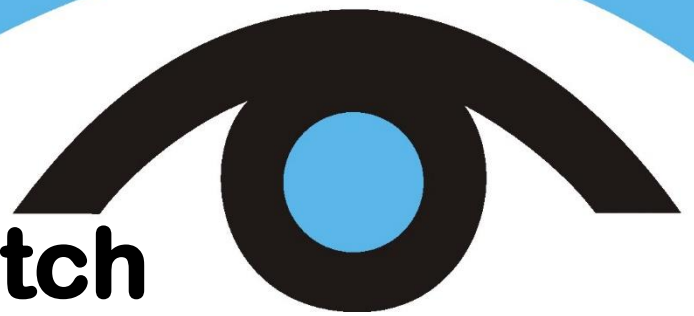


Seagrass-Watch

Proceedings of a workshop for monitoring
seagrass habitats in Wuthathi Sea Country

James Cook University, Smithfield, Queensland

14-16 June 2022



Len McKenzie & Rudi Yoshida

First Published 2022

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Front cover photos (left to right): Aerial view of Shelburne Bay from the giant white silica sand dunes and perched lakes (Apr14); *Halodule uninervis* in the shallow waters of Shelburne Bay (Sep12); and dense *Halodule uninervis* meadow on intertidal banks at Shelburne Bay (May12). Photos courtesy Louise Johns.

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Yule Point field exercise, located 39km north of James Cook University on the Cook Highway (approx 45min drive).

Overview

Seagrass-Watch is a global seagrass observing network, where scientists, coastal managers and local stakeholders from across the globe collaborate to assess the status of their seagrass meadows to provide an early warning of coastal ecological decline. The program started in 1998 in Australia, using standardised global monitoring protocols, and has so far expanded to include 445 sites across 26 countries. Anyone can participate in Seagrass-Watch, as it responds to local needs, and includes some elements of citizen science. Seagrass-Watch is a monitoring program that brings people together for seagrass conservation.

Seagrass-Watch implements a globally standardised seagrass assessment and monitoring protocol, that has a rigorous quality assurance and quality control procedure to ensure data is of the highest quality and that time and resources are not wasted. The only condition is that on-ground data collection must be overseen by a qualified scientist or trained and competent participant (18 years or over). The program identifies areas important for seagrass species diversity and conservation. The information collected can be used to assist the management of coastal environments and to prevent significant areas and species being lost.

Monitoring seagrass resources is important for two reasons: it is a valuable tool for improving management practices; and it allows us to know whether resource status and condition is stable, improving or declining. Successful management of coastal environments (*including seagrass resources*) requires regular monitoring of the status and condition of natural resources. Early detection of change allows coastal management agencies to adjust their management practices and/or take remedial action sooner for more successful results. Monitoring is important in improving our understanding of seagrass resources and to coastal management agencies for:

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is for experienced participants who plan to lead a seagrass monitoring event or conduct seagrass extension activities in Wuthathi Sea Country. Presentations are targeted at participants with a moderate proficiency in English and an education level of year 12 to first year university. As part of the Level 1 workshop we will:

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

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

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Photo: Fergus Kennedy

Workshop trainers



Len McKenzie

Len is the Director of Seagrass-Watch and a Principal Researcher with James Cook University. He is a seagrass Technical Advisor for the CMS Dugong MoU, the Project Manager of the Inshore Seagrass component of the Great Barrier Reef Marine Monitoring Program and principal investigator for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 25 years' experience as a researcher on seagrass ecology, resource mapping/ assessment and biodiversity. He has provided information on seagrass ecosystems that has been vital in management of seagrass resources of the Great Barrier Reef, South East Asia and the Indo-Pacific. Len is a qualified trainer and assessor (Cert IV TAE40110). Len is also the Secretary of the World Seagrass Association.

Current Projects

- Seagrass-Watch
- Great Barrier Reef Marine Monitoring Program: inshore seagrass
- Status and mapping of seagrass resources in Queensland
- Seagrass resilience: seagrass connectivity, community composition and growth
- Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate



Rudi Yoshida

Rudi is the Data Manager of Seagrass-Watch and a Researcher at James Cook University. Rudi has over 20 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 and assists with training workshops.

Current Projects

- Seagrass-Watch
- Great Barrier Reef Marine Monitoring Program: inshore seagrass



Lucas Langlois

Lucas is a Researcher at James Cook University with over 10 years' experience in seagrass related research and monitoring. Lucas has been involved in several projects, looking at seagrass productivity under various environmental gradients, and seagrass condition and trend. Lucas has strong statistical and coding skills, especially in temporal and spatial modelling. He also uses Machine- and Deep-learning models to assist with assessing seagrass photoquadrats and producing seagrass maps from imagery (including UAVs and satellite).

Current Projects

- Great Barrier Reef Marine Monitoring Program: inshore seagrass
- Seagrass Monitoring and Protection in Wuthathi Sea Country
- Subtidal Seagrass Detector

Agenda - Level 1 (basic)

Tuesday 14th June 2022 (Sir Robert Norman Building, James Cook University)

0830 - 0900	Registration
0900 - 0915 (15min)	Welcome & Introduction
0915 - 0945 (30min)	Seagrass Biology and Taxonomy*
0945 - 1030 (45min)	Seagrass Identification
1030 - 1100 (30min)	<i>Break</i>
1100 - 1145 (45min)	Seagrass Identification <i>continued</i> *
1145 - 1230 (45min)	Seagrass Biology 2 and Ecology
1230 - 1315 (45min)	<i>Lunch</i>
1315 - 1445 (90min)	Seagrass importance*
1445 - 1515 (30min)	Seagrass monitoring*
1515 - 1530 (15min)	Wrap up for day

Wednesday 15th June 2022 (James Cook University & Yule Point)

0845 - 0900 (15min)	recap day 1
0900 - 1015 (75min)	Seagrass-Watch: how to sample
1015 - 1030 (15min)	<i>Break</i>
1030 - 1145 (75min)	Seagrass-Watch: how to sample 2*
1145 - 1200 (15min)	Risk assessment
1200 - 1330 (90min)	<i>Lunch & relocate to field site</i>
1330 - 1700 (3.5hrs)	Field exercise: Seagrass-Watch monitoring Yule Point
1700 - 1715 (15min)	Wrap up for day

Thursday 16th June 2022 (James Cook University & Yule Point)

0900 - 0915 (15min)	recap day 2
0915 - 1015 (60min)	Seagrass threats*
1015 - 1030 (15min)	Seagrass-Watch: QAQC
1030 - 1100 (30min)	<i>Break</i>
1100 - 1130 (30min)	Seagrass-Watch: QAQC <i>continued</i>
1130 - 1200 (30min)	Seagrass-Watch: how data is used*
1200 - 1245 (45min)	<i>Lunch</i>
1245 - 1345 (60min)	Seagrass Mapping
1345 - 1430 (45min)	<i>relocate to field site</i>
1430 - 1630 (2 hrs)	Field exercise: drone mapping, Yule Point
1630 - 1645 (15min)	Wrap up & Workshop close

Assessment requirements

To successfully attain a **Certificate of Achievement**, you will need to demonstrate you have the knowledge, skills, abilities and experience to competently conduct monitoring using Seagrass-Watch protocols.

Successful achievement must to be demonstrated across 9 core units, by completing:

- 1 a training workshop (classroom, laboratory and field), and
- 2 three post workshop monitoring events (within 12 months)

Training workshop (6 units)

Demonstrates you have the knowledge, skills and abilities to conduct monitoring

Classroom (4 units): attendance + achieve 80% of formal assessment (multiple choice, open book)

Laboratory (1 unit): identify 3 local seagrass species correctly and demonstrate how to preserve seagrass samples for an herbarium

Field (1 unit): perform the following to the satisfaction of the trainer:

- layout a site and quadrat placement
- description of sediment & comments
- estimation of seagrass cover
- identification of seagrass species
- estimation of seagrass species composition
- measuring seagrass canopy height
- estimation of macro algae cover
- estimation of epiphyte cover
- taking a quadrat photo
- accurately record data

3 post workshop monitoring events (3 units)

Demonstrates you have the experience and competency to conduct monitoring on your own

Must be completed within 12 months: starting no sooner than 1 month after the training workshop. Tentative monitoring events (dates) to be nominated within 1 month of a training workshop. Minimum of 1 site, maximum of 5 sites, per monitoring event assessed. Sites must be sampled within a 2 week period each sampling event. Each monitoring event/period must be separated by at least 1 month, regardless of number of sites monitored. Each participant must assess a minimum of 1 transect per site per sampling event (name must be clearly legible on field datasheet). *A Certified participant can oversee data collection, however, participant being assessed must collect the required data along transect and the name of Certified participant must be clearly legible on datasheet.*

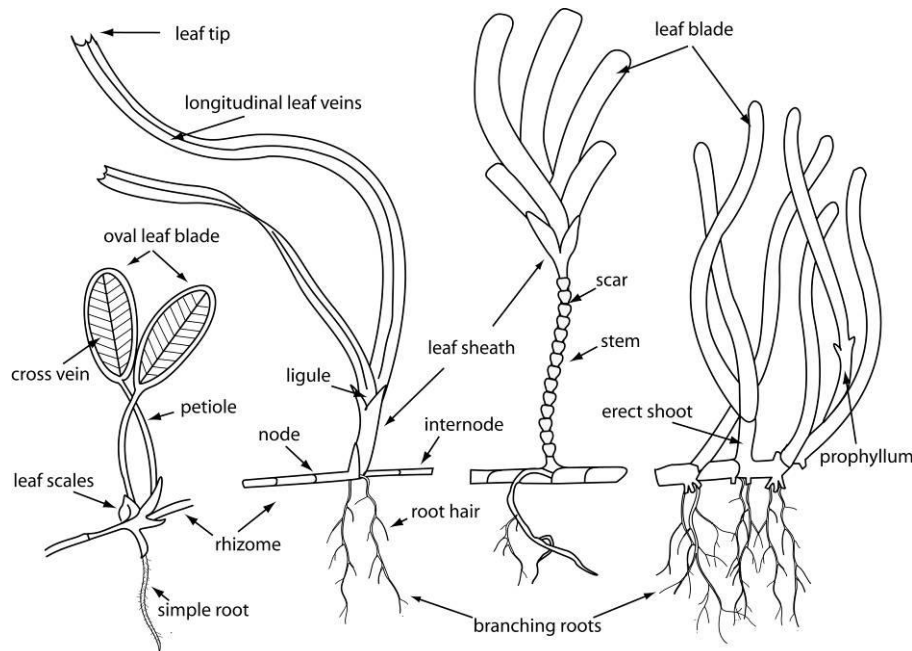
Original datasheets, photos, etc, must be submitted to Seagrass-Watch HQ within 2 weeks after each monitoring event. Data submitted must be compliant and must pass QAQC by achieving the following:

- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within acceptable limits
- epiphyte cover estimates within acceptable limits
- compliant quadrat photos

Once all QAQC has been completed and the participant has demonstrated they have the skills, ability, experience and competency to conduct monitoring, a certificate will be issued by Seagrass-Watch HQ.

Background

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



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

Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. These names are not consistently applied across countries.

Like terrestrial (land living) plants, a seagrass can be divided into its leaves (which contain veins), rhizome, 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.

These marine plants 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), a fern, a long spaghetti/noodle form and a ribbon. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea*, *Thalassia*, *Thalassodendron*, *Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The **remnants of leaf attachment** are seen as **scars**.

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

Seagrass are marine flowering plants

Seagrasses have roots, stems and leaves

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

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

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

diffusion into them from the surrounding water. Seagrass leaves also contain **veins** (lignified conducting tissue that **transports food, nutrients and water around the plant**) (i.e. **an internal vascular system**). Veins can be across the leaf blade or run parallel to the leaf edge. Also within the leaves are chloroplasts, which use the sun's light to convert carbon dioxide and water into oxygen and sugar (photosynthesis).

The roots and horizontal stems (**rhizomes**) of seagrass are often buried in sand or mud. They **anchor the plant, store carbohydrates and absorb nutrients**. Roots can be simple or branching and all have fine hairs to help absorb nutrients. Rhizomes are formed in segments with leaves or vertical stems rising from the 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, **mainly by water currents**. *Halophila* and *Thalassia* have spherical pollen grains, but they remain joined together in long chains, giving the same effect as having elongated, filamentous pollen grains.

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

Seagrass taxonomy

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

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

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

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% of surface irradiance** on average, 4.4% minimum and 29% maximum depending on species) 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 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 are more closely related to lilies

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

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

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

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

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

Seagrasses require two key nutrients, nitrogen and phosphorous, for growth. In the coastal regions, seagrasses appear to be primarily limited by nitrogen and secondarily by phosphorus. The demand for nutrients by seagrasses appears 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 clay the greater the adsorptive capacity - and, calcium carbonate binds phosphorus, limiting its bioavailability.

Sediment quality, depth and mobility are important factors for seagrass composition, growth and persistence. Most seagrasses live in sand or mud substrates where their roots and rhizomes anchor the plants to the sea floor. Some seagrasses, such as *Cymodocea* spp., prefer deeper sediments while others can tolerate a broad range of sediment depths. Colonising seagrasses such as *Halophila* spp. and *Halodule* spp. 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 and dispersal of vegetative material and seeds depends on currents. Without current flows, vegetative material and seeds will not be transported to new areas, and species will not be exchanged between meadows. Factors such as the photosynthetic rate of seagrasses depend on the thickness of the diffusive boundary layer that is determined by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

Where are seagrasses found?

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the arctic (freezing) regions. Seagrass are mainly found in sheltered 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.

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, dispersal and exchange of gases from the water to the plant

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

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

Seagrasses 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 **food, 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 sand crabs 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** (wet weight) of seagrass a day while an adult dugong eats about 28 to 40 kilograms (wet weight) a day. Although dugongs and turtles will feed on any seagrass species within their range, if a range of species is available, they select seagrass species for food which are **high nitrogen, high starch and low fibre**. For example, the order of seagrass species preference for dugongs is *Halophila ovalis* ≥ *Halodule uninervis* > *Syringodium isoetifolium*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

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

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.

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

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.

The value of seagrasses

The value of ecosystem goods and benefits (contributions) is a controversial topic in today's literature. Ecosystem services are the structures and processes by which the environment produces contributions to our quality of life, 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 goods they provide has been estimated at US\$ 28,916 ha⁻¹ yr⁻¹ (in 2007 dollars).

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.

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)

Seagrasses can change due to both natural and human impacts

What threatens seagrass?

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

Some losses are natural due to storms and herbivory, 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 unbalance the rhizome mat. Storms can further exacerbate the damage by the physical force of waves and currents ripping up large sections of the rhizome mat. Uncontrolled digging for bait worm can also physically damage seagrasses and some introduced marine pests and pathogens also have the potential to damage seagrass meadows.

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

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

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

Coastal development can have a major impact on seagrass meadows

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

Seagrass in the Wuthathi Sea Country

Modified from ^[1]

The Wuthathi people are the traditional custodians and owners of Wuthathi land and sea country surrounding Shelburne Bay on the north eastern coast of Cape York Peninsula. The sea country extends from Captain Billy Landing in the north to the Olive River in the south, and encompasses the adjacent lagoon and reefs of the Great Barrier Reef World Heritage Area, including Raine Island. The region covers an area of marine waters approximately 8,050 km².

The majority of the land in Cape York Peninsula is relatively undeveloped and waters entering the GBR lagoon are perceived to be of a high quality. The tropical coast of the Wuthathi sea country is influenced by monsoonal rains and associated pulses of turbid waters draining from adjacent catchments. The region has a monsoonal climate with distinct wet and dry seasons with mean annual rainfall ranging to 2159 mm (Lockhart River airport, the closest weather station 100 km south). Most rain falls between December and April. The major catchment in the region is the Olive-Pascoe. Mean daily air temperatures in the area range from 19 – 32°C. The prevailing winds are from the south east and persist throughout the year^[2]. Cape Grenville provides shelter to Shelburne and Margaret Bays from the prevailing winds.

Seagrass meadows in the Wuthathi Sea Country play a vital role in supporting coastal marine communities and in maintaining diverse flora and fauna. The meadows support dugong (*Dugong dugon*) and green sea turtles (*Chelonia mydas*), and economically valuable fish and prawns populations^[3-5]. Seagrasses are critical to the survival of these animals. The meadows also provide a range of other important ecological goods and benefits. Seagrass produce natural biocides and improve water quality by controlling pathogenic bacteria to the benefit of humans, fishes, and marine invertebrates such as coral^[6]. Nutrient cycling in seagrass meadows makes them one of the most economically valuable ecosystems in the world and the retention of carbon within their sediments contributes significantly to Blue Carbon sequestration^[7-10]. Much of the connectivity in reef ecosystems depends on intact and healthy non-reef habitats, such as seagrass meadows. In addition, the incorporation of carbon within seagrass tissues can affect local pH and increase calcification of coral reefs, thereby mitigating the effects of ocean acidification^[7,8]. The ecosystem contributions provided by seagrass therefore makes them a high conservation priority^[11,12].

Seagrass in the Wuthathi Sea Country was first mapped as part of broad scale surveys of the Queensland coast from Cape York to Cairns in November 1984^[13]. The survey however included only nearshore seagrass to a depth of approx 15m. Since the 1980s, inshore mapping surveys occurred in August 2001^[14] and waters deeper than 15m were examined in November 1998^[15] and January/February 2005^[16] (Fig. 1). It has been estimated from mapping surveys over the last three and a half decades that there is as much as 76.9 km² of seagrass in the Wuthathi Sea Country waters shallower than 15m^[16]. There is also at least an additional 33.6 km² of meadows in the Wuthathi Sea Country waters deeper than 15m^[15,17,18].

Fifteen species of seagrass are reported in Queensland^[19], nine are reported to occur within Wuthathi sea country^[13-15, 20]: *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila capricorni*, *Halophila decipiens*, *Halophila ovalis*, *Halophila spinulosa*, *Syringodium isoetifolium* and *Thalassia hemprichii*. The highest species diversity of seagrass in the Wuthathi sea country is found in the waters of Margaret Bay^[14]. Most species in the region are classified as colonising or opportunistic, capable of rapid recovery from losses due to fast asexual growth rates and capacity for generating large seed banks^[21]. Only seagrass of the genus *Halophila* are found in waters deeper than 15m^[15]. No seagrass species are listed as Endangered, Vulnerable, Near Threatened or Data Deficient under the IUCN Red List criteria^[22].

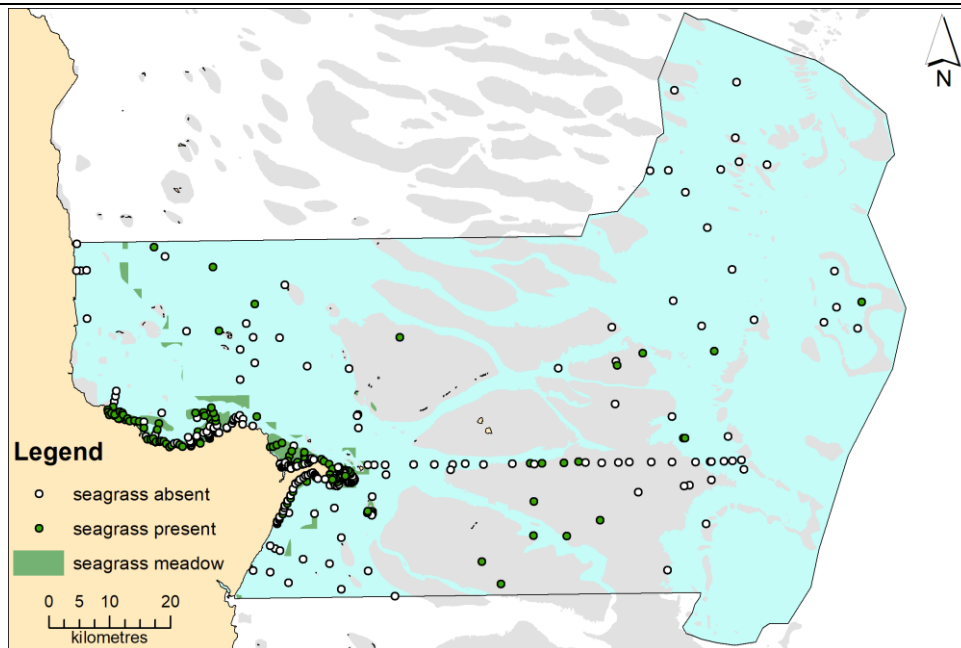


Figure 1: Seagrass distribution and location of field validation points within the Wuthathi Sea Country. Seagrass distribution is composite of all maps pooled. Sources [15-18].



Left: Aerial view of northern Shelburne Bay – October 2021. Right: Long-term monitoring site in *Halodule uninervis* and *Halophila ovalis* meadow, Shelburne Bay. – October 2020.

Seagrass meadows in the Wuthathi sea country occur mostly in the sheltered areas of the bays and on reef flats: on intertidal sand banks throughout Shelburne, Margaret and Indian Bays, and on intertidal reef flats around the Home Islands and offshore around Haggerston and Cockburn Islands^[20]. Seagrass in the region can be found on sand or muddy intertidal flats, in reef lagoons, and on sandy and muddy bottoms down to approximately 37m below Mean Sea Level (MSL)^[15]. The Wuthathi sea country's seagrass ecosystems are a complex mosaic of different habitat types comprised of multiple seagrass species. Most extensive seagrass meadows occur in Margaret Bay, particularly in subtidal habitats. The majority of seagrass meadows in the region are low in seagrass cover (<10% cover)^[14]. Coastal intertidal meadows in Shelburne, Margaret and Indian Bays are dominated by *Halodule uninervis* (narrow leaf form) and *Halophila ovalis*. Small isolated patches of *Enhalus acoroides* are scattered throughout the region in sheltered embayments and reef flats. Meadows of *Halophila spinulosa* with *Cymodocea serrulata* / *Halodule uninervis* / *Halophila ovalis* and *Halodule uninervis* with *Cymodocea serrulata*/mixed species dominate subtidal habitats^[14].

Inshore meadows are influenced by coastal topography and shelter. All but the outer reef habitats are significantly influenced by seasonal and episodic pulses of sediment-laden, nutrient-rich river flows, resulting from high volume summer rainfall. Cyclones, severe storms, wind and waves as well as macro grazers (e.g. fish, dugongs and turtles) influence all habitats in this region to varying degrees. The result is a series of dynamic, spatially and temporally variable seagrass meadows.

SEAGRASS-WATCH IN WUTHATHI SEA COUNTRY

To understand the status of seagrass ecosystems in the Great Barrier Reef World Heritage Area and provide an early warning of change, long-term monitoring has been established at Shelburne Bay since 2012 and Margaret Bay since 2021 as part of Seagrass-Watch and the Great Barrier Reef Marine Monitoring Program (MMP)^[23].

Environmental pressures 2020-21^[23]:

- Environmental pressures affecting seagrass across the region include river discharge, winds, light availability and sea temperature.
- River discharge during the 2020–21 wet season from the Olive–Pascoe, Lockhart and Stewart Rivers in central Cape York, which likely influenced Shelburne and Margaret Bays, were more than twice the long-term average. However, no tropical cyclones directly affected the region over the same period.
- Inshore waters were predominantly 'brown', sediment laden, through the wet season (December–April). Shelburne Bay sites (SR1 and SR2) had highest exposure to turbid primary water for the Cape York region, consistent with previous years.
- Since 2015, the sediments at Shelburne Bay sites have been predominately Sand, but previous were Sand/Mud.
- Daily incident light reaching the top of the seagrass canopy is generally very high and in 2020–21, daily light ($16.5 \text{ mol m}^{-2} \text{ d}^{-1}$) was around the long-term average.
- daily tidal exposure (hours water has drained from the meadow) was below the long-term average, which may have provided some respite from the elevated temperatures.

Shelburne Bay

Shelburne Bay has a limited catchment with two main rivers being the Harmer and Macmillian Rivers and a number of other smaller creeks and tributaries. The catchment contains one of the least disturbed parabolic sand dunes areas in the world and is made up of seasonal wetlands and sand ridges. There was a pastoral lease issued in 1957 in Shelburne Bay which was not renewed in 1999. There are no current land use activities occurring in this catchment. The monitoring site at Shelburne Bay is approximately 5 km west of the mouth of the Harmer River.

Monitoring frequency: ongoing, *annual (established 2012)*

Principal watchers: Seagrass-Watch HQ / James Cook University

Location: on the large naturally dynamic intertidal sand banks in the south of the bay

Site code: SR1, SR2

SR1 position: S11.887 E142.9142167 (*heading 0 degrees*)

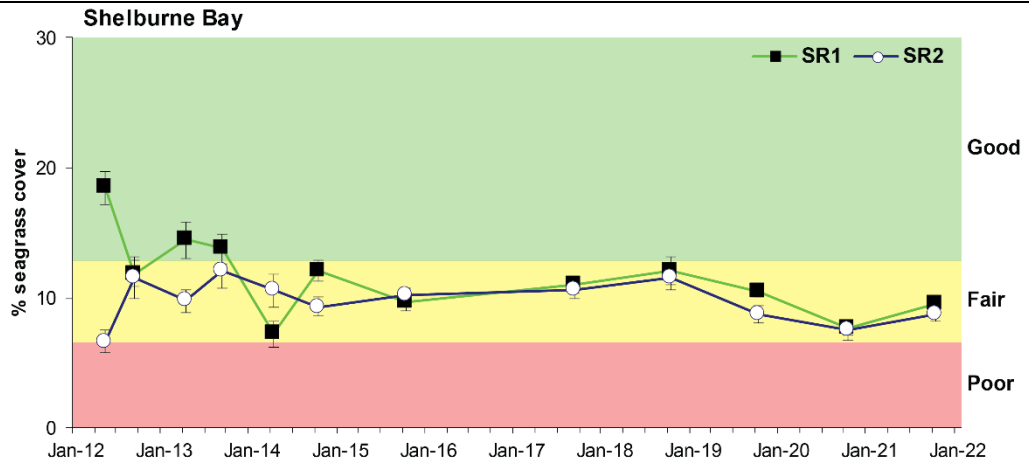
SR2 position: S11.8873 E142.9156667 (*heading 0 degrees*)

Best tides: <0.7m (*port Round Pt 58601*)

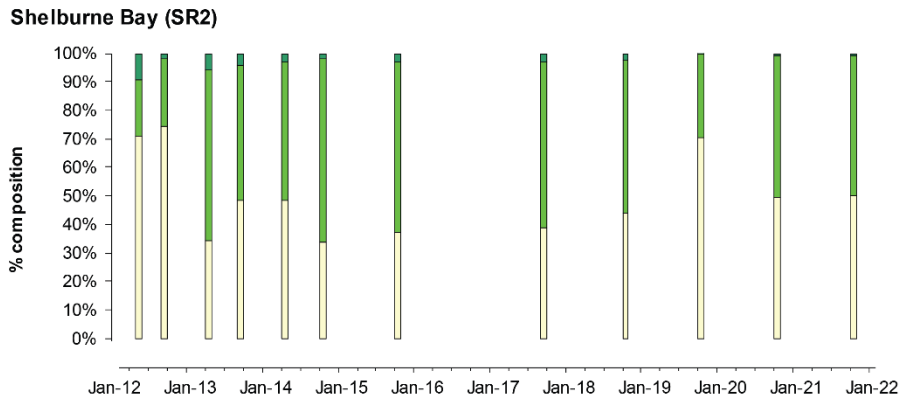
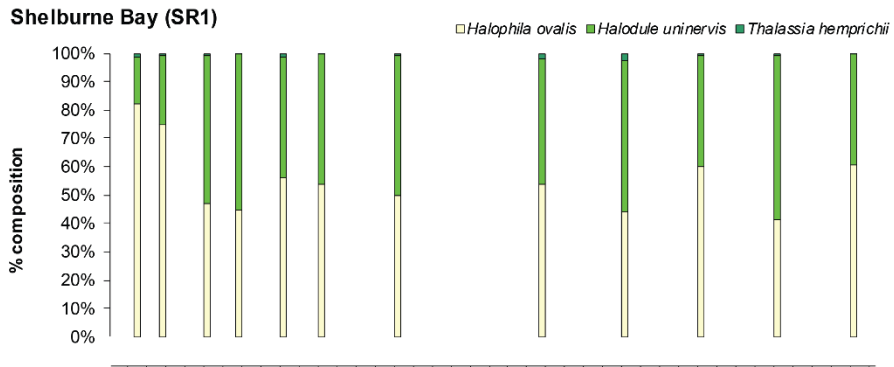
Comments: Extensive *Halodule uninervis* / *Halophila ovalis* dominated meadow. Dugong feeding trails common.

Seagrass Status (Oct21):

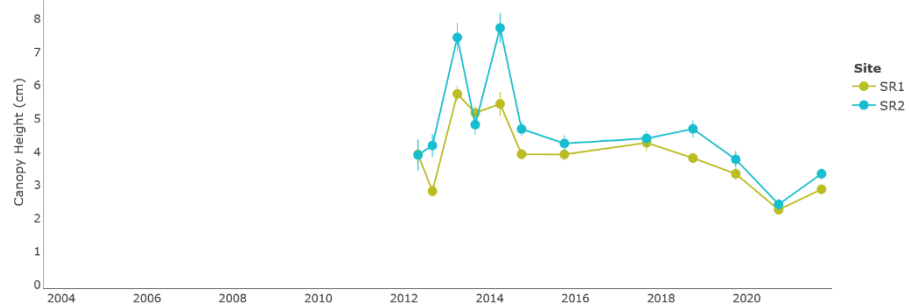
- Seagrass abundance has remained stable over the last seven years and no long-term (2012-2020) trend (increase or decrease) is apparent
- seagrass abundance declined temporarily at SR1 in early 2013 & 2014, but has remained in a fair state since. In October 2021, seagrass abundance at Shelburne Bay was in a Fair state.



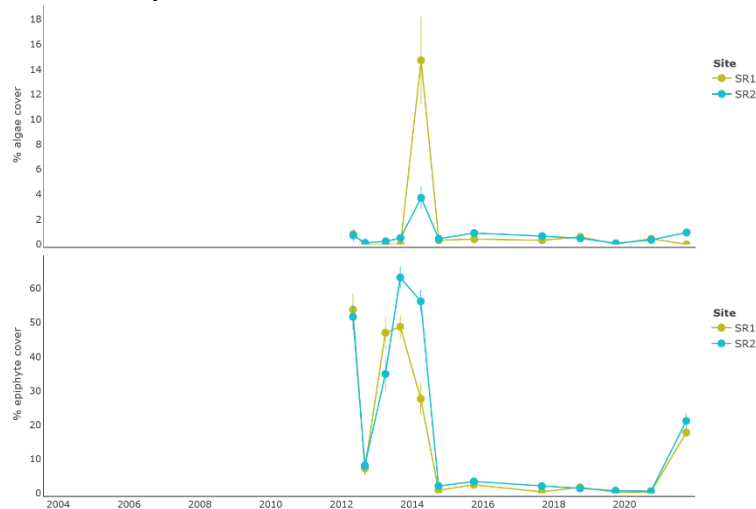
- Sites are dominated by *Halodule uninervis* and *Halophila ovalis*, with some *Thalassia hemprichii* and a few isolated *Enhalus acoroides* adjacent to the monitoring site.
- The colonising species *Halophila ovalis* fluctuates in composition between years, but is generally higher at SR1. The colonising opportunistic foundational species *Halodule uninervis* dominates SR2.



- Seagrass canopy height (*Halodule uninervis* leaf length) is similar at both sites and correlated with *Halodule uninervis* abundance



- Macro-algae abundance is generally low, with significantly higher abundances in 2014
- Epiphyte abundance was higher from early 2013 to early 2014, but declined in late 2014 and remained very low until 2021.



For more information, visit <https://www.seagrasswatch.org/capeyork/#SR>

Margaret Bay

Margaret Bay is north-west of Cape Grenville and approximately 10 km south-east of Shelburne Bay. Margaret Bay has a limited catchment with one main river, the MacMillan. There are no current land use activities occurring in this catchment. Seagrass monitoring sites are located in the shallow subtidal waters to the eastern section of the bay.

Monitoring frequency: ongoing, *annual (established 2021)*

Principal watchers: Queensland Parks and Wildlife

Location: within the shallow subtidal waters in the central section of the bay

Site code: MA1, MA2

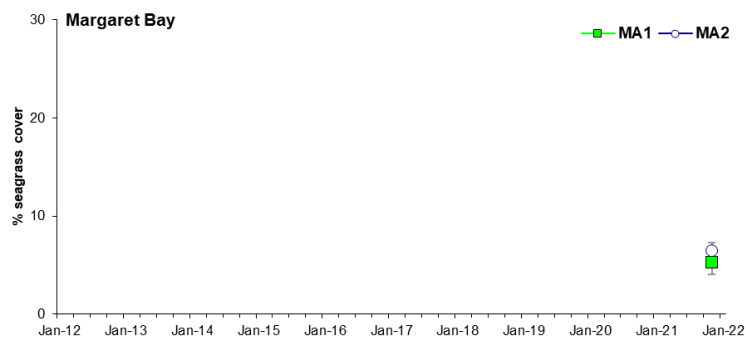
MA1 position: S11.9574 E143.1935833

MA2 position: S11.9559 E143.2033833

Comments: Extensive *Halophila spinulosa* and *Halophila ovalis* / *Halodule uninervis* dominated meadow, with some and *Syringodium isoetifolium*. Dugong feeding trails common.

Seagrass Status (Nov21):

- Seagrass abundance in November 2021 was below 10% cover, which was slightly lower than first reported in August 2001.



- Both sites were predominately *Halophila spinulosa* with *Halophila ovalis*, however MA1 also included some *Halodule uninervis*.
- Macro-algae abundance is very low (<3% cover) at both sites
- Epiphyte abundance was similarly low (<12% cover) at both sites

For more information, visit <https://www.seagrasswatch.org/capeyork/#SR>

A guide to the identification of seagrasses in Wuthathi Sea Country

Adapted from ^[24].

Leaves cylindrical



cylindrical

Syringodium isoetifolium

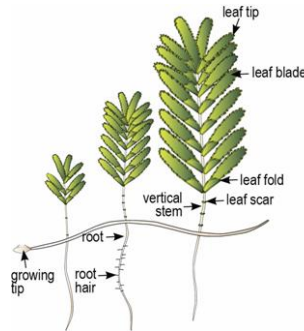
- leaves noodle/spaghetti like and taper to a point
- leaves contain air cavities
- leaves 5-50cm long, 1-3mm diameter
- rhizome thin, whitish & smooth
- roots white or pinkish, highly branched

Leaves oval to oblong



oval to oblong

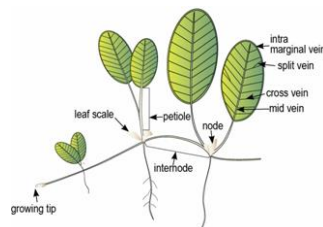
obvious vertical stem with more than 2 leaves



Halophila spinulosa

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

leaves with petioles, in pairs



Halophila capricorni

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

Halophila decipiens

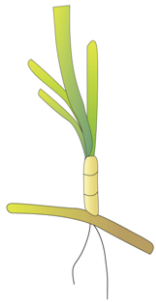
- leaf margins finely serrated
- fine hairs on both sides of leaf blade
- leaf apex rounded to slightly pointed
- leaf 10-25mm long and 3-10mm wide
- 6-8 cross vein pairs

Halophila ovalis

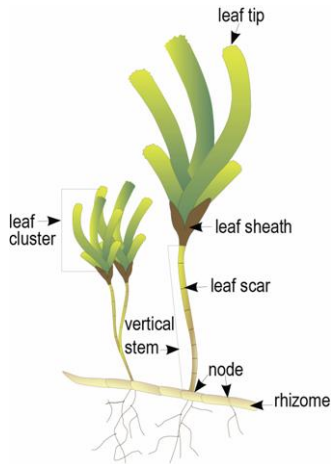
- cross veins 8 or more pairs
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

Leaves strap-like

Leaves can arise from vertical stem



straplike



Cymodocea serrulata

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

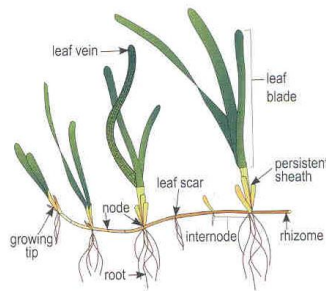
Halodule uninervis

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

Thalassia hemprichii

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

Leaves always arise directly from rhizome



Enhalus acoroides

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

Notes:

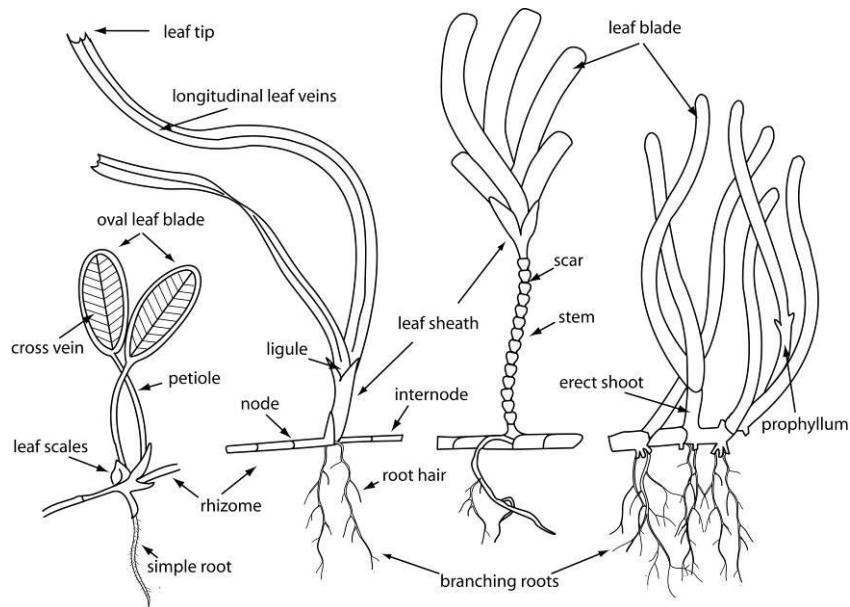
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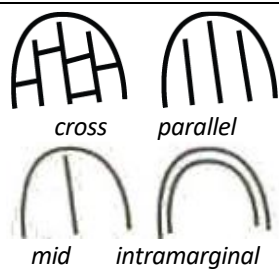

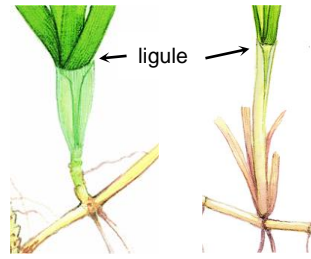

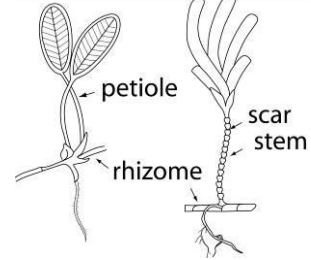
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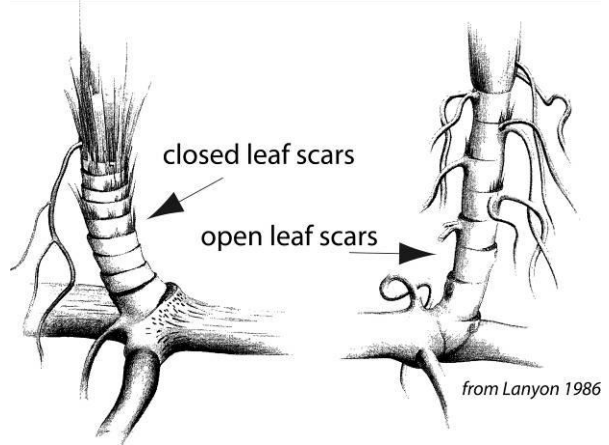
Parts of a seagrass plant



Leaf		
Tip	Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.	 <p>rounded pointed</p>
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. <ul style="list-style-type: none"> • 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 	 <p>cross parallel mid intramarginal</p>
Edges	The edges of the leaf can be either serrated, smooth or inrolled	 <p>serrated smooth inrolled</p>
Ligule	Membranous structure found at the junction of the blade and sheath. Clasps leaf sheaths, aiding protection of enclosed younger plant parts.	 <p>ligule</p>
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.	 <p>clean & flattened fibrous</p>
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. <i>Halophila ovalis</i> .	 <p>petiole rhizome scar stem</p>

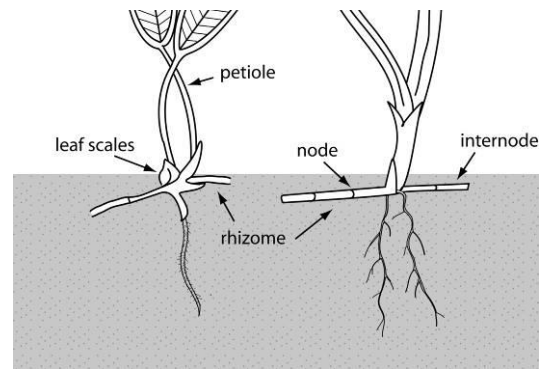
Stem

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



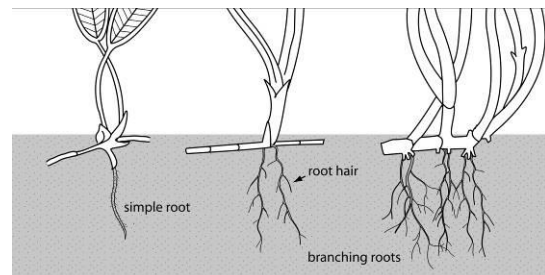
Rhizome

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



Root

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



Notes:

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Mapping seagrass extent

To make informed management decisions, coastal managers need maps containing information on the characteristics of seagrass resources such as where species of seagrasses occur and in what proportions and quantities, how seagrasses respond to human induced changes, and whether damaged meadows can be repaired or rehabilitated. Knowledge of the extent of natural changes in seagrass meadows is also important so that human impacts can be separated from normal background variation. Changes can occur in the location, areal extent, shape or depth of a meadow, but changes in abundance, species composition, growth and productivity, flora and fauna associated with the meadow, may also occur with, or without, a distributional change. When planning a mapping exercise, 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.

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. Using a handheld 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 mapping approach

Seagrass resources can be mapped using a range of approaches from direct *in situ* observation to spaceborne remote sensing. The choice of approach is scale and site dependent, and may include a range of specific approaches. McKenzie *et al.* ^[25] provided a decision tree to facilitate the formulation of a survey/mapping strategy (see Table 1).

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 field validation points.

Table 1. A decision tree. The data capture methods used to map the distribution of seagrass meadows vary according to the information required and the spatial extent.

What is the size of the locality to be mapped?	
Less than 1 hectare	1
1 hectare to 1 km ²	2
1km ² to 100 km ²	3
greater than 100 km ²	4
1. Fine/Micro-scale (Scale 1:100 1cm = 1m)	
Intertidal	in situ observer, airborne imagery (e.g. UAV)
Shallow subtidal (<10m)	in situ diver, benthic drop-camera, airborne imagery if clear water
Deepwater (>10m)	NA
2. Fine to Meso-scale (Scale 1:10,000 1cm = 100m)	
Intertidal	in situ observer, airborne imagery (e.g. UAV, aircraft), spaceborne imagery (e.g. PlanetScope)
Shallow subtidal (<10m)	in situ diver, drop-camera, benthic grab, airborne or spaceborne imagery if clear water
Deepwater (>10m)	in situ diver, drop-camera, benthic grab
3. Meso-scale (Scale 1:250,000 1cm = 250 m)	
Intertidal	helicopter, airborne imagery (e.g. UAV, aircraft), spaceborne imagery (e.g. PlanetScope)
Shallow subtidal (<10m)	airborne or spaceborne imagery if clear water, active remote sensing (e.g. sonar), drop camera, real time towed video camera
Deepwater (>10m)	active remote sensing (e.g. sonar), drop camera, real time towed video camera
4. Broad/Macro-scale (Scale 1:1,000,000 1cm = 10 km)	
Intertidal	satellite, aerial photography
Shallow subtidal (<10m)	airborne or spaceborne imagery if clear water, active remote sensing, drop camera, real time towed video camera
Deepwater (>10m)	active remote sensing (e.g. sonar), drop camera, real time towed video camera

Choosing a field survey strategy

Nearshore field survey

The objective of the field survey is to determine the edges/boundaries of any seagrass meadow and record information on species present, abundance, sediment, and depth (if subtidal). Field surveys are also essential if using airborne or spaceborne imagery to validate image signatures observed, or examine areas where the imagery does not provide information (e.g., such as in areas of heavy turbidity), and produce reference information for later accuracy assessment.

When mapping, field validation observations need to be taken at regular intervals relative the Area of Interest (AoI) being mapped. The location of each observation is referred to a point, and the intervals they are taken at may vary depending on the topography. Generally, an area can be mapped using a grid pattern or a combination of transects and spots.

When conducting mesoscale mapping of a region of relatively homogenous coastline between 10 and 100 km long, we recommend that transects of points 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.

When validating a point (spotcheck), 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 the point must be recorded using a GPS. 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 3-5m radius. Although only one observation (sample) is necessary at a field validation point (spotcheck), we recommend 3 replicate samples spread within the point 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 % cover) and species composition. Also record the water 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 (e.g., gravel, coarse sand, sand, fine sand or mud), or distance from other habitats (reefs or mangroves).

General field procedure

You will need:

- Handheld Geographic Positioning System (GPS) unit*
- Standard 50 centimetre x 50 centimetre quadrat*
- Seagrass identification and percent cover sheets*
- Clipboard with data sheets and pencils.*
- Suitable field clothing & footwear (e.g., hat, dive booties, etc)*
- Aerial photographs or marine charts (if available) of the locality*
- Plastic bags with waterproof labels - for seagrass samples*
- Waterproof camera (optional)*

First, define the extent of the survey area. Check the tides to help you plan when it is the easiest to do the mapping, e.g., spring low is best for intertidal meadows. If mapping can be conducted at low tide when the seagrass meadow is exposed, the boundaries of meadows can be mapped by walking around the perimeter of each meadow with the GPS on the track setting. Alternatively, a UAV (Drone) can be used to collect images that can be meshed into an orthomosaic. An important element of the mapping process is to find the inner (near to the beach) and outer (towards the open sea) edges of the seagrass meadow.

The number of mapping points you survey will be entirely up to you. If you need to accurately map an area, then intensive surveying (sample lots of points/spotcheck) is recommend. It is also beneficial to try to get a good spread of mapping points over the area, as some of the changes in the seagrass meadow will not necessarily be obvious.

Field survey point measures

Step 1. Use a GPS to record the geographic position of the point

Step 2. Use a camera with geotagging capabilities to capture a photoquadrat image

Step 3. If you have time, record information such as sediment composition, seagrass cover/abundance and species composition from within 3 haphazardly tossed 50cm x 50cm quadrats, estimate algae percent cover, note other features if interest (e.g. macrofauna, presence of herbivore activity, etc)

Step 4. Collect a voucher specimen of each new seagrass species encountered.

Remote sensing

The remote sensing of seagrass is based on the principle that a remote sensor can “see” the substrate and the vegetation growing on that substrate. A remote sensing instrument measures light from the sun after it has passed through the atmosphere, interacted with the target, and has been reflected back through the atmosphere to where it is measured by a sensor mounted on an aircraft or a satellite (remote sensing can also include acoustic techniques conducted from a vessel on the sea surface). Whether a benthic feature such as seagrass can actually be discriminated depends on the spectral optical depth of the water column, on the brightness and density of the seagrass and the spectral contrast between it and the substrate, as well as on the spectral, spatial and radiometric sensitivity of the remote sensing instrument. As the remote sensing image usually covers a much larger area than a field survey, extrapolation is performed using a variety of either subjective or statistically developed techniques.

The most traditional remote sensing technique is aerial photographs or spaceborne satellite imagery. Today, Unoccupied Aerial Vehicles (UAVs), commonly referred to as drones, are becoming popular platforms for spatial assessment of ecological phenomena, effectively bridging the gap between satellite and onground data collection. These high earth observing platforms have the capacity for acquiring remotely sensed imagery of very fine spatial resolution (0.01–5 cm), have increased flexibility for image acquisition, and generally have lower operational costs. There are a few techniques used to derive maps from UAV imagery, but regardless of the method, all imagery requires field validation points to ensure accuracy in the interpretation and confidence in the mapping product. Interpretation of digital imagery requires a combination of mathematical and software capabilities, and in some instances physics and biogeochemistry skills. Such resources can often be prohibitively expensive, although freeware platforms are slowly becoming available.

Remote sensing however does have limitations beyond expense and training. It can provide accurate boundaries of intertidal and sub-tidal (clear shallow water up to 6 m) meadows, however for many tropical environments it can be challenging to discriminate meadow boundaries or information on species, habitat use, etc, without intensive field sampling. To assist potential users of remotely sensed data, a toolkit is available ^[26]; <http://www.gpem.uq.edu.au/cser-rstoolkit/>) which provides guidance for delineating suitable remote sensing data and techniques and background information on the marine remote sensing process.

Creating the map

The simplest way to map the extent of seagrass meadows is to draw the meadow boundaries on a paper marine chart from the GPS positions of the ground truth sites. The problem with this type of approach is that the final map is in a format that does not permit 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 seagrass mapping.

GIS are software systems of highly accurate digital maps that can be overlaid to reveal relationships that might not otherwise be detected on traditional paper maps. Digitally-stored cartographic databases can be altered much quicker than hard copies and shared data can be standardised. The key element of a GIS is the separation of differing data sets into thematic layers. GIS software provides the functions and tools needed to store, analyse, and display geographic information. The most common GIS packages is ArcGIS[®], and there are both online and desktop versions available. Mapping seagrass meadows with a GIS can help to identify emergent patterns or relationships in geographically referenced data.

Boundaries of meadows can be determined using field based approaches (e.g. walking the meadow boundary), remotely sensed imagery (airborne and/or spaceborne) using the positions of field spotchecks, or a combination of methods including various forms of interpolation and modelling. Errors that to be considered when interpreting GIS maps include those associated with digitising and rectifying the imagery onto the basemap and those associated with GPS fixes for field points/spotchecks.

In certain cases, seagrass meadows form very distinct edges that remain consistent over many growing seasons. However, in other cases the seagrass tends to grade from dense continuous cover to zero cover over a continuum that includes small patches and shoots of decreasing density. Boundary edges in patchy meadows derived from direct observation are vulnerable to interpreter variation. Given the uncertainty surrounding the determination of meadow edges it is suggested that each mapping effort should include some measure of confidence in the map product based on the approach and methodologies used, the validation implemented, how representative of the Aoi the validation was, how direct the measures were and what the measured mapping error was.

The final map can be presented on screen and in hard copy. The final maps need a clear legend describing the features highlighted, a scale, and a source. The maps are best accompanied by metadata. Metadata is information about the data and not to be confused with a summary of the data. Metadata describes data source, data reliability, conditions of use, limits on interpretation and use-by date, and usually includes the correct form of citation to be used for acknowledging the data source. It holds information about the quality of the data. The project metadata for all spatial data should have some statement about the accuracy of a map product.

We also recommend archiving your maps with a spatial data publisher such as the World Data Center PANGAEA® (www.pangaea.de). PANGAEA® is free of charge and a member of the World Data System (WDS) of the International Council for Science (ICSU). Published data are open access and fully citable; can be cross-referenced with a digital object identifier (DOI) name for each data supplement. The Creative Commons Attribution license requires that author(s) are referenced if the data are reused and authorship for your data publications is automatically assigned in ORCID.

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Monitoring a seagrass meadow

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

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

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

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

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

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

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

Monitoring seagrass condition

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

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

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

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

Seagrass-Watch

A method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses globally standardised measurements taken from sites established within representative 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 its genesis in **28 March 1998** in Australia, Seagrass-Watch has expanded internationally to more than 26 countries. Monitoring is currently occurring at over 425 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 scientists and volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with universities & research institutions, government (local & state), non-government organisations or established local stakeholder groups.

Seagrass-Watch integrates with existing scientific programs to raise awareness and protect this important marine habitat for the benefit of the community. The program has a strong scientific underpinning with an emphasis on consistent data collection, recording and reporting. Seagrass-Watch identifies areas important for seagrass species diversity and conservation and the

information collected is used to assist the management of coastal environments and to prevent significant areas and species being lost.

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

QUALITY ASSURANCE-QUALITY CONTROL

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

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

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

Seagrass-Watch HQ has implemented a quality assurance management system to ensure that data collected is organised and stored and able to be used easily. All data (datasheets and photographs) received are entered onto a relational database on a secure server. Receipt of all original data hardcopies is documented and filed within the Seagrass-Watch File Management System, a formally organised and secure system. Seagrass-Watch HQ operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for

reporting purposes. Access to the IT system and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

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

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

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

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

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

DATA PROPERTY AND OWNERSHIP

All raw data collected throughout the Seagrass-Watch program is the property of the individual/group/institution (*Principal*) who collected it, and Seagrass-Watch Ltd is custodian. When a Principal (*data collector*) submits data to Seagrass-Watch HQ, they do so under the proviso that Seagrass-Watch HQ can conduct a data quality assessment as part of the Seagrass-Watch program's QAQC protocols and that the validated data is available for condition and trend reporting at location, regional, state, national and global scales (e.g., State of the Environment). Copies of raw data are provided to third parties only when permission from the Principal is provided.

Ownership of data within the Seagrass-Watch program is determined by mutual agreement based on who is collecting the raw data, whether the data undergoes a quality assessment as part of Seagrass-Watch QAQC protocols and the funding sources that support the monitoring:

- **Raw Data** ownership (intellectual property rights) lies with the Principal (*data collector*). Seagrass-Watch Ltd is custodian of the **Raw Data**.
- **Validated Data** ownership (intellectual property rights) is shared between the Principal and Seagrass-Watch Ltd.

All data interpretation is conducted by Seagrass-Watch HQ. This ensures that the interpretation of data is consistent, unbiased and of scientific merit. Seagrass-Watch HQ also encourages peer review of published results.

Apart from the regional & state-wide report cards, the data has also been used for:

- understanding and responding to impacts from catchment runoff^[27, 28], coastal developments (e.g., marina constructions) and dredging proposals.
- Understanding natural levels of change^[29-31] and supporting marine habitat conservation (e.g., GSS Ramsar Wetland, Cooloola World Heritage area, and Great Sandy Marine Park).

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.*

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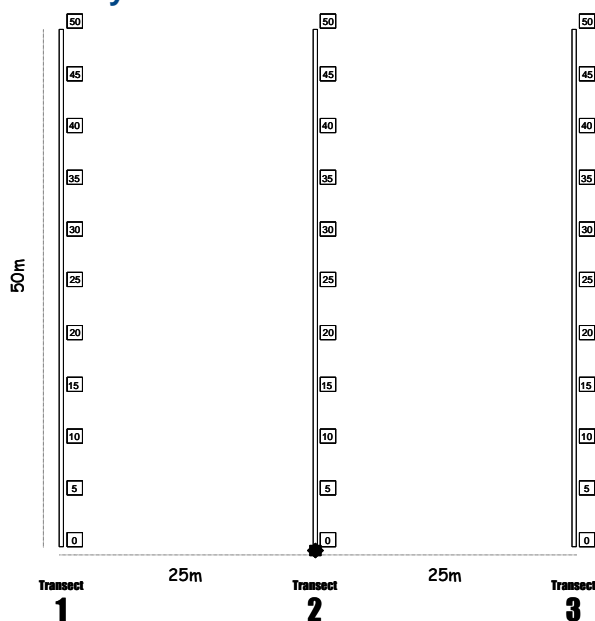
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Seagrass-Watch Protocols

Source: McKenzie et al. 2003⁽³²⁾ (www.seagrasswatch.org/manuals/)

Site layout



Quadrat code = site + transect+quadrat

e.g., C11225 = Chek Jawa. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Each sampling event

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

Step 1. Take a Photograph of the quadrat

- Photographs are taken of every quadrat along each transect. Use a quadrat free of strings and place the photo quadrat labeller beside the quadrat and tape measure with the correct code on it.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat label and tape measure. Avoid having any shadows or patches of reflection off any water in the field of view. Check the photo taken box on datasheet for quadrat.

Step 2. Describe sediment composition

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

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

- Note and count (whole numbers - never use < or > symbols) any features which may be of interest (e.g. gastropods, hermit crabs, dugong excavating, turtle cropping, bioturbation, sediment ripples) within the comments column.
- If water covers half or more of the quadrat, measure depth in cm.

Step 4. Estimate seagrass percent cover

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

Step 5. Estimate seagrass species composition

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

Step 6. Measure seagrass canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

Step 10. Move to next quadrat

- Repeat steps 1 to 8 for the remaining 32 quadrats

Step 11. At completion of monitoring

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

At completion of monitoring

Step 1. Wash & pack gear

- Rinse all tapes, pegs and quadrats with freshwater and let them dry. Do this every day of monitoring.
- Review supplies for next sampling and request new materials.
- Store gear in a safe and dry place for next sampling.

Step 2. Press any voucher seagrass specimens if collected

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

Step 3. Submit all data

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

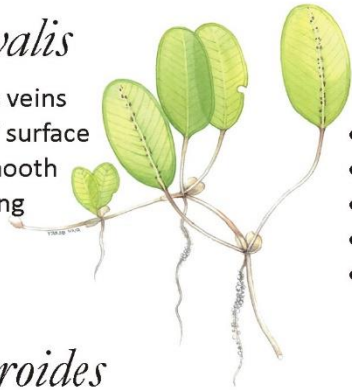
Seagrass-Watch HQ
For postal address, see
<https://www.seagrasswatch.org/contact/>

SEAGRASS SPECIES CODES

Ho

Halophila ovalis

- 8 or more cross veins
- no hairs on leaf surface
- leaf margins smooth
- leaf 5-40mm long



Hd

Halophila decipiens

- oval leaf, slightly pointed
- leaf hairs on both sides
- 6-8 cross veins
- leaf margins finely serrated
- leaf 10-25mm long



Ea

Enhalus acoroides

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



Th

Thalassia hemprichii

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



Hu

Halodule uninervis

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



Cs

Cymodocea serrulata

- serrated leaf tip
- wide leaf blade (4-9mm wide)
- leaves 6-15cm long
- 13-17 longitudinal veins
- robust/strong rhizome
- triangular shaped sheath



Si

Syringodium isoetifolium

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



Hs

Halophila spinulosa

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



SEAGRASS-WATCH MONITORING



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

START of transect (GPS reading)

Latitude: Longitude:

OBSERVER: Beverly Citizen DATE: 17/2/21
 LOCATION: Burren Heads
 SITE code: BHT1 TRANSECT no.: 2
 START TIME: 1304 END TIME: 1340

Quadrat (metres from transect origin)	Sediment (eg. mud/sand/shell)	Comments (eg 1lx 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			
1 (0m)	Sand	SCx3 DFTx1 HCx1	40	30	70	0	5417	5	33
2 (5m)	Fs/S	GASx2 RAYpt x2	33	50	50	0	61616	10	18
3 (10m)	CS	HCx3	0			0	-	0	-
4 (15m)	m/s	CHx10	0			1cm	-	17	-
5 (20m)	m/s	Turtle cropping GASx3	18	5	90	5	71516	12	57
6 (25m)	m/s/sh	SCx3 mwx2	36	90	90	10	81616	2	95
7 (30m)	Fine Sand	CHx9 GWSx1	48	100			-	0	10
8 (35m)	CS/S	Nothing	0.7	100			61515	0	36
9 (40m)	FS	HCx2	23	96	4		551516	5	38
10 (45m)	S/m	GWSx2	41	3	97		81817	3	90
11 (50m)	mud	CHx2 SCx1	16	3	7	90	71718	38	95

END of transect (GPS reading)
 Latitude: Longitude:
 FS = Fine Sand
 CS = Coarse Sand
 m = mud
 S = Sand
 SC = Sea Cucumber
 HC = Hermit Crab
 GAS = Gastropod
 CH = Crab Hole
 mw = mud worm
 CW = Green worm
 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.

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

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

Pressing

Tools

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

Preparation

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

Arrangement

It is very important that the seagrass specimen be arranged so that you can immediately see all the main characters of that particular species; so do not focus only at the aesthetics of the mounted specimen. It is advisable to arrange specimens before being placed in the press as once dried, plant specimens can easily be broken if handled without care. The best manner to place the plants on the mounting sheets is to align them with the right side of the page (or diagonally if space is required) and to have the heaviest parts and specimens at the bottom. Leaves can be folded in larger specimens if a larger press 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, or pinning. We recommend the strapping method using removable adhesive tape (e.g. Magic Tape). The tape pulls off easily, leaves behind no messy residue, and can be pulled up and moved around. To fix the specimen to the mounting paper, lay small strips of tape across a few sturdy parts of the plant (e.g. either end of rhizome or a stem) at a minimal number of points. This method will allow a certain degree of movement for further examinations, but the specimen will not fall from the mounting paper

Herbaria

Once the specimen is mounted it can be stored in a dry place or lodged in Herbaria. If you do not have a Herbaria nearby (usually located at a University or Government agency), you can submit specimens to Seagrass-Watch HQ which maintains a Herbaria in collaboration with the Australian 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 <https://www.seagrasswatch.org/herbarium/>.

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.

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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 ^[33].

	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
	<hr/>	
	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
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	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).

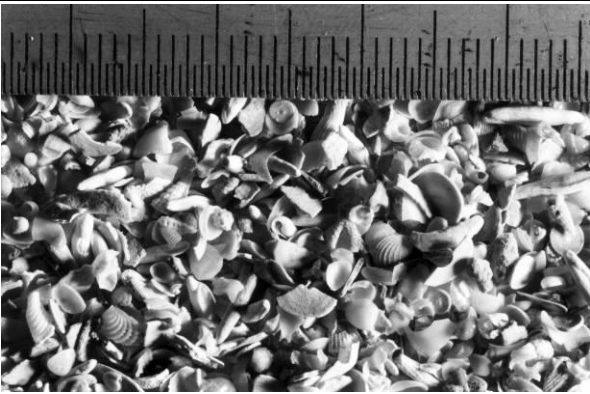
The sediment **Primary Descriptors** are written down from left to right in decreasing order of abundance: e.g. Mud/Sand is mud with sand, where mud is determined as the dominant constituent (by volume).

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

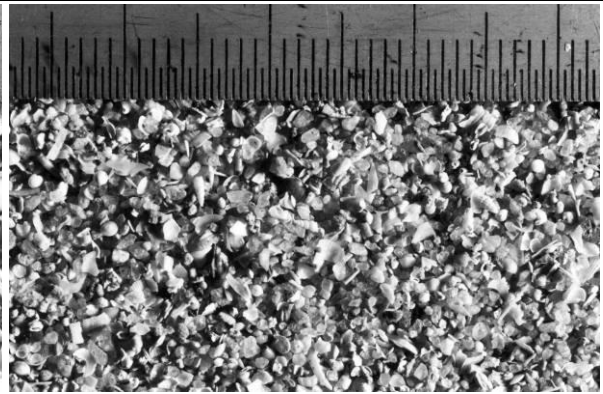
Sediment type **Modifiers** are also commonly used, however these are recorded in the comments section. Modifiers include: coral, shell grit, forams, diatoms, etc.

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 ^[34],

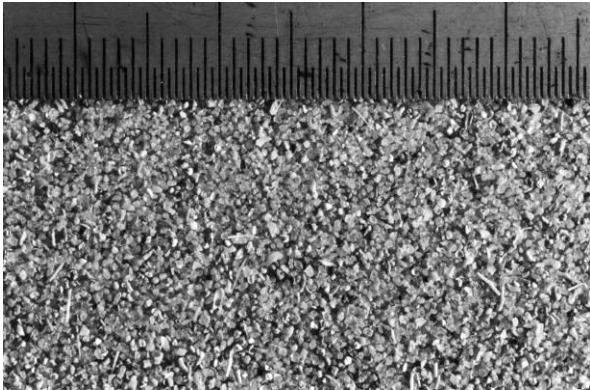
<https://bit.ly/3pITowW>.



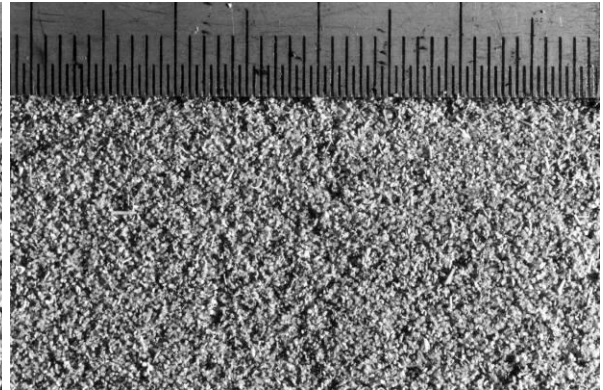
gravel (>2mm)



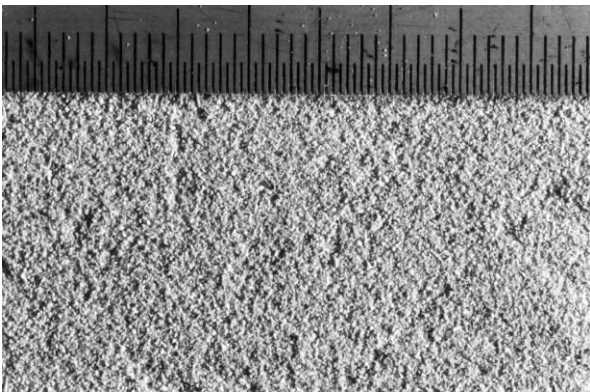
very coarse sand (1 – 2 mm)



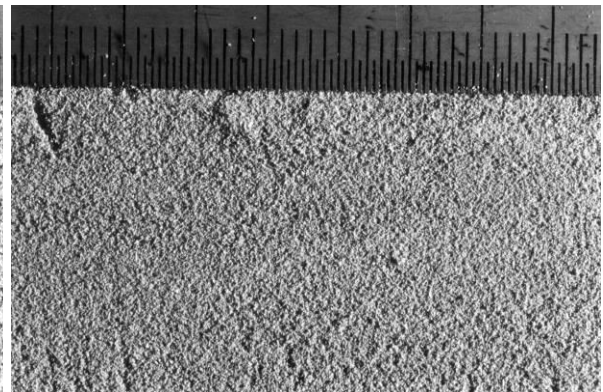
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

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Seagrass conservation

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. Global climate change is further undermining the resilience of seagrass ecosystems. Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world: transplantation, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitat through law and environmental policy.

Management

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

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

Methods of direct protection range from legislative instruments and associated legal sanctions through to education ^[35]. These can be separated into three approaches: a proscriptive legal approach; a non-proscriptive broad based approach ranging from planning processes to education; and a reactive approach designed to respond to a specific issue such as a development proposal. These may overlap and be used simultaneously in many cases. It is these three approaches that Seagrass-Watch supports for the protection/conservation of seagrass.

Reactive (on-ground)

Reactive processes generally occur in response to a perceived operational threat such as a coastal development proposal^[35]. Reactive processes can include port contingency planning, risk management plans and environmental impact assessments.

Prescriptive (legal)

Prescriptive management of seagrass issues can range from local laws to a Presidential Decree, or Executive Order. Laws can directly safeguard seagrasses or can protect them indirectly by protecting habitat types (all aquatic vegetation) or by influencing a process, e.g., prevention of pollution^[35].

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

Non-prescriptive (planning & education)

Non-prescriptive methods of protecting seagrasses are usually part of planning processes and may have a strong extension/education focus^[35]. Providing information is important as it enables individuals to voluntarily act in ways that reduce impacts to seagrasses. Non-prescriptive methods range from simple explanatory guides to complex industry codes of practice.

Coastal management decision making is complex, and much of the information on approaches and methods exists only in policy and legal documents that are not readily available. There may also be local or regional Government authorities having control over smaller jurisdictions with other regulations and policies that may apply. Many parts of South East Asia and the Pacific Island nations have complex issues of land ownership and coastal sea rights.

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 Western view of the sea as common domain, open to all and managed by governments^[36]. Unlike contemporary Western 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 thousands 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^[37].

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.

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Useful web links

Seagrass-Watch Official Site <https://www.seagrasswatch.org>

SeagrassSpotter A conservation and education tool that could lead to new discoveries about one of the ocean's most under-appreciated habitats – seagrass. With SeagrassSpotter, ocean enthusiasts around the world can become citizen scientists who contribute to marine conservation with just a few taps of their phone. <https://seagrassspotter.org/>

Project Seagrass A marine conservation charity dedicated to ensuring that seagrass meadows are protected globally, for the biodiversity and people that depend on them. <https://www.projectseagrass.org/>

Dugong & Seagrass Research Toolkit Helps you refine your research questions and provide you with a list of recommended techniques and tools to answer them. Designed for use by marine natural resource managers and decision-makers and for dugong and seagrass researchers, the Toolkit will show you which techniques are the most effective and efficient for your team capacity, budget and timeline. <http://www.conservation.tools/>

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

Reef Guardians and ReefEd Education site of the Great Barrier Reef Marine Park Authority. Includes a great collection of resources about the animals, plants, habitats and features of the Great Barrier Reef. Also includes an on-line encyclopedia, colour images and videos for educational use, a range of free teaching resources and activities. <http://www.gbrmpa.gov.au/our-work/our-programs-and-projects/reef-guardians>

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>

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