Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in the Burdekin and Wet Tropics regions, Queensland

Girringun Training Centre, Cardwell, Queensland
7-8 August 2014

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Front cover photos (left to right): Goold Island reef flat with Garden Island in the background (Jun08) by Naomi Smith; *Zostera muelleri, Halodule uninervis* and *Halophila ovalis* mixed meadow (Shelley Beach, Oct13) by Len McKenzie; and dugong grazing trails (Shelley Beach, Oct13) by Len McKenzie.

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We acknowledge the traditional custodians of the lands on which we conduct this workshop and our monitoring.

We pay our respects to ancestors and elders, past, present and future.

Overview

Seagrass-Watch is a scientific monitoring and education program, where scientists, coastal managers and local stakeholders from across the globe collaborate to assess the status of their seagrass meadows to provide an early warning of coastal ecological decline. The program started in 1998 in Queensland (Australia), using standardised global monitoring protocols, and has so far expanded to include 355 sites across 19 countries. Anyone can participate in Seagrass-Watch, as it responds to local needs, and includes some elements of citizen science. Seagrass-Watch is a monitoring program that brings people together for seagrass conservation.

Seagrass-Watch implements a standardised, non-destructive, seagrass assessment and monitoring protocol, that has a rigorous quality assurance and quality control procedure to ensure data is of the highest quality and that time and resources are not wasted. The only condition is that on ground data collection must be overseen by a qualified scientist or trained and competent participant (18 years or over). The program 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 funded by the Threatened Species Division, Department of Environment & Heritage Protection (EHP), as part of the Indigenous sea country management project, and supported by Seagrass-Watch HQ.

This workshop is for experienced participants who plan to lead seagrass monitoring at a site/location or conduct seagrass extension activities. As part of the Level 1 workshop we will:

- *study seagrass biology;*
- *learn seagrass taxonomy;*
- *discuss the present knowledge of seagrass ecology, including importance and threats;*
- *gain knowledge of monitoring;*
- *learn about the Seagrass-Watch program and techniques for monitoring seagrass resources; and*
- *become skilled at conducting a Seagrass-Watch field monitoring event.*

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

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Photo: Fergus Kennedy

Workshop leaders

Len McKenzie

Len is a Principal Researcher with TropWATER (James Cook University) and Seagrass-Watch Program Leader. He is also the Manager of the Reef Rescue Marine Monitoring Program – Inshore Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 25 years experience as a researcher on seagrass ecology, assessment and fisheries habitats. This includes experience within Australia and internationally in seagrass research, resource mapping/ assessment and biodiversity. He has provided information on seagrass ecosystems that has been vital in management of seagrass resources of the Great Barrier Reef and 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 a qualified trainer and assessor (TAE40110). Len is also the Secretary of the World Seagrass Association.

Current Projects

- Seagrass-Watch
- Reef Rescue Marine Monitoring Program: inshore seagrass
- Status and mapping of seagrass resources in Queensland
- Identification of indicators and thresholds of concern for water quality and ecosystem health on a bioregional scale for the Great Barrier Reef
- Seagrass resilience: seagrass connectivity, community composition and growth
- Investigations on the macrofauna associated with seagrass meadows

Rudi Yoshida

Rudi is a Research Officer with TropWATER (James Cook University). Rudi has over 15 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
- Reef Rescue Marine Monitoring Program: inshore seagrass

Agenda - Level 1 (basic)

Thursday 7th August 2014 (Girringun Training Centre, Cardwell)

0900 - 0915 *(15min)*	Welcome & Introduction
0915 - 0935 *(20min)*	Seagrass Biology and Taxonomy*
0935 - 1015 *(40min)*	Seagrass Identification
1015 - 1030 *(15min)*	*Break*
1030 - 1130 *(60min)*	Seagrass Identification *continued**
1130 - 1230 *(60min)*	Seagrass Biology 2 and Ecology
1230 - 1330 *(60min)*	*Lunch*
1330 - 1415 *(45min)*	Seagrass importance
1415 – 1500 *(45min)*	Seagrass threats*
1500 – 1520 *(20min)*	Seagrass monitoring*
1520 – 1530 *(10min)*	Wrap up for day

Friday 8th August 2014 (Girringun Training Centre, Cardwell)

0830 - 0845 *(15min)*	recap day 1
0845 - 0945 *(60min)*	Seagrass-Watch: how to sample*
0945 - 1045 *(60min)*	Seagrass-Watch: QAQC & how data is used*
1045 - 1130 *(45min)*	prepare for field & relocate to boat ramp
1130 - 1230 *(60min)*	*Lunch* & boat transfer to Goold Island
1230 - 1430 *(2hrs)*	**Field exercise:** Seagrass-Watch monitoring

Where: Goold Island (GO1)

What to bring:

- *hat, sunscreen (Slip! Slop! Slap!)*
- *dive booties or old shoes that can get wet*
- *wear long pants, but keep clothes light and breathable*
- *drink/refreshments and energising snack*
- *wet weather gear: poncho/raincoat*
- *insect repellent*
- *polaroid sunglasses (not essential)*
- *simple medical kit in case of injuries to yourself*
- *change of footwear and clothes*
- *enthusiasm*

You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet!

Please remember, seagrass meadows are an important resource. We ask that you use discretion when working/walking on them.

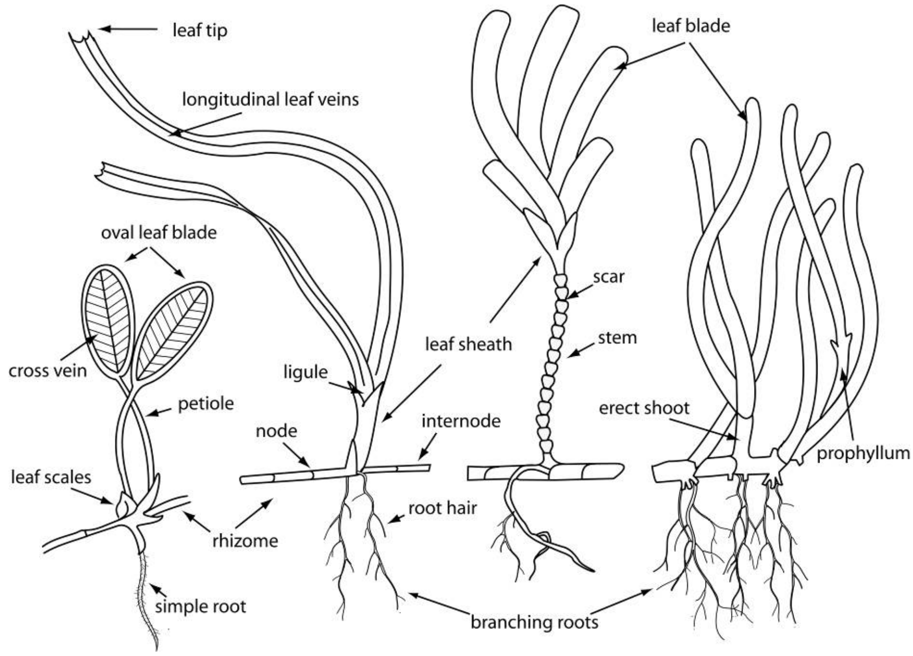
1430 - 1530 *(60min)*	Wrap up & boat transfer back to Cardwell

Tide: 1308, 0.2m

Background

Seagrass are marine flowering plants

Seagrasses are unique flowering plants that have evolved to live in sea water. Seagrasses belong to a group of plants known as angiosperms (flowering plants).



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

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 across countries.

Like terrestrial (land living) plants, a seagrass can be divided into its leaves (which contain veins), stem, roots (buried in the substrate) and reproductive parts such as flowers and fruits. Algae do not have veins in their leaves nor do they possess roots (anchoring to the surface of the substrate by a holdfast) or produce flowers or seeds.

Seagrasses have roots, stems and leaves

Seagrass is different to seaweed (algae) as seagrass have internal veins, true roots and produce flowers, fruits and seeds

They are called "seagrass" because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover) shape, a fern shape, a long spaghetti like leaf and a ribbon shape. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea, Thalassia, Thalassodendron, Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as **scars**.

Leaves of different seagrass species can be shaped like a flattened ribbon, look like a fern, round like a clover, or even spaghetti shaped

Seagrass leaves lack stomata (microscopic pores on the under side of leaves) but have thin cuticle to allow gas and nutrient exchange. They also possess large thin-walled aerenchyma (air channels). Aerenchyma are specialised tissue having a regular arrangement of air spaces, called lacunae, that both provide buoyancy to the leaves and facilitate gas exchange throughout the plant. Leaves have a very thin cuticle, which allows gas and some nutrient

Seagrass have veins and air channels in their leaves and stems so they can carry water, food and absorb gases diffusion into them from the surrounding water. Seagrass leaves also contain **veins** (lignified conducting tissue that transports food, nutrients and water around the plant) (i.e. an internal vascular system). Veins can be across the leaf blade or run parallel to the leaf edge. Also within the leaves are chloroplasts, which use the suns light to convert carbon dioxide and water into oxygen and sugar (photosynthesis). The sugar and oxygen are then available for use by other living organisms.

Seagrasses rely on light to convert carbon dioxide and water into oxygen and sugar (photosynthesis)

The roots and horizontal stems (**rhizomes**) of seagrass are often buried in sand or mud. They anchor the plant, store carbohydrates and absorb nutrients. Roots can be simple or branching and all have fine hairs to help absorb nutrients. Rhizomes are formed in segments with leaves or vertical stems rising from the joins, called **nodes** or scars. Sections between the nodes are called internodes. Seagrasses depend upon the growth of rhizomes to increase the area they occupy. This vegetative growth is the most common mode of growth for seagrasses. Although the rhizome mainly runs horizontally, some lateral branches are more or less erect and bear leaves (erect shoots). Sometimes the leaves are on a special type of stalk, called a petiole.

Roots can be simple or branching and all have fine hairs to help absorb nutrients

The roots and rhizomes of seagrasses are well endowed with aerenchyma and the lacunae are extensive and continuous with leaf tissues. **Oxygen** transport to the roots creates an oxic environment around the roots, facilitating nutrient uptake.

Seagrass pump oxygen into the sediment via their roots

Seagrasses have flowers and pollination systems that are well adapted for pollination by water. Seagrass form tiny flowers, fruits and seeds. Most seagrasses have separate male and female plants. In most species, flowers are small, white and are borne at the base of the leaf clusters. The stamens (male parts) and pistils (female parts) extend above the petals to facilitate pollen release and pollination respectively.

Seagrass have flowers, fruits and seeds

Most seagrasses reproduce by pollination while submerged and complete their entire life cycle underwater. Pollination in seagrasses is hydrophilic (aided by water), and can occur by: (i) pollen transported above water surface (e.g., *Enhalus*); (ii) pollen transported on water surface (e.g., *Halodule*), or; (iii) pollen transported beneath water surface (e.g., *Thalassia*).

Pollination occurs in the water

Seagrass pollen grains are elongated into a filamentous shape. The filamentous nature of pollen grains facilitates transport within the water medium, mainly by water currents. *Halophila* and *Thalassia* have spherical pollen grains, but they remain joined together in long chains, giving the same effect as having elongated, filamentous pollen grains.

Pollen from male seagrass flowers is mainly dispersed to female seagrass flowers by tidal currents

After fertilization, the ovary of the female flower develops into a fruit. In seagrasses, fruit development and fruit structure are as diversified as their flowering patterns and floral structures. In general the seeds, ranging in the size from 0.3 to 0.5mm in some *Halophila* species to more than 1–2 cm in *Enhalus*, are furnished with a nutrition reserve and sink rather than float. The number of seeds within a fruit also varies from 1 (e.g. *Halodule uninervis*) up to 25 (e.g. *Halophila ovalis*).

Seagrass taxonomy

Seagrasses are monocotyledons that are not true grasses (true grasses belong to the family Poaceae), but are rather more closely related to the lily family.

Seagrasses are not true grasses

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in at least four separate lineages. Thus, seagrasses are not a taxonomically unified group but a 'biological' or 'ecological' group. The evolutionary adaptations required for survival in the marine environment have led to convergence (similarity) in morphology.

Seagrasses are more closely related to lilies

Seagrass evolved 100 million years ago from land plants that returned to the sea

Worldwide, there are about 12 major divisions, consisting of approximately 60 species (possibly up to 72) of seagrass. The highest concentration of species occurs in the Indo-West Pacific region.

Over 30 species can be found within Australian waters. The most diverse seagrass communities are in the waters of north-eastern Queensland and southern Western Australia. Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, and spoon grass. Seagrasses are not seaweeds. Seaweed is the common name for algae.

There are around 60 species of seagrass found in oceans throughout the world

Seagrass requirements for growth

Seagrasses require light, nutrients, carbon dioxide, substrate for anchoring, tolerable salinity, temperature and pH to survive. The requirements for a seagrass to be able to exist in the marine environment include:

1. adaptation to life in saline (salty) medium
2. growth when completely submerged
3. anchoring system able to withstand the forces of wave action and tidal currents
4. hydrophilous pollination (pollination aided by water).

Seagrasses need plenty of sun and clean water to grow.

The need for physiological adaptations to life in sea water is obvious when one considers that seagrasses evolved from land plants, and most land plants are unable to tolerate even small quantities of salt. In contrast to land plants, some seagrasses can tolerate a salinity range from 4 to 65 parts per thousand (2x seawater concentration). Typically, seagrasses grow best in salinities of 35 parts per thousand. Not all species tolerate all salinities equally well, and salinity tolerance may be a factor promoting different species distributions along salinity gradients, e.g., going up estuaries. Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline (very salty). A limiting factor for many intertidal seagrasses is osmotic impacts resulting from hypersalinity due to evaporation

Seagrasses are physiologically adapted to life in sea water

Seagrasses can tolerate a range of salinities. Some species are less tolerant than others

Seagrasses being plants need light for photosynthesis. Light availability is the most dominant overriding factor in seagrass growth. Seagrasses have high minimum light requirements (e.g. 10-20% on average, 4.4% minimum and 29% maximum depending on species) of surface irradiance) because: (i) they have a high respiratory demand to support a large non-photosynthetic biomass (e.g. roots, rhizomes); (ii) they lack certain pigments and therefore can utilise only a restricted spectral range; and (iii) they must regularly oxygenate their root zone to compensate for anoxic sediment. However, light in the intertidal can be in excess of requirements and excess light can cause temporary photo damage. UV exposure can also have significant impacts on seagrasses.

Light availability is the most important factor determining seagrass growth

Seagrasses require between 10-20% of surface light to grow

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO_2 concentration. The cause of thermal stress at higher temperatures (38°C to 42°C) is the disruption of electron transport activity via inactivation of the oxygen producing enzymes (proteins) of

Water temperature influences the rate of growth and the health of seagrass photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

Temperature also controls the range of pH and dissolved carbon dioxide (CO_2) concentrations in the water column; factors critical in plant survival in the marine environment.

Seagrasses require inorganic carbon for growth. They uptake inorganic carbon at the leaf surface via two pathways which are species-specific. Some species use bicarbonate (HCO_3^-) as an inorganic carbon source (e.g. *Halophila ovalis, Cymodocea rotundata, Syringodium isoetifolium* and *Thalassia*), whereas others use enzymes to make CO_2 available as the inorganic carbon source (e.g. *Enhalus acoroides, Halodule, Cymodocea serrulata*).

Seagrasses require two key nutrients, nitrogen and phosphorous, for growth. In the coastal regions, seagrasses appear to be primarily limited by nitrogen and secondarily by phosphorus. The demand for nutrients by seagrasses appears to be seasonally dependent. During the growing season the demand for nutrients is high, however during the senescent season elevated nutrients may become toxic.

The availability of nutrients to seagrasses may also be dependent on sediment quality / geochemistry. Bioavailability of nutrients is dependent on particle size and type. For example, clay content influences sediment adsorptive capacity — the more clays the greater the adsorptive capacity — and, calcium carbonate binds phosphorus, limiting its bioavailability.

Sediment quality, depth and mobility are important factors for seagrass composition, growth and persistence. Most seagrasses live in sand or mud substrates where their roots and rhizomes anchor the plants to the sea floor. Some seagrasses such as *Cymodocea* spp. prefer deeper sediments while others can tolerate a broad range of sediment depths. Colonising seagrasses such as *Halophila* spp. and *Halodule uninervis* are better suited to mobile sediments than larger species. The biogeochemical characteristics of sediment that can affect the nutrient content/binding capacity, organic content and oxygen levels. Seagrasses are unable to grow in sediments of high organic content.

Currents and hydrodynamic processes affect almost all biological, geological and chemical processes in seagrass ecosystems at scales from the smallest (physiological and molecular) to the largest (meadow wide). The pollination of seagrass flowers depends on currents and without current flows, vegetative material and seeds will not be transported to new areas, and species will not be exchanged between meadows. Factors such as the photosynthetic rate of seagrasses depend on the thickness of the diffusive boundary layer that is determined by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

Where are seagrasses found?

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the arctic (freezing) regions. Seagrass are mainly found in bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 metres. Most species are found in clear shallow inshore areas between mean sea-level and 25 metres depth.

Seawater temperatures above 40ºC will stress tropical seagrass. Death occurs at temperatures above 43ºC

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

Seagrass require two key nutrients, nitrogen and phosphorous, for growth

Nutrient availability to seagrass is dependent on the type of sediment they grow in

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

Tidal currents are important for pollination and exchange of gases from the water to the plant

Seagrass are commonly found in estuaries, shallow coastal locations, and on reef-tops.

Seagrasses survive in the intertidal zone especially in locations sheltered from wave action or where there is pooling of water at low tide, (e.g., reef platforms and tide pools), which protects seagrass from elevated temperatures and drying.

Seagrass are mainly found in clear shallow inshore areas between mean sea-level and 25 metres depth.

Seagrasses inhabit all types of ground (substrates), from mud to rock. The most extensive seagrass meadows occur on soft substrates like sand and mud.

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.

The depth that seagrass are found underwater depends on the light availability (water clarity)

Seagrass plants form small patches that develop into large continuous meadows. These meadows may consist of one or many species: sometimes up to 12 species present within one location.

Seagrass plants form small patches that develop into large meadows

How are seagrasses important to the marine ecosystem?

Seagrass communities are one of the most productive and dynamic ecosystems globally. Seagrasses may significantly influence the physical, chemical and biological environments in which they grow by acting as 'ecological engineers'. They provide habitats and nursery grounds for many marine animals and act as substrate stabilisers.

Seagrasses are important habitat and feeding grounds for marine organisms.

Seagrass meadows are highly productive. They have been documented to create habitat complexity compared with unvegetated areas, providing up to 27 times more habitable substrate, as well as providing refuge and food for a range of animals. About 40 times more animals occur in seagrass meadows than on bare sand.

About 40 times more animals occur in seagrass meadows than on bare sand.

One of the most important roles of seagrasses is providing a nursery and shelter area for fish and prawns which are valuable to fisheries. Juveniles of some important species which depend on seagrass meadows include fish such as perch, mullet, whiting, tailor, bream, snappers, emperors and sweetlips. Commercial penaeid prawns such as red spot king, brown tiger, grooved tiger and endeavour also live in seagrass meadows as juveniles. Tropical rock lobsters also live in seagrass meadows as juveniles. Shellfish such as some oysters and pearl shell may be more likely to settle and survive where there is seagrass. Juvenile and adult sandcrabs and flathead are just two species which spend most of their lives in seagrass meadows, where there is not only food but also protection from strong tidal currents and predators. Larger predatory animals such as herons, cormorants, sharks, barramundi, salmon, crocodiles, etc, are also attracted to the seagrass meadows by the schools of forage fish which seek shelter there.

Seagrasses are important nursery grounds for fish, and they support many human commercial activities.

Seagrass meadows are a major food source for a number of grazing animals and are considered very productive pastures of the sea. The dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*) mainly feed on seagrass. An adult green turtle eats about two kilograms of seagrass a day while an adult dugong eats about 28 to 40 kilograms a day. Although dugongs and turtles will feed on any seagrass species within their range, if a range of species is available, they select seagrass species for food which are high nitrogen, high starch and low fibre. For example, the order of seagrass species preference for dugongs is *Halophila ovalis ≥ Halodule uninervis > Halophila spinulosa > Syringodium isoetifolium > Zostera*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

Dugongs can eat up to 40kg of seagrass per day.

Dugongs and turtles select seagrass species for food which are high nitrogen, high starch and low fibre

Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The decaying leaves are broken down by fungi and bacteria which in turn provide food for other microorganisms such as flagellates and plankton. Microorganisms provide food for the juveniles of many species of marine animals such as fish, crabs, prawns and molluscs.

Seagrasses also contribute to the productivity of ecosystems via the detrital food pathway

The rhizomes and roots of the grasses bind sediments on the substrate, where nutrients are recycled by microorganisms back into the marine ecosystem. The leaves of the grasses slow water flow, allowing suspended material to settle on the bottom. This increases the amount of light reaching the seagrass meadow and creates a calm habitat for many species.

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

Seagrasses are nutrient sinks, buffering or filtering nutrient and chemical inputs to the marine environment. Seagrasses uptake nitrogen and phosphorus from coastal run-off that, in overabundance, can lead to algal blooms that can impair water quality.

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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).

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.

Seagrasses, mangroves and coral reef interact, providing physical and biological support for other communities

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 value of seagrasses

The value of ecosystem services is a very controversial topic in today's literature. Ecosystem Services are the processes by which the environment produces resources that we often take for granted. For seagrasses it is services such as clean water, preventing erosion, and habitat for fisheries. The 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 US$ 28,916 ha^{-1} yr^{-1} (in 2007 dollars).

Seagrass meadows are rated the 3rd most valuable ecosystem globally (more valuable than mangroves or coral reefs)

What causes seagrass areas to change?

Tropical seagrass meadows vary seasonally and between years, and the potential for widespread seagrass loss has been well documented. Factors which affect the distribution of seagrass meadows are sunlight and nutrient levels, water depth, turbidity, salinity, temperature, current and wave action.

Seagrasses respond to natural variations in light availability, nutrient and trace element (iron) availability, grazing pressure, disease, weather patterns, and episodic floods and cyclones. The dynamic nature of seagrass meadows in

Seagrasses can change due to both natural and human impacts response to natural environmental variation complicates the identification of changes caused by humans.

What threatens seagrass?

Seagrass meadows can be easily damaged. Approximately 58% of seagrass meadows globally, have lost part of their distribution. According to reports, the documented losses in seagrass meadows globally since 1980 are equivalent to two football fields per hour.

Some losses are natural due to storms and herbivores, however most losses are the result of human activities. Human pollution has contributed most to seagrass declines around the world.

People can damage or destroy seagrass by pollution (sewage, oil spills and coastal runoff) and physical destruction (dredging, bait & clam digging, boat propellers and anchors/moorings).

The most widespread and pervasive cause of seagrass decline is a reduction in available light. Processes that reduce light penetration to seagrasses include pulsed turbidity events during floods, enhanced suspended sediment loads and elevated nutrient concentrations. Poor farming practices can result in excess sediments and fertilizers washing down creeks to the sea. Sewage discharge and stormwater runoff from urban development can elevate nutrients in coastal areas. Boating activity may also stir up sediment, reducing light levels. Phytoplankton and fast-growing macroalgae are also better competitors for light than benthic plants and their biomass can shade seagrasses during progressive eutrophication.

Poor farming practices can result in runoff which can damage seagrass by elevating nutrients, reducing available light and releasing herbicides.

Oil and trace metal contamination can exert direct toxic effects on some seagrass species. Seagrasses are able to bioaccumulate the trace metals and this can have ramifications for grazers such as dugongs.

People can also physically damage or destroy seagrass. Coastal development for boat marinas, shipping ports and housing generally occurs on the coast in areas which are sheltered and seagrass like to grow. Seagrass meadows are either removed or buried by these activities. Coastal developments can also cause changes in water movement. Dredging boat channels to provide access to these developments not only physically removes plants, but can make the water muddy and dump sediment on seagrass. Litter and rubbish can also wash into the sea if not properly disposed. Rubbish can physically and chemically damage seagrass meadows and the animals that live within them.

Coastal development can have a major impact on seagrass meadows

Boating and fishing activities can physically impact or destroy seagrasses. Boat anchors and their chains can dig into seagrass. Propellers can cut into seagrass meadows and unstabilise the rhizome mat. Storms can further exacerbate the damage by the physical force of waves and currents ripping up large sections of the rhizome mat. Uncontrolled digging for bait worm can also physically damage seagrasses and some introduced marine pests and pathogens also have the potential to damage seagrass meadows.

Climate change can threaten intertidal seagrass by increased seawater temperature and greater physical disturbance from storms

One of the other significant impacts to seagrass is climate change. The major vulnerability of seagrass to climate change is loss of seagrass in the coastal zone, particularly near river mouths and in shallow areas. The greatest impact is expected to result from elevated temperatures, particularly in shallower habitats where seagrasses grow (e.g., affecting distribution and reproduction). In addition, reduced light penetration from sediment deposition and resuspension are expected due to more intensive cyclones/hurricanes and elevated flooding frequency and amplitude. This will result in even greater seagrass losses, and changes in species composition are expected to occur particularly in relation to disturbance and recolonisation. Following such events, a shift to more ephemeral species and those with lower minimum light requirements is expected.

Seagrass in the Wet Tropics and Burdekin NRM regions of Queensland

Seagrass meadows in the north eastern regions of Queensland play a vital role in supporting coastal marine communities and in maintaining diverse flora and fauna. They are an important component of coastal fisheries productivity, which includes being nursery grounds for many commercially important species. They play an important role in maintaining coastal water quality and clarity. The importance of seagrass in the regions to commercial and recreational fisheries production, and threatened species such as dugong and turtle populations is widely recognised. The value of seagrass areas is recognised with the Hinchinbrook and Cleveland Bay areas being declared Dugong Protection Area's. The loss of seagrass habitat due to human impacts would further reduce the viability of dugong surviving in the long term.

Wet Tropics

Seagrass in the Wet Tropics region were first mapped as part of broad scale surveys of the Queensland coast in 1984 (Wujula Wujal to Trinity Inlet) and 1987 (Cairns Harbour to Halifax Bay) (Coles et al., 1985; Coles et al., 1989). The surveys included only nearshore seagrass to a depth of approx 15m. Since the 1980s, mapping has been issue focused at local scales (e.g. Cairns Port, Mourilyan Harbour, Green Island, Low Isles, Port Hinchinbrook (Oyster Point) and the Hinchinbrook Dugong Protection Area from Dunk Island to Halifax) (Lee Long et al., 1996b; McKenzie et al., 1996; Lee Long et al., 1998; Udy et al., 1999; Lee Long et al., 2001; McKenzie et al., 2001; McKenzie et al., 2014c). Unfortunately, seagrass mapping across the Wet Tropics includes some of the poorest mapped areas in Queensland. One of the most data poor areas is Wujula Wujal to Trinity Inlet, as many locations were missed during the broadscale survey.

Approximately 6.5% of the maximum habitable area of seagrass mapped in the shallow waters (<15m) of the GBR occurs in the Wet Tropics (McKenzie et al., 2010). The most extensive areas of seagrass in this region occur around Low Isles, Cairns Harbour, Green Island, Mourilyan Harbour and Hinchinbrook Island (between Dunk Island and Lucinda) (Coles et al., 2007). Thirteen seagrass species have been recognised for this region (Lee Long et al., 1993). Nearshore seagrass meadows are situated on sand and mud banks and mostly dominated by *Halodule uninervis* with some *Halophila* in the northern and southern areas. Intertidal meadows in Cairns Harbour and southern Hinchinbrook channel are dominated by *Zostera muelleri* ssp. *capricorni*. Shallow subtidal coastal meadows consist of *Halodule uninervis* and *Halophila* communities mostly 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).

Information on seagrass status in the region is provided by Ports North's annual monitoring at the ports of Cairns and Mourilyan Harbour (Jarvis et al., 2014; York et al., 2014), and as part of the Great Barrier Reef Marine Park Authorities (GBRMPA) Marine Monitoring Program (Low Isles, Yule Point, Green Island, Dunk Island and Lugger Bay) (McKenzie et al., 2014a). Ports North monitoring is conducted to identify any impacts associated with port activities (e.g. maintenance dredging), while the Marine Monitoring Program is focused primarily on agricultural runoff.

Current indications from the MMP are that inshore water quality, largely driven by fluctuations in total suspended sediment, and seagrass across the Wet Tropics region are in a poor to very poor state (Brodie et al., 2013). Although seagrass abundance has increased over the last 12 months at some locations, seagrass in the overall region has been in a poor state since 2009 and remains in a vulnerable condition, with weaker resistance and a lower capacity to recover from major disturbances (McKenzie et al., 2013). Unprecedented declines in biomass and distribution of estuarine meadows have also been reported since 2009 in the Ports of Cairns and Mourilyan Harbour, and there has been limited recovery since (McKenna and Rasheed, 2013; Rasheed et al., 2013).

Hinchinbrook Channel & Girringun sea country

Large areas in this region are sheltered from waves and currents providing extensive potential areas for seagrass habitation: from intertidal to a depth of 15m. The increase in seagrass depth range from the inshore mainland to offshore localities is most likely related to a general decrease in turbidity offshore (increase increasing availability of light for photosynthesis) (Lee Long et al., 1998). Within the channel, the maximum depth seagrasses have been found was 4m probably due the high turbidity within this area as a result of high loadings of phytoplankton and suspended solids (Furnas, 2003). These meadows are regionally important to fisheries, dugong and turtle populations (Coles et al., 1992; Lee Long et al., 1993).

Based on current taxonomic knowledge, eleven species of seagrass have been recognized for this region: *Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis, Syringodium isoetofolium, Halophila decipiens, Halophila ovalis, Halophila spinulosa, Halophila tricostata, Enhalus acoroides, Thalassia hemprichii* and *Zostera muelleri* ssp*. capricorni* (Lee Long et al., 1998; Roder et al., 1998; Coles et al., 2007; McKenzie et al., 2010).

Seagrass meadows within the Girringun sea country area were first mapped during a broad-scale survey in October/November 1987 (Coles et al., 1992). More comprehensive surveys were conducted across the region in 1996 (Lee Long et al., 1998) and at the southern end of the region in 2007 (Rasheed et al., 2007). The general location of major seagrass meadows were similar between surveys, however changes in areal extent and density differed between surveys (Coles et al., 1992; Lee Long et al., 1998; Rasheed et al., 2007).

Cymodocea species, *Thalassia* and a suite of *Halophila* species tend to dominate island habitats to the north (e.g. Dunk ,Goold and northern Hinchinbrook Islands). Large areas of dense seagrass were mapped in Missionary and Shepherd Bay. The large subtidal seagrasses found in these bays of Hinchinbrook Island are probably an important alternative food sources for dugong and turtle, when the narrow intertidal habitat areas along the coast are inaccessible at low tide. Dense meadows of mostly *Halophila* and *Halodule* were also found along the Cardwell foreshore and in the lee of Hinchinbrook Island, though mostly on the western side of the channel. Very few creek banks supported seagrass (Lee Long et al., 1998).

Intensive mapping of the seagrass adjacent to Oyster Point during and after capital and maintenance dredging of the boat channel and marina at the Port Hinchinbrook development from 1995 to 1999 (Lee Long et al., 2001) reported 5 species of seagrass: the three dominant species (*Halophila ovalis, Halophila decipiens* and *Halodule uninervis/pinifolia*) are fast-growing and naturally highly variable in abundance. *Halophila spinulosa* and *Halophila tricostata* occurred in small amounts in baseline surveys, and were uncommon, or not found, in later surveys. There were initial losses of low-density seagrasses (up to 0.3ha) where capital dredging of the access channel cut through existing meadows. There has been no seagrass regrowth in the dredged channel and regrowth was not expected because of tidal flows and low light intensities under the turbid silt layer. The seagrass community on the edges immediately adjacent to the dredged access channel were similar each year before and after dredging. There were declines in seagrass biomass (all species pooled) in the study area from 1995 to 1998, followed by a return to near pre-dredging (1995) biomass in 1999. The changes were within the ranges of natural variability measured in the region and were uneven across the study area (Lee Long et al., 2001).

The southern end of the Hinchinbrook channel, intertidal meadows were dominated by *Zostera muelleri*. Further south, near Lucinda, dense meadows of *Halodule uninervis* (narrow leaf morphology) were mapped for the first time during the 2007 survey (Rasheed et al., 2007). Seagrass habitat in this southern part was recently recognised as being under high threat from agricultural run-off from the Herbert River; fuel and/oil spills and shipping accidents in the commercial port area of Lucinda (Rasheed et al., 2007).

In the southern Hinchinbrook/Herbert River Estuary the total area of intertidal seagrass meadows increased from 1996 and 2007, while areas of subtidal meadows decreased (Coles et al., 2007). The observed changes in area and density of intertidal and subtidal seagrasses between the surveys are evidence for large natural variability in these habitats. Long term and moderate scale changes in seagrass abundance could influence herbivore populations that rely on seagrass habitat by impacting fecundity, and reproductive success. The most likely cause of habitat variability is region-wide changes in climatic conditions. Seagrass growth is largely influenced by availability of photosynthetically active light (Dennison et al., 1993), so years of reduced light (e.g., prolonged climatic conditions of strong wind and cloud cover) will likely inhibit seagrass growth and survival (McKenzie, 1994). Conversely, years of clear, calm weather would contribute to greater seagrass growth and survival. Species at sub-tidal depths and at the deep extent of their distribution would be most vulnerable to changes in the amount of available light for photosynthesis.

In the first half of 2014, seagrasses were examined at a number of locations across the southern Wet Tropics (McKenzie et al., 2014b). In the vicinity of the Frankland Islands, seagrass was limited to a few shallow water locations with the only significant meadow located at Normanby Island. Seagrass was absent from the estuaries of the Hull and Tully Rivers, equating to a loss of approximately 7ha of seagrass over the last 25 years. An assessment of the intertidal seagrass status on the banks adjacent to Lucinda found no seagrass present, indicating no recovery since reported losses in early 2011. Seagrass recolonisation may have been hindered due to the excessive sediment movement across the intertidal banks or lack of viable seagrass propagules (e.g. depleted seed banks and deficient donor meadows). Similarly, an assessment at Goold Island found showed no significant recovery over the last 24 months with only isolated patches of low cover *Halophila ovalis* and few shoots of *Enhalus acoroides* and *Halodule uninervis*.

BURDEKIN

There are extensive and diverse seagrass meadows in the Burdekin Region. Intertidal and shallow subtidal seagrasses predominate and tend to form multi-specific meadows that are arranged in mono-specific bands across a depth gradient. True reefal seagrasses are also rare in this region, but most fringing reefs associated with continental islands support moderately dense mixed species meadows.

Approximately 18% of the maximum habitable area of seagrass mapped in the shallow waters (<15m) of the GBR occurs in the Burdekin NRM region (McKenzie et al., 2010). Intertidal seagrasses and shallow subtidal seagrasses dominate, the majority of which are within coastal habitats (Coles et al., 2007). Extensive seagrass meadows occur in Upstart, Cleveland (8394± 323 ha), and Bowling Green Bays and off Magnetic Island (4404 ±331 ha for Townsville & Magnetic Island). Twelve species have been found within this region (Lee Long et al., 1993, Lee Long et al., 1996a). The main seagrass species in shallow waters near are *Halophila ovalis, Halodule uninervis, Zostera muelleri*, and *Cymodocea serrulata*. *Halophila spinulosa* that has been washed up from deeper waters can sometimes be found.

The distribution of seagrasses along the regions coastline is predominately influenced by seasonal (April-November) south-easterly trade winds. Seagrass meadows generally establish in places that offer protection from these winds, such as the large north opening bays and the leeward sides of continental islands. Within the bays, the coastal seagrasses are located on naturally dynamic shallow sand banks and are subject to sand waves and erosion blowouts moving through the meadows. While 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 costal zone that is likely to be a major short term driver. 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. Consequently seagrasses that inhabit this area are subjected to low light regimes, and high influxes of freshwater and sediment. To survive this regime seagrasses need to exhibit high vegetative growth rates and prolific seed banks. This has probably led to the predominance of opportunistic and ephemeral species, such as *Halodule* and *Halophila* within this region.

The reef habitats are mainly represented by fringing reefs on the many continental islands within this area. Most fringing reefs have seagrass meadows growing on their shallow banks. Nutrient supply to these meadows is by terrestrial inputs via riverine discharge, re-suspension of sediments and groundwater supply. The meadows are typically composed of zones of seagrasses: *Cymodocea serrulata, Thalassia hemprichii* and *Halodule uninervis* (wide leaf) often occupy the lower littoral/subtidal area, blending with *Halodule uninervis* (narrow leaved) and *Halophila ovalis* in the upper intertidal zone. Phosphate is often 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.

Deep water (>15m) seagrasses occur in this region but are not as common or dense as occurs in regions further north (Coles et al., 2009).

Major threats to seagrass meadows in the region include: coastal development (reclamation); 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 (Scheltinga and Heydon, 2005; Haynes et al., 2001). The greatest threat to seagrass throughout this region is agricultural land clearing (both grazing and cropping) and its inherent problems of soil erosion and associated loads of nutrients and pesticides.

SEAGRASS-WATCH IN THE WET TROPICS AND BURDEKIN NRM REGIONS

Other than the specific threats to seagrasses in the southern area of this region (Rasheed et al., 2007; Grech et al., 2008), the greatest threat to seagrasses throughout this region is land clearing with respect to agricultural - grazing and cropping and coastal/urban development. Land clearing with its inherent problems of soil erosion and associated loads of nutrients and pesticides are problematic for the long term survival of seagrasses that are already stressed by natural events.

To provide an early warning of change, long-term monitoring has been established at a number of locations across eastern Cape York as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org) (McKenzie et al., 2000). Establishing a network of monitoring sites in Cape York region provides valuable information on temporal trends in the health status of seagrass meadows in the region and provides a tool for decision-makers in adopting protective measures. The following is a summary of the current status of Seagrass-Watch monitoring in the eastern Cape York region.

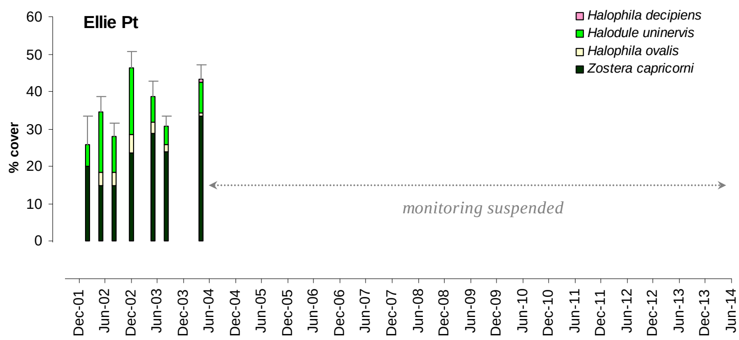
To provide an early warning of change, long-term monitoring has been established at a number of locations across the Wet Tropics as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org) (McKenzie et al., 2000).

Establishing a network of monitoring sites in the Wet Tropics region provides valuable information on temporal trends in the health status of seagrass meadows in the region and provides a tool for decision-makers in adopting protective measures. Monitoring is conducted by Seagrass-Watch HQ (James Cook University) as part of the Marine monitoring Program. The following is a summary of the current status of Seagrass-Watch monitoring in the Wet Tropics region.

Ellie Point

Monitoring: suspended
Past watchers: Tom Collis, Seagrass-Watch HQ
Location: on the north of Cairns Harbour, adjacent to the mouth of the Barron River
Site code: EP
EP1 position: S16.87617 E145.77796
Best tides: <0.8m Cairns *(Port 59060)*
Issues: Land runoff & boat traffic
Comments: popular recreational fishing area and turtle feeding grounds
Status (Feb05):

- site has not been examined since 6 April 2004
- site appears to be showing a fairly typical seasonal pattern of seagrass abundance (higher in late spring-summer than winter)
- site is dominated by *Zostera muelleri* ssp. *capricorni* with *Halodule uninervis* and *Halophila ovalis*
- site appears to be recovering in distribution and cover since the substantial loss of seagrass area and abundance reported in December 2001 (Campbell et al., 2002)
- results of monitoring indicate that seagrasses at Ellie Point appear relatively healthy and that there had been an overall increase from values recorded in February 2002



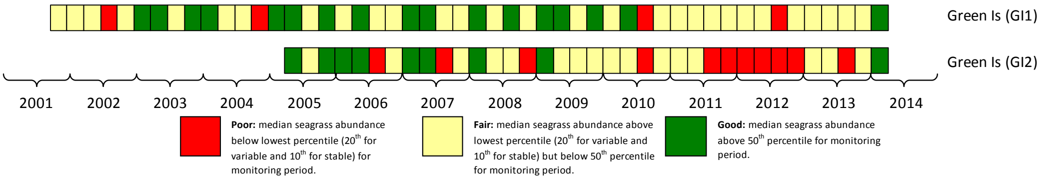
Green Island

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Location: reef-platform on Great Barrier Reef mid shelf reef approximately 27 km north east of Cairns
Site code: GI1, GI2
GI1 position: S16.76163 E145.97290 *(heading: 180 degrees)*
GI2 position: S16.76140 E145.97614 *(heading: 180 degrees)*
Best tides: <0.8m Green Island (Port 59070)
Issues: Elevated nutrients and land runoff
Comments: Green Island is a vegetated sand cay approximately 12 ha in area with a maximum elevation of 4.5m. There are extensive seagrass meadows in the waters surrounding Green Island with at least 9 species (*Halodule, Cymodocea, Halophila, Thalassia, Syringodium*) identified. Abundance of seagrasses highest in the sub-tidal area in the north western lagoon. Monitoring of reef habitats occurs at Green Island, 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 distribution of seagrass around Green Island has changed substantially in the last 50 years, possibly from poor water quality, a consequence of increases in tourist visitation and increased

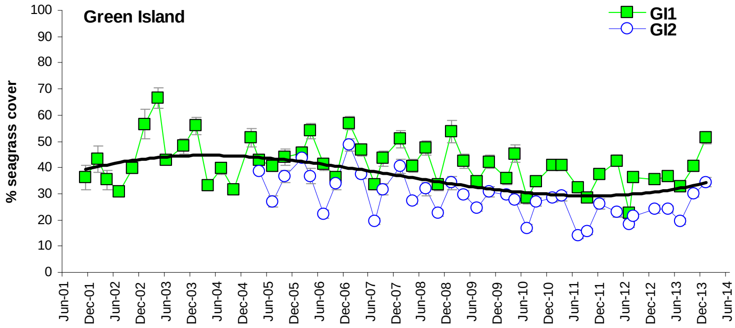
nutrients emanating from the adjacent sewage outfall. The most dramatic change however, has been the seagrass species composition, with the species *Syringodium isoetifolium* now dominating most of the lagoon meadows. How these changes in the seagrass composition and abundance on Green Island will effect the sea turtle, dugong and fisheries is unknown. Further reading Udy et al.,). The location is a green (no fishing) zone of the GBRMP, and a dugong and turtle feeding ground.

Status (March 2014):

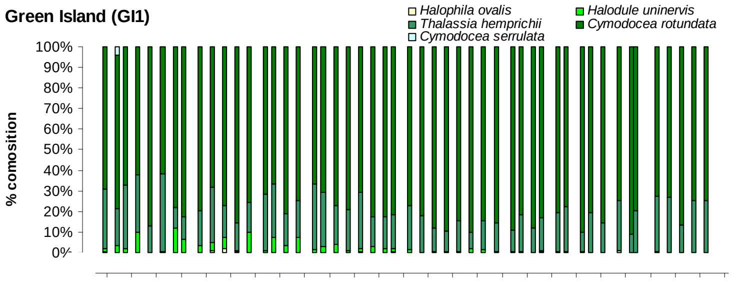
- Seagrass abundance appears to follow typical season pattern (higher in late spring-summer than winter).
- Seagrass abundance relative to the seagrass guidelines indicates that the seagrass meadows at Green Island are in a GOOD state.
- Figure below shows the seagrass status for each quarterly monitoring event since November 2001.

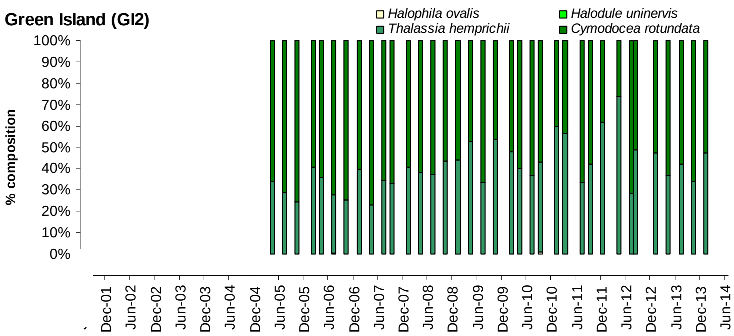


- Seagrass abundance has increased slightly over the past 12 months at both sites.

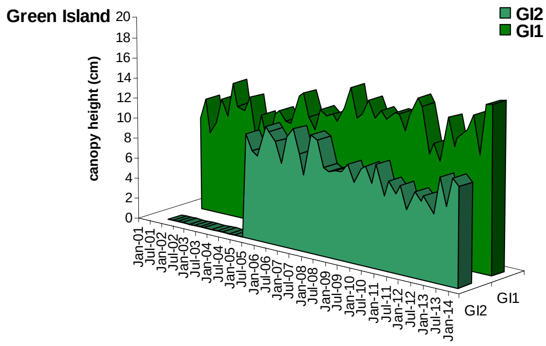


- Sites are dominated by *Cymodocea rotundata, Thalassia hemprichii, Halodule uninervis* and *Halophila ovalis*.
- Seagrass species composition appears to fluctuate throughout the year, however no long-term trend is apparent.
- No seeds have ever been found at Green Island meadows.

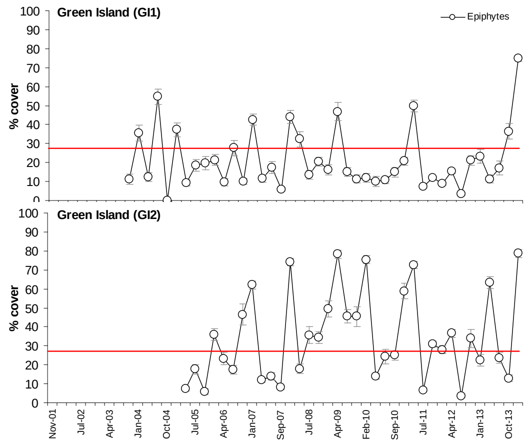


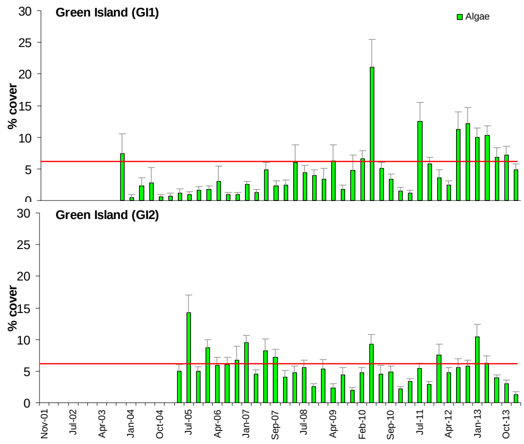


- Seagrass canopy height is generally higher at GI1 than GI2.



- Macro-algae at Green Island is predominately composed of *Halimeda* spp. and abundance generally increases in spring/early summer. Mean abundance is higher at GI1 than GI2, and currently below the GBR long-term average (red line in graphs).
- Epiphyte cover on seagrass leaf blades at Green Island sites has varied greatly over the years, and is currently above the GBR long-term average for reef habitats.

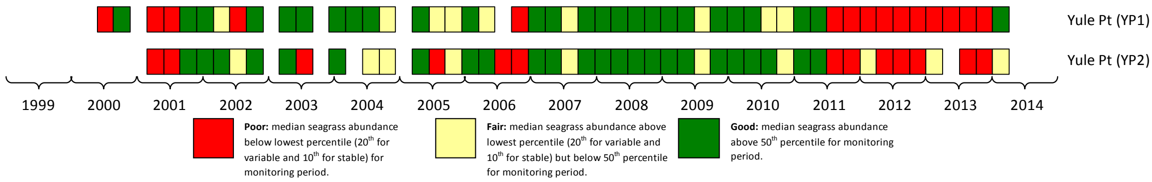




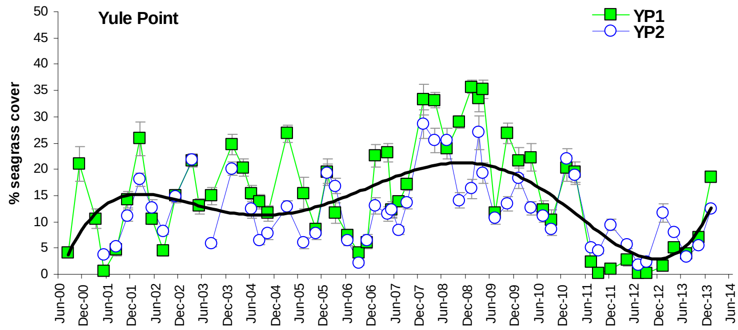
Yule Point

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Occasional and past watchers: Tom Collis
Location: Coastal intertidal sand banks, protected by an extensive fringing reef
Site codes: YP1 YP2
YP1 position: S16.56932 E145.51240 (heading: 50 degrees)
YP2 position: S16.56387 E145.50925 (heading: 50 degrees)
Best tides: <0.8m Port Douglas (Port 59040)
Issues: Storm water & land runoff
Comments: The seagrass meadows at Yule Point are located on naturally dynamic intertidal sand banks. These meadows are dominated by *Halodule uninervis* with some *Halophila ovalis*. A small patch of *Zostera muelleri* ssp. *capricorni* has appeared closer inshore in recent years, however it is outside the monitoring sites. The meadows at Yule Point are often exposed to regular periods of disturbance from wave action and consequent sediment movement. The sediments are relatively unstable restricting seagrass growth and distribution. The meadows are also popular dugong feeding grounds, and grazing trails are abundant.
Status (March 2014):

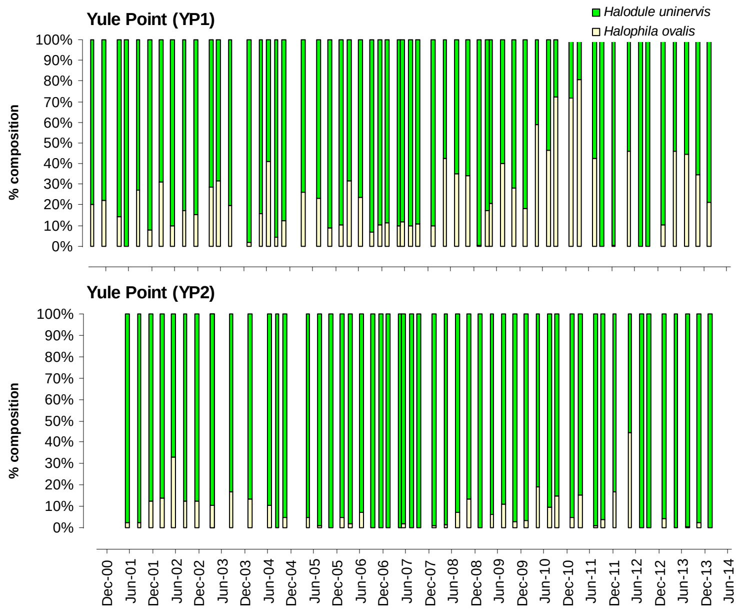
- Seagrass abundance appears to follow typical season pattern (higher in late spring-summer than winter). Sites are dominated by *Halodule uninervis* and *Halophila ovalis*.
- Seagrass abundance relative to the seagrass guidelines indicates that the seagrass meadows at Yule Point are in a **FAIR** state.
- Seagrass abundance has increased over the past 12 months at both sites from the lowest abundances recorded at this location in a decade .
- Figure below shows the seagrass status for each quarterly monitoring event since August 2000.



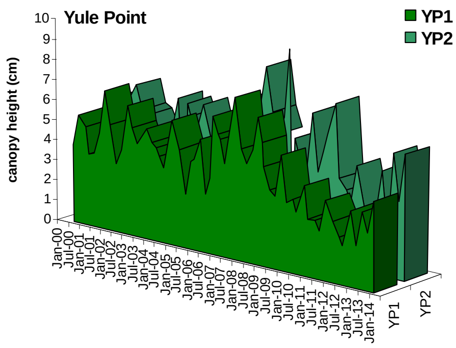
- Although the seagrass abundance and meadow extent has fluctuated over the last decade, sites appear similar to 1967, when den Hartog, 1970 photographed the area and described the species present and sediment condition.



- Sites are dominated by *Halodule uninervis* and *Halophila ovalis*.
- The proportion of *Halophila ovalis* at the YP1 meadow remains high (relative to it's long-term average of 22.5%), indicating higher levels of physical disturbance (e.g., drainage channels) across the site.

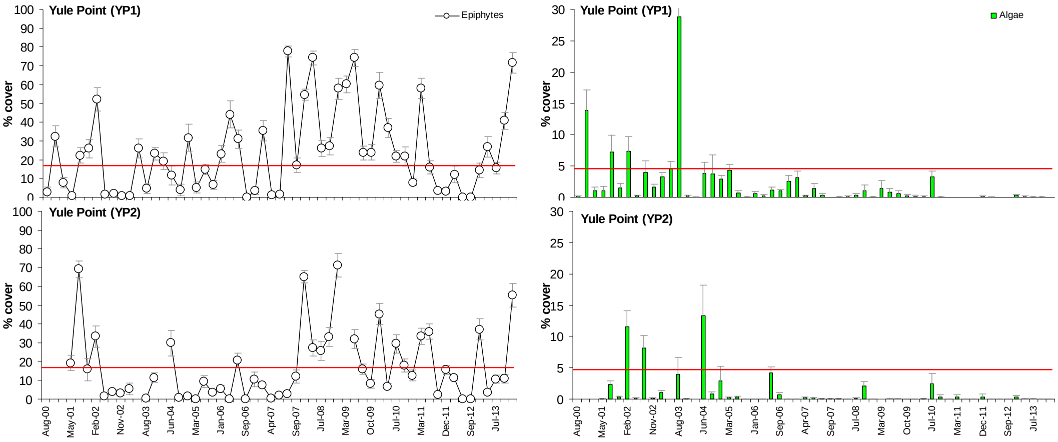


- Seagrass canopy height shows a clear season pattern - correlating with abundance of *Halodule uninervis*.
- Canopy height is slightly higher at YP2 than YP1.



- Epiphyte cover on seagrass leaves has fluctuated greatly over the last decade.

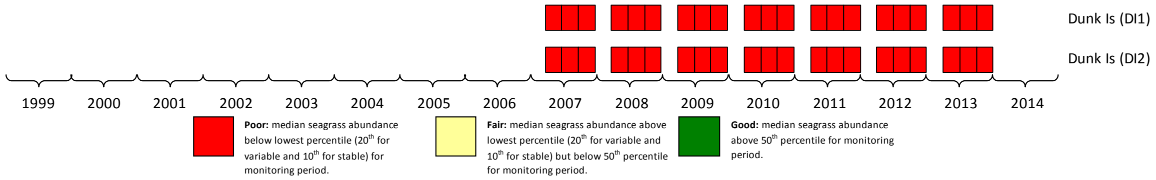
- Epiphyte cover has continued to remain high and above the GBR long-term average at Yule Point over the past 12 months.
- Macroalgae generally increases in spring/early summer, but has remained well below the GBR long-term average for coastal habitats since 2006.



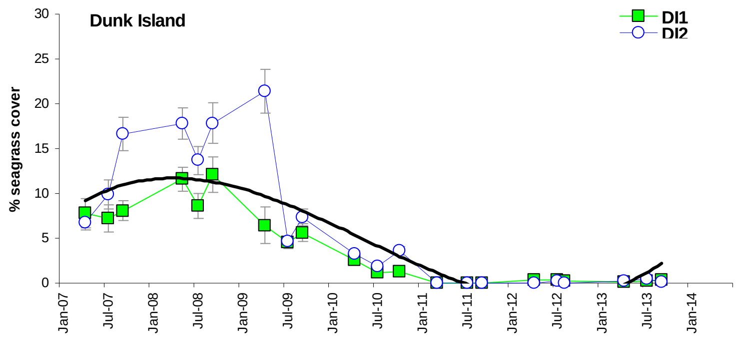
Dunk Island

Monitoring: triennial
Principal watchers: Seagrass-Watch HQ
Location: Monitoring occurs on the large reef-platform on the western side of the island. The sites are located on the intertidal bank between Pallon Beach and Kumboola Island.
Site codes: DI1, DI2
DI1 position: S17.94416 E146.14109 *(heading: 290 degrees)*
DI2 position: S17.94566 E146.14104 *(heading: 290 degrees)*
Best tides: <0.5m Dunk Island *(Port 59170)*
Issues: agricultural runoff from adjacent rivers
Comments: Dunk Island lies 4 km off Mission Beach, Queensland. It is a continental island with a range of hills running almost parallel with the main coastal range. The Family Islands National Park covers 7.3 km² while an airstrip, resort and farm cover the remaining 2.4 km² in the north-west. The Indigenous Australian name for Dunk Island is Coonanglebah, "The island of peace and plenty." It received its European name from Captain Cook in 1770 after George Montague-Dunk, 2nd Earl of Halifax.
Status (Mar11):

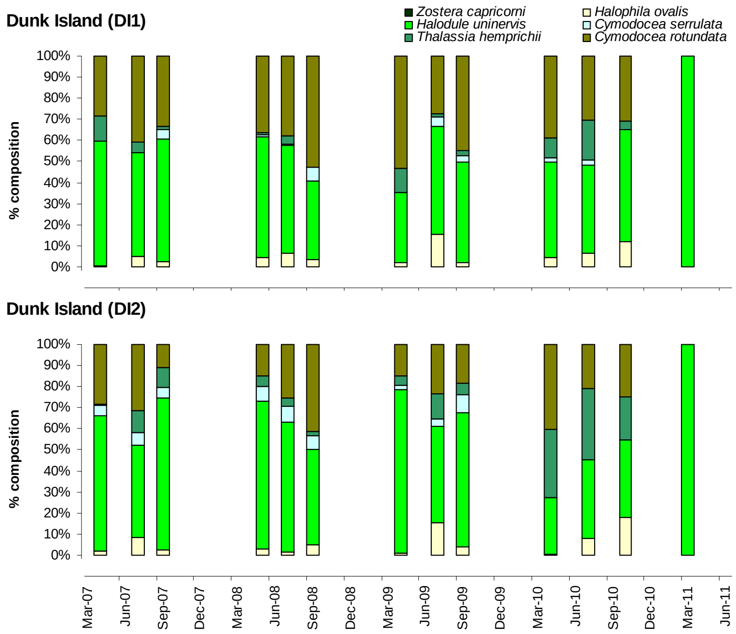
- seagrass abundance at Dunk Island is currently in a **poor state**



- seagrass cover is generally less than 20%, and peaked in late 2008/early 2009. Since mid 2009 abundance significantly declined and has remained low.
- on the 3rd February 2011, severe Tropical Cyclone Yasi (Category 5) passed directly over Dunk Island. Rated as one of the most powerful cyclones to have affected Queensland since records commenced, TC Yasi impacted the island with sustained winds of 205 km/h, gusting up to 285 km/h.
- erosion and sand movement over the intertidal banks from TC Yasi severely impacted the seagrass meadows. Only a few isolated shoots remain.
- prior to TC Yasi, a seasonal trend in abundance was present, with slightly higher abundance in the late dry season (Sep-Nov)



- prior to TC Yasi, Dunk Island sites were dominated by *H. uninervis* and *C. rotundata* with *T. hemprichii/ H. ovalis* and *C. serrulata*.
- post TC Yasi, only isolated shoots of *Halodule uninervis* are present scattered across the intertidal bank or in shallow sheltered pools



- seagrass tissue nutrient concentrations in the late dry 2009, indicated these sites were nutrient poor or reduced P pool
- epiphyte cover was variable and above the GBR long-term average for reef habitats. Macro-algae abundance was relatively stable, with mean covers less than 10%
- pre TC Yasi, the distribution of the meadow at Dunk Island had remained stable since monitoring was established
- post TC Yasi, no distinguishable meadow was present
- reproductive effort is poor and seed banks non existent. This suggests that seagrass meadows will take longer to recover following disturbance and may be at risk from repeated impacts.

Goold Island

Monitoring: annual
Principal watchers: Girringun Rangers, the Cardwell Indigenous Rangers Unit and Seagrass-Watch HQ
Location: the meadow is on the extensive reef flat meadow on the leeward side of the island.
Site codes: GO1
GO1 position: S18 10.437 E146 09.196 *(heading: 300 degrees)*
Best tides: <0.4m Goold Island *(Port 59180)*
Issues: agricultural runoff from adjacent rivers
Comments: Goold Island is a small (8.3km^2) continental island located 17 km offshore from Cardwell. The Island is a national park within the Great Barrier Reef World Heritage Area. The Bandjin and Girramay Aboriginal people are the Traditional Owners of Goold Island (traditionally know as Marrajumban). Traditional use of the island is well established and evidence of early Aboriginal

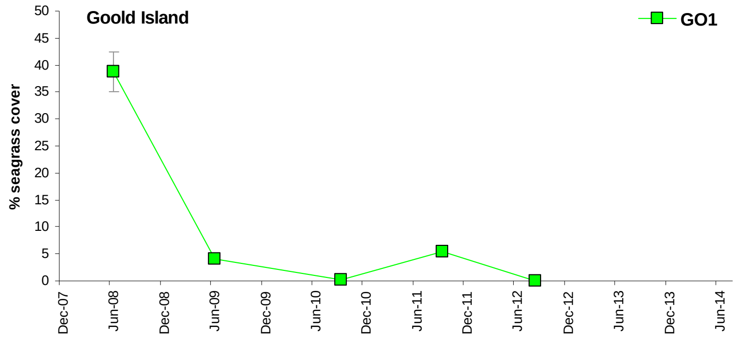
occupation includes the large stone fish trap on the northern end of Western Beach, a large campsite, and some shell middens. As well as the physical evidence of Aboriginal use, Goold Island, in common with many other areas, had cultural and spiritual significance to the Aboriginal people of the area, values which remain today for descendants of the original inhabitants.

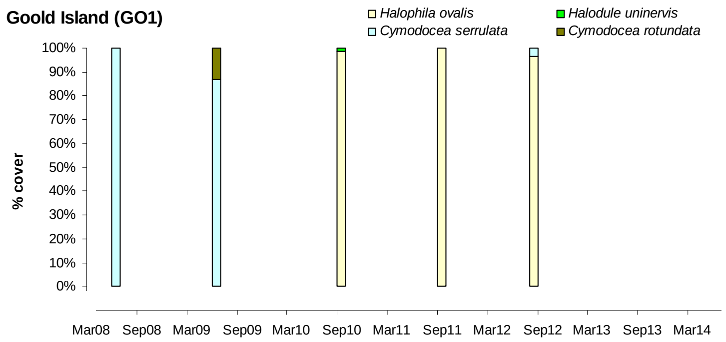
Intertidal seagrass meadows are found on the fringing reef flats on the south western and southern shores of the island. The site is predominantly *Cymodocea serrulata* with some *Halodule uninervis*. *Enhalus acoroides* is also found within the meadow.

The site is being monitored as part of the turtle and dugong monitoring plan for Girringun Sea Country. Girringun traditional owners have also signed a formal agreement (TUMRA) that describes how traditional Owners wish to manage the use of their marine resources in the region. A Traditional Use of Marine Resources Agreement (TUMRA) is accredited by the Great Barrier Reef Marine Park Authority (GBRMPA) and the Department of Environment & Resource Management/Queensland Parks and Wildlife (DERM/QPW). It recognises the special relationship that indigenous groups have with the Sea and its resources in relation to their culture, society, economy and well being. The agreement was developed by the six Girringun sea country groups: Djiru, Gulnay, Girramay, Bandjin, Warragamay and Nywaigi. It applies to the sea country between Rollingstone and Mission Beach and focuses on the sustainable harvest of marine resources using culturally appropriate methods. The sustainability of dugong and turtle populations within this region also relies on the condition and health of their major food source – seagrass.

Status (Sep 12):

- seagrass abundance at Goold Island is currently in a poor state
- In 2008 when the site was established, there was a lush meadow of *Cymodocea serrulata* with some *Halodule uninervis*, and *Enhalus acoroides* with around 45% cover. In 2009 the meadow significantly declined with only isolated *Cymodocea serrulata* shoots remaining.
- In September 2010, the meadow state changed, becoming dominated by the colonising *Halophila ovalis*. The meadow has remained in this state with a recent appearance of a few isolated *Cymodocea serrulata* seedlings.
- Dugong grazing trails have been observed in the meadow over the last 12 months.

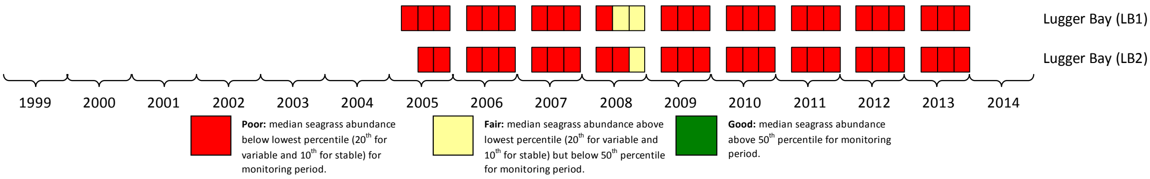




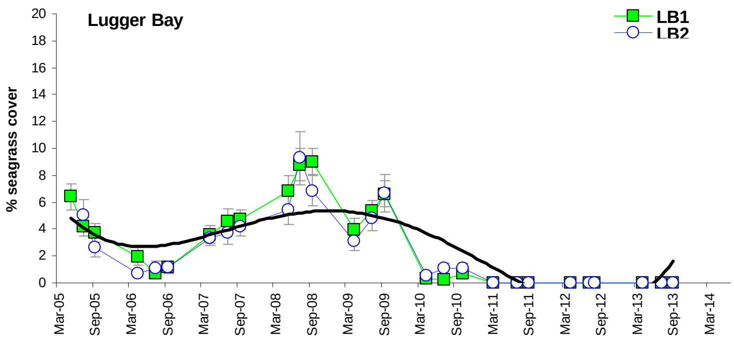
Lugger Bay

Monitoring activity: triennial
Principal watchers: Seagrass-Watch HQ
Location: South Mission Beach, on the northern section of the large intertidal sandbank within Lugger Bay
Site codes: LB1, LB2
LB1 position: S17.96079 E146.09342 *(heading: 50 degrees)*
LB2 position: S17.96124 E146.09353 *(heading: 75 degrees)*
Best tides: <0.4m Dunk Island *(Port 59170)*
Issues: agricultural runoff from adjacent rivers
Comments: Lugger Bay is a coastal habitat and the sites are located on naturally dynamic intertidal sand banks, protected by a fringing reef. 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. The sediments in these locations are relatively unstable restricting seagrass growth and distribution. The meadows are dugong feeding grounds, and grazing trails are often present. Access to Lugger Bay is by just over 1 kilometre walk via the path to Tam O'Shanter Point. The path is popular with hikers and has beautiful views of the sea and Dunk Island.
Status (Mar11):

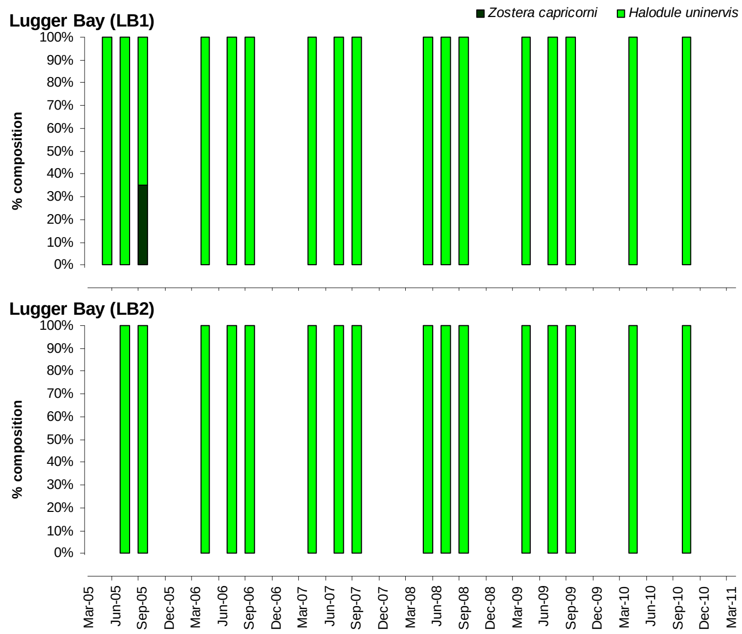
- seagrass abundance at Lugger Bay is currently in a **poor state**



- on the 3rd February 2011, severe Tropical Cyclone Yasi (Category 5) passed directly over South Mission Beach and Lugger Bay. Rated as one of the most powerful cyclones to have affected Queensland since records commenced, TC Yasi impacted the region with sustained winds of 205 km/h, gusting up to 285 km/h.
- erosion and sand movement over the intertidal banks from TC Yasi severely impacted the seagrass meadows. No plants were found within 100m of each site.
- prior to TC Yasi, seagrass cover was generally low (<10%) and similar to observations in the early 90's 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. In April 2008, the seagrass had recovered to 2005 abundances, but has since declined significantly.
- seagrass abundance at Lugger Bay is generally lower in the late monsoon and increases throughout the year until the monsoon



- the sites at Lugger Bay were monospecific *Halodule uninervis* meadows. Although *Zostera capricorni* was present at LB1 in late 2005, it was lost due to the impact of TC Larry in early 2006 and has not re-established.

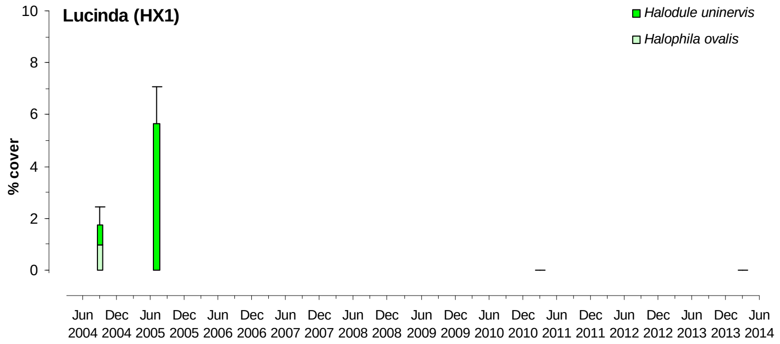


- seagrass tissue nutrients in Lugger Bay indicate a nutrient rich environment where light may be limiting to growth
- the distribution of the seagrass meadow changed little throughout 2009, however significantly declined during the late monsoon and throughout 2010
- no seagrass meadows currently exist in Lugger Bay.
- reproductive effort is poor and seed banks non existent. This suggests that seagrass meadows will take longer to recover following disturbance and may be at risk from repeated impacts.

Lucinda

Monitoring activity: *ad hoc*
Principal watchers: Seagrass-Watch HQ
Location: on the northern section of the large intertidal sandbank adjacent to the jetty
Site code: HX1
HX1 position: S18.52525 E146.34318 *(heading: 0 degrees)*
Best tides: <0.7m Lucinda (offshore) *(Port 59200)*
Issues: agricultural runoff from adjacent rivers
Comments: Historically, the seagrass meadows adjacent to Lucinda township have fluctuated in extent since first mapped in 1987. The loss of seagrass in 2011, a consequence of TC Yasi, and the absence of seagrass plants for at least 3 years suggests either the seed bank (if any) has depleted, that no suitable donor meadows remain in the near vicinity to supply propagules (seeds or vegetative fragments), or that sediment movement across the banks is too excessive for seagrass settlement. To provide insight to whether recovery is possible will require closer investigation to determine the presence of seed banks and a more detailed survey of seagrass meadows in the region (Dunk Island to Cleveland Bay).
Status (Mar14):

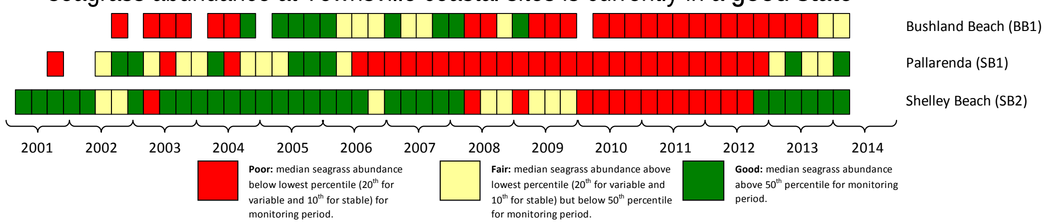
- monitoring site was established within the meadow adjacent to Lucinda township on 26 September 2004
- site composed of the ephemeral species Halophila ovalis and the opportunistic species Halodule uninervis. In July 2005, only H. uninervis was present, suggesting the meadow was stabilising and possibly more enduring in character. However, in 2011 following TC Yasi, seagrass was lost from the site and no seagrass has been found across the entire intertidal banks.

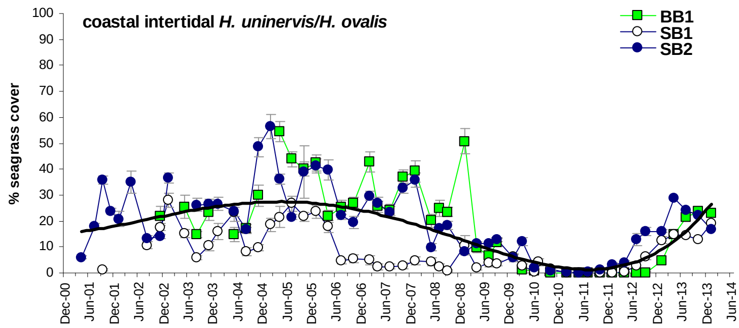


Bushland Beach & Pallarenda

Monitoring: *ongoing*
Principal watchers: Seagrass-Watch HQ
Occasional and past watchers: Jackie Stein, Sharon Taylor, Rose Zahrn, Gary Stein, Lux Foot, Sue Mulvany, Posa Skelton, Sandra Quintemeyer, Angelina, Peter Taylor, Belinda, Linda Davis, Jason Vains, Michelle Waycott, Steve McGuire, Dick Wickenden, Ann Ferguson, Dave Watson, David Reid, Des Wells, Deb Bass, Lyn McAndrew, Mandy Young, Ray Matten, Sally Puet, Barry Bendell
Location: on the large intertidal sand bank in front of the Bushland Beach township, between the Bohle and Black Rivers, and southward to Cape Pallarenda
Site code: BB1, SB1, SB2
BB1 position: S19.18381 E146.68247 (heading 5 degrees)
SB1 position: S19.18626 E146.77102 *(heading 35 degrees)*
SB2 position: S19.18255 E146.76273 *(heading 10 degrees)*
Best tides: <0.7m (port Townsville, 59250)
Issues: Coastal development, land runoff
Comments: The area is a sediment deposition zone, so the meadow must also cope with incursions of sediment carried by long shore drift. The meadows are frequented by dugongs and turtles as witnessed by feeding trails. These meadows are also visited regularly by recreational fishers. 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.
Status (January 2014):

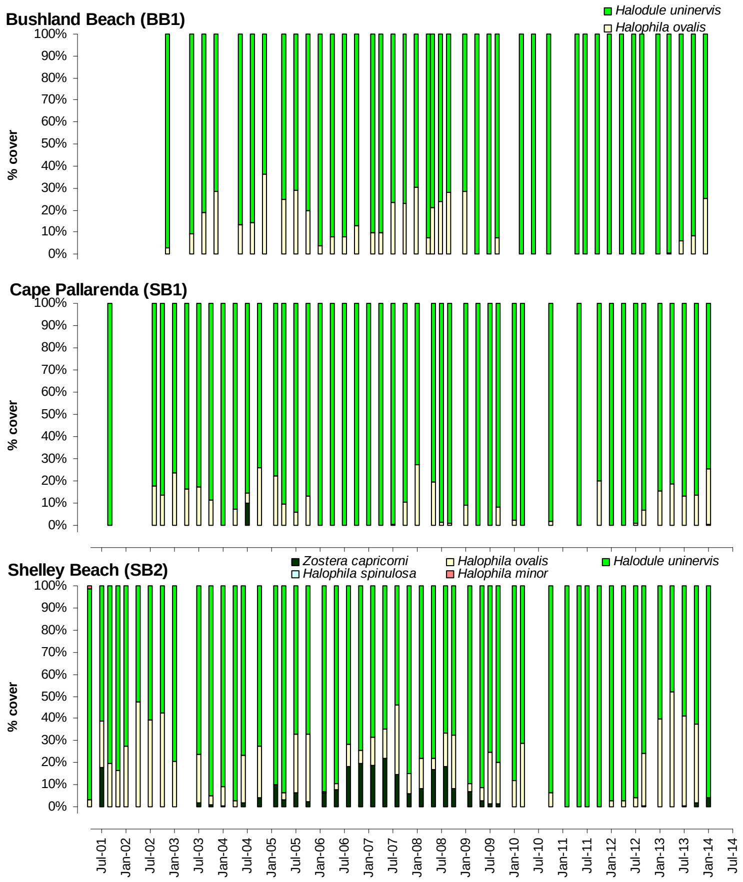
- seagrass cover appears to have recovered from the losses experienced between 2009 - 2012 and is currently similar to when sites were established in 2002
- prior to 2009, abundance appears to follow a typical seasonal pattern (higher in late spring-summer than winter).
- seagrass abundance at Townsville coastal sites is currently in a **good state**



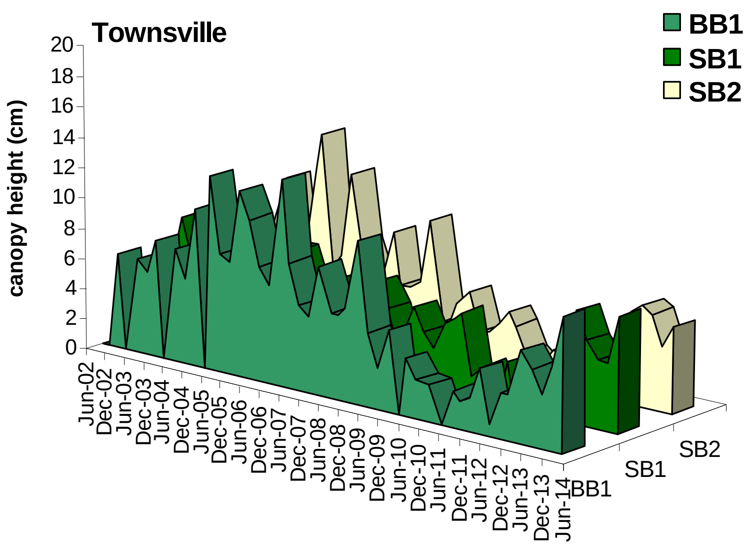


- sites dominated by *Halodule uninervis* with some *Halophila ovalis*. *Zostera muelleri* has started to appear at SB2.

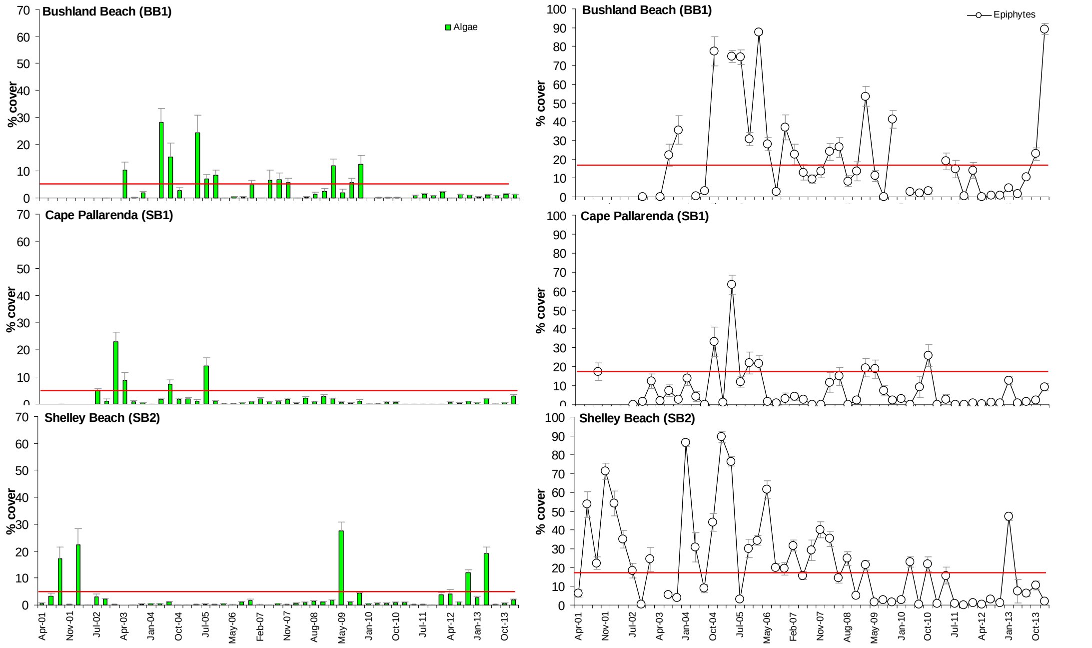
- slight increases in composition of *Halophila ovalis* over previous 6 months may indicate some level of disturbance



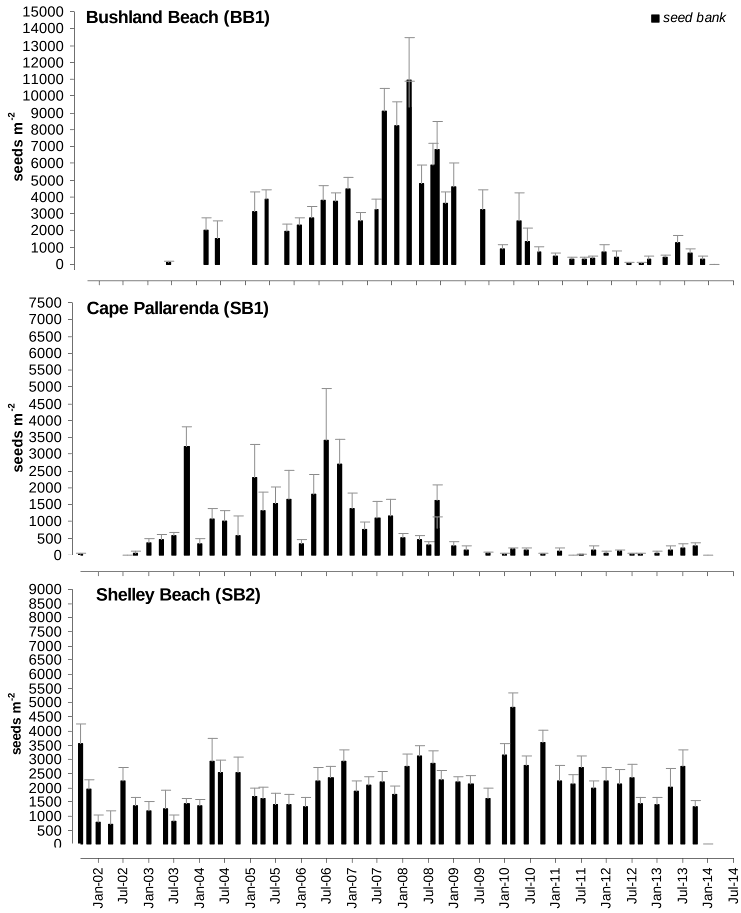
- Canopy height showing a fairly typical seasonal pattern



- macroalgae appears to be generally higher over the summer months, and although more prevalent at SB2 than SB1, it is currently below the GBR long-term average for coastal habitats (red line in figure below).
- epiphyte abundance appears to reflect a similar seasonal pattern at both sites, and although slightly increased over last 12 months, remains below the GBR long-term average for coastal habitats (red line in figure below).



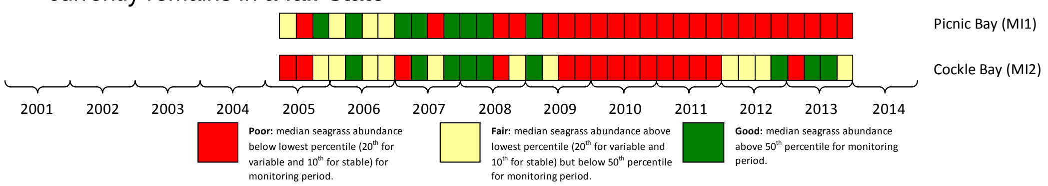
- *Halodule* seed banks currently small at BB1 relative to the peaks experienced in 2007. A large seed bank persists at SB2, and the relatively smaller seed bank at SB1 increased slightly over the last 12 months.

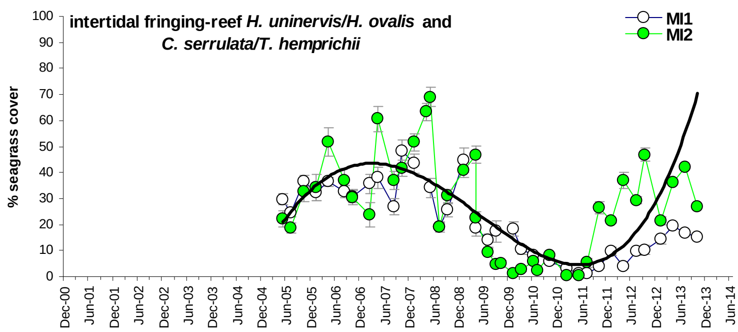


Magnetic Island

Monitoring: *ongoing*
Principal watchers: Seagrass-Watch HQ
Occasional and past watchers: Rhonda Stevens, Karen Landt, Michelle Waycott, Hannah Laurie, Don Kinsey, Barbara Kinsey, University of the Third Age, Linda Davis, Sue Mulvaney, David Reid, Catherine Walsh, Elena Peirano, Michelle Waycott, Carla Wegscheidl, Ainsley Calladine
Location: Magnetic Island, just offshore from Townsville, in Cleveland Bay is a 52 km² mountainous island which has effectively become a suburb of Townsville having well over 2000 permanent residents. Sites are located on the intertidal fringing reef flat in the north of Picnic Bay, adjacent to the wreck, and on the fringing reef flat in the eastern corner of Cockle Bay, adjacent to the excavated boat harbour.
Site codes: MI1, MI2
MI1 position: S19.17898 E146.84126 *(heading 154 degrees)*
MI2 position: S19.17686 E146.82895 *(heading 205 degrees)*
Best tides: <0.7m *(port Townsville, 59250)*
Issues: Coastal development, ground-water seepage, boat and pedestrian traffic, runoff from quarry and hobby farm activities. Sea turtle feeding area.
Comments: Picnic Bay is fringed by coral reefs on its seaward edge and has seagrass growing on its intertidal flat and subtidally, beyond the reef crest. Hermit crabs, sesarmid crabs, Astropecten starfish are quite abundant within the site with the occasional dugong feeding trail. Cockle Bay has been extensively studied over the years and was the location of a ten year seagrass survey along two permanent transects conducted post being decimated by cyclone Althea in 1971. This historical survey documented the different recovery rates of the individual species, with some species re-colonising the area only to be out-competed by other species in subsequent years (Birch and Birch 1984). Birch and Birch's (1984) study showed that after ten years of recovery this seagrass meadow was replaced by the coralline algae *Halimeda opuntia*.
Status (October 2013):

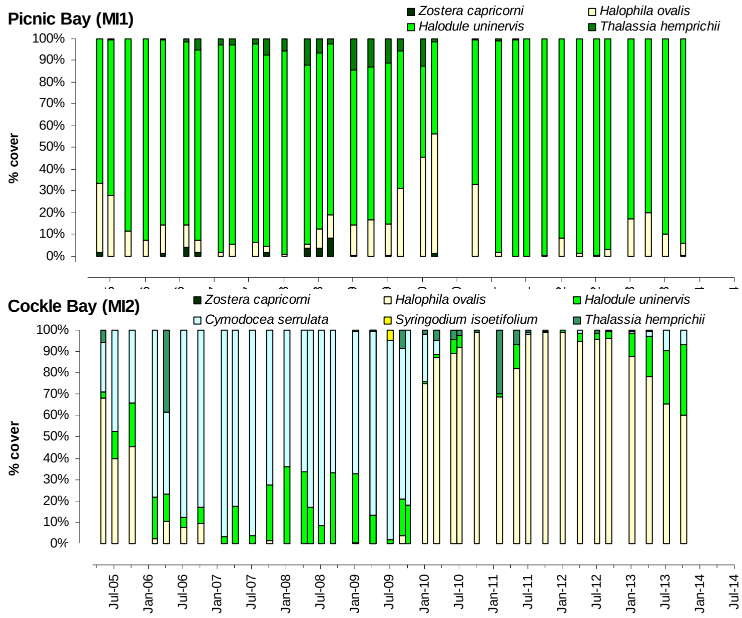
- prior to 2009, abundance appeared to follow a typical seasonal pattern (higher in late spring-summer than winter).
- seagrass cover continues to recover from the losses experienced between 2009 - 2012, but currently remains in a **fair state**



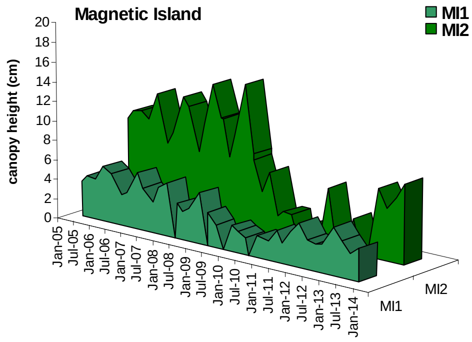


- sites dominated by *Halodule uninervis* with some *Halophila ovalis*.
- Picnic Bay meadows are multispecific with stands of *Cymodocea serrulata* with *Thalassia hemprichii, Halophila ovalis* (lower intertidal, subtidal), *Halodule uninervis* (wide) (middle intertidal) and *Halophila ovalis/Halodule uninervis* (narrow) occupying the upper intertidal region. Patches of *Syringodium isoetifolium* (shallow subtidal) and *Zostera capricorni* (intertidal) have also been observed within this meadow. *Cymodocea rotundata* has also been previously recorded from this meadow. Within MI1 *Halodule uninervis*(narrow) /*Halophila ovalis* are present with some *Zostera capricorni*.
- The seagrasses at Cockle bay form an extensive, multi-specific, fringing reef flat meadow. Species found within this meadow include *Halophila ovalis, Halodule uninervis*, (narrow and wide leaved

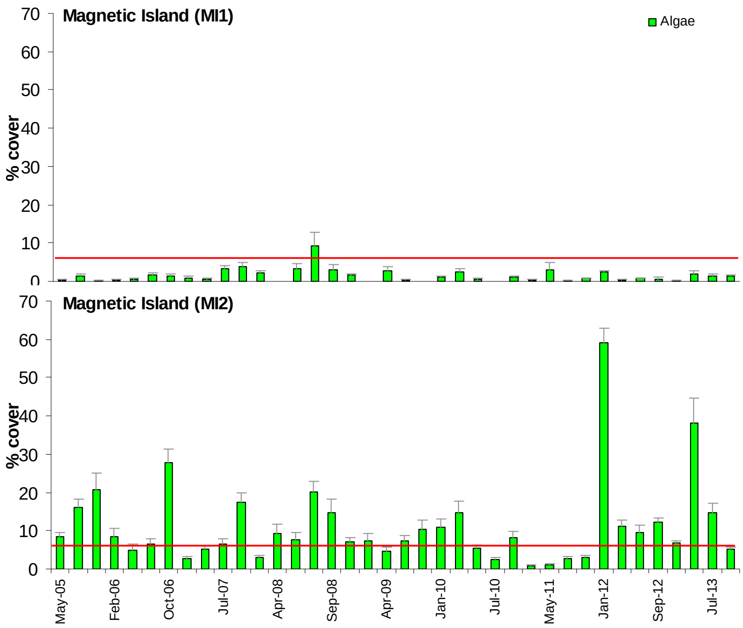
morphologies) *Cymodocea serrulata, Thalassia hemprichii* and, recently, a patch of *Syringodium isoetifolium* has been observed. Until recently, meadows dominated by colonising species (*Halophila ovalis*), but foundational species started to appear in 2013.



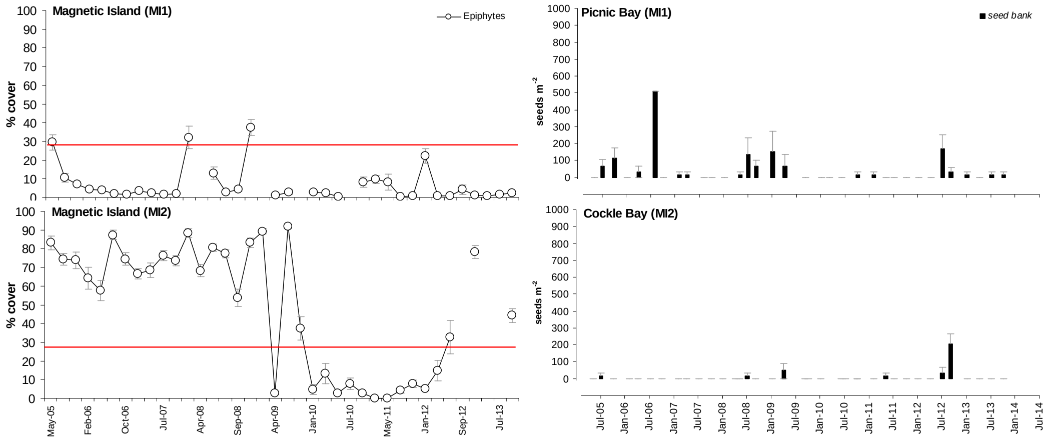
- canopy height showing a fairly typical seasonal pattern, and is taller at Cockle Bay (MI2) than Picnic Bay (MI1)



- macroalgae cover at Picnic Bay (MI1) remained low and below GBR long-term average for reef habitats, however macroalgae at Cockle Bay is highly variable (predominately composed of *Halimeda* spp) and abundances generally above GBR long-term average (red line in figure below).

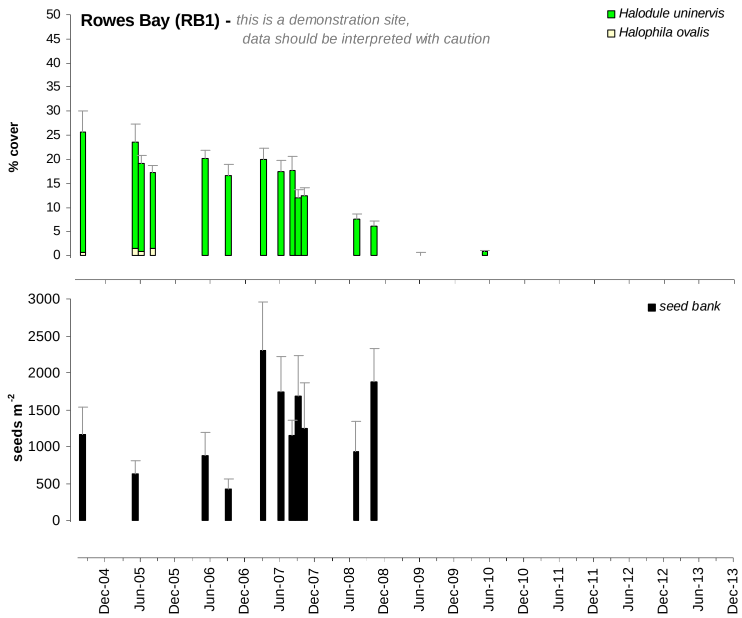


- epiphytes at Picnic Bay (MI1) were low, however at Cockle Bay (MI2) remained high and above the GBR long-term average for reef habitats (red line in figure below).
- A highly variable but small seed banks persists at Picnic Bay, however no seed bank is currently present at Cockle Bay



Rowes Bay

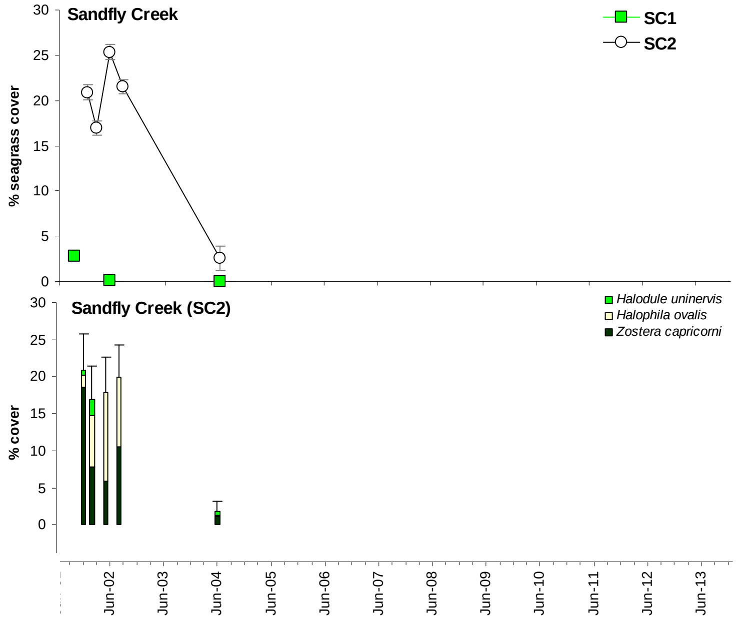
Monitoring: *training/demonstration site*
Occasional & past watchers: Rowes Bay Junior Rangers- Belgian Gardens State School, Gayle Joyce, Brett Murphy, Mundy CreekWatch, Catherine Walsh, Posa Skelton, Seagrass-Watch HQ
Location: Rowes Bay, Townsville
Site code: RB1, RB2
RB1 position: S19.23976 E146.79315 *(heading 30 degrees)*
Best tides: <0.8m *(port Townsville, 59250)*
Issues: Downstream from estuarine creek, storm water and urban runoff, beach replenishment works.
Comments: The intertidal area of Rowes Bay includes several different marine habitats such as a mangrove forest, a rocky shoreline, a small muddy, coarser sandy and several rubbly reefal areas, one of which includes a tropical sponge garden on the seaward edge. Interspersed between and within all these habitats are seagrasses. Over the years this seagrass meadow has come and gone, clearly demonstrating the ephemeral nature of intertidal seagrass meadows. The Seagrass-Watch site is south-east of the estuarine creek and predominantly *Halodule uninervis*, interspersed with small amounts of *Halophila ovalis*. Macroalgae is also quite common within this site. This meadow is a highly disturbed site with regular pedestrian traffic, inputs of freshwater and associated sediment loads. Invertebrate diversity is high.



Sandfly Creek

Monitoring: *suspended*
Principal watchers: Deb Bass, Steve McGuire, Dick Wickenden and Seagrass-Watch HQ
Occasional and past watchers: Dez Wells, David Reid, Ann Ferguson, Jason Jeffery, Nicole Hudson, Sally Peut
Location: Southern shore of Cleveland Bay
Site code: SC1, SC2
SC1 position: S19.29140 E146.86773 *(heading 25 degrees)*
SC2 position: S19.29497 E146.87082 *(heading 35 degrees)*
Best tides: <0.6m *(port Townsville, 59250)*
Issues: Sewage treatment outfall, land runoff, coastal development
Comments: Fishing grounds, dugong and turtle feeding grounds. Nursery area for mud and sand crabs.
Status (June 2004):

- The sites have not been examined since 2004.
- Insufficient data to describe long-term trends, but early data indicated that abundances showed typical seasonal pattern (higher in late spring-summer than winter).
- Seagrass abundance at SC2 significantly decreased since mid-2002. Isolated patches of *Zostera capricorni* were in the vicinity.
- SC1 has always had low seagrass abundance and appears to have remained similar.
- Species composition appears unchanged over sampling period
- Canopy height slightly lower although not significant as highly variable
- Algae and epiphyte currently lower than expected, but not significant as highly variable. The seagrass and mangrove aerial roots were covered in filamentous algae in July 2004, but this seems to be widespread phenomena at this time of year.
- Sediment appears similar, although at present possibly less muddy

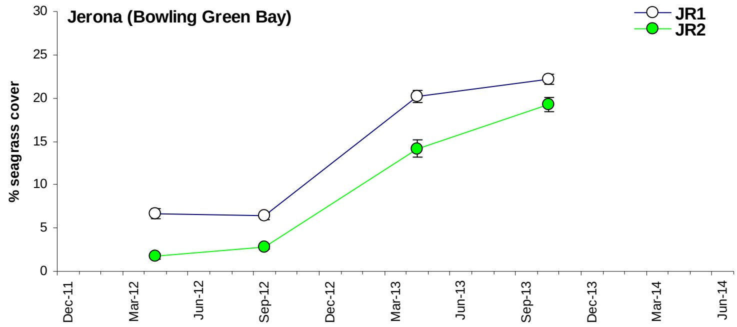


Jerona (Bowling Green Bay)

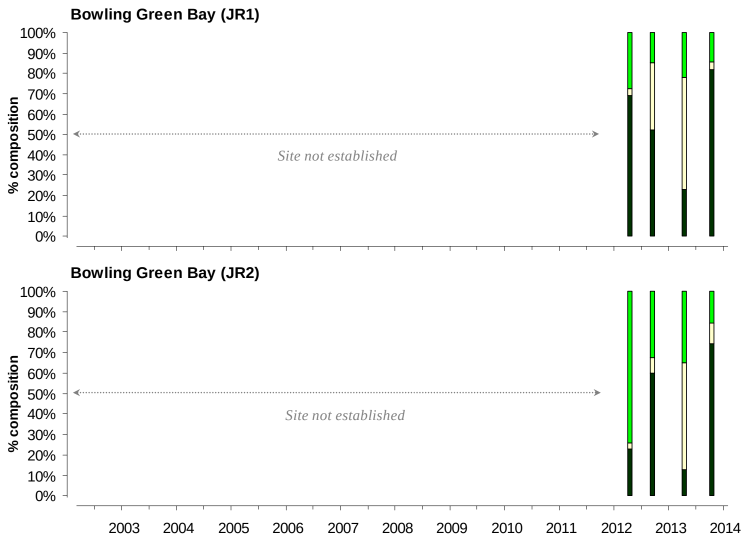
Monitoring activity: *biannual*
Principal watchers: Seagrass-Watch HQ
Location: on the intertidal mud/sand banks on the northern side of Barratta Creek mouth
Site codes: JR1, JR2
JR1 position: S19.42300 E147.24133 *(heading: 40 degrees)*
JR2 position: S19.42135 E147.24041 *(heading: 45 degrees)*
Best tides: <0.7m Cape Ferguson (*Port 59260*)
Issues: agricultural runoff from adjacent rivers
Comments: sites established in early 2012 as part of the Marine Monitoring Program

Status (October 2013):

- seagrass abundance has increased since 2012.
- as only examined biannually, and the meadows have been recovering from losses in 2011, no seasonal trend in abundance is apparent.



- sites dominated by *Zostera muelleri* and *Halodule uninervis*, with *Halophila ovalis*.
- composition of *Zostera muelleri* has increased during meadow recovery

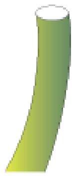


For more information, visit http://www.seagrasswatch.org/

A guide to the identification of Queensland's seagrasses

Adapted from *Waycott et al., 2004.*

Leaves cylindrical



cylindrical

Syringodium isoetifolium

- leaves noodle/spaghetti like and taper to a point
- leaves contain air cavities
- leaves 7-30cm long

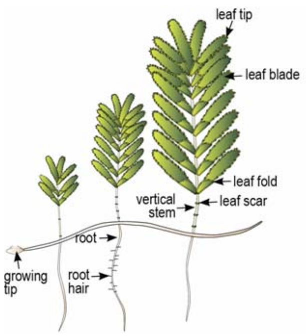
Ruppia maritima

- leaves fine and thread-like,
- leaf tip pointed, sometimes serrated
- leaves up to 15cm long
- rhizome fragile
- inflorescence on a long stalk, sometimes spiralled

Leaves oval to oblong

oval to oblong

obvious vertical stem with more than 2 leaves



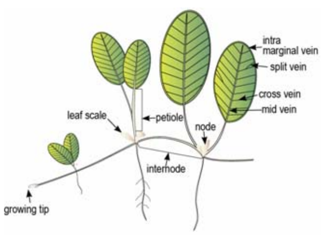
Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated
- 10-20 pairs of leaves per shoot
- leaf 15-20mm long and 3-5mm wide

Halophila tricostata

- leaves arranged in clusters of 3, at a node on vertical stem
- leaf margin sparsely serrated
- leaf clusters do not lie flat
- 5-12 leaf clusters per shoot
- leaf 12-20mm long and 2-4mm wide

leaves with petioles, in pairs



Halophila capricorni

- leaf margins finely serrated
- fine hairs on one side of leaf blade
- leaf 15-30mm long and 5-9 mm wide
- 9-14 cross vein pairs, occasionally forked

Halophila decipiens

- leaf margins finely serrated
- fine hairs on both sides of leaf blade
- leaf apex rounded to slightly pointed
- leaf 10–25mm long and 3–10mm wide
- 6-8 cross vein pairs

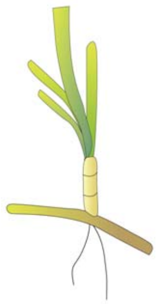
Halophila minor

- less than 8 pairs of cross veins
- leaf 5-15mm long and 3.5-6mm wide
- leaf margins smooth
- no leaf hairs

Halophila ovalis

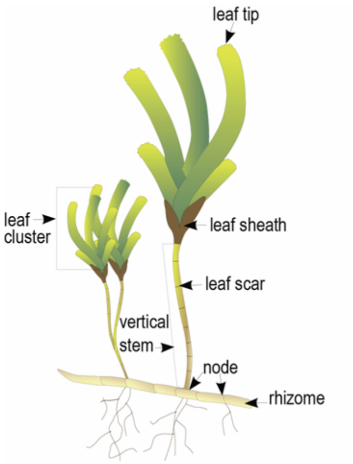
- cross veins 8 or more pairs
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

Leaves strap-like



straplike

Leaves can arise from vertical stem



Cymodocea rotundata

- leaf tip rounded with smooth edge
- leaf 2-4mm wide with 9-15 parallel veins
- leaf sheath scars continuous around stem
- old sheaths forming a fibrous mass at the base of each shoot

Cymodocea serrulata

- leaf tip rounded with serrated edge
- leaf 4-9mm wide with 13-17 parallel veins
- leaf sheath broadly flat and triangular, not fibrous
- leaf sheath scars not continuous around upright stem

Halodule uninervis

- leaf tip tri-dentate or pointed, not rounded
- leaf blades 0.5-5mm wide
- leaf with 3 distinct parallel veins, sheaths fibrous
- rhizome usually white with small black fibres at the nodes

Halodule pinifolia

- leaf tip rounded
- narrow leaf blades 0.25-1.2mm wide
- leaf with 3 distinct parallel veins, sheaths fibrous
- rhizome usually white with small black fibres at the nodes

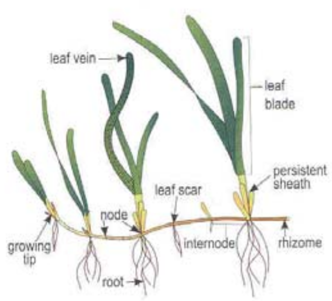
Thalassia hemprichii

- leaf tip rounded, may be slightly serrated
- leaf 4-12mm wide with 9-11 parallel veins
- leaf with obvious red flecks, 1-2mm long
- leaf often distinctly curved
- rhizome thick with distinct scars, usually triangular in shape
- one short root per rhizome node

Thalassodendron ciliatum

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

Leaves always arise directly from rhizome



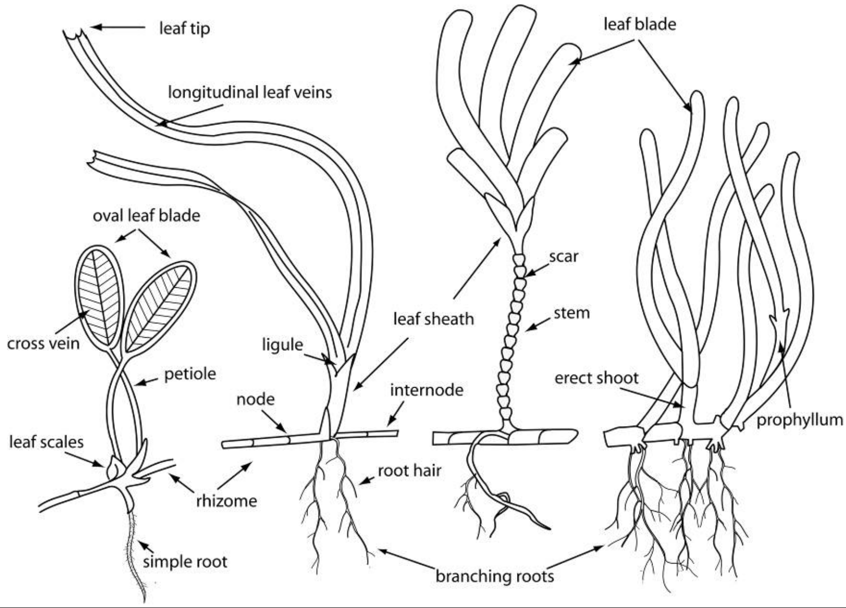
Enhalus acoroides

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

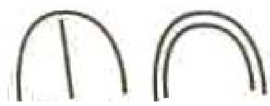
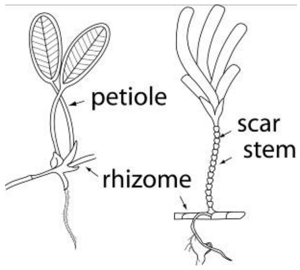
Zostera muelleri subsp. *capricorni*

- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point
- rhizome usually brown or yellow in younger parts
- prophyllum present, i.e. single leaf originating from rhizome instead of from vertical, leaf bearing shoot.

Parts of a seagrass plant

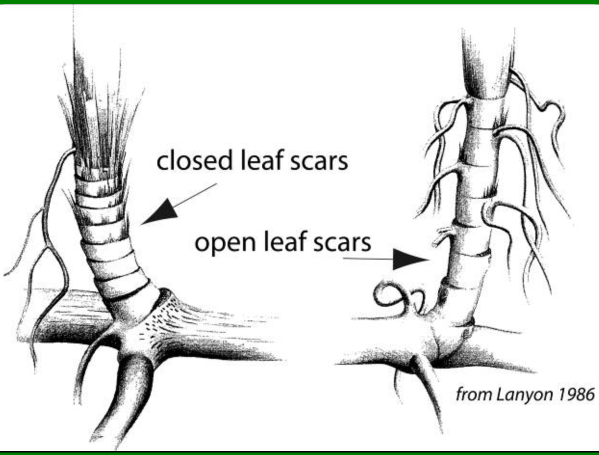


Leaf

Tip	Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.	 *rounded* *pointed*
Veins	Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for Identification. • cross-vein: perpendicular to the length of the leaf • parallel-vein: along the length of the leaf • mid-vein: prominent central vein • intramarginal-vein: around inside edge of leaf	 *cross* *parallel*  *mid* *intramarginal*
Edges	The edges of the leaf can be either serrated, smooth or inrolled	 *serrated* *smooth* *inrolled*
Sheath	A modification of the leaf base that protects the newly developing tissue. The sheath can entirely circle the vertical stem or rhizome (continuous) or not (non-continuous); fully or partly cover the developing leaves and be flattened or rounded. Once the leaf has died, persistent sheaths may remain as fibres or bristles.	 clean & flattened fibrous
Attachment	The leaf can attach directly to the rhizome, where the base of the leaf clasps the rhizome, or from a vertical stem or stalk (petiole) e.g. *Halophila ovalis*.	

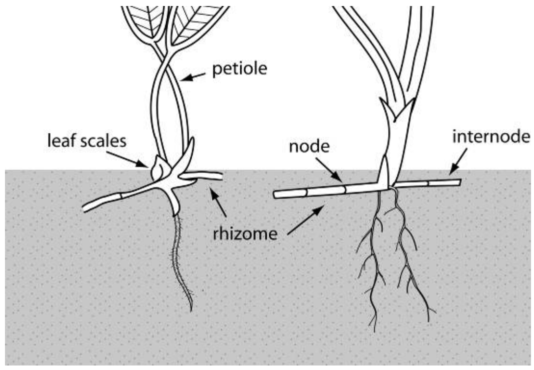
Stem

The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as scars. Scars can be closed (*entirely circle the vertical stem*) or open (*do not entirely circle the vertical stem*).



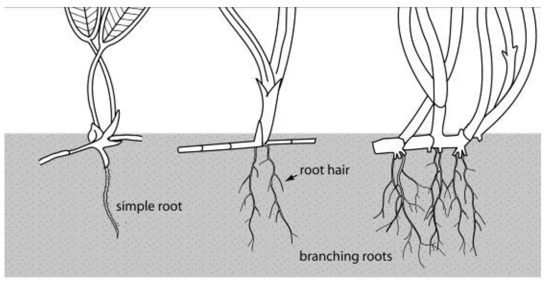
Rhizome

The horizontal axis of the seagrass plant, usually in sediment. It is formed in segments, with leaves or vertical stem arising from the joins of the segments, the nodes. Sections between the nodes are called internodes. Rhizomes can be fragile, thick and starchy or feel almost woody and may have scars where leaves were attached.



Root

Underground tissues that grow from the node, important for nutrient uptake and stabilisation of plants. The size and thickness of roots and presence of root hairs (very fine projections) are used for identification. Some roots are simple or cordlike, others may be branching, depending on seagrass species.



Notes:

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Monitoring a seagrass meadow

Monitoring is the repeated observation of a system, usually to detect change. It is an integrated activity to evaluate the condition of the physical, chemical and biological character of the environment. Environment monitoring programs provide coastal managers with information and assist them to make decisions with greater confidence.

Environmental monitoring programs are ideally designed to: quantify the causes of change; examine and assess acceptable ranges of change for the particular site; and to measure levels of impacts.

Common drivers (reasons) for monitoring include: community interest; government policies such as Coastal Strategies and Plans, Oceans Policy, State of the Environment Reporting (SoE), Water Quality guidelines or Best Practice Guidelines; and Government Legislation (e.g., Fish Habitat Protection).

Users of the monitoring program information/results are diverse, including for example: the general public, environmental regulators - legislators, resource managers and scientists.

There are a number of issues to consider when implementing a monitoring program, including: ensure the protocols used have explicit objectives; clearly identified responsibilities of the partners (e.g. Gov agencies, consultants, community groups); a clear and defensible rationale for using the parameters that are measures (e.g. physico/chemico, biological indicators); to have a baseline (first) assessment / measure against which subsequent changes can be measured/compared; knowledge of spatial and temporal variation prior to designing the program (i.e. pilot study); clearly defined field protocols; data management procedures, ensure the level of change and accuracy of the detection is appropriate (as will vary according to the methodology); selection of statistical tools; and a mechanism to reduce and manage errors (i.e. QA/QC program).

Appropriate Quality Assurance/Quality Control (QA/QC) procedures are an integral component of all aspects of sample collection and analysis in monitoring programs. This includes participation in relevant inter-laboratory studies, proficiency testing, and the use of standard reference materials. Monitoring programs often include the following guidelines for implementation by data collectors and reporters:

- appropriate methods must be in place to ensure consistency in field procedures to produce robust, repeatable and comparable results including consideration of sampling locations, replication and frequency;
- all methods used must be fit for purpose and suited to a range of conditions;
- appropriate accreditation of participating laboratories or provision of standard laboratory protocols to demonstrate that appropriate laboratory QA/QC procedures are in place for sample handling and analysis;
- participation in inter-laboratory performance testing trials and regular exchange of replicate samples between laboratories;
- rigorous procedures to ensure ‘chain of custody’ and tracking of samples;
- appropriate standards and procedures for data management and storage; and
- a process to ensure data collectors are aware of any errors and provide an opportunity to clarify or correct data.

Monitoring seagrass

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. Seagrass make good **bioindicators** of environmental health because they are:

- are widely distributed;
- have an important ecological role;
- are sessile plants which show measurable and timely responses to external stressors/impacts (rather than relocating to a less stressful environment) and;
- are integrative of environmental conditions.

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 affect 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 method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses standardised measurements taken from 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 March 1998 in Australia, Seagrass-Watch has now expanded internationally to more than 26 countries. Monitoring is currently occurring at over 350 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 volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with universities & research institutions, government (local & state), non-government organisations or established local community groups.

Seagrass-Watch integrates with existing scientific programs to raise awareness and 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 methods were developed to be rigorous, yet relatively simple and easy to use. Each of the parameters used have been carefully chosen with a clear and defensible rationale. The protocols used have explicit objectives and the sampling strategy is prepared using baseline and knowledge of spatial and temporal variation. This ensures data is of the highest quality and that time and resources are not wasted. The only condition is that on ground data collection must be overseen by a qualified scientist or trained and competent participant (18 years or over). After 6–9 hours of training, participants can produce reliable data. Training includes both formal and informal approaches. Formal training is conducted by Seagrass-Watch HQ for participants 18 years of age and over, and includes formal lectures and on-site assessments with a tired level of certification for competency. Formally trained participants are certified to supervise on-site monitoring and demonstrate (i.e. informally train) monitoring methods. At least a professional scientist or a formally trained volunteer must be present at each monitoring event. Evidence of competency is securely filed at Seagrass-Watch HQ.

Seagrass-Watch has an accepted Quality Assurance-Quality Control program in place to ensure that the program is producing data of high quality, and that time and resources are not wasted. Seagrass-Watch HQ has systems in place to manage the way Seagrass-Watch data is collected, organised, documented, evaluated and secured. The Seagrass-Watch program collects and collates all data in a standard format. By using simple and easy methods, Seagrass Watch ensures completeness (the comparison between the amounts of valid or useable data originally planned to collect, versus how much was collected). Standard seagrass cover **calibration sheets** are used to ensure precision (the degree of agreement among repeated measurements of the same characteristic at the same place and the same time) and consistency between observers and across sites at monitoring times to ensure percentage covers are close to a true or standardised value.

Other QAQC procedures include the selection of intertidal seagrass sites which are **permanently marked** with either plastic star pickets or an accurate (±3m) GPS waypoint. Labels identifying the sites and contact details for the program are attached to these pickets. Positions of 0 m and 50 m points for all three transects at a site are also noted using GPS. This ensures that the same site is monitored each event and that data can be compared between periods of time.

Ongoing standardisation of observers is achieved by on-site refreshers of standard percentage covers by all observers prior to monitoring and through *ad hoc* comparisons of data returned from duplicate surveys (e.g. either a site or a transect will be repeated by Seagrass-Watch HQ – preferably the next day and unknown to volunteers). Any discrepancy in these duplicates is used to identify and subsequently mitigate bias. For the most part, uncertainties in percentage cover or species identification are mitigated in the field via direct communication (as at least one experienced/certified observer is always present), or the collection of voucher specimens (to be checked under microscope and pressed in herbarium) and the use of a digital camera to record images (protocol requires at least 27% of quadrats are photographed) for later identification and discussion.

Seagrass-Watch HQ has implemented a quality assurance management system to ensure that data collected is organised and stored and able to be used easily. All data (datasheets and photographs) received are entered onto a relational database on a secure server. Receipt of all original data hardcopies is documented and filed within the James Cook University Management System, a formally organised and secure system. Seagrass-Watch HQ operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for reporting purposes. Access to the IT system and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

Seagrass-Watch HQ checks all data for completeness, consistency and accuracy. All data submitted to Seagrass-Watch HQ it is first checked for compliancy:

- *legible original datasheets,*
- *good quality quadrat photographs (high resolution),*
- *voucher specimens (if required) and*
- *completed MS Excel spreadsheet.*

Validation is provided by checking observations against photographic records to ensure consistency of observers and by identification of voucher specimens submitted. In accordance with QA/QC protocols, Seagrass-Watch HQ advises observers via an official **Data Notification** of any errors encountered/identified and provides an opportunity for correction/clarification (this may include additional training).

Once Seagrass-Watch HQ has completed all checks, a field in the Master database identifies data as either passed, quarantined, non-compliant or not-passed. Non-compliant data is used for large-scale summary reporting only if the data quality is deemed acceptable, i.e. if it was collected by a scientist or formally trained participant, that the scans/copies of datasheets are OK (*only if originals are not available*), and/or that the quadrat images were acceptable to complete QAQC, *etc*. If data quality is unacceptable, the data is either not entered into the Master database or remains quarantined/not-passed (excluded from analysis & reporting). If predominantly non-compliant data is used for detailed analysis and reporting at a site or location/region, it is marked on the outputs with a notice of non-compliancy (e.g., site graphs). If officially requested data is non-compliant, a note in the metadata advises of non-compliancy and includes a caveat to "use with caution". Any data considered unsuitable (e.g. nil response to data notification within thirty days) is quarantined or removed from the database.

Seagrass-Watch employs a proactive approach to monitoring, involving ongoing training for observers and the continued development of new methods and refinement of existing methods, including location/habitat specific calibration sheets, operation & validation of autonomous temperature and light loggers, *etc*. Quality data reassures the data users (e.g., coastal management agencies) that they can use the data to make informed decisions with confidence.

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.

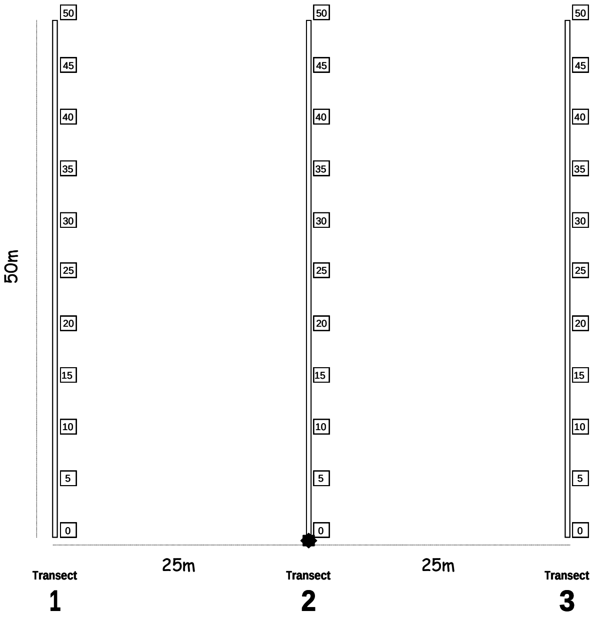
THE GOALS OF THE PROGRAM ARE:

- *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 et al., 2003 (www.seagrasswatch.org/manuals.html)

Site layout



Quadrat code = site + transect+quadrat

e.g., CJ1225 = Chek Jawa. 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 participants 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.
- 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*

Each sampling event

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 taken of every quadrat (or at 5m, 25m and 45m if film is limited) along each transect. Use a quadrat free of strings and 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 (whole numbers - never use < or > symbols) any features which may be of interest (e.g. gastropods, hermit crabs, evidence of dugong or turtle feeding, bioturbation, sediment ripples) within the comments column.
- If water covers half or more of the quadrat, measure depth in cm.

Step 4. Estimate seagrass percent cover

- Looking down on the quadrat from above, estimate the total percentage of the seabed (substrate) within the quadrat covered by seagrass. Estimate the footprint/shadow provided by the seagrass shoots.
- Always use the percent cover photo standards (calibration sheets) as your guide, estimating cover as accurate as possible, e.g. 27%, 61%
- If cover is below 3%, you can count the seagrass shoots and calculate percent cover using the rule of 1 shoot = 0.1%. Please note: this will be greater for shoots of larger sized species.

Step 5. Estimate seagrass species composition

- Identify the species of seagrass within the quadrat and determine the percent contribution of each species (starting with least abundant, total composition must equal 100%)
- Use seagrass species identification keys provided and use more than 1 feature to identify each species

Step 6. Measure seagrass canopy height

- Measure canopy height (in centimetres) of the dominant strap-leaf species, ignoring the tallest 20%.
- Measure from the sediment to the leaf tip of 3 shoots, entering all 3 measures onto datasheet

Step 7. Estimate algae percent cover

- Looking down on the quadrat from above, estimate the total percentage of the seabed (substrate) within the quadrat covered by macroalgae (independent of seagrass cover)
- Macroalgae is not attached to seagrass leaves and may be attached to rocks, shells or may be drift

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 an average seagrass leaf surface is covered, and then how many of the leaves in the quadrat are covered. For example, if 20% of the blades are each 50% covered by epiphytes, then quadrat epiphyte cover is 10%. Use the epiphyte matrix to assist you.
- Do not include epifauna with epiphytes. Epifauna are sessile animals attached to seagrass blades – record % cover of epifauna in the comments or an unused/blank column – do not add to epiphyte cover.

Step 9. Take a voucher seagrass specimen if required

- Place seagrass samples in a labelled plastic bag with a little seawater and a waterproof label. Select a representative specimen of the species and ensure that you have all the plant parts including the rhizomes and roots. Collect plants with fruits and flowers structures if possible.

Step 10. Move to next quadrat

- Repeat steps 1 to 8 for the remaining 32 quadrats

Step 11. At completion of monitoring

- Check data sheets are filled in fully.
- Remove equipment from site (e.g. non-permanent pegs)

At completion of monitoring

Step 1. Wash & pack gear

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

Step 2. 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.
- Allow to dry the press in a dry/warm/dark place for a minimum of two weeks. For best results, replace the newspaper after 2-3 days.

Step 3. Submit all data

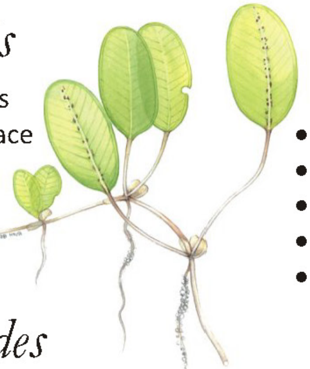
- Data can be entered into the MS-Excel file downloadable from www.seagrasswatch.org. Email completed files to hq@seagrasswatch.org
- Mail original datasheets, photos and herbarium sheets

Seagrass-Watch HQ
TropWATER (James Cook University)
PO Box 6811
Cairns QLD 4870 AUSTRALIA

SEAGRASS SPECIES CODES

Ho
Halophila ovalis

- 8 or more cross veins
- no hairs on leaf surface
- leaf margins smooth
- leaf 5-20mm long



Hd
Halophila decipiens

- small oval leaf blade
- leaf hairs on both sides
- 6-8 cross veins
- leaf 1-2.5cm long
- found at subtidal depths

Ea
Enhalus acoroides

- very long (>30cm) ribbon-like leaves with inrolled leaf margins
- thick rhizome with long black bristles and cord-like roots

Th
Thalassia hemprichii

- ribbon-like, curved leaves 10-40cm long
- leaf tip rounded, slightly serrated
- short black tannin cells, 1-2mm long, in leaf blade
- thick rhizome with scars between shoots

Hs
Halophila spinulosa

- fern like
- leaves arranged in opposite pairs
- erect shoot to 15cm long
- found at subtidal depths

Hu
Halodule uninervis

- trident leaf tip
- 1 central vein
- usually pale rhizome, with clean black leaf scars

Cs
Cymodocea serrulata

- serrated leaf tip
- wide leaf blade (5-9mm wide)
- leaves 6-15cm long
- 13-17 longitudinal veins
- robust/strong rhizome

Cr
Cymodocea rotundata

- rounded leaf tip
- narrow leaf blade (2-4mm wide)
- leaves 7-15 cm long
- 9-15 longitudinal veins
- well developed leaf sheath

Zc
Zostera muelleri subsp. *capricorni*

- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- leaf grows directly from rhizome ie no stem
- rhizome usually brown or yellow in younger parts

Si
Syringodium isoetifolium

- narrow spaghetti-like leaves
- cylindrical in cross section, 1-2mm diameter
- leaves contain air cavities
- leaf tip tapers to a point
- leaves 7-30cm long
- fleshy white rhizomes

SEAGRASS-WATCH MONITORING

ONE OF THESE SHEETS IS TO BE FILLED OUT FOR EACH TRANSECT YOU SURVEY

Seagrass-Watch

OBSERVER: Bev Citizen **DATE:** 17 / 2 / 09
LOCATION: Burrum Heads
SITE code: BH1 **TRANSECT no.:** 2
START TIME: 1304 **END TIME:** 1340

START of transect (GPS reading)
Latitude: 25° ∘ 11.2878 , S **Longitude:** 152° ∘ 37.5372 E

Quadrat (metres from transect origin)	Sediment (eg, mud/sand/shell)	Comments (eg 10x gastropods, 4x crab holes, dugong feeding trails, herbarium specimen taken)	📷 (✓)	% Seagrass coverage	% Seagrass species composition: HO	HU	ZC		water	Canopy height (cm)	% Algae cover	% Epi-cover
1 (0m)	Sand	Sc x 3 HC x 1		40	30	70			0	5,4,7	5	33
2 (5m)	S	GAS x 3	✓	33	50	50			0	10,7,8	10	18
3 (10m)	mud/sand	worm x 1		18	70	20	10		0	6,8,5	0	48
4 (15m)	m/s	DFT x 1		0					0	0	17	0
5 (20m)	m/s/shell	HC x 3		36	5	90	5		1cm	9,7,5	12	57
6 (25m)	m/s/sh	—	✓	48	100				1cm	NA.	2	96
7 (30m)	Fine Sand	Turtle cropping		0					1.5cm	0	23	0
8 (35m)	FS	SC x 2		0.7		100			2cm	7,7,7	18	31
9 (40m)	s/m	CH x 3		23	96	4			2cm	2,4,6	6	17
10 (45m)	m	Mud whelk x 2 HC x 1	✓	41	2	95	3		2cm	5.5,6 9	3	21
11 (50m)	m/s			16	3	7	90		2cm	7,6,7	38	6

END of transect (GPS reading)
Latitude: 25° ∘ 11.2656 , S **Longitude:** 152° ∘ 37.5546 E

SC = Sea Cucumber
GAS = gastropod.
DFT = Dugong feeding trail.
HC = Hermit Crab.
CH = Crab Hole.

Making a herbarium press specimen

Herbaria are repositories of preserved and labelled plant specimens, arranged to allow easy access and archival storage. The specimens are typically in the form of herbarium sheets: pressed and dried plants that have been attached to a sheet of heavy paper together with a data label. A herbarium specimen is simple in form and low-tech in preparation, yet it preserves a wealth of valuable information. If properly stored, a herbarium specimen will last for centuries without much deterioration. Specimens document the variation in form and geographical range of species. Herbaria also document valuable historical collections, such as "type specimens", the original specimens on which a plant's Latin name is based. Many herbarium specimens record the existence of plants in habitats now developed and lost.

COLLECTION

Before collecting any seagrass specimens, ensure you have the appropriate permits.

In the field, collect a handful of representative seagrass shoots, including the leaves, rhizomes and roots. Keep in mind that it is not always possible to get a successful classification if you do not have particular parts such as flowers, fruits, seeds and roots, so try to select shoots which have these features. Ideally, collect plants with growing tips (apical meristems) as they contain higher concentrations of DNA which could aid genetic identification in the future.

Specimens should be pressed as soon as possible after collection. If it is more than 2 hours before you press the specimen, then you should refrigerate to prevent any decomposition. Do not refrigerate longer than 2 days, press the sample as soon as possible.

PRESSING

Tools

First you will need some clean white cartridge-type paper (photocopy paper will suffice) and herbarium sheets (if available). You will also need forceps, scissors/scalpel, a dish of clean fresh water and a herbarium press. It is not difficult to build a home-made press, keeping in mind that what must be accomplished is to keep the specimens squeezed between layers of paper (newspapers or blotting paper) until they are totally devoid of the original content of water. The upper and lower parts of the press might be made of heavy cardboard or thick plywood or equivalent material. A more advanced kind of press might be built for an optimal drying of your plants. This press can be made with two wooden boards with screws and nuts placed at each corner: turning the nuts the two boards will come closer pushing together the paper with the plants. This kind of press can be built at home or bought in some art tools stores.

Preparation

Wash the seagrass specimen in clean fresh water and carefully remove any debris, epiphytes or sediment particles.

Arrangement

It is very important that the seagrass specimen be arranged so that you can immediately see all the main characters of that particular species; so do not focus only at the aesthetics of the mounted specimen. It is advisable to arrange specimens before being placed in the press as once dried, plant specimens can easily be broken if handled without care. The best manner to place the plants on the mounting sheets is to align them with the right side of the page (or diagonally if space is required) and to have the heaviest parts and specimens at the bottom. Leaves can be folded in larger specimens if a larger press in not available. It is better to leave an empty space at the borders of the mounting sheets; but you can either arrange your specimens (along with the label) in a regular way from page to page, or stagger the specimens at different positions on each sheet, so that each group of sheets will have a more equally distributed pressure.

Labels

Each specimen must have a label on its own sheet, which should include the taxonomic denomination (*at least family, genus and species*) along with information on the date and place of collection. The name of the collector and of the individual who did the determination should also be added. Use permanent and water resistant ink (black or blue) to write your labels; otherwise a pencil can be used (medium lead). Specimen labels should include:

- species name (*if known)*
- location & site code (*if applicable*)
- date collected
- latitude/longitude
- water depth
- % seagrass cover
- sediment type
- other seagrass species present
- name of collector and who identified the specimen
- comments -*such as presence of flowers/fruits or ecological notes*

Place the label on the lower right hand corner of the paper.

Drying

Place another clean sheet of paper over the specimen and place within several sheets of newspaper. As circulating air is very important to get your specimens dried in a short time, the assemblage of specimen/paper should be placed within two sheets of corrugated cardboard and then into a herbarium press. Corrugated cardboard ensures air can penetrate and speed up the drying process. If no corrugated cardboard is available, keep the filled press size small.

Once in the herbarium press, wind down the screws until tight (*do not over tighten*). If you do not have a press, the specimens can be pressed by putting some heavy object on top, i.e. bricks or large books. It is important that the plants are put under sufficient pressure; otherwise more time will be required to achieve a good desiccation, besides they could be damaged by dampness and moulds.

The press should be exposed to a gentle heat source, avoiding excessive heat that will "cook" the specimens. Sometimes it is possible to use the heat from the sun. In this case the presses should be small. If fire is the heat source, keep the press at a safe distance to prevent fire starting on the press.

Changing the paper is a very important step. In the first three or four days a paper change should take place every day, then you can leave more time between changes. If you neglect the change of paper the plants will take more time to loose their water content, besides they could be damaged if the paper stays wet for a few days. When changing the paper you must keep the specimens intact and ensure the label travels with the specimen. The minimum time required for complete dying ranges from two to four days or more. Once a specimen has become dry and stiff, it can be mounted and placed into the herbarium.

Mounting

Once the specimen is completely dry, you will need to mount it to herbarium sheets if available or a new clean white cartridge-type paper.

There are different ways to mount the specimens to the herbarium sheets, such as strapping, gluing, or pinning. We recommend the strapping method using removable adhesive tape (e.g. Magic Tape). The tape pulls off easily, leaves behind no messy residue, and can be pulled up and moved around. To fix the specimen to the mounting paper, lay small strips of tape across a few sturdy parts of the plant (e.g. either end of rhizome or a stem) at a minimal number of points. This method will allow a certain degree of movement for further examinations, but the specimen will not fall from the mounting paper

HERBARIA

Once the specimen is mounted it can be stored in a dry place or lodged in Herbaria. If you do not have a Herbaria in your region or state (usually located at a University or Government agency), you can submit specimens to Seagrass-Watch HQ which maintains a Herbaria as part of the Australian Tropical Herbarium.

Alternatively, you can email a scanned image of the pressed specimen. Please ensure that the scanned image is no less then 600 dpi and includes the specimen and label. Scanned images can be sent to hq@seagrasswatch.org and will be lodged in the Seagrass-Watch Virtual Herbarium http://www.seagrasswatch.org/herbarium.html.

The Virtual Herbarium is an electronic gateway to the collections of the Seagrass-Watch HQ herbaria. The goals of the Virtual Herbarium are to make specimen data available electronically for use in biodiversity research projects; to reduce transport of actual specimens for projects where digital representations will suffice for study; and to provide a source of reference information for Seagrass-Watch participants.

Understanding sediment

Seagrasses, especially structurally large species, affect coastal and reef water quality by trapping sediments and acting as a buffer between catchment inputs and reef communities. Seagrass meadows have the ability to modify the energy regimes of their environments, and help stabilise sediment by trapping and binding the sediment. However, the trapping ability of seagrass is in reality an equilibrium established between deposition/sedimentation and erosion/resuspension.

Studies have shown that sediment characteristics are important in determining seagrass growth, germination, survival, and distribution. As part of Seagrass-Watch, field descriptions of sediment type collected 0-2 cm below the sediment/water interface are determined by visual and tactile inspection of (wet) samples and constituents (primary descriptors) differentiated according to the Udden – Wentworth grade scale.

Grain size classes used, based on the Udden – Wentworth grade scale Wentworth, 1922.

Mud	Fine-medium Clay	0 – 0.002 mm
	Coarse Clay	0.0021 – 0.004 mm
	Very Fine Silt	0.0041– 0.008 mm
	Fine Silt	0.0081 – 0.016 mm
	Medium Silt	0.0161 – 0.031 mm
	Coarse Silt	0.0311 – 0.063 mm
Sand	Very Fine Sand	0.0631 – 0.125 mm
	Fine Sand	0.1251 – 0.250 mm
	Medium Sand	0.2501 – 0.500 mm
	Coarse Sand	0.5001 – 1.000 mm
	Very Coarse Sand	1.0001 – 2.000 mm
Gravel	Granules	2.0001 – 4.000 mm
	Pebbles and larger	>4.0001 mm

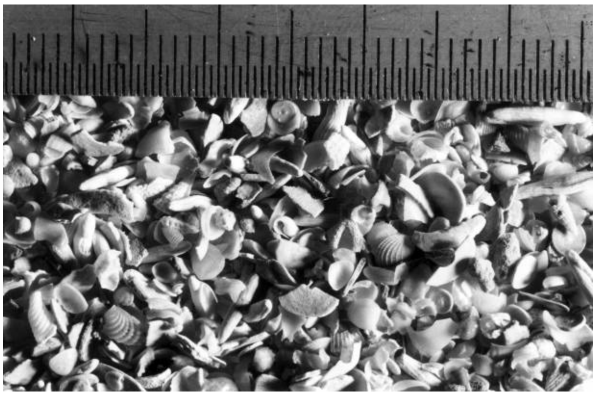
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

The sediment ***Primary Descriptors*** are written down from left to right in decreasing order of abundance: e.g. Mud/Sand is mud with sand, where mud is determined as the dominant constituent (by volume).

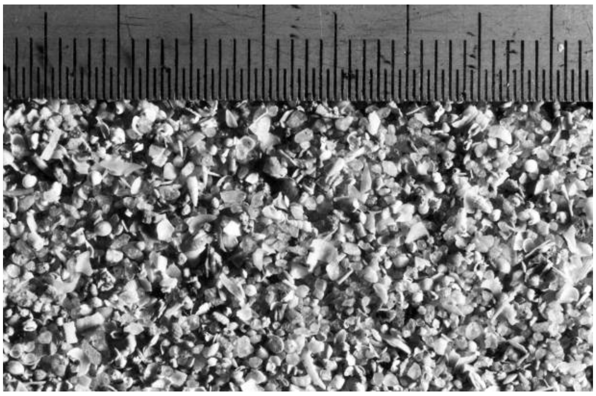
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

Sediment type ***Modifiers*** are also commonly used, however these are recorded in the comments section. Modifiers include: coral, shell grit, forams, diatoms, *etc*.

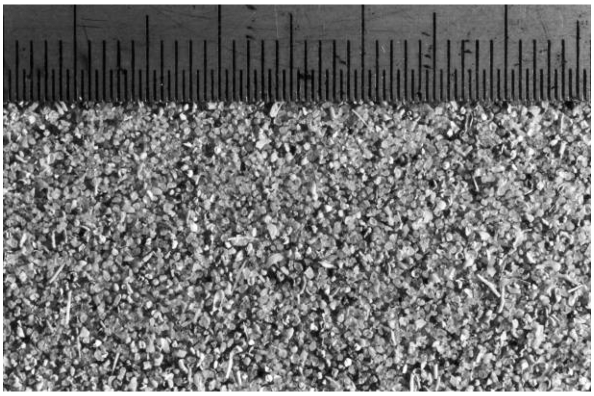
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments McKenzie, 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf.



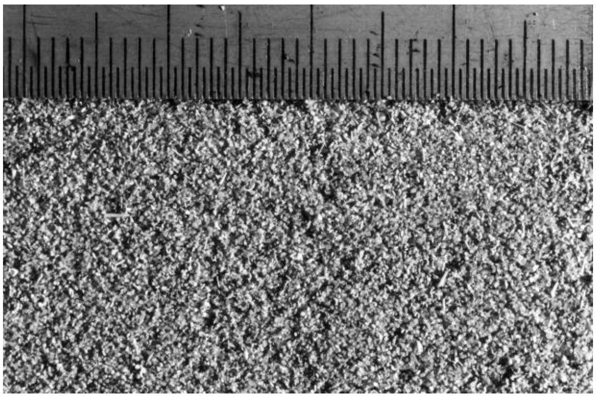
gravel (>2mm)



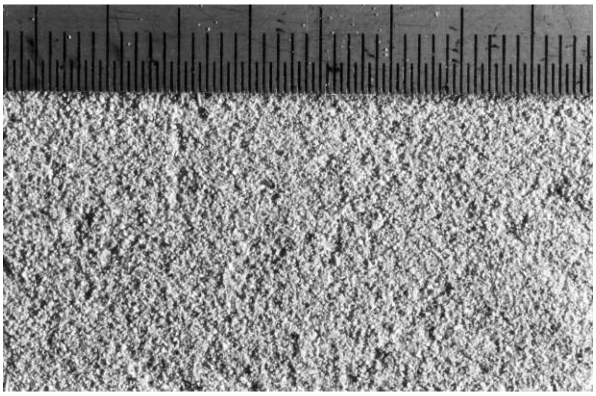
very coarse sand (1 – 2 mm)



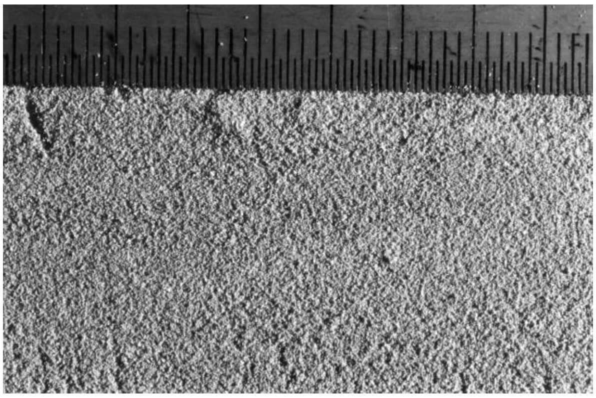
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

Notes:

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.

Methods of direct protection range from legislative instruments and associated legal sanctions through to education Coles and Fortes, 2001. These can be separated into three approaches: a proscriptive legal approach; a non-proscriptive broad based approach ranging from planning processes to education; and a reactive approach designed to respond to a specific issue such as a development proposal. These may overlap and be used simultaneously in many cases. It is these three approaches that Seagrass-Watch supports for the protection/conservation of seagrass.

Reactive (on-ground)

Reactive processes generally occur in response to a perceived operational threat such as a coastal development proposal Coles and Fortes, 2001. Reactive processes can include port contingency planning, risk management plans and environmental impact assessments.

Prescriptive (legal)

Prescriptive management of seagrass issues can range from local laws to a Presidential Decree, or Executive Order. Laws can directly safeguard seagrasses or can protect them indirectly by protecting habitat types (all aquatic vegetation) or by influencing a process, e.g., prevention of pollution Coles and Fortes, 2001.

In some locations, protection is often strongest at the village or community level. This may be by Government supported agreements or through local management marine area level. In these cases successful enforcement is dependent on community support for the measure.

Non-prescriptive (planning & education)

Non-prescriptive methods of protecting seagrasses are usually part of planning processes and may have a strong extension/education focus Coles and Fortes, 2001. Providing information is important as it enables individuals to voluntarily act in ways that reduce impacts to seagrasses. Non-prescriptive methods range from simple explanatory guides to complex industry codes of practice.

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; Gaskell, 2003; Aswani and Weiant, 2004; George et al., 2004; Turnbull, 2004; Middlebrook and Williamson, 2006. 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.

Notes:

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Further reading:

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Useful web links

Seagrass-Watch Official Site www.seagrasswatch.org

Seagrass Adventures Interactive website designed by students from Bentley Park College in Cairns (Australia). Website includes games, puzzles and quizzes for students to learn about seagrass and their importance. crcreef.jcu.edu.au/seagrass/

World Seagrass Association A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses. wsa.seagrassonline.org

Seagrass Outreach Partnership Excellent website on seagrass of Florida. Provides some background information on seagrasses and has a great section with educational products and Seagrass Activity Kit for schools. www.flseagrass.org

Seagrass forum A global forum for the discussion of all aspects of seagrass biology and the ecology of seagrass ecosystems. Because of their complex nature, discussion on all aspects of seagrass ecosystems is encouraged, including: physiology, trophic ecology, taxonomy, pathology, geology and sedimentology, hydrodynamics, transplanting/restoration and human impacts. lists.murdoch.edu.au/mailman/listinfo/seagrass_forum

Reef Guardians and ReefEd Education site of the Great Barrier Reef Marine Park Authority. Includes a great collection of resources about the animals, plants, habitats and features of the Great Barrier Reef. Also includes an on-line encyclopedia, colour images and videos for educational use, a range of free teaching resources and activities. www.reefed.edu.au

Integration and Application Network (IAN) A website by scientists to inspire, manage and produce timely syntheses and assessments on key environmental issues, with a special emphasis on Chesapeake Bay and its watershed. Includes lots of helpful communication products such as fact sheets, posters and a great image library. ian.umces.edu

Reef Base A global database, information system and resource on coral reefs and coastal environments. Also extensive image library and online Geographic Information System (ReefGIS) which allows you to display coral reef and seagrass related data on interactive maps. www.reefbase.org

for more links, visit **www.seagrasswatch.org/links.htm**