Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in the Mackay Whitsunday NRM Region, Queensland

QPWS Whitsunday Information Centre, Jubilee Pocket, Airlie Beach
16-17 July 2016

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Disclaimer

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

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

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Front cover photos (left to right): dugong grazing trails in *Zostera muelleri* meadow on intertidal banks at Pioneer Bay, Cannonvale (Oct14) by Len McKenzie; *Halodule uninervis* and *Cymodocea rotundata* on reef flat at Hydeaway Bay (Sep13) by Rudi Yoshida; and dense *Zostera muelleri* meadow on intertidal banks at Sarina Inlet (Sep15) by Len McKenzie.

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Overview

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is funded by Reef Catchments, with local coordination by Jacquie Sheils, and supported by Seagrass-Watch HQ.

This workshop is for experienced participants who plan to lead seagrass monitoring at a site/location or conduct seagrass extension activities. Presentations are targeted at participants with 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 monitoring activities. For further information, please do not hesitate to contact us at

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Photo: Fergus Kennedy

Workshop leaders

Len McKenzie

Len is a Principal Researcher with TropWATER (James Cook University) and Seagrass-Watch Program Leader. He is also the Task Leader of the Reef 2050 Plan Marine Monitoring Program – Inshore Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 20 years' experience as a researcher on seagrass ecology, assessment and fisheries habitats. This includes experience within Australia and internationally in seagrass research, resource mapping/ assessment and biodiversity. He has provided information on seagrass ecosystems that has been vital in management of seagrass resources of the Great Barrier Reef and at the state, national and international levels. He has also advised on fisheries and coastal resource-use issues for managers, fishing organisations, conservation and community groups. Len is a qualified trainer and assessor (TAE40110). Len is also the Secretary of the World Seagrass Association.

Current Projects

- Seagrass-Watch
- Reef 2050 Plan Marine Monitoring Program: inshore seagrass
- Status and mapping of seagrass resources in Queensland
- Identification of indicators and thresholds of concern for water quality and ecosystem health on a bioregional scale for the Great Barrier Reef
- Seagrass resilience: seagrass connectivity, community composition and growth
- Investigations on the macrofauna associated with seagrass meadows

Rudi Yoshida

Rudi is a Research Officer with TropWATER (James Cook University). Rudi has over 15 years' experience in seagrass related research and monitoring. He is also a core member of Seagrass-Watch HQ, and ensures data submitted is managed and QA/QC protocols applied. He is also responsible for maintenance of the Seagrass-Watch website.

Current Projects

- Seagrass-Watch
- Reef 2050 Plan Marine Monitoring Program: inshore seagrass

Agenda - Level 1 (basic)

Saturday 16th July 2016 (QPWS offices)

0900 - 0930 *(30min)*	Welcome & Introduction
0930 - 0950 *(20min)*	Seagrass Biology and Taxonomy*
0950 - 1030 *(40min)*	Seagrass Identification
1030 - 1045 *(15min)*	*Break*
1045 - 1230 *(105min)*	Seagrass Identification *continued**
1230 - 1315 *(45min)*	*Lunch*
1315 - 1415 *(60min)*	Seagrass Biology 2 and Ecology
1415 - 1500 *(45min)*	Seagrass importance
1500 – 1545 *(45min)*	Seagrass threats*
1545 – 1600 *(15min)*	Wrap up for day

Sunday 17th July 2016 (QPWS offices & Pioneer Bay, Cannonvale)

0900 - 0915 *(15min)*	recap day 1
0915 - 0945 *(30min)*	Seagrass monitoring*
0945 - 1045 *(60min)*	Seagrass-Watch: how to sample*
1045 - 1100 *(15min)*	*Break*
1100 - 1130 *(30min)*	Seagrass-Watch: QAQC
1130 - 1215 *(45min)*	Seagrass-Watch: how data is used*
1215 - 1230 *(15min)*	Risk assessment
1230 - 1330 *(60min)*	*Lunch* & relocate to field site
1330 - 1530 *(2hrs)*	**Field exercise:** Seagrass-Watch monitoring

Where: Pioneer Bay (PI1)
- *meet at car park corner Beach Rd and Coral Esplanade, Cannonvale*
- *be punctual*

What to bring:
- *hat, sunscreen (Slip! Slop! Slap!)*
- *dive booties or old shoes that can get wet*
- *drink/refreshments and energising snack*
- *wet weather gear: poncho/raincoat*
- *insect repellent*
- *polaroid sunglasses (not essential)*
- *enthusiasm*

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

1530 - 1600 *(30min)* Wrap up *(on foreshore)*
- check gear
- feedback

Tide: 1451, 0.5m

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 two day training workshop (classroom, laboratory and field), and*
2. *three post workshop monitoring events (within 12 months)*

Two day 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 a 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 conducted within 12 months: no sooner than 1 month after the 2-day training workshop. Tentative monitoring events (dates) to be nominated within 1 month of 2-day 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:

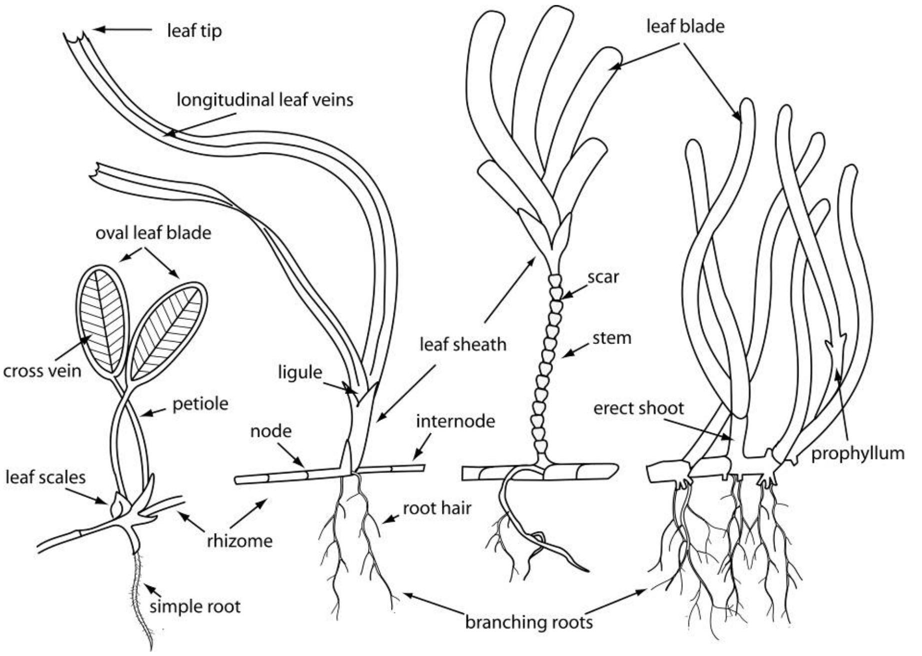
- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within acceptable limits
- epiphyte cover estimates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

Seagrass are marine flowering plants



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

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

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

Seagrasses have roots, stems and leaves

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

They are called "seagrass" because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover), a fern, a long spaghetti like leaf 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**.

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

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

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

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

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

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

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

Seagrass pump oxygen into the sediment via their roots

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

Seagrass have flowers, fruits and seeds

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

Pollination occurs in the water

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

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

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

Seagrass taxonomy

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

Seagrasses are not true grasses

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

Seagrasses are more closely related to lilies

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

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

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

Seagrass requirements for growth

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

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

Seagrasses need plenty of sun and clean water to grow.

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

Seagrasses are physiologically adapted to life in sea water

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

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

Light availability is the most important factor determining seagrass growth

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

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO_2 concentration. The cause of thermal stress at higher temperatures (38°C to 42°C) is the disruption of electron transport activity via inactivation of the oxygen producing enzymes (proteins) of photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

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

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

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

Seagrass require inorganic carbon for growth

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

Seagrass uptake carbon via two different pathways

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

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.

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

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

Most seagrass live in sand or mud sediments

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

Sediment movement can determine the presence of seagrass species

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

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

Where are seagrasses found?

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

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.

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

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

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

The depth range of seagrass is most likely to be controlled at its deepest edge by the availability of light for photosynthesis. Exposure at low tide, wave action and associated turbidity and low salinity from fresh water inflow determines seagrass species survival at the shallow edge.

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.

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

Seagrass plants form small patches that develop into large meadows

How are seagrasses important to the marine ecosystem?

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

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

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

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

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

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

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

Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The decaying leaves are broken down by fungi and bacteria which in turn provide food for other microorganisms such as flagellates and

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.

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

Tropical seagrasses are important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities).

Seagrasses, mangroves and coral reef interact, providing physical and biological support for 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 services is a very controversial topic in today's literature. Ecosystem Services are the processes by which the environment produces resources that we often take for granted. For seagrasses it is services such as clean water, preventing erosion, and habitat for fisheries. The economic values of seagrass meadows are very large, although not always easy to quantify. Seagrass meadows are rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. The average global value of seagrasses for their nutrient cycling services and the raw product they provide has been estimated at US$ 28,916 ha^{-1} yr^{-1} (in 2007 dollars).

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

What causes seagrass areas to change?

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

Seagrasses can change due to both natural and human impacts

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

What threatens seagrass?

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

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).

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

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

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

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

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

Coastal development can have a major impact on seagrass meadows

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

One of the other significant impacts to seagrass is climate change. The major vulnerability of seagrass to climate change is loss of seagrass in the coastal zone, particularly near river mouths and in shallow areas. The greatest impact is expected to result from elevated temperatures, particularly in shallower habitats where seagrasses grow (e.g., 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.

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

Seagrass in the Mackay Whitsunday region of Queensland

Updated from McKenzie and Yoshida, 2012

The Mackay Whitsunday NRM region on the central-east Queensland coast extends from Adelaide Point (Edgecumbe Bay) in the north to Clairview (Clairview Bluff) in the south and includes several large continental islands. The Great Barrier Reef protects the coastline from predominantly south-easterly winds which often accompany a light south-easterly ocean swell. Coastal waters adjacent to the large rivers and mangrove-lined inlets are generally very turbid and shallow, with predominantly muddy sediments. Tidal range in the south of the region is large, and in some places has the effect of creating extensive tidal banks. The region receives rainfall between 500-3000 mm annually, which falls mostly from December to April. The major land use of each catchment is livestock grazing, and crops such as sugar cane.

Seagrasses are a major component of the Mackay Whitsunday region marine ecosystems and their contribution to the total primary carbon production is critical to regionally important dugong and turtle populations (Marsh and Lawler, 2001) and productive fisheries (Coles *et al.*, 2003). Coastal meadows are important nursery habitat to juvenile fish and prawns (Coles *et al.*, 2007), and provide habitat for migratory wading birds. Extensive seagrass meadows occur both on intertidal mudflats and in nearshore and offshore subtidal areas in the region. Approximately 448 km^2 of seagrass habitat has been mapped in the Mackay Whitsunday region over the past 3 decades, with 154 km^2 in shallow waters and 293 km^2 in deeper (>15m) waters (McKenzie *et al.*, 2010). In 1999-00, 5553 ±1182 hectares of seagrass was mapped from Midge Point in the south to Hydeaway Bay in the north (Campbell *et al.*, 2002). This represented a 40% increase in overall seagrass habitat compared to the 1987 historic baseline, however losses had occurred at some localities.

Thirteen species of seagrass have been recorded in the Mackay Whitsunday region (Carter *et al.*, 2016; Council of Heads of Australian Herbaria, 2016; Seagrass-Watch HQ, 2016), representing 80% of the known species found in Queensland waters. The wide range of physical habitats where seagrasses were found undoubtedly contributes to the high species diversity. Habitats include intertidal and subtidal areas of estuary, coastal fringing reef environments and deepwater environments. Based on the mapped seagrass areas, the majority of seagrass meadows in the Mackay Whitsunday region are within coastal and estuary habitats (Table 1). Of these, 36% are protected within declared Fish Habitat Areas and 10% are located within port boundaries. Only 5% of these seagrass meadows (excluding deepwater) are covered by the highest levels of protection within the GBRWHA zoning.

Table 1. Area (km^2) of seagrass within each habitat type, port area and GBR protection zones. Shaded areas afford highest levels of protection for seagrass. From Coles *et al.* 2007. *NB: total seagrass within zones does not add to total area of seagrass, due to many zones having overlapping boundaries.*

Habitat	Declared Fish Habitat Area	Ports	General Use Zone	Habitat Protection	Conservation Park Zone	Buffer Zone	Scientific Research	Marine National Park	Preservation Zone	Estuarine Conservation	Unzoned	Total Area
Estuary	29.36	0.00	12.87	16.22	4.30	0.00	0.00	0.25	0.00	0.00	0.00	**33.85**
Coast	39.15	19.42	34.44	43.38	44.17	0.00	0.00	10.09	0.00	0.00	0.00	**154.73**
Reef	0.58	2.26	0.30	8.51	3.06	0.00	0.00	0.35	0.00	0.00	0.00	**14.49**

Seagrass distribution throughout the region is most likely influenced by shelter, sediment characteristics, water turbidity and tidal exposure. Seagrass meadows are mostly found in the sheltered bays along the mainland coast. The most abundant seagrass areas along the mainland coast are found along the northern mainland coast (863 ha), northern Repulse Bay (822 ha) and southern Repulse Bay (678 ha) (Campbell *et al.* 2002).

The majority of the meadows are low - moderate in abundance, and are dominated by *Halophila* and *Halodule* species. Expansive meadows of *Halodule uninervis* / *Halophila ovalis* or *Zostera muelleri ssp. capricorni* exist on the coastal intertidal flats with reef top seagrass present on the numerous fringing reefs associated with the islands along this coastline. Deepwater seagrasses were generally not found in the central and northern parts of this region, apart from occasional sites in the lee of islands or reefs. These large areas devoid of seagrass are likely to be due to the scouring currents caused by large tides.

Edgecombe Bay

Seagrass meadows have a discontinuous distribution in Edgecumbe Bay, being found both subtidally and intertidally (Coles *et al.*, 2007) and represent significant nursery grounds for fisheries: supporting large populations of juvenile brown tiger king and endeavour prawns – species of high commercial value. Within Edgecumbe Bay, six species of seagrass have been recorded – *Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Cymodocea serrulata, Halophila decipiens* and *Zostera muelleri*. This combined with other habitat and fisheries values make Edgecumbe Bay a standout candidate for declaration as a Fish Habitat Area which occurred in 2005 (www.nprsr.qld.gov.au/managing/area-summaries/edgecumbe.html).

The distribution of coastal seagrass meadows along this coastline are predominately influenced by seasonal (April-November) south-easterly trade winds (Coles *et al.*, 2007). Seagrass meadows generally establish in places that offer protection from these winds, such as the large north opening bays and the leeward sides of continental islands. Episodic riverine delivery of freshwater nutrients and sediment are also an important factor structuring seagrass meadows in the medium time scale. The combination of seasonal terrestrial run-off, frequent cyclones, strong south-easterly trade winds and tidal runs create significant natural coastal turbidity. Seagrasses that inhabit this area are therefore, subjected to low light regimes, and high influxes of freshwater and sediment. To survive this regime seagrasses need to exhibit high vegetative growth rates and prolific seed banks. This has probably led to the predominance of opportunistic species, such as *Halodule* and *Halophila* within this region.

The greatest threat to seagrasses throughout this region is land clearing with respect to agricultural - grazing and cropping and coastal/urban development. Land clearing with its inherent problems of soil erosion and associated loads of nutrients and pesticides are problematic for the long term survival of seagrasses that are already stressed by natural events.

Cape Gloucester to Cape Conway

Coastal seagrass meadows from Cape Gloucester to Cape Conway do not extend beyond 1km from land, and are limited to waters less than 11m depth below MSL (Campbell *et al.*, 2002). Seagrass habitats include coastal intertidal mud/sand banks and fringing coral reefs. The greatest areas of seagrass occur in the northern section at Hydeaway / Dingo Bay and Pioneer Bay. The lowest biomass and area of seagrass occurs along the central Whitsundays coast from Earlando to Woodcutters Bay.

The highest diversity of seagrasses in the region occurs between Dingo Beach and Bluff Point, in north facing bays protected from south-easterly winds. Fringing reefs protect many of these bays from northerly winds, providing an ideal sheltered habitat for seagrass to grow. There are no major rivers flowing into this coastal section and a high proportion of the catchment in this region is covered with native terrestrial vegetation.

From Hydeaway Bay/Dingo Beach to George Point, seagrass meadows are dominated by *Thalassia hemprichii*, *Halodule uninervis* (wide leaf form), *Halophila spinulosa* and *Halophila ovalis* (Campbell *et al.*, 2002). Hydeaway Bay meadows cover approximately 157ha and are predominately mixed meadows of *H. uninervis, H. ovalis, Cymodocea rotundata* and *T. hemprichii*. Seagrass meadows in Dingo Beach cover approximately 55ha, which are predominately *Halodule uninervis* with *Halophila ovalis.* Other species (including *Thalassia hemprichii*, *Syringodium isoetifolium* and *Cymodocea serrulata*) are present within the bay.


Thalassia hemprichii, Cymodocea rotundata, and Halodule uninervis meadow, Hydeaway Bay – October 2009.
Photos: Len McKenzie.

Seagrass in the region represents a significant food source and valuable habitat for green sea turtle and dugong moving between Edgecombe Bay and the Whitsunday Islands. Cone shells and unidentified gastropods dominated the macrofauna of the fringing reef platform seagrass habitats. Decapods were mainly hermit crabs - abundances were highly variable. Holothurian abundance in Hydeaway Bay was relatively high (large species of *Holothuria* sp.), but similarly variable. Bioturbation was also high, due to lots of crab burrows. Land based development contributing to high sediment runoff poses a threat to seagrass meadows in the region.

Coastal seagrass habitats are found in areas such as the leeward side of inshore continental islands and in north opening bays. These areas offer protection from the south-easterly trades. Coastal mainland areas were characterised by meadows of *Halodule uninervis* or *Zostera muelleri* growing in sheltered intertidal habitats. *Halodule uninervis* (narrow leaf form) meadows occurred mostly in intertidal reaches of Pioneer Bay and in most of the embayments of the mainland coast. *Zostera muelleri* meadows were located along the mainland coast from Pioneer Bay to Cape Conway, on mostly muddy sediments. Sub-tidal communities of mixed wide-bladed species also occur in some coastal locations where water clarity and light penetration are sufficient for seagrass growth (Campbell *et al.*, 2002).

The meadows in Pioneer Bay declined in area by approximately 74% between 1987 and 1999-2000 (519 ha to 134 ha respectively) (Campbell et al. 2002). This apparent decline was due to the contraction of up to 1.3 km in the seaward extent (deep edge) of the meadow mapped in 1987. The inshore meadow edge seemed relatively unchanged. This inshore meadow covers approximately 60ha and was dominated by *Halodule uninervis* and *Zostera muelleri* mixed with *Halophila ovalis*. Dugong feeding trails are often observed in the bay, with highest feeding activity recorded in September/October.

Dugong grazing trails in *Zostera muelleri* (left - October 2009) and *Halodule uninervis* meadow (right - October 2007), Cannonvale (Pioneer bay). Photos: Len McKenzie (L) and Rudi Yoshida (R).

Potential impacts to these meadows are issues of water quality associated with urban, marina development and agricultural land use. The abundance of filamentous algae commonly found throughout the year at Pioneer Bay is of potential concern to the nutritional requirements of dugong and turtles. Algae may comprise a small percentage (2% volume) of dugong diets (Marsh *et al.*, 1982), but dugong have been shown to avoid feeding on seagrass carrying large quantities of epiphytic algae (Preen, 1995).

Whitsunday Islands

Island seagrass communities are mostly sub-tidal meadows of mixed wide-bladed species. The most extensive meadows are dominated by *Halodule uninervis* and these are found growing in the less turbid waters of Cid Harbour along the north-west coast (1431 ha) and Whitehaven Beach (Campbell *et al.* 2002). In waters off Whitsunday Island *H. uninervis* (wide leaf form) meadows occur in association with *Cymodocea serrulata, Halophila spinulosa* and *Halophila ovalis*. A small *H. uninervis* (narrow leaf form) meadow was found at the northern end of Whitehaven Beach. Small meadows of *Halophila tricostata* and *Halophila spinulosa* were found in subtidal island and coastal locations often in deeper waters (> 5m) than *H. uninervis*.

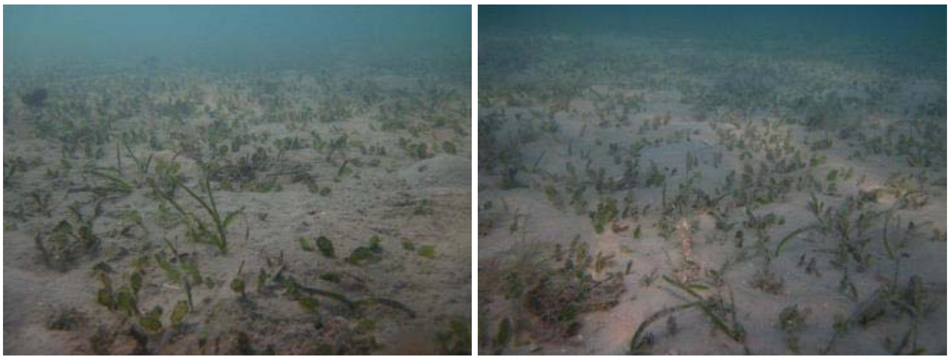
Reef habitat seagrass meadows occur intertidally on the top of the coastal fringing reefs or fringing reefs associated with the many islands in this region. Subtidal reef associated meadows are found at the base of these fringing reefs on the leeward, protected sides of the continental islands. The location where most seagrass species occur is Hamilton Island. Nine seagrass species can be found in Catseye Bay: *Halodule uninervis* and *Halophila ovalis* are scattered over the sandy intertidal areas; patches of *Zostera muelleri* occur in the intertidal areas at the eastern end of the bay; *Thalassia hemprichii, Cymodocea serrulata* and *C. rotundata* are mixed in amongst the coral on the reef flat; *Syringodium isoetifolium* is present on the outer edge of the reef flat in the shallow subtidal waters; *H. spinulosa* occurs just over the edge of the reef crest in deeper waters (>3m); and on the shoreward edge of the coral area are small patches of rare *Thalassodendron ciliatum*.

Dugong grazing trail in *Halodule uninervis* meadow (left - October 2009) and *Zostera muelleri* meadow (right - September 2012), Catseye Bay, Hamilton Island. Photos: Len McKenzie.

Halodule uninervis meadow (left) and *Thalassodendron ciliatum* (right), Catseye Bay, Hamilton Island - October 2007.
Photos: Rudi Yoshida.

The seagrasses in Catseye Bay are an important component of Hamilton Island's marine ecosystem, providing shelter for fish and prawns and food for green sea turtles. In recent years there has been some concern about the co-existence of tourism and the environment, and the resort is doing its best to ensure impacts are minimised. For example, several years ago an island resident expressed some concerns that jet-skis operating on the fringing reef were close to where he had observed turtles foraging daily. He witnessed one turtle hit by a jet ski and several near misses. Although jet-skis and high speed motorised water sports are permitted in the Whitsunday Plan of Management, the resort operators repositioned the buoys marking the jet-ski circuit to increase their distance from the fringing reef where turtles forage most frequently.

Subtidal seagrass meadows at Whitehaven Beach increased in area between 1987 and 1999-2000, however the meadows had declined by more than 20% in mid-2004. It is difficult to say whether this decline is ecologically significant or whether the meadow has recovered. Relatively few macrofauna were observed in the subtidal coastal habitat of Whitehaven Beach. Foraminifera dominated, with only a few gastropods observed grazing on the seagrass. Bioturbation was low, as only a few unidentified burrows (not crab) were observed.



Mixed *Halophila ovalis* and *Halodule uninervis* meadow, Whitehaven Beach– September 2012. Photos: Jacquie Shiels.

Cape Conway to Midgeton

Extensive seagrass meadows occur in Repulse Bay within 3 km of land and generally limited to waters less than 5.1m below MSL (Campbell *et al.* 2002). The greatest areas of seagrass at coastal regions were at northern and southern Repulse Bay which were dominated by *Zostera muelleri* (Campbell *et al.* 2002). *Halodule uninervis* (narrow leaf form) meadows occurred mostly in intertidal reaches of intertidal sand flats adjacent to Midgeton.

Dugong grazing trails (left) and green turtle basking (right) in *Zostera muelleri* meadow, Midge Point – October 2011. Photos: Len McKenzie.

Newry Bay to Mackay

The region supports diverse and extensive seagrass meadows, which were first mapped during a broad scale survey in 1987. The total cover of seagrass meadows in these areas was estimated at approximately 490 ha, however this may have been an underestimate of total seagrass area as surveying the large exposed mud and sand banks was not possible due to tidal conditions at the time.

Expansive meadows of *Halodule uninervis/ Halophila ovalis* or *Zostera muelleri* exist on the coastal intertidal flats of the region. Much of the coastline is exposed to south-east winds, with sheltered areas generally few and small. *Halodule* or *Halophila* spp. meadows are found in the lee or bays of islands. Strong tidal currents and associated high water turbidity in this region limit light penetration and therefore the depth to which seagrasses can grow. *H. ovalis, H. decipiens, H. spinulosa* and *H. tricostata* are found in deeper waters.

The Port Newry region north of Mackay is a Dugong Protected Area (DPA), declared in January 1998. St. Helens Bay and Seaforth are popular areas for recreational boating, camping, and fishing. The area offers sheltered estuarine and reef fishing, easily and safely accessed by small vessel via an all-tide, all-weather public boat ramp. In 1999, approximately 2,450 ha of seagrass habitat was mapped on mud through to sand substrates and extending to 5.5 m below MSL in St Helens Bay. The main seagrass habitat types were identified were large continuous meadows on intertidal banks (dominated by either *Halodule uninervis* (narrow) or *Zostera muelleri*), patchy meadows on intertidal sand banks in St. Helen's Bay (*Halodule uninervis* (narrow) or *Zostera muelleri*), or shallow sub-tidal meadows found in the Seaforth region and eastern parts of St. Helen's Bay (mixed species *Cymodocea serrulata, Halophila spinulosa, Halophila ovalis* and *Halodule uninervis*).

Subtidal mixed *H. spinulosa/H. ovalis/H. uninervis* meadow adjacent to Newry Island reef (left) and *H. ovalis* meadow in St Helens Bay (left) – October 1999. Photos: JCU.

In the offshore sections of this region, seagrasses occur on the fringing reef flats or in the sheltered shallow subtidal waters adjacent to the islands south of the Whitsunday Island group, however, information is nearly 30 years old: from the historic baseline survey in March 1987. Approximately 190.2ha of shallow subtidal meadows, dominated by a *Halodule*, *Halophila* spp., *Cymodocea serrulata* or *Syringodium*, were reported in the bays around the Lindeman and Shaw Island group (Coles *et al.*, 1987). Similarly, 71.2 ha of mixed *Halodule*, *Halophila* spp., *Cymodocea serrulata* or *Syringodium* meadows were mapped in the shallow subtidal water along the leeward side of the Goldsmith Island group.

Further south, information on seagrass from the Brampton Island group is poor, as no mapping surveys have ever been conducted around the islands. There have, however, been anecdotal reports of seagrass from the island group, of particular the presence of *Thalassodendron ciliatum* on the fringing reef flat of Brampton Island: the southernmost occurrence of this species in the Pacific.

Thalassodendron ciliatum meadow on the fringing reef flat, Brampton Island (September 2010). Photos: Jacquie Shiels.

The most southern of the island groups is the Keswick Island group. In October/November 2014, 147.1 ±79.5ha of subtidal seagrass was mapped in predominately isolated and aggregated patches around Keswick and St Bees Islands (McKenna and Rasheed, 2015). Five seagrass species were observed around the Keswick Island group: *H. uninervis, H. decipiens, H. ovalis, Halophila spinulosa* and *Halophila tricostata*. The largest meadow was located on the northern side of St Bees Island and was composed of *H. tricostata* with *H. decipiens* (McKenna and Rasheed, 2015).

Along the mainland coast, two small seagrass meadows were mapped within the Mackay Port limits (Slade Point to Bakers Creek), adjacent to the north-western shores of Flat and Round Top Islands in March 1987 (Coles *et al.*, 1987). These meadows were comprised of a single species *Halodule uninervis* (wide), with less than 10% cover at Flat Top and 10-50% cover adjacent to Round Top Island (Coles *et al.* 1987). In a survey of Mackay Port limits in February 2001, three seagrass meadows were mapped (Rasheed *et al.*, 2001). Three seagrass species were present: *H. uninervis* (wide), *Halophila decipiens* and *Halophila ovalis*. Two deepwater (17 - 22m) meadows dominated by *H. decipiens* were located approximately 7 km offshore and 12 km east of the harbour, covering of 272.6 ha and 293.8 ha (Rasheed *et al.*, 2001). A small (2.2ha) coastal *H. uninervis* (wide)/*H. ovalis* meadow was mapped adjacent to the north-western shore of Round Top Island (Rasheed *et al.*, 2001).

South of Mackay, seagrass has been mapped in the areas adjacent to Hay and Dudgeon Points. The offshore area at the Port of Hay Point has been surveyed for seagrasses on five occasions between July 2004 and October/November 2014 (Rasheed *et al.*, 2004; Chartrand *et al.*, 2008; Thomas and Rasheed, 2011; McKenna and Rasheed, 2015). The offshore area of Hay Point was dominated by open substrate with low density *Halophila decipiens*. The maximum depth recorded for offshore seagrass was 17.8m below MSL (Thomas and Rasheed 2011). Several small low biomass *Halophila ovalis* and *Halodule uninervis* meadows have been found around the shallow coastal areas adjacent to Dudgeon Point (Thomas and Rasheed, 2011), and in 2014 a patch of *Zostera muelleri* was reported (McKenna and Rasheed, 2015). In addition, offshore seagrasses were monitored at several key locations on a regular basis between December 2005 and October 2009 (Chartrand *et al.*, 2008). Results of these programs have found that offshore seagrasses at the Port of Hay Point were naturally highly variable with peak abundances and distribution occurring in winter and spring before seasonal declines over summer.

Sarina Inlet to Cape Palmerston

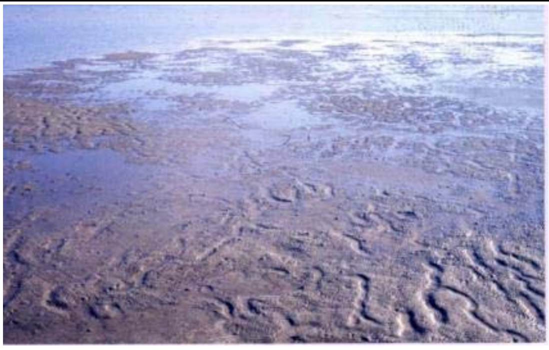
Sarina Inlet is an estuary located 35km south of Mackay. Sarina Inlet was poorly assessed in the historic baseline seagrass surveys between in March 1987: no seagrass was reported (Coles *et al.* 1987). Nevertheless, meadows of *Zostera meulleri* with *Halodule uninervis* and *Halophila ovalis* occur across intertidal banks in the north of the estuary. It is a tide-dominated estuary with moderate sediment trapping efficiency; naturally high turbidity, well mixed circulation and some risk of habitat loss due to sedimentation (reefcatchments.com.au/water/wqip-map/plane-creek). Plane Creek catchment drains into Sarina Inlet estuary. Plane Creek has been assessed as having a highly modified catchment, little riparian vegetation and modified catchment hydrology. Fish kills occur regularly as a result of poor water quality (Great Barrier Reef Marine Park Authority, 2013).

Zostera muelleri / *Halophila ovalis* meadow (left - October 2011) and with dugong grazing trails (right - September 2012), Sarina Inlet. Photos: Len McKenzie.

A detailed survey of Llewellyn Bay in 1999 (Roder and Roelofs, 2002) reported 11 small isolated seagrass meadows within a 1.5km strip along the coast in the southern section of the bay (Deception Inlet, Armstrongs Beach and the mouth of Rocky Dam Creek) which had not been reported previously (Coles *et al.* 1987). Total area of seagrass was approximately 116 ha, which changed little between May and October. Three seagrass species were found in Llewellyn Bay during May 1999 and four in October 1999 (Roder and Roelofs, 2002). Small isolated patches of *Halophila decipiens* and *Halophila spinulosa* were found in deeper water in October.

Seagrasses on the intertidal flats of Ince Bay were first mapped in March 1987 (Coles *et al.* 1987). A total of 1471 ha of seagrass was mapped between Allom Point and Glendower Point, Cutlack Island and Hogans Camp Island (Lee Long *et al.*, 1993). Lee Long *et al.* (1993) reported that the areas of seagrass habitat surveyed by Coles *et al.* (1987) included 575ha <10% cover, and 549ha of 10-50% cover. Ince Bay seagrass species included *Halophila ovalis, Halodule pinifolia* and *Halophila spinulosa*.

A survey of Ince Bay seagrass habitat in June - July 1997, reported a decline of approximately 50% in area (FRC Coastal Resource & Environmental, 1997). However, extensive meadows were mapped on the inter-tidal banks of Ince Bay in 1999, with four species present in May 1999 and five in October 1999 (Roder and Roelofs, 2002). The total area of seagrass increased from May (1203.6 ±133.8 ha) to October (1572.75 ±187.1 ha). The larger meadows were dominated by *Halodule uninervis* (narrow) and *Zostera muelleri*. An isolated patch of *Halophila spinulosa* mapped in May increased from 4.3ha to 58.1 ha in October. Smaller meadows of *Halophila ovalis/ Halodule uninervis* (narrow) mixed, and *Halodule uninervis* (wide) were also found on banks, channels and shallow sub-tidal areas in the eastern part of Ince Bay, north of the mouth of Cape Creek.

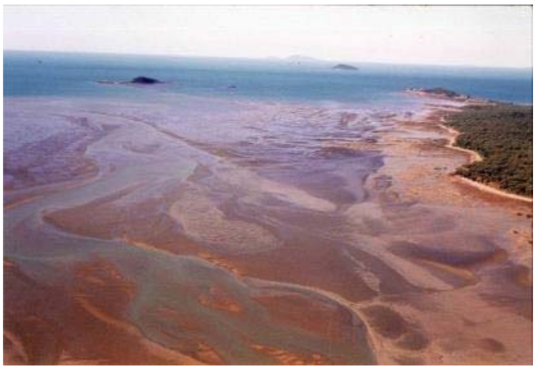


Intertidal *Halodule uninervis* meadow (left, Oct99) and dugong grazing trails (right, Apr99) in Ince Bay,–. Photos: JCU.

Cape Palmerston to Clairview

Seagrass meadows in the Clairview region were first mapped during a broad scale survey of seagrasses in April 1987 (Coles *et al.* 1987; Lee Long *et al.* 1993; Coles *et al.*, 2001). A total of 1880 ha of seagrass meadows were mapped (1476 ha of <10% cover and 404 ha of 10% cover). Five species of seagrass were identified, including *Halophila ovalis, Halophila spinulosa, Halodule uninervis* (narrow leaf form), *Halodule pinifolia* and *Zostera muelleri* (Lee Long *et al.* 1993; Coles *et al.* 2001).

In April 1999, a reconnaissance survey was conducted of only the inshore intertidal seagrasses meadows present in the Clairview region DPA (Roder *et al.*, 2002). Only two species were observed: *Halophila ovalis* and *Halodule uninervis*. *H. uninervis* was the most abundant and occurred along most of the wide coastal band of exposed intertidal sandbanks (up to 3km perpendicular from shore). Three additional intertidal areas of seagrass were observed in April 1999 where no seagrass was observed during the 1987 survey (between Carmila and Flaggy Rock Creek, off the southern coast of Flock Pigeon Island and a small north facing bay of Clairview Bluff).



Intertidal *Halodule uninervis* meadows (left) and dugong grazing trails (right), Clairview – April 1999. Photos: JCU.

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SEAGRASS-WATCH IN THE MACKAY WHITSUNDAY REGION

The Whitsundays was one of the first regions in which the Seagrass-Watch was established globally. To provide an early warning of change, long-term monitoring has been established at thirteen locations as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org). Establishing a network of monitoring sites in the Mackay Whitsunday region provides valuable information on temporal trends in the health status of seagrass meadows in the region and provides a tool for decision-makers in adopting protective measures. It encourages local communities to become involved in seagrass management and protection. Working with both scientists and local stakeholders, this approach is designed to draw attention to the many local anthropogenic impacts on seagrass meadows which degrade coastal ecosystems and decrease their yield of natural resources.

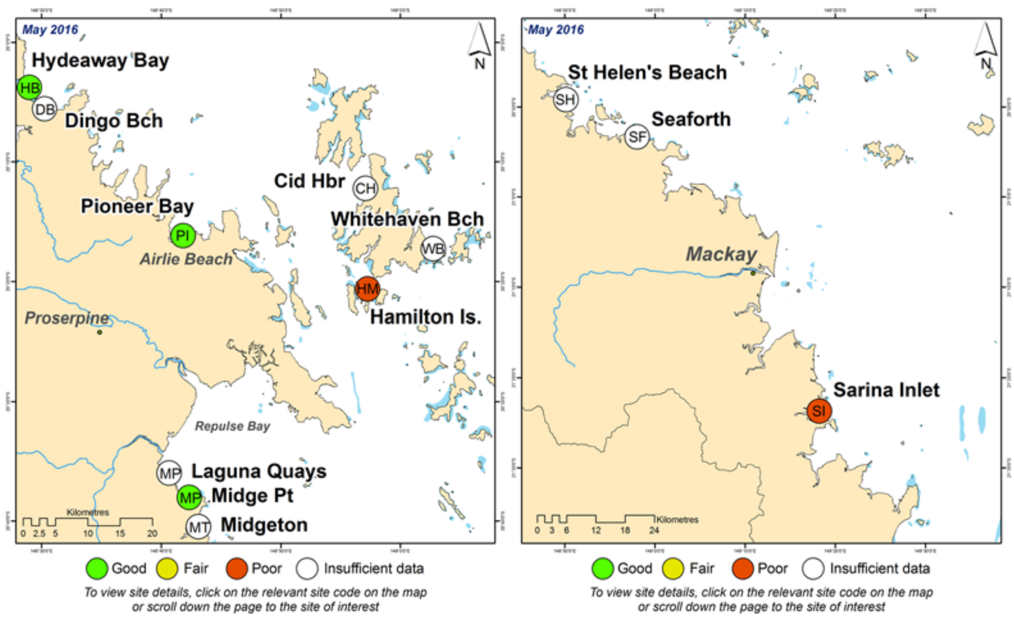


Figure 1. Status of seagrass abundance at Mackay Whitsunday monitoring locations, May 2016.

The following is a summary of the current status of Seagrass-Watch monitoring in the Mackay Whitsunday region.

Hydeaway Bay

Monitoring: ongoing, *biannual*
Principal watchers: Jacquie Shiels, Elmer Ten-Haken, Marty Mol, John Williams, Penny Taylor, Sheena Barrett, Heather Marshall, Wendy Galloway & Seagrass-Watch HQ
Occasional and past watchers: Maren Mathews, Tony Ayling, Avril Ayling, Valda, Dawn, Margaret Parr, Sunnee Goudy, Valerie Bunn, Victoria Ayling, Yvonne, Harm, Trent Hams & Dell Williams
Location: intertidal fringing reef-flat in north facing mainland bay, in the north of the region
Site code: HB1, HB2
HB1 position: S20.07479 E148.48216 *(heading 48 degrees)*
HB2 position: S20.07162 E148.48076 *(heading 56 degrees)*
Best tides: <0.8m *(port Double Bay 59360)*
Issues: Urban expansion, sewage and groundwater, siltation due to clearing and erosion
Comments: sea turtle and fish feeding ground
Status (May16):

- Seagrass abundance declined at both sites from 2009, but started to recover from 2013. Abundances in late 2011 were the lowest reported since monitoring was established.
- Seagrass canopy height and abundance follows a seasonal trend, characterised by maximum cover (>20% cover) in summer/autumn (December –April) and minimum cover (<20% cover) in winter (June-July). This suggests that seagrass meadows at these sites are primarily influenced by natural factors (temperature, light, wave action).

- Seagrass is dominated by either *Thalassia hemprichii, Halodule uninervis* or *Cymodocea rotundata*.
- Maximum epiphyte cover (>35-75%) occurs in summer (December) and autumn (March), and minima in winter. Algal cover has remained below 20% with no seasonal pattern. High epiphyte cover in spring-summer may be the result of higher water temperatures and light availability. High rainfall during summer may also enrich waters with nutrients necessary for epiphyte growth.
- The presence of large sea cucumbers present across the reef flat at both sites is significant. The low numbers of gastropods, crabs and worms at Hydeaway Bay may be due to the different seagrass mix at these sites and a low supply of detrital matter in the coarse sand sediments.
- Sites at Hydeaway Bay were comprised of fine to medium sand sediments, exposed to wave action and generally had a low seagrass abundance (<20% cover). Hydeaway Bay sand sediments had a low proportion of organic matter and seagrasses compete for space with corals (soft and hard) and macroalgae.

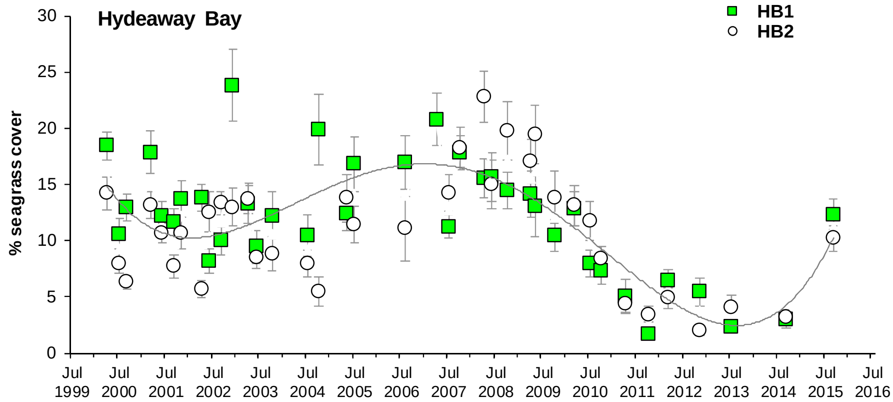


Figure 2. Changes in seagrass abundance (% cover ±Standard Error) at fringing reef intertidal monitoring sites, Hydeaway Bay.

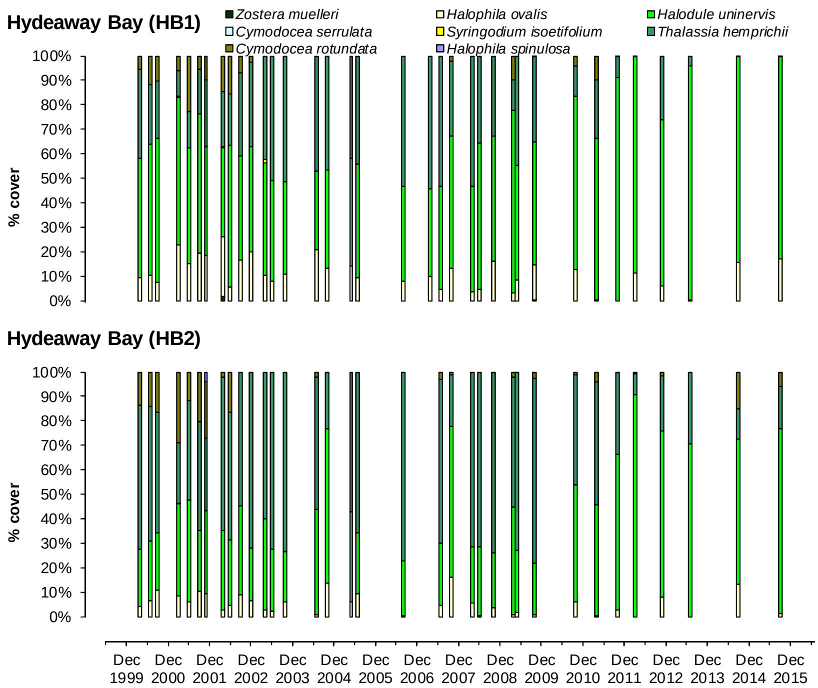


Figure 3. Seagrass species composition at intertidal fringing reef monitoring sites at Hydeaway Bay.

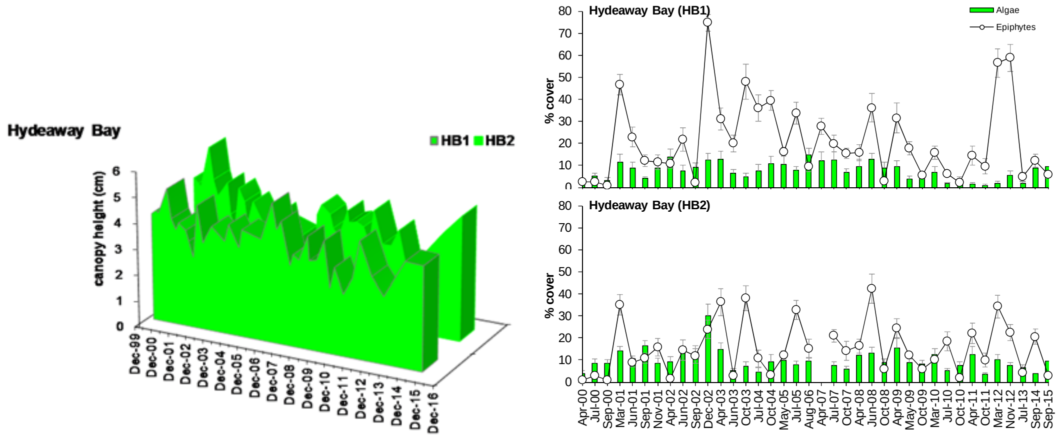


Figure 4. Canopy height of strap leaved seagrass at each monitoring site (left), abundance of epiphytes covering the seagrass leaf surface (right) and abundance of macro-algae (right) at each monitoring site, Hydeaway Bay.

Dingo Beach

Monitoring: *ad hoc*
Principal watchers: Maren Mathews, Tony Ayling & Avril Ayling
Occasional and past watchers: Geoff Bunn, Margaret Parr, Valerie Bunn, Wendy Galloway, Betty Wilson, Carolyn Williams, Dianne Turner, Jean Wells, Joyce Patullo & Seagrass-Watch HQ
Location: intertidal sand flats in north facing mainland bay, in the north of the region.
Site code: DB1, DB2
DB1 position: S20.08770 E148.49800 *(heading 10 degrees)*
DB2 position: S20.08920 E148.50220 *(heading 25 degrees)*
Best tides: <0.8m *(port Double Bay 59360)*
Issues: Urban expansion, sewage and groundwater, siltation due to clearing and erosion
Comments: turtle and fish feeding grounds.
Status (Jul13):

- The seagrass cover is generally moderate (5-30%). Seagrass abundance declined in 2010 and has continued to remain very low.
- Prior to 2009, seagrass abundance within years followed a seasonal trend, characterised by maximum cover (>20% cover) in summer/autumn (December –April) and minimum cover (<20% cover) in winter (June-July). This suggests that seagrass meadows at these sites are primarily influenced by natural factors (temperature, light, wave action).
- At Dingo Beach maximum epiphyte cover (>35-75%) occurred in summer (December) and autumn (March), and minima in winter. Algal cover remained below 20% with no seasonal pattern. High epiphyte cover in spring-summer may have been caused by high water temperatures and light availability. High rainfall during summer may also enrich waters with nutrients necessary for epiphyte growth.
- Gastropods, hermit crabs and polychaete worms were abundant at Dingo Beach. The high abundance of invertebrate fauna at these sites suggested that seagrass provides an adequate supply of detritus, grazing matter and faunal prey.
- Sites at Dingo Beach were comprised of fine to medium sand sediments, were exposed to wave action and generally had a low seagrass abundance (<20% cover). At Dingo Beach wave action from prevailing south-easterly winds and strong tides results in sediment movement where fine muds are displaced with coarse sands and shell.

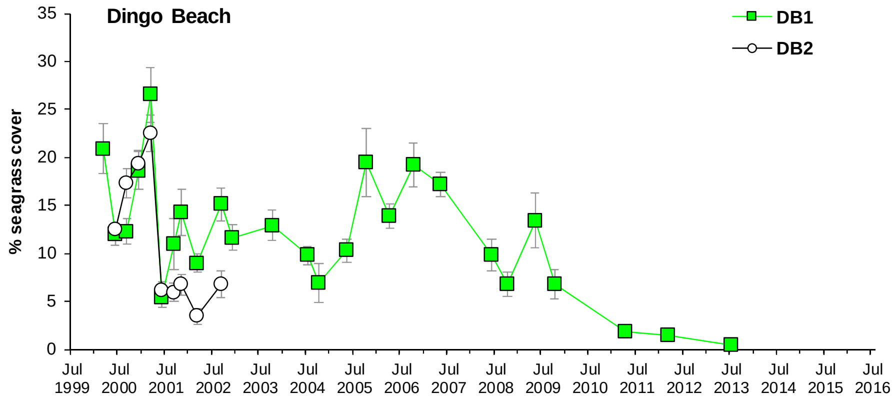


Figure 5. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Dingo Beach.

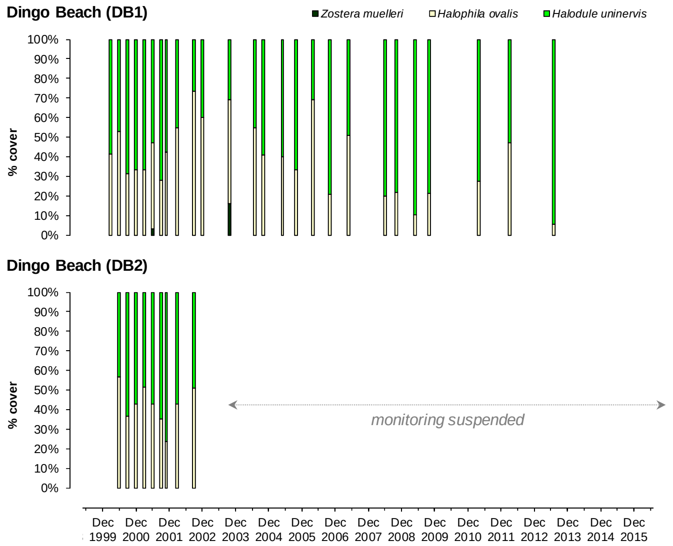


Figure 6. Seagrass species composition at coastal intertidal monitoring sites, Dingo Beach.

Pioneer Bay

Monitoring: ongoing, *quarterly*
Principal watchers: Jacquie Sheils, Dell Williams, John Williams, Heather Marshall, Kim Hodgon, Sheena Barrett, Elmer Ten-Haken & Seagrass-Watch HQ
Occasional and past watchers: Margaret Parr, Amanda Parr, Geoff Bunn, Robin Salmon, Valerie Bunn, Sandra Hardy, Betty Wilson, Eileen Lewis, Helen Debnam, John Schmidt, Alderd Lenting, Eileen Lavis, Emily Smart, Yvonne Chaloner, Brad Harris, Erin Prince, Pat Taggart, Yvonne Chaloner, Nah Judd, Nicky and Masao Yoshida, Carolyn Poid, Aileen Gleeson, Carolyn Williams, Fran Guard, Joanne, Judy Chapman & Lise Schimdt
Location: intertidal sand/mud flats adjacent to Cannonvale township in southern Pioneer Bay
Site code: PI1, PI2, PI3, PI4
PI1 position: S20.27056 E148.68901 *(heading 315 degrees)*
PI2 position: S20.26958 E148.69313 *(heading 340 degrees)*
PI3 position: S20.27077 E148.69743 *(heading 10 degrees)*
PI4 position: S20.27184 E148.70028 *(heading 20 degrees)*
Best tides: <0.4m *(port Shute Harbour 59410)*
Issues: High marina & urban development, adjacent to sewage treatment outfall
Comments: Dugong and turtle feeding grounds
Status (May16):

- Intertidal meadows in Pioneer Bay in the vicinity of Pigeon Island cover approximately 60ha, which are predominately *Halodule uninervis* and *Halophila ovalis* mixed with low amounts *Zostera muelleri* inshore

- Seagrass abundance declined across all sites in 2009 as a consequence of physical disturbance from the effects of tropical cyclones and flood events. In 2013 seagrass started to recover and has continued to progressively improve. In late 2015, seagrass cover was similar to pre-2009 abundances.
- Seagrass abundance generally follows a seasonal trend, characterised by maximum cover (>20% cover) in summer/autumn (December –April) and minimum cover (<20% cover) in winter (June-July). This suggests that seagrass meadows at these sites are primarily influenced by natural factors (temperature, light, wave action). At PI1 and PI2 seagrass cover was relatively high, a possible consequence of elevated nutrients from an adjacent sewage outfall.
- At most Pioneer Bay sites the composition of seagrass species has fluctuated over the monitoring period with an increase in *H. ovalis* and *H. uninervis* indicative of natural and/or anthropogenic disturbance: particularly between 2009 and 2013.
- Epiphyte cover on seagrass leaves is high (30-70%) and persists throughout much of the year. Algal cover was high (10-50%) in winter (June), spring (September) and summer (December). High algal growth at Pioneer Bay indicates nutrient enrichment from local sources (i.e. marina development, sewage outfall, stormwater runoff).
- Dugong grazing trails are abundant at Pioneer Bay sites. The occurrence of grazing trails varied between sites but highest feeding activity was recorded in March and September.
- Anthropogenic disturbance (e.g. stormwater runoff, dredging) results in accumulation of fine muds with a high organic component. In 2003, the accumulation of fine mud across the monitoring sites was of some concern (see newsletter 17, June 2003), however the mud levels in the sediment composition have since abated.

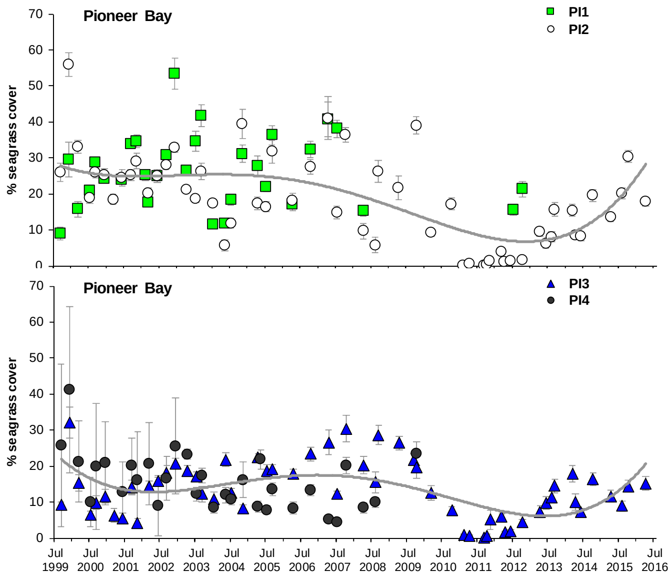


Figure 7. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Cannonvale (Pioneer Bay).

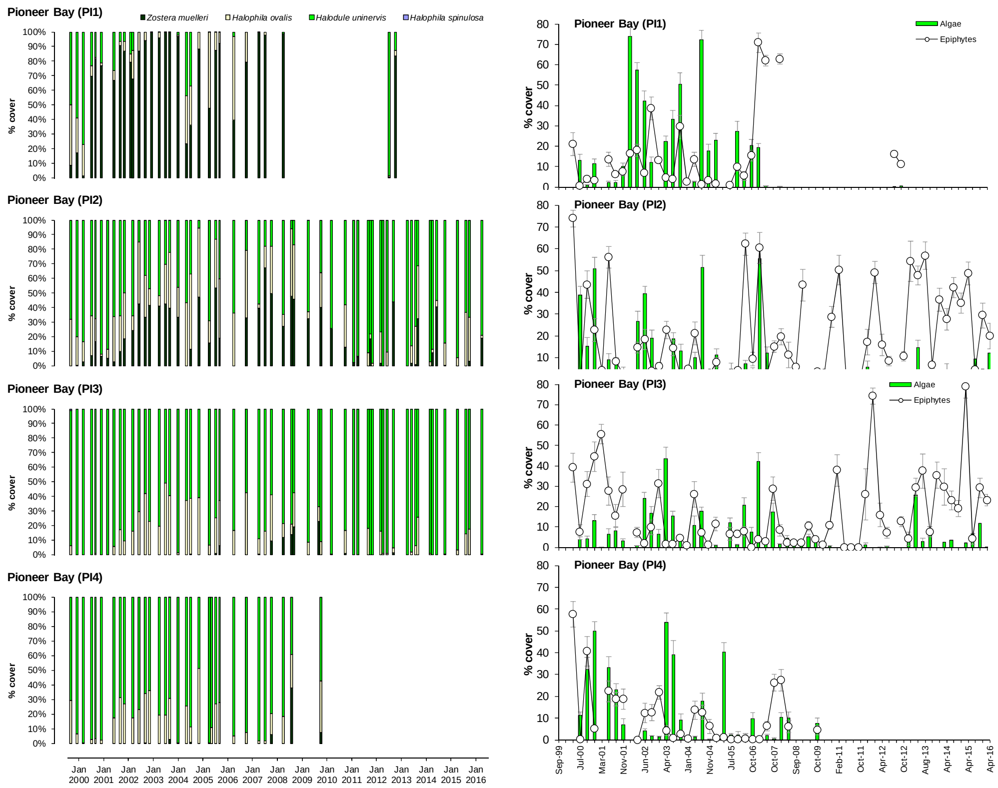


Figure 8. Seagrass species composition (left), abundance of epiphytes covering the seagrass leaf surface (right) and abundance of macro-algae (right) at each monitoring site, Cannonvale (Pioneer Bay).

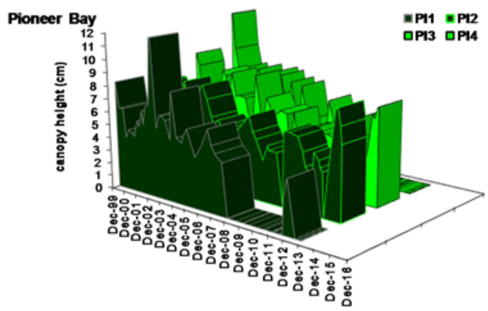


Figure 9. Canopy height of strap leafed seagrass at each monitoring site, Cannonvale (Pioneer Bay).

Hamilton Island

Monitoring: ongoing, *biannual*
Principal watchers: Seagrass-Watch HQ
Location: intertidal sand flats at either end of Catseye Bay.
Site code: HM1, HM2
HM1 position: S20.34415 E148.95740 *(heading 335 degrees)*
HM2 position: S20.34673 E148.97057 *(heading 345 degrees)*
Best tides: <0.6m *(port Dent Island 59415)*
Issues: sewage and groundwater
Comments: Dugong and turtle feeding grounds. In mid 2007, Seagrass-Watch monitoring sites (HM1 and HM2) were established on Hamilton Is as part of the Great Barrier Reef – Marine Monitoring Program. The island is also surrounded by fringing coral reefs, the largest in Catseye Bay in front of the main resort.
Status (May16):

- seagrass abundance declined after monitoring sites were established, reaching the lowest levels in 2011. Abundances and distribution increased briefly in 2012 before subsequently declining.

- Both sites are intertidal and located at either ends of Catseye Bay. HM1 is dominated by *Halodule uninervis*, with some *Halophila ovalis*, and located in front of the main resort within an area where motorised vessels are prohibited. This site is also the main feeding area frequented by green sea turtles. HM2 on the other hand is in the far east of the Bay and dominated by *Zostera muelleri* with *Halodule uninervis* and *Halophila ovalis*. This site has relatively no impacts from boating or resort activities.

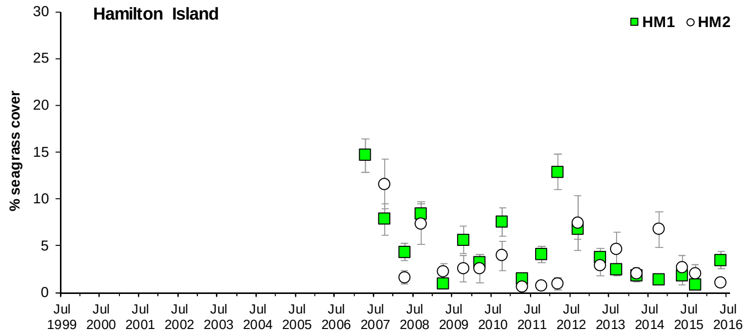


Figure 10. Changes in seagrass abundance (% cover ±Standard Error) at intertidal monitoring sites on the reef flat of Catseye bay, Hamilton Island.

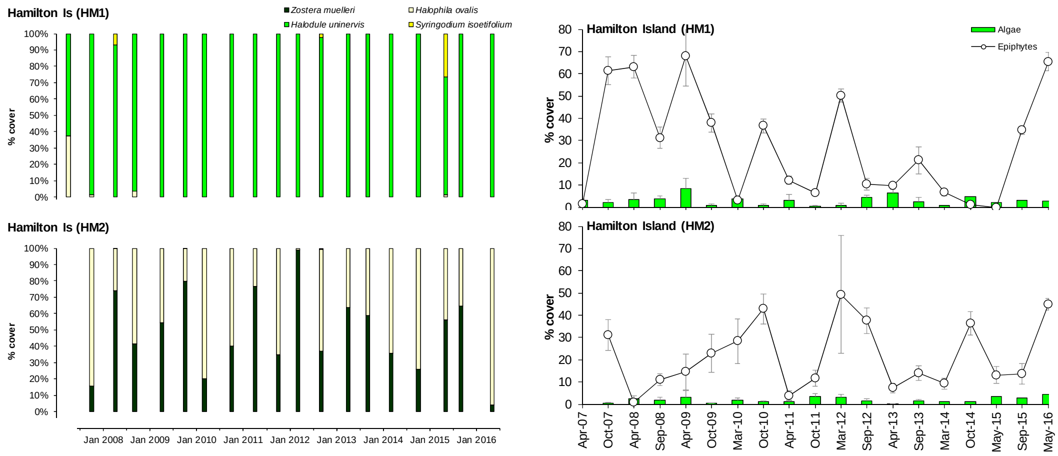


Figure 11. Seagrass species composition (left), abundance of epiphytes covering the seagrass leaf surface (right) and abundance of macro-algae (right) at each monitoring site, Hamilton Island.

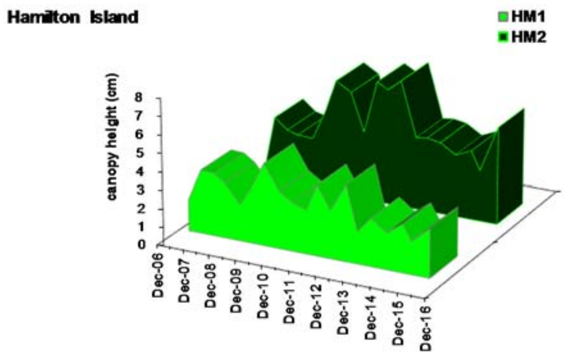


Figure 12. Canopy height of strap leafed seagrass at each monitoring site, Hamilton Island.

Whitehaven Beach

Monitoring: suspended
Principal watchers: TBA
Past watchers: Tony Fontes, Jacquie Sheils, Amanda Parr Chris Chandler, Glenn Carvath & Sean Andrew
Location: Subtidal shores of beach on the eastern coast of Whitsunday Island
Site code: WB1, WB2, WB3
WB1 position: S20.28078 E149.03855

WB2 position: S20.29030 E149.04750
WB3 position: S20.29440 E149.05340
Issues: High boat usage, anchoring
Comments: Turtle and fish feeding grounds
Status:

- No monitoring has been conducted since early 2004.
- Subtidal meadows at Whitehaven Beach covered approximately 365ha, which were predominately a mix of *Halodule uninervis, Halophila ovalis, Cymodocea serrulata* and *Syringodium isoetifolium*.
- Sites were established in relation to anchoring impacts - high impact site (WB3) and low impact site (WB2). Species composition at WB3 (high impact site) contained a higher proportion of H. ovalis and *S. isoetifolium* than at the low impact site (WB2). Both species colonise disturbed areas and were in highest abundance from spring to summer when light and temperature are favourable for fast growth.
- From 1987 to 1999-2000 seagrass meadows at Whitehaven Beach increased in area, with the seaward edge extending up to 300m beyond the edge mapped in 1987.
- Seagrass abundance is characterised by maximum cover in spring/summer (September – December) and minimum cover (<15%) in winter (June-July). At initiation of monitoring, seagrass cover was significantly higher at the low anchor use site (WB2) compared with high anchor use site (WB3), suggesting that boat anchors cause a reduction in seagrass abundance. These areas are subject to few disturbances compared with sites situated near heavy tourism. A study was conducted to identify the type of damage to seagrass caused by anchor chains and anchors from boats of different size classes (see Campbell and McKenzie 2001). The findings suggest that larger boats cause greater damage to seagrass than small boats because of longer anchor chains and the thickness of chain used. The use of plough anchors in preference to sand anchors may also contribute to increased seagrass damage, because of the high probability of anchor and chain movement causing deep anchor scars and long chain scars. Since late 2001, seagrass abundance has shown a steady decline at both the impacted and unimpacted sites – in fact, the unimpacted site is no longer significantly better.
- Abundance of epiphytic and non-attached algae at WB2 and WB3 was generally low (<10%) for most of the monitoring period. In autumn (March 2001) the blue green algae *Lyngbya majuscula* covered extensive areas (35-70%) of seagrass. *Lyngbya majuscula* is a toxic filamentous cyanobacterium found in tropical and sub-tropical marine and estuarine environments worldwide. This cyanobacterium is commonly called "mermaids hair" or "fireweed". In bloom conditions *Lyngbya* forms dense mats that cover the sea floor, smothering underlying seagrass meadows. The cause of the bloom is unknown, but may be associated with favourable light and temperature conditions, and/or a local source of nutrients from nearby freshwater inputs and boat discharges.
- Epi-fauna on seagrass blades at Whitehaven Beach sites were less abundant than other subtidal sites in the region, suggestive of disturbance from boat anchors and chains.
- Evidence of dugong and turtle grazing was low at Whitehaven Beach.
- Sediments at Whitehaven Beach sites were composed of fine mud, sand and shell with a high organic component. Disturbance at Whitehaven Beach sites from boat anchors was high and resulted in decreased seagrass cover and epi-faunal abundance. Anchor damage and algal overgrowth were the primary causes of seagrass damage in these areas.

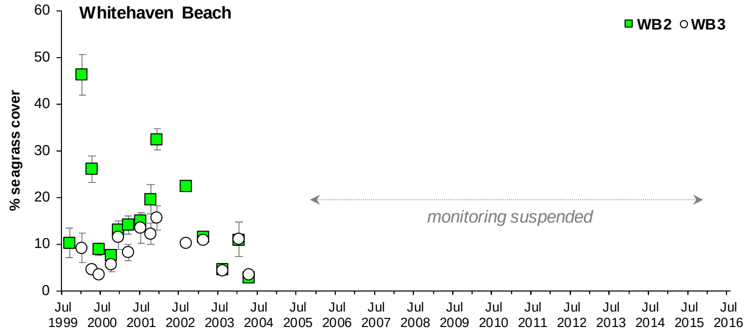


Figure 13. Changes in seagrass abundance (% cover ±Standard Error) at subtidal monitoring sites, Whitehaven Beach.

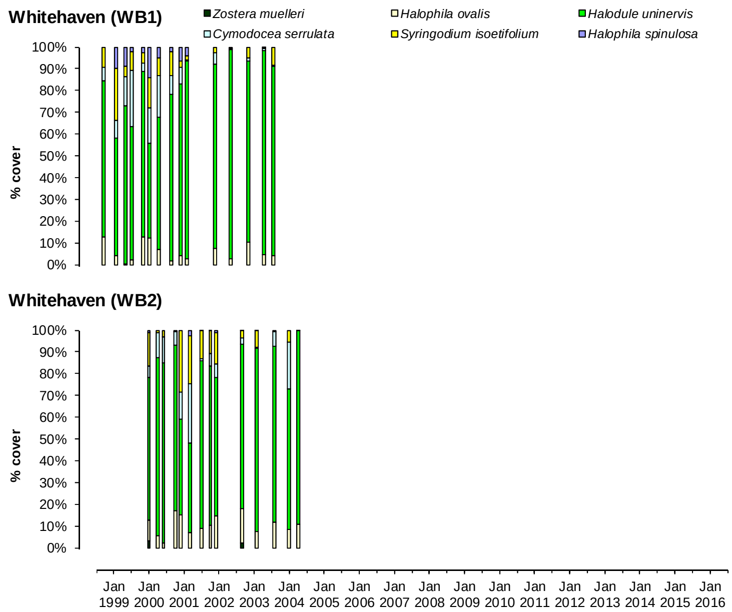


Figure 14. Seagrass species composition at subtidal monitoring sites, Whitehaven Beach.

Cid Harbour

Monitoring: suspended
Principal watchers: Elmer Ten-Haken, Jackie Shiels & Seagrass-Watch HQ
Occasional and past watchers: Conway, Jason C, Kevin, Paul, Siwan, Tony Fontes & Traun
Location: subtidal banks on the north-western coast of Whitsunday Island (Hook Is to Daniel Point)
Site code: CH1, CH2, CH3, CH4, CH5
CH1 position: S20.18628 E148.95572
CH2 position: S20.19395 E148.95405
CH3 position: S20.20328 E148.95088
CH4 position: S20.21345 E148.95055
CH5 position: S20.22162 E148.94505
Issues: vessel movement, anchoring
Comments: important foraging habitat for green sea turtles and dugongs
Status:

- Sites have not been visited since 2004.
- The meadow on the north-western coast of Whitsunday Island adjacent to Cid Harbour is one of the largest in the region, extending 5.6 km along the coast and 3.4 km perpendicular from the coast (1432.7±113 ha)
- Seagrass abundance near Cid Harbour showed a steady decline from 2000 to 2004, when monitoring was suspended. Meadow appeared to show fairly typical season pattern of seagrass abundance (higher in late spring-summer than winter).
- These meadows were subject to few disturbances compared with sites situated near heavy tourism.
- Cid Harbour meadows consisted mainly of *Halodule uninervis* (wide leaf form) found in association with *Cymodocea serrulata, Halophila spinulosa* and *Halophila ovalis*. A spring-summer increase in the proportion of *H. spinulosa* occurred in some of the meadow, suggestive of its preference for high light conditions. *Halodule uninervis* remained the dominant species across most of the meadow. Low proportions of *H. ovalis* and negligible *S. isoetifolium* indicated little disturbance within the meadow.
- Epiphyte and algae cover were generally higher in spring (September), reflecting a seasonal response to increasing light and temperature.
- Epi-fauna attached to seagrass blades were common throughout the Cid Harbour meadow and consisted mostly of ascidians and foraminifera. Sponges were also common throughout the area.
- Sediments at Cid Harbour sites were composed of fine mud, sand and shell with a high organic component. Disturbance from boat anchors at Cid Harbour sites was minimal.

- Turtle and dugong grazing common from September to February. Dugong were commonly observed at this location and some tour vessel operators reported that dugong can be seen regularly at the southern section of this large meadow. High-speed vessels transiting through the Hook Island passage, at the northern end of this meadow, are causes of vessel impact or propeller strike on turtles or dugong that feed in the area. Boating can also disturb feeding patterns in dugongs resulting in loss of body condition, movement away from feeding areas, reduced fecundity as well as direct mortality.

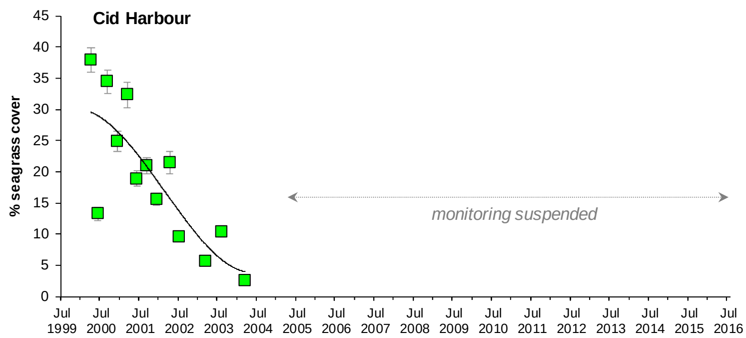


Figure 15. Changes in seagrass abundance (% cover ±Standard Error) at subtidal monitoring sites, Cid Harbour.

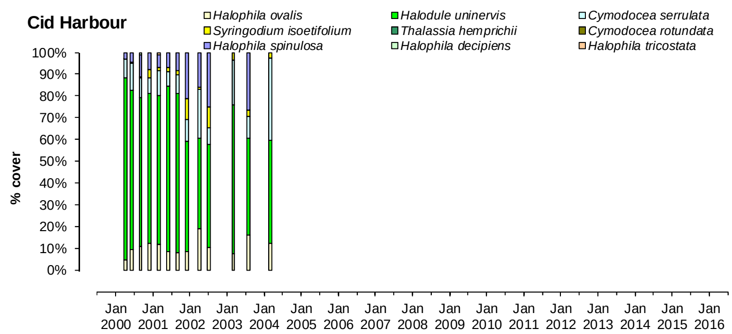


Figure 16. Seagrass species composition at subtidal monitoring sites, Cid Harbour.

Laguna Quays

Monitoring: archived
Past watchers: Margaret Parr, Geoff Bunn, Betty Wilson, John Thornely, Carolyn Williams & Seagrass-Watch HQ
Location: sand/mud flat along western coast of Repulse Bay, 3km south of O'Connell River mouth
Site code: MP1, MP4
MP1 position: *S20.59918 E148.67675 (heading 40 degrees)*
MP4 position: *S20.60212 E148.68007 (heading 15 degrees)*
Best tides: <0.7m *(port East Repulse I, 59440)*
Issues: Resort and marina development, vessel traffic near dugong and turtle habitat, catchment inputs from agriculture, mangrove clearing
Comments: important foraging habitat for green sea turtles and dugongs
Status:

- Monitoring concluded in mid-2007
- Seagrass abundance at Laguna Quays followed a seasonal trend, characterised by maximum cover (>20% cover) in spring/summer (September –January) and minimum cover (<20% cover) in winter (June-July). This suggested that seagrass meadows at these sites were primarily influenced by natural factors (temperature, light, wave action).
- At Laguna Quays, MP1 was dominated by *Halodule uninervis*, and MP4 was dominated by *Z. muelleri*. The relative proportions of species at each site remained stable over the monitoring period.
- Low epiphyte cover (<30%) and algal cover (<1%) was recorded at Laguna Quays sites.
- Dugong feeding trails were abundant at Laguna Quays. The occurrence of feeding trails varied between sites but highest feeding activity was recorded in March and September 2000.

- The abundance of invertebrate fauna was less common at Laguna Quays compared to other locations in the region.
- Sites at Laguna Quays had fine to medium sand sediments, were exposed to wave action and generally had a low abundance of seagrass (<20% cover) consisting of *Halodule uninervis* and *Halophila ovalis*.

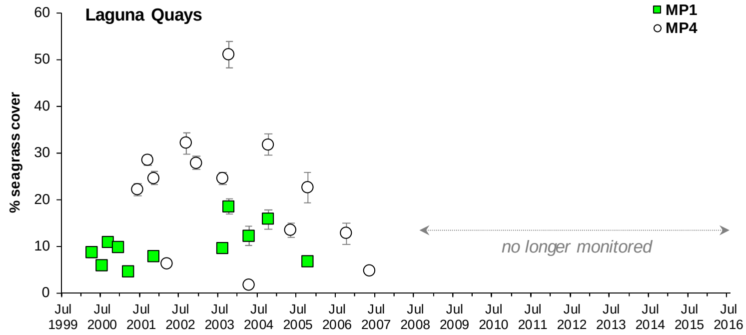


Figure 17. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Laguna Quays (Repulse Bay).

Midge Point

Monitoring: ongoing, *quarterly*
Principal watchers: Seagrass-Watch HQ
Past watchers: Paul Wenzler, Jennifer Wenzler, Tara Wenzler & Andrew Wenzler
Location: sand/mud flat along coast of southern Repulse Bay
Site code: MP2 & MP3
MP2 position: *S20.63498 E148.70180 (heading 0 degrees)*
MP3 position: *S20.63467 E148.70467 (heading 0 degrees)*
Best tides: <0.7m *(port East Repulse I, 59440)*
Issues: Low urban development, close to mangroves
Comments: Fish, dugong and turtle feeding grounds
Status (Jul12):

- Seagrass abundance at Midge Point sites have been relatively stable, although they declined significantly in mid-2011 at MP3 for 6-9 months. Seagrass cover has since recovered to pre-2009 abundances.
- Seagrass abundance at Midge Point follows a seasonal trend, characterised by maximum cover (>20% cover) in spring/summer (September –January) and minimum cover (<20% cover) in winter (June-July). This suggests that seagrass meadows at these sites were primarily influenced by natural factors (temperature, light, wave action).
- Midge Point intertidal meadows cover approximately 30ha, which are predominately *Zostera muelleri* mixed with low amounts *Halodule uninervis* and *Halophila ovalis*. The relative proportions of species at each site remained stable over the monitoring period.
- Low epiphyte cover (<30%) and algal cover (<1%) was recorded at Midge Point sites.
- Dugong grazing trails were abundant at Midge Point, and a large population of green sea turtle frequent to meadows, evident from the number of animals commonly basking during the low spring tides.
- Gastropods and hermit crabs were common at Midge Point where high seagrass abundance provided a supply of detritus, grazing matter and faunal prey.
- Tidal dominated localities at Midge Point were composed of fine mud and sand sediments with a high organic component. Disturbance to seagrass meadows may be caused by a number of factors. At Midge Point wave action from prevailing south-easterly winds and strong tides resulted in sediment movement where fine muds were displaced with coarse sands and shell.

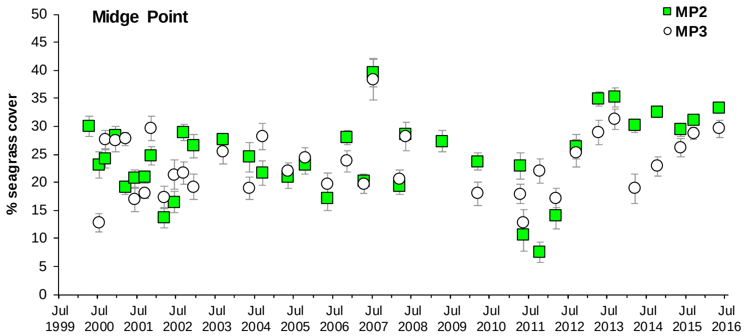


Figure 18. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Midge Point (Repulse Bay).

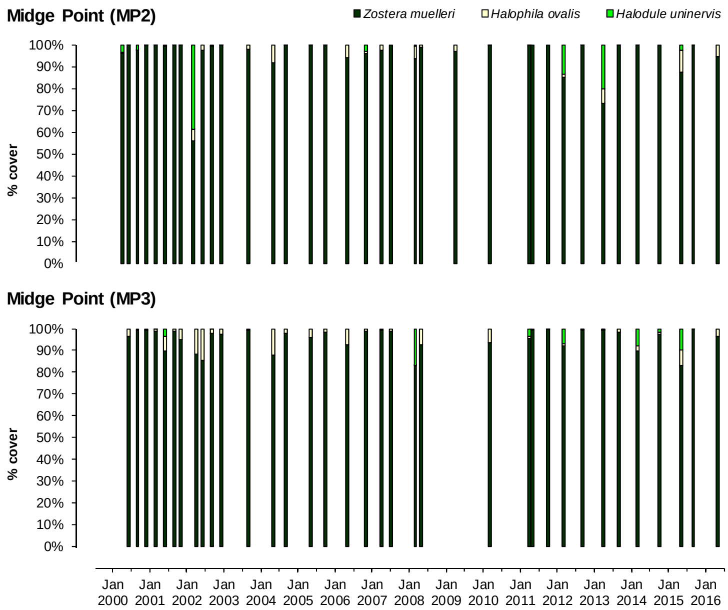


Figure 19. Seagrass species composition at coastal intertidal monitoring sites, Midge Point.

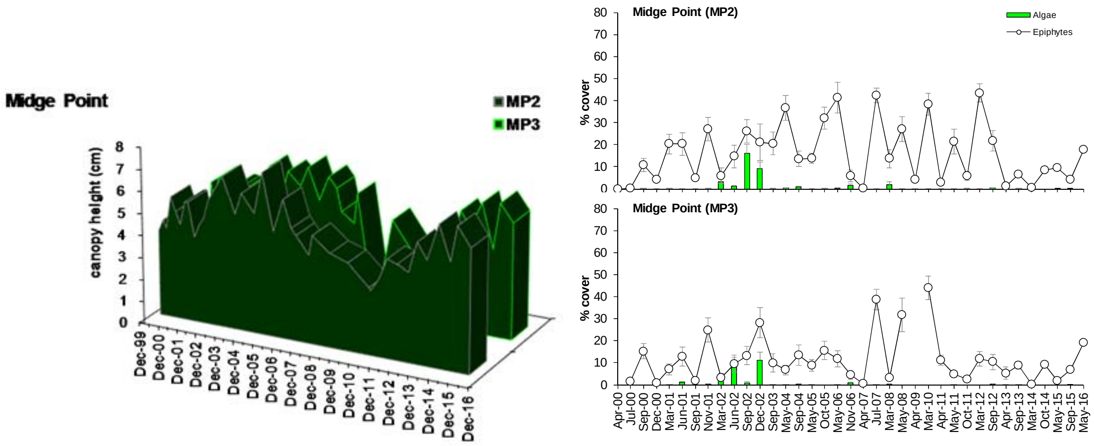


Figure 20. Canopy height of strap leafed seagrass at each monitoring site (left), abundance of epiphytes covering the seagrass leaf surface (right) and abundance of macro-algae (right) at each monitoring site, Midge Point.

Midgeton

Monitoring: archived
Past watchers: Margaret Parr, Dell Williams Graeme Hyde, Betty Wilson, John Williams, Heather Hyde, Valerie Bunn & Seagrass-Watch HQ
Location: Near mouth of Dempster Creek estuary south of Midge Point
Site code: MT1 & MT2

MT1 position: S20.66530 E148.71570 *(heading 115 degrees)*
MT2 position: S20.66830 E148.71120 *(heading 115 degrees)*
Best tides: <0.6m *(port East Repulse I, 59440)*
Issues: Native vegetation adjacent Exposed sand/mud flat
Comments: Dugong, turtle and fish feeding grounds.
Status:

- Monitoring concluded in mid-2007.
- Seagrass abundance at Midgeton followed a seasonal trend, characterised by maximum cover (>20% cover) in spring/summer (September –January) and minimum cover (<20% cover) in winter (June-July). This suggested that seagrass meadows at these sites was primarily influenced by natural factors (temperature, light, wave action).
- Sites at Midgeton consisted of an equal mix of *Z. muelleri, H. uninervis* and *H. ovalis*. The relative proportions of species at each site remained stable over the monitoring period.
- Epiphyte cover (40-70%) at Midgeton sites was high in spring-summer (December) and low in winter (June). Algal cover remained low (<2%).
- Dugong grazing trails were abundant at Midgeton. The occurrence of grazing trails varied between sites but highest feeding activity was recorded in March and September 2000.
- The abundance of invertebrate fauna was less common compared to other locations in the region.
- Tidal dominated localities at Midgeton were composed of fine mud and sand sediments with a high organic component. At Midgeton sites freshwater flows from the Dempster Creek may also contribute to sediment disturbance.

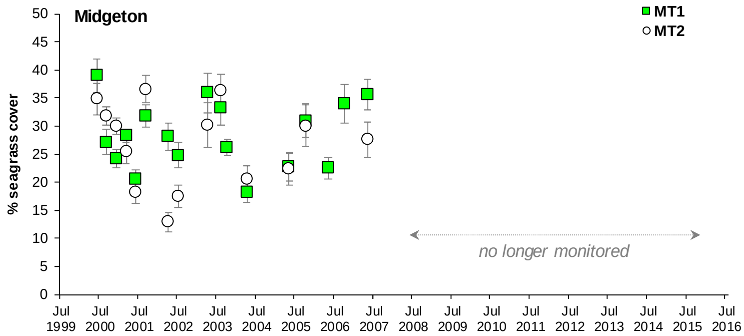


Figure 21. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Midgeton.

Seaforth

Monitoring: suspended
Principal watchers: TBA
Occasional and past watchers: Jon Woodworth, Annette Whitney, John Williams, Mackay Turtlewatch & Australian Bird watchers and Seagrass-Watch HQ
Location: Port Newry, south of Finlayson Point near Seaforth township, 40km north west of Mackay.
Site code: SF1, SF2
Issues: Coastal development, boat traffic (propeller scarring, outboard pollution and minor fuel spills), stormwater & sediment runoff
Comments: Important nursery areas for fish and prawns. Dugong & Turtle feeding grounds. The coastal waters of Seaforth are zoned Marine Park General Use B.
Status (May16):

- The original site (SF1) has not been sampled since April 2005, and the second site was only recently established in May 2014.
- Three species of seagrass were present at Seaforth: *Zostera muelleri, Halophila ovalis* and isolated patches of *Halodule uninervis*
- Insufficient data to describe long-term trends.

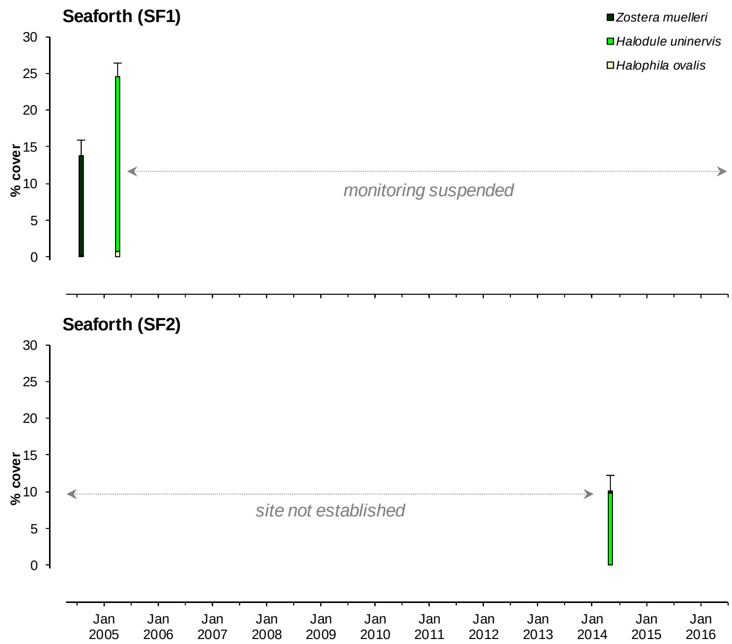


Figure 22. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, Seaforth.

St Helen's Beach

Monitoring: suspended
Principal watchers: TBA
Past watchers: Jon Woodworth, Justin Yaserie, John Williams, Diversity Queensland & Seagrass-Watch HQ
Location: Western shore of St Helen's Bay, 55km north west of Mackay
Site code: SH1
SH1 position: S20.82240 E148.83540
Issues: Coastal development, boat traffic (propeller scarring, outboard pollution and minor fuel spills), stormwater & sediment runoff
Comments: Site is very muddy. Dugong & turtle feeding grounds. Important nursery areas for fish and prawns. St. Helens Bay is Fish Habitat Areas (FHA) to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend. The coastal waters of St. Helens Bay are zoned Marine Park General Use A.
Status:

- Site has not been assessed since August 2005.
- Meadow appeared relatively healthy with very few epiphytes.
- Only two species present
- Some of the quadrats had 85% to 95% cover, insufficient data to describe long-term trends.

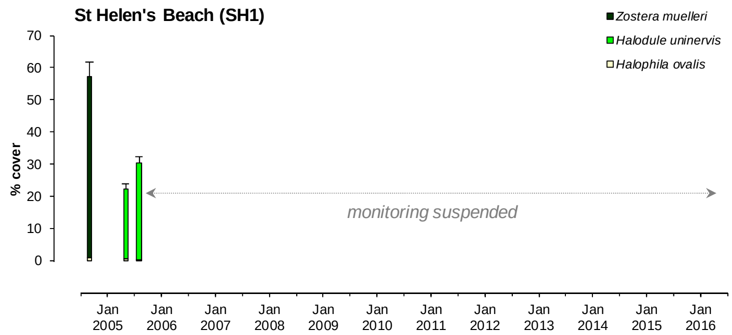


Figure 23. Changes in seagrass abundance (% cover ±Standard Error) at coastal intertidal monitoring sites, St Helen's Beach.

Sarina Inlet

Monitoring: ongoing, *quarterly*
Principal watchers: Seagrass-Watch HQ
Past watchers: Noel Kane, Catherine Walsh, John Ryder & Jon Woodworth
Location: intertidal opposite boat ramp at Sarina Inlet
Site code: SI1, SI2
SI1 position: S21.39602 E149.30395 *(heading 120 degrees)*
SI2 position: S21.39519 E149.30460 *(heading 120 degrees)*
Best tides: <0.5m *(port Hay Pt. 59511)*
Issues: Agricultural and urban runoff
Comments: Sarina Inlet is at Sarina Beach, a small township coastal of the main town of Sarina in Central Qld, 34 km south of Mackay. Industries in the catchment that flows into Sarina Inlet include sugar cane growing and milling, cattle grazing and agriculture. Proximity to the coast and mountains also attracts tourists to this area. It is a major supplier of ethanol through the Sarina sugar mill and distillery.
Status (May16):

- Sites are dominated by *Zostera muelleri* with some *Halophila ovalis*.
- Seagrass cover has fluctuated greater since monitoring was established in early 2005, with seagrass dramatically declining in the late wet season of 2006, and recovering within 18 months, to only start declining again in 2008. Seagrass cover continued to decline after2008, reaching in minima in 2011. Since 2011, seagrass cover has continued to recover, although still remains lower than pre-2008 abundances.
- Although there is insufficient spread of sampling across months within years, the seagrass abundance and canopy heights appear greater in the late dry than late monsoon.
- Algal abundances has generally remained low, however epiphyte abundances are generally high.

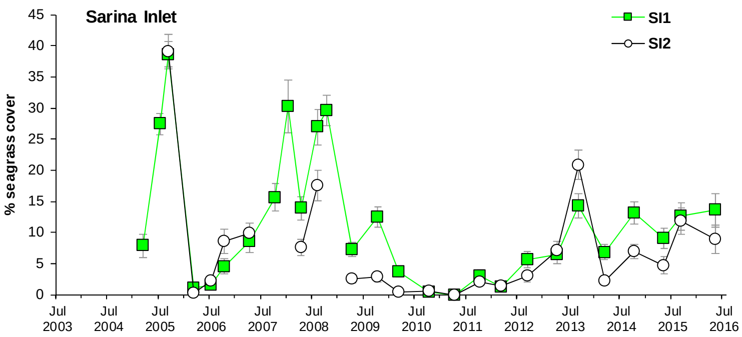


Figure 24. Changes in seagrass abundance (% cover ±Standard Error) at estuarine intertidal monitoring sites, Sarina Inlet.

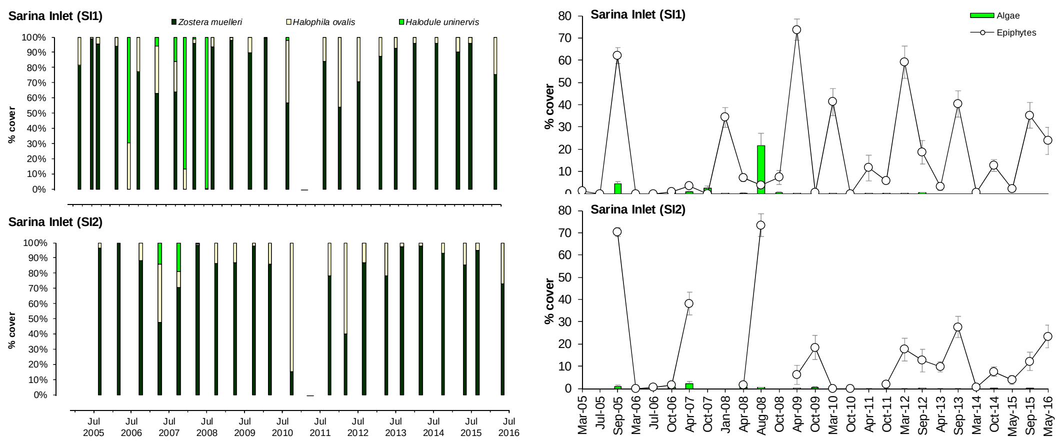


Figure 25. Seagrass species composition (left), abundance of epiphytes covering the seagrass leaf surface (right) and abundance of macro-algae (right) at each monitoring site, Sarina Inlet.

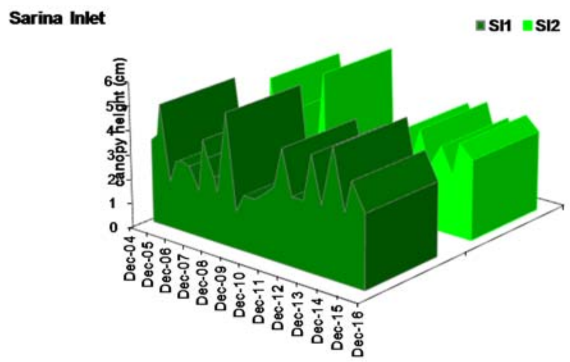


Figure 26. Canopy height of strap leafed seagrass at each monitoring site, Sarina Inlet.

Regional seagrass abundance report card – May 2016

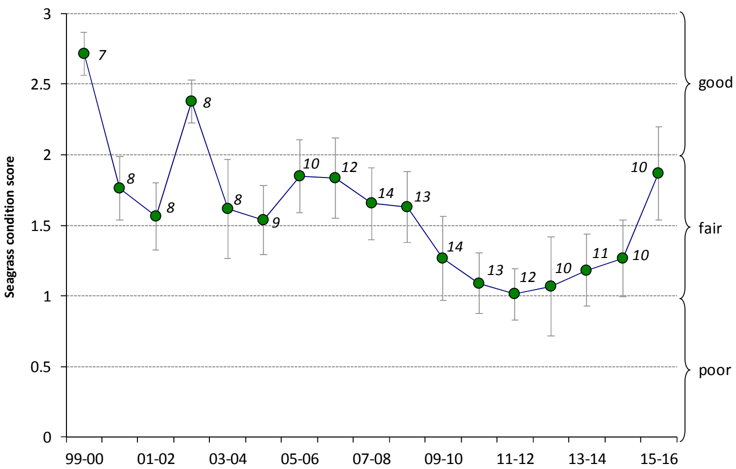
- Healthy seagrass meadows throughout Mackay Whitsunday support fisheries, turtle and dugong populations
- Seagrass meadows in the Mackay Whitsunday region are in a **Fair to Good state**.
- Prior to 2009, most seagrass meadows across the region had shown a relatively stable trend in abundance since monitoring commenced in 1999. The only exceptions were at Hamilton Island where seagrass state has been consistently poor, and at Sarina Inlet, where seagrass declined in 2006 with only minor recovery in early 2008.
- From 2009, seagrass abundance declined across the region, reaching its lowest abundances in 2011. Seagrass was absent from Sarina Inlet in late 2011.
- Since 2012, seagrass abundance has continued to improve. Over the past couple of years, seagrass abundance has continued to increase at coastal and estuarine habitats (Pioneer Bay, and Sarina Inlet), but remained relatively stable at all other locations in the Mackay Whitsunday region. However, abundance continues to remain considerably lower than historical peaks, particularly at Sarina Inlet and Hydeaway Bay.
- At a local level, some meadows have faced short term impacts from which they have recovered. These impacts include *Lyngbya* outbreaks, sedimentation from marina developments and burning off from temperature stress (Campbell and McKenzie, 2001; Campbell *et al.* 2002). While these meadows have demonstrated resilience to these changes the region faces continued pressure from coastal and urban development.
- The absence of ongoing monitoring of subtidal meadows has limited the ability to assess seagrass trends in the region. Information collected on subtidal meadow from 1999 to 2004 at Whitehaven Beach also indicated that small scale disturbances from anchoring may have been contributing to a seagrass decline.
- Using the seagrass guidelines values, seagrass state was determined for each monitoring event at each site by scoring the median percent cover values relative to the long-term percentiles.

Poor: median seagrass abundance below lowest percentile (20th for variable and 10th for stable) for monitoring period.

Fair: median seagrass abundance above lowest percentile (20th for variable and 10th for stable) but below 50th percentile for monitoring period.

Good: median seagrass abundance above 50th percentile for monitoring period.

- Overall indications are that seagrass abundance in the Mackay Whitsunday region in mid-2016 was in a **fair to good state** *(state scored on a scale of 0 to 3 against the guidelines and relative to the previous sampling event)*.



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

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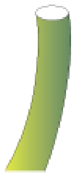
A guide to the identification of seagrasses in the Mackay Whitsunday region

Adapted from *Waycott et al., 2004.*

Leaves cylindrical



cylindrical

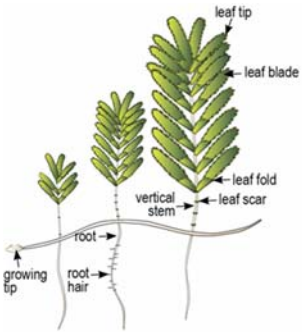
Syringodium isoetifolium

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

Leaves oval to oblong

oval to oblong

obvious vertical stem with more than 2 leaves



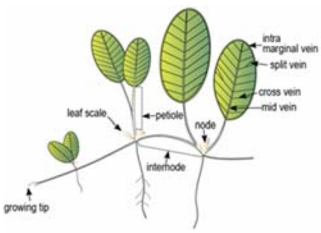
Halophila spinulosa

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

Halophila tricostata

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

leaves with petioles, in pairs



Halophila capricorni

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

Halophila decipiens

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

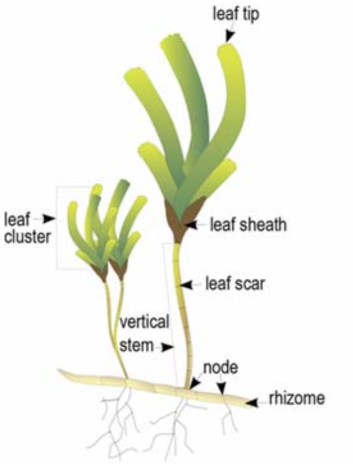
Halophila ovalis

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

Leaves strap-like

straplike

Leaves can arise from vertical stem



Cymodocea rotundata

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

Cymodocea serrulata

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

Halodule uninervis

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

Halodule pinifolia

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

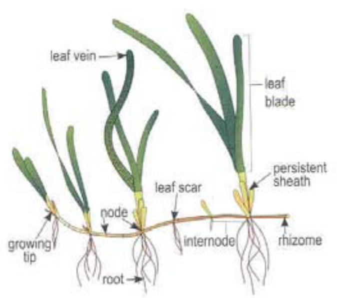
Thalassia hemprichii

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

Thalassodendron ciliatum

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

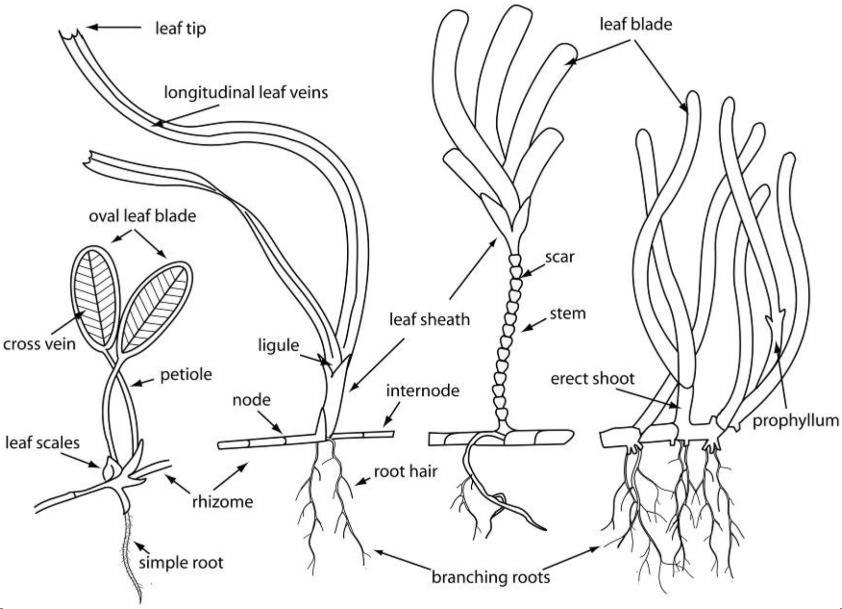
Leaves always arise directly from rhizome



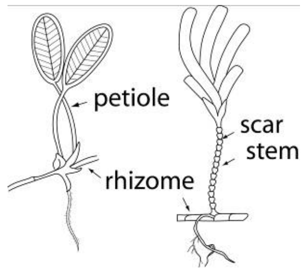
Zostera muelleri subsp. *capricorni*

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

Parts of a seagrass plant

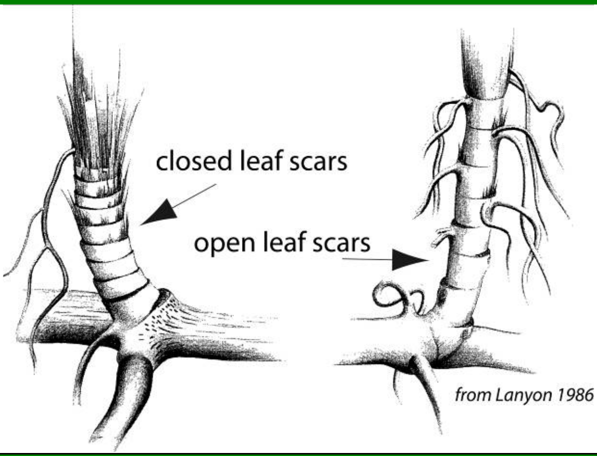


Leaf

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

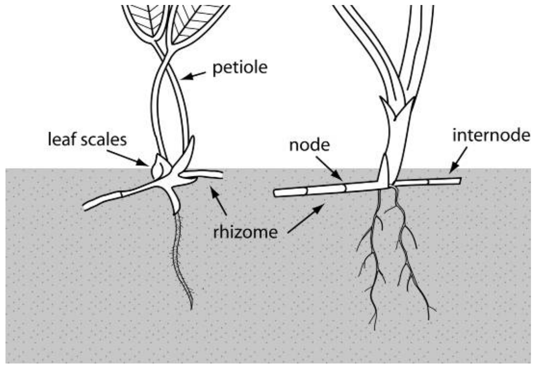
Stem

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



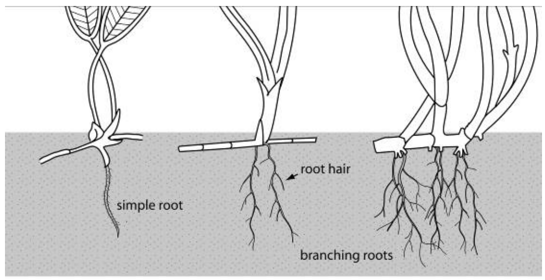
Rhizome

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



Root

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



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Monitoring a seagrass meadow

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

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

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

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

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

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

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

Monitoring seagrass

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

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

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

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

Seagrass-Watch

A method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses standardised measurements taken from sites established within representative intertidal meadows to monitor seagrass condition. The number and position of sites can be used to investigate natural and anthropogenic impacts.

Seagrass-Watch is one of the largest seagrass monitoring programs in the world. Since its genesis in March 1998 in Australia, Seagrass-Watch has expanded internationally to more than 26 countries. Monitoring is currently occurring at over 350 sites. To learn more about the program, visit www.seagrasswatch.org .

Seagrass-Watch aims to raise awareness on the condition and trend of nearshore seagrass ecosystems and provide an early warning of major coastal environment changes. Participants of Seagrass-Watch are generally volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with universities & research institutions, government (local & state), non-government organisations or established local community groups.

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

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

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 (±3m) GPS waypoint. Labels identifying the sites and contact details for the program are attached to these pickets. Positions of 0 m and 50 m points for all three transects at a site are also noted using GPS. This ensures that the same site is monitored each event and that data can be compared between periods of time.

Ongoing standardisation of observers is achieved by on-site refreshers of standard percentage covers by all observers prior to monitoring and through *ad hoc* comparisons of data returned from duplicate surveys (e.g. either a site or a transect will be repeated by Seagrass-Watch HQ 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 James Cook University Management System, a formally organised and secure system. Seagrass-Watch HQ operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for reporting purposes. Access to the IT system and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

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

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

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

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

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

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 HQ 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 Queensland, State of the Environment Australia and State of the Environment GBR). 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.

- Ownership (intellectual property rights) of the Raw Data lies with the Principal (*data collector*). Seagrass-Watch is custodian of the Raw Data.
- Ownership (intellectual property rights) of the Validated Data 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 (Campbell and McKenzie, 2004), coastal developments (e.g., marina constructions) and dredging proposals.
- Understanding natural levels of change (e.g., McKenzie *et al.*, 2016) 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.*

Notes:

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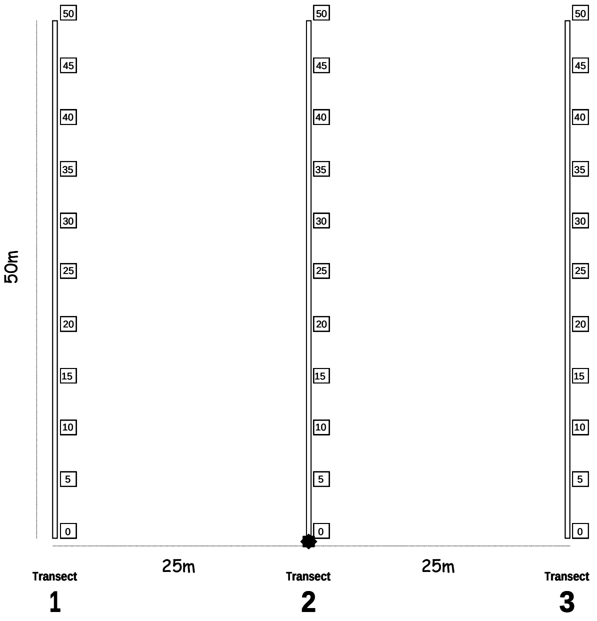
Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

e.g., CJ1225 = Chek Jawa. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Each sampling event

Within the 50m by 50m site, lay out the three 50 transects parallel to each other, 25m apart and perpendicular to shore (see site layout). For alternative sampling designs, please contact Seagrass-Watch HQ. Within each of the quadrats placed for sampling, complete the following steps:

Step 1. Take a Photograph of the quadrat

- Photographs are taken of every quadrat (or at 5m, 25m and 45m if film is limited) along each transect. Use a quadrat free of strings and place the photo quadrat labeller beside the quadrat and tape measure with the correct code on it.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat label and tape measure. Avoid having any shadows or patches of reflection off any water in the field of view. Check the photo taken box on datasheet for quadrat.

Step 2. Describe sediment composition

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

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

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

Step 4. Estimate seagrass percent cover

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

Step 5. Estimate seagrass species composition

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

Step 6. Measure seagrass canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

Step 10. Move to next quadrat

- Repeat steps 1 to 8 for the remaining 32 quadrats

Step 11. At completion of monitoring

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

At completion of monitoring

Step 1. Wash & pack gear

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

Step 2. Press any voucher seagrass specimens if collected

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

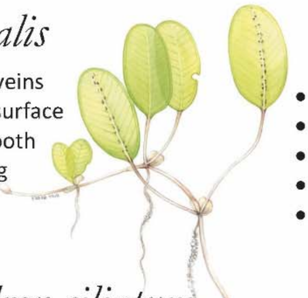
Step 3. Submit all data

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

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

SEAGRASS SPECIES CODES

Ho
Halophila ovalis

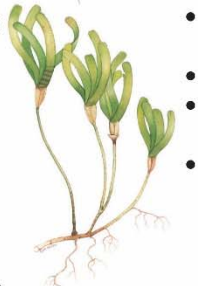


- 8 or more cross veins
- no hairs on leaf surface
- leaf margins smooth
- leaf 5-20mm long

Hd
Halophila decipiens

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

Tc
Thalassodendron ciliatum



- erect stem up to 65cm long bearing leaf cluster
- rhizome tough and woody
- ribbon-like, sickle -shaped leaves with ligule
- round, serrated leaf tip
- often found attached to rock or coral substrate

Th
Thalassia hemprichii

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

Hs
Halophila spinulosa

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

Hu
Halodule uninervis

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

Cs
Cymodocea serrulata

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

Cr
Cymodocea rotundata

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

Zc
Zostera muelleri subsp. *capricorni*

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

Si
Syringodium isoetifolium

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

SEAGRASS-WATCH MONITORING

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

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

START of transect (GPS reading)
Latitude: .... ° .... ' .... **Longitude:** .... ° .... ' ....

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

END of transect (GPS reading)
Latitude: .... ° .... ' .... **Longitude:** .... ° .... ' ....

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

Making a herbarium press specimen

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

COLLECTION

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

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

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

PRESSING

Tools

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

Preparation

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

Arrangement

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

Labels

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

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

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

Drying

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

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

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

Changing the paper is a very important step. In the first three or four days a paper change should take place every day, then you can leave more time between changes. If you neglect the change of paper the plants will take more time to 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 dying ranges from two to four days or more. Once a specimen has become dry and stiff, it can be mounted and placed into the herbarium.

Mounting

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

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

HERBARIA

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

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

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

Understanding sediment

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

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

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

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

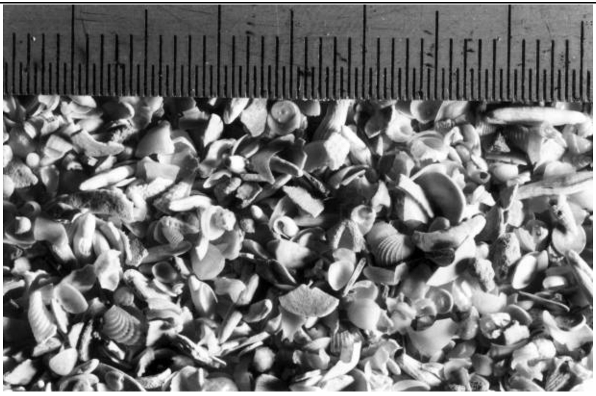
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000μm); coarse sand (>500 μm); sand (>250 μm); fine sand (>63 μm); and mud (<63 μm).

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

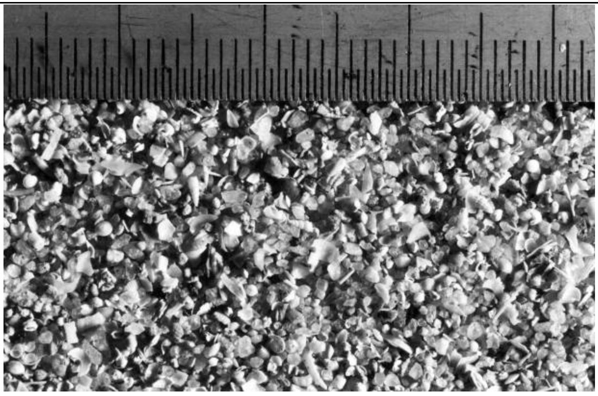
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

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

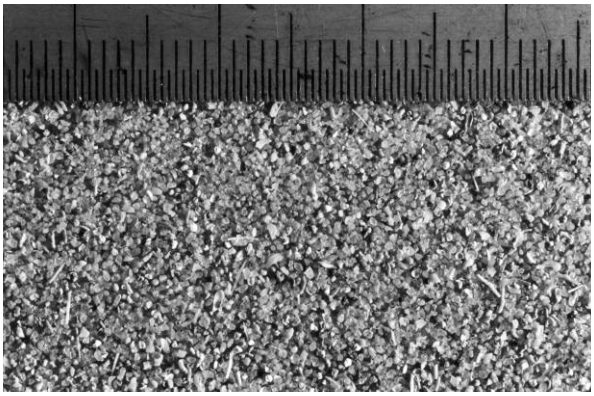
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments McKenzie, 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf.



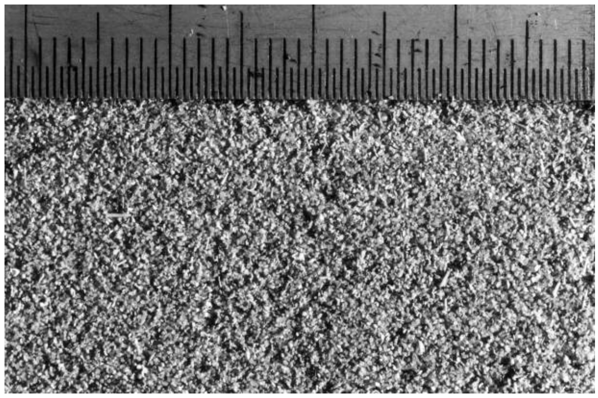
gravel (>2mm)



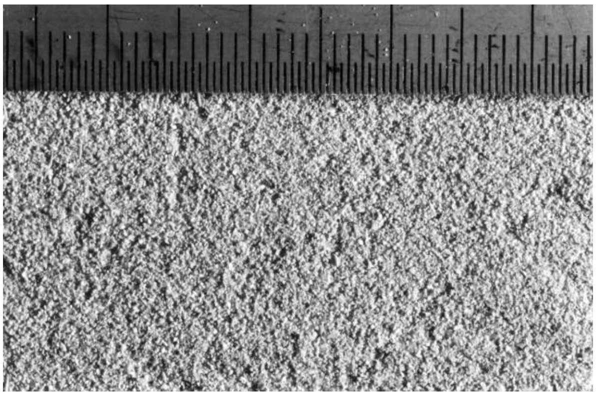
very coarse sand (1 – 2 mm)



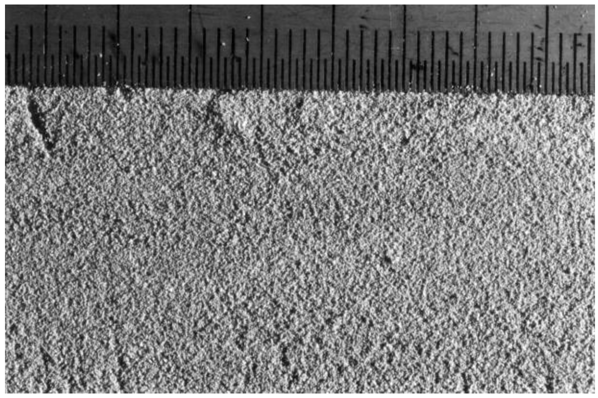
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

Notes:

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Managing seagrass resources

Threats to seagrass habitats

Destruction or loss of seagrasses have been reported from most parts of the world, often from natural causes, e.g., "wasting disease" or high energy storms. However, destruction commonly has resulted from human activities, e.g., as a consequence of eutrophication or land clamation and changes in land use. Increases in dredging and landfill, construction on the shoreline, commercial overexploitation of coastal resources, and recreational boating activities along with anthropogenic nutrient and sediment loading has dramatically reduced seagrass distribution in some parts of the world. Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease the function and value of seagrass meadows including their contribution to fisheries. It is possible global climate change will have a major impact. Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world: transplantation, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitat through law and environmental policy.

Management

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

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

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

Reactive (on-ground)

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

Prescriptive (legal)

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

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

Non-prescriptive (planning & education)

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

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

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

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

Indigenous concepts of management of the sea differ significantly from the introduced European view of the sea as common domain, open to all and managed by governments (Hardin, 1968). Unlike contemporary European systems of management, indigenous systems do not include jurisdictional boundaries between land and sea. Indigenous systems have a form of customary ownership of maritime areas that has been operating in place for 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 (Smyth *et al.*, 2006).

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

1. Important fish habitat is known and mapped
2. Habitat monitoring is occurring

3. Adjacent catchment/watershed impacts and other threats are managed
4. Some level of public goodwill/support is present
5. Legal powers exist hat are robust to challenge
6. There is effective enforcement and punishment if damage occurs

The key element is a knowledge base of the seagrass resource that needs to be protected and how stable/variable that resource is. It is also important to know if possible any areas that are of special value to the ecosystems that support coastal fisheries and inshore productivity. It is important as well that this information is readily available to decision makers in Governments in a form that can be easily understood.

Consequently a combination of modern "western" science and indigenous knowledge should be brought together within a co-management framework for the successful management of these resources (Johannes, 2002; Gaskell, 2003; Aswani and Weiant, 2004; George *et al.*, 2004; Turnbull, 2004; Middlebrook and Williamson, 2006). This can only occur if the resource owners actively involve themselves in the management of their resources. Western science also needs to recognise that resource owners have practical and spiritual connections with the resources found within their environment. Once this is recognized then this approach will have the added benefit of empowering communities who own the knowledge to be the primary managers and leaders in decisions about their land and sea country.

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Useful web links

Seagrass-Watch Official Site www.seagrasswatch.org

Project Seagrass An environmental charity devoted to the conservation of seagrass ecosystems through education, influence, research and action. www.projectseagrass.org

Dugong and Seagrass Conservation Project The first coordinated global effort to conserve dugongs and their seagrass habitats. www.dugongconservation.org

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

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

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