Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in Singapore

Botany Centre, Singapore Botanic Gardens

June 2013

Len McKenzie & Rudi Yoshida

First Published 2013

Disclaimer

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

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

The correct citation of this document is

McKenzie, LJ & Yoshida, R.L. (2013). Seagrass-Watch: Proceedings of a workshop for monitoring seagrass habitats in Singapore, June 2013. (Seagrass-Watch HQ, Cairns). 58pp.

Produced by Seagrass-Watch HQ

Front cover photos (left to right): male flowers of *Enhalus acoroides*, Cyrene Reef by Ria Tan; estuarine seahorse (*Hippocampus kuda*) in *Halophila spinulosa* meadow, Changi, by Rian Tan; monitoring Pulau Semakau by Len McKenzie.

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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.*

Seagrass-Watch in Singapore is an initiative of TeamSeagrass in close partnership with the Biodiversity Centre of the National Parks Board. This workshop is supported by the National Parks Board Biodiversity Centre, Seagrass-Watch HQ, and TeamSeagrass Singapore. 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.*

As part of the Level 2 workshop we will:

1. *refresh seagrass identification skills;*
2. *revise seagrass biology knowledge;*
3. *review Seagrass-Watch protocols;*
4. *address data collection issues (QAQC);*
5. *demonstrate Seagrass-Watch field monitoring skills; and*
6. *conduct a vulnerability analysis for seagrass in Singapore.*

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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courtesy Ria Tan, www.wildsingapore.com

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 – Intertidal Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal fisheries habitats. Len has over 20 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 8th June 2013 (Botany Centre, Singapore Botanic Gardens)

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

Sunday 9th June 2013 (Botany Centre, Singapore Botanic Gardens)

1030 - 1100 *(30min)*	Seagrass importance
1100 – 1145 *(45min)*	Seagrass threats*
1145 – 1200 *(15min)*	Seagrass monitoring*
1200 - 1230 *(30min)*	*Lunch*
1230 - 1330 *(60min)*	Seagrass-Watch: how to sample*
1330 – 1430 *(60min)*	Seagrass-Watch: QAQC & how data is used*
1430 – 1445 *(15min)*	*Wrap up for day*

Saturday 15th June 2013 (Chek Jawa)

0800 – 1100 **Field exercise:** Seagrass-Watch monitoring

How to get there:

- *if you have signed up on the teamseagrass database (http://groups.yahoo.com/group/teamseagrass/database), you will be sent an email with more details closer to the date of the trip*
- *be punctual. Arrive 15 mins at the meeting point before the stated departure time. We usually board 5-10 minutes before departure time.*
- *be well rested, well fed, and well hydrated beforehand. Do not come if you are not feeling well.*

What to bring:

- *your IC in case of checks by security*
- *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.

Tides (Tanjong Changi): 0800=0.6m, 0900=0.5m, 1000=0.6m, 1100=0.9m

Agenda - Level 2 *(advanced)*

Saturday 15th June 2013 (Chek Jawa)

0800 – 1100	**Field exercise:** Seagrass-Watch monitoring

How to get there:

- *if you have signed up on the teamseagrass database (http://groups.yahoo.com/group/teamseagrass/database), you will be sent an email with more details closer to the date of the trip*
- *be punctual. Arrive 15 mins at the meeting point before the stated departure time. We usually board 5-10 minutes before departure time.*
- *be well rested, well fed, and well hydrated beforehand. Do not come if you are not feeling well.*

What to bring:

- *your IC in case of checks by security*
- *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.

Tides (Tanjong Changi): 0800=0.6m, 0900=0.5m, 1000=0.6m, 1100=0.9m

Sunday 16th June 2013 (Botany Centre, Singapore Botanic Gardens)

0900 - 0910 *(10min)*	Welcome & Introduction
0910 - 0930 *(20min)*	Seagrass Biology and Identification refresher
0930 - 1030 *(60min)*	**Classroom activity:** Seagrass Identification
1030 - 1045 *(15min)*	*Break*
1045 - 1130 *(45min)*	Seagrass-Watch protocols refresher
1130 - 1145 *(15min)*	Seagrass-Watch QAQC
1145 - 1230 *(45min)*	**Classroom activity:** QAQC
1230 - 1300 *(30min)*	*Lunch*
1300 - 1330 *(30min)*	**Classroom activity:** Seagrass-Watch data entry
1330 - 1410 *(40min)*	Factors important for seagrass growth
1410 - 1415 *(5min)*	Seagrass threats
1415 – 1515 *(45min)*	**Classroom activity:** vulnerability analysis
1515 – 1530 *(15min)*	*Break*
1530 – 1615 *(45min)*	**Classroom activity:** continued.....
1615 – 1630 *(15min)*	Wrap up

Notes:

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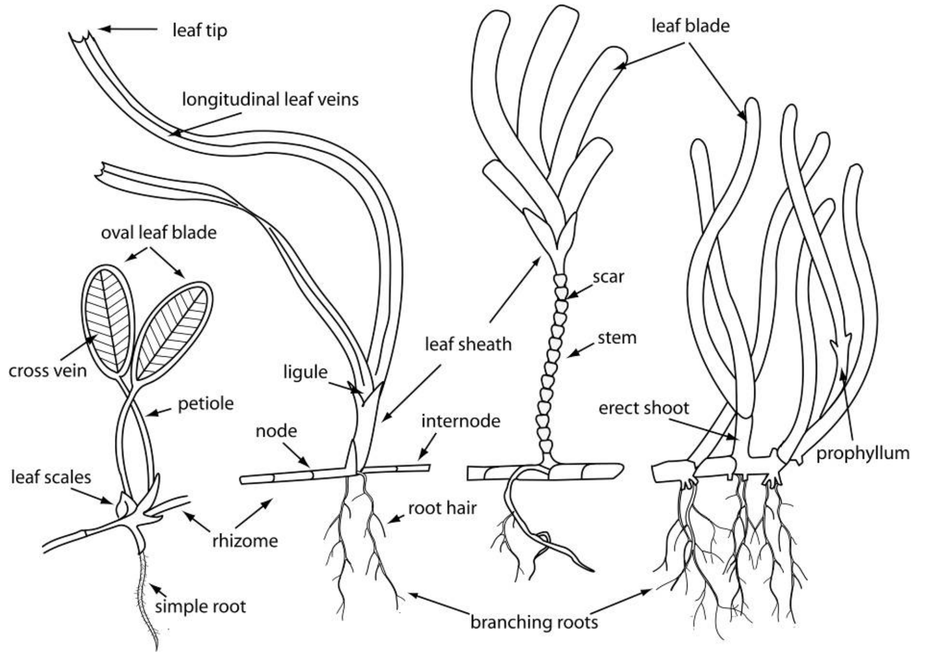
Background

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).

Seagrass are marine 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.

Seagrasses have roots, stems and leaves

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.

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

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

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

Seagrass leaves lack stomata (microscopic pores on the under side of leaves) but have thin cuticle to allow gas and nutrient exchange. They also possess large thin-walled aerenchyma. 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 are not true grasses

Seagrasses are more closely related to lilies

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.

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

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

Twelve species have been found within Singapore's waters. Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. Seagrasses are not seaweeds. Seaweed is the common name for algae.

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

Seagrass requirements for growth

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

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

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea 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 can tolerate a range of salinities. Some species are less tolerant than others

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

Light availability is the most important factor determining seagrass growth

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

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

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.

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 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.

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

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.

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.

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.

Seagrass meadows are a major food source for a number of grazing animals and are considered very productive pastures of the sea. The dugong

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

(*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.

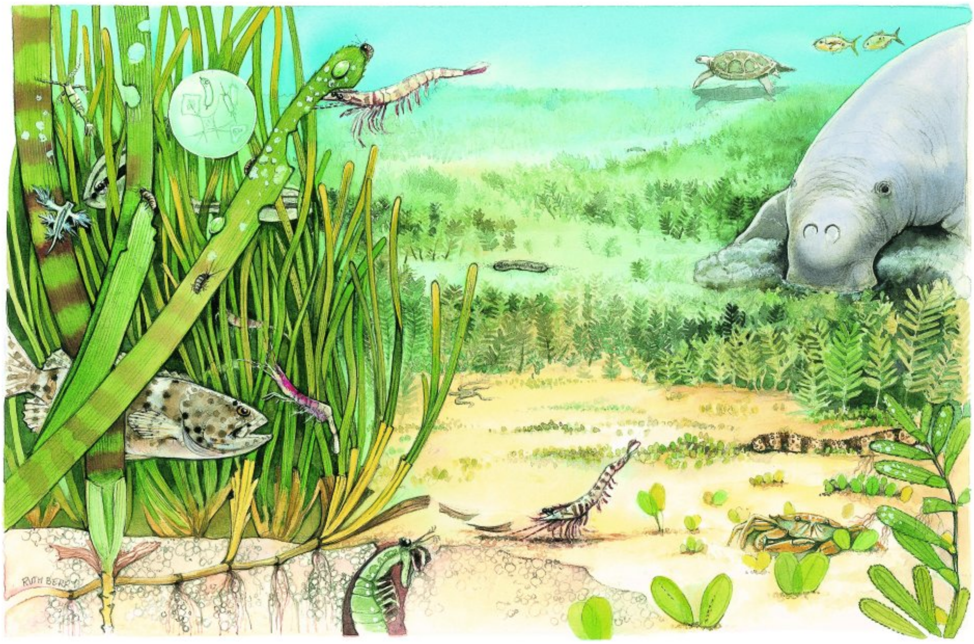
Coastal development can have a major impact on seagrass meadows

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:

Seagrasses of Singapore

Updated from McKenzie, Yaakub, & Yoshida. (2009).

Seagrass meadows in Singapore play a critical role in supporting coastal marine communities and in maintaining diverse flora and fauna. They are an important component of coastal fisheries productivity and they play an important role in maintaining coastal water quality and clarity. The seagrasses of Singapore are also important food for marine green turtles and dugongs.

The coastal and marine ecosystems of Singapore are however, limited and modified by development and the port industry (which is one of the biggest income-earning businesses in the country). Port limits extend to almost all the entire territorial waters, and reclamation has transformed almost the entire southern and northeastern coasts of the main island considerably (Chou and Goh 1998). The steep beach front along the southeastern coast was once composed of sandy beaches and mudflats and original rocky shores are found mainly on the southern offshore islands and small parts of the northern coast. There are currently no specific laws for the protection of existing seagrass meadows (ICRI 1997).

There are 12 seagrass species found in Singapore: *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule pinifolia, Halodule uninervis, Halophila beccarii, Halophila decipiens, Halophila minor, Halophila ovalis, Halophila spinulosa, Syringodium isoetifolium* and *Thalassia hemprichii* (Green & Short 2003; den Hartog 1970; Yaakub, 2008). Seagrasses were reported to be common between late 1950's and the early 1970's on reef-flats and the intertidal zones at Kranji and West Johore Strait (Chuang 1961; Johnson 1973). Loo et al. (1996) reported seagrass at Changi beach and Beting Bemban Besar (patch reef). Other studies reported the presence of seagrasses from locations south of the main island of Singapore which included Pulau Hantu, Pulau Semakau, Terumbu Raya (patch reef) and Hantu West (patch reef) and in the north, Pulau Tekong (Hsu and Chou, 1989a,b). A patch of *Halophila decipiens* was recently discovered in the waters off Pulau Semakau at a depth of about 8m, by Eugene Goh, who was diving off the island in January 2008 (Yaakub, 2008). It has been sighted at other locations in the waters of Southern Singapore, including the sandy intertidal lagoon of Pulau Sekudu (Ria Tan, Pers. Comm. April 2009).

Above: Halophila decipiens in sandy intertidal lagoon, Pulau Sekudu – May 2007. Photo courtesy Ria Tan.

Left: Halophila decipiens off Pulau Semakau in 8m – 28 Jan 2008. Photo courtesy Karenne Tun.

Mapping of seagrass distribution in Singapore is limited and *ad-hoc*. It is estimated that seagrass cover around 150ha of the predominately intertidal areas of Singapore (Yaakub *et al.,* 2013). We are not aware of any significant efforts to map the distribution of subtidal seagrasses within the territorial waters of Singapore, but it is unlikely the resource is large due to the relatively turbid waters, which would possibly prohibit seagrass below 10m water depth. Although seagrass meadows can be found scattered in various coastal areas, a few notable locations are the extensive reef flats of the southern shores (e.g. Cyrene reefs, west of Pulau Semakau) and off Pulau Ubin.

To provide an early warning of change, a long-term monitoring and community engagement program has been established across Singapore as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org; McKenzie *et al.* 2003). Establishing a network of monitoring sites in Singapore 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.

The following is a summary of the current status of Seagrass-Watch monitoring in Singapore.

CHEK JAWA (PULAU UBIN)

Tanjong Chek Jawa is a cape and the name of its surrounding areas located on the south-eastern tip of Pulau Ubin, a small island (10.19 km^2) off the north-eastern coast of the main island of Singapore. The island was once a cluster of five smaller ones separated by tidal rivers, but the building of bunds for prawn farming has since united these into a single island. Two other islets, Pulau Ketam (Crab Island) and Pulau Sekudu (Frog Island), lie to its south. Pulau Ubin is one of the last areas in Singapore that has been preserved from urban development.

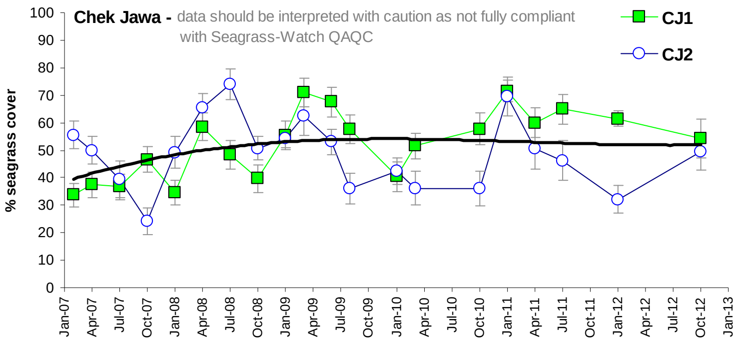
Located at the eastern tip of Pulau Ubin, Chek Jawa is a collection of six distinct habitats - coastal forest, mangroves, sand bars, seagrass lagoon, rocky shore & coral rubble. Slated for land reclamation in 1992, the assets of Chek Jawa wetlands were unveiled only in December 2000. After carefully considering all public submissions and extensive consultations with scientific experts and relevant government agencies, it was announced in 2001 that reclamation works would be deferred as long as Pulau Ubin is not required for development.

Eight seagrass species have been reported from Chek Jawa: *Halophila beccarii, Halophila spinulosa, Cymodocea rotundata, Halophila ovalis, Halophila minor, Halodule uninervis, Thalassia hemprichii* and isolated clumps of *Enhalus acoroides*. The meadows are predominately within a shallow protected lagoon behind a large sand bank. Meadows are mainly intertidal, however the seaward edges of the sand bank are fringed by large *Halophila spinulosa* meadows.

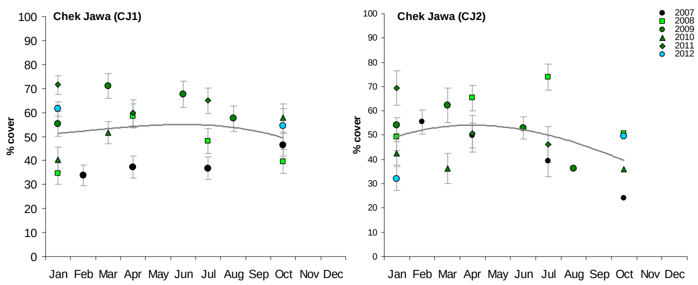
Monitoring: ongoing, *triannual*
Principal watchers: TeamSeagrass
Location: shallow lagoon on north east shore of Pulau Ubin
Site code: CJ1, CJ2
CJ1 position: N1.40991 E103.99235 *(heading 95 degrees)*
CJ2 position: N1.41249 E103.99299 *(heading 97 degrees)*
Best tides: <0.5m *(port Victoria Dock)*
Issues: marine debris/litter, coastal development, land reclamation, land runoff
Status (Jun13):

- Seagrass cover is generally between 25 and 65%, and is slightly higher at CJ1 than CJ2.

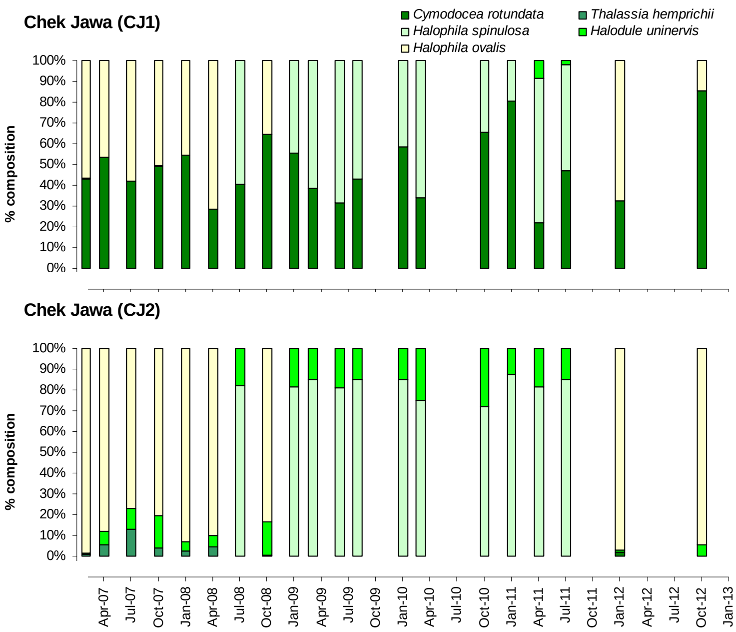
- The long-term trend in abundance suggests the meadow abundance has stabilised, after increasing in 2007-2008.



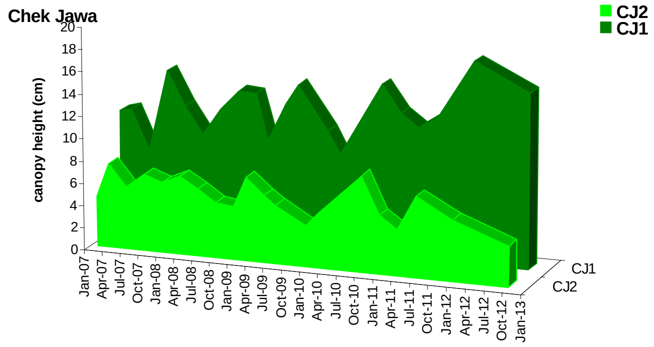
- A seasonal trend in seagrass abundance is apparent at both sites, with higher abundances from April to June, and lower abundance October to December.



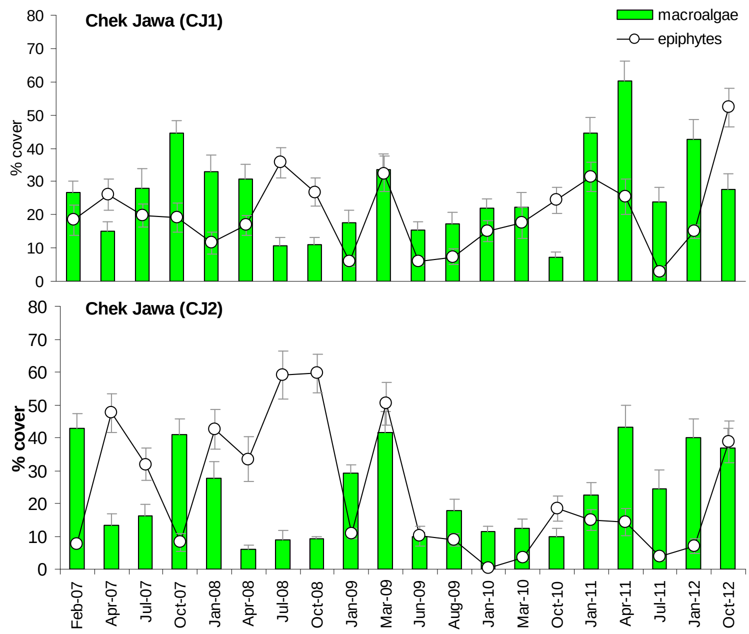
- Of the eight seagrass species found at Chek Jawa, five are within the monitoring sites: *Halophila spinulosa, Cymodocea rotundata, Halophila ovalis, Halodule uninervis,* and *Thalassia hemprichii.*
- Site CJ1 has been mainly dominated by *C. rotundata* since monitoring commenced, but from Jun08-Jun11, the abundance of *Halophila spinulosa* increased across the meadow. Species composition has fluctuated greatly at CJ2, but has been dominated by *Halophila* species.



- Canopy height is greater at CJ1 as the site has a high composition of *C. rotundata*. Although *H. ovalis* dominates CJ2, canopy height is driven by the *H. uninervis* present.



- Macro-algal abundance is similar at both sites (25-30% on average) and fluctuates greatly within and between years. The long-term average for macroalgae abundance at Chek Jawa is 25%. Patterns in epiphyte abundance are similar between sites, however the amplitudes differ. Epiphytes were higher at CJ2 in 2008, however abundances are now slightly higher at CJ1. The long-term average for epiphyte abundance at Chek Jawa is 22%. Epiphyte abundances has increased at both sites in 2012 to above the long-term average. Whether this is natural fluctuations or a consequence of elevated nutrients is currently unknown.



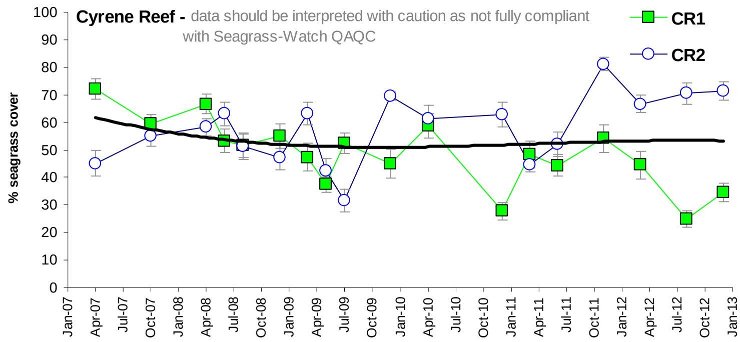
CYRENE REEF (TERUMBU PANDAN)

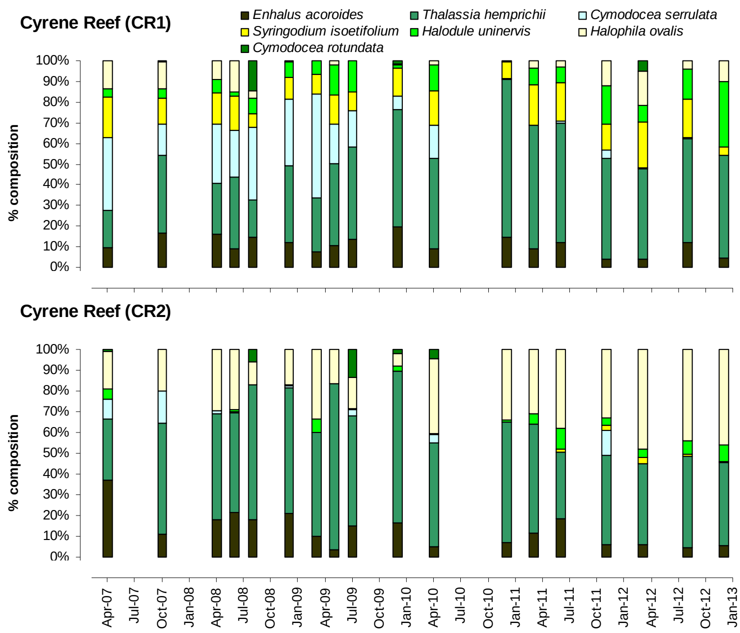
Cyrene is comprised of 3 patch reefs - Terumbu Pandan, Pandan Beacon and South Cyrene Beacon, and is one of the largest patch reef systems in Singapore. Cyrene Reef is a key maritime crossroad where east-west traffic routes cross north-south routes. Approximately five hundred ships transit the waters around the reef every day. The reef is also next to massive industrial sites like Jurong Island and Pulau Bukom, and opposite Singapore's container terminals. With abundant seagrass meadows and other marine life, Cyrene is a natural wonder. The reef top meadow is a mixture of *Enhalus acoroides, Cymodocea serrulata, Cymodocea rotundata, Halodule uninervis, Halophila ovalis, Thalassia hemprichii* and *Syringodium isoetifolium*.

Monitoring: ongoing, *quarterly*
Principal watchers: TeamSeagrass
Location: reef platform on patch reef within harbour, south of mainland Singapore
Site code: CR1, CR2
CR1 position: N1.25992 E103.75311 *(heading 235 degrees)*
CR2 position: N1.25791 E103.75650 *(heading 240 degrees)*

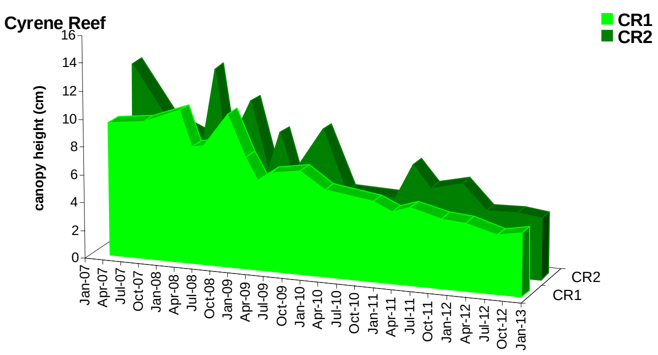
Best tides: <0.2m *(port Victoria Dock)*
Issues: marine debris/litter, port/industrial development, land reclamation, industrial runoff
Status (Jun13):

- Seagrass abundance long-term trend for the location appears stable, however there are differences between the sites.
- Seagrass abundance increased at CR2 in 2011-12, but this appears a consequence of increasing abundance of *Halophila ovalis*. As *H. ovalis* is an early colonising species, this may suggest an increased level of disturbance (e.g. sediment movement, wave action) at the site.
- Seagrass abundance at CR1 decreased, although composition of *Thalassia hemprichii* appears unchanged. Cover also appears to show a seasonal trend, with increases Mar-May, and decreasing until late in the year.



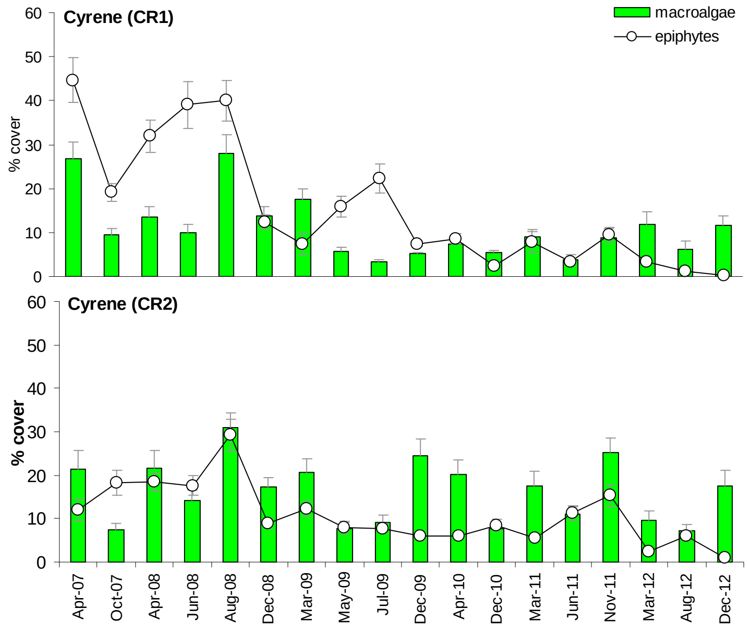


- Seagrass canopy height has decreased at both sites over the long-term.



- The long-term (5 year) average for macroalgae abundance at Cyrene Reef is 14%, which is lower than Pulau Semakau and Chek Jawa (30% and 25%, respectively). Macroalgae abundance has also decreased slightly at CR1 over the long-term, but has remained relatively stable at CR2.

- The long-term (5 year) average for epiphyte abundance at Cyrene Reef is 17%, which is lower than Pulau Semakau and Chek Jawa (43% and 22%, respectively). Epiphyte cover has similarly decreased over the long-term at CR1 and remained relatively stable at CR2.



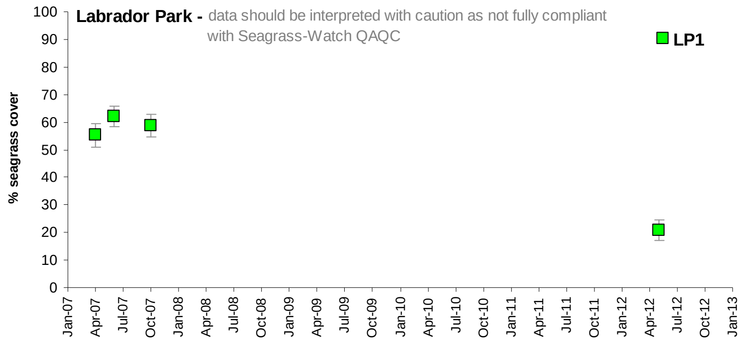
LABRADOR

Labrador Nature Reserve, also known as Labrador Park, is located on the southern coast of mainland Singapore. It contains the only rocky sea-cliff on the mainland that is accessible to the public for recreation, education and scientific research. Since 2002, 10 hectares of coastal secondary vegetation and its rocky shore have been gazetted as a Nature Reserve. Labrador Nature Reserve has a rich variety of flora and fauna. The rocky shore contains a multitude of corals and crabs, seagrasses (*Halophila ovalis, Thalassia hemprichii*, and *Enhalus acoroides*), sandworms and horseshoe crabs. The Common Hairy Crab (*Pilumnus vespertilio*) is often spotted in the area. At the eastern end of the Reserve is Berlayar Creek (aka Berlayar Canal), which is adjacent to the Keppel Golf Club.

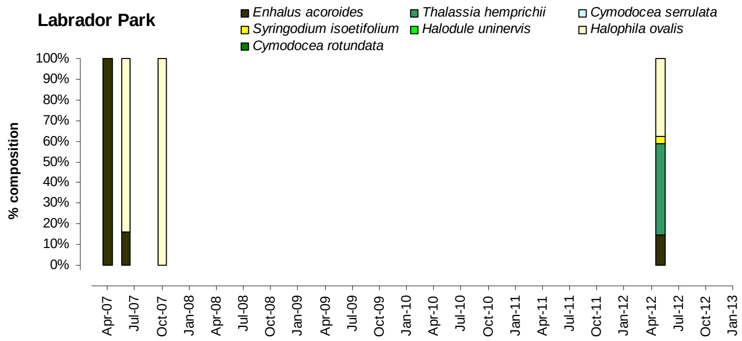
Monitoring: ongoing, *ad hoc*
Principal watchers: Ria Tan and TeamSeagrass.
Past watchers: Koh Li Ling Cheryl, Chua Jiemin, Joyce Lim Li-Keng, Fang Xinyi, Wu Dan Qiong Danielle, Yeo Weiying Jolyn (Raffles Girls School).
Location: intertidal rocky shore
Site code: LP1 (Labrador Nature Reserve)
Site code: LP2 (Berlayar Creek)
LP1 position: N1.26622 E103.80109 *(heading 300 degrees)*
LP2 position: N1.26475 E103.80895 *(east bank, heading west),*
N1.26520 E103.80715 *(west bank, heading south west),*
Best tides: <0.3m *(port Victoria Dock)*
Issues: marine debris/litter, port/industrial development, land reclamation, industrial runoff
Comments: Project initiated in early 2007 to investigate leaf growth rates of *Thalassia hemprichii* at Labrador beach. Supervisors: Mr Lim Cheng Puay (Raffles Girls School) and Ms Siti Maryam Yaakub (TeamSeagrass). To learn more, visit blog at http://labradorpark.wordpress.com/ LP1 transects run parallel to shoreline due to elongated shape of the meadow. LP2 at Berlayar Creek is haphazard sampling from a point on the east bank and a point on the west bank.
Status (Jun13):

- mean total seagrass abundance has decreased between 2007 and 2012, however due to limited available data, the trend cannot be investigated.

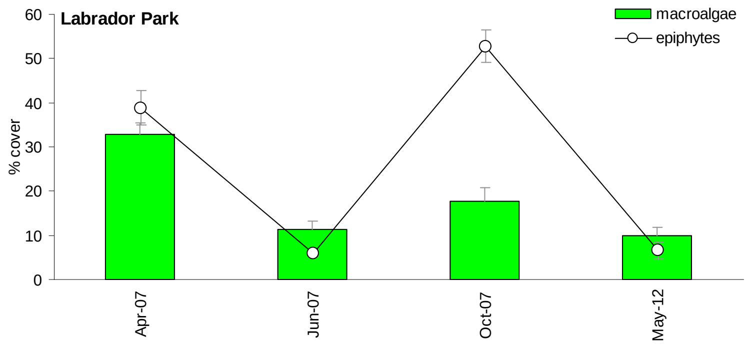
- Site LP2 has also been examined over the last couple of years, however, data is similarly unavailable to examined trends or condition.



- In 2007 only two seagrass species were present (*Enhalus acoroides* and *Halophila ovalis*), however in 2012 four species were reported, the additional species including *Thalassia hemprichii* and *Syringodium isoetifolium*. Only *Halophila ovalis* is present at Berlayar Creek.



- With a limited dataset, it is not possible to examine trends is abundance of macroalgae or epiphytes.



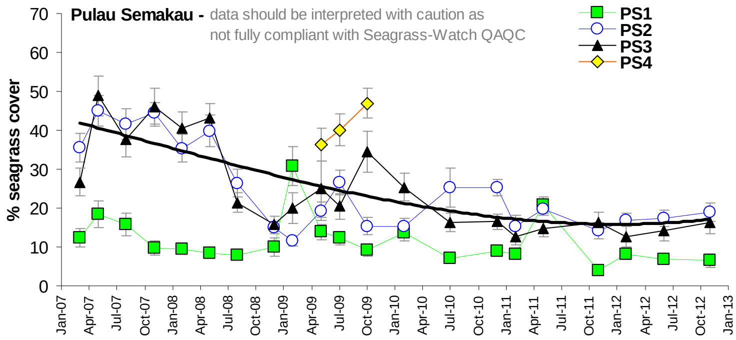
PULAU SEMAKAU

Pulau Semakau is located to the south of the main island of Singapore, off the Straits of Singapore. The Semakau Landfill is located on the eastern side of the island, by the amalgamation of the smaller Pulau Sakeng and "anchored" to Pulau Semakau with a rock bund. In operation since 1999, Semakau landfill is Singapore's first offshore landfill and now the only remaining landfill in Singapore. Semakau Landfill is filled mainly with inert ash produced by Singapore's incineration plants, which incinerate the country's waste, shipped there in a covered barge (to prevent the ash from getting blown into the air) every night.

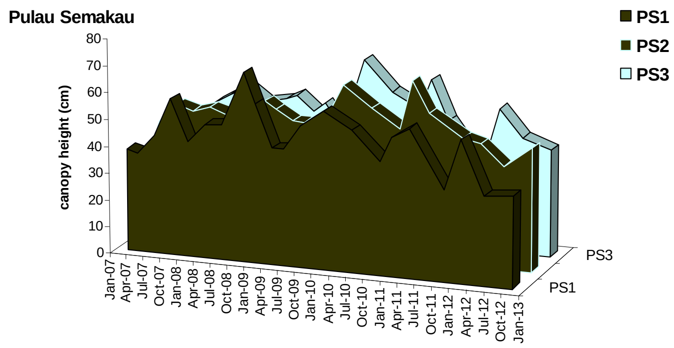
The western half of Pulau Semakau was left natural, unaffected by the landfill construction, and this is where the seagrass monitoring sites are located. Vast tracts of *Enhalus acoroides* (tape seagrass) fringe the island, stretching for kilometres. Pulau Semakau is one of the few places in Singapore where *Syringodium isoetifolium* occurs in abundance.

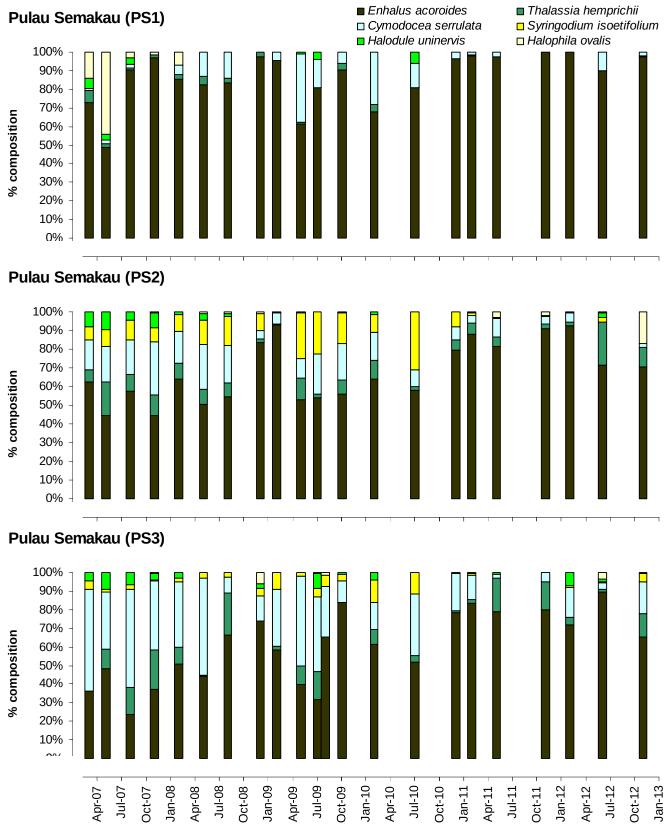
Monitoring: ongoing, *quarterly*
Principal watchers: TeamSeagrass
Location: fringing reef platform on western shore of island
Site code: PS1, PS2, PS3, PS4
PS1 position: N1.21344 E103.75809 *(heading 285 degrees)*
PS2 position: N1.21108 E103.75772 *(heading 285 degrees)*
PS3 position: N1.20837 E103.75714 *(heading 285 degrees)*
PS4 position: N1.20532 E103.75662 *(heading 285 degrees)*
Best tides: <0.3m *(port Victoria Dock)*
Issues: marine debris/litter, industrial runoff
Status (Jun13):

- Seagrass cover is significantly lower at PS1 than the other sites, and has remained low since monitoring was established. Seagrass abundance at PS1 varies between 8-18% on average.
- PS2 and PS3 decreased in abundance in late 2008 (18 months after being established). Since 2008, abundance has changed little, varying between 15-40%.
- Although seagrass abundance has declined over the long term, there has been little decline since 2008 with abundance remaining relatively stable between 2009-2012. Within years, a seasonal trend in abundance is apparent, with higher abundances Mar-May, and lower from Aug-Dec.

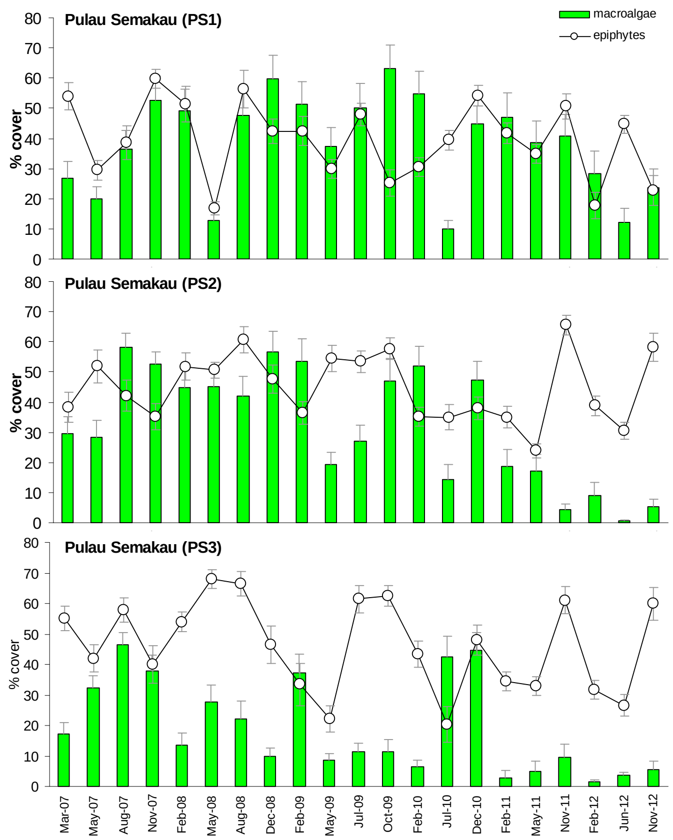


- There appears a transition in species composition between the sites, from *Enhalus* to *Cymodocea* dominating, from PS1 to PS3 respectively in the period prior to 2009.
- Species composition appears to fluctuate, primarily a consequence of the composition of *Halophila ovalis* or *Cymodocea serrulata*. The decline in composition of *C. serrulata* corresponds with the decreasing abundance. In 2009-2010 the composition of *Syringodium isoetifolium* also increased at PS2.
- Canopy height has not changed greatly over the monitoring period, and canopy heights are representative of the change in species dominance between sites.





- The Pulau Semakau epiphyte long-term average is 43%, the highest of all monitoring locations in Singapore. Epiphyte abundance is also seasonally higher in Sep-Nov of each year.
- The Pulau Semakau macroalgae long-term average is 30%, the highest of all monitoring locations in Singapore. Macroalgae has differed between years, decreasing at PS2 and PS3 in 2011 and at PS1 in 2012. Within years, macroalage is seasonally higher in Aug-Nov of each year.

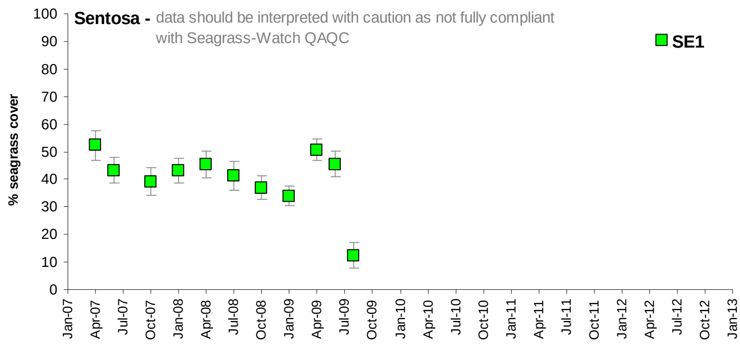


SENTOSA (PULAU BLAKANG MATI)

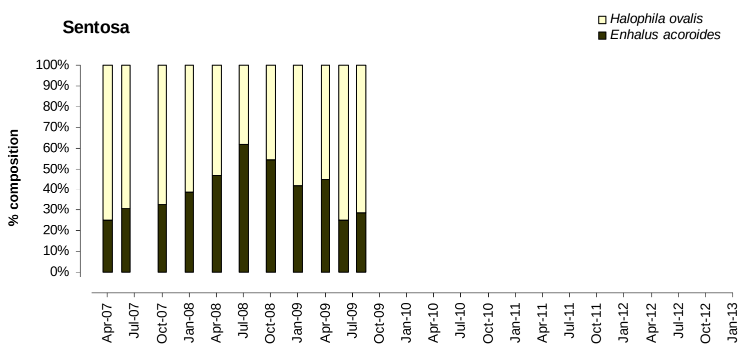
Sentosa, which means peace and tranquillity in Malay, is a popular island resort in Singapore, visited by some five million people a year. Attractions include a two-kilometre long sheltered beach, Fort Siloso, two golf courses, two five-star hotels and the Resorts World Sentosa; featuring the theme park Universal Studios Singapore and the worlds largest aquarium (S.E.A. Aquarium). Sentosa contains 5ha of natural rocky shore beneath Fort Siloso, between Underwater World and Rasa Sentosa, with coral reefs and some seagrasses (*Enhalus acoroides* and *Halophila ovalis*). In 2006, a group of volunteers conducted a seagrass survey of Sentosa. As a result of the Sentosa transect, TeamSeagrass was established.

Monitoring: ongoing, *quarterly*
Principal watchers: TeamSeagrass
Location: fringing reef on north western shore of island
Site code: SE1
SE1 position: N1.25848 E103.80737
Best tides: <0.2m *(port Victoria Dock)*
Issues: marine debris/litter, coastal development
Comments: Because the Sentosa shore is narrow, haphazard quadrat sampling from 4 points is used at this site.
Status (Jun13):

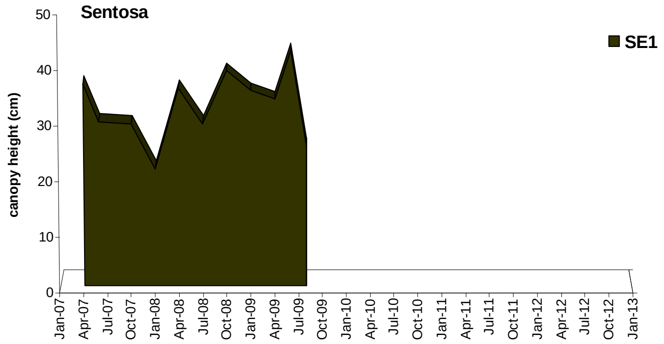
- Prior to July 2009, seagrass cover did not vary greatly between years, although a seasonal pattern may be apparent with years, with lower abundance later in the calendar year. In August 2009, seagrass abundance declined, however whether it has since improved is unknown.



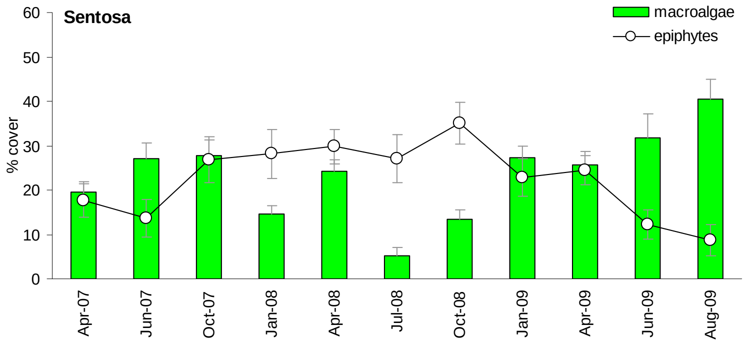
- The site is dominated by *Halophila ovalis*, however in 2008, the abundance of *H. ovalis* declined for 6 months, during which period *Enhalus acoroides* dominated.



- *Enhalus acoroides* canopy height has changed little over the monitoring period.



- Macroalgae cover is generally between 10 - 30% on average. There is a significant ($p<0.05$) inverse relationship between epiphyte cover and macroalgae cover (i.e. epiphyte increases when macroalgae decreases).

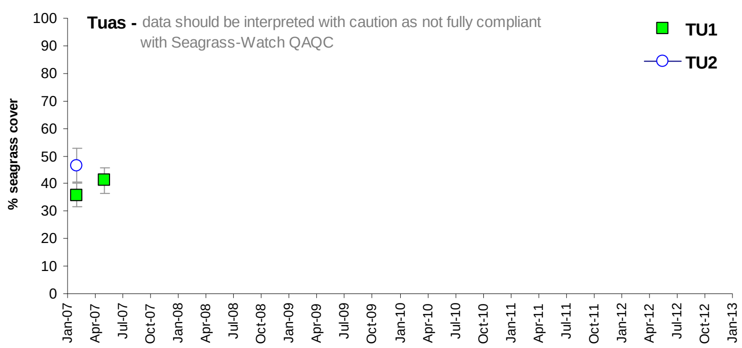


TUAS

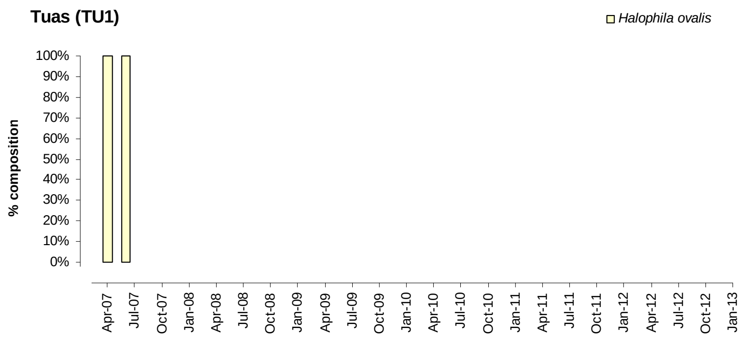
Tuas is largely an industrial zone located in the western part of Singapore. The Tuas Planning Area is located within the West Region, and is bounded by Tengah Reservoir to the north, Strait of Johor to the west, Straits of Singapore to the south, and the Pan Island Expressway to the east. Seagrass meadows (*Enhalus acoroides* and *Halophila ovalis*) are scattered over the narrow intertidal banks of Tuas. The site is monitored by volunteers from Schering Plough, with assistance from TeamSeagrass. Schering Plough volunteers also replant mangroves along the Tuas shoreline.

Monitoring: ongoing, *quarterly*
Principal watchers: Schering Plough
Location: fringing reef platform on western shore of island
Site code: TU1, TU2
TU1 position: N1.32864 E103.62941
Best tides: <0.5m *(port Victoria Dock)*
Issues: marine debris/litter, industrial runoff, coastal development, land reclamation
Comments: Because the Tuas shore is narrow, haphazard quadrat sampling is used at this site.
Status (Jun13):

- Seagrass cover is moderate along the shore, although patchy. Current status is unknown.



- The only species present in the Tuas sites was *Halophila ovalis*.

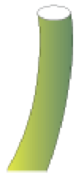


For more information, visit http://www.seagrasswatch.org/Singapore.html

A guide to the identification of seagrasses in Singapore

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

Leaves cylindrical



cylindrical

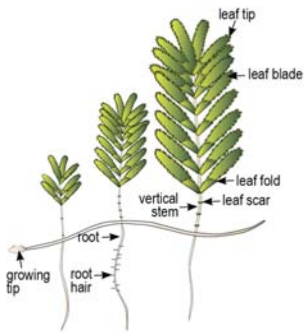
Syringodium isoetifolium

- 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



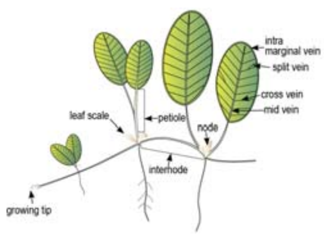
Halophila spinulosa

- 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

Halophila beccarii

- leaves arranged in clusters of 5-10, at a node on vertical stem
- short vertical stem between clusters
- leaf clusters do not lie flat
- leaves elongate, with mid-vein and no obvious cross-veins
- leaf margin finely serrated

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

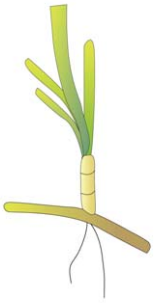
Halophila decipiens

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

Halophila minor

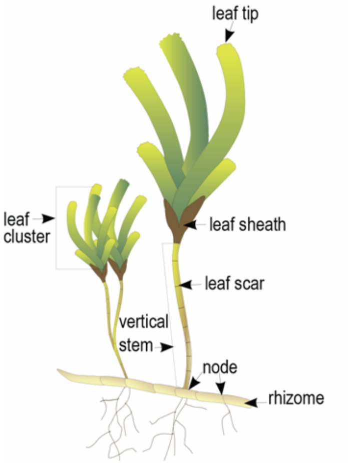
- oval leaf less than 5mm wide
- less than 8 pairs of cross veins
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Leaves strap-like



straplike

Leaves can arise from vertical stem



Cymodocea rotundata

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

Cymodocea serrulata

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

Halodule uninervis

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

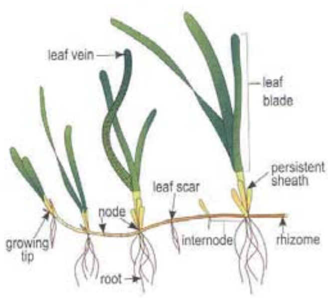
Halodule pinifolia

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

Thalassia hemprichii

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

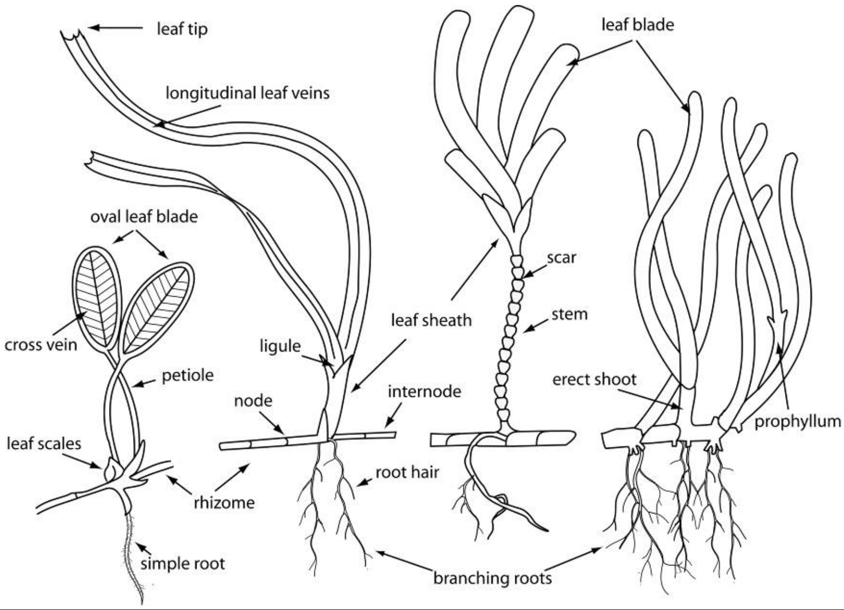
Leaves always arise directly from rhizome



Enhalus acoroides

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

Parts of a seagrass plant



Leaf

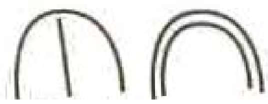
Tip — Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.

rounded *pointed*

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

- cross-vein: perpendicular to the length of the leaf
- parallel-vein: along the length of the leaf
- mid-vein: prominent central vein
- Intramarginal-vein: around inside edge of leaf

cross *parallel*



mid *intramarginal*

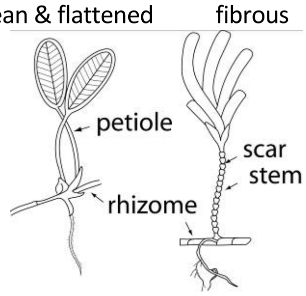
Edges — The edges of the leaf can be either serrated, smooth or inrolled

serrated *smooth* *inrolled*

Sheath — A modification of the leaf base that protects the newly developing tissue. The sheath can entirely circle the vertical stem or rhizome (continuous) or not (non-continuous); fully or partly cover the developing leaves and be flattened or rounded. Once the leaf has died, persistent sheaths may remain as fibres or bristles.

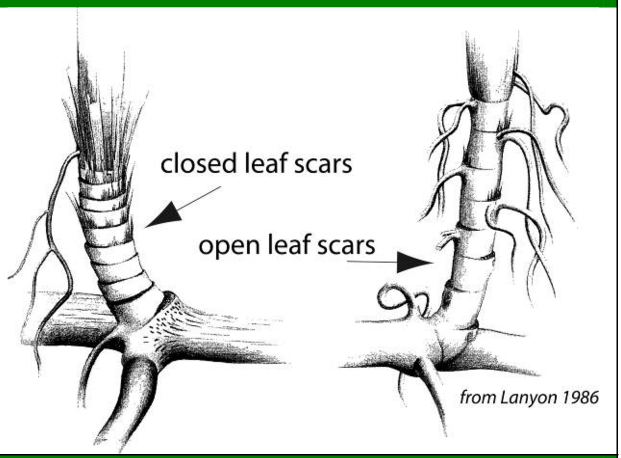
clean & flattened fibrous

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



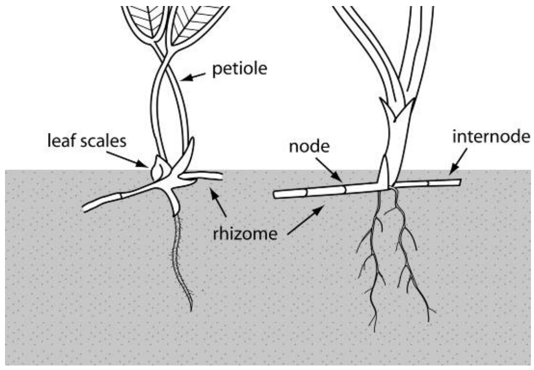
Stem

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



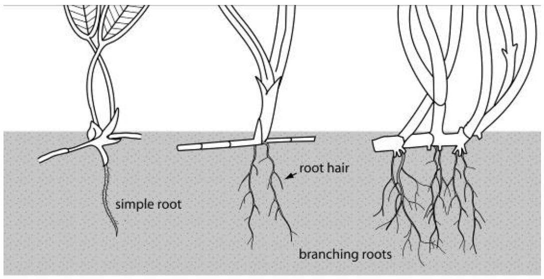
Rhizome

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



Root

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



Notes:

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Monitoring a seagrass meadow

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

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

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

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

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

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

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

Monitoring seagrass

Seagrasses are often at the downstream end of catchments, receiving runoff from a range of agricultural, urban and industrial land-uses. Seagrass communities are generally susceptible to changes in water quality and environmental quality that make them a useful indicator of environmental health. Seagrass make good **bioindicators** of environmental health because they are:

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

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

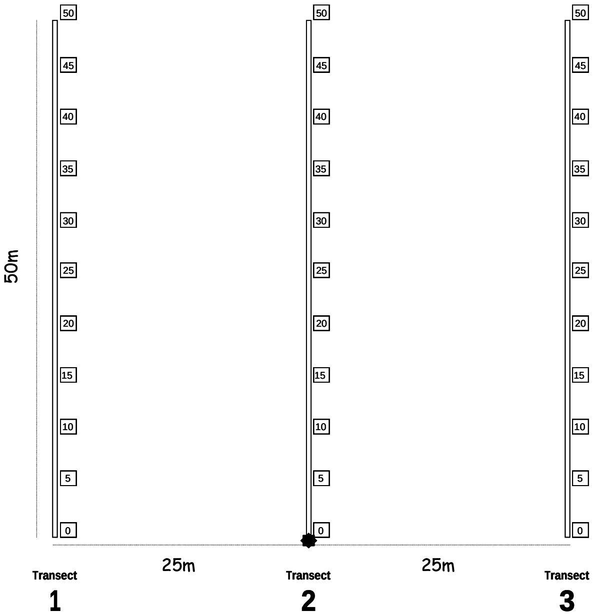
THE GOALS OF THE PROGRAM ARE:

- *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, L.J., Campbell, S.J. & Roder, C.A. (2003) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers. 2nd Edition. (QFS, NFC, Cairns) 100pp. (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

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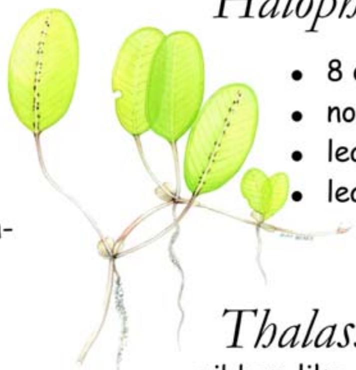
Halophila ovalis



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

Enhalus acoroides

- very long ribbon-like leaves with inrolled leaf margins
- thick rhizome with long black bristles and cord-like roots
- leaves 30-150 cm long

Thalassia hemprichii

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

Halodule uninervis

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

Halodule pinifolia

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

Cymodocea rotundata

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

Cymodocea serrulata

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

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

Halophila minor

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

SEAGRASS-WATCH MONITORING

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

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					Canopy height (cm)	% Algae cover	% Epi-cover
					HO	HU	ZC		water			
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

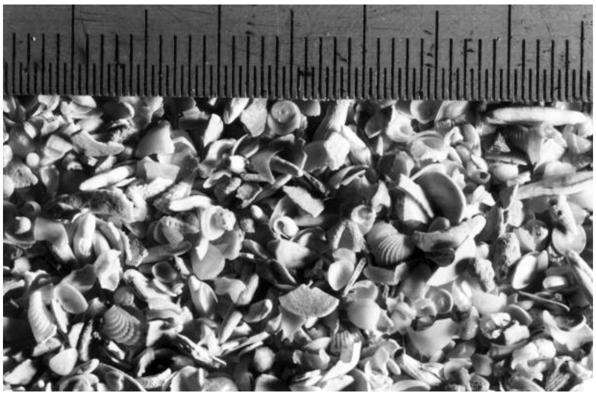
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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).

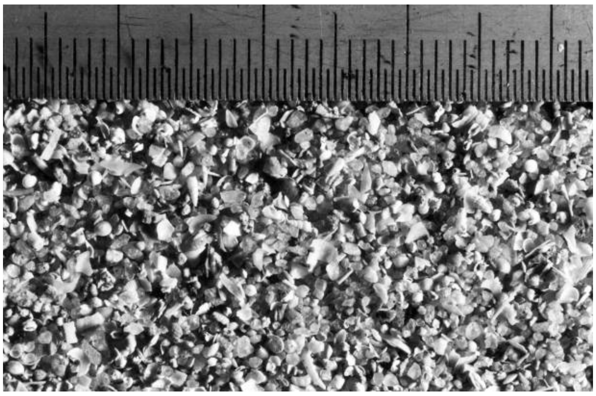
- **mud** *has a smooth and sticky texture.*
- **fine sand** *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
- **sand** *rough grainy texture, particles clearly distinguishable.*
- **coarse sand** *coarse texture, particles loose.*
- **gravel** *very coarse texture,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

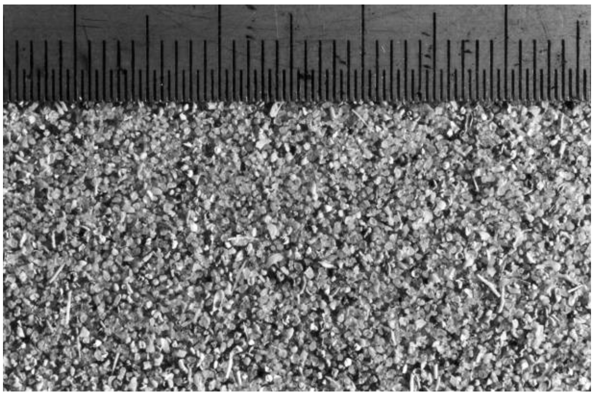
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments (see McKenzie 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf).



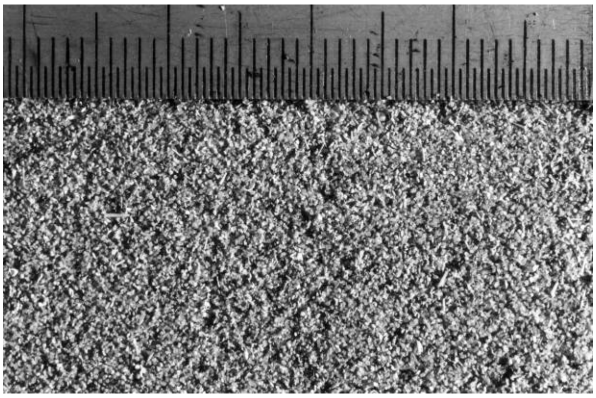
gravel (>2mm)



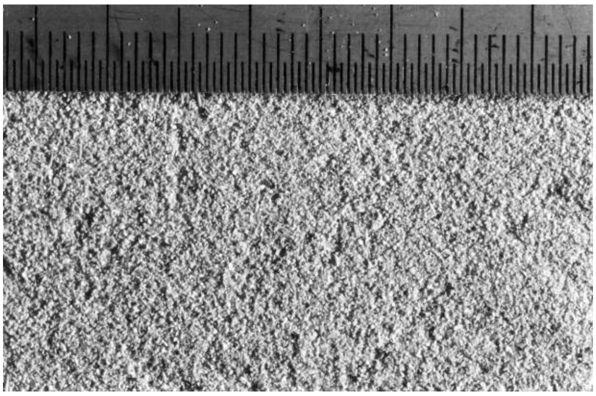
very coarse sand (1 – 2 mm)



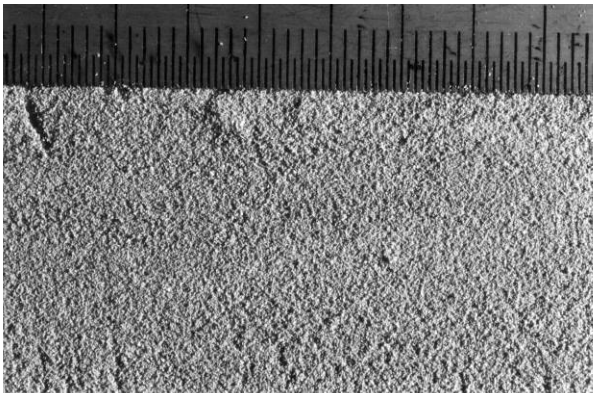
coarse sand (0.5 – 1 mm)



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 & 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 & 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 & 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 & 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 & 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

WildSinagpore a one-stop location for those who want to learn about Singapore's wild places and do more for them. A non-profit site which contains excellent facts and photos about seagrasses and lots more on the wild places, wild activities and wild people that you can find in Singapore. www.wildsingapore.com

TeamSeagrass a blog about a passionate volunteer effort to monitor seagrasses and other intertidal life on Singapore's shores, as part of Seagrass-Watch. Provides updates on the groups activities and how interested volunteers can sign-up and participate. teamseagrass.blogspot.com

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**

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