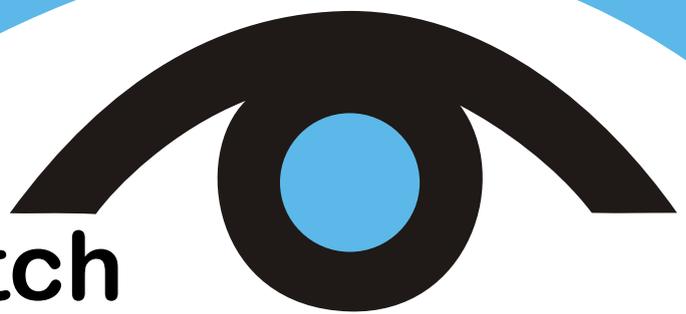




Seagrass-Watch

**Proceedings of a Workshop for Monitoring
Seagrass Habitats in Singapore**

Botany Centre, Singapore Botanic Gardens, Singapore
1st - 3rd May 2009



Len McKenzie, Siti Maryam Yaakub &
Rudi Yoshida

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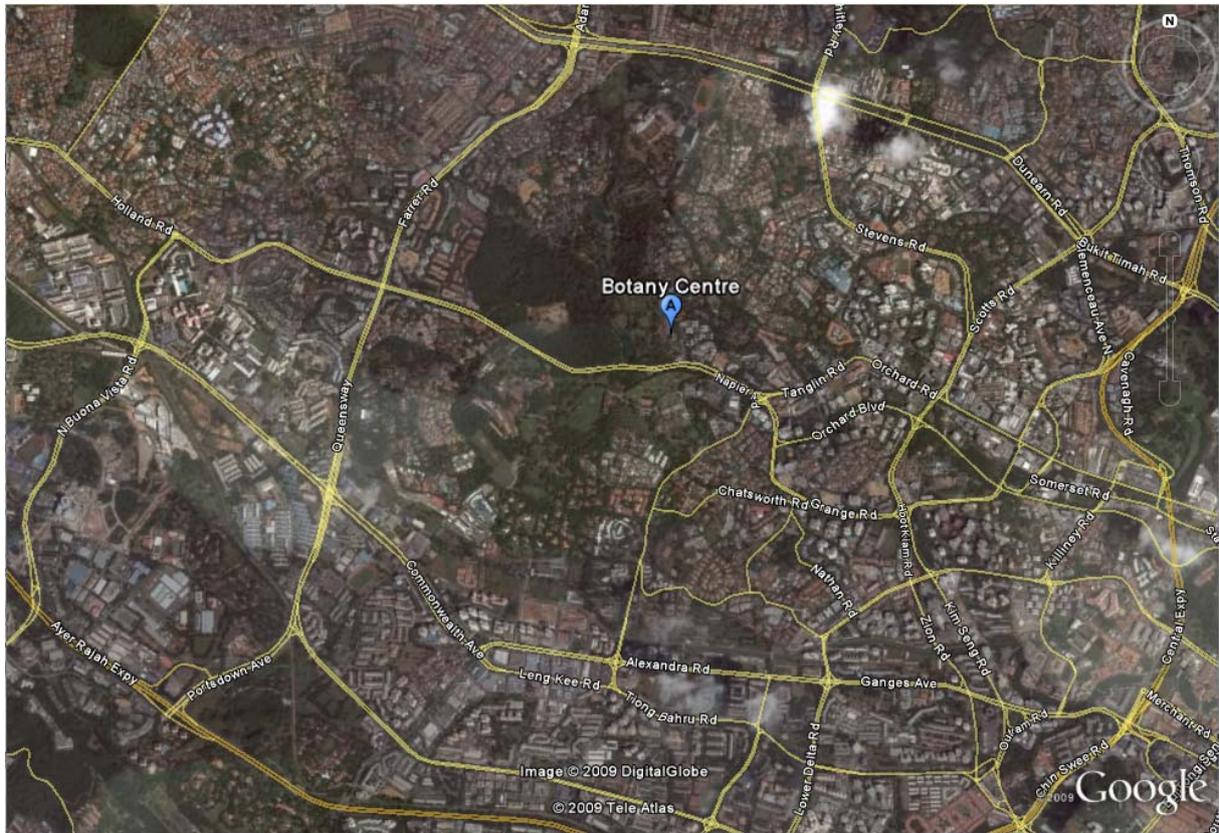
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Botany Centre, Singapore Botanic Gardens, Singapore

Overview

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

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

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:

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

As part of the Level 2 workshop we will:

- *review data collection issues (common errors filling in data sheets, how to take a good photo, etc).*
- *address participants concerns regarding data collection/recording,*
- *learn how to operate a handheld GPS receiver, and*
- *conduct brief lab and field sessions to cover seagrass identification and general monitoring.*

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

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or visit

www.seagrasswatch.org



Workshop leaders



Len McKenzie

Len is a Principal Scientist with Queensland Primary Industries & Fisheries (DEEDI) and Seagrass-Watch Program Leader. He is also chief investigator for the Marine & Tropical Scientific Research Facility (MTSRF) task on the condition, trend and risk in coastal seagrass habitats, Task Leader of the Reef Rescue Marine Monitoring Programme – Intertidal Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal fisheries habitat. Len has over 20 years experience as a research scientist on seagrass ecology, assessment and fisheries habitats. This includes experience within Australia and overseas in seagrass research, resource mapping/ assessment and biodiversity. He has provided information on seagrass communities that has been vital in management of seagrass resources of the Great Barrier Reef and also at the state, national and international levels. He has also advised on fisheries and coastal resource-use issues for managers, fishing organisations, conservation and community groups. Len is also the Secretary of the World Seagrass Association Inc.

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 Scientific Assistant with Queensland Primary Industries & Fisheries (DEEDI). Rudi has over 12 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



Siti Maryam Yaakub

Siti is a Marine Biology graduate of James Cook University. She has about 5 years of experience working on seagrass ecology and genetics under the tutelage of Assoc. Prof. Michelle Waycott (James Cook University) during her undergraduate years. Siti is currently the science leader for TeamSeagrass.

Current Projects

- TeamSeagrass
- Assessment of the distribution and abundance of seagrasses in Singapore

Agenda - Level 1 (basic)

Friday 1st May (Labour Day) 2009 (Singapore Botanic Gardens)

Afternoon	1530 - 1540 (10min)	Welcome & Introduction
	1540 - 1600 (20min)	Seagrass Biology and Identification
	1600 - 1630 (30min)	Classroom activity: Seagrass Identification
	1630 - 1700 (30min)	Seagrass Identification <i>continued</i>
	1700 - 1715 (15min)	Classroom activity: how to prepare a seagrass press specimen
	1715 - 1800 (45min)	<i>Dinner</i>
Evening	1800 - 1900 (60min)	Seagrass Ecology and Threats
	1900 - 1915 (15min)	Seagrass monitoring
	1915 - 2000 (45min)	Seagrass-Watch: how to sample
	2000 - 2045 (45min)	Seagrass-Watch: how data is used
	2045 - 2100 (15min)	<i>Pack up</i>

Saturday 2nd May 2009 (Chek Jawa)

Morning	0800 - 12noon	<p>Field exercise: Seagrass-Watch monitoring</p> <p><i>How to get there:</i></p> <ul style="list-style-type: none"> • 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. <p><i>What to bring:</i></p> <ul style="list-style-type: none"> • 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 breathable • drink/refreshments and energising snack • wet weather gear: poncho/raincoat • insect repellent • polaroid sunglasses (not essential) • simple medical kit in case of injuries to yourself • change of footwear and clothes • enthusiasm <p><i>You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet and muddy!</i></p> <p><i>Please remember, seagrass meadows are an important resource. We ask that you use discretion when working/walking on them.</i></p> <p><i>Low tide (Tg Changi): 0800=1.1m, 0900=0.7m, 1000=0.5m, 1100=0.4m, 1200=0.6m</i></p>
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Agenda - Level 2 (refresher)

Friday 1st May (Labour Day) 2009 (Pulau Semakau)

Morning	0700 – 12noon	<p>Field exercise: Seagrass-Watch monitoring</p> <p><i>How to get there:</i></p> <ul style="list-style-type: none"> 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. <p><i>What to bring:</i></p> <ul style="list-style-type: none"> hat, sunscreen (Slip! Stop! Slap!) dive booties or old shoes that can get wet wear long pants, sandflies may be present. But keep clothes light and breathable drink/refreshments and energising snack wet weather gear: poncho/raincoat insect repellent polaroid sunglasses (not essential) simple medical kit in case of injuries to yourself change of footwear and clothes enthusiasm <p style="text-align: center;"><i>You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet and muddy!</i></p> <p style="text-align: center;"><i>Please remember, seagrass meadows are an important resource. We ask that you use discretion when working/walking on them.</i></p> <p style="text-align: center;"><i>Tides (Bukom) 0800=0.8m, 0900=0.5m, 1000=0.4m, 1100=0.4m, 1200=0.6m, 1300=1.0m</i></p>
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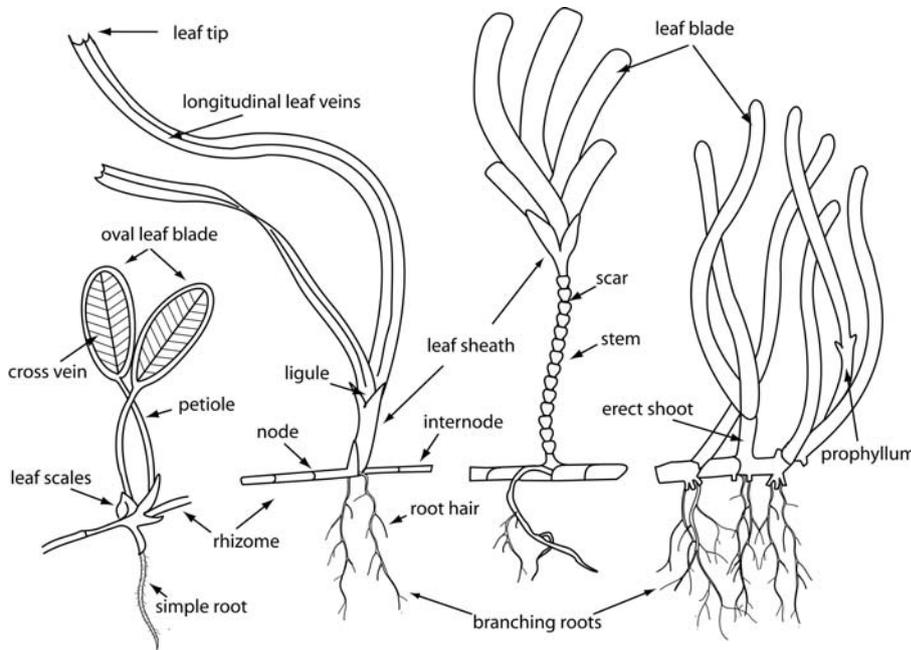
Sunday 3rd May 2009 (Singapore Botanic Gardens)

Morning	0900 - 0910 (10min)	Welcome & Introduction
	0910 - 0930 (20min)	Seagrass Biology and Identification refresher
	0930 - 1000 (30min)	Classroom activity: Seagrass Identification
	1000 - 1045 (45min)	Seagrass-Watch protocols refresher
	1045 - 1100	<i>Break</i>
	1100 - 1200 (60min)	Seagrass-Watch data entry & analysis
		Classroom activity: entering data into MSExcel spreadsheet
	1200 - 1300 (60min)	<i>Lunch</i>
	1300 - 1330 (30min)	GPS training
	1330 - 1415 (45min)	Field activity: using a GPS
	1415 - 1500 (45min)	Open forum + Wrap up

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.

Like terrestrial (land living) plants, a seagrass can be divided into its **veins** (lignified conducting tissue that transports food, nutrients and water around the plant), stem, roots (buried in the substrate) and reproductive parts such as flowers and fruits. Algae do not have veins in their leaves nor do they possess roots (anchoring to the surface of the substrate by a holdfast) or produce flowers or seeds.

They are called “seagrass” because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover) shape, a fern shape, a long spaghetti like leaf and a ribbon shape. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea*, *Thalassia*, *Thalassodendron*, *Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. A prophyllum is a single leaf arising immediately from the horizontal rhizome instead of from an erect shoot. This feature is unique to the genus *Zostera*.

Seagrass leaves lack stomata (microscopic pores on the under side of leaves) but have thin cuticle to allow gas and nutrient exchange. They

Seagrasses have roots, stems and leaves

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

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

also possess large thin-walled aerenchyma. The aerenchyma are commonly referred to as veins as they carry water and nutrients throughout the plant. 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 sun's 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.

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 joints, 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.

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.

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.

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*).

Seagrass pollen grains are elongated into a filamentous shape. The filamentous nature of pollen grains facilitates transport within the water medium. *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.

Seagrass taxonomy

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

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in at least three separate lineages or families. Thus, seagrasses are not a taxonomically unified group but a

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)

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

Seagrass pump oxygen into the sediment via their roots

Seagrass have flowers, fruits and seeds

Pollination occurs in the water

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

Seagrasses are not true grasses

Seagrasses are more closely related to lilies

'biological' or 'ecological' group. The evolutionary adaptations required for survival in the marine environment have led to convergence (similarity) in morphology.

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

Over 30 species can be found within Australian waters. The most diverse seagrass communities are in the waters of north-eastern Queensland and southern Western Australia.

Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. Seagrasses are not seaweeds. Seaweed is the common name for algae.

Seagrass requirements for growth

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

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

The need for physiological adaptations to life in sea water is obvious when one considers that seagrasses evolved from land plants, and most land plants are unable to tolerate even small quantities of salt. In contrast to land plants, some seagrasses can tolerate a salinity range from 4 to 65 parts per thousand (2x seawater concentration).

Typically, seagrasses grow best in salinities of 35 parts per thousand. Not all species tolerate all salinities equally well, and salinity tolerance may be a factor promoting different species distributions along salinity gradients, e.g., going up estuaries. Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline (very salty). A limiting factor for many intertidal seagrasses is osmotic impacts resulting from hypersalinity due to evaporation

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

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 CO₂ concentration. The cause of thermal

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

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

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea water

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

Light availability is the most important factor determining seagrass growth

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

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

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.

Temperature also controls the range of pH and dissolved carbon dioxide (CO₂) 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 (HCO₃⁻) as an inorganic carbon source (eg *Halophila ovalis*, *Cymodocea rotundata*, *Syringodium isoetifolium* and *Thalassia*), whereas others use enzymes to make CO₂ available as the inorganic carbon source (eg *Enhalus acoroides*, *Halodule*, *Cymodocea serrulata*).

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

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

Sediment quality, depth and mobility are important factors for seagrass composition, growth and persistence. Most seagrasses live in sand or mud substrates where their roots and rhizomes anchor the plants to the 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.

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

Where are seagrasses found?

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

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

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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

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

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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

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

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.

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 (*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. Both dugongs and turtles select seagrass species for food which

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

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.

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

are high nitrogen, high starch and low fibre. For example, the order of seagrass species preference for dugongs is *Halophila ovalis* > *Halodule uninervis* > *Zostera capricorni*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

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.

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.

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.

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.

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.

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

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

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

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

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

What causes seagrass areas to change?

Tropical seagrass meadows vary seasonally and between years, and the potential for widespread seagrass loss has been well documented.

Factors which affect the distribution of seagrass meadows are sunlight and nutrient levels, water depth, turbidity, salinity, temperature, current and wave action.

Seagrasses respond to natural variations in light availability, nutrient and trace element (iron) availability, grazing pressure, disease, weather patterns, and episodic floods and cyclones. The dynamic nature of seagrass meadows in response to natural environmental variation complicates the identification of changes caused by humans.

What threatens seagrass?

Seagrass meadows are fragile ecosystems. Approximately 54% of seagrass meadows globally, have lost part of their distribution. According to reports, the documented losses in seagrass meadows globally since 1980 are equivalent to two football fields per hour.

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

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.

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.

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 destabilise 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

Seagrasses can change due to both natural and human impacts

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

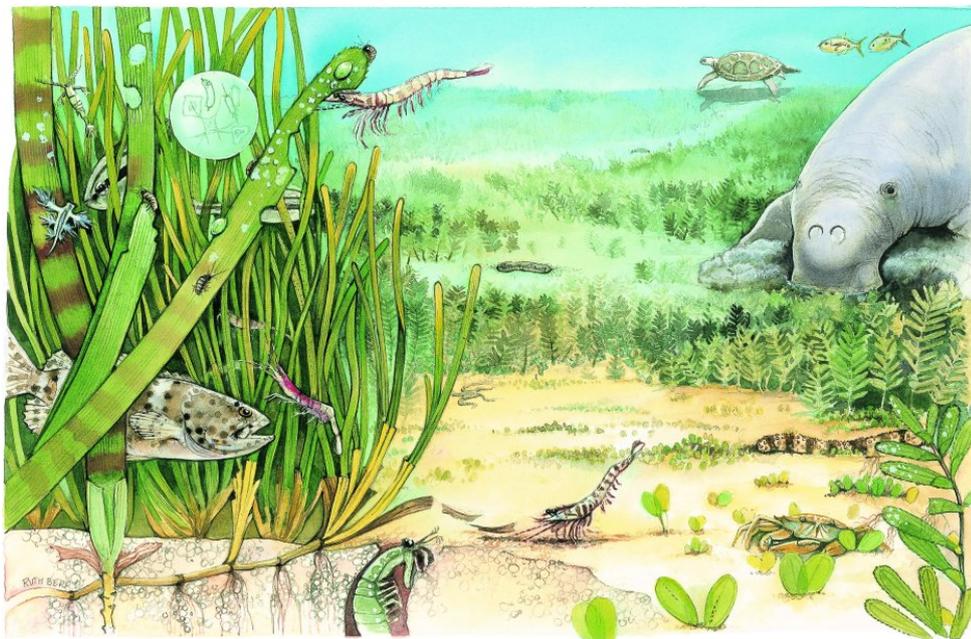
Coastal development can have a major impact on seagrass meadows

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.



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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 coverage of seagrasses globally is over 177,000 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.

A hectare of seagrass sequesters 830 kilograms of carbon per year, equivalent to the CO₂ 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 oceanica* in the Mediterranean Sea).

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!

Seagrasses of Singapore

Seagrass meadows in Singapore play a vital role in supporting coastal marine communities and in maintaining diverse flora and fauna. They are an important component of coastal fisheries productivity 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 is limited and *ad-hoc*. We are not aware of any significant efforts to map the distribution of seagrasses within the territorial waters of Singapore. Although seagrass meadows can be found scattered in various coastal areas, a few notable locations are the extensive reef flats of the 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 Indonesia as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org; McKenzie *et al.* 2001). 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 km²) 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

Principal watchers: TeamSeagrass

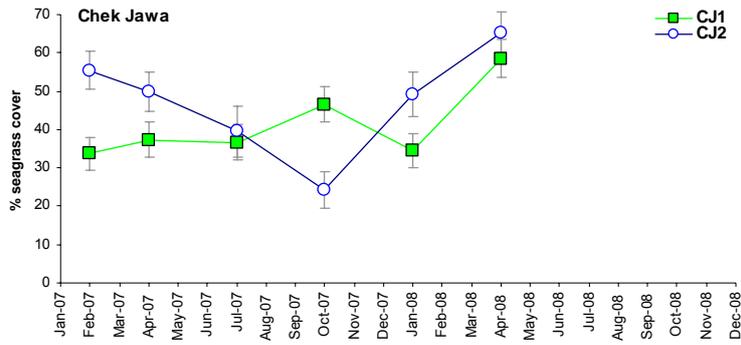
Location: shallow lagoon on north east shore of Pulau Ubin

Site code: CJ1, CJ2

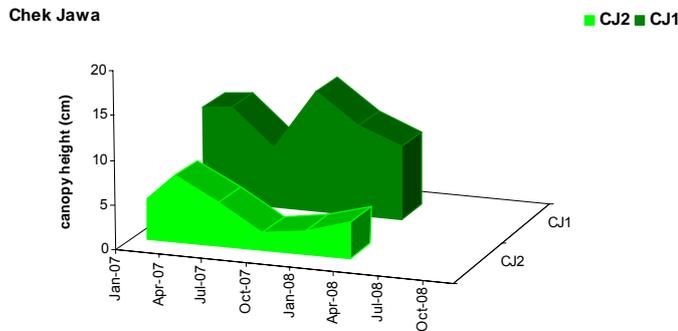
Issues: marine debris/litter, coastal development, land reclamation, land runoff

Status (Dec08):

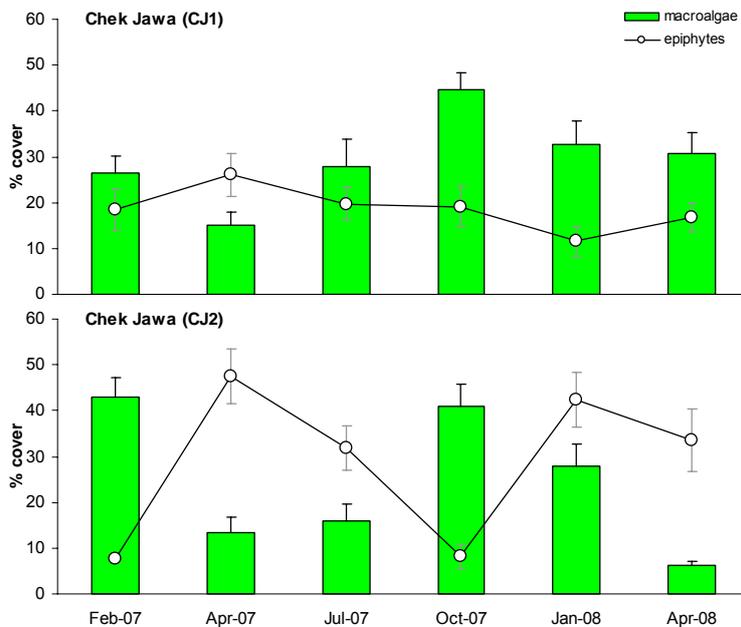
- Seagrass cover is generally between 25 and 65%, and is slightly greater in 2008 than 2007.
- A seasonal trend may be present, however due to the limited dataset it cannot be confirmed.



- Eight seagrass species are found at Chek Jawa: *Halophila beccarii*, *Halophila spinulosa*, *Cymodocea rotundata*, *Halophila ovalis*, *Halophila minor*, *Halodule uninervis*, *Thalassia hemprichii* and isolated clumps of *Enhalus acoroides*.
- Sites are dominated by either *C. rotundata* or *H. ovalis*. The composition of *H. ovalis* fluctuates and may be a seasonal response.
- 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. Epiphytes are slightly higher at CJ2. There is insufficient data to identify any trends.



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*.

LABRADOR

Labrador Nature Reserve, also known as Labrador Park. 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 versperilio*) is often spotted in the area.

Monitoring: ongoing

Principal watchers: Koh Li Ling Cheryl, Chua Jiemin, Joyce Lim Li-Keng, Fang Xinyi, Wu Dan Qiong Danielle, Yeo Weiyong Jolyn (Raffles Girls School), TeamSeagrass and NParks.

Location: intertidal rocky shore

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)
- mean total seagrass abundance general increasing trend between 2007-2008
- seagrass abundance appears to follow seasonal pattern: lower in April, July and October (drier months) compared to February, June and August which may be related in salinity fluctuations
- to learn more, visit blog at <http://labradorpark.wordpress.com/>

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 get 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

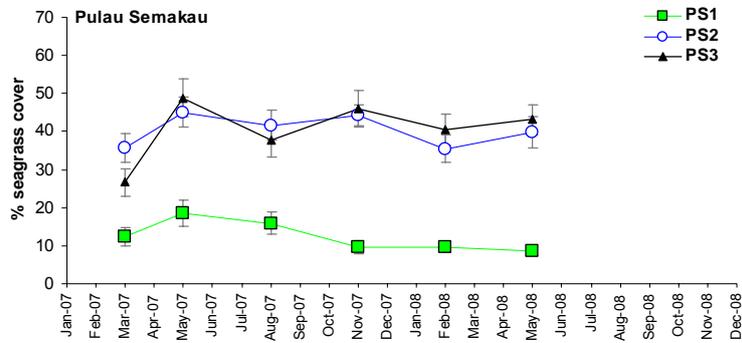
Principal watchers: TeamSeagrass

Location: fringing reef platform on western shore of island

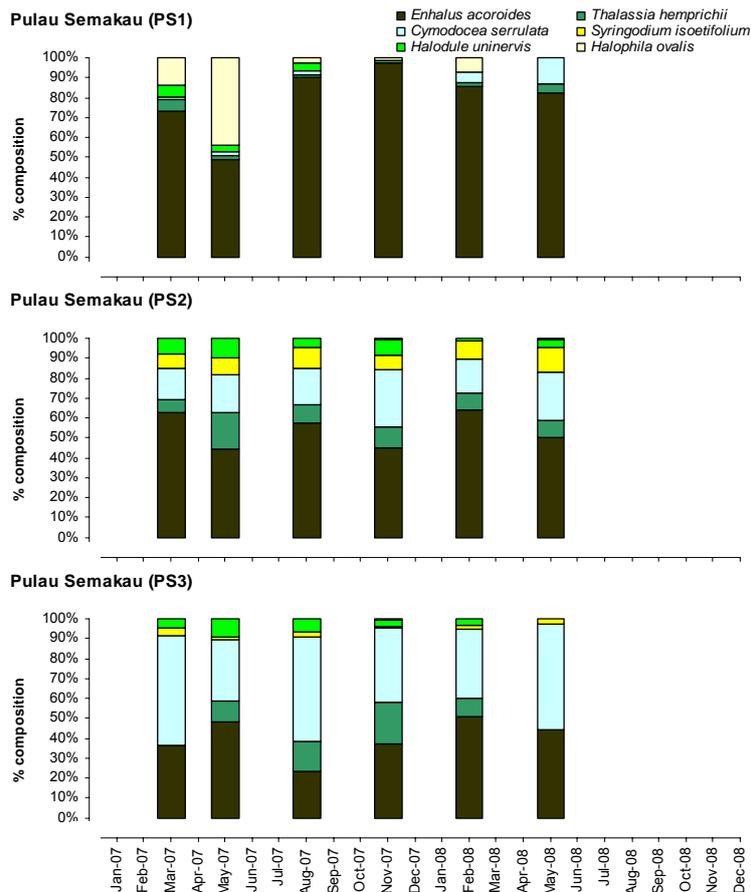
Site code: PS1, PS2, PS3

Status (Dec08):

- Seagrass cover is significantly lower at PS1 than the other sites. Seagrass abundance at PS1 varies between 8-18% on average, whereas PS2 and PS3 vary between 26-50%.
- Seagrass cover was significantly lower in Mar07 when the sites were first established.
- Seagrass abundance was relatively stable over the monitoring period and no seasonal trend is apparent. However due to the limited dataset it cannot be confirmed.

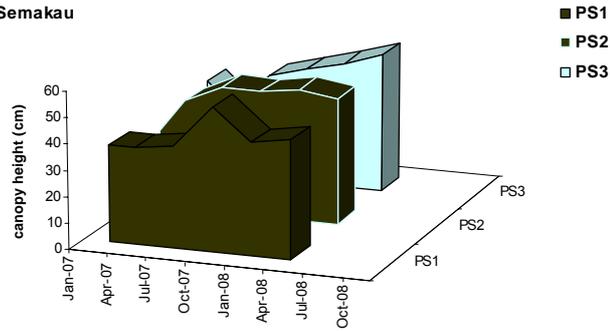


- There appears a transition in species composition between the sites, from *Enhalus* to *Cymodocea* dominating, from PS1 to PS3 respectively.
- Species composition appears to fluctuate, primarily a consequence of the composition of *Halophila ovalis* or *Cymodocea serrulata*.

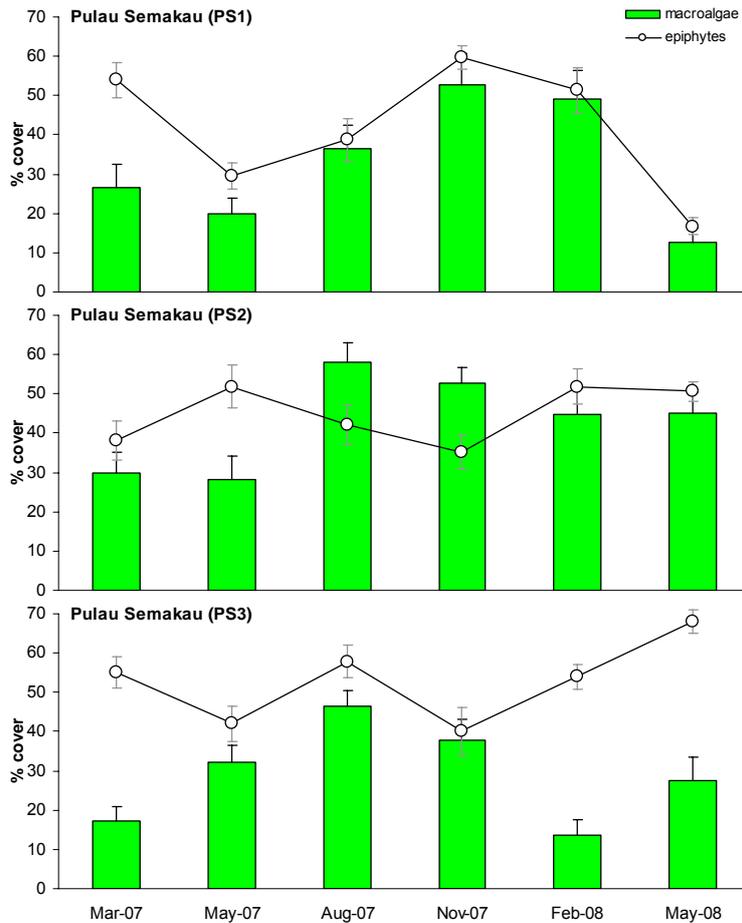


- Canopy height has not changed greatly over the monitoring period, and canopy heights are representative of the change in species dominance between sites.

Pulau Semakau



- The abundance of both macro-algae and epiphytes appears to fluctuate over the monitoring period and is suggestive of a seasonal pattern. However, as there is insufficient data this can only be confirmed in coming years



SENTOSA (PULAU BLAKANG MATI)

Sentosa, which means peace and tranquility 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 and two five-star hotels. It 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.

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. Because the Tuas shore is narrow, “random” sampling is used at this site. Schering Plough volunteers also replant mangroves along the Tuas shoreline.

For more information, visit www.seagrasswatch.org



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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

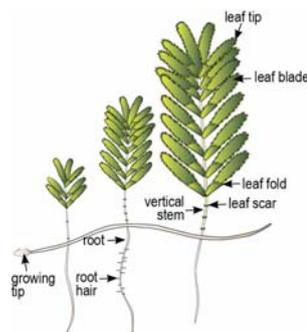
- narrow spaghetti-like leaves, 1-2mm diameter
- leaf tip pointed
- leaves contain air cavities
- inflorescence a “cyme”

Leaves oval to oblong



oval to oblong

obvious vertical stem with more than 2 leaves



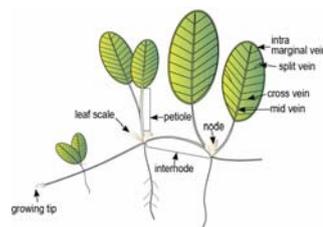
Halophila spinulosa

- 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
- thin rhizomes

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 more than 8 pairs
- leaf margins smooth
- no leaf hairs
- leaf 5-20mm long

Halophila decipiens

- leaf margins serrated
- fine hairs on both sides of leaf blade
- leaves are usually longer than wide

Halophila minor

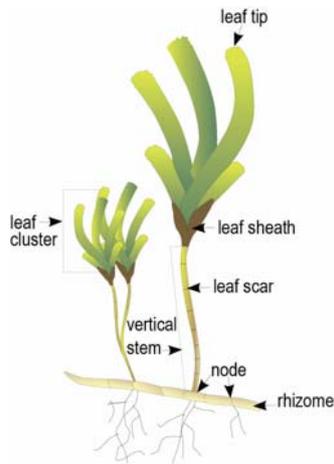
- leaf less than 5mm wide
- cross veins up to 8 pairs
- leaf margins smooth
- no leaf hairs

Leaves strap-like

Leaves can arise from vertical stem



straplike



Thalassia hemprichii

- ribbon-like, curved leaves 10-40cm long
- short red/black bars of tannin cells, 1-2mm long, in leaf blade
- leaf tip rounded may be slightly serrated
- 10-17 longitudinal leaf veins
- thick rhizome (up to 5mm) with conspicuous scars

Cymodocea rotundata

- leaf tip rounded with smooth edge
- leaf sheath not obviously flattened, fibrous
- leaf sheath scars continuous around upright stem

Cymodocea serrulata

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

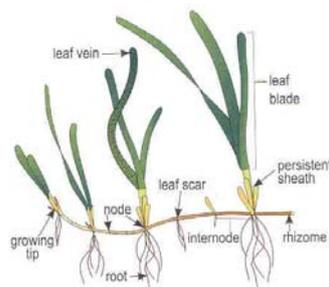
Halodule uninervis

- leaf tip tri-dentate or pointed, not rounded
- leaf with 3 distinct parallel- veins, sheaths fibrous
- narrow leaf blades 0.25-5mm wide
- rhizome usually pale ivory, with small black fibres at the nodes

Halodule pinifolia

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

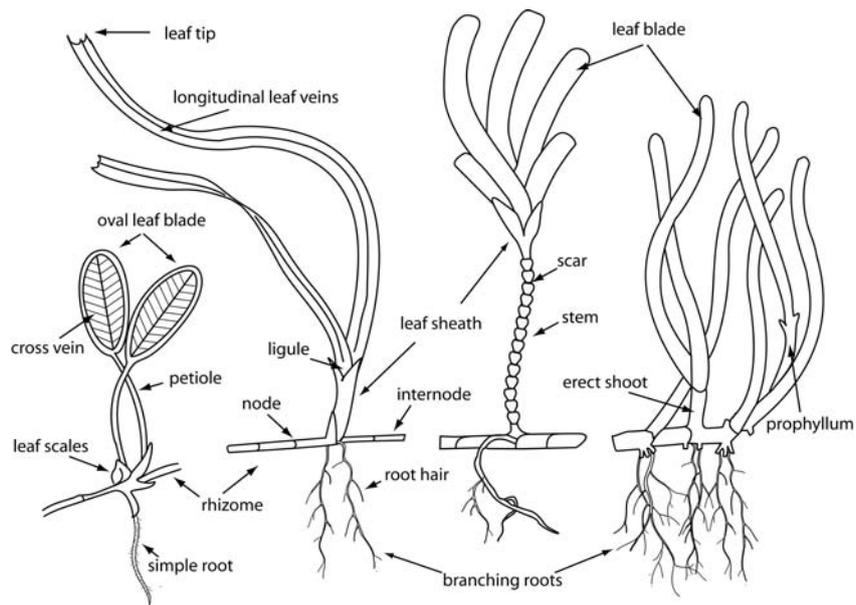
Leaves always arise directly from rhizome



Enhalus acoroides

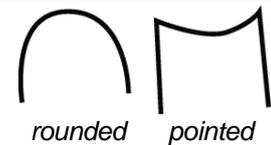
- large plant, leaves >30 cm long, >1 cm wide
- in-rolled edges of leaves
- long, black bristles protruding from thick rhizome
- cord-like roots

Parts of a seagrass plant

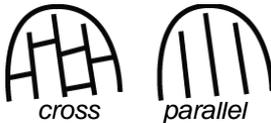


Leaf

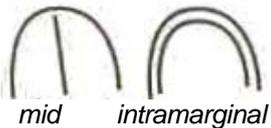
Tip Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.



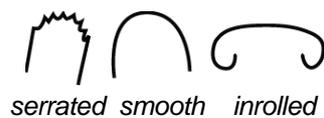
Veins Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for Identification.



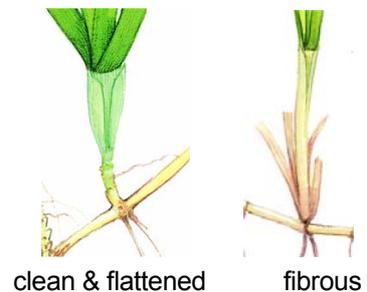
- cross-vein: perpendicular to the length of the leaf
- parallel-vein: along the length of the leaf
- mid-vein: prominent central vein
- intramarginal-vein: around inside edge of leaf



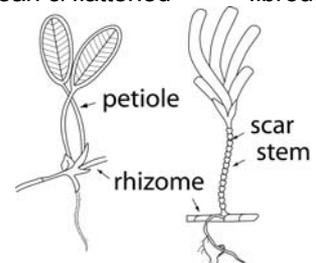
Edges The edges of the leaf can be either serrated, smooth or inrolled



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

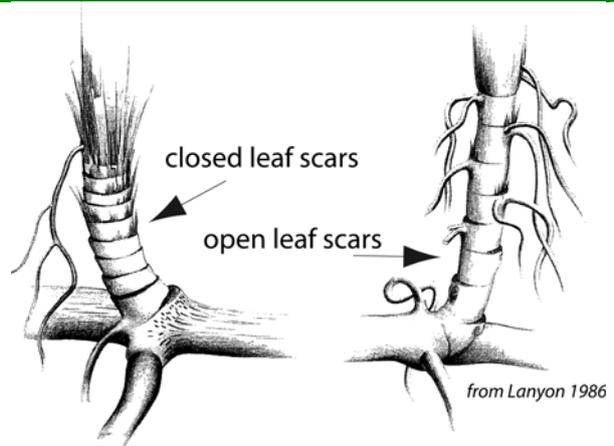


Attachment The leaf can attach directly to the rhizome, where the base of the leaf clasps the rhizome, or from a vertical stem or stalk (petiole) e.g. *Halophila ovalis*.



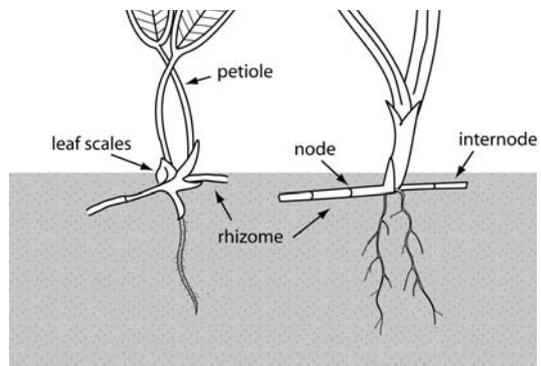
Stem

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



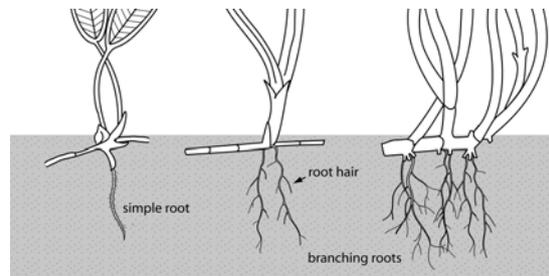
Rhizome

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 cord-like, others may be branching, depending on seagrass species.



Notes:

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Monitoring a seagrass meadow

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

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

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

Seagrass-Watch

A simple method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses 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 1998 in Australia, Seagrass-Watch has now expanded internationally to more than 26 countries. Monitoring is currently occurring at over 250 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 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 @ Chek Jawa

What is Seagrass-Watch?
 Seagrass-Watch is a scientific seagrass assessment and monitoring program. Since its inception in 1998 in Australia, Seagrass-Watch has expanded internationally with monitoring occurring at over 150 sites in more than 20 countries. Seagrass-Watch in Singapore started in Jan 2007 and is run by TeamSeagrass - a group of local volunteers in close collaboration with the Biodiversity Centre of the National Parks Board. The project aims to raise awareness of the conditions and trends of nearshore seagrass ecosystems. Monitoring occurs four times a year at regular intervals during suitably low tides. For more information on TeamSeagrass and Seagrass-Watch, please visit <http://teamseagrass.blogspot.com> or <http://www.seagrasswatch.org>

Why monitor seagrasses?
 Seagrass habitats worldwide are in decline from human activities. Regular monitoring of seagrass habitats help with tracking global and regional patterns in seagrass health. It can also be used to assess human impacts on seagrass ecosystems and provide an early warning of major coastal environment changes.

Seagrasses of Chek Jawa

Seagrasses are a group of marine flowering plants that grow in sheltered coastal waters. They grow in sediment on the sea floor with erect leaves and a buried root-like structure. Seagrasses are often confused with algae, but can be distinguished by the presence of roots and rhizomes (underground stems) as well as flowers, pollen and seeds. Almost half of all Indo-Pacific seagrass species can be found in Singapore (11 out of 23 species), an impressive number given our relatively small land area.

There are seven species of seagrasses found at Chek Jawa: *Cymodocea rotundata* (Ribbon seagrass), *Halodule uninervis* (Needle seagrass), *Halophila ovalis* (Spoon seagrass), *Halophila spinulosa* (Fern seagrass), *Halophila beccarii* (Beccaria's seagrass), *Thalassia hemprichii* (Bottle seagrass) and *Enhalus acoroides* (Tape seagrass). Of these, Beccaria's seagrass is considered one of the rarest species.

Seagrasses serve as both a home and food source to many animals such as fish, crabs, snails and dugongs. In fact, dugong feeding trails have been observed at Chek Jawa on a few occasions. The seagrass lagoon at Chek Jawa is one of the few remaining seagrass meadows found in Singapore. It is unique because of the diversity of seagrasses as well as the flora and fauna it supports.






Relative abundance of seagrass species at Chek Jawa
 (in main lagoon*, based on data from 24th Feb '07 monitoring session)

Species	Relative Abundance
<i>Halophila ovalis</i>	61%
<i>Cymodocea rotundata</i>	36%
<i>Thalassia hemprichii</i>	2%
<i>Halodule uninervis</i>	1%

* Seagrasses also occur on the seaward edge of the sand bar

A dugong feeding trail through a *H. ovalis* patch in the seagrass lagoon at Chek Jawa (29 Jan 07)

The seagrass lagoon at C3 is predominantly made up of *Halophila ovalis*. This is good news for me because its juicy leaves are a major component of my diet!





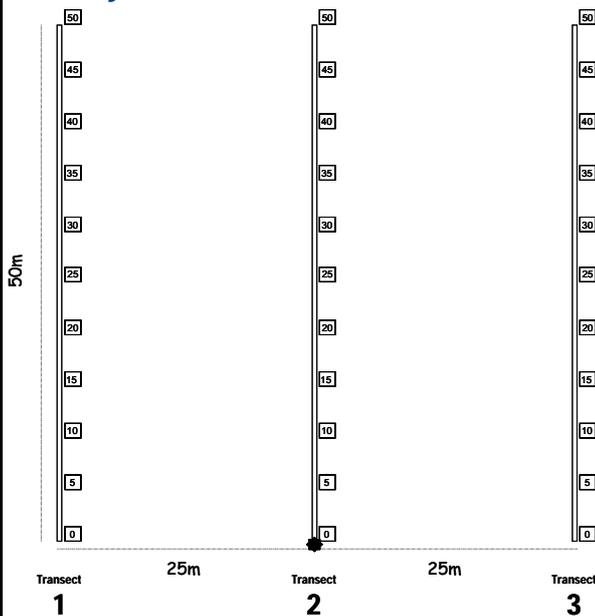


TeamSeagrass and Seagrass-Watch, Singapore

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

e.g., P11225 = Pigeon Is. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Quarterly sampling

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

Step 1. Take a Photograph of the quadrat

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

Step 2. Describe sediment composition

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

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

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

Step 4. Estimate seagrass percent cover

- Estimate the total % cover of seagrass within the quadrat – use the percent cover photo standards (calibration sheets) as your guide.

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). Use seagrass species identification keys provided.

Step 6. Measure canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

At completion of monitoring

Step 1. Check data sheets are filled in fully.

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

Step 2. Remove equipment from site

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

Step 3. Wash & pack gear

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

Step 4. Press any voucher seagrass specimens if collected

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

Step 5. Submit all data

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

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

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

Halophila ovalis



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

Thalassia hemprichii



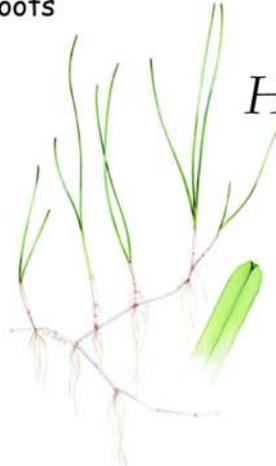
- ribbon-like, curved leaves 10-40cm long
- leaf tip rounded, slightly serrated
- short black tannin cells, 1-2mm long, in leaf blade
- thick rhizome with scars between shoots

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



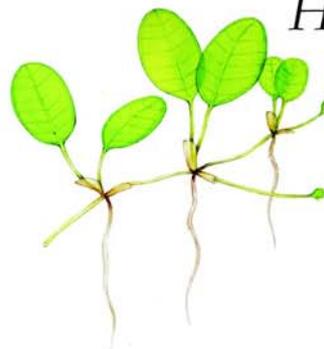
Syringodium isoetifolium

- 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

START of transect (GPS reading)

Latitude: $25^{\circ} 11.2878' S$ Longitude: $152^{\circ} 37.5372' E$

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

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	514.7	5	33
2 (5m)	S	GAB x 3	33	50	50		0	1017.8	10	18
3 (10m)	mud/sand	worm x 1	18	70	20	10	0	618.5	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	917.5	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 CH x 3	0.7		100		2cm	717.7	18	31
9 (40m)	s/m		23	96	4		2cm	214.6	6	17
10 (45m)	m	Mudwreck x 2 HC x 1	41	2	95	3	2cm	551.6	3	21
11 (50m)	m/s		16	3	7	90	2cm	716.7	38	6

END of transect (GPS reading)
 Latitude: $25^{\circ} 11.2656' S$ Longitude: $152^{\circ} 37.5516' E$
 SC = Sea Cucumbers HC = Hermit Crab
 GAB = Gastropod CH = Crab Hole
 DFT = Dugong feeding trail.

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 if required.

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 is 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 lose 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 drying 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 (eg 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 (eg 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 (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 than 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).

	Fine-medium Clay	0 – 0.002 mm
	Coarse Clay	0.0021 – 0.004 mm
Mud	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
	Very Fine Sand	0.0631 – 0.125 mm
	Fine Sand	0.1251 – 0.250 mm
Sand	Medium Sand	0.2501 – 0.500 mm
	Coarse Sand	0.5001 – 1.000 mm
	Very Coarse Sand	1.0001 – 2.000 mm
	Granules	2.0001 – 4.000 mm
Gravel	Pebbles and larger	>4.0001 mm

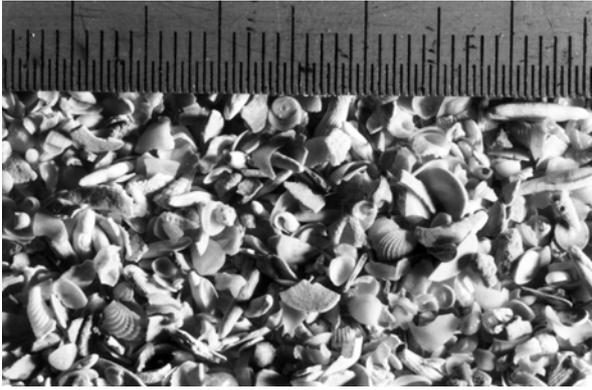
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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).

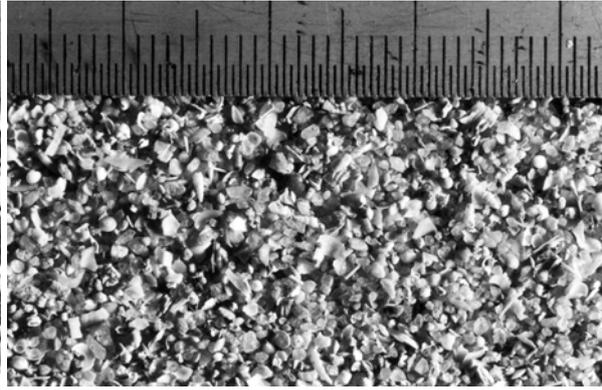
- mud** *has a smooth and sticky texture.*
- fine sand** *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
- sand** *rough grainy texture, particles clearly distinguishable.*
- coarse sand** *coarse texture, particles loose.*
- gravel** *very coarse texture, with some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

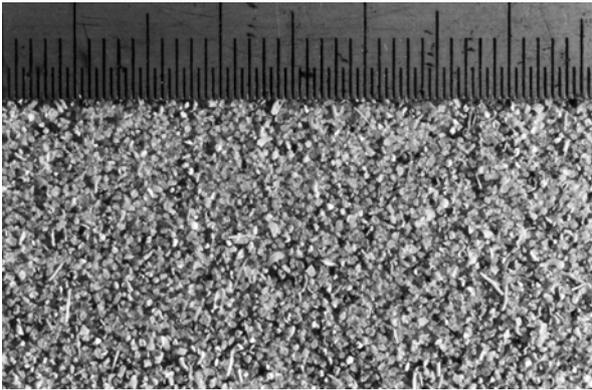
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments (see McKenzie 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf).



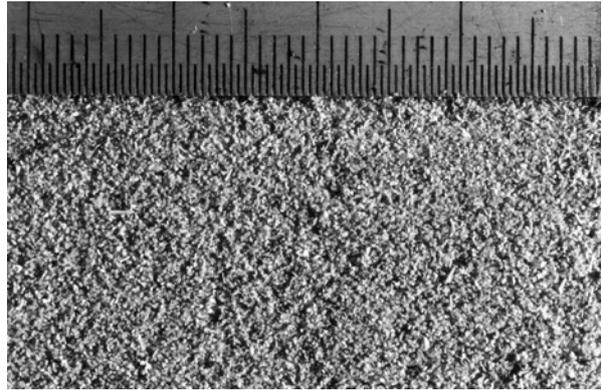
gravel (>2mm)



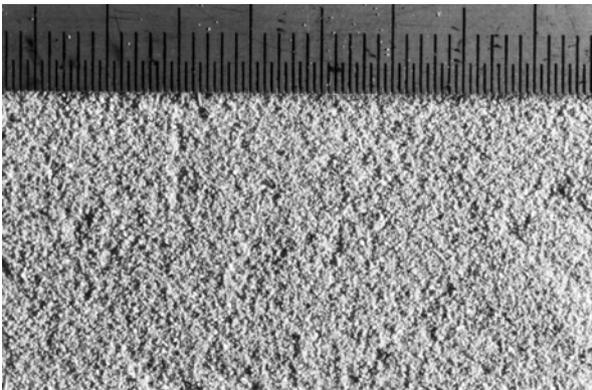
very coarse sand (1 - 2 mm)



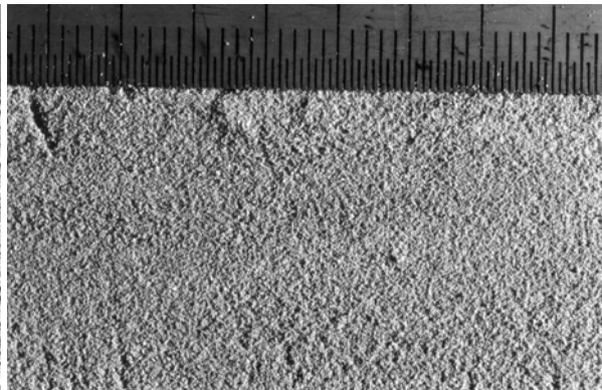
coarse sand (0.5 - 1 mm)



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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Seagrass mapping

Seagrass-Watch activities initially map the distribution of seagrass meadows at a locality or in a region to better understand the seagrass resources of an area. Mapping is often limited to the accessible intertidal seagrasses, although in some cases subtidal seagrass meadows can be included.

The most important information that is required for management of seagrass resources is their distribution, ie. a map. It would be inappropriate to set up a monitoring program if the most basic information is unavailable - that is, whether seagrass is present or absent.

When planning a mapping task, there are several issues that need to be considered, including:

Scale

Mapping requires different approaches depending on whether survey area is relative to a region (tens of kilometres), locality (tens of metres to kilometres) or to a specific site (metres to tens of metres). Scale includes aspects both of extent and resolution. In both broad and large scale approaches, the intensity of sampling will be low (low resolution), with a statistical sampling design that allows the results to be extrapolated from a few observations to the extent of the study area. For finer scale examinations of seagrass meadows, the sampling intensity required can be high with greater precision (high resolution). Scale also influences what is possible with a limited set of financial and human resources. The financial, technical, and human resources available to conduct the study is also a consideration.

Accuracy

Determining the level of detail required when mapping an area also depends on the level of accuracy required for the final map product. Errors that can occur in the field directly influence the quality of the data. It is important to document these. GPS is a quick method for position fixing during mapping and reduces point errors to <3m in most cases. It is important for the observer to be as close as possible to the GPS aerial receiver to minimise position fix error.

Choosing a Survey/Mapping strategy

The selection of a mapping scale represents a compromise between two components. One is the maximum amount of detail required to capture the necessary information about a resource. The other is the logistical resource available to capture that level of detail over a given area. Generally, an area can be mapped using a grid pattern or a combination of transects and spots. When mapping a region of relatively homogenous coastline between 10 and 100 km long, we recommend that transects should be no further than 500-1000 m apart. For regions between 1 and 10 km, we recommend transects 100-500 m apart and for localities less than 1 km, we recommend 50-100 m apart. This however may change depending on the complexity of the regional coastline, i.e., more complex, then more transects required.

To assist with choosing a mapping strategy, it is a good idea to conduct a reconnaissance survey. An initial visual (reconnaissance) survey of the region/area will give you an idea as to the amount of variation or patchiness there is within the seagrass meadow. This will influence how to space your ground truthing sites.

When mapping, ground truthing observations need to be taken at regular intervals (usually 50 to 100m apart). The location of each observation is referred to a point, and the intervals they are taken at may vary depending on the topography.

When ground truthing a point, there are a variety of techniques that can be used depending on resources available and water depth (free dives, grabs, remote video, etc). First the position of a point must be recorded, preferably using a GPS. Otherwise use a handheld compass to determine the bearing, triangulating to at least 3 permanent landmarks or marker established as reference points. A point can vary in size depending on the extent of the region being mapped. In most cases a point can be defined as an area encompassing a 5m radius. Although only one observation (sample) is necessary at a ground truth point, we recommend replicate samples spread within the point (possible 3 observations) to ensure the point is well represented.

Observations recorded at a point should ideally include some measure of abundance (at least a visual estimate of biomass or % cover) and species composition. Also record the depth of each point (this can be later converted to depth below mean sea level) and other characteristics such as a description of the sediment type (eg. shell grit, rock, gravel, coarse sand, sand, fine sand or mud), or distance from other habitats (reefs or mangroves).

For details on the necessary materials & equipment and the general field procedure for mapping a seagrass meadow, please see Chapter 4 of the Seagrass-Watch manual (www.seagrasswatch.org/manuals.html).

Creating the map

The simplest way to map the distribution of seagrasses is to draw the meadows on a paper marine chart from the GPS positions of the ground truth sites. The problem with this type of mapping is that the final map is in a format that does not allow manipulation and transformation. The layout of a paper map is permanent, which makes it difficult for future seagrass mapping studies to be compared, queried and analysed. If resources are available, we recommend that the data be transferred to a digital format and a Geographic Information System (GIS) be used. A detailed description of using and mapping with GIS is beyond the scope of this manual, and we recommend consulting with a scientist experienced in mapping and reading McKenzie *et al.* (2001b).



Using a Global Positioning System (GPS) to map the edge/boundary of a seagrass meadow

The meadow boundary is mapped by recording (or marking) a series of waypoints or tracks along the edge of the meadow from which a line representing the meadow boundary can then be drawn.

To map the boundary you should:

- Walk along the meadow edge, stopping to record (mark) waypoints on your GPS approximately every 10 steps or where there is a change in direction of the meadow boundary.
- Alternatively, you can use the “track” feature if the meadow boundary is clear. Set the track interval time to 3 or 5 seconds for best results.
- Only record a waypoint when you are sure you are on the edge of the meadow. For meadows where the edge is patchy you may have to do some reconnaissance to make sure you are at the edge of the seagrass meadow before recording a waypoint. A good rule of thumb to define an edge when the meadow is patchy is “if patches are within 3 steps, they are within the same meadow”.
- Keep in mind that others may be using the points that you record on the GPS to draw a line (*“join the dots”*) that represents the meadow boundary, so it is better to have too many points than too few.
- Stand still for approximately 10 seconds on a point before recording (marking) a waypoint. If you have a more accurate/expensive handheld GPS, then you need to only stand for 3-5 seconds. It is good to keep checking the accuracy (in the top right of the GPS screen) to ensure the point is as accurate as possible (generally less than 5m).
- As waypoints are labelled by sequential numbers, ensure you record the label of the first and last waypoint. If you make an error, either delete the waypoint or note the erroneous waypoint.
- At the conclusion of the sampling trip the waypoints you record should be downloaded onto your computer ASAP (see later section)

Using the GARMIN GPS 72

Turn GPS Receiver On.

Hold down the Red button for 2 seconds. Wait a few seconds and the GPS unit will begin to track available satellites. Make sure to hold the GPS in a vertical position (top to the GPS pointing to the sky) for best reception of satellite signals.

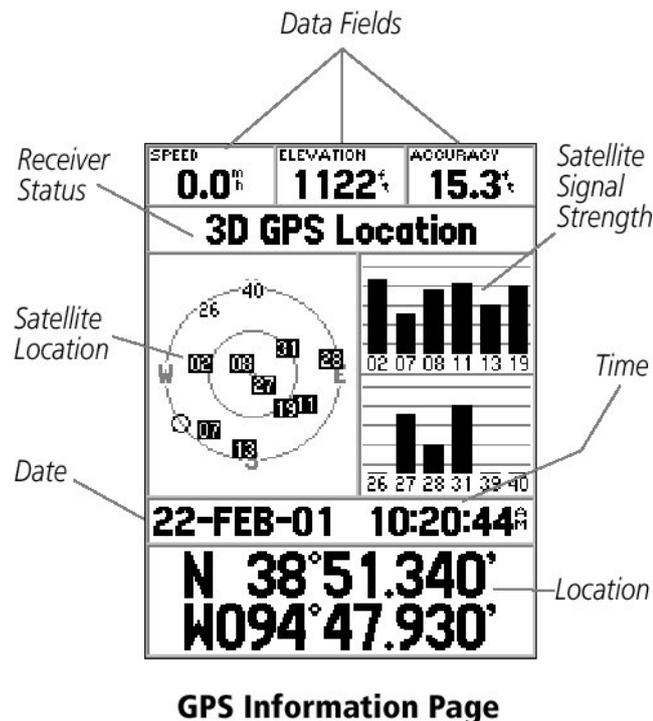


Using the Interface Keys on the GPS

- **IN & OUT** keys – used on the Map Page to zoom in and out.
- **GOTO/MOB** key – used to begin or stop navigation to a waypoint.
- **PAGE** key – used to cycle through the five main display pages in sequence.
- **POWER** key – used to turn the GPS on or off by holding the button down for 2 seconds.
- **MENU** key – used to display a variety of GPS options which can be altered to suit usage. Press the Menu key twice to access the Main Menu.
- **QUIT** key – used to cycle in reverse to the Page key. Also used to cancel operation in progress.
- **ENTER/MARK** key – used to activate or confirm a selection. To record a Waypoint, press and hold down the ENTER/MARK key.
- **ROCKER** key – used to move up/down and left/right to access and change menu options, and for data entry. The ROCKER key is always used to scroll through the different menu options and the ENTER key is used to activate or confirm the selection.

Tracking satellites.

Continue to press the PAGE key until the GPS Information Page appear (the Information Page looks like the diagram just below). When the GPS receiver is tracking enough satellites (minimum four), the GPS Information appears.



Receiver is now ready to record Waypoints. It is recommended that at least four satellites are present and have a strong signal when marking waypoints. The more satellites available the better the accuracy.

Before any waypoints are to be collected, you must check that the GPS settings are correct. The settings are in the Main Menu.

Setting up the correct properties in the Main Menu

- To get to the Main Menu you must press the **Menu** key twice.
- Scroll down to highlight “Setup” and press **Enter**.
 - You must use the **ROCKER** key and move to the appropriate field and use the **ENTER** key to activate the field.
 - Then use the **ROCKER** key (to move up/down and left/right) to access the appropriate setting and use the **ENTER** key to confirm selection.
 - Once changes are made, use the **QUIT** to exit each of the option or menu.
- Scroll across to the “Time” tab and change to the Time settings.

Time Setup

Time Format: 24 Hour

Time Zone: Other

UTC Offset: +8:00

- Scroll across to the “Location” tab and change to the Time settings.

Units Setup

Elevation: Meters

Distance and Speed: Metric

Temperature: Celsius

- Scroll across to the “Location” tab and change to the Time settings.

Location Setup

Location Format: hddd.ddddd

MAP DATUM: WGS84

- Scroll across to the “Interface” tab and change to the Time settings.

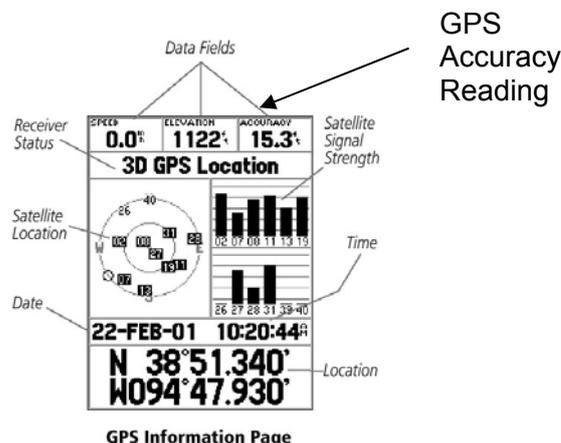
Interface Setup

Serial Data Format: Garmin

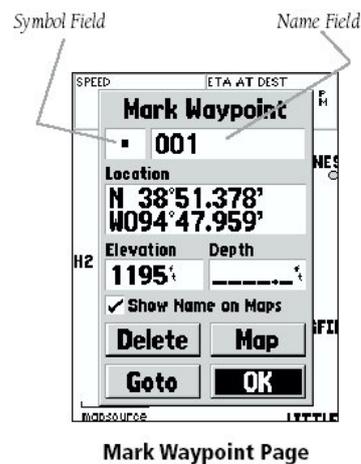
Mark Location as Waypoints

Marked Waypoints are stored as point locations.

To record Waypoints, it is best to be in the Information Page (continue to press the PAGE button until the Information page appears). Before you record a Waypoint, you must look at the accuracy reading on the GPS Information Page. An acceptable accuracy should be less than 15 metres (<15 m).



Step 1. Press and hold the **ENTER** key. The following screen appears:



Mark Waypoint Page

To save the waypoint without any changes, press **ENTER** on the OK button to save the waypoint.

- Step 2.** You can choose to rename the waypoint number to another name by using the **ROCKER** key to highlight the Name field, then press **ENTER**.
- Step 3.** Use the **ROCKER** key as an Alpha-numeric key selection to type in the new waypoint name. Press the **ENTER** key to accept the name.
- Step 4.** You can choose to delete the waypoint by highlighting 'DELETE?', press **ENTER** and then highlight the 'Yes' prompt and press **ENTER** again to confirm.

Use the Goto option to get to a location.

- Press the **GOTO** key.
- Highlight the "Waypoint" then press the **ENTER** key.
- Use the **ROCKER** key to highlight the waypoint you want to go to, press the **ENTER** key.
- Press the **PAGE** key until you get to the Map Page to see where you are (use the **IN** or **OUT** key to zoom in or out). Press the **PAGE** key until you get to the Compass Page to see where you need to be heading to get to the waypoint.

Installing the program MAPSOURCE to download information from your GPS to your computer

Step 1: Installing MapSource

Before installing MapSource, all programs should be closed.

1. Put CD into the CD Drive (Place the CD in with CD labels facing up)
2. If the MapSource setup menu does not appear automatically, Go to **Windows Explorer** (Select Start, Programs, Windows Explorer)
 - Double Click on CD Drive (This could either be D: or E: drive on your computer)
 - Double click on "**Setup.exe**" (To startup the setup program [about 70kb])
 - i. Click **Next** (To say OK to the Welcome Page)
 - ii. Click **Yes** (To accept License Agreement)
 - iii. Click **No** (When ask to check GPS)
 - iv. Click **No** (To confirm not checking the GPS)
 - v. Click **Next** (To select typical install)
 - vi. Click **Finish** (To complete installation)

Step 2: Installing Updated files for Mapsource

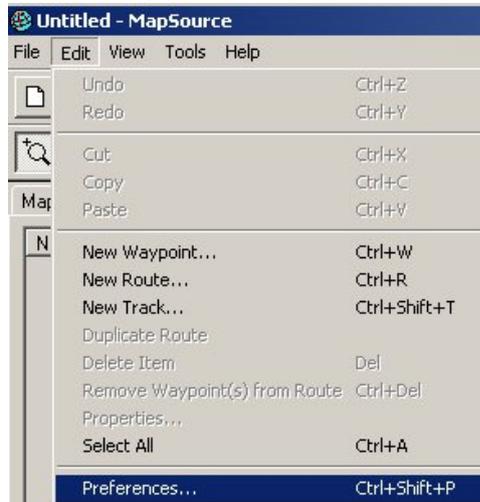
While the **CD** is still in the CD drive,

1. Go to Windows Explorer (Select Start, Programs, Windows Explorer)
2. Double Click on CD Drive (This could either be D: or E: drive on your computer)
3. Double Click the **Mapsource Upgrade** folder (You will see a MapSource_680.exe file)
4. Double Click on the file **mapsource_680.exe** (This will startup the setup program to MapSource)
5. Click Next (To choose English language)
6. Click Next (To accept MapSource Version 6.8)
7. Click Yes (To accept License Agreement)
8. Click Finish (To complete installation)
9. Eject CD and take disc out

Step 3: Setting the correct Properties for MapSource

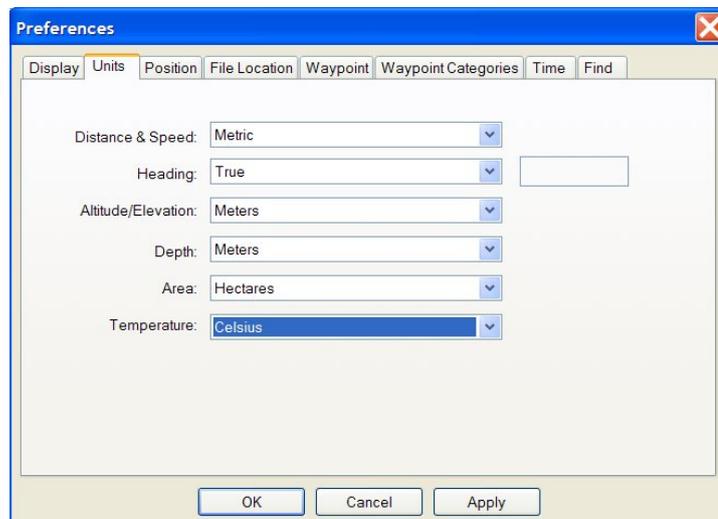
Before using MapSource you must set up some map properties to view the data.

1. Start MapSource (Click the MapSource Icon on the desktop)
2. Go to the **Edit** menu and select **Preferences**



3. The Preferences window will appear.

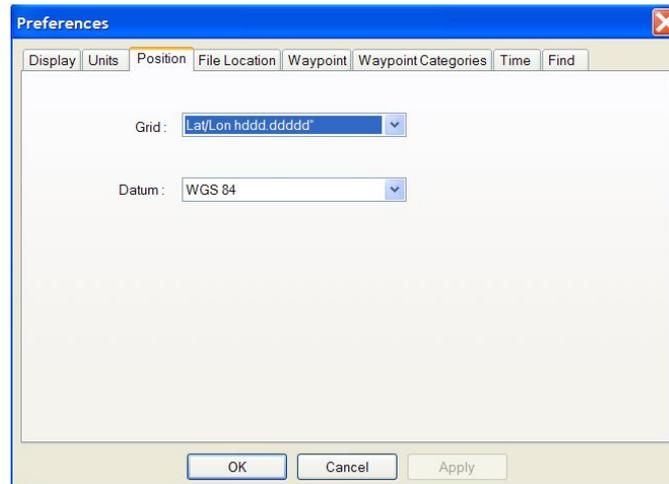
Go to the **Units** tab



You must set the following properties:

- Distance & Speed Metric
- Heading True
- Altitude/Elevation Meters
- Depth Meters
- Area Hectares
- Temperature Celsius

4. Go to the **Position** tab



You must set the following properties:

- Grid Lat/Lon hddd.dddd
- Datum WGS 84

5. Click OK to finish.

6. MapSource is now correctly set up for use.

Downloading information from your GPS using the MapSource program

Step 1: Downloading GPS data using MapSource (download software)

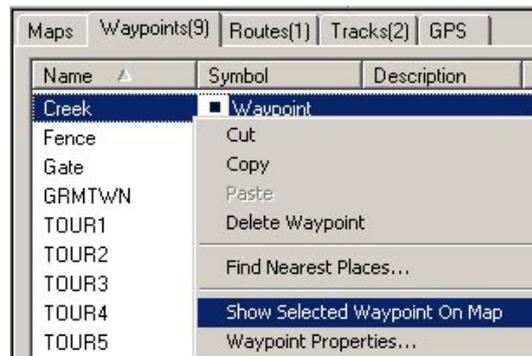
1. Start MapSource (Double click on the MapSource Icon) or (start, programs, MapSource, MapSource)
2. Plug the Garmin serial cable from your GPS unit to the communications port on your computer.
3. On the GPS unit, make sure that the Garmin interface is set to “**GARMIN**” on the GPS 72. To Check this, go to the “Setup menu”, select “Interface”, select “GARMIN”.
4. In the MapSource program, go to the **Transfer** menu and select “**Receive from Device.**”. The following menu will appear.



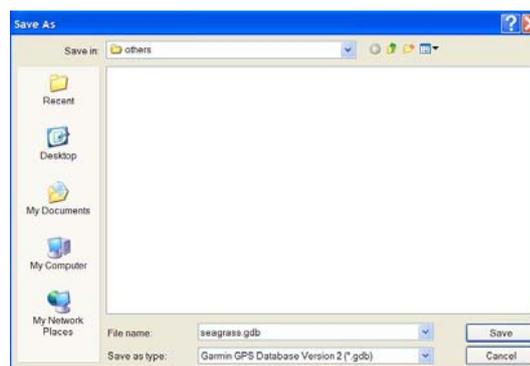
5. Click on the **Receive** button.
6. The GPS data will begin to download to the MapSource software. Click OK after data is successfully opened.

Saving GPS data in MapSource

1. To Check the GPS data that has just been downloaded, click on the “Waypoints” tab (the full list of all waypoints are listed).
2. To view the waypoints on the MapSource map area, right click on any of the waypoints (a context menu will appear) and select “**Show Selected Waypoint On Map**”. The waypoint will be shown on the map



3. You must always save the GPS data that has been downloaded to MapSource. To save the GPS data in MapSource, Click on “**File**” menu, then select “**Save**”. A “Save As” window will appear. Browse to the directory where you want to save the file in and type in a file name. Click “Save” and the MapSource file is saved (this file contains all the GPS data). NB: if you plan to open the file in a Geographic Information System (GIS), save the file as *.dxf as this will open such easily in programs such as ArcGIS®.



The advantages for saving the GPS data are:

- GPS data will not be lost when the data is save in a Garmin database file (*.gdb) to your PC.
- The GPS data on the GPS unit can be deleted. The GPS unit will have the maximum memory space available for any further data capture use.
- Once the GPS data is saved as a MapSource file, the data can always be uploaded back onto the GPS unit.

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 reclamation and changes in land use. Increases in dredging and landfill, construction on the shoreline, commercial overexploitation of coastal resources, and recreational boating activities along with anthropogenic nutrient and sediment loading has dramatically reduced seagrass distribution in some parts of the world. Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease the function and value of seagrass meadows including their contribution to fisheries. It is possible global climate change will have a major impact. Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world: transplantation, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitat through law and environmental policy.

Management

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

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

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

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

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

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

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

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

1. Important fish habitat is known and mapped
2. Habitat monitoring is occurring
3. Adjacent catchment/watershed impacts and other threats are managed
4. Some level of public goodwill/support is present
5. Legal powers exist that 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

WildSingapore 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. www.science.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. www.science.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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