Seagrass-Watch

Proceedings of a workshop for monitoring seagrass in Butchulla Sea Country

The Tree House - Urangan Community Wellness Centre, Hervey Bay

11-13 March 2024

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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): shorebird feeding in *Nanozostera muelleri* meadow on intertidal banks at Shelley Beach, Hervey Bay (May08, by Len McKenzie); *Nanozostera muelleri* meadow at Burrum Heads (May08, by Rudi Yoshida); sea anemone in *Nanozostera muelleri* meadow at Inskip Point, Great Sandy Strait (Aug05, by Len McKenzie).

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The Tree House - Urangan Community Wellness Centre

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Burrum Heads field exercise site, located 39km from The Tree House (approx 40min drive).

We acknowledge Australia's First Nations People as the first original inhabitants and traditional custodians of this continent, and acknowledge the Butchulla people, the Traditional Custodians and Owners of the land on which we conduct this workshop. We pay our respects to ancestors and elders, past, present and emerging.

Overview

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is for experienced participants who plan to lead a seagrass monitoring event or conduct seagrass extension activities in Butchulla Sea Country. As part of the Level 1 workshop we will:

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

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

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AUSTRALIA
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Photo: Fergus Kennedy

Workshop trainers

Len McKenzie

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

Current Projects

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

Rudi Yoshida

Rudi is the Data Manager of Seagrass-Watch and a Researcher at James Cook University. Rudi has over 20 years' experience in seagrass related research and monitoring. He is also a core member of Seagrass-Watch HQ, and ensures data submitted is managed and QA/QC protocols applied. He is also responsible for maintenance of the Seagrass-Watch website and assists with training workshops.

Current Projects

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

Agenda - Level 1 (basic)

Monday 11th March 2024

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

Tuesday 12th March 2024

0930 - 0945 *(15min)*	recap day 1
0945 - 1100 *(75min)*	Seagrass-Watch: how to sample
1100 - 1130 *(30min)*	*Break*
1130 - 1245 *(75min)*	Seagrass-Watch: how to sample 2*
1245 - 1300 *(15min)*	Risk assessment
1300 - 1430 *(90min)*	*Lunch & relocate to field site*
1430 - 1645 *(2hrs 15min)*	**Field exercise:** Seagrass-Watch monitoring (Low tide 1634 0.50)
1645 - 1700 *(15min)*	Wrap up for day

Wednesday 13th March 2024

0830-845 *(15min)*	recap day 2
0845-945 *(60min)*	Seagrass threats*
0945-1000 *(15min)*	Seagrass-Watch: QAQC
1000-1015 *(30min)*	*Break*
1015-1045 *(30min)*	Seagrass-Watch: QAQC *continued*
1045-1145 *(45min)*	Seagrass-Watch: how data is used*
1145-1200 *(15min)*	Discussion & **Workshop close**

Assessment requirements

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

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

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

Training workshop (6 units)

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

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

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

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

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

3 post workshop monitoring events (3 units)

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

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

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

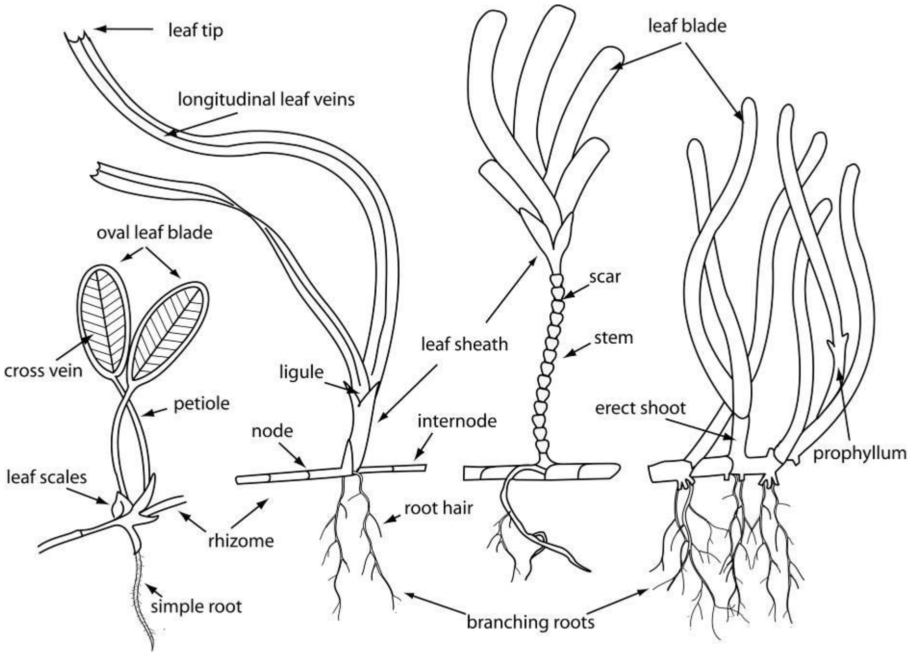
- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within acceptable limits
- epiphyte cover estimates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

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

Background

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

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), rhizome, roots (buried in the substrate), and reproductive parts such as flowers and fruits. Algae do not have veins in their leaves nor do they possess roots (anchoring to the surface of the substrate by a holdfast) or produce flowers or seeds.

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

These marine plants are called “seagrass” because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover), a fern, a long spaghetti/noodle form and a ribbon. Species that have a paddle or fern shaped leaf are of the genera *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea, Oceana, Thalassia, Thalassodendron, Halodule* and *Nanozostera*. 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 underside of leaves) but have thin cuticle to allow gas and nutrient exchange. They also possess large thin-walled aerenchyma (air channels). Aerenchyma are specialised tissue having a regular arrangement of air spaces, called lacunae, that both provide buoyancy to the leaves and facilitate gas exchange throughout the plant. Leaves have a very thin cuticle, which allows gas and some nutrient

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

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 (in the sediments), 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.

Seagrass requirements for growth

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

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

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

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

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

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

Seagrasses are more closely related to lilies

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

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

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea water

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

Light availability is the most important factor determining seagrass growth

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

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

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

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, Oceana 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 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 clay 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* spp. are better suited to mobile sediments than larger species. The biogeochemical characteristics of sediment that can affect the nutrient content/binding capacity, organic content and oxygen levels. Seagrasses are unable to grow in sediments of high organic content.

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 and dispersal of vegetative material and seeds depends on currents. Without current flows, vegetative material and seeds will not be transported to new areas, and species will not be exchanged between meadows. Factors such as the photosynthetic rate of seagrasses depend on the thickness of the diffusive boundary layer that is determined by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

Tidal currents are important for pollination, dispersal 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 sheltered bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 metres. Most species are found in clear shallow inshore areas between mean sea-level and 25 metres depth.

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

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

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

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

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

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

How are seagrasses important to the marine ecosystem?

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

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

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

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

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

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

Seagrass plants form small patches that develop into large meadows

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

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

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

Seagrasses also contribute to the productivity of ecosystems via the detrital food pathway plankton. Microorganisms provide food for the juveniles of many species of marine animals such as fish, crabs, prawns and molluscs.

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

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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

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

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

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

The value of seagrasses

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

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

What causes seagrass areas to change?

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

Seagrasses can change due to both natural and human impacts

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

What threatens seagrass?

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

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

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

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

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

Boating and fishing activities can physically impact or destroy seagrasses. Boat anchors and their chains can dig into seagrass. Propellers can cut into seagrass meadows and 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 and clams can also physically damage seagrasses and some introduced marine pests and pathogens also have the potential to damage seagrass meadows.

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

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

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

Coastal development can have a major impact on seagrass meadows

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

Seagrass in Butchulla Sea Country

Updated from [1]

The Butchulla people are the Custodians, Traditional Owners and the Common Law Holder of K'gari (formerly Fraser Island) and surrounding areas. Butchulla sea country covers ~865 km^2 and includes the Great Sandy Strait (excluding the very southern reaches of Tin Can Inlet) and the southern nearshore area of Hervey Bay (Burrum Heads to Urangan) to the 2m bathymetric contour.

Seagrass meadows in Butchulla Sea Country play a vital role in supporting coastal marine communities and in maintaining diverse flora and fauna. The meadows support dugong (*Dugong dugon*) and green sea turtles (*Chelonia mydas*), and economically valuable fish and prawns populations[2-4]. Seagrasses are critical to the survival of these animals. The meadows also provide a range of other important ecological goods and benefits. Seagrass produce natural biocides and improve water quality by controlling pathogenic bacteria to the benefit of humans, fishes, and marine invertebrates [5]. Nutrient cycling in seagrass meadows makes them one of the most economically valuable ecosystems in the world and the retention of carbon within their sediments contributes significantly to Blue Carbon sequestration [6-9]. The ecosystem contributions provided by seagrass therefore makes them a high conservation priority [10, 11].

Nine species of seagrass are reported in the waters of the Great Sandy Marine Park and within Butchulla sea country: *Halodule uninervis* (Forssk.) Asch.; *Halodule pinifolia* (Miki) Hartog; *Halophila spinulosa* (R.Brown) Ascherson, 1875; *Halophila decipiens* Ostenfeld, 1902; *Halophila ovalis* (R.Brown) Hooker f., 1858; *Nanozostera muelleri* (Irmisch ex Ascherson) Tomlinson & Posluszny, 2001 (Syn.: *Zostera muelleri* subsp. *capricorni; Zostera capricorni)*; *Oceana serrulata* (R.Brown) Byng & Christenhusz 2018 (Syn.: *Cymodocea serrulata* (R.Br.) Asch. & Magnus); *Ruppia maritima* Linnaeus, 1753; *Syringodium isoetifolium* (Ascherson) Dandy, 1939 [12]. The highest species diversity of seagrass in Butchulla sea country is found in the southern Great Sandy Strait. Most species in the region are classified as colonising or opportunistic, capable of rapid recovery from losses due to fast asexual growth rates and capacity for generating large seed banks[13]. Only seagrass of the genus *Halophila* are found in waters deeper than 15m. No seagrass species are listed as Endangered, Vulnerable, Near Threatened or Data Deficient under the IUCN Red List criteria[14].

Seagrass meadows in the Great Sandy Strait Marine Park are one of the largest single areas of seagrass resources on the eastern Australian seaboard. The seagrass temporal composite extent (generated by overlaying all seagrass observations generated over time to produce a single composite layer) within Butchulla Sea Country is ~129 km^2; which is approximately 5% of the temporal composite extent for the Great Sandy Marine Park (2,574 km^2).

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 [15]. Seagrass distribution was estimated to be a least 1,026 km^2 [2] 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. The large area in the north-east of the bay was not surveyed [2].

Approximately 1,000 km^2 of seagrass was lost in Hervey Bay after two major floods and a cyclone, within a 3 week period in 1992 [16]. The deeper water seagrasses died, likely 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 subtidal and intertidal seagrasses.

Recovery of subtidal (at depths >5m) seagrasses began within two years of the initial loss [16], but recovery of intertidal seagrasses was much slower and only appeared evident after 4-5 years (J. Comans, HBDSMP, Pers Comm). The seagrasses appeared to be fully recovered by December 1998 [17].

In December 1998 a detailed dive and remote camera survey of the region estimated 2,307 ±279 km^2 of seagrass within Hervey Bay [17]. 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 *Nanostera muelleri*, or *Halodule uninervis*, with *H. ovalis*. A narrow intertidal band of sparse (1-10% cover) *N. muelleri* 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 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 recorded by light meters at 4 locations 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 [17]. Shallow subtidal (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 [17].

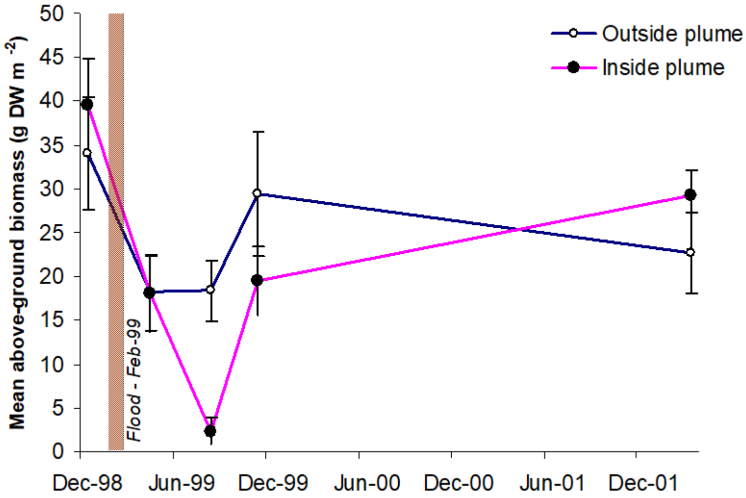


Figure 1. *Plot of above-ground seagrass biomass (g DW m^{-2}, all species pooled) from survey sites inside (Impact) and outside (Reference) the area impacted by the Mary River flood plume following flooding in Hervey Bay and the Great Sandy Strait in February 1999. Error bars represent 95% confidence 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 [18]. 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 *Nanozostera muelleri* [19].

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 [18].

Long term monitoring at Seagrass-Watch sites within Booral wetlands by trained 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 trends 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.

Post 2002, no mapping was conducted within Hervey Bay for two decades, however, long-term monitoring at intertidal and subtidal sentinel sites showed periods of loss and recovery associated with climatic events. For example, assessment of subtidal sentinel sites (10m to 23m depth) within Hervey Bay in February 2011 found seagrass cover had declined to below 4% across the bay. This was because above average rainfall in the December 2010 and January 2011 period, resulted in significantly higher discharges (floodwaters) from the Mary River than any other period in over the previous decade. Assessment of the subtidal sentinel sites in August 2011, found that seagrass had either fully or >50 % recovered.

In early 2022, three sizable flow events occurred in the Mary River; the first two resulting in significant flooding [20]. The first event coincided with the rain generated by Ex-Tropical Cyclone Seth where the Mary River peaked on the 9th January 2022 at 664,000 ML/day [20]. The second event peaked on the 28th February 2022 at 658,000 ML/day and the third event was much smaller, peaked on the 15th May 2022 at 202,000 ML/day [20]. In May 2022, mapping was conducted for the first time in two decades and reported the total area of seagrass was 744 ±212 km^2, approximately 68% lower than the 1998 extent [21]. Nine months later the seagrass extent in October/November 2022 had increased to 1,343 ±339 km^2, but remained ~40% lower than the 1998 distribution [21]. Seagrass meadows were located across a wider depth range in the October/November 2022 survey, especially in deep-water where seagrass occurred from 10.5 m to 29.6 m compared with 16.2 m to 25.6 m in May 2022 [21]. The increase in seagrass extent in October/November 2022 was due to the expansion of the deep-water meadow in the middle of the bay, which was dominated by *H. spinulosa* with *H. ovalis* and *H. decipiens.* A shallow subtidal *H. uninervis* meadow near Burrum Heads persisted after the floods, but changed little throughout 2022. A number of intertidal meadows composed almost exclusively of vey sparse, isolated patches of *Nanozostera muelleri* and *H. uninervis*, were mapped from Burrum Heads to Urangan in May 2022. The meadows increased in extent during 2022, but abundance remained low. Biannual monitoring of intertidal sites by Seagrass-Watch within variable coastal seagrass meadows showed considerable declines in cover at Burrum Heads following the 2022 flood events, however, cover at Urangan had been at low levels since late 2017 and had shown signs of recovery in 2021 before a further reduction in cover following the floods.

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 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 [22]. 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 points, were used to map an area of seagrass covering >4,800 hectares (~5,232 hectares digitised from Fig 2 in [22]). 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 in 1990 [23] estimated that the Great Sandy Strait had approximately 12,300 hectares of seagrass covering extensive intertidal and subtidal areas. This estimate was based on low confidence remote sensing analysis and may have overestimated the intertidal (confused with algae) and underestimated the subtidal (high turbidity limiting visibility) seagrass habitat.

In October-November 1992 an aerial photographic survey of the Great Sandy Strait was conducted and significant decreases were reported in Tin Can Inlet [24]. Increases in seagrass distribution, however, were reported in the northern section of the Strait, between River Heads and Urangan, and Black Creek and Moon Point. Seagrass community changes were also reported, especially in the dense monospecific *Oceana serrulata* meadow off Kauri Creek, which changed to sparse *O. serrulata* subtidally and *N. muelleri* intertidally.

In 1993, 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 [25]. 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 [26].

In December 1998 a detailed dive survey of the Great Sandy Strait was conducted which estimated 5,554 ±1,446 ha of seagrass meadows [17]. Seven species of seagrass were present in the Great Sandy Strait (*Nanozostera muelleri, Halodule uninervis, Halophila ovalis, Halophila decipiens, Halophila spinulosa, Oceana serrulata* and *Syringodium isoetifolium*). Most of the meadows throughout the Great Sandy Strait were intertidal on large mud- and sand-banks, and located 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 *N. muelleri*. 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 Great Sandy Strait in February 1999 caused the complete loss of seagrass meadows in the northern Strait and loss of some other regions in the central and southern Strait [17]. In February 2002 the total area of seagrass throughout the Great Sandy Strait had recovered to 7,007 ±1,945 hectares (Figure 2) [18, 27]. This was greater than the pre-flood survey conducted in December 1998.

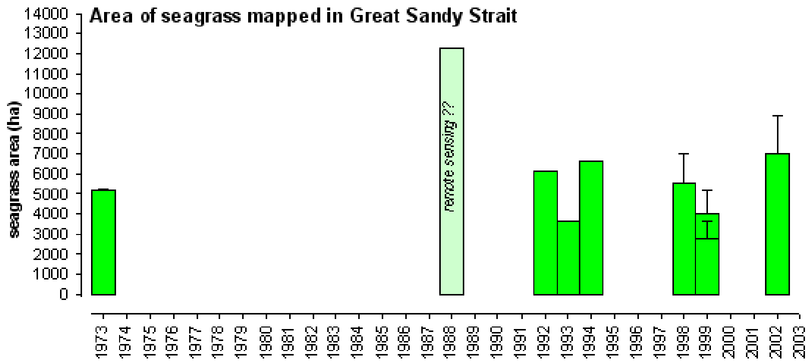


Figure 2. *Mean area ±R (estimate of reliability) for seagrass mapped in the Great Sandy Strait pre- and post-flood.*

In February 2002, approximately 92% of the area of seagrass meadows in the Great Sandy Strait was dominated by *Nanozostera muelleri*. 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 [28]. Most meadows appeared to be of similar pre-flood abundances with biomasses approximately the same or marginally lower.

After 2002, similar to Hervey Bay, long-term monitoring at sentinel sites throughout the Great Sandy Strait continued over the next two decades, however, no mapping was conducted until 2022 following the Mary River flooding events. The total area of intertidal seagrass mapped by helicopter in the Great Sandy Strait in May 2022 (12.1 ±4.1 km^2) was less than a quarter of that mapped in December 1998 and only 17.3% of the area mapped in 2002 [21]. Seagrass meadows present in May 2022 were of similar species assemblages to those mapped in 2002, except at Moon Point where the meadow was dominated by *H. uninervis* rather than *Nanozostera muelleri* [21]. Seagrass abundance in May 2022 was also extremely low (<1 %). *Oceana serrulata* remained absent from the southern Great Sandy Strait, and has not been observed since in December 1998 [28]. *Syringodium isoetifolium* was also absent in 2022.

Flood events in the Mary River can have devastating impacts on not only the extent and abundance of the regions seagrass meadows, but can have consequent impacts on the megafauna and a wide range of other biota.

Cleguer *et al*. [29] conducted the most recent survey of dugong populations in the Great Sandy region in November 2022, as part of their survey of the Queensland coast south from Mission Beach. The dugong population size in the Great Sandy Marine Park was estimated to be 1,533 ±634 animals [29]. This estimate was similar to 2005 (1,388 ±323) and 2011 (1,438 ±438), but much lower than the 2016 estimate (2,055 ±382) [29]. There was also a marked change in the distribution of dugongs in region in 2022 compared with previous surveys. No dugongs were sighted in the Great Sandy Strait in 2022. There was a 3.7-fold decrease in the estimated number of dugongs present in the southern section of Hervey Bay and the estimated number of dugongs in the middle, deeper part of the bay increased from an estimated 610 ±272 in 2016 to 1,025 ±592 dugongs in 2022 [29]. Only nine mother-calf pairs were detected in the region during the 2022 survey. Overall, the dugong population density in 2022 was estimated at 0.094 ±0.03 individuals per square kilometre; declining at an estimated -5.7% per year since 2005.

SEAGRASS-WATCH IN BUTCHULLA SEA COUNTRY

To provide an early warning of change, long-term monitoring has been established at a number of locations across the Great Sandy Marine Park within Butchulla Sea Country as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org) [30]. 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, 44 sites (16 locations) have been established across the Great Sandy Marine Park; 35 within Butchulla Sea Country. Sampling frequency varies between locations and sites, and 10 sites are no longer monitored (i.e. archived). Monitoring a network of permanent sites in Butchulla Sea Country 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 Butchulla Sea Country.

Regional report card - October 2023

- Seagrass meadows throughout Butchulla Sea Country support significant fisheries, turtle and dugong populations
- The abundance within seagrass meadows in Butchulla Sea Country was classified as **poor** in 2023.
- Seagrass abundance in Butchulla Sea Country has fluctuated between years, however, 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 [31], seagrass state was determined for each monitoring event at each site, relative to the previous sampling event, and allocated as very poor, poor, fair or good state.

Figure 3. *Status of seagrass abundance in Butchulla Sea Country relative to the seagrass guidelines since monitoring was established in 1999. Each block represents a 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 Butchulla Sea Country has been in declining since 2017, reaching a very poor state in 2022, before recovering slightly in 2023 back to a poor state. and was in a poor state. Although state has fluctuated over the long-term, there is no apparent overall trend.

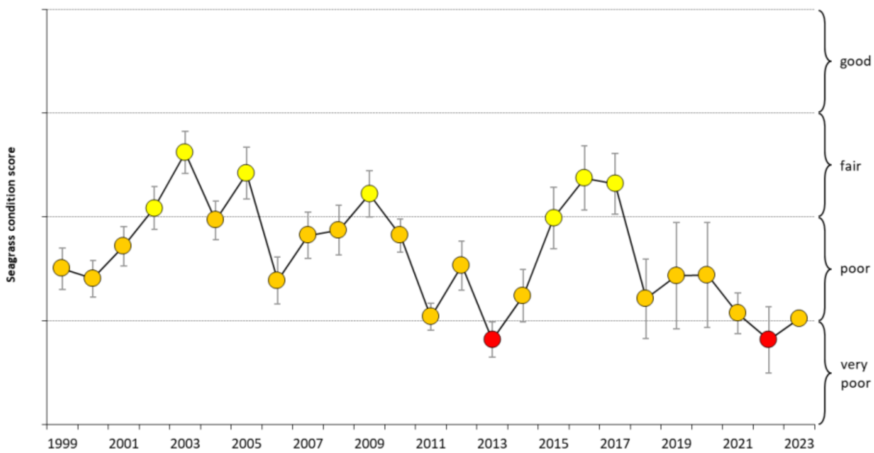


Figure 4. *Summary of annual average seagrass abundance/condition status (±standard error) in Butchulla Sea Country relative to the seagrass guidelines since monitoring was established in 1999. The number and frequency of sites sampled varies between years.*

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

Burrum Heads

Monitoring: ongoing, *biannual*
Location: Mouth of the Burrum River on the western shore of Hervey Bay
Site codes: BH1, BH2, BH3
Issues: urban development, stormwater & land runoff, boat traffic
Comments: dugong and turtle feeding grounds
Status (Oct23):

- seagrass abundance at Burrum Heads is currently in a **fair state**
- Seagrass cover increased at all sites from 2002, reaching peaks between 2003 and 2007, after which cover has fluctuated; decreasing and subsequently increasing on an infrequent basis in relation to climatic events.
- Seagrass canopy height (leaf length) has fluctuated in a similar trend to abundance, however it also 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 *Nanozostera muelleri* is more common at BH2, however, the site has not been assessed since 2016.
- 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).

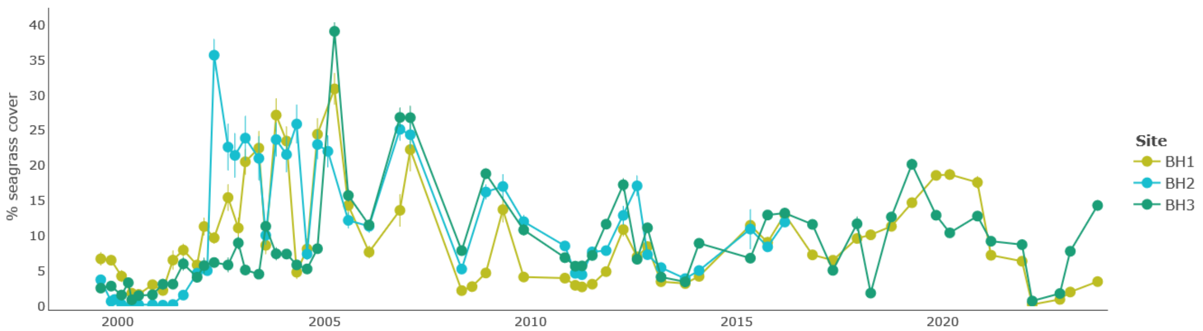


Figure 5. *Change in seagrass percentage cover (±SE) at the Burrum Heads intertidal meadows.*

Toogoom

Monitoring: archived
Location: On the western coastline of Hervey Bay
Site codes: TG1, TG2, TG3
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. Its current state is unknown.
- 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.

- The dominant seagrass species included *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. Species composition varied over the monitoring period with losses of both *Nanozostera muelleri* and *H. uninervis* due to sediment burial.
- algae was generally low with occasional episodic blooms
- 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.

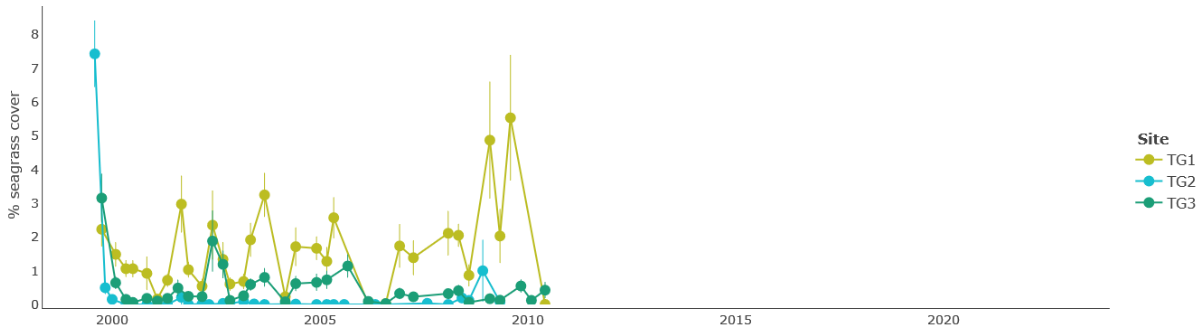


Figure 6. *Change in seagrass percentage cover (±SE) at the Toogoom intertidal meadows.*

Dundowran

Monitoring: ongoing, *quarterly*
Location: On the western coastline of Hervey Bay
Site codes: DD1, DD2, DD3
Issues: urban development, stormwater & land runoff
Comments: dugong and turtle feeding grounds
Status (Oct23):

- seagrass abundance at Dundowran has remained in a **poor to very poor state** since 2008 (monitoring at DD1 has been ad hoc since 2010)
- seagrass cover has remained low, with significant increases (followed by declines) in late 2007, late 2011 and late 2015. Fluctuations appear mainly the result of mobile sediments.
- Meadows are predominately the opportunistic and colonising species *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*, respectively, with the infrequent appearance of *Nanozostera muelleri* from time to time at DD2 and DD3.
- Algae and epiphytes show occasional episodic blooms – generally in middle of the year.
- 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).

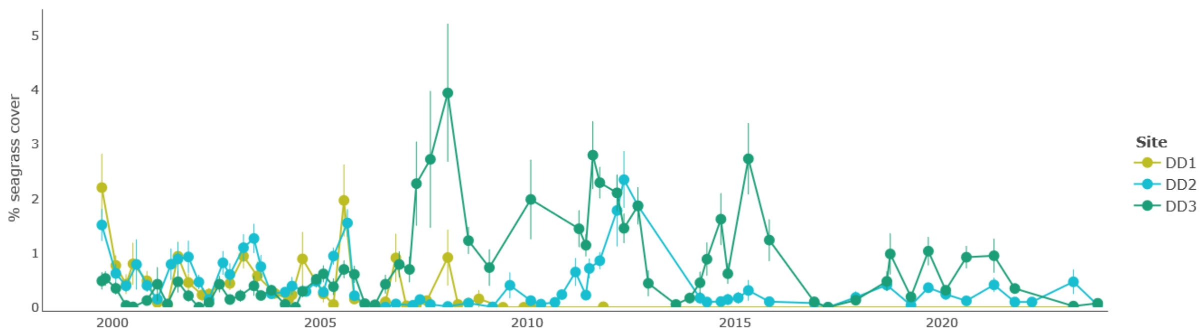


Figure 7. *Change in seagrass percentage cover (±SE) across the Dundowran intertidal meadows.*

Urangan

Monitoring: ongoing, *biannual*
Location: immediately south of the marina and north of the Mary River mouth
Site codes: UG1, UG2
Issues: urban development, worm digging, sewerage treatment, stormwater, marina development & catchment/land runoff
Comments: dugong and turtle feeding grounds
Status (Oct23):

- 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 *Nanozostera muelleri* 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 gradually increased in abundance and extent. Seagrass abundance progressively declined from 2017, until it was completely lost in late 2022 following the flooding events early in the year. The onset of recovery occurred in early 2023.
- Canopy height has continued to fluctuate in close correlation with *Nanozostera muelleri* abundance.
- Percentage cover of macro-algae is generally low, although blooms occur at irregular intervals, including late 2023.
- Epiphyte cover on seagrass leaf blades at Urangan were high and variable over the years of monitoring, however has been persistent and gradually increasing since 2009, suggesting chronic elevated nutrients.
- Sediment grain size has changed relatively little over the monitoring period, however, following flood events, the presence of dispersive soils can persist for some time.
- Dugong grazing 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.

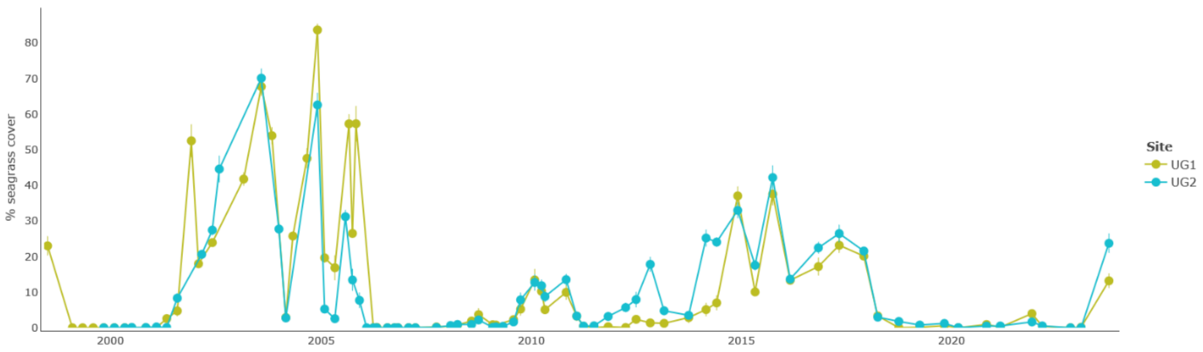


Figure 8. *Change in seagrass percentage cover (±SE) at the Urangan intertidal meadows.*

Booral

Monitoring: archived
Location: 2.5-6.5 km south of Urangan and mid-way to River Heads (the mouth of the Mary River)
Site codes: UG3, UG4
Issues: urban development, stormwater & land runoff
Comments: Dugong, turtle and shorebird feeding grounds
Status (Dec06):

- seagrass abundance at Booral was in a **poor state** when last assessed, however, current state is unknown.

- 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.

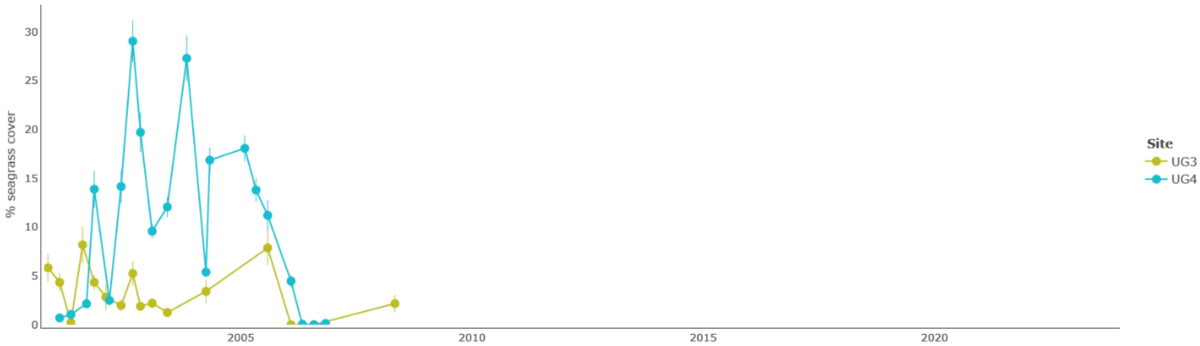


Figure 9. *Change in seagrass percentage cover (±SE) at the Boral intertidal meadows.*

Wanggoolba & Bennett's Creek

Monitoring: suspended
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
Issues: access dredging & spoil disposal, boat traffic
Comments: Dugong and turtle feeding grounds. Wanggoolba Creek is a declared Fish Habitat Area (FHA) to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend.
Status (Jul04):

- sites have not been monitored since July 2004
- 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, and 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 grazing was absent until late 2001, coinciding with seagrass recovery. Grazing trails are regularly observed across the meadows.

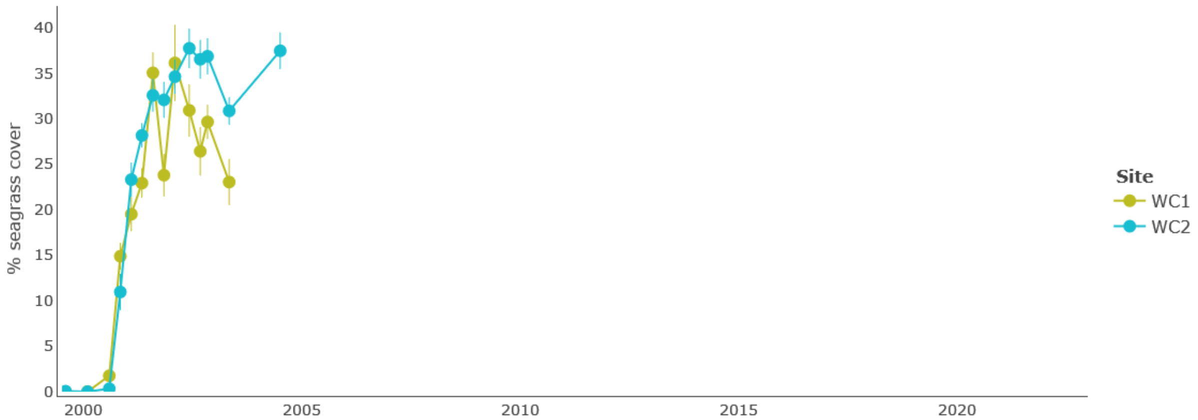


Figure 10. *Change in seagrass percentage cover (±SE) at the Wanggoolba & Bennett's Creek intertidal meadows.*

Boonooroo

Monitoring: ongoing, *biannual*
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
Issues: Small unsewered village, boat traffic & land use
Comments: significant nursery grounds for juvenile prawns and fish. Dugong and turtle feeding grounds.
Status (Nov22):

- seagrass abundance at Boonooroo was in a **very poor state** when last assessed, and was in a poor state since 2017.
- seagrass abundance at both “impacted” (BN1 & BN2) and “control” (BN3) sites declined from 1999 to 2005, however, from 2008 to 2017 seagrass abundance recovered at BN1 and BN3. Since 2017, only BN1 has been assessed, showing very poor abundances across the site – the lowest since 2008.
- seagrass species composition has varied over the monitoring period, particularly at BN1 where *Nanozostera muelleri* was becoming more dominant until 2009 when the meadow reverted back to *Halodule uninervis*, where it has remained since. *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 latter 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 grazing trails are 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) are common. The diversity and abundance of gastropods appears dependent on seagrass abundance, most likely due to associated detrital and prey food sources.

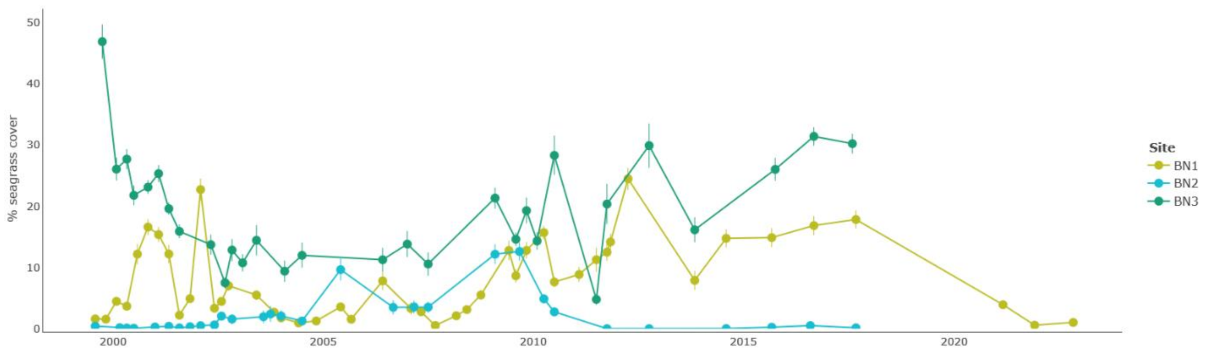


Figure 11. *Change in seagrass percentage cover (±SE) at the Boonooroo intertidal meadows.*

Poona

Monitoring: ongoing, *annual*
Location: Intertidal banks adjacent to township
Site codes: PN1, PN2, PN3
Issues: small unsewered village increasing development, access channel dredging, boat traffic, stormwater, land runoff
Comments: significant fish habitat. Dugong and turtle feeding grounds
Status (Sep17):

- seagrass abundance at Poona was in a **good state** from late 2014, however, current state is unknown.

- seagrass abundance has fluctuated greatly since monitoring was established in 1999, in line with other locations across the Great Sandy Strait.
- Sites are generally dominated by Halodule uninervis, with varying composition of other species (e.g. Halophila ovalis and Nanozostera muelleri) from time to time.
- sediment grain size has remained relatively stable at PN1 and PN2, however PN3 appears to have become muddier during the period 2001 to 2006 (this corresponds with the abundance of *Nanozostera* which is better adapted to muddier sediments).
- dugong grazing trails are 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.

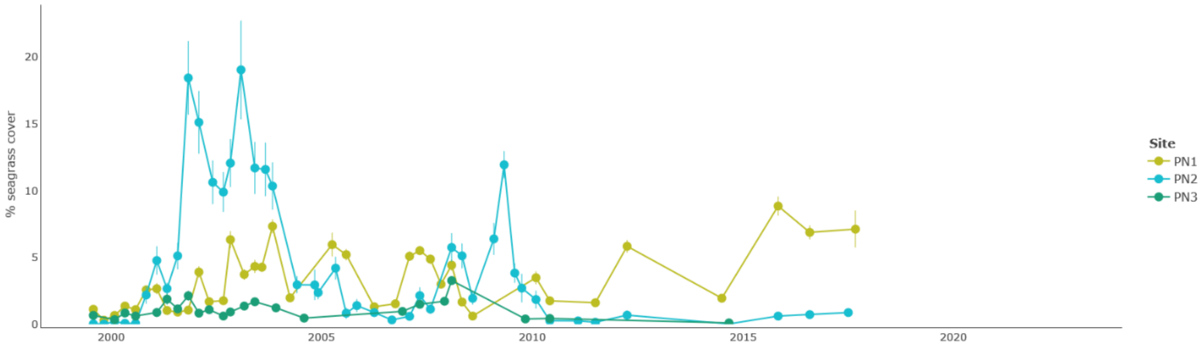


Figure 12. *Change in seagrass percentage cover (±SE) at the Poona intertidal meadows.*

Reef Islands

Monitoring: ongoing, *annual*
Location: central Great Sandy Strait
Site codes: RI1, RI2, RI3
Issues: Boat traffic, oyster leases, land runoff
Comments: significant nursery grounds for juvenile prawns and fish. Dugong and turtle feeding grounds
Status (Sep17):

- seagrass abundance at the Reef Islands was in a **good state** when last assessed, however, current state is unknown.
- seagrass abundance fluctuates (either doubling or halving) at times, but the long-term trend was stable until 2011, after which the meadows significantly declined, reaching its lowest levels in October 2013, after which it recovered.
- algal abundance was generally low with the exception being a significant algal bloom at RI1 in late 2003 and a moderate increase in August 2016.
- 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 the monitoring period.
- dugong grazing trails are 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.

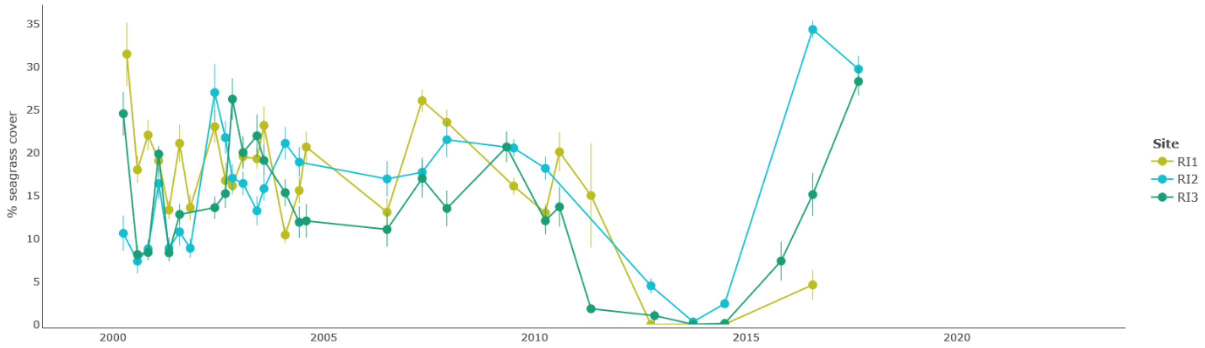


Figure 13. *Change in seagrass percentage cover (±SE) at the Reef Islands intertidal meadows.*

Tootoowah Creek

Monitoring: suspended
Location: Shallow anchorage on the western shores of Fraser Island.
Site codes: TC1 TC2
Issues: boat traffic, land runoff
Comments: Dugong and turtle feeding grounds
Status (Aug02):

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

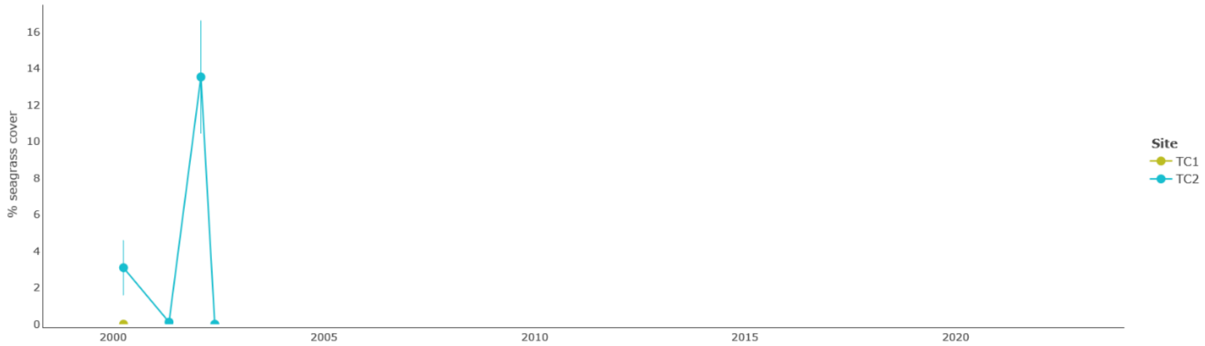


Figure 14. *Change in seagrass percentage cover (±SE) at the Tootoowah Creek intertidal meadows.*

Tinnanbar

Monitoring: ongoing, *biannual*
Location: southern Great Sandy Strait on the intertidal banks in front of the Tinnanbar township & caravan park.
Site codes: TN1 TN2 TN3
Issues: high urban development, boat traffic, stormwater, land runoff
Comments: Dugong and turtle feeding grounds. Popular fishing (recreational & commercial)
Status (Nov22):

- seagrass abundance at Tinnanbar was in a **very poor state** when last assessed, however, current state is unknown.
- seagrass abundance has fluctuated over the monitoring period as a result of climatic events (e.g. floods). After some recovery was observed in 2014, seagrass declined from 2017 to near its lowest level in 2021.
- Since 2010, algae cover has followed a similar pattern of abundances as seagrass.
- epiphyte cover is high and variable, suggesting elevated nutrients in the water column, although epiphyte abundance has been decreasing since 2015
- sediment grain size and species composition relatively stable over monitoring period.

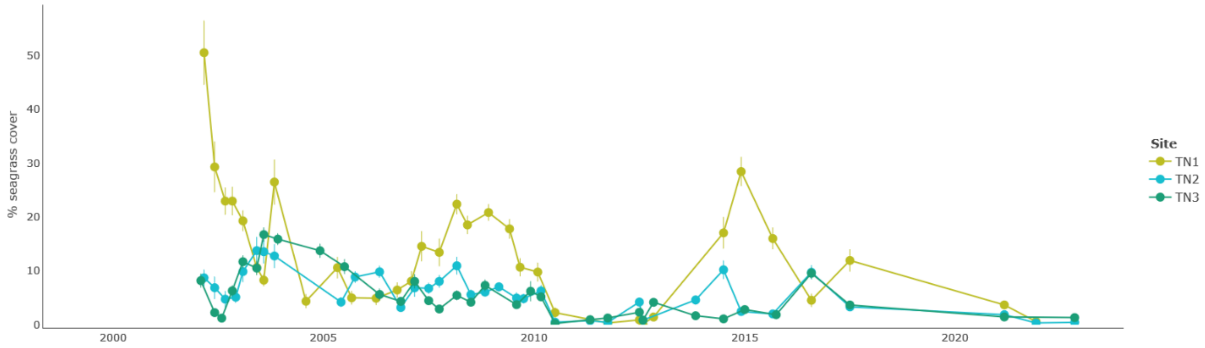


Figure 15. *Change in seagrass percentage cover (±SE) at the Tinnanbar intertidal meadows.*

Brown's Gutter

Monitoring: suspended
Location: shallow anchorage on the south western shores of Fraser Island
Site codes: BG1 BG2 BG3
Issues: stormwater & land runoff, boat traffic
Comments: dugong and turtle feeding grounds
Status (Nov17):

- seagrass abundance at Brown's Gutter was in a **good state** when last assessed, however, current state is unknown.
- Seagrass abundance progressively increased from 2000 to 2009, but rapidly declined in 2010 and 2011, before recovering in 2016.
- seagrass abundance appears seasonal within years, with lower levels from Jun-Aug and highest levels from Nov-Jan.
- episodic algal bloom occurred in early 2012 and mid-2016, however the algal abundances subsequently declined early in the new year.
- sediment grain size changed little over the monitoring period.
- species composition remained stable - dominated by *Zostera*.
- polychaete worms and gastropods (including mud whelks) are common.

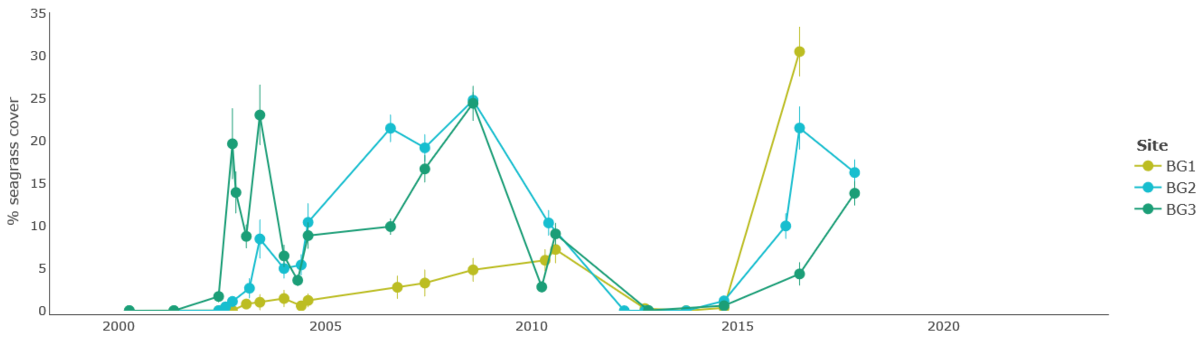


Figure 16. *Change in seagrass percentage cover (±SE) at the Brown's Gutter intertidal meadows.*

Kauri Creek

Monitoring: ongoing, *ad hoc*
Location: on intertidal bank (Ballast Bank) on the southern side of the mouth to Kauri Creek
Site code: KC1
Issues: defence land runoff
Comments: dugong and turtle feeding grounds
Status (Jun17):

- seagrass abundance at Kauri Creek was in a **poor state** when last assessed, however, current state is unknown.

- seagrass abundance has fluctuated since monitoring was established, and abundances since 2010 have varied between poor and fair state.
- canopy height shows a close correlation with seagrass abundance.
- epiphyte abundance appears highly variable, but has been declining since 2010.
- sediment grain size and seagrass species composition appear stable.

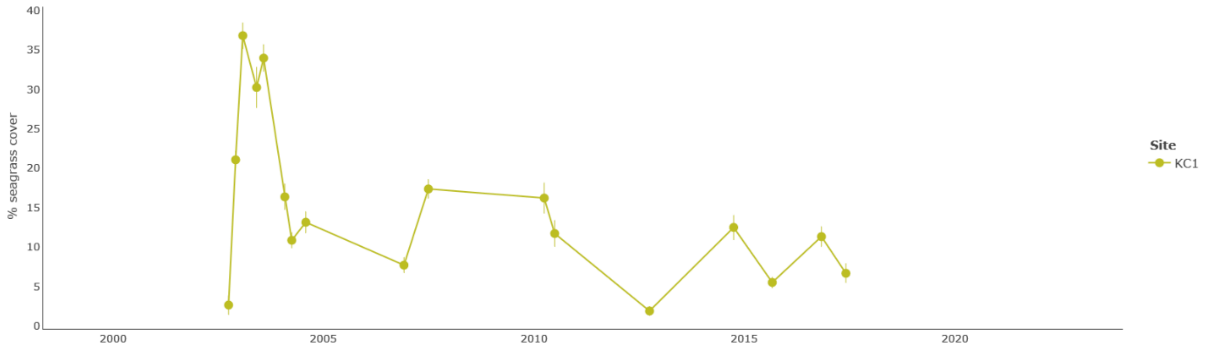


Figure 17. *Change in seagrass percentage cover (±SE) at the Kauri Creek intertidal meadow.*

Tin Can Inlet

Monitoring: ongoing, biannual
Location: Southern Great Sandy Strait, including Pelican Bay and on intertidal flats in front of Tin Can Bay township
Site codes: TB1, PB1, PB2
Issues: Tourism (periodic camping) & urban development, vehicles, stormwater, sewerage & restoration of old wharf
Comments: Dugong and turtle feeding grounds, popular fishing (recreational & commercial)
Status (Nov22):

- seagrass abundance at Inskip Point (PB1) was in a **good state** when last assessed, however, current state is unknown.
- Long-term seagrass abundance at Tin Can Bay sites is low (<5% cover), with occasional episodic peaks, e.g. 2005.
- Meadows at Inskip Point (PB1) are mostly *Nanozostera muelleri* with a mixture of *Halodule uninervis* and *Halophila ovalis*.
- 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.
- 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.

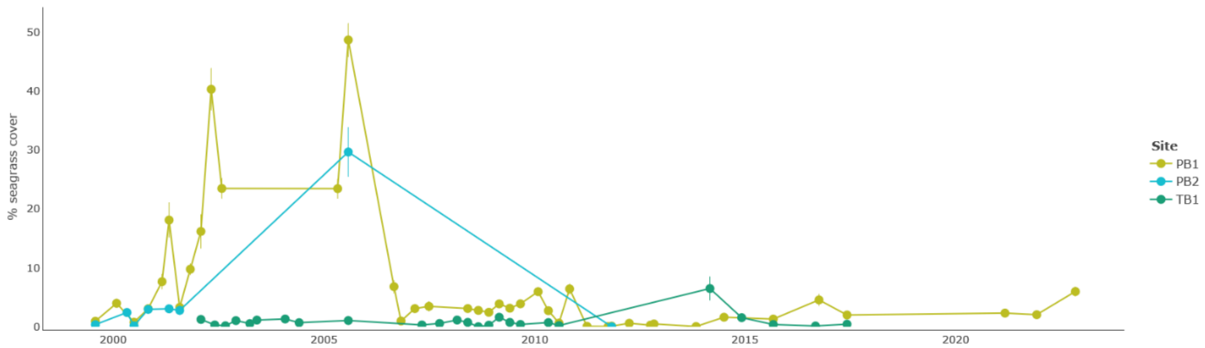


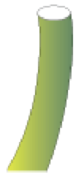
Figure 18. *Change in seagrass percentage cover (±SE) at the Tin Can Inlet intertidal meadows.*

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

A guide to the identification of seagrasses in Butchulla Sea Country

Adapted from [32].

Leaves cylindrical



cylindrical

Syringodium isoetifolium

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

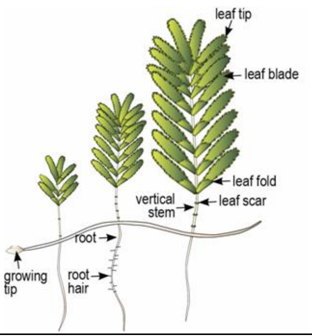
Ruppia maritima

- 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

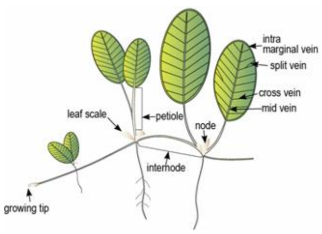
obvious vertical stem with more than 2 leaves



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



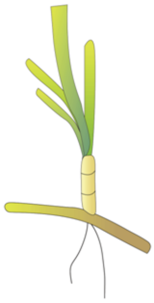
Halophila decipiens

- 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

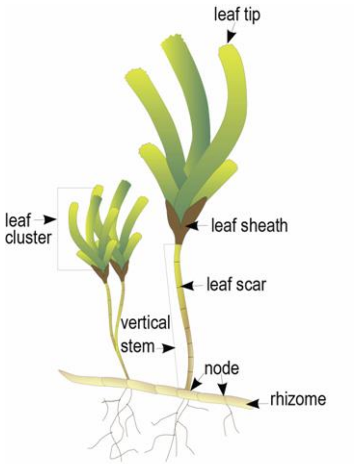
- cross veins 8 or more pairs
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

Leaves strap-like



straplike

Leaves can arise from vertical stem



Oceana serrulata (Syn.: 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

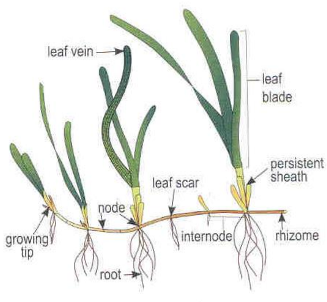
Halodule uninervis

- 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



Nanozostera muelleri (Syn.: Zostera muelleri subsp. *capricorni* and *Zostera 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.

Notes:

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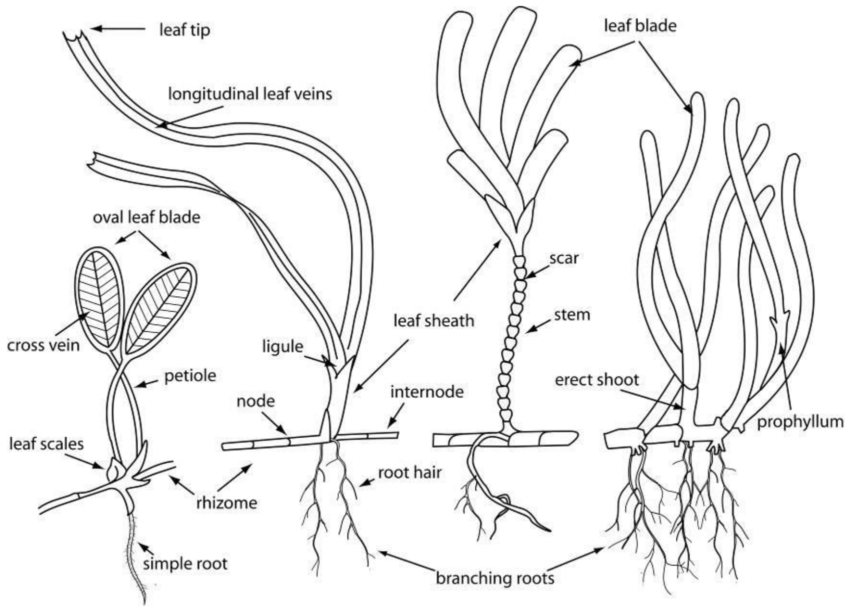
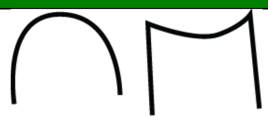
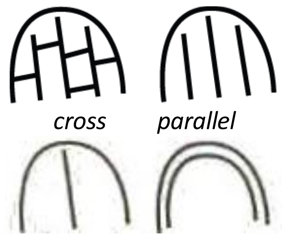
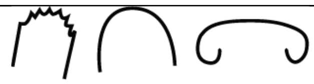
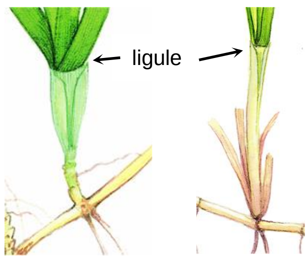
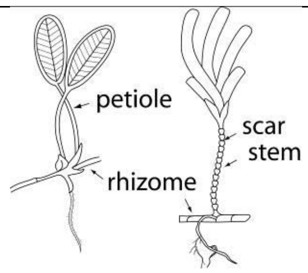
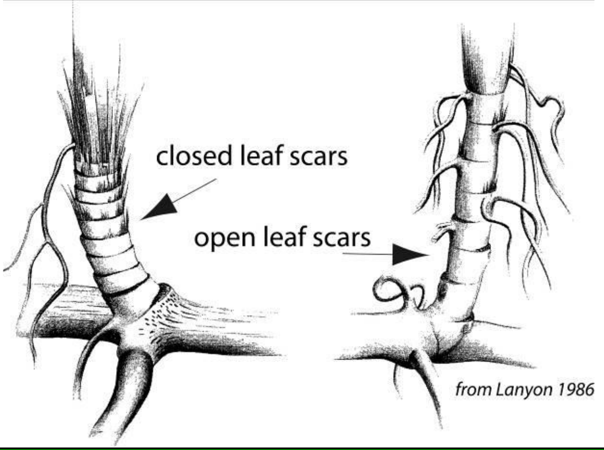
Parts of a seagrass plant



Leaf		
Tip	Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.	 *rounded* *pointed*
Veins	Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for identification. • cross-vein: perpendicular to the length of the leaf • parallel-vein: along the length of the leaf • mid-vein: prominent central vein • intramarginal-vein: around inside edge of leaf	 *cross* *parallel* *mid* *intramarginal*
Edges	The edges of the leaf can be either serrated, smooth or inrolled	 *serrated* *smooth* *inrolled*
Ligule	Membranous structure found at the junction of the blade and sheath. Clasps leaf sheaths, aiding protection of enclosed younger plant parts.	 ligule ligule clean & flattened fibrous
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.	
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*.	 petiole rhizome scar stem

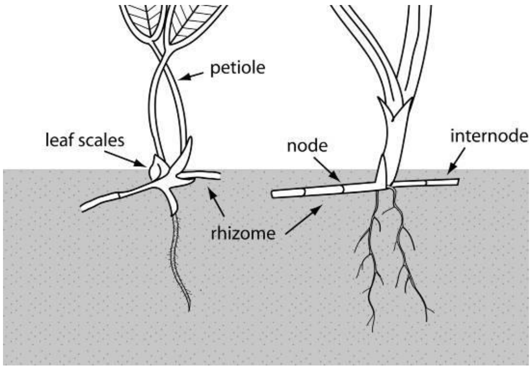
Stem

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*).



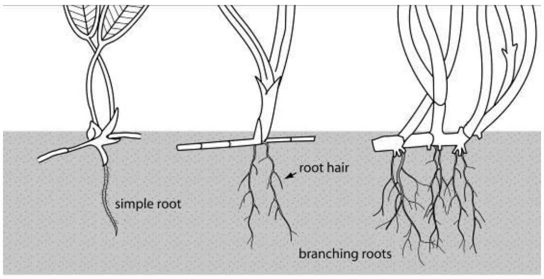
Rhizome

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 Improvement Plans or Best Practice Guidelines; and Government Legislation.

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

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

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

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

Monitoring seagrass condition

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

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

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

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

Seagrass-Watch

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

Seagrass-Watch is one of the largest seagrass monitoring programs in the world. Since its genesis in 28 March 1998 in Australia, Seagrass-Watch has expanded internationally to more than 26 countries. Monitoring is currently occurring at over 425 sites. To learn more about the program, visit www.seagrasswatch.org .

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

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

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

Quality Assurance-Quality Control

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

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

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

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

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

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

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

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

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

Data Property And Ownership

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

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

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

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

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

- understanding and responding to impacts from catchment runoff[27, 33], coastal developments (e.g., marina constructions) and dredging proposals.
- Understanding natural levels of change[34-36] and supporting marine habitat conservation.

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

THE GOALS OF THE PROGRAM ARE:

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

Notes:

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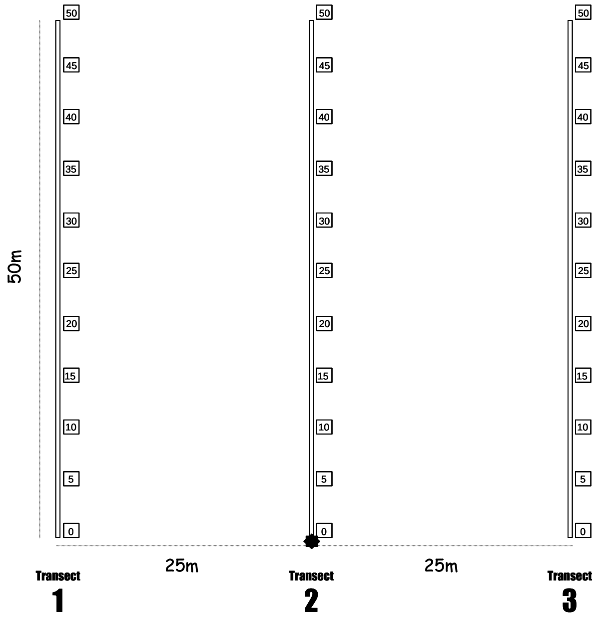
Permanent Transect Monitoring Protocols

Source: McKenzie et al. 2003[30] (www.seagrasswatch.org/manuals/)

Site layout



Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Each sampling event

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

Step 1. Take a Photograph of the quadrat

- Photographs are taken of every quadrat along each transect. Use a quadrat free of strings and place the photo quadrat labeller beside the quadrat and the tape measure, with the correct site code displayed.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat labeller 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).
- Note features such as ripples across the sediment surface (indicates the level of sediment movement from wave action)

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

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

Step 4. Estimate seagrass percent cover

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

Step 5. Estimate seagrass species composition

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

Step 6. Measure seagrass canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

Step 10. Move to next quadrat

- Repeat steps 1 to 8 for the remaining 32 quadrats

Step 11. Monitoring seed banks (an indicator of meadow resilience)

- Using the seed corer, sample sediment to a depth of 10cm every 10m along five transects, 12.5m apart.
- Release each core into a sieve, wash away the sediment and count the number of seeds retained.

At completion of monitoring

Step 1. Before leaving the site

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

Step 2. Wash & pack gear

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

Step 3. Press any voucher seagrass specimens if collected

- The voucher specimen should be pressed as soon as possible after collection. Do not refrigerate >2 days.

Step 3. Submit all data

- Data can be entered into the MS-Excel file downloadable from www.seagrasswatch.org.
- Upload full resolution quadrat photos, high resolution scans of datasheets and data files to a file hosting service or similar.
- If required, mail original datasheets and herbarium sheets

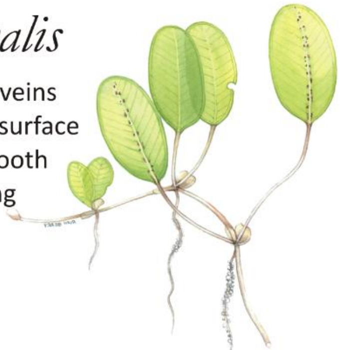
Seagrass-Watch HQ
For postal or email address, see
https://www.seagrasswatch.org/contact/

SEAGRASS SPECIES CODES

Ho

Halophila ovalis

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



Hd

Halophila decipiens

- Small oval leaf, slightly pointed
- fine leaf hairs on both sides
- leaf margins finely serrated
- 6-8 cross veins
- leaf 10–25mm long and 3–10mm wide

Hs

Halophila spinulosa

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

Cs

Oceana serrulata

formerly *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

Rm

Ruppia maritima

- leaves fine and thread-like
- pointed tip on leaves, sometimes serrated
- inflorescence on a long stalk, sometimes spiralled
- rhizome fragile

Zc

Nanozostera muelleri

formerly *Zostera muelleri* subsp. *capricorni*

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

Si

Syringodium isoetifolium

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

Illustrations not to scale

SEAGRASS-WATCH MONITORING

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

Seagrass-Watch

OBSERVER: Beverly Citizen **DATE:** 17 / 2 / 21
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 DFT x 1	✓	40	30	70			0	5,4,7	5	33
2 (5m)	Fs/S	GAS x 2 Ray pit x 2	✓	33	50	50			0	6,6,6	10	18
3 (10m)	CS	Hc x 3	✓	0					0	–	0	–
4 (15m)	m/S	CH x 10	✓	0					1cm	–	17	–
5 (20m)	m/S	Turtle cropping GAS x 3	✓	18	5	90	5		1cm	7,5,6	12	57
6 (25m)	m/S/sh	SC x 3 mw x 2	✓	36		90	10		1cm	8,6,6	2	95
7 (30m)	Fine Sand	CH x 9 GW x 1	✓	48	100				3cm	–	0	10
8 (35m)	CS/S	Nothing	✓	0.7		100			2.5cm	6,5,5	0	36
9 (40m)	FS	HC x 2	✓	23	96	4			1cm	5.5,5,6	5	38
10 (45m)	S/m	GW x 2	✓	41	3		97		1cm	8,8,7	3	90
11 (50m)	mud	CH x 2 SC x 1	✓	16	3	7	90		0	7,7,8	38	95

END of transect (GPS reading)

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

FS = Fine Sand
CS = Coarse Sand
m = mud
S = Sand
Sh = shell

SC = Sea Cucumber
HC = Hermit Crab
GAS = Gastropod
CH = Crab Hole
mw = mud whelk
GW = Green worm

DFT = Dugong feeding trail

Making a herbarium press specimen

Herbaria are repositories of preserved and labelled plant specimens, arranged to allow easy access and archival storage. The specimens are typically in the form of herbarium sheets: pressed and dried plants that have been attached to a sheet of heavy paper together with a data label. An herbarium specimen is simple in form and low-tech in preparation, yet it preserves a wealth of valuable information. If properly stored, an 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. For example, in Queensland, all marine plants, including seagrass, are protected under the Fisheries Act 1994.

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

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

Pressing

Tools

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

Preparation

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

Arrangement

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

Labels

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

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

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

Drying

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

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

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

Changing the paper is a very important step. In the first three or four days a paper change should take place every day, then you can leave more time between changes. If you neglect the change of paper the plants will take more time to lose their water content, besides they could be damaged if the paper stays wet for a few days. When changing the paper, you must keep the specimens intact and ensure the label travels with the specimen. The minimum time required for complete dying ranges from two to four days or more. Once a specimen has become dry and stiff, it can be mounted and placed into the herbarium.

Mounting

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

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

Herbaria

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

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

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

Notes:

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Understanding sediment

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

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

Grain size classes used, based on the Udden – Wentworth grade scale [37].

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

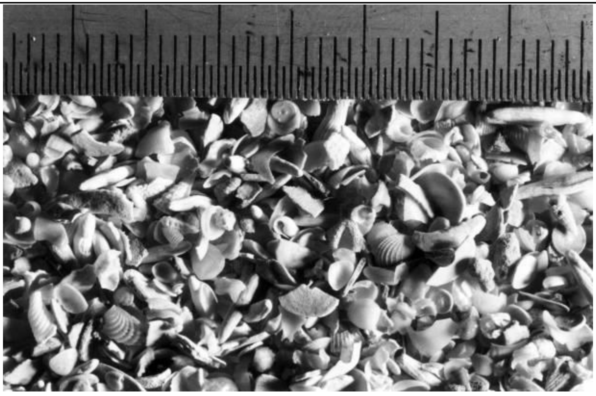
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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).

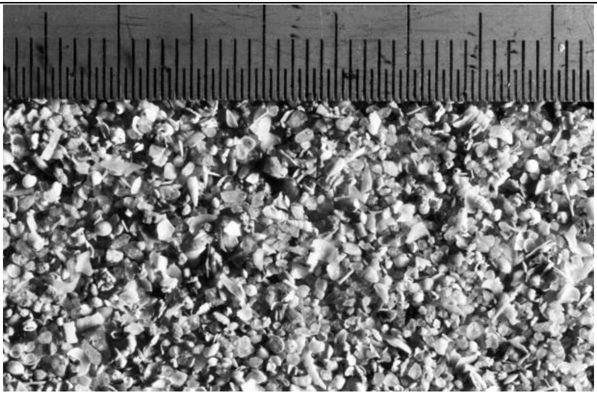
mud	*has a smooth and sticky texture.*
fine sand	*fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand	*rough grainy texture, particles clearly distinguishable.*
coarse sand	*coarse texture, particles loose.*
gravel	*very coarse texture, with some small stones.*

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

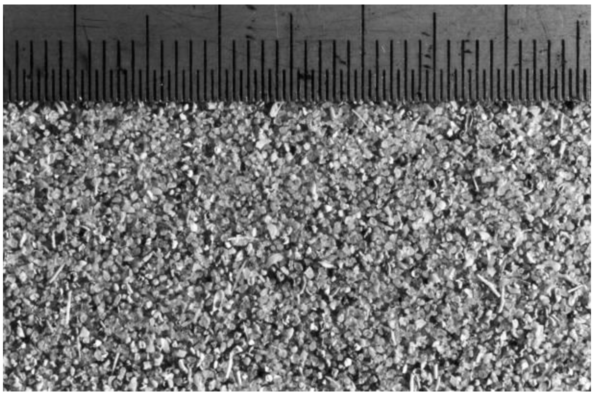
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments [38], https://bit.ly/3pjTowW .



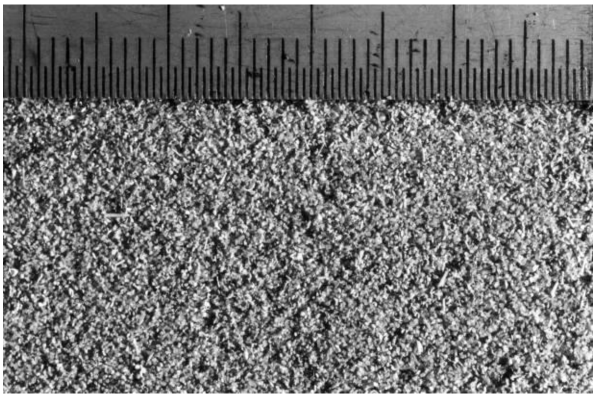
gravel (>2mm)



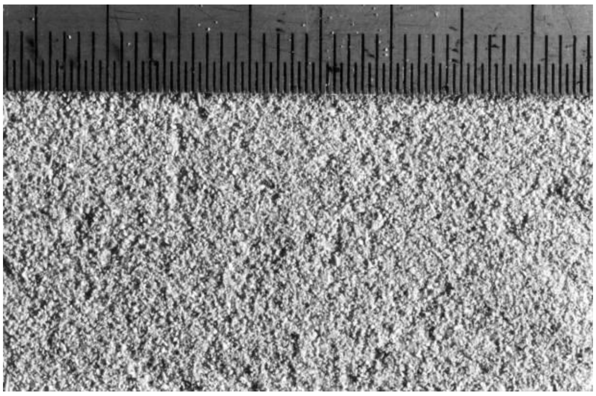
very coarse sand (1 – 2 mm)



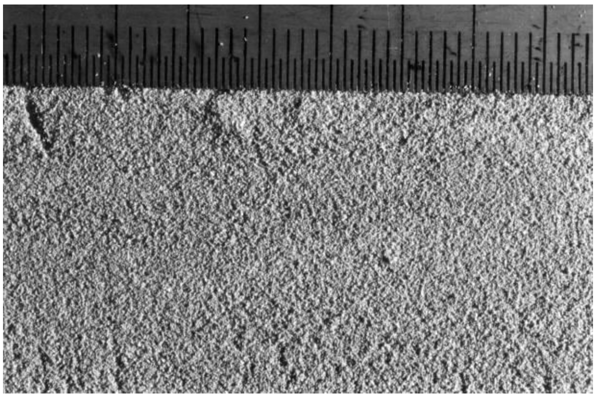
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

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Seagrass conservation

Threats to seagrass habitats

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

Management

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

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

Methods of direct protection range from legislative instruments and associated legal sanctions through to education [39]. 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[39]. 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[39].

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[39]. Providing information is important as it enables individuals to voluntarily act in ways that reduce impacts to seagrasses. Non-prescriptive methods range from simple explanatory guides to complex industry codes of practice.

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

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

Indigenous concepts of management of the sea differ significantly from the introduced Western view of the sea as common domain, open to all and managed by governments [40]. Unlike contemporary Western systems of management, indigenous systems do not include jurisdictional boundaries between land and sea. Indigenous systems have a form of customary ownership of maritime areas that has been operating in place for thousands of years to protect and manage places and species that are of importance to their societies.

Marine resource management these days should, therefore, attempt to achieve the following interrelated objectives: a) monitor the wellbeing (e.g. distribution, health and sustainability) of culturally significant species and environments (e.g. dugong, marine turtles, fish, molluscs, seagrass etc.); and b) monitor the cultural values associated with these culturally significant species and environments [41].

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 [42-47]. 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 https://www.seagrasswatch.org

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

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

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

World Seagrass Association A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses. https://worldseagrass.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

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. https://ian.umces.edu/

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