Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in South East Queensland

QPWS, Moreton Bay Manly Office
August 2013

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Front cover photos by Len McKenzie (left to right): *Zostera muelleri* ssp *capricorni* adjacent to mangroves, King Island, Wellington Point (26 march 2012); *Cymodocea serrulata*, Wanga Wallen Banks off Amity Point, North Stradbroke Island (18 March 2013); members of Moreton Bay Community Seagrass Monitoring Project monitoring WP3, Wellington Point (24 November 2007).

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Overview

Seagrass-Watch is a participatory monitoring program developed in 1998 to provide an early warning of coastal ecological decline. Anyone can participate in Seagrass-Watch, as it responds to local needs. Program participants include scientists, rangers and volunteers (e.g., local residents, indigenous groups, tertiary institutions, non-government organisations). Seagrass-Watch is a monitoring program that brings people together for seagrass conservation. Participants range in ages from 18 to 68 and represent a diverse cross-section of the community, including tradespeople, engineers, school teachers, fishers, divers, retirees, high school and university students, biologists and ecologists. Many are involved with local environmental groups and have a keen interest in conservation and environmental issues.

Seagrass-Watch is a global scientific, non-destructive, seagrass assessment and monitoring program. It identifies areas important for seagrass species diversity and conservation. The information collected can be used to assist the management of coastal environments and to prevent significant areas and species being lost.

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is sponsored by Wildlife Preservation Society of Queensland – Bayside Branch, BAC (Brisbane Airport Corporation), SEQ Catchments and Seagrass-Watch HQ (TropWATER, James Cook University). Local coordination by Debra Henry (OceanWatch Australia Ltd). As part of the Level 1 workshop we will:

1. *study seagrass biology;*
2. *learn seagrass taxonomy;*
3. *discuss the present knowledge of seagrass ecology, including importance and threats;*
4. *gain knowledge of monitoring;*
5. *learn about the Seagrass-Watch program and techniques for monitoring seagrass resources; and*
6. *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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Sea star in *Cymodocea serrulata* meadow, Wanga Wallen Banks off Amity Point, North Stradbroke Island (18 March 2013)

Workshop leaders

Len McKenzie

Len is a Principal Researcher with TropWATER (James Cook University) and Seagrass-Watch Program Leader. He is also the Task Leader 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 communities 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
- Status and mapping of seagrass resources in Queensland
- Condition, trend and risk in coastal habitats: Seagrass indicators, distribution and thresholds of potential concern
- Identification of indicators and thresholds of concern for water quality and ecosystem health on a bioregional scale for the Great Barrier Reef
- Assessment of primary and secondary productivity of tropical seagrass ecosystems
- Investigations on the macrofauna associated with seagrass meadows
- Great Barrier Reef Water Quality Protection Plan – Reef Rescue Marine Monitoring Program: seagrass

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
- Great Barrier Reef Water Quality Protection Plan – Reef Rescue Marine Monitoring Program: seagrass

Agenda - Level 1 *(basic)*

Saturday 17th August 2013 (QPWS Training Room, Manly Office)

0900 - 0915 *(15min)*	Welcome & Introduction
0915 - 0935 *(20min)*	Seagrass Biology and Identification*
0935 - 1015 *(40min)*	**Classroom activity:** Seagrass Identification
1015 - 1030 *(15min)*	*Break*
1030 - 1130 *(60min)*	Seagrass Identification *continued**
1130 - 1230 *(65min)*	Seagrass Biology 2 and Ecology
1230 - 1315 *(45min)*	*Lunch*
1315 - 1345 *(30min)*	Seagrass importance
1345 – 1430 *(45min)*	Seagrass threats*
1430 – 1445 *(15min)*	Wrap up for day

Sunday 18th August 2013 (QPWS Training Room, Manly Office)

0900 – 0915 *(15min)*	Seagrass monitoring*
0915 - 1015 *(60min)*	Seagrass-Watch: how to sample*
1015 - 1115 *(60min)*	Seagrass-Watch: QAQC & how data is used*
1115 - 1130 *(15min)*	Risk assessment
1130 - 1200 *(30min)*	*Lunch* & relocated to field site
1200 - 1400 *(2hrs)*	**Field exercise:** Seagrass-Watch monitoring Wynnum

What to bring:

- *hat, sunscreen (Slip! Slop! Slap!)*
- *dive booties or old shoes that can get wet*
- *wear long pants, sandflies may be present. But keep clothes light and breatheable*
- *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 and muddy!

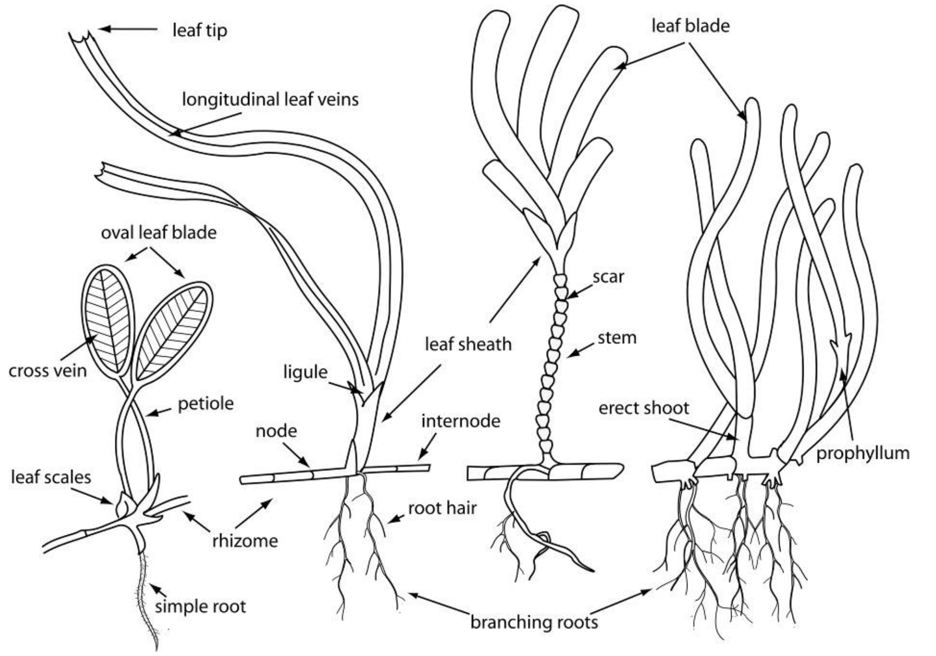
Please remember, seagrass meadows are an important resource. We ask that you use discretion when working/walking on them.

1400 - 1430 *(30min)*	Wrap up

Tides (Brisbane Bar): 1254, 0.3m

Background

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 seagrass 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 among countries. Coastal communities would almost certainly recognise the term "turtle grass" as referring to the shallow subtidal and intertidal seagrasses that turtles are associated with.

Like terrestrial (land living) plants, a seagrass can be divided into its **veins** (lignified conducting tissue that transports food, nutrients and water around the plant), 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.

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**.

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

Seagrass are marine flowering plants

Seagrasses have roots, stems and leaves

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

Leaves of different seagrass species can be shaped like a flattened ribbon, look like a fern, round like a clover, or even spaghetti shaped large thin-walled aerenchyma. The aerenchyma are commonly referred to as veins as they carry water and nutrients throughout the plant (i.e. an internal vascular system). Aerenchyma is specialized tissue having a regular arrangement of air spaces, called lacunae, that both provides buoyancy to the leaves and facilitate gas exchange throughout the plant. Leaves have a very thin cuticle, which allows gas and some nutrient diffusion into them from the surrounding water. 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.

Seagrass have veins and air channels in their leaves and stems so they can carry water, food and absorb gases

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 evolved approximately 100 million years ago from land plants that returned to the sea in a least three separate lineages or families. 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.

Worldwide, there are about 12 major divisions, consisting of approximately 60 species (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.

Seagrasses are not true grasses

Seagrasses are more closely related to lilies

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

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).

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 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.

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea water

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

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 photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

Water temperature influences the rate of growth and the health of seagrass

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

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*).

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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.

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

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 absorptive capacity — and, calcium carbonate binds phosphorus, limiting its bioavailability.

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

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 see 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.

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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.

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

Where are seagrasses found?

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the artic (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.

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

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

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.

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 > Syringodium isoetifolium*. 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.

Valuation of seagrasses

The valuation 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 1994 US$ 19,004 ha^{-1} yr^{-1}.

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 can change due to both natural and human impacts

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 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 decline 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.

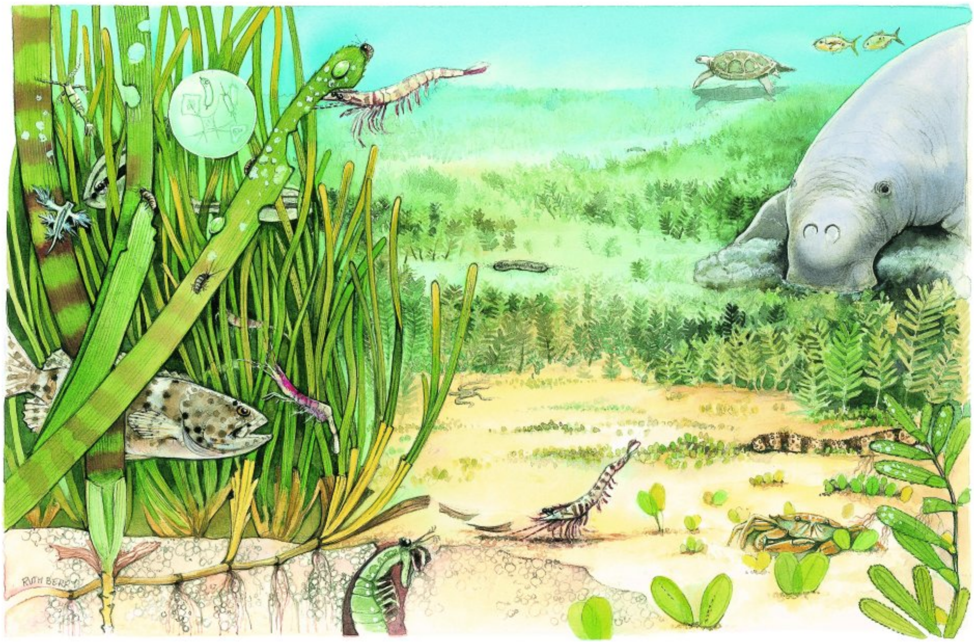
Coastal development can have a major impact on seagrass meadows

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.

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., effecting 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.

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

Please note: citations have been removed for ease of reading. Please see *References* & *Further Reading* for source/citations on scientific facts.



Notes:

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Interesting facts:

Over a billion people live within 50 km of a seagrass meadow. Millions of people obtain their protein from animals that live in seagrasses.

The estimated global coverage of seagrass is between 300,000 and 600,000 square kilometres.

A hectare of seagrass absorbs 1.2 kilograms of nutrients per year, equivalent to the treated effluent from 200 people.

In northern Australia, whole seagrass meadows are able to completely replace their leaves (turnover) in around 14 days during the growing season.

A hectare of seagrass sequesters 830 kilograms of carbon per year, equivalent to the CO_2 emissions from an automobile travelling 3,350 km.

One square metre of seagrass can produce up to 10 litres of oxygen per day

In northern Australia, the primary productivity of seagrass meadows is higher than a mangrove forest, a terrestrial forest or grassland.

Seagrasses occupy only 0.1% of the seafloor, yet are responsible for 12% of the organic carbon buried in the ocean, which helps reduce greenhouse gases.

The only endangered marine plant is a species of seagrass (*Halophila johnsonii* in Florida).

There is a single clone of seagrass that is over 6,000 years old (*Posidonia ocea*nica in the Mediterranean Sea). It is possibly the world's oldest plant!

The deepest growing seagrass (*Halophila decipiens*), 86 metres, was reported from Cargados Carajos Shoals in the Indian Ocean northeast of Mauritius.

Seagrass produce the longest pollen grains on the planet.

Some intertidal species of seagrasses can lose up to 50% per cent of their water content and still survive.

Did you know that Australia has the highest number of seagrass species of any continent in the world?

In Alaska, seagrasses remain frozen and in a dormant state over winter and do not start to grow again until the thaw.

The longest known seagrass 7.3 metres in length has been reported from Funakoshi Bay, Japan.

40,000 seeds of *Halodule uninervis* have been found in 1 square metre of mudflat.

In Florida, 80% of the above ground seagrass biomass is consumed by parrot fish.

The anchor and chain from one cruise boat can destroy an area of seagrass the size of a football field!

Notes:

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Seagrasses in the Moreton Bay region of South East Queensland

Updated from McKenzie and Yoshida, 2007).

The South East Queensland (SEQ)region extends from Noosa in the north to Coolangatta in the south, and includes the Gold Coast region. SEQ is one of Queensland's most important natural, recreational, cultural and economic resources.

Seagrasses are a major component of the SEQ marine ecosystems and their contribution to the total primary carbon production (estimated at 105 tonnes of carbon per day (Queensland Museum, 1998)) is critical to regionally important dugong and turtle populations (Chilvers et al., 2005; Hazel et al., 2009), and productive fisheries (Coles et al., 1993). Coastal meadows are important nursery habitat to juvenile fish and prawns (Williams, 1997; Coles et al., 1993; Blaber, 1980; Beumer et al., 1997; Zeller, 1998; Masel and Smallwood, 2000); the East Coast commercial catch of tiger, endeavour and red spot prawns for 1995 totalling 3,500 tonnes was valued at $50 million and dependent on seagrass meadows (Williams, 1997). Seagrass also provides habitat for migratory wading birds and food for black swans. Extensive seagrass meadows occur both on intertidal mudflats and subtidal areas.

Eight seagrass species occur in the SEQ region (*Cymodocea serrulata, Halophila decipiens, Halophila minor, Halophila ovalis, Halophila spinulosa, Halodule uninervis, Syringodium isoetifolium and Zostera muelleri* ssp. *capricorni* (synonym *Zostera capricorni*)), with *Zostera capricorni* and *Halophila ovalis* the most common, and *Halophila minor* the rarest (Phillips et al., 2008); although *H. minor* taxonomy remains under review (see Waycott et al., 2004).

The first descriptions of seagrass extent in Moreton Bay were by Welsby, 1905), however mapping has only occurred in the last 40 years, to varying degrees and accuracies. In early 1972, following a preliminary survey, Young and Kirkman, 1975) conducted a comprehensive study of Moreton Bay in which all the littoral areas were visited by shallow draft boats and the composition of their seagrass communities determined by eye. Seagrass extent (9,358 ±2,107 ha, mapping error estimated using GIS) was also corroborated by aerial survey. They further investigated 24 locations within the region and five distinct seagrass community types were identified, including: *Zostera capricorni / Halophila ovalis*; *Cymodocea serrulata / Syringodium isoetifolium / Zostera capricorni*, *Halodule uninervis / Halophila ovalis*; *Halophila ovalis / Halophila spinulosa*. During the early-mid seventies, seagrass meadows in northern Moreton Bay dramatically declined (Kirkman, 1976). This was primarily attributed to sand movement but cropping by fish was a secondary contributing factor (Kirkman, 1978).

Between August and December 1987 the first detailed survey documented the broad extent of seagrass distribution in Moreton Bay and adjacent estuaries (Hyland et al., 1989). Hyland et al., 1989) identified seven species of seagrass, and estimated approximately 14,170 ha of seagrass meadows (light to dense) and 12,500 ha of sparse or patchy seagrass areas between Coolangatta and Noosa. A recovery of seagrass in Deception Bay and Pumicestone Passage was evident between 1981 and 1987 following the large scale declines of seagrass in these areas during the early seventies.

In August 1998, the distribution of seagrass between Caloundra and Logan River mouth (southern Moreton Bay) was mapped as part of the initiation of the Healthy Waterways Initiative (Dennison and Abal, 1999). Approximately 19,109 ±700 ha was mapped within Moreton Bay. The greatest coverage was found in the eastern Bay, Waterloo Bay and northern Deception Bay. The Bay was dominated by *Zostera capricorni* and the greatest diversity can be found in the eastern Bay (Dennison and Abal, 1999).

In 2001 a number of the sites examined in 1998 were re-visited (476 in total), however the meadow extent was not interpreted (EHMP 2001, unpublished data). The majority of sites ground truthed were within Moreton Bay (south of Bribie Island bridge). Only two meadows (intertidal banks) were examined in southern Pumicestone Passage.

From March to July 2002, seagrass was mapped in Pumicestone Passage between Caloundra and the Bribie Island bridge, including several of the major creeks (EHMP 2002, unpublished data). Approximately 750 ground truth points were examined and non-rectified aerial photography (Beach Protection Authority, July 1999 at 1830m) was used to assist with boundary determination.

The most detailed survey of the bay (between the Bribie Island bridge and Kangaroo Island, from July to August 2004), mapped 183 km^2 of seagrass meadows (revised from original 189 km^2 using GIS and excluding macroalgae) (Roelfsema et al., 2009). Approximately 10% of Moreton Bay was covered by seagrass, most of which was found on the shallow banks (<5m) (Roelfsema et al., 2009). An additional 10km^2 of deep water seagrass (5-12m depth) meadows was mapped in the Middle Banks areas south and west of Tangalooma Point in 2002 and 2005 (Udy and Levy, 2002; Stevens and Connolly, 2005). Overall, this equates to just under 5% of the total area of seagrass shallower than 15m along eastern Queensland coast. Roelfsema et al., 2009) estimated that a little over half (56%) of the seagrass meadows in Moreton Bay were of low cover (between 1-25%). Although the % cover is low, these meadows are of high importance to the dugong of the bay as they are grazed on more heavily than denser meadows (McMahon, 2005). As adult dugongs have been reported to eat about 28 to 40 kilograms a day (Marsh et al., 2011), it is no coincidence, that one the highest population of dugongs adjacent to a major population centre occurs in the region.

The area of highest dugong population in the bay is the Eastern Banks (Chilvers et al., 2005), where seagrass cover has been mapped annually from 1988-2010 using course scale resolution (30 m pixel size) archived satellite imagery (Landsat Thematic Mapper) (Lyons et al., 2013).

The most recent mapping of seagrass communities in Moreton bay has been in response to the impacts from flooding. From mid December 2010 to mid January 2011, heavy rainfall across southern Queensland river catchments, due to TC Tasha combining with a trough during the strongest La Niña weather pattern since 1973, resulted in some of the highest floods in over 30 years. On 11 January 2011 at around 2:30 pm EST, the Brisbane River broke its banks and on 13 January it peaked at 4.46 metres in Brisbane. The floods were the sixth highest in the city's history. Significant flood plumes were reported along the western shores of the bay, immediately adjacent to the Brisbane River mouth. Using the 2004 approach (Roelfsema et al., 2009), Roelfsema et al., in review) remapped the Bay between June and September 2011, and reported 182.3 km^2 of seagrass meadows. The survey, however, did not include 23 km^2 areas that were mapped in 2004 as seagrass, due to limited resources. If the same survey areas are compared between the 2004 and 2011 surveys, the seagrass extent increased from 160 km^2 to 182.3 km^2 (i.e. 14%) respectively. The increase in seagrass extent was driven by an increase in area on the Eastern Banks, which was greater than the net loss predominantly occurring on the Western and Southern Bay areas (Roelfsema et al., 2012). No significant conclusion can be drawn as to whether the loss in seagrass cover on the Western side of the Bay was due to the 2011 floods, as no sufficient data was available immediately prior to the flood.

Following on from the post-flood surveys of 2011, ongoing research on the Eastern Banks area of the Moreton Bay, has mapped seagrass percentage cover, species and biomass in June 2011, February 2012, and June 2012 (C. Roelfsema, UQ, Pers. Comm.). The project is currently finalising the February/March 2013, and June 2013 mapping. This project will compare the results with previous surveys in September 2004, August 2007, September 2008, and December 2009.

During the last week of January 2013, ex-TC Oswald moved south and produced extreme rainfall and flooding in the Brisbane catchments and the ranges along the NSW/QLD border (the area-averaged rainfall for the Brisbane River catchment was very similar to that in the 2011 event) (www.bom.gov.au, accessed 04 March 2013). This resulted in Brisbane River flood waters discharging into Moreton Bay, the second time in 24 months. However, coupled with the floodwaters in 2013 were strong-gale force winds, high tides and associated wave action, resulted in damage to littoral systems and resuspension of sediments throughout the bay.

Concerns have been raised of widespread sediment discharges throughout Moreton Bay and Pumicestone having a more extensive effect on seagrass and marine systems than occurred in January 2011. The extent of the January 2013 sediment pollution plume has been described as heavy and extensive, which was possibly in part exacerbated by the high levels of sediment pollution 'left in the system' following the January 2011 floods (SEQ Catchments, 2013). The general perception is that "damage to seagrass and dependent iconic dugong and turtle species is likely to be significant" (SEQ Catchments, 2013). There are also concerns that the 'easily mobilised sediment and nutrients' in the upper catchments have again been 'recharged' and vulnerable to further flushing during future rains.

Findings from all the assessments conducted to date, indicate that seagrass presence throughout the region is most likely influenced by shelter, sediment characteristics, water turbidity and tidal exposure. The most extensive seagrass meadows in the region occur in the intertidal zone. Large seagrass meadows occur in areas of wide intertidal flats while small but dense seagrass meadows are found in association with narrow or confined channels. Subtidal seagrass in Moreton Bay are mostly sparse and generally occur in less than 10m, except in the eastern Bay where significant meadows are found extending into waters >10m. The restricted subtidal distribution of seagrass in Moreton Bay is generally attributed to high turbidity which restricts light penetration. The distribution, species composition and abundance of seagrass meadows differ in each of the main regions of SEQ depending on levels of exposure (waves and tidal), sediment characteristics, water turbidity and seabed topography.

The distribution, species composition and abundance of seagrass meadows differ in each of the main sections of Moreton Bay depending on levels of exposure (waves and tidal), sediment characteristics, water turbidity and seabed topography.

Southern Moreton Bay

This section contains communities of *Z. capricorni, Z. capricorni / H. ovalis, Z. capricorni/ H. ovalis/H. spinulosa* and *H. ovalis/H. spinulosa*. Intertidal areas of mainly patchy seagrass have been reported in the region from the Broadwater to Jacobs Well (Hyland et al., 1989). Very little seagrass has been reported close to the Jumpinpin Bar, although dense meadows occur along the eastern shores of Kangaroo Island (EHMP, 2006). Dense meadows of *Z. capricorni* have been reported north of Russell Island. Some mixed species communities of *Z. capricorni/H. ovalis* and of *Z. capricorni/H. spinulosa* have also been reported in this section of the bay (Hyland et al., 1989).

Abal and Dennison, 1996) conducted visual underwater surveys and photographs from aerial overflights in October 1992 and August 1994, and reported the complete loss of seagrass in the vicinity (9 km) of the Logan River mouth since the 1987 survey.

Dense meadows of *Z. capricorni* and *Z. capricorni/H. ovalis* were reported along the shore of North Stradbroke Island north from Canaipa Passage. Extensive sparse meadows of *H. ovalis, H. spinulosa* and *H. decipiens* with some *Z. capricorni* occur north of Coochiemudlo Island. This sparse meadow area changes to a continuous meadow of mainly *Z. capricorni* along the foreshore between Point Halloran and Cleveland.

Halophila decipiens was also reported in a sparse meadow in the region northwest of Pannikin Island (Hyland et al., 1989). A meadow of *S. isoetifolium* was reported along a short stretch of the shore of North Stradbroke Island as a single species community and also in association with *Z. capricorni* and *H. ovalis* (Hyland et al., 1989). A variety of dense, light, sparse and patchy meadows of mainly *Z. capricorni* with some *Z. capricorni/H. ovalis* occur around Peel Island.

Amity Banks

Extensive meadows of abundant *Z. capricorni* occur on Amity and Warrengamba Banks. Sparse meadows of *H. ovalis* and *H. spinulosa* occur on the Maroom Banks and Chain Banks. A mixture of H*. ovalis, H. spinulosa* and *Z. capricorni* form dense and light meadows on the Chain Banks.

Dense meadows of *Z. capricorni* occur along the Wanga Wallen Banks, North Stradbroke Island (between Dunwich and Amity). In various areas, *Z. capricorni* occurred in association with *H. ovalis, H. spinulosa, C. serrulata, S. isoetifolium* or *H. uninervis* (EHMP, 2004; Hyland et al., 1989). The abundance of *S. isoetifolium* in these meadows appears to have increased over the last decade. Subtidal meadows of *C. serrulata* also occur along the edge of this bank (EHMP, 20066; Hyland et al., 1989).

Moreton Banks and Moreton Island

Moreton Banks contain dense meadows of *Z. capricorni* with sparse *H. ovalis* and *H. spinulosa* in the region between Moreton Banks and Rous Channel (around Fishermans Gutter) (Hyland et al., 1989; EHMP, 2006). Dense meadows of *Z. capricorni* occur on Boolong Bank, to the west of the mangrove island south of Blue Hole. Dense meadows of *S. isoetifolium* are interspersed with the *Zostera* meadows particularly towards the southeast region of Moreton Banks. A mixture of patchy and light meadows of mainly *Z. capricorni* and *H. ovalis,* but with some *H. uninervis* occur to the west of the dense *Z. capricorni* meadows. Sparse *Z. capricorni, H. ovalis* and *H. uninervis* occur on the outer edge of the banks down to depths of 3m. Patchy *Z. capricorni* and *H. ovalis* occur along the western side of Moreton Island.

Udy and Levy, 2002) reported the occurrence of *H. spinulosa* and *H. ovalis* growing at depths of up to 12m south west of Tangalooma Point, and estimated these meadows possibly covered more than 10km^2. Udy and Levy, 2002) also proposed that based on studies which reported dugong regularly dive to 15 and 20m, and remain at that depth for up to 3 minutes, it is likely that seagrasses are present in much deeper waters in eastern Moreton Bay.

West of Tangalooma Point is Middle Banks; proposed as an extraction site for dredging 15 Mm^3 of sand for airport land reclamation. In November 2005, WBM Oceanics Australia conducted a broad scale seagrass survey of the Middle Banks (BAC Australia, 2006). 153 points were examined (within an area of ~89 km^2) by underwater video camera. Only two seagrass species were recorded at Middle Banks (*H. ovalis* and *H. spinulosa*) growing exclusively on shallow (between ~4-10m) subtidal sand banks and covering an estimated 1.87 km^2 (BAC Australia, 2006). These meadows were highly fragmented, dominated by *H. ovalis* and ranging from sparse (<5%) to moderately dense (10 - 50%) cover. Other potentially substantial areas of unmapped seagrass were identified on the shallow sand banks to the north and east of the study area (BAC Australia, 2006).

Based on these finding, mitigation to minimise the impact on seagrasses as a result of the planned dredging will include: selecting an area where the dredge footprint will avoid interference with seagrass and avoid those areas where seagrass could potentially grow (i.e. unvegetated sand banks up to 10 m in depth); minimizing the duration and size of any predicted turbid plume; and monitoring the extent and duration of turbid plumes.

Prior to 2003, there were no records of seagrass on any of the other sand bank complexes in the northern Moreton Bay delta; however, more recent finer-scale surveys have reported the presence of seagrass in some of these areas. For instance Stevens, 2003) recorded seagrass (species not reported) in deep water at the northern entrance to Moreton Bay, an area where no seagrass had previously been reported. More recently (mid-2005), patches of *H. ovalis* were recorded in the Spitfire Banks area (WBM unpublished data). As previously mentioned, a recent survey by Udy and Levy, 2002) found extensive regions of seagrass species *H. spinulosa* and *H. ovalis* growing at depths up to 12 m at Tangalooma Point on the west coast of Moreton Island.

It is unknown whether all these new records of seagrass in the northern Moreton Bay area are due to an actual increase in seagrass extent, or (more likely), reflect inadequate sampling effort in these areas in the past. Seagrass meadows within these dynamic and exposed environments are highly fragmented and generally sparse, which may have been difficult to detect in past surveys.

Raby Bay, Waterloo Bay and Fisherman Island

Z. capricorni and *H. ovalis* meadows of varying abundances (25-75%) are scattered throughout Raby Bay (EHMP, 2006). Smaller meadows of *H. decipiens* and *H. spinulosa* were reported in Raby Bay in 1987 (Hyland et al., 1989), however there has been little ground truthing since.

Hyland et al., 1989) mapped a dense meadow of *Z. capricorni* in the embayment south of Wellington Point, however since then the meadow has deteriorated and decreased significantly in abundance (EHMP, 2006). Waterloo Bay contains dense intertidal meadows of *Z. capricorni*, which mix with *H. ovalis* seaward. These meadows appear to have increased significantly since the late 1980s's (Hyland et al., 1989; EHMP, 2004). Sparse subtidal meadows of *H. ovalis, H. spinulosa* and *H. decipiens* occur subtidally in depths of 2 to 4 m at low water (Hyland et al., 1989; EHMP, 2006).

Extensive intertidal meadows of *Z. capricorni* and sparse meadows of *H. ovalis* and *H. spinulosa* occur on the southern side of Fisherman Island. Isolated patches of *Z. capricorni* are found in depressions on the coral rubble of the upper intertidal zone around Mud Island, St Helena Island and Green Island (Hyland *et al*., 1989; EHMP 2001, unpublished data).

Bramble Bay and Redcliffe

There are no documented records verifying seagrass occurring in Bramble Bay, Hays Inlet or the foreshore of the Redcliffe Peninsula (Hyland *et al*., 1989; EHMP, 2006). Dennison and Abal, 1999) reported that historically, seagrass meadows dominated by *Zostera capricorni* covered the intertidal shoreline of Bramble Bay prior to the 1980's, however, this cannot be substantiated, as reports are anecdotal.

Deception Bay and Pumicestone Passage

Seagrass meadows were once extensive in the southwest corner of Deception Bay (Hyland et al., 1989). In 1987, dense intertidal meadows of *Z. capricorni* occurred near-shore. Adjacent to these were sparse meadows of *Z. capricorni* intertidally and *H. ovalis, H. spinulosa* and *H. decipiens* in the shallow subtidal areas (Hyland et al., 1989). No seagrass has been reported in this area since the late 1980's (EHMP 1998, 2001, unpublished data; EHMP, 2006).

Isolated dense meadows of *Z. capricorni* have also been reported up to 3 km within the Caboolture River, (Hyland et al., 1989), however it is unknown if they are present today as more recent surveys have not examined the river (EHMP, 2006).

Z. capricorni communities occur in dense (75-100% cover) and patchy meadows in northern Deception Bay on the intertidal banks around Toorbul Point. Seaward, moderate (50-75% cover) meadows of *Z. capricorni, H. ovalis* and *S. isoetifolium* occur and sparse meadows of *H. ovalis* and *H. spinulosa* occur close by in slightly deeper waters (3-5m) (Hyland et al., 1989; EHMP, 2006). Between June 1974 and December 1975, Kirkman (Kirkman, 1976; Kirkman, 1978) examined the seagrass communities at Toorbul Point, and showed that sand movement was an important factor in the seagrasses' decline, and that cropping was of secondary importance. Sediment deposition had elevated the topography of the area resulting in the area exposing at low tide, causing the *S. isoetifolium* to disappear for many years, but recovering by 1987 (Hyland et al., 1989).

A variety of dense, light and patchy meadows of *Z. capricorni, H. ovalis, H. spinulosa* and *H. decipiens* occur in Pumicestone Passage. They appear to have changed little over the last two decades (Hyland et al., 198989; EHMP 2002, unpublished data).

Seagrass threats and losses

Long term changes in seagrass distribution may occur through natural changes or may be related to human activities. Losses of seagrass have been documented in Deception Bay (Kirkman, 1978) and southern Moreton Bay (Abal and Dennison, 1996), as consequence of turbidity due to the resuspension of deposited muds by tidal currents, wind waves and oceanic swell (Dennison and Abal, 1999). Dennison and Abal, 1999) also report historically seagrass meadows dominated by *Zostera capricorni* covered the intertidal shoreline of Bramble Bay, and that losses occurred prior to the 1980's. However, this cannot be substantiated, as reports are anecdotal and no documents verifying seagrass occurrence at that location can be found.

Fertilization experiments indicate that seagrasses in the eastern sections of the Bay (Moreton Island and Pelican Banks) are nutrient limited, whereas seagrasses in the western Bay (Waterloo bay and Deception Bay) may have an excess of sediment nutrients (Dennison and Abal, 1999). Further studies suggest that seagrass growth in the western Bay may be limited by light availability (Dennison and Abal, 1999).

Direct impacts associated with use of the Bay and its foreshores, plus the effects of disposal and runoff from adjacent areas, have threatened the Bay's values. A key means of managing the Bay is the Moreton Bay Marine Park. Declared in 1993 (and extended in 1997), the marine park covers most of Moreton Bay's tidal lands and tidal waters seawards to the limit of Queensland waters. The marine park allows most people to do most things while still protecting the natural environment. A zoning plan over the marine park, provides a balance between human needs and the need to conserve the Bay's special values.

In 1999, the Ecosystem Health Monitoring Program (EHMP) was established in the Bay. It is a major part of the Healthy Waterways' Monitoring and Evaluation Program, which was updated in 2011 (see www.healthywaterways.org). The EHMP uses science to quantify and evaluate waterway health using a range of biological, physical and chemical indicators. Each year Healthy Waterways produces an annual Ecosystem Health Report Card. *Zostera muelleri* subsp. *capricorni* depth range is monitored biannually at 18 sites, and baywide seagrass extent is assessed very 3 years as part of the EHMP. Depth range provides an indication of water clarity at a site, as the depth to which seagrass can grow is directly dependent on the penetration of light through the water. This provides the EHMP with a link between changes in water quality throughout Moreton Bay and the effects it has on biological systems.

In 2012, the overall rating for Moreton bay was B- (EHMP, 2012). The improvement in Moreton Bay (from C- in 2011) resulted from an increase in water clarity and a decrease in nutrients and algae. Central Bay showed the greatest improvement (D+ to A-) as a result of a large decrease in algae. The only two regions in Moreton Bay that declined were Broadwater

(B to C-) and the southern end of Pumicestone Passage which caused an overall decline (C+ to C-). The health of seagrass beds and corals appear to have returned to pre-flood conditions. This was unexpected as the 2011 flood deposited large amounts of mud on seagrass and coral habitats. Moreton Bay's recovery from such an extreme weather event is encouraging and highlights the resilience of the bay.

SEAGRASS-WATCH IN THE MORETON BAY REGION

To provide an early warning of change, long-term monitoring was established in Moreton Bay in May 2001 in conjunction with Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org; McKenzie et al., 2000). Establishing a network of monitoring sites in Moreton Bay 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. It encourages local communities to become involved in seagrass management and protection. Working with both scientists and local stakeholders, this approach is designed to draw attention to the many local anthropogenic impacts on seagrass meadows which degrade coastal ecosystems and decrease their yield of natural resources.

Many of the seagrass monitoring sites in the Bay have been established in conjunction with the EHMP depth monitoring. The EHMP has expressed interest in the Moreton Bay Community Seagrass Monitoring Project (using Seagrass-Watch protocols), especially in terms of its potential for the early detection of *Lyngbya* blooms. EHMP is currently providing some financial assistance to the program. Seagrass-Watch monitoring in Moreton Bay is coordinated by the Moreton Bay Community Seagrass Monitoring Project: a project of Wildlife Queensland Bayside Branch (http://seagrassmb.wordpress.com/). To date, 51 sites have been established at 15 different locations (Finn et al., 2010). Sites are monitored three times per year in March/April, July/August and November/December to minimise damage to the seagrass meadows, most of which grow in a muddy substrate.

Seagrass-Watch training Moreton bay:
left - Wynnum, 2 May 2001 and right – Wellington Point, 24 November 2007

The following is a summary of the status of seagrass monitoring in Moreton Bay 2001-2008 *(NB: no data has been submitted to Seagrass-Watch since July 2008)*

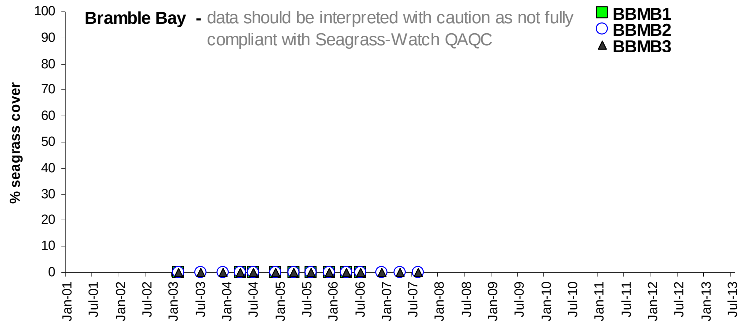
BRAMBLE BAY

Principal watchers: Jennifer Singfield, Ross Coe and Mary-Ann Pattison
Occasional and past watchers: David Sinlfeld, Kathryn Crouch, Liza Reyes, Paul Finn, S Stevens-Hoare, Mary-Ann Pattison, Sean Galvin & Sue Reid.
Location: Bramble Bay extends from the mouth of the Brisbane River north to Woody Point, Redcliffe Peninsula. BBMB1 is located close to Brisbane Airport, BBMB2 and BBMB3 are on the southern shores at Sandgate
Site code: BBMB1, BBMB2, BBMB3 *(non compliant site codes)*

Threats: riverine discharge, a number of sewage treatment plants discharge almost directly into the bay (e.g. Redcliffe, Sandgate and Luggage Point), wind-driven re-suspension of fine fluvial sediments
Comments: Bramble Bay receives discharges from Hays Inlet, the Pine Rivers, Cabbage Tree Creek and the Brisbane River. Bramble Bay water have the longest residence time (~60 days) of any region in Moreton Bay, so flushing does not help to remove polluted discharge. Excess nutrients have caused the proliferation of the macroalgae Ulva lactuca (sea lettuce) in several sections of the system. *Ulva* requires a rocky substrate and its growth is rapidly stimulated by elevated nutrients.
No seagrass meadows persist in Bramble Bay although seasonal occurrences of *Halophila ovalis* have been recorded. Water quality conditions are unsuitable for seagrass to re-establish. Due to it's proximity to Brisbane, Bramble Bay is an important area for recreational pursuits like boating and fishing.
Lyngbya majuscula has not been recorded in Bramble Bay, this may be due to poor light penetration and the lack of seagrass or other supporting substrates.

Status (Jun08):

- No seagrass has been observed in Bramble Bay since monitoring established.
- Bramble Bay is characterised by poor water quality and poor biological health, a consequence of elevated nutrients, low dissolved oxygen and high sewage nitrogen. Bramble Bay had the poorest ecosystem health of all Moreton Bay in 2012 (EHMP 2012).

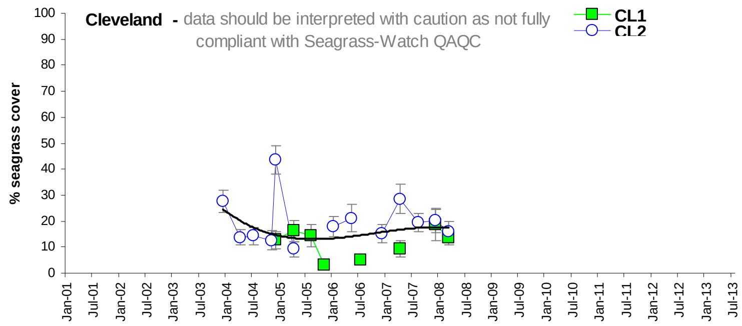


CLEVELAND

Principal watchers: Don Baxter, Will Glynn, Gary Millar, Deidre Morrow, Graham Barr, Deborah Heavey.
Occasional and past watchers: Paul Finn.
Location: : Located on the south eastern banks of Cleveland Point
Site code: CL1, CL2
Threats: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Major urban and coastal development is occurring in this location. A major ferry terminal and associated facilities for the Moreton Bay islands is present approximately 1km south of the monitoring site

Status (Jun08):

- Seagrass dominated by *Zostera capricorni* with some *Halophila ovalis*
- Although seagrass abundance declined late in 2005, it recovered by early 2008.
- Declines in abundance are associated with increases in the composition of *Halophila ovalis,* (an early colonising species) indicating some level of disturbance.
- Although seagrass abundance fluctuates within and between years, no long-term trends are apparent.

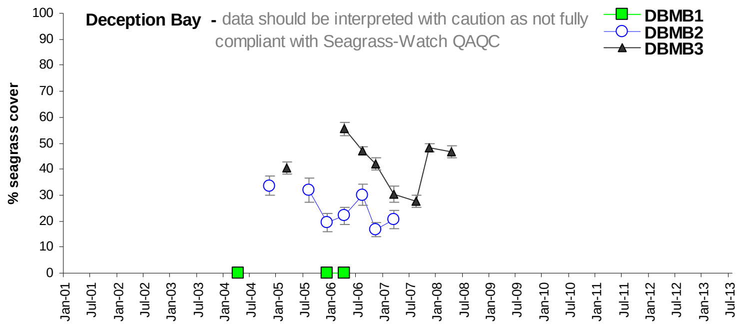


DECEPTION BAY

Principal watchers: Wayne Young,Jennifer Singfield, Barbara Miller, Karen Francis, Joe Patiniott, Sue Stevens-Hoare, Brian Vernon, Anita Cross, Karrel Cassey, Ross Rule, Hannah Rowan.
Occasional and past watchers: Paul Finn & Sean Galvin.
Location: DB1 located on the southern banks of Deception Bay, east of a large canal development.
Site codes: DBMB1, DB2MB, DBMB3 *(non compliant site codes)*
Threats: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Deception Bay is situated at the northern section of Moreton Bay and receives input from the Caboolture River and Pumicestone Passage. Flushing from the North Passage and relatively low inputs of nutrients and sediments from the Caboolture River maintain good water quality in the northern part of the Bay. Extensive (~1300ha) seagrass meadows (mostly *Zostera capricorni*, with *Halophila ovalis, Syringodium isoetifolium*) are present in the northern part of the bay, but have been covered with a toxic cyanobacterium, *Lyngbya majuscula*, on an annual basis since 1990. It is suggested that terrigenous runoff containing iron and humic substances is stimulating the annual blooms. Two sites (DB2 and DB3) are planned for the northern banks of Deception Bay adjacent to Sandstone Point.
Extensive (~2100ha) seagrass meadows were present in the southern part of Deception Bay in December 1987 (Hyland et al., 1989). These included meadows of *Zostera capricorni* with some *Halophila ovalis* inshore, and meadows generally <10% cover of *Halophila ovalis, Halophila spinulosa, Halophila decipiens* subtidally. Approximately 15km^2 of seagrass meadows were lost in the southern Bay in 1996 following a 1-in-20 year flood event and there has been no subsequent recovery. Lack of seagrass recovery is likely due to discharge of poor quality water from the Caboolture River which remains a pressure on Deception Bay's overall ecosystem health. Poor flushing in that area of Deception Bay compounds the impact of this discharge. Recovery in the area is most likely being limited by the poor water clarity.
During 2002-2003, *Lyngbya* blooms covered up to 30% of seagrass meadows in northern Deception Bay. *Lyngbya* was found predominantly on the meadows at Godwin's Beach extending to the mouth of Pumicestone Passage. A similar result was recorded in 2001-2002.
Water quality is improving in Deception Bay and in the 2012 report card it was rated a C- (up from D+ in 2011) (EHMP, 2012). The improved rating was a consequence of decreased nitrogen concentration and sewage indicator. *Lyngbya majuscula* coverage decreased slightly. Seagrass, however, remained sparse and very intermittently occurring.

Status (Jun08):

- Seagrass abundance decreased significantly from 2005 to 2007. Subsequent increases were reported in 2008, however only 1 site was examined.
- Sites are dominated by *Zostera capricorni*, with a minor component of *Halophila ovalis* from time to time.



FISHERMAN ISLANDS

Principal watchers: Don Baxter, Will Glynn, Gary Millar Deidre Morrow, Graham Barr, Deborah Heavey.

Occasional and past watchers: Lou Coles,Michael Murphy, Paul Finn, Gavin Leese & Rebecca McMillan.

Location: South of the Brisbane River mouth, near the southern end of the sea wall, north of south point, at the most northern section of Waterloo Bay.

Site codes: FI1, FI2, FI3

Threats: worm digging, urban stormwater, sewage and agricultural runoff, coastal & port development

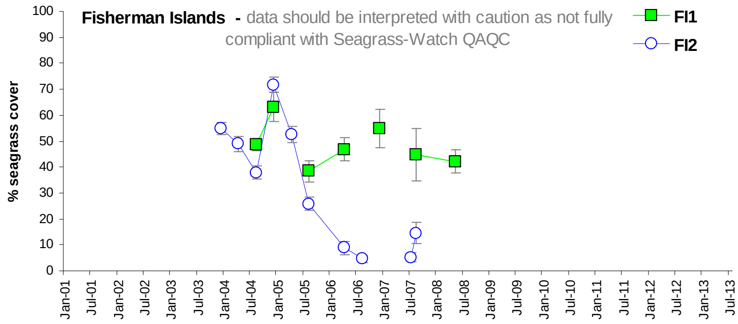
Comments: Waterloo Bay on the western side of Moreton Bay, extends from the mouth of the Brisbane River south to Wellington Point. Numerous small creeks make up the Redland Catchment which drains directly into Waterloo Bay. These creeks include Tingalpa, Coolnwynpin, Tarradarrapin, Hilliards, Eprapah, Moogurrapum and Weinum Creeks. There are a range of land uses within the catchment such as poultry farming, plant nurseries, flower farms, market gardens, urban areas and bushland. Tingalpa Reservoir impounds Tingalpa Creek. There are five sewage treatment plants discharging in the Redlands/Waterloo Bay catchment.

Waterloo Bay is characterised by relatively stable water quality with good (A-) biological health (EHMP 2012). Although the region is affected by the Brisbane River through Boat Passage, water currents generally force nutrients and sediments from the river mouth northward away from Waterloo Bay. It is the only western embayment of Moreton Bay that still supports a mosaic of coral, macroalgal and seagrass communities. Generally stress tolerant species capable of withstanding sediment loading dominate. Healthy meadows of the seagrass *Zostera capricorni* are present in Waterloo Bay and depth ranges of most meadows have not changed since 1993, indicating that these meadows are generally stable.

Seagrass depth range monitored at Fisherman Islands at the end of Boat Passage as part of the EHMP, is the shallowest, corresponding to the poorest water clarity in the region.

Status (Jun08):

- Sites are dominated by *Zostera capricorni* with *Halophila ovalis*. *Halophila spinulosa* also occurs at FH1, although its abundance declined in 2007 and 2008.
- Seagrass abundance has remained relatively high (>40% cover) at FI1, however, abundance signficantly from 2005 to 2007 at FH2
- Insufficient data to describe long-term trends.

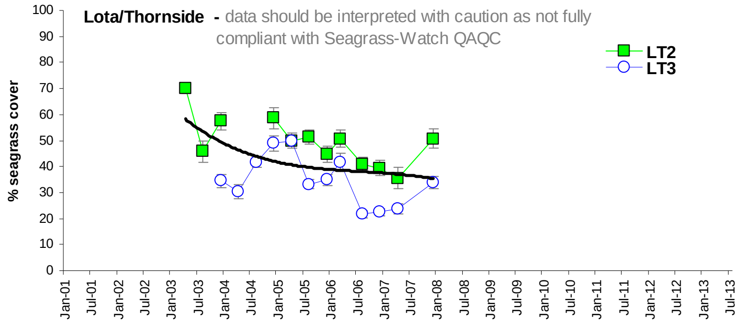


LOTA / THORNSIDE

Principal watchers: Josef Major, Rose Penfold, Lisa West, Lou Coles, Tina Antill, Rebecca Goddard, Julie Meles.
Occasional and past watchers: Belinda Daly, M Beec, Tim.
Location: On the western banks of Waterloo Bay, south of Manly
Site codes: LT2, LT3
Threats: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Monitoring sites are immediately adjacent to the discharge from Redland Catchment. There are a range of land uses within the catchment such as poultry farming, plant nurseries, flower farms, market gardens, urban areas and bushland. Tingalpa Reservoir impounds Tingalpa Creek. There are five sewage treatment plants discharging in the Redlands/Waterloo Bay catchment. Waterloo Bay is characterised by relatively stable water quality with good (A-) biological health (EHMP 2012). Although the region is affected by the Brisbane River through Boat Passage, water currents generally force nutrients and sediments from the river mouth northward away from Waterloo Bay. Generally stress tolerant species capable of withstanding sediment loading dominate. Healthy meadows of the seagrass *Zostera capricorni* are present in Waterloo Bay and depth ranges of most meadows have not changed since 1993, indicating that these meadows are generally stable.

Status (Jun08):

- Seagrass meadows are dominated by *Zostera capricorni* with some *Halophila ovalis*.
- Slightly more *Halophila ovalis* in the earlier months of the year.
- Although a seasonal trend in abundance is apparent at both sites (with higher abundances in the late spring and summer months), long-term trends suggest abundances are declining.
- Very minor amounts (<1% cover) of *Lyngbya* was reported at LT3 on 7 Dec 2003.



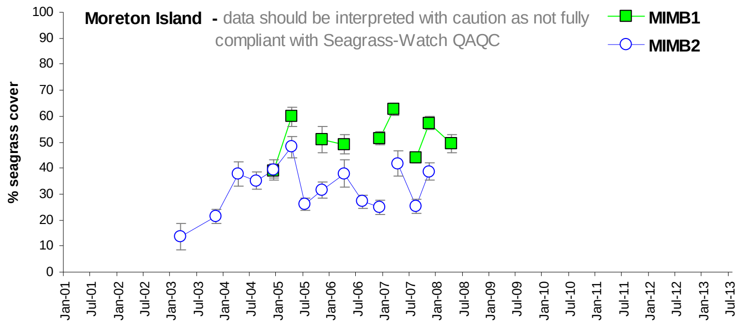
MORETON ISLAND

Principal watchers: Ed Boast, Jill Ferguson, Trish Cavanaugh, Janet Dovers, Nanette Kempel, Jenni van Rooyen, Linda Back, Phillip Back, Petra Janoschka.
Occasional and past watchers: Dennis, Val Young.
Location: Located at the south western end of Moreton Island. MIMB1 is on Coonungai Bank, adjacent to Crab Island, and MIMB2 is 4km north on the banks of Moreton Island.
Site codes: MIMB1 and MIMB2 *(non compliant site codes)*
Comments: The Eastern Banks region of Moreton Bay covers approximately 100km^2 and includes Moreton, Boolong, Chain, Maroom and Amity Banks. This area is considered pristine with excellent water quality, extensive and diverse seagrass meadows growing in deep waters and diverse faunal assemblages. There is significant oceanic flushing through the Rous Channel. There have, however, been recent outbreaks of the toxic cyanobacteria *Lyngbya majuscula* occurring annually since 2000. During the summer months, up to 28% of the seagrass was covered in *Lyngbya*, which are primary grazing meadows for turtles and dugongs.
Zostera capricorni meadows at Crab Island are reported to extend to 3m depth, the deepest in Moreton Bay, a consequence of excellent water clarity. Deep-growing species (e.g. *Halophila spinulosa*) have been recorded at depths of 10m offshore of Moreton Island, highlighting the importance of maintaining good water clarity in the region.

Overall, the ecosystem health has improved slightly (rated A in 2012, up from A- in 2011) due to increased water clarity and decreased algae concentration (EHMP, 2012). Lyngbya coverage decreased in 2012, and Seagrass Depth Range and occurrence of corals remained stable.

Status (Jun08):

- The Eastern Banks region of Moreton Island is characterised by near pristine water quality and excellent biological health (EHMP 2012). The water quality in the Eastern Banks is generally low in nutrient levels and sediment load.
- Seagrass abundance at both sites has remained stable between years, after an initial increased in 2003/04. Seagrass cover is slightly lower at MIMB2 than MIMB1.
- Species composition has remained relatively stable.

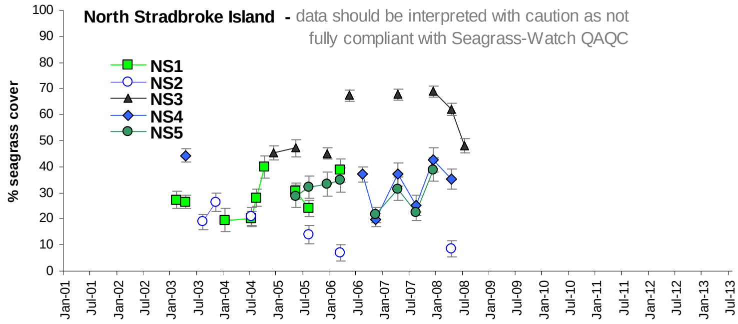


NORTH STRADBROKE ISLAND

Principal watchers: Kathy Townsend, Dan O'Sullivan, Rachael Hanna, Allister Gee, Paula Williams, Jo Barkworth, Coralie Dodd, Donna Smit Jeanette Watson, Murray Watson.
Occasional and past watchers: Chris Matthews, John Osborne, Margaret Grenfell, Paul Finn, Andy Morison, Annette Gaupp, Barry Brown, Carmen & Pip, Dunwich State School Year 7, Evelyn Chen, Hannabella, Jan Connolly, Lauren, Lou Coles, Kathryn Crouch, Sarah & Stephanie Esentrager.
Location: All sites located on the north western banks of North Stradbroke Island. NS1 is in One Mile Harbour. NS2 is 2.8km north at Myora, NS3 is the most northern site on western Amity Point. Both NS2 and NS3 are on the eastern banks of Rainbow Channel. Ns4 is the most southern site, located at Adams Beach
Site codes: NS1 NS2 NS4
Threats: minor storm water and sewage inputs
Comments: The Eastern Bay region which includes North Stradbroke Island, has excellent water quality with low nutrient levels, low sediment loads, and diverse coral assemblages. Tidal flushing through the South Passage removes any minor storm water and sewage inputs. Phytoplankton communities are diverse and have adapted to live in low nutrient environments. There are extensive seagrass meadows that provide food and habitat to fish and crustaceans as well as turtles and dugong.
A large meadow (~6.5km^2) dominated by *Zostera capricorni* with a mixture of other species (*Halophila ovalis, Halophila spinulosa, Syringodinm isoetifolium, Cymodocea serrulata, Halodule univervis*) is located along the eastern banks of Rainbow Channel.
Expanding populations of the nuisance algae *Caulerpa taxifolia* have been recorded at One Mile Harbour and Adams Beach off North Stradbroke Island. *Caulerpa taxifolia* occupies the same niche as seagrasses, and because of expanding populations, hey are frequently found competing with seagrasses for substrate and light availability.
In 2012, the water clarity improved in the Eastern Bay, algae and nitrogen concentrations decreased, and the zone was rated A- (up from B- in 2011) (EHMP, 2012). Seagrass Depth Range and occurrence of corals remained stable.

Status (Jun08):

- Seagrass meadows being monitored appear to be in a relatively fair state, although NS3 appears to fluctuate between years.
- Macroalgae abundances are relatively high, with greatest abundances in the late spring period. Sites NS2 and NS4 generally have more macroalgae present than the other sites.

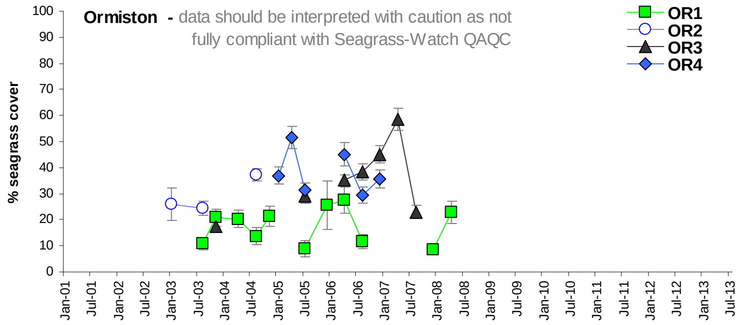


ORMISTON

Principal watchers: Jacquie Sheils, Matt Scougal, Scott Watson, Alicia Axam, Aimee Van Polanen Petel, Chloe Rhoades, Hamish Axam, Nicola Rae, Chris Fraser.
Occasional and past watchers: Ben Cook, Boglary, Decalie Newton, Carol Conacher, John Thorougood, Keira Price, Kylie Asher, Nicola Udy, Paul Finn, Peter London, Sharon, Simon Baltais & Wendy Boglary.
Location: Northern banks of Raby Bay, OR1 is adjacent to a canal development, OR2 is the most northern site, adjacent to Wellington Point.
Site codes: OR1 OR2 OR3
Threats: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Sites are particularly muddy. Rapid urbanisation of the catchment has occurred over recent years including the construction of canal developments.

Status (Jun08):

- Seagrass abundance variability within and between sites is high.
- Meadows dominated by *Zostera capricorni* with *Halophila ovalis*
- Abundance increases seasonally over the summer months, a consequence of warmer temperatures and possibly clearer water.



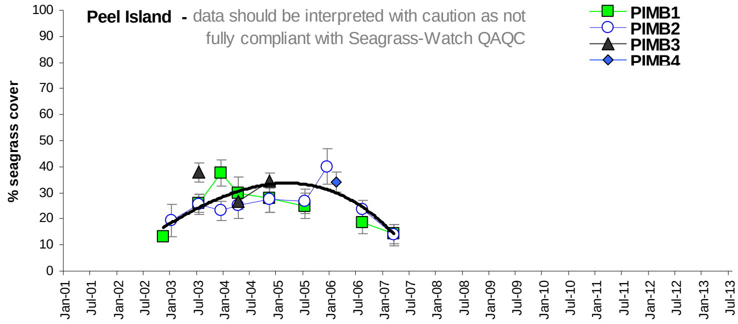
PEEL ISLAND

Principal watchers: Sam Ledger, Stu Ledger, Chris Ayres, Rhonda Ayres, James Wright, Janet Dovers.
Occasional and past watchers: Don Burton, Lou Coles, Michael Salini, Richie Pigeon, Shon Schooler, Damien Guppitt, John Berry, Lucas Batton, Nicola Udy, Alice Yeates, Bethan Haughton, Paul Finn, Donovan Burton & S Raghu & Rebecca Fowler.
Location: In central Moreton Bay, located midway between Cleveland and North Stradbroke Island. Sites located in the small bay on the southern side of the island, adjacent to Platypus.
Site codes: PIMB1 PIMB2 PIMB3 *(non compliant site codes)*
Threats: minor storm water and sewage inputs, boat traffic & anchoring
Comments: Sites are subtidal - monitored by free diving. Peel Island area has relatively good water quality with low nutrient levels and low sediment loads (EHMP 2004). Diverse coral assemblages are located around the island. Tidal flushing through the South Passage removes any minor storm water

and sewage inputs. There are extensive seagrass meadows that provide food and habitat to fish and crustaceans as well as turtles and dugong.
Seagrass meadows occur around the island and appear relatively healthy due to good water clarity. The shallow subtidal Zostera capricorni dominated meadow (~44ha) at Peel Island, in which the moniotirng sites are located, has been very stable for the past 5 years and extends to 2m in depth. The last major bloom of Lyngbya majuscula was reported in early 2002, before Seagrass-Watch monitoring was initiated.

Status (Jun08):

- Sites mainly dominated by *Zostera capricorni* with *Halophila ovalis* and *Syringodium isoetifolium. Halophila spinulosa* is present in minor amounts.
- Site PIMB3 is dominated by *Syringodium isoetifolium* and *Halophila spinulosa*, with small amounts of *Zostera capricorni* and *Halophila ovalis*.
- Abundances generally variable within sites and between monitoring events. Abundance increased from 2003, but declined back to 2003 levels in 2007.



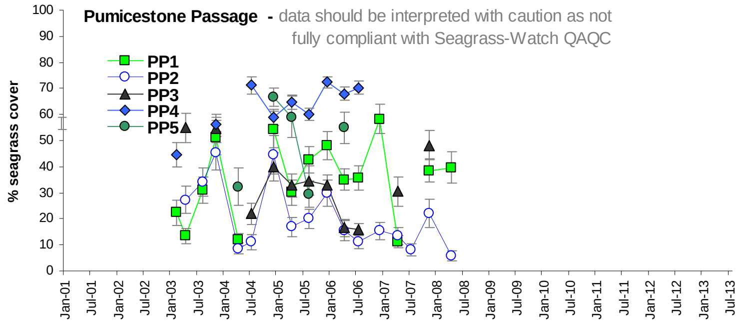
PUMICESTONE PASSAGE

Principal watchers: Joyce Newell, Bob Newell, John McConnell, Jackie McConnell, Maureen Hickling, Warwick Bright, Shaylee Bright, Michael Salini, Jenny Reynolds, Allen Reynolds, Kim Reynolds, Denis Evans, Bob (Edward Robert) Davis, Mick (Malcolm) Graham, Jennifer Graham, Michael Kelly.
Occasional and past watchers: Brett Williams, Chris Penning, Kathryn Crouch, Denis Evans, Lou Coles, Nathan Kirby & Tarni Williams.
Location: Pumicestone Passage is a narrow shallow estuary extending between the coastal plain in the west and Bribie Island in the east.
Site codes: PP1 PP2, PP3, PP4, PP5
Threats: Major land uses in the catchment include pine plantations, forestry and intensive agriculture, sewage discharge, coastal urban development.
Comments: Pumicestone Passage receives inflows from numerous small creeks on the mainland and Bribie Island. Tidal flushing of the southern passage from Deception Bay dominates the estuary and there is a net northern movement of water through the Passage.
The main population centre is Caloundra in the north, with the smaller townships of Beerburrum, Beerwah and Landsborough located in the hinterland. Population growth in the catchment is high and there is an increasing demand for urban and rural residential development. Extensive areas of native vegetation in the catchment have been cleared for agriculture and pine plantations, however, remaining remnants of *Melaleuca*, heathland, saltmarsh, seagrass and mangroves survive within the estuary providing valuable habitat to a range of organisms.
Seagrass covered approximately 1200ha of Pumicestone Passage in 2002 (EHMP 2004), with extensive meadows characterising Tripcony Bight and the south-western intertidal areas of the Passage. Poorer water clarity and narrow channels north of Tripcony Bight restrict seagrass growth to a predominantly sparse cover of *H. ovalis*.

Status (Jun08):

- The site most frequently monitored is PP1. Seagrass abundance at this site appears to be showing a fairly typical season pattern of seagrass abundance (higher in late spring-summer than winter).

- Seagrass abundance at PP2 has declined since early 2005, and although other sites have fluctuated greatly between years, no long-term trend is apparent.
- No significant changes in species composition is apparent over the long-term
- Macroalgae is generally more abundant at PP1 than at the other sites. Macroalgae abundance is chronically low (0-33% cover), with acute blooms over the summer months.

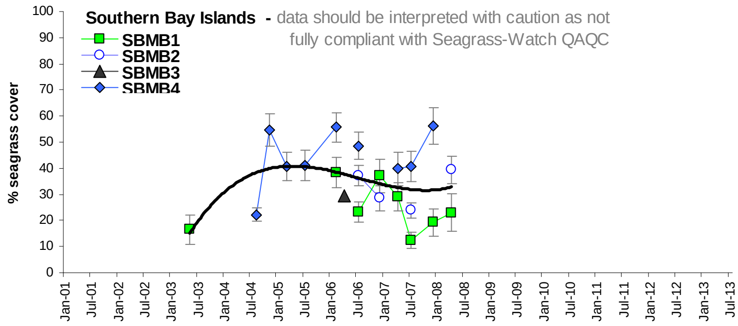


Southern Bay Islands

Principal watchers: John Cameron, Joanne Gates, Ken Orme, John Lind, Susan Lind, Max Baker, David Cummings, Don Marshall, Nadia O'Carroll, Kerry O'Carroll.
Occasional and past watchers: Glenda Crowther & Glenn.
Location: Tipplers Passage, northern end of South Stradbroke Island between Logan and Pimpama Rivers
Site codes: SBMB1, SBMB2 *(non compliant site codes)*
Threats: none identified
Comments: Sites are located in or adjacent to Southern Moreton Bay Islands National Park .
There are a range of habitats within the region including mangrove islands and Jumpinpin Passage (between North and South Stradbroke Islands). The Logan River has the greatest influence on the water quality in Southern Moreton Bay, however much of the discharge appears to travel to the north and has relatively little effect on the monitoring sites. There are extensive mangrove areas present in this region of the Bay and tidal flushing through the Passage removes most inputs.
The region contains expansive and diverse mangrove forests that are for the most part in good health. The eastern channels, especially Canaipa Passage, which are less influenced by Logan River, have healthy seagrass meadows and greater biological diversity than the rest of the system corresponding to better flushing and excellent water quality.

Status (Jun08):

- Seagrass meadows dominated by *Zostera capricorni* and *Halophila ovalis*, which are patchy in places.
- Seagrass abundance fluctuates between and within years. A seasonal pattern in abundance is apparent with higher abundances over the late spring/summer months. No long-term trends in abundance are apparent

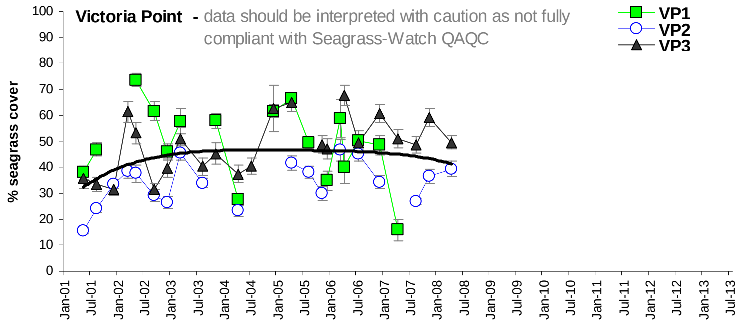


VICTORIA POINT

Principal watchers: Belinda Daley, Jill Praeger, Tim Roe, Ken Callan Stephen Cox, Amanda White, Keira Price
Occasional and past watchers: Katie Ewington, Katie Martin, Lyndon Harris, Paul Finn, Ray Rowe, Stephen Cox, Allison Brunott, Andrew Petro, Ben Longstaff, Bronwyn Smith, Gary Miller, Harold Waring, Ivell Whyte, Lynn Roberts, Narelle, Narelle Renn, Rebecca Lewis, Saren Starbridge, Sharen, Tone Iveson,Debbi McManus, Nicola Udy, Conor McManus, Michael Salini, Simon Baltais, Danielle Ewington, Keira Price, Beryl House & Ulrike Keysner.
Location: In northern Redland Bay, on the southern side of Victoria Point
Site codes: VP1 VP2 VP3
Threats: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Located in Southern Moreton Bay, which extends from the Logan River mouth north to Peel Island. There are a range of habitats within the region including mangrove islands and the urbanised areas of Russell and Macleay Island and Redland Bay. The Logan River has the greatest influence on the water quality in the region. It contributes sediment and nutrients from numerous point and non-point sources.
Due to numerous shallow, muddy channels and its proximity to the Logan River mouth, the area has typically poor water clarity, fair water quality and poor to fair biological health (EHMP 2004). The sewage nitrogen signal from poor riverine discharge is also a concern for the region.
The system supports seagrass meadows and large stands of mangrove forest, but both are under threat from poor water quality. The seagrass meadows in the region are shallow and variable, corresponding to the fluctuating water clarity in the system. During the last decade seagrass meadows have decreased in size due to declining water clarity, although seasonal occurrences of colonising species such as *Halophila ovalis* and *Halophila spinulosa* have been noted near the Logan River mouth.

Status (Jun08):

- Seagrass abundance at all sites show similar patterns.
- *Zostera capricorni* grows to approximately 2m around Victoria Point.
- Seagrass meadows around Victoria Point appear to be in a fair condition
- Abundances are variable, corresponding to variable water clarity in the region.
- Macroalgae are persistent at Victoria Point. Abundances increased significantly in late 2003 to medium-high (34-100% cover). In 2004, however, abundances decreased to what appears to be their typical levels for this location (0-33% cover).
- Epiphyte abundances are generally low, and no significant patterns in epiphyte abundance were apparent.



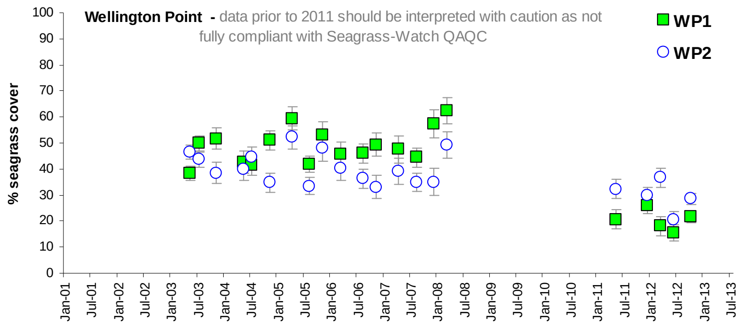
WELLINGTON POINT

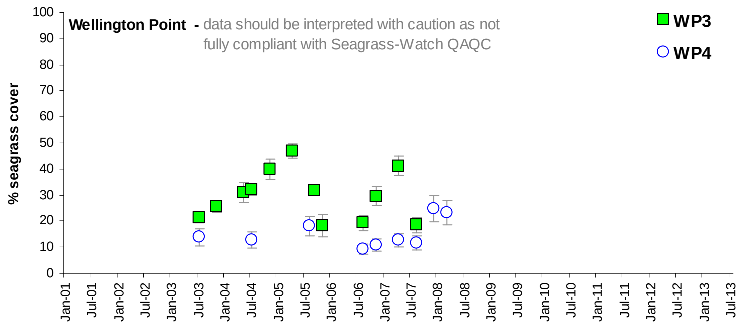
Principal watchers: Don Gilmour, Helen Gilmour, Desley Loch, John Henderson, Barry Johns, David Joseph, Cathy Dexter, Julie Zubevich, Nicola Udy, Jacquetta Udy, Danielle Udy, Seagrass-Watch HQ
Occasional and past watchers: Justine Grant, Amanda Luxford, Kath Dexter, Kathryn Crouch, Lou Coles, Melodee Brenchev, Rebecca Fowler, Paul Finn & Ruth Dexter
Location: On the eastern banks of Waterloo Bay, on the western side of Wellinton Point. WP2 is close to King Island.
Site codes: WP1, WP2, WP3, WP4

Issues: Urban stormwater, sewage and agricultural runoff, coastal development
Comments: Monitoring sites are on the opposite side of Waterloo Bay to the discharge from Redland Catchment. There are a range of land uses within the catchment such as poultry farming, plant nurseries, flower farms, market gardens, urban areas and bushland. Tingalpa Reservoir impounds Tingalpa Creek. There are five sewage treatment plants discharging in the Redlands/Waterloo Bay catchment.
Waterloo Bay is characterised by relatively stable water quality with good (A-) biological health (EHMP 2012). Although the region is affected by the Brisbane River through Boat Passage, water currents generally force nutrients and sediments from the river mouth northward away from Waterloo Bay. It is the only western embayment of Moreton Bay that still supports coral, macroalgal and seagrass communities. Generally stress tolerant species capable of withstanding sediment loading dominate. Healthy meadows of the seagrass *Zostera capricorni* are present in Waterloo Bay and depth ranges of most meadows have not changed since 1993, indicating that these meadows are generally stable.

Status (Jun13):

- Seagrass meadows are dominated by *Zostera capricorni* with some *Halophila ovalis*.
- Seagrass abundance is variable within and between sites, indicating localised impacts.
- As no data was available between mid-2008 and early 2011, Seagrass-Watch HQ began monitoring WP1 and WP2 after the 2011. Although seagrass abundances post flood were lower than reported prior to 2008, it is unknown if the decline occurred between 2008 and 2011 or as a result of the flood event. Similarly, as QAQC was not conducted on data prior to 2011, it is unknown if the differences in abundance are an artefact of observer error,





WYNNUM

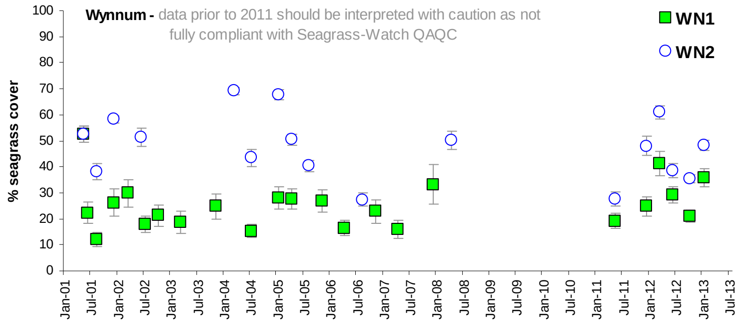
Principal watchers: Dinah Hall, Jenny Job, Dianne MacLean, Steve Macpherson, Matthew Taylor, Beth Clouston, David Wilson, Denise Wilson, Noel Wison, Debbi McManus, Connor McManus, Seagrass-Watch HQ.
Occasional and past watchers: Steve MacPherson, Vicki Cox, Brendan Vollemaere, Christie Currie, David & Maureen Champion, Dianne Maclean, Don Baxter, Hall , Job, Katie Martin, Kerry McGregor, Lyndon Harris, Maureen Champion, N Clouston, Noel Wilson, Sheryl Keates, Stephen Pesch,Nicola Udy, Ian Curtis Simon Baltais, Ray Rowe & Tony Iveson.
Location: Close to Oyster Point, adjacent to the seawall. WN3 is at Darling Point, WN4 is south of Darling Point.
Site codes: WN1, WN2, WN3, WN4
Issues: Baitworm digging, urban stormwater, sewage and agricultural runoff, coastal development

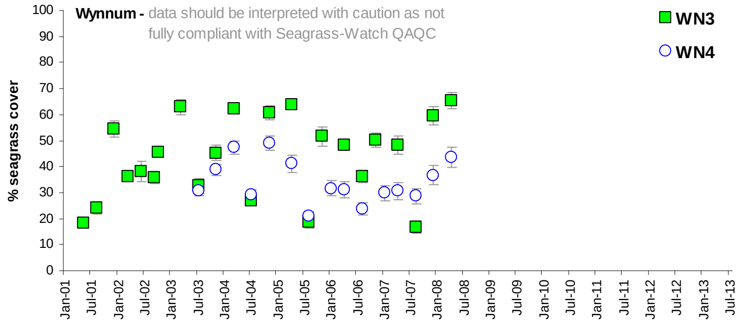
Comments: Waterloo Bay on the western side of Moreton Bay, extends from the mouth of the Brisbane River south to Wellington Point. Numerous small creeks make up the Redland Catchment which drains directly into Waterloo Bay, These creeks include Tingalpa, Coolnwynpin, Tarradarrapin, Hilliards, Eprapah, Moogurrapum and Weinum Creeks. There are a range of land uses within the catchment such. as poultry farming, plant nurseries, flower farms, market gardens, urban areas and bushland. Tingalpa Reservoir impounds Tingalpa Creek. There are five sewage treatment plants discharging in the Redlands/Waterloo Bay catchment.

Waterloo Bay is characterised by relatively stable water quality with good (A-) biological health (EHMP 2012). Although the region is affected by the Brisbane River through Boat Passage, water currents generally force nutrients and sediments from the river mouth northward away from Waterloo Bay. It is the only western embayment of Moreton Bay that still supports coral, macroalgal and seagrass communities. Generally stress tolerant species capable of withstanding sediment loading dominate. Healthy meadows of the seagrass *Zostera capricorni* are present in Waterloo Bay and depth ranges of most meadows have not changed since 1993, indicating that these meadows are generally stable.

Status (Jun08):

- Seagrass abundance appears to follow typical season pattern (higher in late spring-summer than winter).
- Post 2010, WN1 and WN2 sites monitored by Seagrass-Watch HQ.
- Sites are dominated by **Zostera capricorni** with **Halophila ovalis**. Species composition appears relatively stable. A few plants of *Halophila spinulosa* were reported in late 2003 at the Darling Point site.
- Site WN3 at Darling Point appears to be in the best condition, as seagrass abundances have continued to increase against a background seasonal trend. This site is less impacted and has higher tidal flushing.
- Site WN1 is possibly the highest impacted site. Seagrass abundance at this site are generally lower and more variable, macroalgae are medium to high and epiphytes appear to persist.



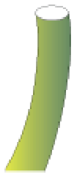


For more information, visit http://www.seagrasswatch.org/moreton_bay.html

A guide to the identification of South East Queensland's Seagrasses

Adapted from *Waycott et al., 2004*)

Leaves cylindrical

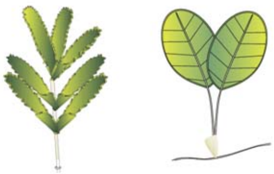


cylindrical

Syringodium isoetifolium

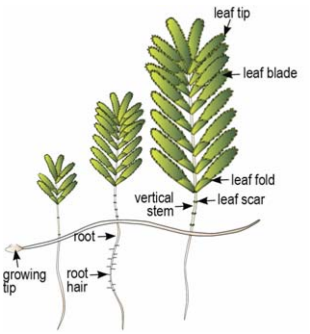
- leaves taper to a point
- leaves contain air cavities
- inflorescence a "cyme"
- leaves 7-30cm long

Leaves oval to oblong



oval to oblong

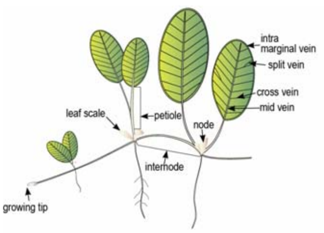
obvious vertical stem with more than 2 leaves



Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated
- shoots can be up to 15cm long
- 10-20 pairs of leaves per shoot
- leaf 15-20mm long and 3-5mm wide

leaves with petioles, in pairs



Halophila ovalis

- cross veins 8 or more pairs
- leaf margins smooth
- no leaf hairs
- leaf 5-20mm long
- separate male & female plants

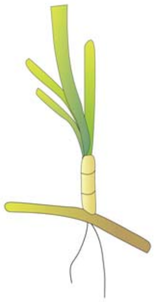
Halophila decipiens

- leaf margins serrated
- 6-8 cross vein pairs
- fine hairs on both sides of leaf blade
- leaves are usually longer than wide

Halophila minor

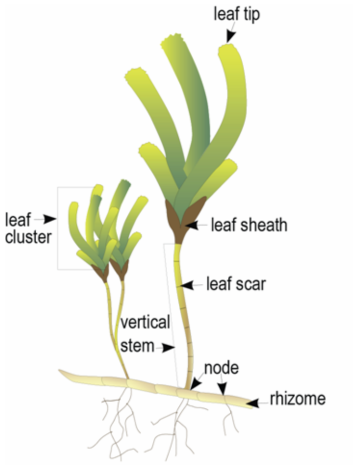
- oval leaf less than 5mm wide
- less than 8 pairs of cross veins
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Leaves strap-like



straplike

Leaves can arise from vertical stem



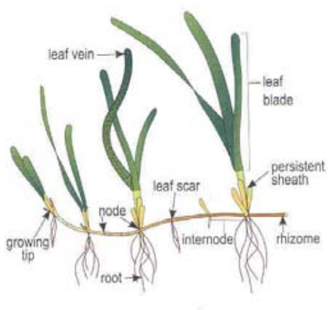
Cymodocea serrulata

- leaf tip rounded with serrated edge
- 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 with 3 distinct parallel- veins, sheaths fibrous
- narrow leaf blades 0.25-5mm wide
- rhizome usually pale ivory, with small black fibres at the nodes

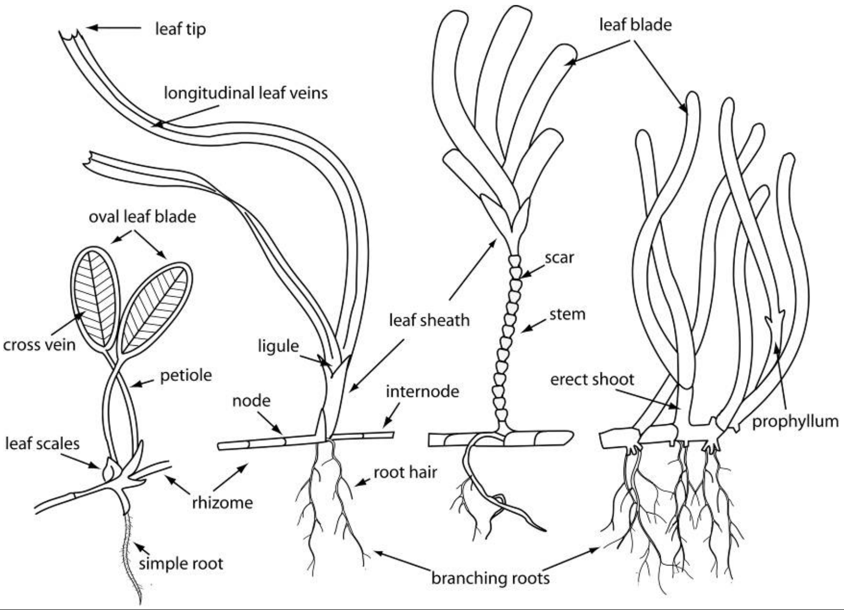
Leaves always arise directly from rhizome



Zostera muelleri subsp. *capricorni*

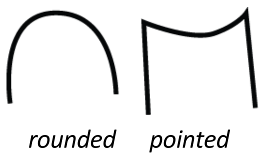
- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- rhizome usually brown or yellow in younger parts
- prophyllum present, i.e. a single leaf originating from the rhizome instead of from the vertical, leaf bearing shoot.

Parts of a seagrass plant



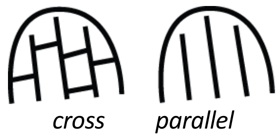
Leaf

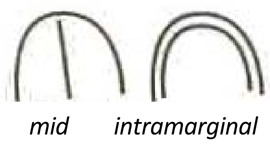
Tip Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.



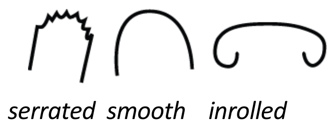
Veins Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for Identification.

- 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

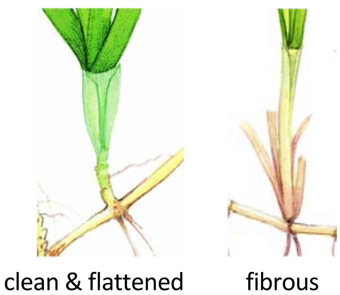




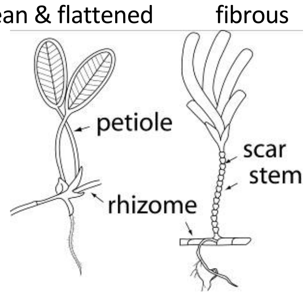
Edges The edges of the leaf can be either serrated, smooth or inrolled



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.

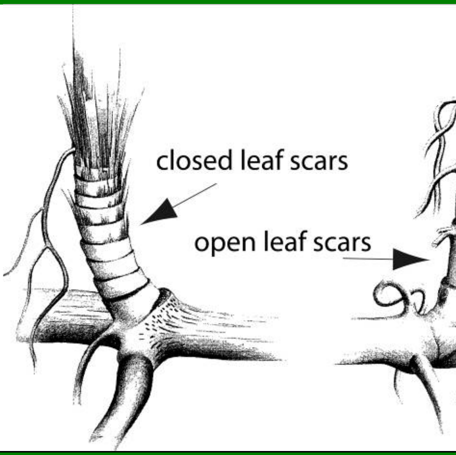


Attachment The leaf can attach directly to the rhizome, where the base of the leaf clasps the rhizome, or from a vertical stem or stalk (petiole) e.g. *Halophila ovalis*.



Stem

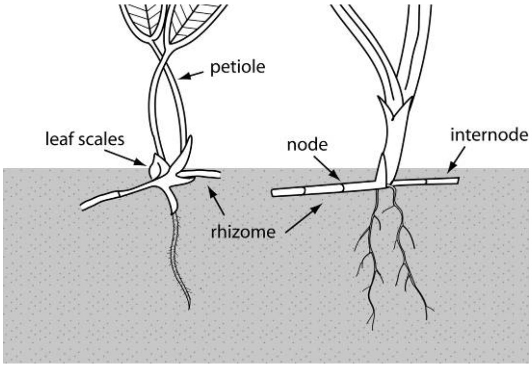
The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as scars. Scars can be closed (*entirely circle the vertical stem*) or open (*do not entirely circle the vertical stem*).



from Lanyon 1986

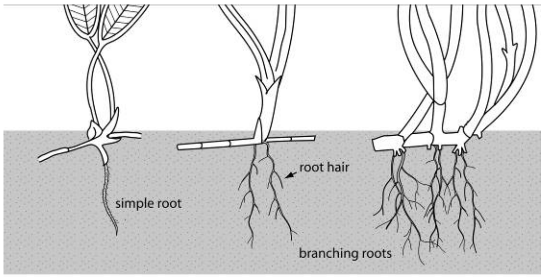
Rhizome

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 effect growth and survival. Factors include:

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

Seagrass-Watch

A simple method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses 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 established local community groups, schools, universities & research institutions, government (local & state) or non-government organisations.

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

Seagrass-Watch 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. As the collection of data by a diversity of participants necessitates a high level of training to ensure that the data is of a standard that can be used by management agencies. 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. Informal training is also conducted by local coordinators and/or scientists. Ideally, at least one formally trained volunteer is 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 scientist – 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 however 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 from 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 Error 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 Level 1 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 participants 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.

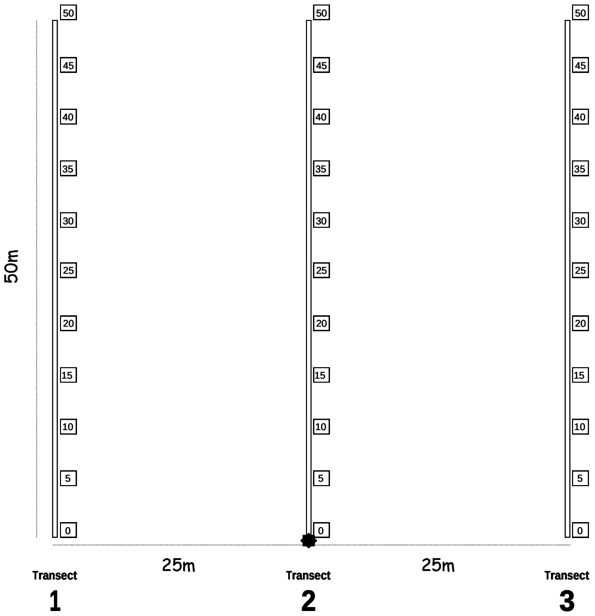
THE GOALS OF THE PROGRAM ARE:

- *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 volunteers involved in advance so they can make their arrangements to get to the site on time. List on this timetable what the volunteers need to bring.

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

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 usually taken at the 5m, 25m and 45m quadrats along each transect, or of quadrats of particular interest. 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, turtle feeding) within the comments column.

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%

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 the 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 epipfauna 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 (eg 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 quarterly sampling and request new materials
- Store gear for next quarterly 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, press the sample as soon as possible.
- Allow to dry in a dry/warm/dark place for a minimum of two weeks. For best results, replace the newspaper after 2-3 days.

Step 3. Submit all data

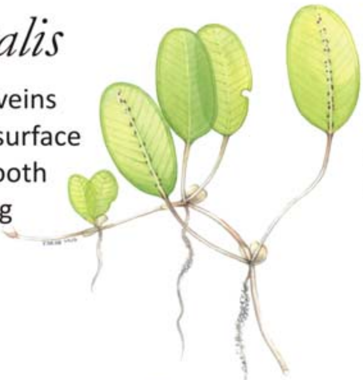
- Data can be entered into the MS-Excel file downloadable from www.seagrasswatch.org. Email completed files to hq@seagrasswatch.org
- Mail original datasheets, photos and herbarium sheets

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

SEAGRASS SPECIES CODES

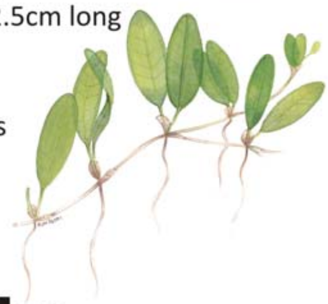
Ho
Halophila ovalis

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



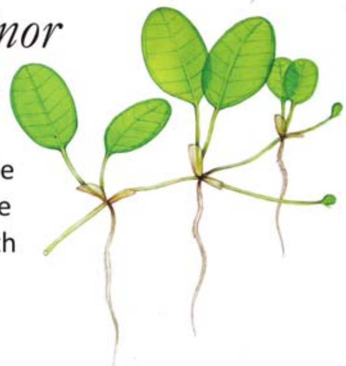
Hd
Halophila decipiens

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



Hm
Halophila minor

- less than 8 pairs of cross veins
- small oval leaf blade less than 5mm wide
- leaf margins smooth
- no leaf hairs



Hu
Halodule uninervis

- flat leaf, 0.25-5mm wide
- 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

Hs
Halophila spinulosa

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

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

Zc
Zostera muelleri subsp. *capricorni*

- flat leaf, 2-5mm wide
- 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

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 (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, pinning or nothing. 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 Australia 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 of 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

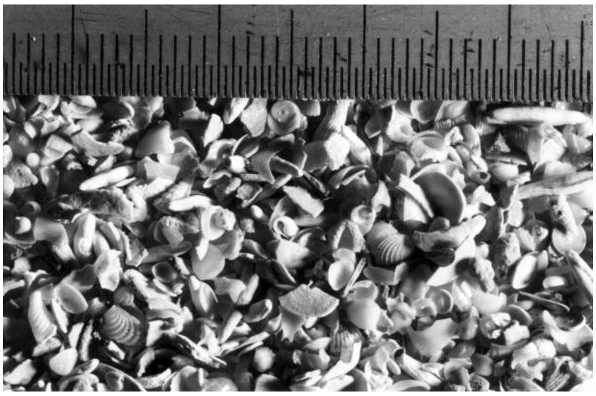
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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).

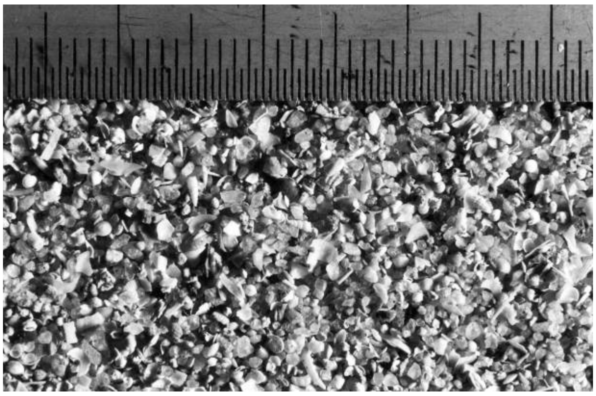
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

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

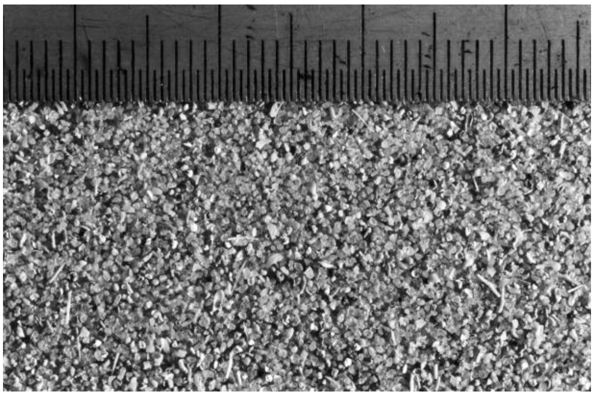
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments (see McKenzie, 2007), http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf).



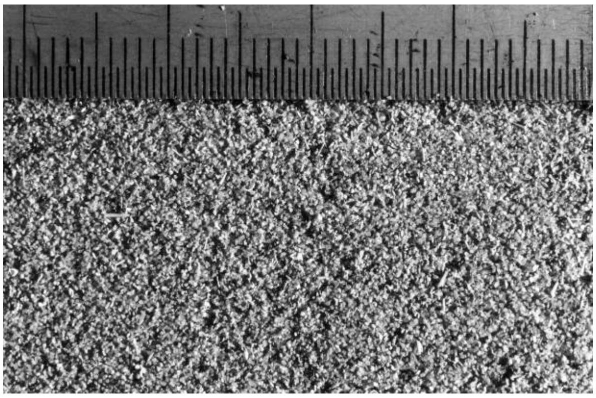
gravel (>2mm)



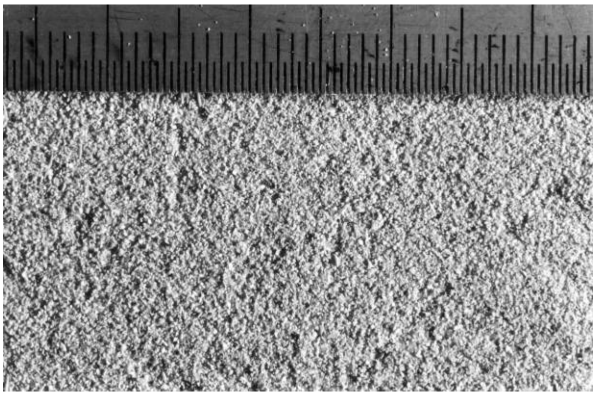
very coarse sand (1 – 2 mm)



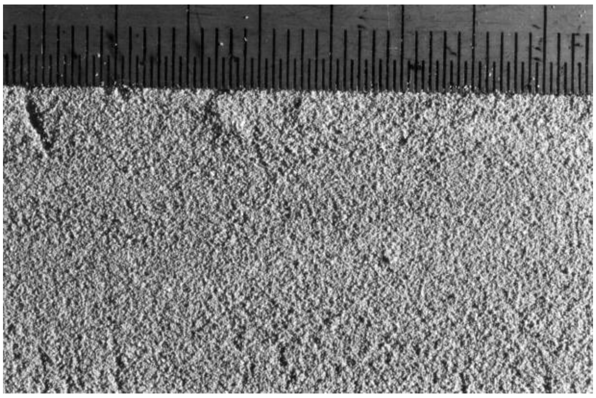
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

Notes:

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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; Aswani and Weiant, 2004; Turnbull, 2004; Middlebrook and Williamson, 2006; Gaskell, 2003; George et al., 2004). This can only occur if the resource owners actively involve themselves in the management of their resources. Western science also needs to recognise that resource owners have practical and spiritual connections with the resources found within their environment. Once this is recognized then this approach will have the added benefit of empowering communities who own the knowledge to be the primary managers and leaders in decisions about their land and sea country.

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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. www.reef.crc.org.au/seagrass/index.html

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. wwwscience.murdoch.edu.au/centres/others/seagrass/seagrass_forum.html

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

Western Australian Seagrass Webpage Mainly focused on Western Australian research, but provides some general information and links to international seagrass sites. wwwscience.murdoch.edu.au/centres/others/seagrass/

UNEP - World Conservation Monitoring Centre Explains the relationship between coral reefs, mangroves and seagrasses and contains world distribution maps. www.unep-wcmc.org

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

Notes:

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

Please complete the following statements in your own words

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

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What I enjoyed most about the training was..

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It could have been better if ....

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I did not realize that..

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Now I understand that ....

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

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

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Other comments...

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Please hand in your form once you have completed it.

Thank you