Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in the Burnett Mary NRM Region, Queensland

USQ Fraser Coast Campus, Hervey Bay
29-30 August 2015

Len McKenzie & Rudi Yoshida

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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 (note flipper marks) in *Zostera muelleri* ssp. *capricorni* meadow on intertidal banks at Urangan, Hervey Bay (May15) by Len McKenzie; soldier Crab in *Zostera muelleri* ssp. *capricorni* meadow at Burrum Heads (May08) by Rudi Yoshida workshop participants identifying seagrass specimens (Aug14) by Rudi Yoshida, and juvenile green sea turtle basking on intertidal banks at Urangan, Hervey Bay (May15) by Len McKenzie.

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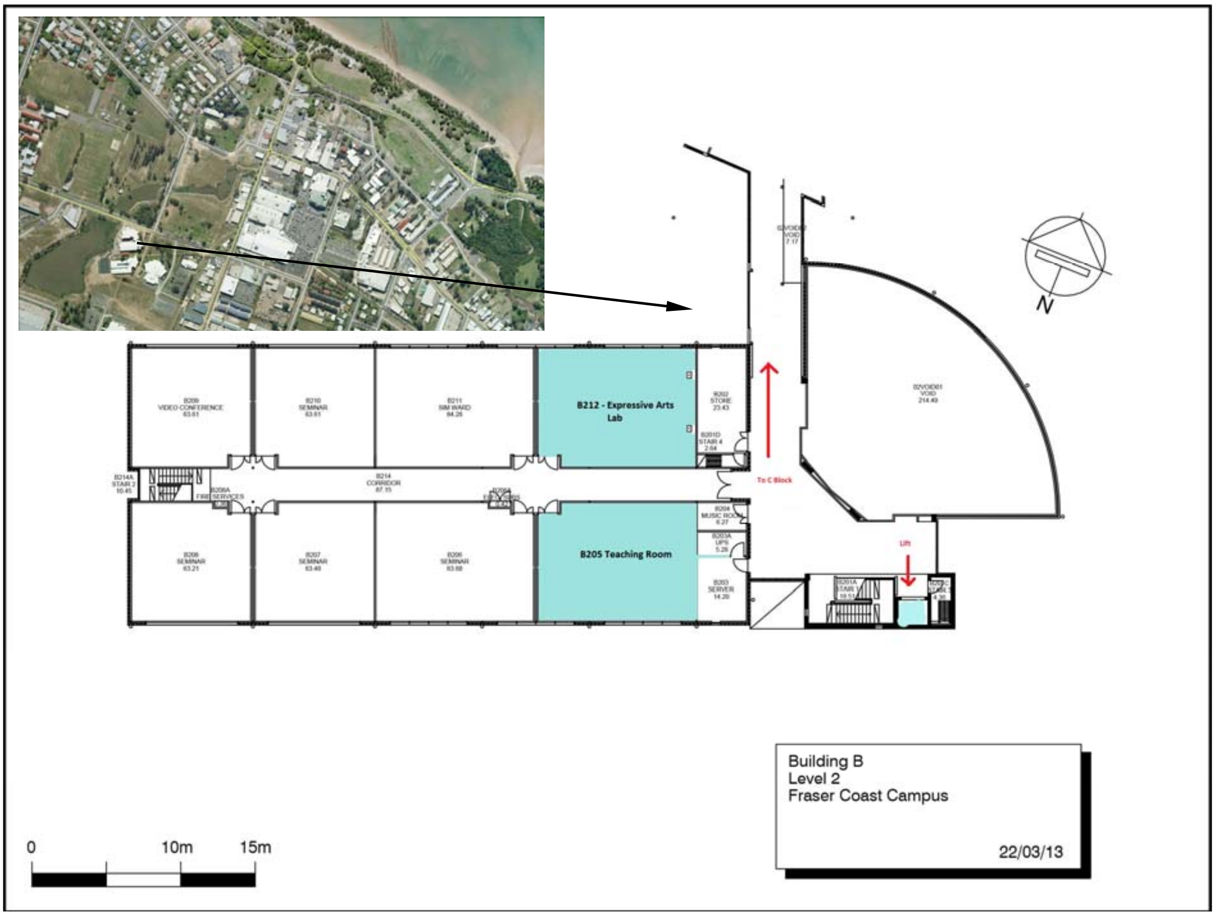

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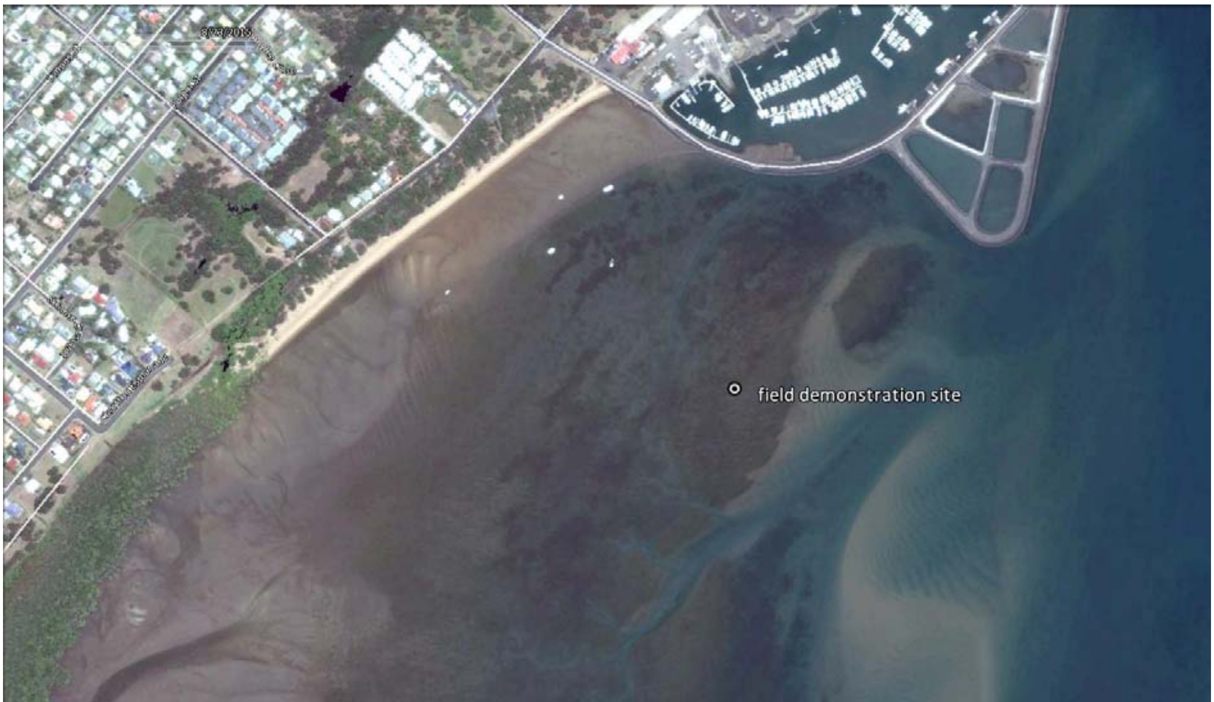

Urangan field exercise, located 8km from USQ Fraser Coast Campus (approx 11min drive).

Image 15Oct14,courtesy GoogleEarth.

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 the Burnett Mary Regional Group (BMRG) and Cooloola Coastcare Association, with local coordination by Maree Prior, 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

Seagrass-Watch HQ
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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 29th August 2015 (USQ Fraser Coast Campus)

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

Sunday 30th August 2015 (USQ Fraser Coast Campus & Urangan)

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: Urangan
- *meet opposite Boat Harbour Resort, Charlton Esplanade*
- *be punctual*

What to bring:
- *hat, sunscreen (Slip! Slop! Slap!)*
- *dive booties or old shoes that can get wet*
- *wear long pants, but keep clothes light and breathable*
- *drink/refreshments and energising snack*
- *wet weather gear: poncho/raincoat*
- *insect repellent*
- *polaroid sunglasses (not essential)*
- *simple medical kit in case of injuries to yourself*
- *change of footwear and clothes*
- *enthusiasm*

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

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

1530 - 1600 *(30min)*	Wrap up

Tide: 1500, 0.2m

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 7 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 -

- 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 (1 unit)

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 and each monitoring event/period must be separated by at least 1 month, regardless of number of sites monitored.

After each monitoring event, original datasheets, photos, *etc* must be submitted to Seagrass-Watch HQ and data must pass QAQC, i.e.

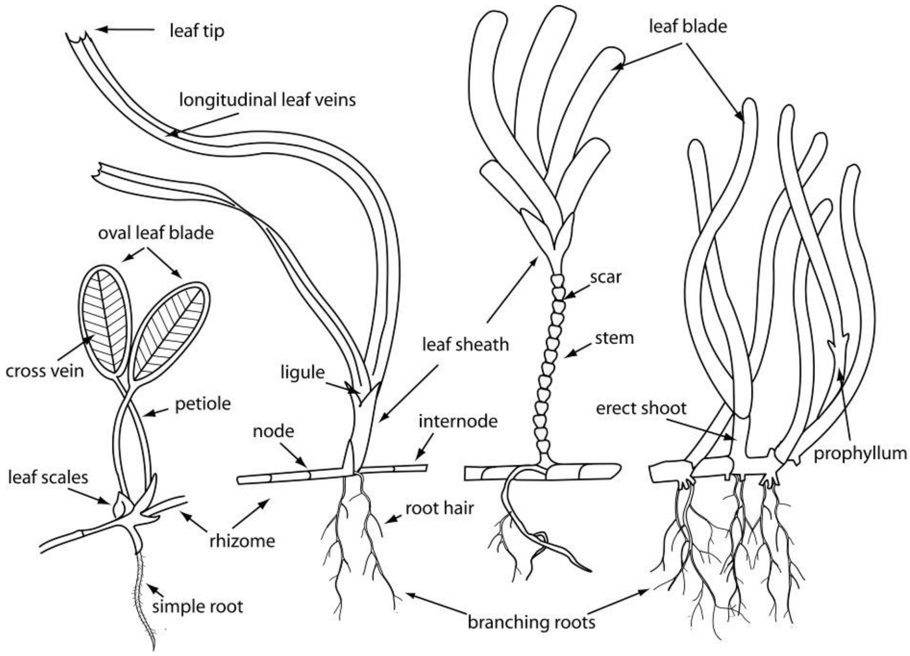
- compliant datasheets completed accurately
- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within 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) shape, a fern shape, a long spaghetti like leaf and a ribbon shape. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea, Thalassia, Thalassodendron, Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as **scars**.

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

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

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.

Over 30 species can be found within Australian waters. The most diverse seagrass communities are in the waters of north-eastern Queensland and southern Western Australia. Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, and spoon grass. Seagrasses are not seaweeds. Seaweed is the common name for algae.

Seagrass requirements for growth

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

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

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

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

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given 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

Seagrasses are more closely related to lilies

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

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

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea water

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

Light availability is the most important factor determining seagrass growth

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

Water temperature influences the rate of growth and the health of seagrass photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

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

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

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

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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

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

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

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

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

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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

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

Where are seagrasses found?

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the arctic (freezing) regions. Seagrass are mainly found in bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 metres. Most species are found in clear shallow inshore areas between mean sea-level and 25 metres depth.

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

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

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

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

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

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

Seagrass plants form small patches that develop into large continuous meadows. These meadows may consist of one or many species: sometimes up to 12 species present within one location.

Seagrass plants form small patches that develop into large meadows

How are seagrasses important to the marine ecosystem?

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

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

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

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

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

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

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

Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The decaying leaves are broken down by fungi and bacteria which in turn provide food for other microorganisms such as flagellates and plankton. Microorganisms provide food for the juveniles of many species of marine animals such as fish, crabs, prawns and molluscs.

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

The rhizomes and roots of the grasses bind sediments on the substrate, where nutrients are recycled by microorganisms back into the marine ecosystem. The leaves of the grasses slow water flow, allowing suspended material to settle on the bottom. This increases the amount of light reaching the seagrass meadow and creates a calm habitat for many species.

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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

Barrier reefs protect coastlines, and the lagoon formed between the reef and the mainland is protected from waves, allowing mangrove and seagrass communities to develop. Seagrasses trap sediment and slow water movement, causing suspended sediment to fall out. This trapping of sediment benefits coral by reducing sediment loads in the water.

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

Mangroves trap sediment from the land, reducing the chance of seagrasses and corals being smothered. Sediment banks accumulated by seagrasses may eventually form substrate that can be colonized by mangroves. All three communities trap and hold nutrients from being dispersed and lost into the surrounding oceanic waters.

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 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

Seagrasses can change due to both natural and human impacts response to natural environmental variation complicates the identification of changes caused by humans.

What threatens seagrass?

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

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

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

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

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

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

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

Coastal development can have a major impact on seagrass meadows

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

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

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.

Seagrass in the Burnett Mary NRM region of Queensland

Updated from McKenzie and Yoshida, 2008

Seagrass meadows in Hervey Bay and the Great Sandy Strait are one of the largest single areas of seagrass resources on the eastern Australian seaboard. Seagrasses are a major component of the Hervey Bay and Great Sandy Strait marine ecosystems and their contribution to the total primary carbon production is the basis for such regionally important dugong and turtle populations and productive fisheries.

Hervey Bay

Seagrasses in Hervey Bay were first mapped during a broad-scale survey between Water Park Point and Hervey Bay in October and November 1988 (Lee Long *et al.*, 1992). Seagrass distribution was estimated to be a least 1026.34 km^2 (Lee Long *et al.*, 1993) and mainly in large, dense meadows in the southern and western parts of the bay, extending from intertidal areas to 25 m depths in the centre of the bay.

Approximately 1000 km^2 of seagrass was lost in Hervey Bay after two major floods and a cyclone within a 3 week period in 1992 (Preen *et al.*, 1995). The deeper water seagrasses died, apparently as a result of light deprivation caused by a persistent plume of turbid water that resulted from the floods and the resuspension of sediments caused by the cyclonic seas. The heavy seas uprooted shallow water and intertidal seagrasses.

Recovery of sub-tidal seagrasses (at depths >5m) began within two years of the initial loss (Preen *et al.*, 1995), but recovery of inter-tidal seagrasses was much slower and only appeared evident after 4-5 years (J. Comans, HBDSMP, Pers Comm). The seagrasses appeared to be fully recovered in December 1998 (McKenzie *et al.*, 2000).

In December 1998 a detailed dive and remote camera survey of Hervey Bay and the Great Sandy Strait estimated 2,307 ±279 km^2 of seagrass existed in Hervey Bay (McKenzie *et al.*, 2000). Seagrass meadows extended from the intertidal and shallow subtidal waters to a depth of 32 m. The dominant (43%) deep water (>10 m) meadows in the southern section of Hervey Bay were large continuous meadows of medium-high biomass *Halophila spinulosa* with *Halophila ovalis* (high cover of drift algae).

The south eastern section of the bay consisted of generally bare substrate with isolated patches of *Halophila spinulosa/ H. ovalis/ H. decipiens*. In the south western section of the bay however, the subtidal seagrass meadows were generally patchy, medium to high biomass, *H. spinulosa* with *H. ovalis/H. decipiens* on sand down to 15 m. The shallow subtidal Dayman Bank, extending from near Urangan out to near the fairway buoy, was covered with low biomass *H. spinulosa/ H. decipiens*.

Seagrass meadows were also present on the intertidal sand banks between Burrum Heads and Eli Creek (Point Vernon). These meadows were generally low biomass *Zostera muelleri* ssp. *capricorni*, or *Halodule uninervis*, with *H. ovalis*. A narrow intertidal band of sparse (1-10% cover) *Z. muelleri ssp. capricorni* with *H. ovalis* was also present on the sand banks adjacent to the Esplanade from Pialba to Torquay.

In mid February 1999, the Mary River once again flooded into Hervey Bay. The flood was the fifth highest in the last 50 years, and ninth highest since reliable recordings were first made in 1870. The flood was only 0.75 m less than the February 1992 floods which, when combined with the effects of tropical cyclone "Fran", caused devastating losses of seagrass resources within Hervey Bay. The 1999 flood produced a large freshwater plume of suspended sediments which extended 35 km north-west into Hervey Bay. Substantially reduced light conditions were logged by light meters at 4 sites coinciding with the fairway buoys and lead markers. Light conditions in the main plume were significantly reduced for 19 days before returning to pre-flood levels (Ben Longstaff, UQ, Pers. Comm.).

The Mary River flood of February 1999 had the greatest adverse effect on the intertidal and shallow subtidal seagrasses in Hervey Bay that were in the path of the flood plume (McKenzie *et al.*, 2000). Shallow sub-tidal (2–10 m depth below MSL) seagrass resources of Hervey Bay (adjacent to the City of Hervey Bay) declined dramatically in abundance (from 23.24 ±5.05 grams DW m^{-2} above-ground abundance in December 1998) and distribution after the flood. By November 1999 the seagrass had completely disappeared. Deepwater seagrass resources in Hervey Bay within the path of the flood plume also declined significantly in abundance six months after the impact and remained significantly lower than outside the impact area after nine months (McKenzie *et al.*, 2000).

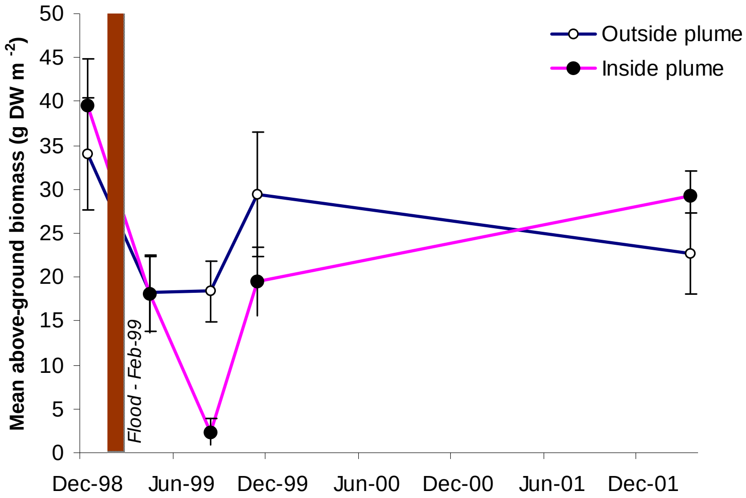


Figure 1. *Plot of above-ground seagrass biomass (g DW m^{-2}, all species pooled) from survey sites inside (Impact) and outside (Reference) the area impacted by the Mary River flood plume following flooding in Hervey Bay and the Great Sandy Strait in February 1999. Error bars represent 95% confidence limits.*

In February 2002, the sites examined in the deep water meadows of Hervey Bay were generally patchy, with light to moderate abundance of *H. spinulosa* with *H. ovalis/H. decipiens* on sand (McKenzie and Campbell, 2003). The meadow mapped in December 1998 on the shallow subtidal Dayman Bank, extending from near Urangan out to near the fairway buoy, showed little recovery in the northern tip with light *H. spinulosa/ H. decipiens* (<5% cover). More recent studies have suggested that these shallow subtidal meadows, often dominated by *H. ovalis*, are more vulnerable to light deprivation than intertidal populations dominated by *Z. muelleri ssp. capricorni* (Bité *et al.*, 2007).

Mean above-ground seagrass biomass at deepwater sites within the flood plume (Impacted sites) and for sites outside the flood plume (Reference sites) were pooled respectively for analysis. Impact and Reference sites did not appear to differ significantly in abundance in February 2002, and the all sites appear to have recovered to near or above pre-flood levels (McKenzie and Campbell, 2003).

Long term monitoring at Seagrass-Watch sites within Booral wetlands by local volunteers, found that initial re-colonisation of seagrass occurred in November 2000, 21 months post-flood. Full recovery of meadows to pre-flood cover values (~20-40%) occurred August 2002, 30 months post-flood. Monitoring sites also exhibited seasonal tends in abundances with highest cover in November and lowest seagrass cover post-summer from April to June. This typical seasonal response coupled with a trend of increasing seagrass cover indicates a post-flood recovery.

Recovery was also apparent in the deeper water seagrass communities of Hervey Bay, however in February 2002, deepwater seagrass abundances at monitoring sites within the impacted area had recovered to near pre-flood levels. The areas of seagrass that showed little recovery were the shallow sub-tidal seagrasses (2-4 m) along Dayman Bank. Only a few isolated patches of seagrass had recovered off the northern tip of the bank in February 2002. Further reading - Campbell and McKenzie, 2004.

Great Sandy Strait.

Seagrass meadows provide a major marine habitat in the Great Sandy Strait. The meadows form part of significant Ramsar wetlands sites, are within the proposed Great Sandy Marine Park (Northern Section), and provide critical nursery habitat for regional prawn and finfish fisheries.

Seagrass distribution was first mapped in the Great Sandy Strait in July/December 1973 (Dredge *et al.*, 1977). Seagrass was found south of the co-tidal line, which occurs at Moonboom Islands (25°20' S) and within Tin Can Inlet. No seagrass was found north of Moonboom Islands, including Urangan. Aerial photographs and ground truthing at 25 locations, were used to map an area of seagrass covering >4,800 hectares (~5,232 hectares digitised from Fig 2 in Dredge *et al.*, 1977). There were six species of seagrass within the study area, although the total extent of the subtidal *Halophila spinulosa* meadows could not be estimated.

Lennon and Luck, (1990) estimated that the Great Sandy Strait had approximately 12,300 hectares of seagrass covering extensive intertidal and subtidal areas. This estimate is based on remote sensing analysis and may have overestimated the intertidal (confused with algae) and underestimated the subtidal (high turbidity) seagrass habitat.

In October-November 1992 an aerial photographic survey of the Strait was conducted and significant decreases were reported in Tin Can Inlet (Fisheries Research Consultants 1993). Increases in seagrass distribution however, were reported in the northern section of the Strait, between River Heads and Urangan, and Blackfellow's Point and Moon Point. Seagrass community changes were also reported, especially in the dense monspecific *Cymodoea serrulata* meadow off Kauri Creek, which changed to sparse *C. serrulata* subtidally and *Z. muelleri ssp. capricorni* intertidally.

In 1994, a broad scale survey of the Great Sandy Strait seagrass meadows was conducted (mainly by air) which reported an increase in distribution of meadows south of Urangan to River Heads compared with 1992 (Fisheries Research Consultants 1994a). In June 1994, long-term monitoring transects were established throughout the Great Sandy Strait. Resurveys were conducted in March 1995, November 1996, February 1998, September 1998 and February 1999. Large decreases in seagrass distribution were recorded in 1996 and recovery to February 1999 remained low (Conacher *et al.*, 1999).

In December 1998 a detailed dive survey of the Great Sandy Strait was conducted which estimated 5,554 ±1,446 ha of seagrass habitat (McKenzie *et al.*, 2000). Seven species of seagrass were present in the Great Sandy Strait (*Zostera muelleri ssp. capricorni, Halodule uninervis, Halophila ovalis, Halophila decipiens, Halophila spinulosa, Cymodocea serrulata* and *Syringodium isoetifolium*). Most of the meadows throughout the Great Sandy Strait were intertidal on large mud- and sand-banks, and were predominantly in the northern and central sections.

Subtidal meadows contributed to only 5% (256 ±105 ha) of the total seagrass distribution of the Great Sandy Strait. Subtidal meadows were mostly in the northern and southern sections of the Strait in narrow bands along the edge of intertidal banks, or extending across the large subtidal banks. Subtidal meadows were dominated by *Halophila* species (*H. spinulosa, H decipiens, H. ovalis*) or *Z. muelleri ssp. capricorni*. Algae were often mixed within the subtidal meadows with cover ranging between 5 and 40%.

Flooding of the Mary River and other tributaries in the Sandy Strait in February 1999 caused the complete loss of seagrass meadows in the northern Great Sandy Strait and loss of some other regions in the central and southern Sandy Strait region (McKenzie *et al.*, 2000).

In February 2002 the total area of seagrass throughout the Great Sandy Strait had recovered to 7007 ±1945 hectares (Figure 2) (McKenzie and Campbell, 2003; Campbell and McKenzie, 2004). This was greater than the pre-flood survey conducted in December 1998.

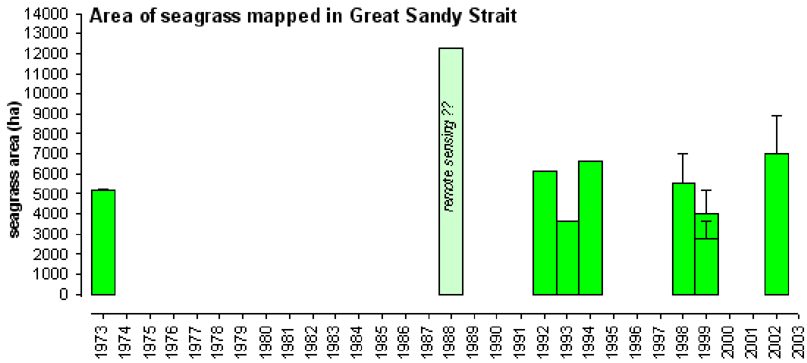


Figure 2. *Mean area ±R (estimate of reliability) for seagrass mapped in the Great Sandy Strait pre- and post-flood.*

In February 2002, approximately 92% of the area of seagrass meadows in the Great Sandy Strait was dominated by *Zostera muelleri ssp. capricorni*. The remainder was dominated by other species including *Halophila spinulosa*, *Halophila ovalis*, *Halophila decipiens*, *Halodule uninervis* and *Syringodium isoetifolium*. In February 2002, 14 seagrass meadow/community types were identified according to the order of species dominance, and meadow boundaries were mapped for each community type (McKenzie and Campbell 2003). Most meadows appeared to be of similar pre-flood abundances with biomasses approximately the same or marginally lower.

Seagrass-Watch in the Burnett mary NRM Region

To provide an early warning of change, long-term monitoring has been established at a number of locations across the Burnett Mary NRM as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org) (McKenzie *et al.*, 2003). The inaugural Seagrass-Watch training workshop was conducted at Urangan in 1998, and the inaugural Seagrass-Watch monitoring site was established at Boonooroo, Great Sandy Strait. To date, 39 sites (18 locations) have been established across the Burnett Mary NRM region. Sampling frequency varies between locations and sites (e.g. 2 sites are assessed quarterly, 13 biannually, 8 annually, 1 *ad hoc*), while monitoring has been suspended at 5 sites (due to insufficient capacity), and 10 sites are no longer monitored (i.e. archived). Monitoring a network of permanent sites in the Burnett Mary NRM region provides valuable information on temporal trends in the health status of seagrass meadows and provides a tool for decision-makers in adopting protective measures. The following is a summary of the current status of Seagrass-Watch monitoring in the Burnett Mary NRM region.

Regional report card - July 2015

- Seagrass meadows throughout the Burnett Mary NRM support significant fisheries, turtle and dugong populations
- The abundance within seagrass meadows in the Burnett Mary region was classified as **fair** in 2015 (NB: calendar year incomplete).
- Seagrass abundance in the Burnett Mary region has remained in a fair state since monitoring was established in 1999, and although status has fluctuated between years, overall there is no apparent long-term trend.
- Species composition has fluctuated across the majority of sites, generally in response to impacts (e.g. floods) and subsequent recovery.
- Algal abundance is generally low, but seasonally increases in the middle of each year at most sites. Episodic algal blooms occurred from time to time.
- Epiphyte blooms regularly occur at most sites in the mid-latter part of the year, with a dramatic decline in the summer months. Epiphyte abundance is generally higher in the Great Sandy Strait and was increasing (not significantly) at some sites on the western shores of the Great Sandy Strait.
- Sediment grain size has remained relatively stable over the monitoring period, with only a few sites becoming either more muddy or more sandy.
- Seagrass-Watch data provides understanding of seasonal trends and effects of climatic patterns on seagrass meadows

Sampling events were first grouped into seasons (Mar-May, Jun-Aug, Sep-Nov, Dec-Feb), and then using the seagrass abundance guidelines (McKenzie, 2009), seagrass state was determined for each monitoring event at each site, relative to the previous sampling event, and allocated as poor, fair or good state.

Figure 3. *Status of seagrass abundance in the Burnett Mary region relative to the seagrass guidelines since monitoring was established in 1999. Each block represents the seasonal monitoring event (dry, late dry, monsoon, late monsoon), with time along the x-axis from left to right.*

To examine the long-term trend in regional seagrass condition, seagrass state was pooled across sites within years. Seagrass abundance in the Burnett Mary region has remained in a fair state since 1999, and although state has fluctuated between years, there is no apparent overall trend.

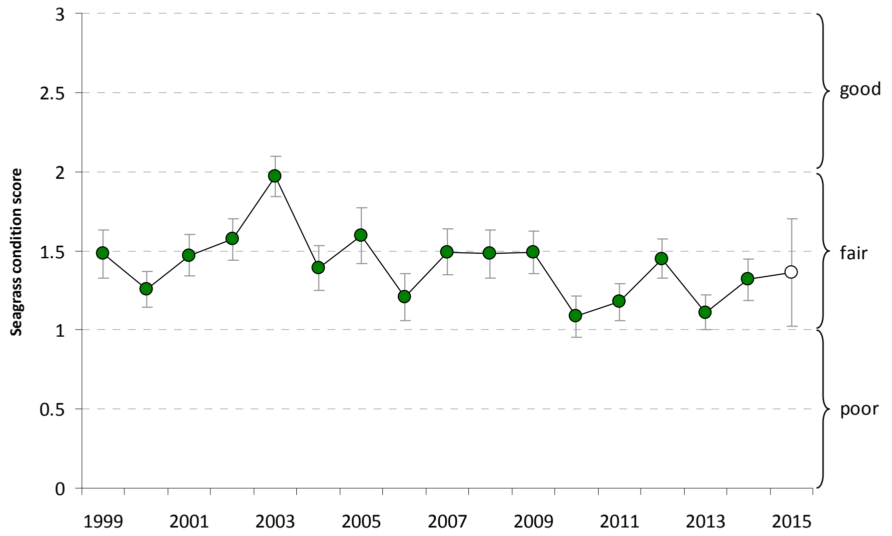


Figure 4. *Summary of annual average seagrass abundance/condition status (±standard error) in the Burnett Mary region relative to the seagrass guidelines since monitoring was established in 1999. The number and frequency of sites sampled varies between years.*

The following is a brief summary of the seagrass status at each location:

Rodds Bay

Monitoring: ongoing, *biannual*
Principal watchers: Seagrass-Watch HQ
Location: on large intertidal mud bank out from Turkey Beach.
Site codes: RD1, RD2
RD1 position: S24.05802 E151.65548 *(heading 10 degrees)*
RD2 position: S24.08110 E151.66264 *(heading 320 degrees)*
Best tides: <0.6m (Gatcombe Head, *port 59740*)
Issues: land runoff
Comments: intertidal banks are extremely muddy.
Status (Jun14):

- Seagrass abundance significantly declined at both sites in Rodds Bay in 2008-09 and the meadow remains in a poor state.
- Until the loss of seagrass in 2009, the sites were dominated by *Zostera muelleri* ssp. capricorni with less than 5% composed of colonising (*Halophila ovalis and Halophila decipiens)* and opportunistic species *(Halodule uninervis)*.
- Seagrass canopy height (leaf length) is correlated to *Zostera* seagrass abundance.
- Macroalgal and epiphyte abundance was low until 2011, after which time it increased.

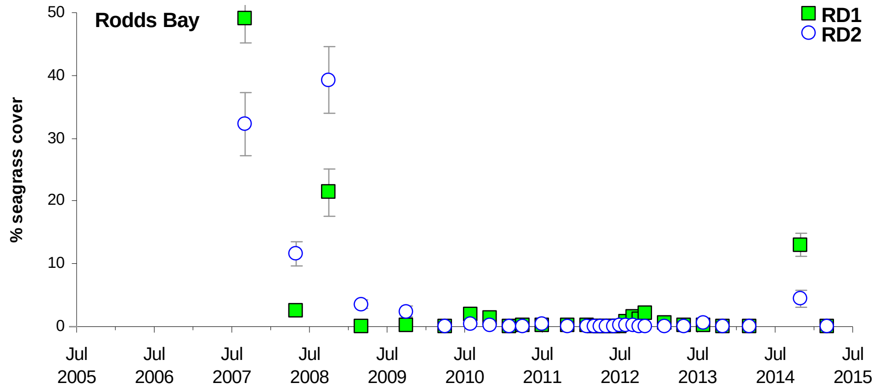


Figure 5. *Change in seagrass percentage cover (±SE) at the Rodds Bay intertidal meadows.*

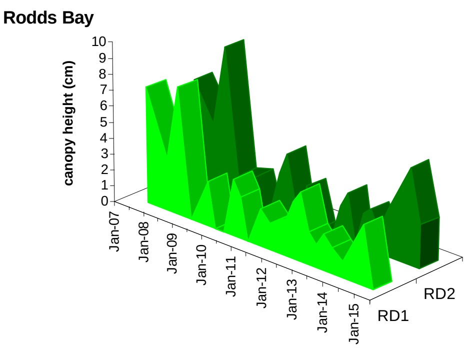


Figure 6. *Change in canopy height of dominant blady seagrass at the Rodds Bay intertidal meadows from 2007 to 2015.*

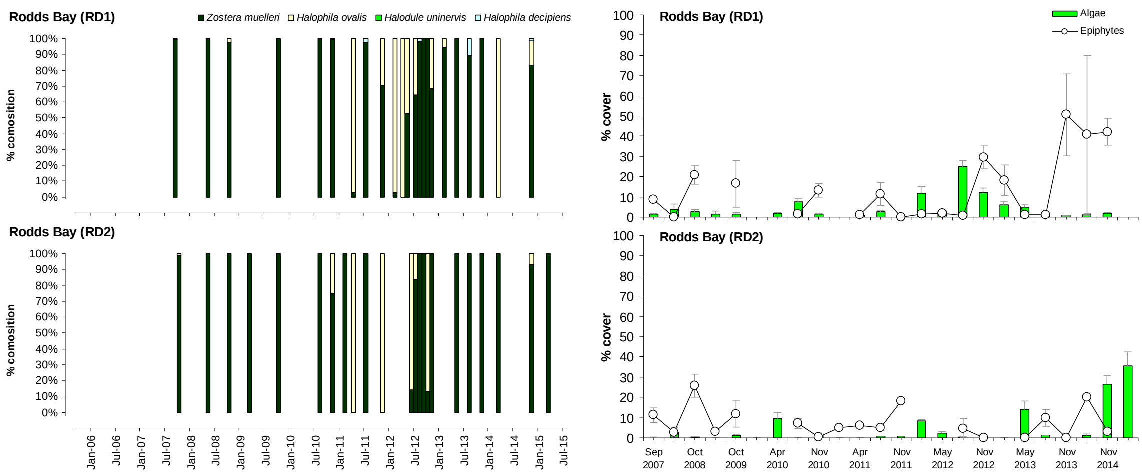


Figure 7. *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site in Rodds Bay from 2007-2015.*

Burrum Heads

Monitoring: ongoing, *biannual*
Principal watchers: Seagrass-Watch HQ
Occasional and past watchers: Wendy Jones, Yvonne Miles, Timothy Trim, Eileen Finglas, Andrew Finglas, Bill Kane, John Lindberg, Paul Sysum, Evelyn Mitchell, Bill Alston, Maree Cliff, Pauline Fowlie and Vanessa Jamieson
Location: Mouth of the Burrum River on the western shore of Hervey Bay
Site codes: BH1 BH2 BH3
BH1 position: S25.18813 E152.62562 *(heading 25 degrees)*
BH2 position: S25.19743 E152.63122 *(heading 21 degrees)*
BH3 position: S25.21031 E152.63932 *(heading 61 degrees)*

Best tides: <1.0m (Urangan, *port 59850*)
Issues: urban development, stormwater & land runoff, boat traffic
Comments: dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at Burrum Heads is currently in a **good state**
- Seagrass cover increased in at all sites from 2002, reaching peaks between 2003 and 2007, after which cover declined and fluctuated (decreasing and subsequently increasing) over the next 7 years.
- Seagrass canopy height (leaf length) changes seasonally, reaching minima mid-year and maxima over the summer months.
- The dominant seagrass species at Burrum Heads include the opportunistic and colonising species *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis, respectively*. The dominance of these species indicates regular disturbance across most of the intertidal banks. The persistent species *Zostera muelleri* ssp. *capricorni* is more common at BH2, and a large dense meadow is present immediately seaward.
- Macro-algae abundance is generally low with episodic blooms, epiphytes appear to increase over late winter and spring then dramatically decline over summer months.
- Dugong feeding trails are commonly found at Burrum Heads (BH1) and are most abundant in May and August.
- Polycheate worms are common but gastropods were relatively scarce. The abundance of polychaetes may be due to high supply of detrital matter, a known food source. Gastropods not only scavenge detrital matter but some graze on seagrass leaves, and some are predatory in their feeding habit. The paucity of gastropods in seagrass meadows may due to low seagrass abundance (i.e. less grazing matter and associated faunal prey).

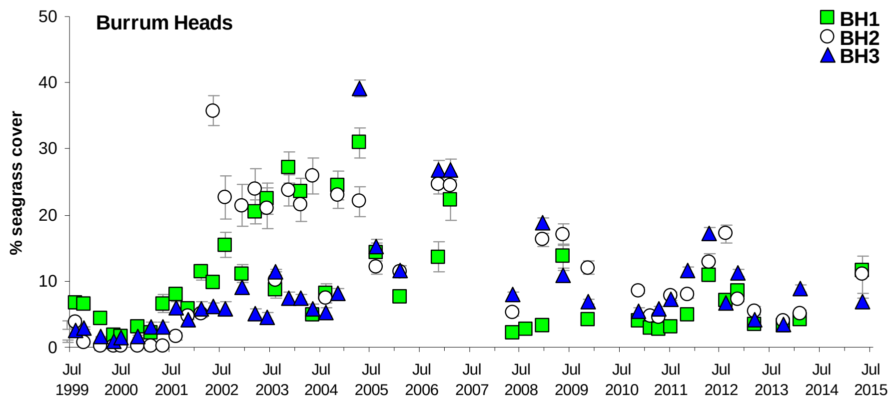


Figure 8. *Change in seagrass percentage cover (±SE) at the Burrum Heads intertidal meadows.*

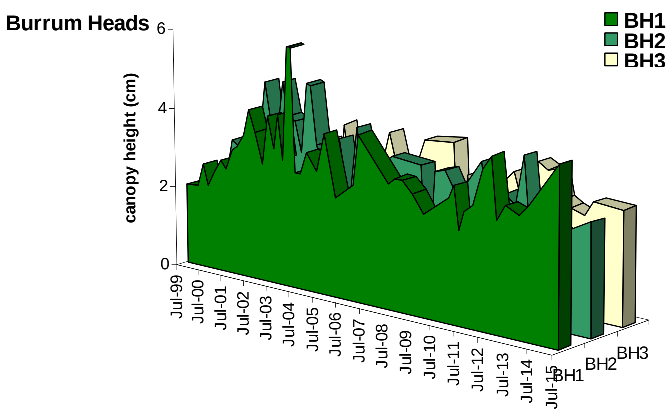


Figure 9. *Change in canopy height of dominant blady seagrass at the Burrum Heads intertidal meadows from 1999 to 2015.*

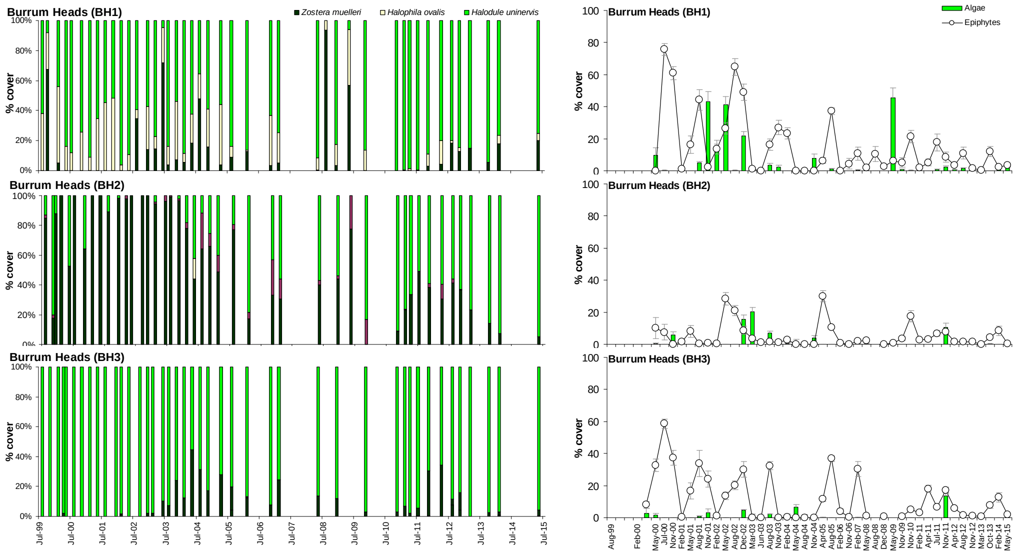


Figure 10 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Burrum Heads from 1999-2015.*

Dundowran

Monitoring: ongoing, *quarterly*
Principal watchers: Greg Lynch
Occasional and past watchers: Lloyd McKay, Sandy Mckay, Greg Lynch, Arnold Family, David & Rhonda Kohler, Seagrass-Watch HQ
Location: On the western coastline of Hervey Bay
Site codes: DD1, DD2, DD3
DD1 position: S25.26351 E152.74080 *(heading 10 degrees)*
DD2 position: S25.26400 E152.75943 *(heading 10 degrees)*
DD3 position: S25.26326 E152.77254 *(heading 10 degrees)*
Best tides: <0.9m (Urangan, *port 59850*)
Issues: urban development, stormwater & land runoff
Comments: dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at Dundowran has remained in a poor state since monitoring was established in 1999
- seagrass cover has remained low, with significant increases (followed by declines) at DD3 in late 2007, late 2011 and late 2014.
- the decline in seagrass cover from August 1999 to May 2000 at most intertidal sites between Burrum Heads and Dundowran was due to burial by mobile sediments.
- seagrass species composition has remained stable, with the infrequent appearance of *Zostera muelleri* ssp. *capricorni* from time to time at DD2 and DD3.
- The dominant seagrass species include the opportunistic and colonising species *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*, respectively. The dominance of these species indicates regular physical disturbance across the intertidal banks
- Algae and epiphytes occasional episodic blooms – generally in middle of the year.
- Sediment grain size has become slightly coarser across all sites over the monitoring period.
- Polycheate worms are common but gastropods were relatively scarce. The abundance of polychaetes may be due to high supply of detrital matter, a known food source. Gastropods not only scavenge detrital matter but some graze on seagrass leaves, and some are predatory in their feeding habit. The paucity of gastropods in seagrass meadows may due to low seagrass abundance (i.e. less grazing matter and associated faunal prey).
- The sites are influenced by wave action and tidal flows with high sediment movement observed throughout the monitoring period. A likely cause for changes in epiphyte and macroalgae cover at some sites (DD2 and DD3) is possibly a consequence of elevated nutrients from agricultural lands and sewage outlets (e.g. Eli Creek).

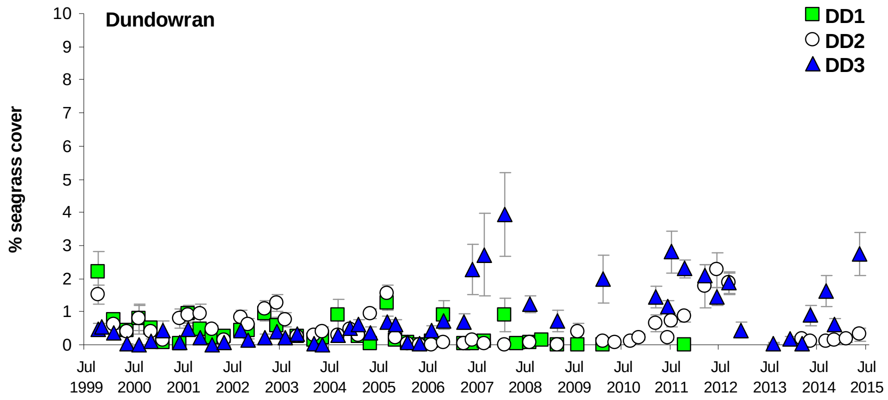


Figure 11. *Change in seagrass percentage cover (±SE) across the Dundowran intertidal meadows.*

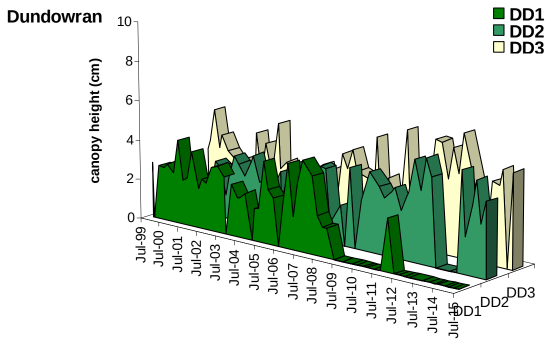


Figure 12. *Change in canopy height of dominant blady seagrass at the Dundowran intertidal meadows from 1999 to 2015.*

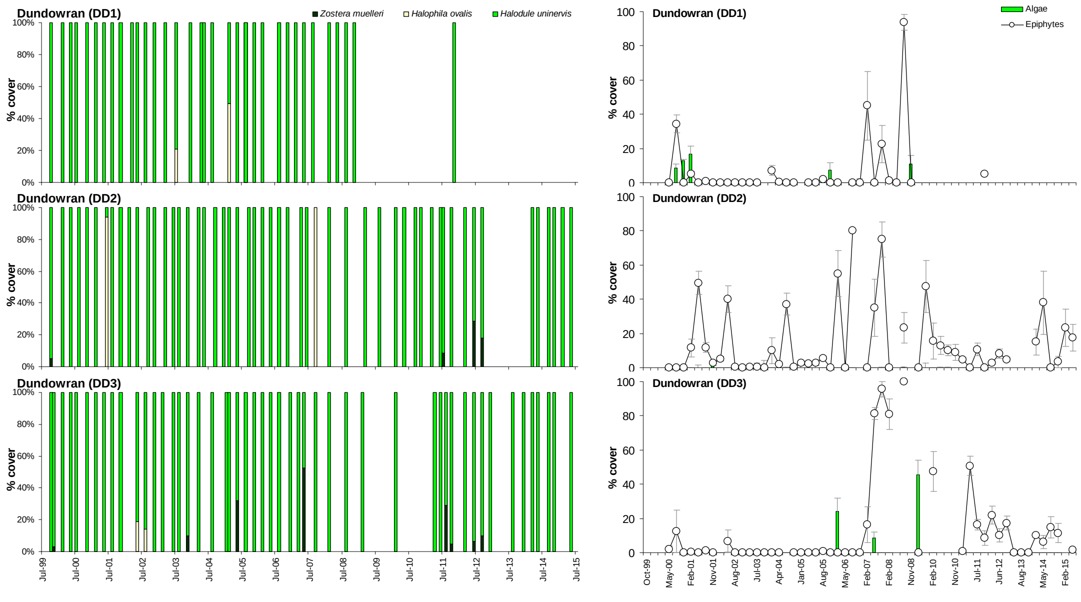


Figure 13 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Dundowran from 1999-2015.*

Toogoom

Monitoring: archived

Past watchers: Maree Cliff, Ian McLaren & Jen Holt, Mark Burnham, Jen Holt, Lauren Curry, Wendy Jones, Robin McLaren & Seagrass-Watch HQ

Location: On the western coastline of Hervey Bay

Site codes: TG1 TG2 TG3

TG1 position: S25.25843 E152.70487 *(heading 10 degrees)*

TG2 position: S25.24794 E152.68376 *(heading 30 degrees)*
TG3 position: S25.26131 E152.71467 *(heading 10 degrees)*
Best tides: <0.9m (Urangan, port 59850)
Issues: urban development, stormwater & agricultural land runoff
Comments: Dugong and turtle feeding grounds
Status (Jul10):

- seagrass abundance at Toogoom was in a **poor state** when last examined in 2010
- seagrass abundance at TG1 has remained stable between years over the monitoring period. Within years seagrass abundance appears to follow a seasonal pattern with slightly higher abundances in the middle of the year from late winter to spring.
- seagrass abundance at TG3 had not recovered to mid 1999 values. Seagrass was showing some seasonal trends in abundance, with significant increases each spring.
- The dominant seagrass species included *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. Species composition varied over the monitoring period with losses of both *Zostera muelleri* ssp. *capricorni* and *H. uninervis* due to sediment burial.
- algae was generally low with occasional episodic blooms
- epiphytes increased dramatically in late 2002 and early 2003, however these declined.
- Sediment grain size remained stable with fine sands.
- The sites are influenced by wave action and tidal flows with high sediment movement observed throughout the monitoring period. A likely cause for change in seagrass cover at some sites (TG2, TG3) was smothering by sand movement and scouring by water channels.

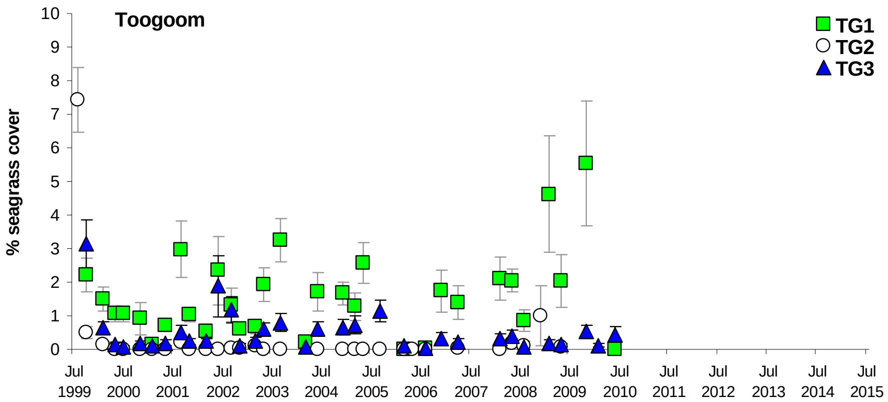


Figure 14. *Change in seagrass percentage cover (±SE) at the Toogoom intertidal meadows.*

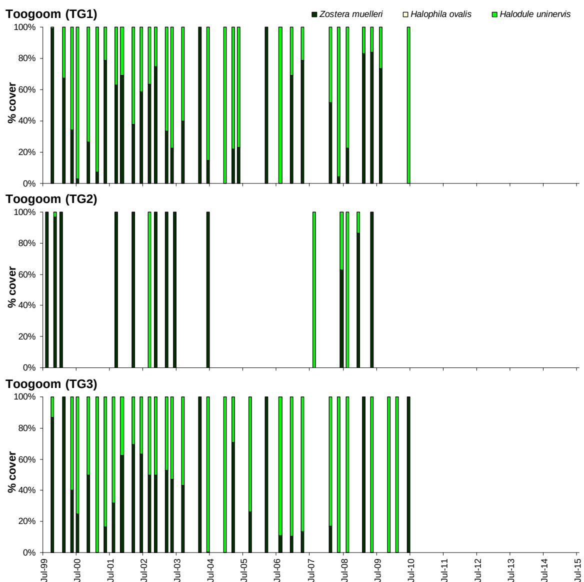


Figure 15 *Seagrass species composition at each monitoring site at Toogoom from 1999-2010.*

Urangan

Monitoring: ongoing, *biannual*
Principal watchers: Seagrass-Watch HQ
Past watchers: Trischelle Lowry, Matt Lowry, Karen Kirk, Kathy Maskey, Natalia Gleeson, Greg Lynch, Di-anne Duffield, Star of the Sea, Sue Olsson, Wendy Jones, David & Rhonda Kohler, Moyra McRee, Paul Evans, & Jerry Comans
Location: immediately south of the marina and north of the Mary River mouth
Site codes: UG1, UG2
UG1 position: S25.30088 E152.90681 (heading 121 degrees)
UG2 position: S25.30328 E152.90607 (heading 110 degrees)
Best tides: <0.8m (Urangan, port 59850)
Issues: urban development, worm digging, sewerage treatment, stormwater, marina development & land runoff
Comments: dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at Urangan is currently in a **fair state**
- Seagrass abundance has fluctuated greatly at Urangan since monitoring was established in 1999. The Urangan meadow has come and gone on an irregular basis. Following a major flood in February 1999, seagrass was absent (0% cover) from August 1999 to May 2000. In July 2000 seedlings of *Zostera muelleri* ssp. *capricorni* appeared. Seagrass abundance recovered significantly. A sudden and dramatic decline in early 2006 was of some concern. In late 2007, *Zostera* seedlings emerged and sparse patches began establishing. In 2008 the meadow continued to recover and aggregated patches of seagrass appeared over the intertidal banks. The subsequent decline following the floods in 2011 once again saw the intertidal banks barren of seagrass. The onset of recovery occurred late in 2011 and the meadows have gradually increased in abundance and size.
- Canopy height has continued to increase at the site in close correlation with *Zostera muelleri* ssp. *capricorni*.
- Percentage cover of macro-algae has continued to remain low. Algae cover is relatively insignificant at these sites, although blooms occur at irregular intervals.
- Epiphytes cover on seagrass leaf blades at Urangan were high and variable over the years of monitoring, however has been gradually increasing since 2009, suggesting chronic elevated nutrients.
- Sediment grain size has changed relatively little over the monitoring period.
- Dugong feeding was absent until late 2001, coinciding with seagrass recovery. Feeding trails are regularly observed across the meadows.
- The high abundance of gastropods may be due to high amounts of mud and organic detrital matter in the sediments. Polychaete worms were also abundant.

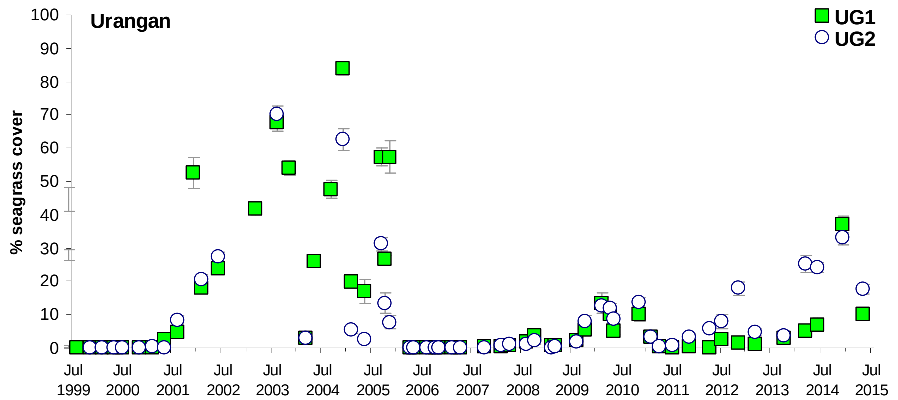


Figure 16. *Change in seagrass percentage cover (±SE) at the Urangan intertidal meadows.*

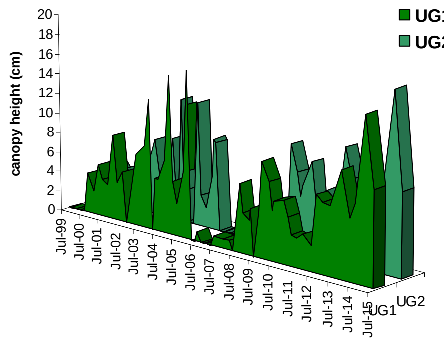


Figure 17. *Change in canopy height of dominant blady seagrass at the Urangan intertidal meadows from 1999 to 2015.*

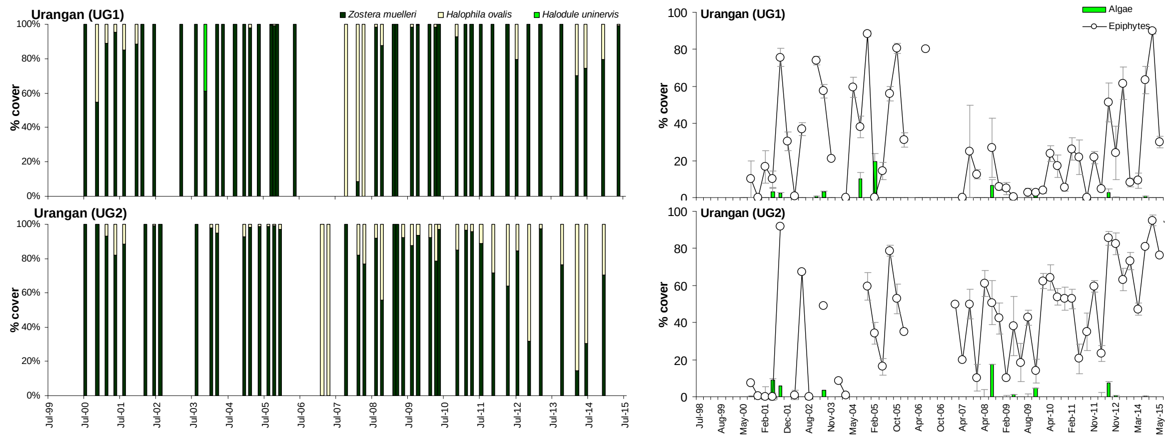


Figure 18 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Urangan from 1999-2015.*

Booral

Monitoring: archived
Past watchers: Trischelle Lowry, Matt Lowry Horst Pfaller, Paul Hatherell, Chris Ashcroft, Brooke & Jemma Donahay, Lynn Child and Seagrass-Watch HQ
Location: 2.5-6.5km south of Urangan and mid-way to River Heads (the mouth of the Mary River)
Site codes: UG3, UG4
UG3 position: S25.36097 E152.91838
UG4 position: S25.36096 E152.91838 (heading 68 degrees)
Best tides: <0.8m (Urangan, port 59850)
Issues: urban development, stormwater & land runoff
Comments: Dugong, turtle and shorebird feeding grounds
Status (Dec06):

- seagrass abundance at Booral was in a **poor state**
- seagrass abundance increased significantly in 2002, but declined in 2005 and not significantly different than was observed when the site was established in late 2000.
- episodic macro-algal blooms occurred in late 2001 and 2002, however the algal abundances subsequently declined early in the new year.
- Epiphyte abundance is positively correlated with seagrass abundance.

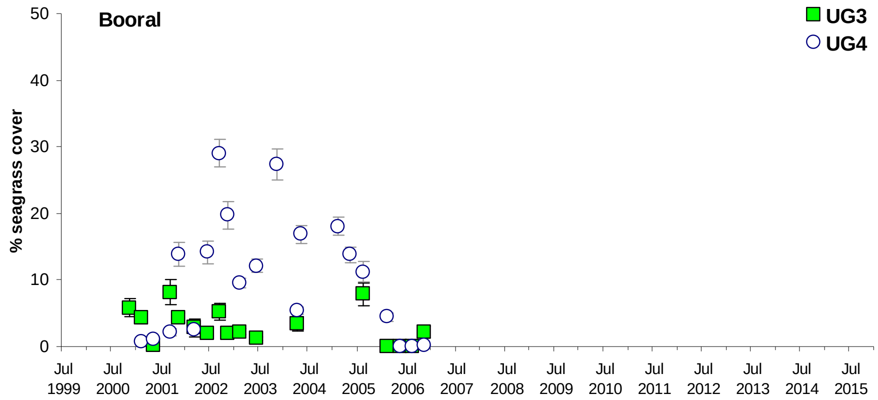


Figure 19. *Change in seagrass percentage cover (±SE) at the Boral intertidal meadows.*

Brown's Gutter

Monitoring: suspended
Past watchers: Gordon Cottle, Robyn Bailey, Pat Cottle, Paul Bailey Gary Nielsen, Steve Winderlich, John Lindberg, John Roberts, Anne O'Dae, Matthew Hamilton, Hanna Larson & Seagrass-Watch HQ
Location: shallow anchorage on the south western shores of Fraser Island
Site codes: BG1 BG2 BG3
BG1 position: S25.74305 E153.00058 *(heading 50 degrees)*
BG2 position: S25.75004 E153.00311 *(heading 70 degrees)*
BG3 position: S25.76155 E153.00830 *(heading 70 degrees)*
Best tides: <0.6m
Issues: stormwater & land runoff, boat traffic
Comments: dugong and turtle feeding grounds
Status (Dec10):

- seagrass abundance at Brown's Gutter was in a poor state
- BG1 progressively increased in abundance after 2000, however seagrass abundance at BG2 & BG3 fluctuated over the following 9 years.
- seagrass abundance appears seasonal within years, with lower levels from Jun-Aug and highest levels from Nov-Jan.
- episodic algal bloom occurred in mid 2002, however the algal abundances subsequently declined early in the new year. Epiphyte blooms regularly occur at most sites in the middle of the year.
- sediment grain size changed little over the monitoring period.
- species composition remained stable - dominated by *Zostera*.
- polychaete worms and gastropods (including mud whelks) were common.

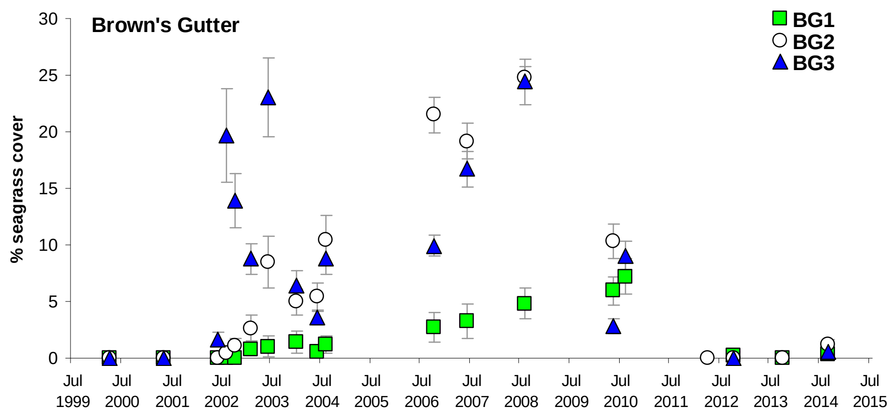


Figure 20. *Change in seagrass percentage cover (±SE) at the Brown's Gutter intertidal meadows.*

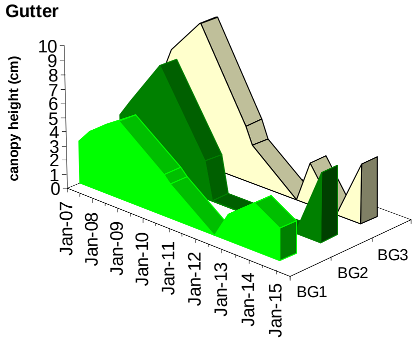


Figure 21. *Change in canopy height of dominant blady seagrass at the Brown's Gutter intertidal meadows from 1999 to 2010.*

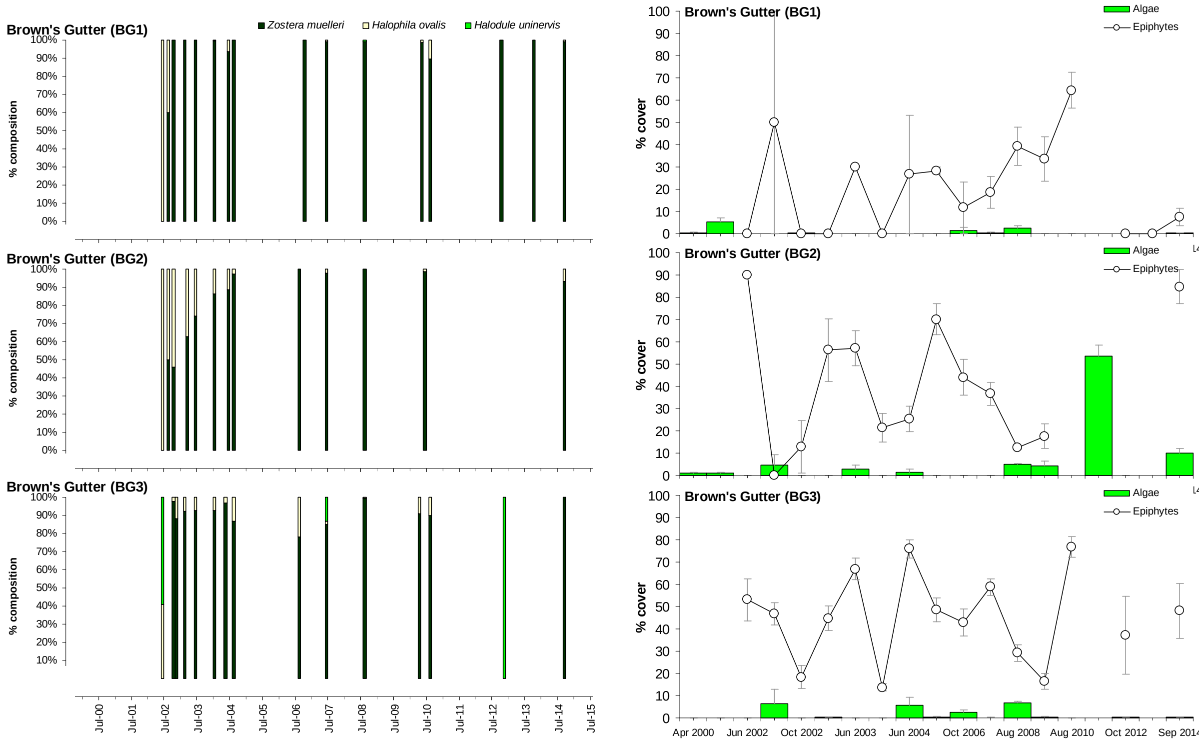


Figure 22 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Brown's Gutter from 1999-2010.*

Boonooroo

Monitoring: ongoing, *biannual*

Principal watchers: Maree Prior, Jess Milne, Helene Hoksburgen, Norma Sanderson, Sarah Mitchell, Kate Houley. Bruce Pollard, Stan Ray, G Naughton & Lyn McPherson

Occasional and past watchers: Gordon Cottle, Robyn Bailey, Pat Cottle, Paul Bailey, John Roberts, Anne O'Dae, Steve Winderlich , Hana Larsson, Wayne Mathews, Peter Lusk, Bill Alston, Maryborough West School, Trischelle Lowry, Faye Fergurson, Mary Starkey & Seagrass-Watch HQ

Location: on the western shores of the Great Sandy Strait, adjacent to Boonooroo township, between Big Tuan Creek and Maroom. BN2 is located close to Big Tuan Creek and BN3 is located approximately 1.6km north, with BN1 midway between BN2 and BN3. BN2 is considered the "impacted" site and BN3 the "control"/"reference" site

Site codes: BN1 BN2 BN3

BN1 position: S25.66866 E152.90736 *(heading 100 degrees)*

BN2 position: S25.68208 E152.89377 *(heading 230 degrees)*

BN3 position: S25.64812 E152.90670 *(heading 280 degrees)*

Best tides: <0.8m

Issues: Small unsewered village, boat traffic & land use

Comments: significant nursery grounds for juvenile prawns and fish. Dugong and turtle feeding grounds.

Status (Jul15):

- seagrass abundance at Boonooroo is currently in a **fair state**
- seagrass abundance at both "impacted" (BN1 & BN2) and "control" (BN3) sites declined from 1999 to 2005, however since 2008 seagrass abundance has continued to increase at BN3.
- seagrass species composition has varied over the monitoring period, particularly at BN1 where *Zostera muelleri* ssp. *capricorni*.was becoming more dominant until 2009 when the meadow reverted back to *Halodule uninervis*. *Halodule uninervis* and *Halophila ovalis* are colonising species and may indicate levels of physical disturbance (eg wave action and sediment movement).
- algae abundance appears seasonal at it generally increases in the later half of each year.
- epiphyte abundance is generally high and variable, possibly indicating elevated nutrients.
- sediment grain size has remained stable of the monitoring period.
- dugong feeding trails found year round, with the most intensive grazing occurred from May to November, coinciding with the nutritional demands of calving from September to December. During this period seasonal forces support high seagrass growth ensuring that losses from grazing are outweighed by tissue production.
- polychaete worms and gastropods (including mud whelks) common. The diversity and abundance of gastropods appears dependent on seagrass abundance, most likely due to associated detrital and prey food sources.

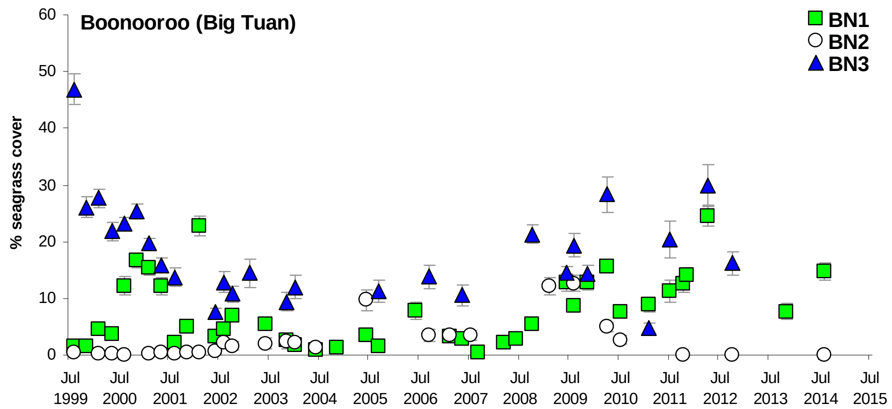


Figure 23. *Change in seagrass percentage cover (±SE) at the Boonooroo intertidal meadows.*

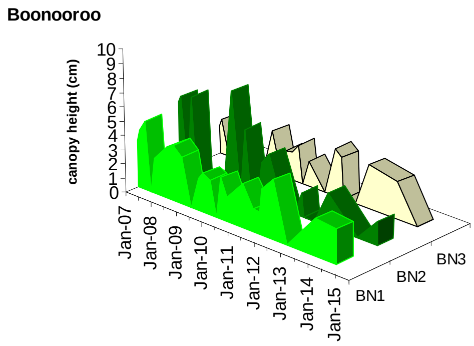


Figure 24. *Change in canopy height of dominant blady seagrass at the Boonooroo intertidal meadows from 1999 to 2015.*

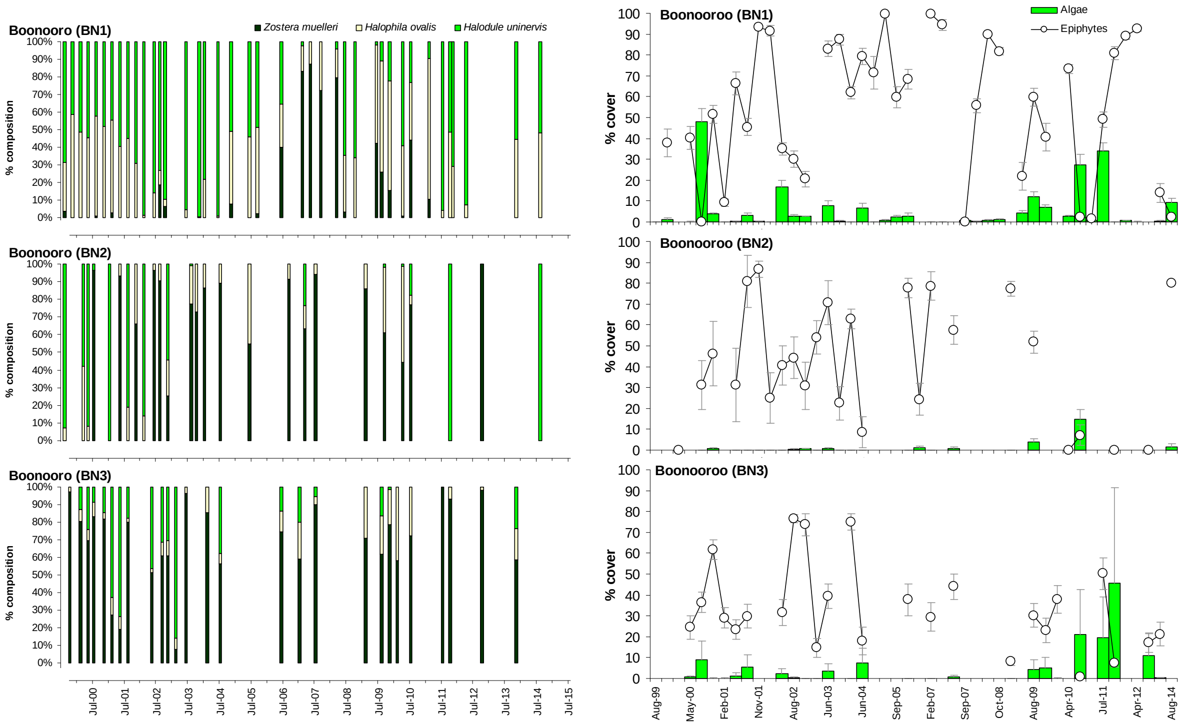


Figure 25 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Boonooroo from 1999-2015.*

Kauri Creek

Monitoring: ongoing, *ad hoc*
Principal watchers: Lyn McPherson, Maree Prior, Sarah Mitchell & Graham Naughton
Occasional and past watchers: Carole Gillies, Norma Sanderson, Gordon Cottle, Robyn Bailey, Steve Winderlich, Gary Nielsen, Wayne Mathews Pat Cottle, Paul Bailey & Anne O'Dae
Location: on intertidal bank (Ballast Bank) on the southern side of the mouth to Kauri Creek
Site code: KC1
KC1 position: S25.79597 E152.98675 *(heading 130 degrees)*
Best tides: <0.8m
Issues: defence land runoff
Comments: dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at Kauri Creek is currently in a **poor state**
- seagrass abundance has fluctuated since monitoring was established, and abundances in 2010 were not significnatly different from 2007.
- canopy height is showing a close correlation with seagrass abundance.
- epiphyte abundance appears highly variable.
- sediment grain size and seagrass species composition appear stable.
- polychaete worms and gastropods were common.

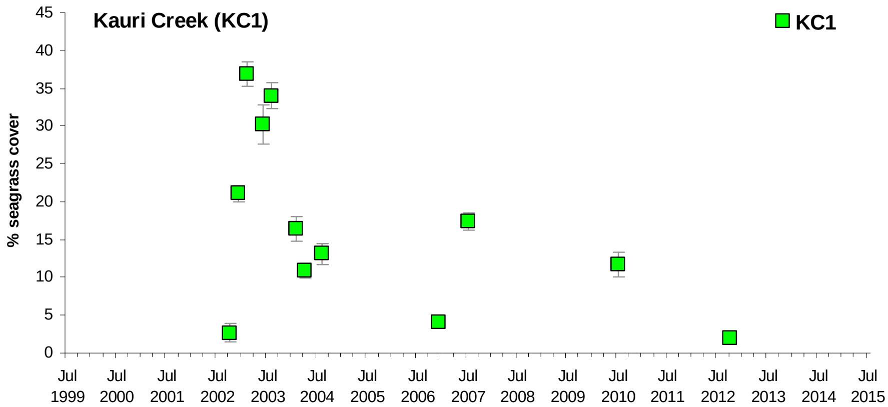


Figure 26. *Change in seagrass percentage cover (±SE) at the Kauri Creek intertidal meadows.*

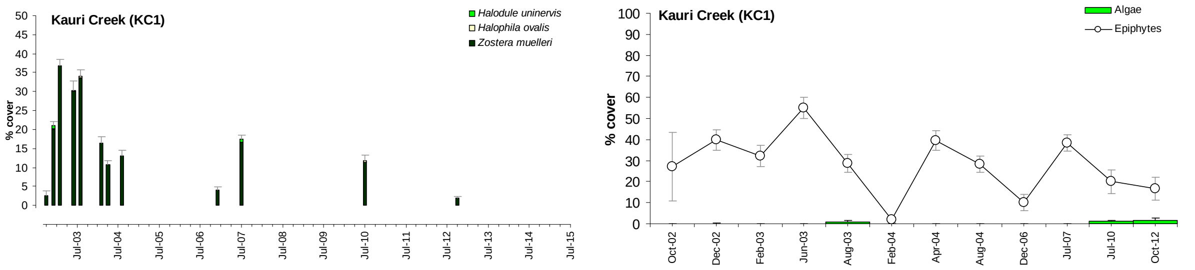


Figure 27 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Kauri Creek from 2002-2012.*

Poona

Monitoring: ongoing, *annual*
Principal watchers: Lyn McPherson, Norma Sanderson, Maree Prior & Jess Milne
Occasional and past watchers: Gordon Cottle, Robyn Bailey, Hanne Larson, Gary Neilsen, Di-anne Duffield, Maryborough Special School, Mary Dixon, Sarah De Ghen, Trischelle Lowry, Wayne Mathews, Desley Nielsen, Anne O'Dae, Steve Winderlich & Seagrass-Watch HQ
Location: Intertidal banks adjacent to township
Site codes: PN1 PN2 PN3
PN1 position: S25.70853 E152.92433 *(heading 30 degrees)*
PN2 position: S25.71847 E152.91953*(heading 117degrees)*
PN3 position: S25.72980 E152.92285 *(heading 15 degrees)*
Best tides: <0.8m
Issues: small unsewered village increasing development, access channel dredging, boat traffic, stormwater, land runoff
Comments: significant fish habitat. Dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at Poona is currently in a poor-fair state
- seagrass abundance has fluctuated greatly since monitoring was established in 1999.
- seagrass composition appears relatively stable at PN1 and PN3.
- PN2 has changed the most of all sites at Poona, both in abundance and species composition. The site appears to be generally dominated by *Zostera muelleri* ssp*. capricorni*, however the composition of the colonising species *Halodule uninervis* and *Halophila ovalis* has fluctuated over the years and has become more dominant in 2008, suggesting a high level of localised physical disturbance.
- sediment grain size has remained relatively stable at PN1 and PN2, however PN3 appears to have become muddier (this corresponds with the abundance of *Zostera* which is better adapted to muddier sediments).
- dugong feeding trails were found year round, with the most intensive grazing occurred from May to November, coinciding with the nutritional demands of calving from September to December. During this period seasonal forces support high seagrass growth ensuring that losses from grazing are outweighed by tissue production. Turtle feeding was evident year round.
- polychaete worms and gastropods were common. The diversity and abundance of gastropods appears to be dependent on seagrass abundance, most likely due to associated detrital and prey food sources.
- seagrass meadows at Poona were predominantly composed of fine mud and fine sand with a high organic component. Meadows near Poona Creek (PN2) had low seagrass cover, contained muddy sediments with a low sand component. At meadows distant from freshwater inputs (PN3) sand rippling indicates the influence of tidal movement and/or a low exposure to catchment influences.

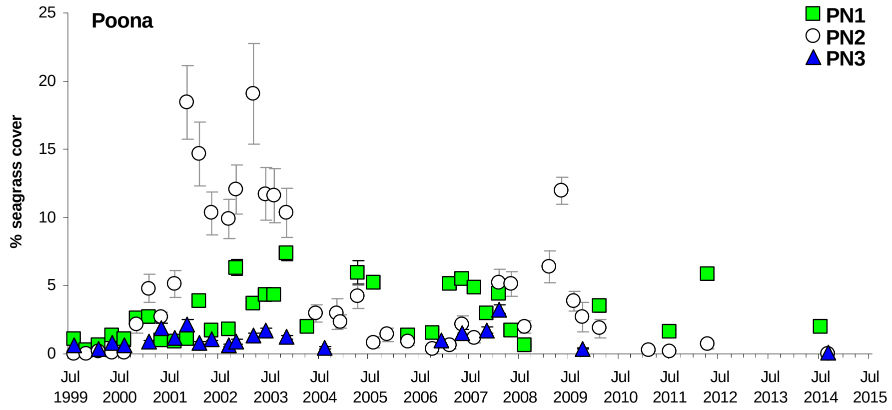


Figure 28. *Change in seagrass percentage cover (±SE) at the Poona intertidal meadows.*

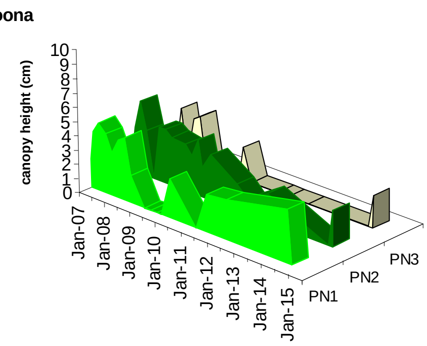


Figure 29. *Change in canopy height of dominant blady seagrass at the Poona intertidal meadows from 1999 to 2014.*

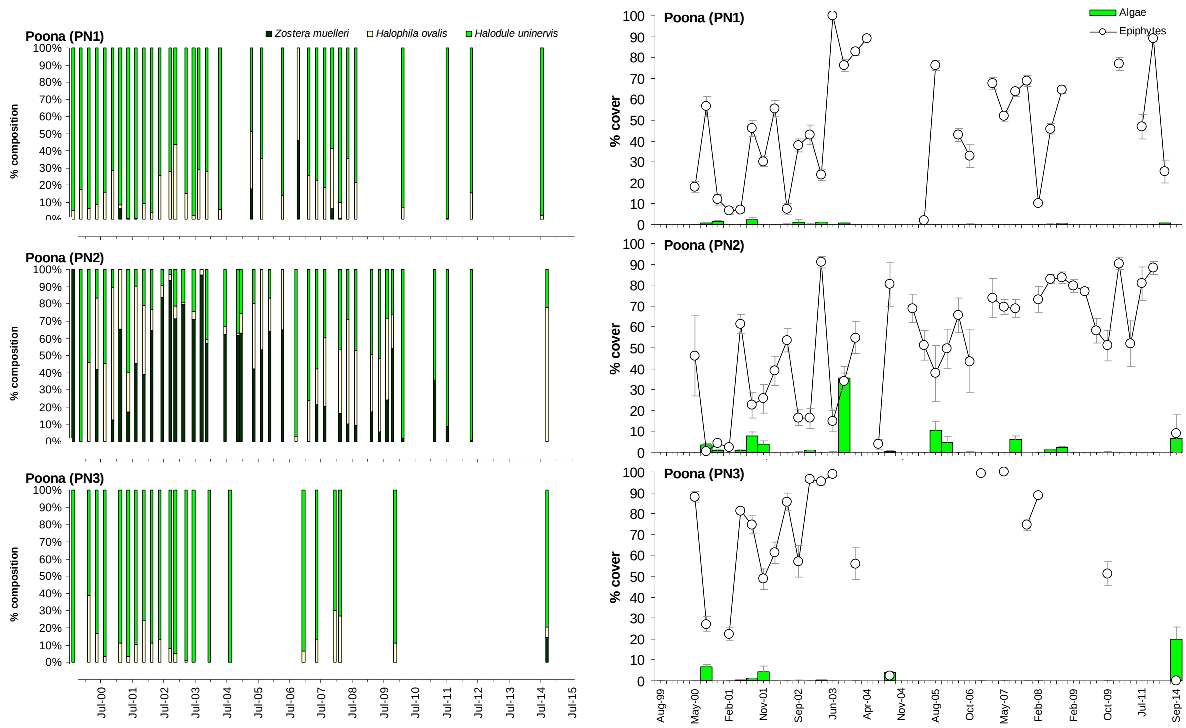


Figure 30 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Poona from 1999-2014.*

Reef Islands

Monitoring: ongoing, *annual*
Principal watchers: Maree Prior, Graham Naughton, Sarah Mitchell, Jess Milne, Helen Bowyer, Ruby Bowyer, Kate Houley, Troy Aithenhead, Peter Burchett & Bruce Pollard
Occasional and past watchers: Gordon Cottle, Robyn Bailey, Hanne Larson, Paul Bailey Steve Winderlich, John Roberts, Anne O'Dae, Gary Nielsen, Michael Ford, Sarah De Ghen, Bill Alston, Jerry Comans,Sue Olsson & Seagrass-Watch HQ
Location: central Great Sandy Strait
Site codes: RI1 RI2 RI3
RI1 position: S25.65463 E152.95354 *(heading 240 degrees)*
RI2 position: S25.65899 E152.94900 *(heading 40 degrees)*
RI3 position: S25.67718 E152.95652 *(heading 90 degrees)*
Best tides: <0.6m
Issues: Boat traffic, oyster leases, land runoff
Comments: significant nursery grounds for juvenile prawns and fish. Dugong and turtle feeding grounds
Status (Jul15):

- seagrass abundance at the Reef Islands is currently in a **poor state**
- seagrass abundance fluctuates (either doubling or halving) at times, but the long-term trend was stable until 2011, after which the meadows significantly declined.
- algal abundance was generally low with the exception being a significant algal bloom at RI1 in late 2003.
- epiphyte abundance is generally high and appears seasonal with greatest increases in the later part of the year, followed by declines in the summer months.
- sediment grain size and species composition relatively stable over monitoring period.
- dugong feeding trails were found year round, with the most intensive grazing occurred from May to November, coinciding with the nutritional demands of calving from September to December. During this period seasonal forces support high seagrass growth ensuring that losses from grazing are outweighed by tissue production. Turtle feeding was evident year round.
- polychaete worms and gastropods were common. The diversity and abundance of gastropods appears to be dependent on seagrass abundance, most likely due to associated detrital and prey food sources. Filter feeding bivalves and oysters were found at Reef Island sites.

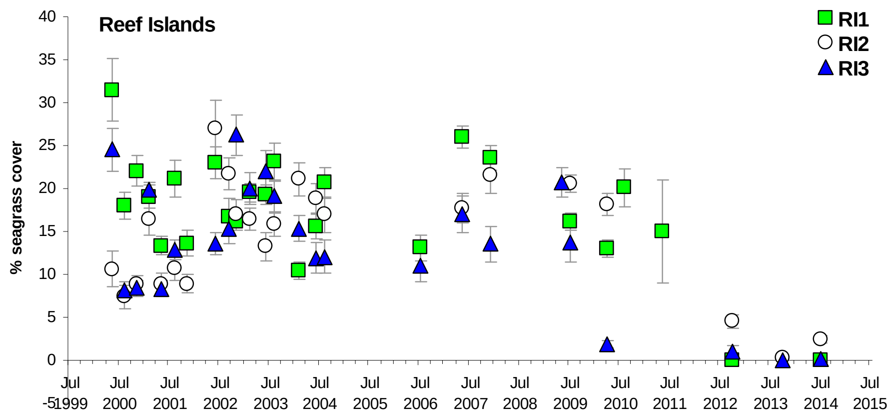


Figure 31. *Change in seagrass percentage cover (±SE) at the Reef Islands intertidal meadows.*

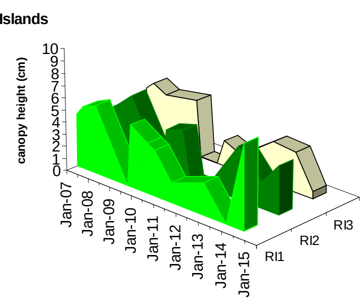


Figure 32. *Change in canopy height of dominant blady seagrass at the Reef Islands intertidal meadows from 1999 to 2014.*

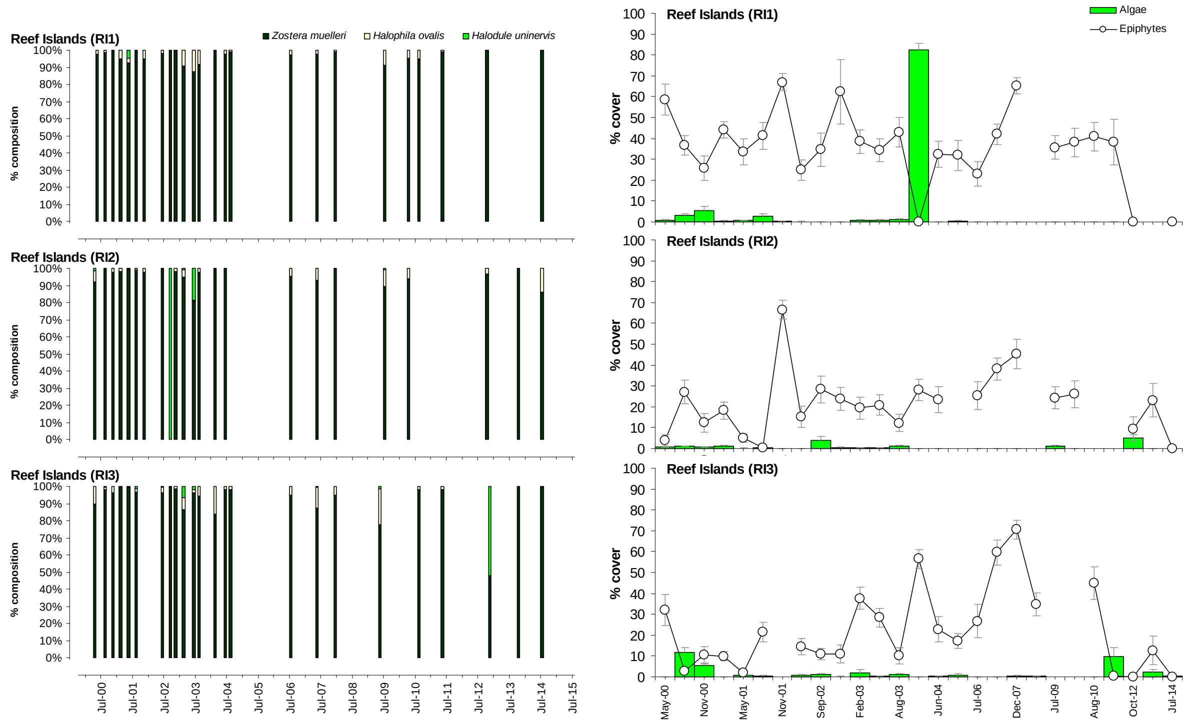


Figure 33 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Reef Islands from 1999-2014.*

Tin Can Inlet

Monitoring: ongoing, biannual
Principal watchers: Maree Prior, Nick Dennett, Lyn McPherson Ben Hoekstra, Norma Sanderson, Jess Milne, Sarah Ballard, Alan Ballard, Darcy Bowyer, Bernard Bowyer & Seagrass-Watch HQ,
Occasional and past watchers: Gordon Cottle, Robyn Bailey, Hanne Larson, Pat Cottle, Wayne Mathews, Dennis Osborn, Marc Dargosch, Dean Richardson, Di-anne Duffield & Sarah De Ghen
Location: Southern Great Sandy Strait, including Pelican Bay and on intertidal flats in front of Tin Can Bay township
Site codes: TB1, PB1, PB2
PB1 position: S25.81285 E153.04767 *(heading 145 degrees)*
Best tides: <1.0m
PB2 position: S25.82231 E153.06244 *(heading 50 degrees)*
Best tides: <0.6m
TB1 position: S25.90615 E153.01533 *(heading 115 degrees)*
Best tides: <0.6m
Issues: Tourism (periodic camping) & urban development, vehicles, stormwater, sewerage & restoration of old wharf
Comments: Dugong and turtle feeding grounds, popular fishing (recreational & commercial)
Status (Jul15):

- seagrass abundance at Boonooroo is currently in a **fair** state
- seagrass abundance has remained low (generally less than 1%) at the site adjacent to the Tin Can Bay township (TB1). The sparse meadows are dominated by the colonising seagrass species *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. The intertidal banks are dynamic (sand movement and physical disturbance from sting rays etc) and predominately sand with shell/gravel. Results suggest that due to the dynamic nature of the intertidal banks and the persistence of colonising species, the banks are adverse to establishment of dense seagrass meadows and little change would be expected in the near future.
- seagrass abundance at PB1 (Inskip Point) has fluctuated greatly over the monitoring period, however it has since decreased in 2008 to 1999-2000 abundances (ie post 1999 flood).
- the site at Bullock Point (PB2) in Pelican Bay was last monitored in August 2005.

- algal abundance appears to increase seasonally in the winter months and epiphyte abundance is highly variable. No persistent long-term trends are apparent, suggesting elevated nutrients are not a significant issue at present.
- seagrass composition at TB1 appears stable, although sediment grain size is variable.
- polychaete worms and gastropods (including mud whelks) were common. The diversity and abundance of gastropods appears to be dependent on seagrass abundance, most likely due to associated detrital and prey food sources.
- seagrass meadows at Pelican Bay were predominantly composed of fine mud and fine sand with a high organic component.

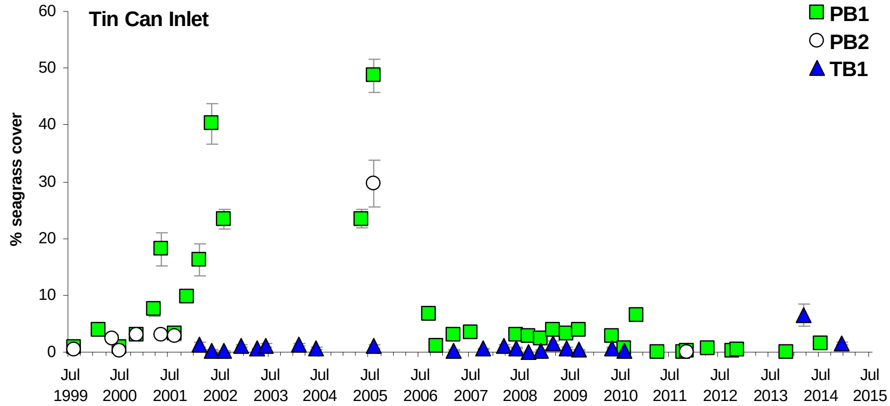


Figure 34. *Change in seagrass percentage cover (±SE) at the Tin Can Inlet intertidal meadows.*

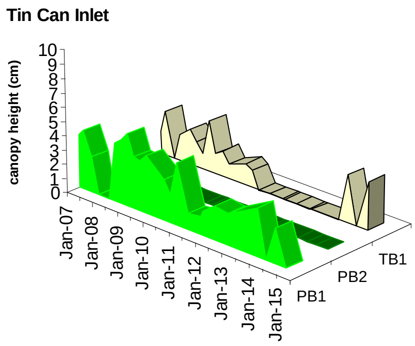


Figure 35. *Change in canopy height of dominant blady seagrass at the Tin Can Inlet intertidal meadows from 1999 to 2015.*

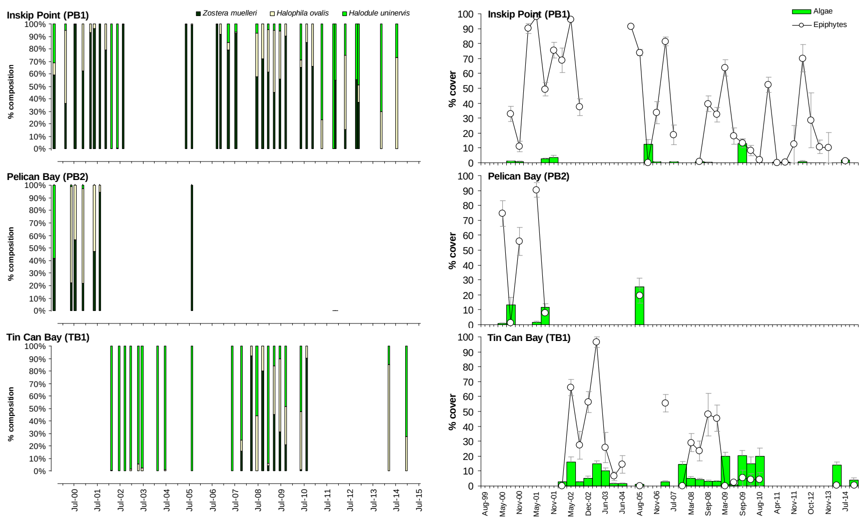


Figure 36 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Tin Can Inlet from 1999-2014.*

Tinnanbar

Monitoring: ongoing, *biannual*
Principal watchers: Norma Sanderson, Lyn McPherson, Maree Prior, Darcy Bowyer, Delwyn Hewitt, Helen Bowyer, Bernard Bowyer, Nick Dennett & Ben Hoekstra
Occasional and past watchers: Gordon Cottle, Robyn Bailey, Hanne Larson, Pat Cottle, Gary Nielsen, Peter Lusk, Wayne Mathews, Hans Van Roey, Sarah De Ghen, Steve Nicol, D. Eckert, Megan Dale, Nigel Woodward, Rex Coleman, Steve Winderlich & Seagrass-Watch HQ
Location: southern Great Sandy Strait on the intertidal banks in front of the Tinnanbar township & caravan park.
Site codes: TN1 TN2 TN3
TN1 position: S25.75617 E152.95235 *(heading degrees)*
TN2 position: S25.75827 E152.96378 *(heading 15 degrees)*
TN3 position: S25.75807 E152.96788 *(heading 55 degrees)*
Best tides: <0.8m
Issues: high urban development, boat traffic, stormwater, land runoff
Comments: Dugong and turtle feeding grounds. Popular fishing (recreational & commercial)
Status (Dec10):

- seagrass abundance at Tinnanbar is currently in a poor-fair state
- seagrass abundance decreased between 2004 and 2006, and although TN1 increased between 2008 and early 2009, all sites subsequently decreased. In 2014 some recovery was observed at TN1 and TN2.
- algae cover is generally low but appears to have increased over the last couple of years.
- epiphyte cover is high and variable, suggesting elevated nutrients in eh water column
- sediment grain size and species composition relatively stable over monitoring period.
- polychaete worms and gastropods were common.

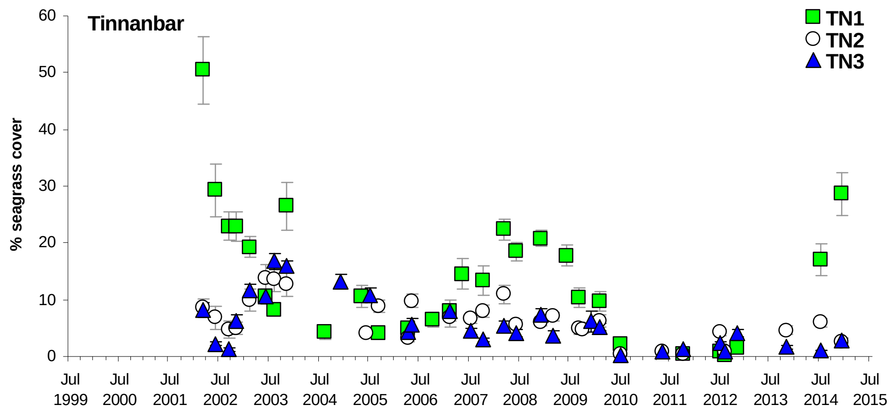


Figure 37. *Change in seagrass percentage cover (±SE) at the Tinnanbar intertidal meadows.*

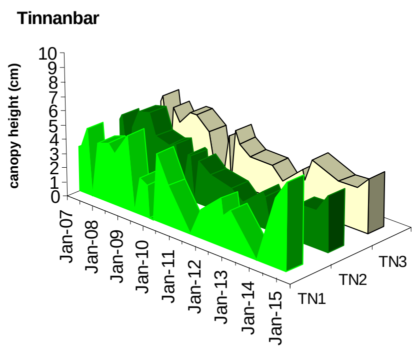


Figure 38. *Change in canopy height of dominant blady seagrass at the Tinnanbar intertidal meadows from 2001 to 2015.*

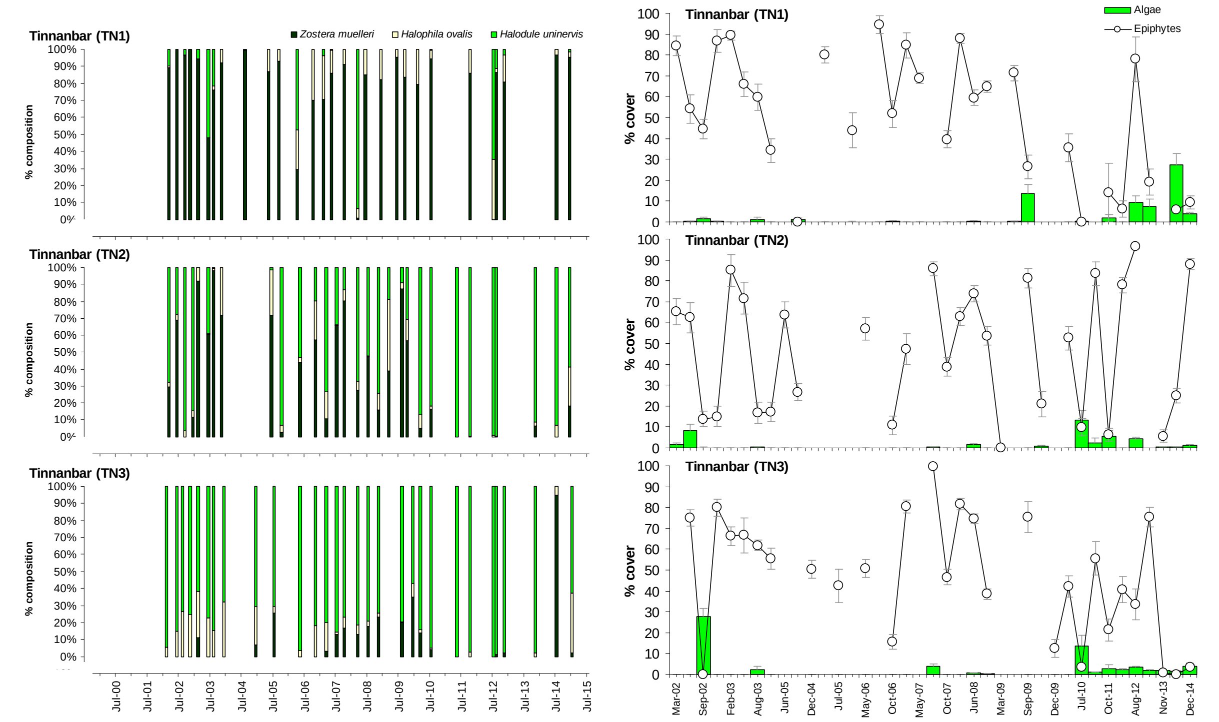


Figure 39 *Seagrass species composition (left), percentage cover of macroalgae and percentage of seagrass leaf surface covered by epiphytes (right) at each monitoring site at Tinnanbar from 2001-2014.*

Tootoowah Creek

Monitoring: suspended

Past watchers: Gordon Cottle, Robyn Bailey, Hanne Larson, Paul Bailey, Wendy Jones, Gary Nielsen, Steve Winderlich, Jerry Comans & Seagrass-Watch HQ

Location: Shallow anchorage on the western shores of Fraser Island.

Site codes: TC1 TC2

TC1 position: S25.69122 E152.98925 *(heading 70 degrees)*

TC2 position: S25.69295 E152.98495 *(heading 270 degrees)*

Best tides: <0.7m

Issues: boat traffic, land runoff

Comments: Dugong and turtle feeding grounds

Status (Jul02):

- Sites have not been examined since June 2002, when nearly the entire loss of seagrass at the location was reported.
- Insufficient data to describe long-term trends.
- Current condition unknown

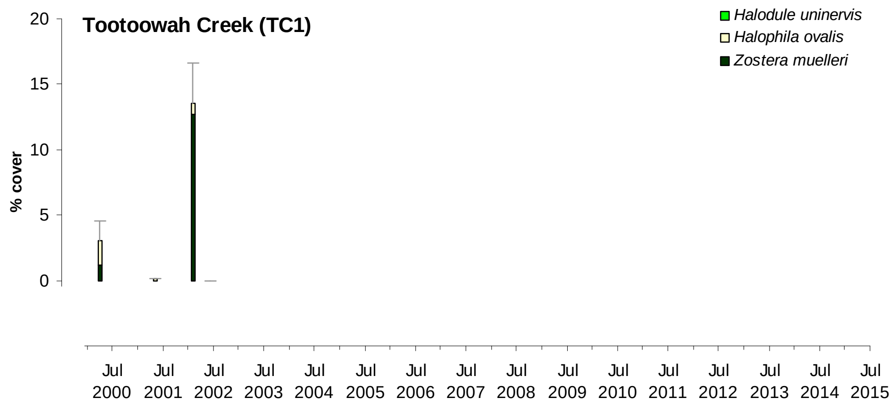


Figure 40. *Change in seagrass percentage cover (±SE) at the Tootoowah Creek intertidal meadows.*

Wanggoolba & Bennett's Creek

Monitoring: suspended
Past watchers: Michael Ford, Anne O'Dae, Bill Alston, John Lindberg, Peter Lusk & Seagrass-Watch HQ
Location: On the western shores of Fraser Island in the northern Great Sandy Strait. Wanggoolba Creek is one of the main access points (ferry) to the World Heritage listed Fraser Island
Site codes: WC1 WC2
WC1 position: S25.41610 E153.00559 *(heading 120 degrees)*
WC2 position: S25.44732 E152.98397 *(heading 105 degrees)*
Best tides: <0.8m
Issues: access dredging & spoil disposal, boat traffic
Comments: Dugong and turtle feeding grounds. Wanggoolba Creek is a declared Fish Habitat Areas (FHA) to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend.
Status (Jun03):

- sites have not been monitored since July 2003
- seagrass abundance recovered significantly after it was lost in February 1999, the result of a major flood.
- canopy height continued to increase at the site in close correlation with seagrass abundance.
- algae cover is relatively insignificant at these sites.
- irregular epiphyte blooms occur at both sites from time to time.
- sediment grain size appears to be less muddy, with more sand present.
- seagrass species composition relatively stable over monitoring period.
- dugong feeding was absent until late 2001, coinciding with seagrass recovery. Feeding trails are regularly observed across the meadows.
- the high abundance of gastropods at Wanggoolba Creek may be due to high amounts of mud and organic detrital matter in the sediments. Polychaete worms and mud whelks (a type of gastropod) were abundant at Wanggoolba Creek. Both animals are detrital feeders and competition for available detrital matter may explain the dominance of one over the other. The occurrence of polychaete worms at sites low in seagrass abundance suggests that they are likely to survive on low amounts of food relative to the larger gastropods. They are possible indicators of low seagrass abundance.

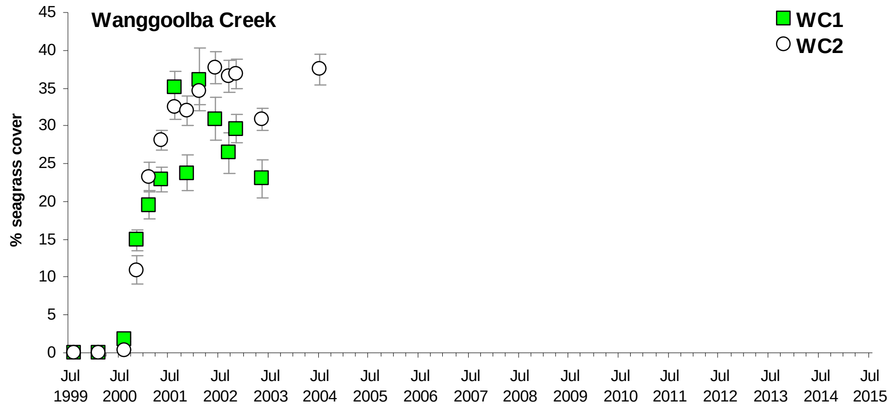


Figure 41. *Change in seagrass percentage cover (±SE) at the Wanggoolba & Bennett's Creek intertidal meadows.*

For more information, visit http://www.seagrasswatch.org/Gladstone.html, http://www.seagrasswatch.org/hervey_bay.html and http://www.seagrasswatch.org/GreatSandyStrait.html

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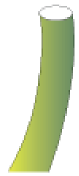
A guide to the identification of seagrasses in the Burnett Mary NRM region

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

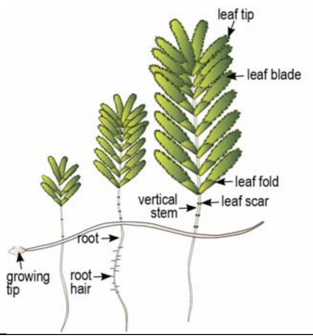
Ruppia maritima

- leaves fine and thread-like,
- leaf tip pointed, sometimes serrated
- leaves up to 15cm long
- rhizome fragile
- inflorescence on a long stalk, sometimes spiralled

Leaves oval to oblong

oval to oblong

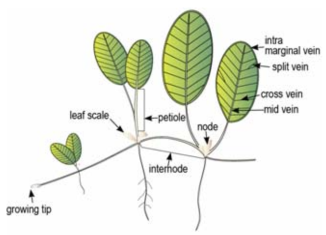
obvious vertical stem with more than 2 leaves



Halophila spinulosa

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

leaves with petioles, in pairs



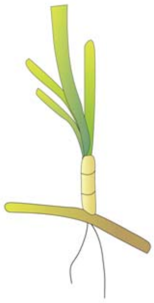
Halophila decipiens

- 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

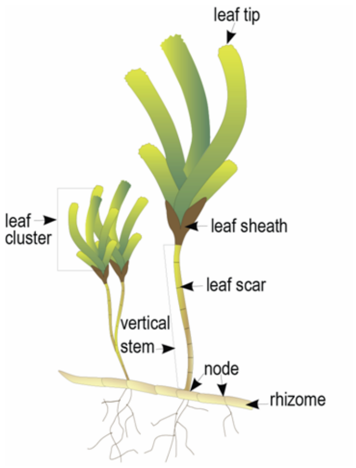
- cross veins 8 or more pairs
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

Leaves strap-like



straplike

Leaves can arise from vertical stem



Cymodocea 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

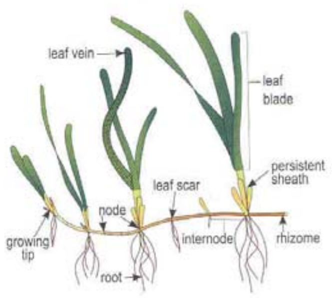
Halodule uninervis

- 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

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.

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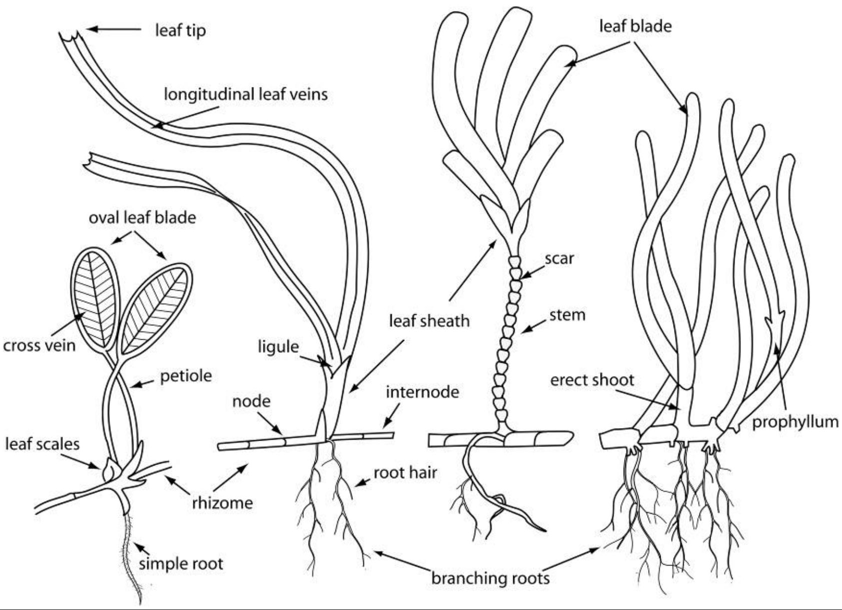
Parts of a seagrass plant



Leaf

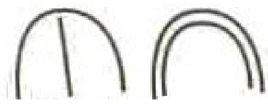
Tip

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

Veins

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

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



Edges

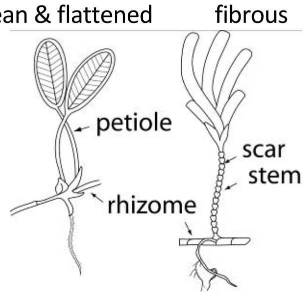
The edges of the leaf can be either serrated, smooth or inrolled

Sheath

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

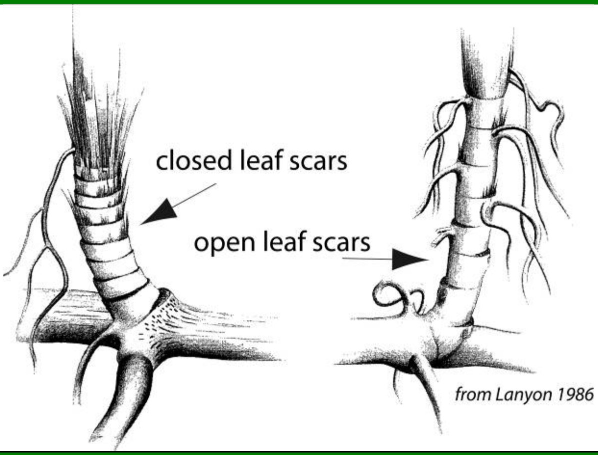
Attachment

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



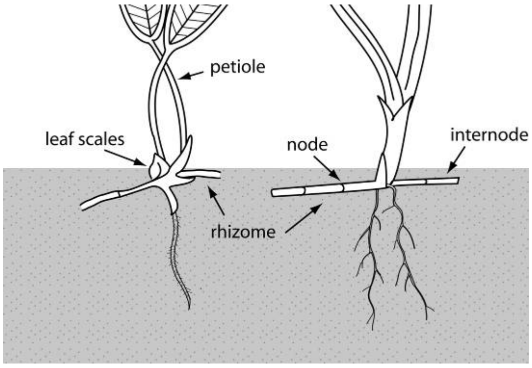
Stem

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



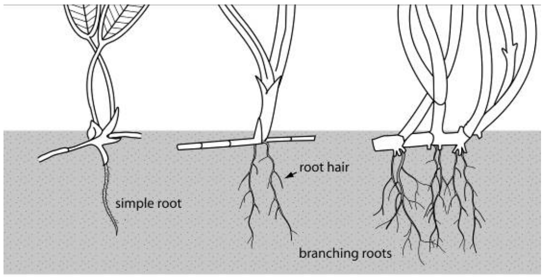
Rhizome

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 it's genesis in March 1998 in Australia, Seagrass-Watch has now expanded internationally to more than 26 countries. Monitoring is currently occurring at over 350 sites. To learn more about the program, visit www.seagrasswatch.org .

Seagrass-Watch aims to raise awareness on the condition and trend of nearshore seagrass ecosystems and provide an early warning of major coastal environment changes. Participants of Seagrass-Watch are generally volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with 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.

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 – preferably the next day and unknown to volunteers). Any discrepancy in these duplicates is used to identify and subsequently mitigate bias. For the most part, uncertainties in percentage cover or species identification are mitigated in the field via direct communication (as at least one experienced/certified observer is always present), or the collection of voucher specimens (to be checked under microscope and pressed in herbarium) and the use of a digital camera to record images (protocol requires at least 27% of quadrats are photographed) for later identification and discussion.

Seagrass-Watch HQ has implemented a quality assurance management system to ensure that data collected is organised and stored and able to be used easily. All data (datasheets and photographs) received are entered onto a relational database on a secure server. Receipt of all original data hardcopies is documented and filed within the James Cook University Management System, a formally organised and secure system. Seagrass-Watch HQ operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for reporting purposes. Access to the IT system and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

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

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

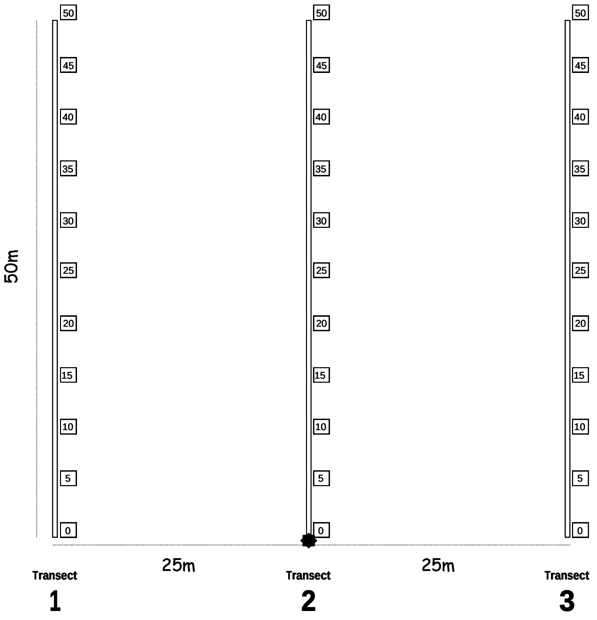
THE GOALS OF THE PROGRAM ARE:

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

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

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

Pre-monitoring preparation

Make a Timetable

Create a timetable of times of departure and arrival back, and what the objective of the day is and what is to be achieved on the day. Give a copy of this to all 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*
- ❑ *Magnifying glass*
- ❑ *3x Monitoring datasheets*
- ❑ *Clipboard, pencils & 30 cm ruler*
- ❑ *Camera & film*
- ❑ *Quadrat photo labeller*
- ❑ *Percent cover standard sheet*
- ❑ *Seagrass identification sheets*

Each sampling event

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

Step 1. Take a Photograph of the quadrat

- Photographs are 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).

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

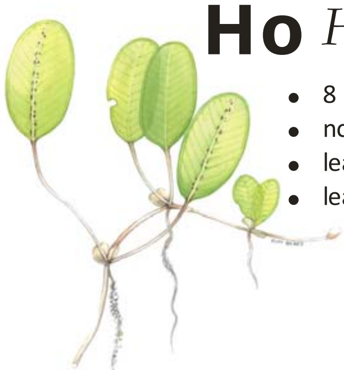
- The voucher specimen should be pressed as soon as possible after collection. Do not refrigerate longer than 2 days.
- Allow to dry the press in a dry/warm/dark place for a minimum of two weeks. For best results, replace the newspaper after 2-3 days.

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*

- small oval leaf, slightly pointed
- 6-8 cross veins
- leaf hairs on both sides
- leaf 10-25mm long
- found at subtidal depths

Hs *Halophila spinulosa*

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

Cs *Cymodocea serrulata*

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

Hu *Halodule uninervis*

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

Hp *Halodule pinifolia*

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

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

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

SEAGRASS-WATCH MONITORING

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

Seagrass-Watch

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

START of transect (GPS reading)

Latitude: .... ° .... ' ...... **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)

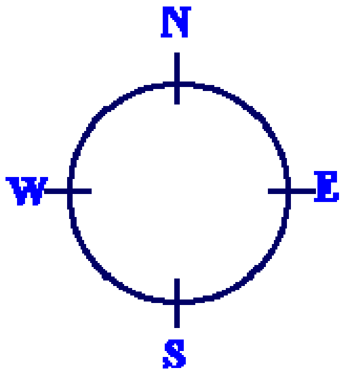
Latitude: .... ° .... ' ...... **Longitude:** .... ° .... ' ......

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

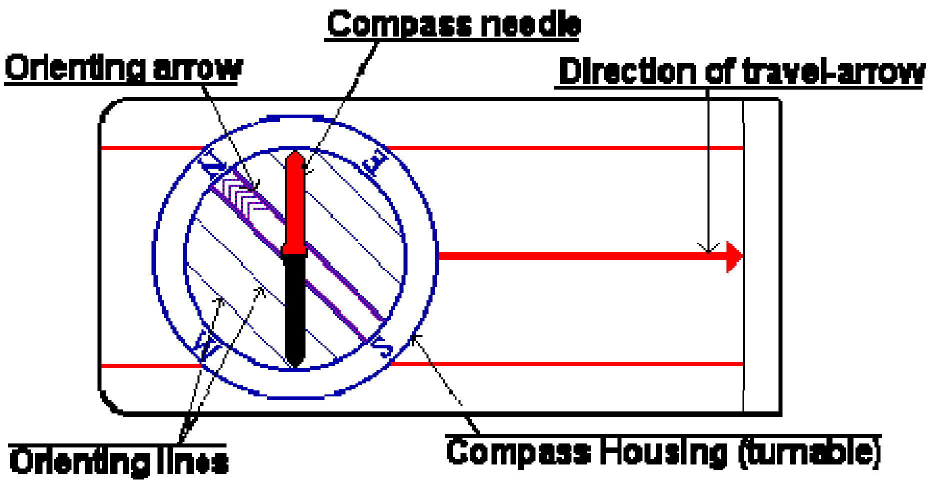
How to use a compass

Modified from Kjetil Kjernsmo (http://www.learn-orienteering.org/old/lesson1.html)

The most important thing you first need to learn before using a compass are the directions **N**orth, **S**outh, **E**ast and **W**est. Look at the figure below and learn how they are. **N**orth is the most important. *Remember the sun rises in the east and sets in the west.*



A type of compass often used in Seagrass-Watch is an orienteering compass. It has a large rectangular base-plate (often of clear rigid plastic), on which is a large red travel arrow. Attached to the base-plate is a turnable dial.

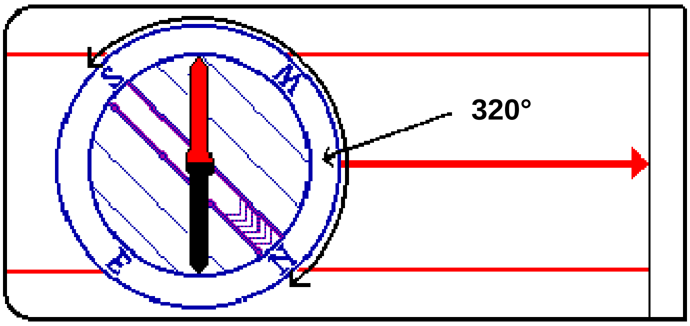


The turnable dial on the compass is called the *Compass housing*. On the edge of the compass housing is a scale from 0 to 360. These are the degrees or the *azimuth*. Also on the housing are the letters N, S, W and E for North, South, West and East.

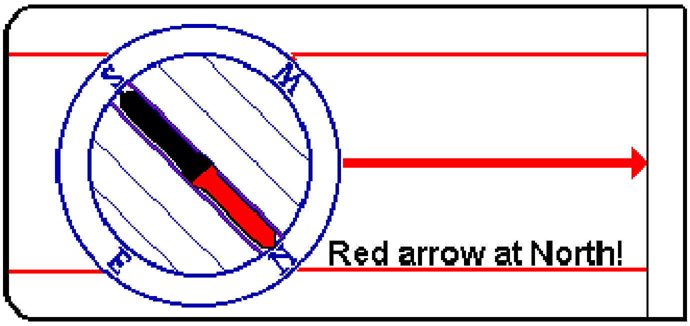
Within the compass housing is a red and black arrow, called the *compass needle (on some compasses it might be red and white)*. T**he red part of the needle always points towards the earth's magnetic north pole.**

To find a direction using the compass, you first turn the compass housing until the direction you desire comes exactly in line with the travel arrow, then holding the compass flat, you then turn the whole compass until the compass needle is aligned within the orienting arrow and the red end of the needle points to **N** (north).

For example, if you have arrived at your site and want to lay out transect 2 at bearing *(compass heading)* of 320 degrees, you first turn the compass housing so that 320 on the housing comes exactly in line with where the large *direction of travel-arrow* meets the housing.



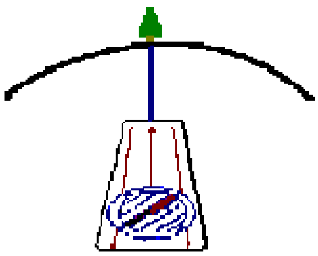
Hold the compass flat in your hand so that the compass needle can turn freely. Then turn yourself, your hand, the entire compass *(make sure the compass housing doesn't turn),* until the compass needle is aligned with the orienting arrow lines inside the compass housing.



It is *extremely* important that the red (**N**orth) part of the compass needle points to **N**orth in the compass housing. If the red points to the **S**outh, you would walk off in the exact opposite direction of what you want!

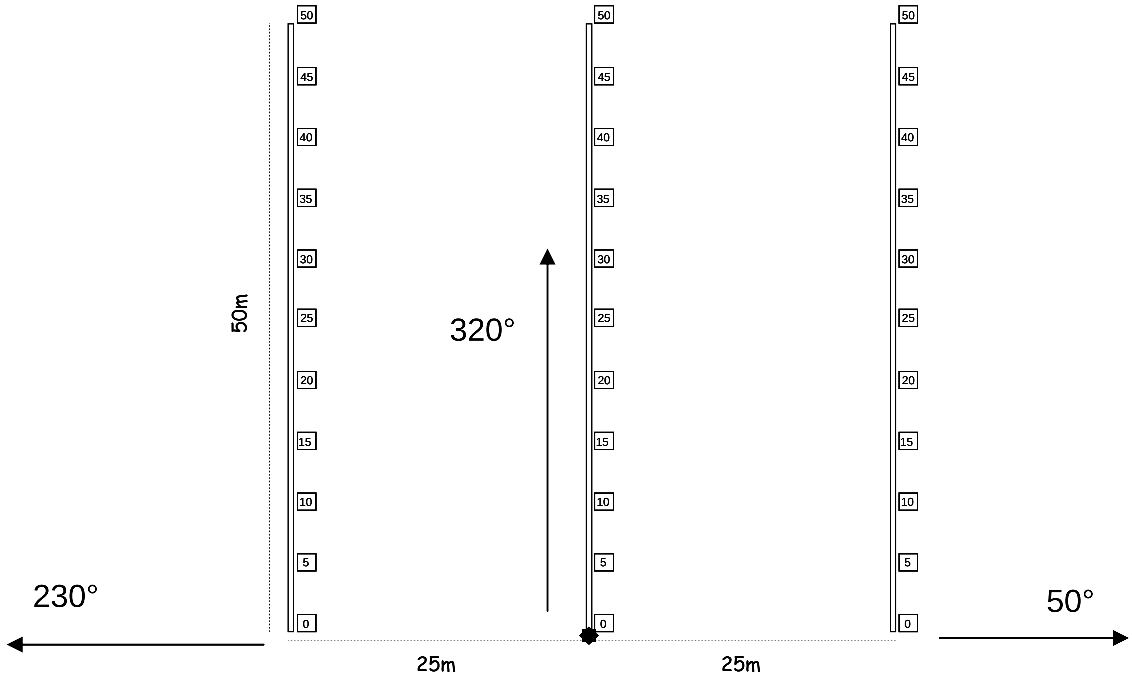
A problem can occur if there is a local magnetic attraction. For example, if you are carrying something of iron, it might disturb the arrow. Even a staple in your book might be a problem. Make sure there is nothing of the sort around. There is a possibility for magnetic attractions in the soil as well, "magnetic deviation", but they are rarely seen.

If the needle is directly aligned, you should now be facing 320 degrees. When you are sure you've got it right, fix your eye on some special feature on the horizon (e.g., a rock or coral) with the travel arrow and now head for it. If you are directing someone, keep them informed and line them up with hand signals when they reach the 50m mark.



When standing at the start of transect 2 and you want to find the start of transect 1, you need to change your compass bearing by subtracting 90 from the transect bearing (e.g., in the previous example, 320-90= 230). Measure 25m from the start of transect 2, heading 230 degrees, and put in the peg. This is the start of transect 1. Lay out transect 1 using the same procedure as you just completed fro transect 2 (heading 320).

To locate the start of transect 3, you need to change your compass bearing by adding 90 from the transect bearing (e.g., in the previous example, 320+90 = 410, but as only 360 in a compass your bearing will be 50). Measure 25m from the start of transect 2, heading 50 degrees, and put in the peg. This is the start of transect 3. Lay out transect 3 using the same procedure as you just completed for both transects 1 and 2 (heading 320).



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 loose their water content, besides they could be damaged if the paper stays wet for a few days. When changing the paper you must keep the specimens intact and ensure the label travels with the specimen. The minimum time required for complete dying ranges from two to four days or more. Once a specimen has become dry and stiff, it can be mounted and placed into the herbarium.

Mounting

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

There are different ways to mount the specimens to the herbarium sheets, such as strapping, gluing, 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 then 600 dpi and includes the specimen and label. Scanned images can be sent to hq@seagrasswatch.org and will be lodged in the Seagrass-Watch Virtual Herbarium http://www.seagrasswatch.org/herbarium.html.

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

Understanding sediment

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

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

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

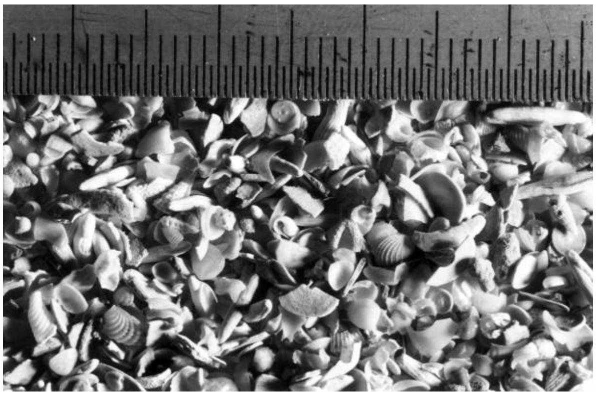
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

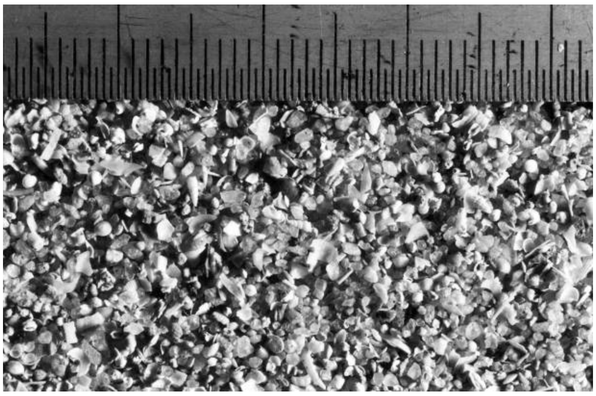
The sediment ***Primary Descriptors*** are written down from left to right in decreasing order of abundance: e.g. Mud/Sand is mud with sand, where mud is determined as the dominant constituent (by volume).

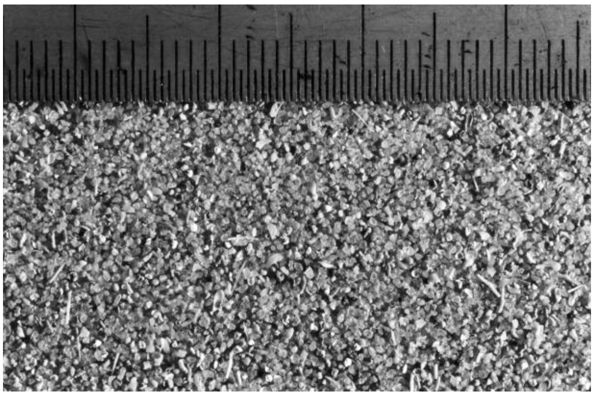
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

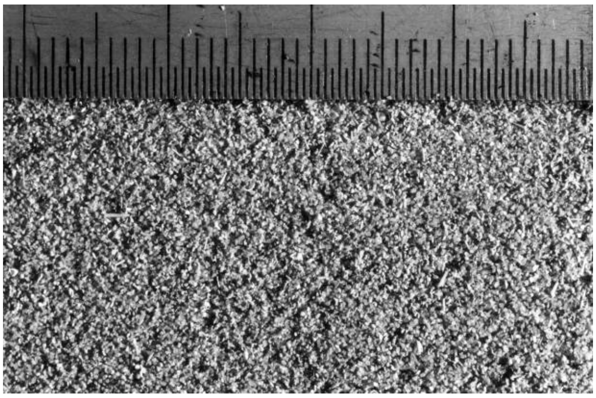
Sediment type ***Modifiers*** are also commonly used, however these are recorded in the comments section. Modifiers include: coral, shell grit, forams, diatoms, *etc*.

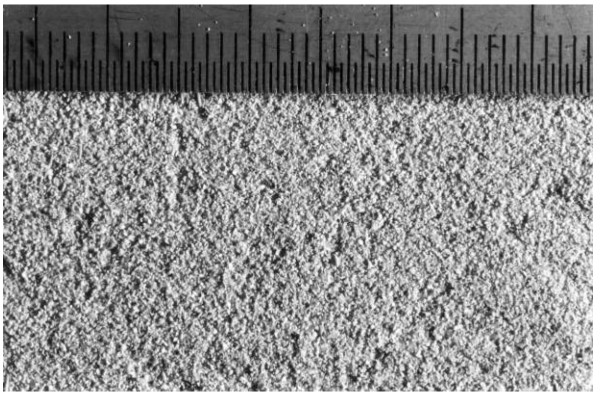
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments McKenzie, 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf.

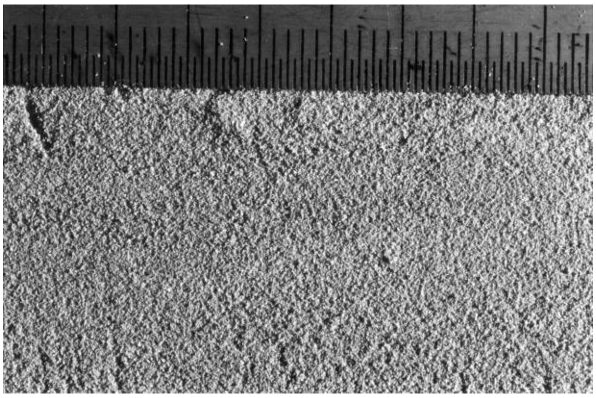

gravel (>2mm)


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 thousand of years to protect and manage places and species that are of importance to their societies.

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

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

1. Important fish habitat is known and mapped
2. Habitat monitoring is occurring
3. Adjacent catchment/watershed impacts and other threats are managed
4. Some level of public goodwill/support is present
5. Legal powers exist hat are robust to challenge
6. There is effective enforcement and punishment if damage occurs

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

Consequently a combination of modern "western" science and indigenous knowledge should be brought together within a co-management framework for the successful management of these resources Johannes, 2002; 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

Seagrass Adventures Interactive website designed by students from Bentley Park College in Cairns (Australia). Website includes games, puzzles and quizzes for students to learn about seagrass and their importance. crcreef.jcu.edu.au/seagrass/

World Seagrass Association A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses. wsa.seagrassonline.org

Seagrass Outreach Partnership Excellent website on seagrass of Florida. Provides some background information on seagrasses and has a great section with educational products and

Seagrass Activity Kit for schools. www.flseagrass.org

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

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

Integration and Application Network (IAN) A website by scientists to inspire, manage and produce timely syntheses and assessments on key environmental issues, with a special emphasis on Chesapeake Bay and its watershed. Includes lots of helpful communication products such as fact sheets, posters and a great image library. ian.umces.edu

Reef Base A global database, information system and resource on coral reefs and coastal environments. Also extensive image library and online Geographic Information System (ReefGIS) which allows you to display coral reef and seagrass related data on interactive maps. www.reefbase.org

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

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