually white with small black fibres at the nodes

Thalassodendron ciliatum

- distinct upright stem
- clusters of curved leaves (>5 mm wide), margins serrated
- stem and rhizome woody

Leaves always arise directly from rhizome



Enhalus acoroides

- large plant, leaves >30 cm long, >1 cm wide
- in-rolled edges of leaves
- long, black bristles protruding from thick rhizome

Zostera capricorni

- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- rhizome usually brown or yellow in younger parts

Monitoring a seagrass meadow

Environment monitoring programs provide coastal managers with information and assist them to make decisions with greater confidence. Seagrasses are often at the downstream end of catchments, receiving runoff from a range of agricultural, urban and industrial land-uses.

Seagrass communities are generally susceptible to changes in water quality and environmental quality that make them a useful indicator of environmental health. Several factors are important for the persistence of healthy seagrass meadows, these include: sediment quality and depth; water quality (temperature, salinity, clarity); current and hydrodynamic processes; and species interactions (e.g., epiphytes and grazers). Seagrass generally respond in a typical manner that allows them to be measured and monitored. In reporting on the health of seagrasses it is important to consider the type of factors that can effect growth and survival. Factors include:

- increased turbidity reduces light penetration through the water, interfering with photosynthesis and limiting the depth range of seagrass;
- increased nutrient loads encourages algal blooms and epiphytic algae to grow to a point where it smothers or shade seagrasses, thereby reducing photosynthetic capacity;
- increased sedimentation can smother seagrass or interferes with photosynthesis;
- herbicides can kill seagrass and some chemicals (e.g., pesticides) can kill associated macrofauna;
- boating activity (propellers, mooring, anchors) can physically damage seagrass meadows, from shredding leaves to complete removal;
- storms, floods and wave action can rip out patches of seagrasses.

Seagrass-Watch

A simple method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses 50m by 50m sites established within representative intertidal meadows to monitor seagrass condition. The number and position of sites can be used to investigate natural and anthropogenic impacts.

Seagrass-Watch is one of the largest seagrass monitoring programs in the world. Since it's genesis in 1998 in Australia, Seagrass-Watch has now expanded internationally to 18 countries. Monitoring is currently occurring at over 165 sites. To learn more about the program, visit www.seagrasswatch.org .

Seagrass-Watch aims to raise awareness on the condition and trend of nearshore seagrass ecosystems and provide an early warning of major coastal environment changes. Participants of Seagrass-Watch are generally community/citizen volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with established local community groups, schools, universities & research institutions, government (local & state) or non-government organisations.

Seagrass-Watch integrates with existing education, government, non-government and scientific programs to raise community awareness to protect this important marine habitat for the benefit of the community. The program has a strong scientific underpinning with an emphasis on consistent data collection, recording and reporting. Seagrass-Watch identifies areas important for seagrass species diversity and conservation and the information collected is used to assist the management of coastal environments and to prevent significant areas and species being lost.

Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assessing human impacts on seagrass meadows, which have the potential to destroy or degrade these coastal ecosystems and decrease their value as a natural resource. Responsive management based on adequate information will help to prevent any further significant areas and species being lost. To protect the valuable seagrass meadows along our coasts, the community, government and researchers have to work together.

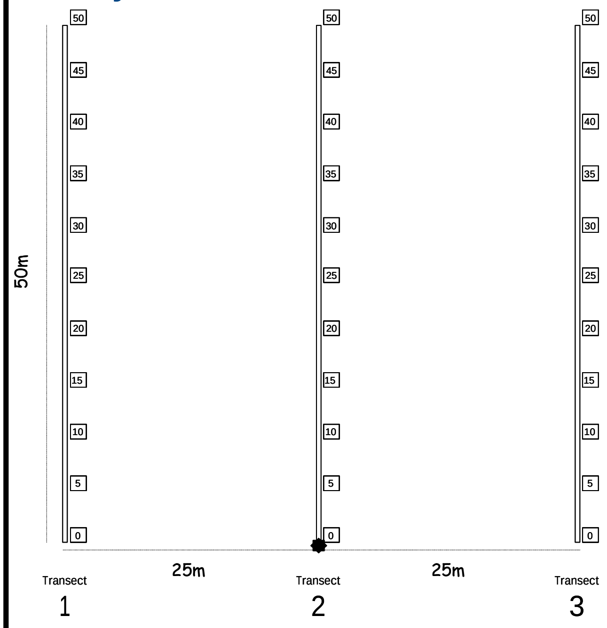
THE GOALS OF THE PROGRAM ARE:

- *To educate the wider community on the importance of seagrass resources*
- *To raise awareness of coastal management issues*
- *To build the capacity of local stakeholders in the use of standardised scientific methodologies*
- *To conduct long-term monitoring of seagrass & coastal habitat condition*
- *To provide an early warning system of coastal environment changes for management*
- *To support conservation measures which ensure the long-term resilience of seagrass ecosystems.*

Seagrass-Watch Protocols

Source: McKenzie, L.J., Campbell, S.J., Vidler, K.E. & Mellors, J.E. (2007) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources. (Seagrass-Watch HQ, Cairns) 114pp (www.seagrasswatch.org/manuals.html)

Site layout



Quadrat code = site + transect+quadrat

e.g., PI1225 = Pigeon Is. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

Create a timetable of times of departure and arrival back, and what the objective of the day is and what is to be achieved on the day. Give a copy of this to all volunteers involved in advance so they can make their arrangements to get to the site on time. List on this timetable what the volunteers need to bring.

Have a Contact Person

Arrange to have a reliable contact person to raise the alert if you and the team are not back at a specified or reasonable time.

Safety

- Assess the risks before monitoring - check weather, tides, time of day, etc.
- Use your instincts - if you do not feel safe then abandon sampling.
- Do not put yourself or others at risk.
- Wear appropriate clothing and footwear.
- Be sun-smart.
- Adult supervision is required if children are involved
- Be aware of dangerous marine animals.
- Have a first aid kit on site or nearby
- Take a mobile phone or marine radio

Necessary equipment and materials

- ❑ *3x 50metre fibreglass measuring tapes*
- ❑ *6x 50cm plastic tent pegs*
- ❑ *Compass*
- ❑ *1x standard (50cm x 50cm) quadrat*
- ❑ *Magnifying glass*
- ❑ *3x Monitoring datasheets*
- ❑ *Clipboard, pencils & 30 cm ruler*
- ❑ *Camera & film*
- ❑ *Quadrat photo labeller*
- ❑ *Percent cover standard sheet*
- ❑ *Seagrass identification sheets*

Quarterly sampling

Within the 50m by 50m site, lay out the three 50 transects parallel to each other, 25m apart and perpendicular to shore (see site layout). Within each of the quadrats placed for sampling, complete the following steps:

Step 1. Take a Photograph of the quadrat

- Photographs are usually taken at the 5m, 25m and 45m quadrats along each transect, or of quadrats of particular interest. First place the photo quadrat labeller beside the quadrat and tape measure with the correct code on it.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat label and tape measure. Avoid having any shadows or patches of reflection off any water in the field of view. Check the photo taken box on datasheet for quadrat.

Step 2. Describe sediment composition

- Dig your fingers into the top centimetre of the substrate and feel the texture. Describe the sediment by noting the grain size in order of dominance (e.g., Sand, Fine sand, Fine sand/Mud).

Step 3. Describe other features and ID/count of macrofauna

- Note and count any other features which may be of interest (eg. number of shellfish, sea cucumbers, sea urchins, evidence of turtle feeding) within the comments column.

Step 4. Estimate seagrass percent cover

- Estimate the total % cover of seagrass within the quadrat – use the percent cover photo standards as a guide.

Step 5. Estimate seagrass species composition

- Identify the species of seagrass within the quadrat and determine the percent contribution of each species to the cover. Use seagrass species identification keys provided.

Step 6. Measure canopy height

- Measure canopy height of the dominant strap-like seagrass species ignoring the tallest 20% of leaves. Measure from the sediment to the leaf tip of at least 3 shoots.

Step 7. Estimate algae percent cover

- Estimate % cover of algae in the quadrat. Algae are seaweeds that may cover or overlie the seagrass blades. Use "Algal percentage cover photo guide". Write within the comments section whether the algae is overlying the seagrass or is rooted within the quadrat.

Step 8. Estimate epiphyte percent cover

- Epiphytes are algae attached to seagrass blades and often give the blade a furry appearance. First estimate how much of the blade surface is covered, and then how many of the blades in the quadrat are covered (e.g., if 20% of the blades are each 50% covered by epiphytes, then quadrat epiphyte cover is 10%).
- Epibionts are sessile animals attached to seagrass blades – please record % cover in the comments or an unused/blank column – do not add to epiphyte cover.

Step 9. Take a voucher seagrass specimen if required

- Seagrass samples should be placed inside a labelled plastic bag with seawater and a waterproof label. Select a representative specimen of the species and ensure that you have all the plant part including the rhizomes and roots. Collect plants with fruits and flowers structures if possible.

At completion of monitoring

Step 1. Check data sheets are filled in fully.

- Ensure that your name, the date and site/quadrat details are clearly recorded on the datasheet. Also record the names or number of other observers and the start and finish times.

Step 2. Remove equipment from site

- Remove all tent pegs and roll up the tape measures. If the tape measures are covered in sand or mud, roll them back up in water.

Step 3. Wash & pack gear

- Rinse all tapes, pegs and quadrats with freshwater and let them dry.
- Review supplies for next quarterly sampling and request new materials
- Store gear for next quarterly sampling

Step 4. Press any voucher seagrass specimens if collected

- The voucher specimen should be pressed as soon as possible after collection. Do not refrigerate longer than 2 days, press the sample as soon as possible.
- Allow to dry in a dry/warm/dark place for a minimum of two weeks. For best results, replace the newspaper after 2-3 days.

Step 5. Submit all data

- Data can be entered into the MS-Excel file downloadable from www.seagrasswatch.org. Email completed files to hq@seagrasswatch.org
- Mail original datasheets, photos and herbarium sheets

Seagrass-Watch HQ
Northern Fisheries Centre
PO Box 5396
Cairns QLD 4870 AUSTRALIA

Managing seagrass resources

Threats to seagrass habitats

Destruction or loss of seagrasses have been reported from most parts of the world, often from natural causes, e.g., "wasting disease" or high energy storms. However, destruction commonly has resulted from human activities, e.g., as a consequence of eutrophication or land clamation and changes in land use. Increases in dredging and landfill, construction on the shoreline, commercial overexploitation of coastal resources, and recreational boating activities along with anthropogenic nutrient and sediment loading has dramatically reduced seagrass distribution in some parts of the world. Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease the function and value of seagrass meadows including their contribution to fisheries. It is possible global climate change will have a major impact. Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world: transplantation, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitat through law and environmental policy.

Management

Seagrasses do not exist in nature as a separate ecological component from other marine plants and are often closely linked to other community types. In the tropics the associations are likely to be complex interactions with mangrove communities and coral reef systems. In temperate waters, algae beds, salt marshes, bivalve reefs, and epiphytic plant communities are closely associated with areas of seagrass. Many management actions to protect seagrasses have their genesis in the protection of wider ecological systems or are designed to protect the overall biodiversity of the marine environment.

Seagrasses are also food for several marine mammal species and turtles, some of which (such as the dugong *Dugong dugon* and green turtle *Chelonia mydas*) are listed as threatened or vulnerable to extinction in the IUCN Red List (www.iucnredlist.org). Seagrasses are habitat for juvenile fish and crustaceans that in many parts of the world form the basis of economically valuable subsistence and/or commercial fisheries. The need to manage fisheries in a sustainable way has itself become a motivating factor for the protection of seagrasses.

Coastal management decision making is complex, and much of the information on approaches and methods exists only in policy and legal documents that are not readily available. There may also be local or regional Government authorities having control over smaller jurisdictions with other regulations and policies that may apply. Many parts of South East Asia and the Pacific Island nations have complex issues of land ownership and coastal sea rights. These are sometimes overlaid partially by arrangements put in place by colonising powers during and after World War II, leaving the nature and strength of protective arrangements open for debate.

Both Australia and the United States have developed historically as Federations of States with the result that coastal issues can fall under State or Federal legislation depending on the issue or its extent. In contrast, in Europe and much of South East Asia, central Governments are more involved. Intercountry agreements in these areas such as the UNEP Strategic Action Plan for the South China Sea and the Mediterranean Countries Barcelona Convention (http://www.unep.org/) are required to manage marine issues that encompass more than one country.

Approaches to protecting seagrass tend to be location specific or at least nation specific (there is no international legislation directly for seagrasses as such that we know of) and depend to a large extent on the tools available in law and in the cultural approach of the community. There is, however, a global acceptance through international conventions (RAMSAR Convention; the Convention on Migratory Species of Wild Animals; and the Convention on Biodiversity) of the need for a set of standardised data/information on the location and values of seagrasses on which to base arguments for universal and more consistent seagrass protection.

Indigenous concepts of management of the sea differ significantly from the introduced European view of the sea as common domain, open to all and managed by governments (Hardin 1968). Unlike contemporary European systems of management, indigenous systems do not include jurisdictional boundaries between land and sea. Indigenous systems have a form of customary ownership of maritime areas that has been operating in place for thousand of years to protect and manage places and species that are of importance to their societies.

Marine resource management these days should, therefore, attempt to achieve the following interrelated objectives: *a*) monitor the wellbeing (e.g. distribution, health and sustainability) of culturally significant species and environments (e.g. dugong, marine turtles, fish, molluscs, seagrass *etc*.); and *b*) monitor the cultural values associated with these culturally significant species and environments (Smyth *et al*. 2006).

To realize objective a) we believe the following also needs to be accomplished if the successful management of coastal seagrasses is to be achieved.

1. Important fish habitat is known and mapped
2. Habitat monitoring is occurring
3. Adjacent catchment/watershed impacts and other threats are managed
4. Some level of public goodwill/support is present
5. Legal powers exist hat are robust to challenge
6. There is effective enforcement and punishment if damage occurs

The key element is a knowledge base of the seagrass resource that needs to be protected and how stable/variable that resource is. It is also important to know if possible any areas that are of special value to the ecosystems that support coastal fisheries and inshore productivity. It is important as well that this information is readily available to decision makers in Governments in a form that can be easily understood.

Consequently a combination of modern *"western"* science and indigenous knowledge should be brought together within a co-management framework for the successful management of these resources. (Johannes 2002; Aswani & Weiant 2004; Turnbull 2004; Middlebrook and Williamson 2006; Gaskell 2003, George *et al.* 2004). This can only occur if the resource owners actively involve themselves in the management of their resources. Western science also needs to recognise that resource owners have practical and spiritual connections with the resources found within their environment. Once this is recognized then this approach will have the added benefit of empowering communities who own the knowledge to be the primary managers and leaders in decisions about their land and sea country.

References

Aswani, S., Weiant, P. (2004). Scientific evaluation in women's participatory management: monitoring marine invertebrate refugia in the Solomon Islands. *Human Organisation* **63** (3), 301-319.

Blaber, S.J.M. (1980). Fish if the Trinity Inlet system of north Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. *Australian Journal of Marine and Freshwater Research* **31**: 137-46.

Beumer, J., Carseldine, L. & Zeller, B. (1997). Declared Fish Habitat Areas in Queensland. Information Series QI97004. Queensland Department of Primary Industries, 178pp.

Brodie J (2004). Mackay Whitsunday Region: State of the Waterways Report 2004 ACTFR Report No. 02/03 for the Mackay Whitsunday Natural Resource Management Group http://www.actfr.jcu.edu.au/Publications/ACTFRreports/02_03%20State%20Of%20The%20Waterways%20Mackay%20Whitsunday.pdf

Campbell, S.J. and McKenzie, L.J. (2001) Seagrass and algal abundance in the Whitsundays region. Status Report: March 2001. (DPI&F, Cairns) 10pp

Campbell SJ, Roder CA, McKenzie LJ and Lee Long WJ (2002). Seagrass Resources in the Whitsunday Region 1999 and 2000. DPI Information Series QI02043 (DPI, Cairns) 50 pp

Carruthers TJB, Dennison WC, Longstaff BJ, Waycott M, Abal EG, McKenzie LJ and Lee Long WJ. (2002). Seagrass habitats of northeast Australia: models of key processes and controls. *Bulletin of Marine Science* **71**(3): 1153-1169.

Coles RG, Lee Long WJ, Watson RA and Derbyshire KJ (1993). Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**: 193 – 210

Coles RG, McKenzie LJ and Campbell SJ. (2003). The seagrasses of eastern Australia. Chapter 11 In: World Atlas of Seagrasses. (EP Green and FT Short eds) Prepared by the UNEP World Conservation Monitoring Centre. (University of California Press, Berkeley. USA). Pp 119-133.

Coles, R. G., McKenzie, L. J., Rasheed, M. A., Mellors, J. E., Taylor, H., Dew, K. McKenna, S., Sankey. T. L., Carter A. B. and Grech A. (2007). Status and Trends of seagrass in the Great Barrier Reef World Heritage Area: Results of monitoring in MTSRF project 1.1.3 Marine and Tropical Sciences Research Facility, Cairns (108 pp).

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil RV, Paruelo J, Raskin RG, Sutton P and van der Belt M. (1997). The Value of the world's ecosystem services and natural capital. *Nature* **387**(15): 253-260.

Gaskell, J. (2003). Engaging science education within diverse cultures. *Curriculum Inquiry*. **33**: 235-249.

George, M., Innes, J., Ross, H. (2004). Managing sea country together: key issues for developing co-operative management for the Great Barrier Reef World Heritage Area. CRC Reef Research Centre Technical Report No 50, CRC Reef Research Centre Ltd, Townsville.

Hardin, G. (1968). The tragedy of the commons. *Science, New Series* **162** (3859), 1243-1248.

Johannes, R.E. (2002). The renaissance of community-based marine resource management in Oceania. *Annu. Rev. Ecol. Syst.* **33**: 317-340.

Marsh, H., Channels, P.W., Heinsohn, G.E., Morrissey, J., 1982. Analysis of stomach contents of dugongs from Queensland. *Australian Wildlife Research* **9**: 55-67

Marsh, H. and Lawler, I. (2001) Dugong distribution and abundance in the southern Great Barrier Reef Marine Park and Hervey Bay: Results of an aerial survey in October- December 1999. Report to Great Barrier Reef Marine Park Authority.

McKenzie, L.J., Campbell, S.J., Vidler, K.E. & Mellors, J.E. (2007) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources. (Seagrass-Watch HQ, Cairns) 114pp

Middlebrook, R., Williamson, J.E. (2006). Social attitudes towards marine resource management in two Fijian villages. *Ecological Management & Restoration* **7** (2): 144-147.

Preen, A.R. (1995). Diet of dugongs: are they omnivores? *Journal of Mammalogy* **76**: 163-171.

Smyth, D., Fitzpatrick, J., Kwan, D. (2006). Towards the development of cultural indicators for marine resource management in Torres Strait. CRC Torres Strait, Townsville. 61 pp.

Turnbull, J. (2004). Explaining complexities of environmental management in developing countries: lessons from the Fiji Islands. *The Geographical Journal* **170** (1), 64–77.

Williams, L.E. (1997). Queensland's Fisheries Resources: current condition & recent trends 1988-1995. *Queensland Department of Primary Industries Information Series* QI97007.100.pp.

Zeller, B. (1998). Queensland .s Fisheries Habitats, Current Condition and Recent Trends. *Queensland Department of Primary Industries Information Series* QI98025. 211pp.

Waycott, M, McMahon, K, Mellors, J., Calladine, A., and Kleine, D (2004) A guide to tropical seagrasses in the Indo-West Pacific. (James Cook University Townsville) 72pp.

Further reading:

den Hartog C. (1970). The seagrasses of the world. (North-Holland Publishing, Amsterdam). 293pp.

Green EP. and Short FT (Eds) (2003). World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. (University of California Press, Berkeley. USA). 298pp.

Kirkman H (1997). Seagrasses of Australia. Australia: State of the Environment .Technical Paper Series (Estuaries and the Sea), Department of the Environment, Canberra.

Lanyon JM, Limpus CJ and Marsh H. (1989). Dugongs and turtles: grazers in the seagrass system. In: Biology of Seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. (AWD Larkum, AJ McComb and SA Shepherd eds). (Elsevier: Amsterdam, New York). pp 610-34.

Lee Long, W. J., Coles, R. G. & McKenzie, L. J. (2000) Issues for seagrass conservation management in Queensland. *Pacific Conservation Biology* 5, 321-328.

Phillips, R.C, E.G Menez. (1988). Seagrasses. Smithsonian Institution Press, Washington, D.C. 104 pp.

Poiner, I.R., Walker, D.I., and Coles, R.G. (1989). Regional Studies - Seagrass of Tropical Australia. In: Biology of Seagrasses. A.W.D. Larkurn, A-J. McComb and S.A.Shepherd (Eds). Elsevier, Amsterdam, New York; 841 pp.

Short, FT and Coles, RG. (Eds.) Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam. 473pp.

We value your suggestions and any comments you may have to improve the Seagrass-Watch program.

Please complete the following statements in your own words

I found the Seagrass-Watch training to be ....

....

....

What I enjoyed most about the training was...

....

....

It could have been better if ....

....

....

I did not realize that...

....

....

Now I understand that ....

....

....

In my area the types of seagrasses and habitats include..

....

....

....

When I go back to my area, I will ....

...

...

...

Other comments..

...

...

...

...

...

...

...

...

...

...

...

...

...

...

...

...