Seagrass-Watch

Proceedings of a Workshop for Monitoring Seagrass Habitats in Hervey Bay and the Great Sandy Strait, Queensland

Urangan Community Centre, Hervey Bay Botanic Gardens,
Elizabeth St, Urangan, Hervey Bay, Queensland
17th – 18th May 2008

Len McKenzie & Rudi Yoshida
Seagrass-Watch HQ
Department of Primary Industries & Fisheries, Queensland

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Enquires should be directed to:
Len McKenzie
Seagrass-Watch Program Leader
Northern Fisheries Centre,
PO Box 5396
Cairns, QLD 4870 Australia

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Overview

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

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is hosted by the Hervey Bay Dugong & Seagrass Monitoring Program (HBDSMP), local coordination by Trischelle Lowry, and supported by the Australian Government's Marine and Tropical Sciences Research Facility (Department of the Environment and Water Resources) represented in North Queensland by the Reef and Rainforest Research Centre, the Great Barrier Reef Marine Park Authority (GBRMPA), Seagrass-Watch HQ, and the Queensland Department of Primary Industries & Fisheries. As part of this workshop we will

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

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

Seagrass-Watch HQ
Northern Fisheries Centre
Queensland Department of Primary Industries & Fisheries
PO Box 5396
Cairns QLD 4870
AUSTRALIA
Telephone (07) 4057 3731
E-mail hq@seagrasswatch.org

or visit

www.seagrasswatch.org

Workshop leaders

Len McKenzie

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

Current Projects

- Seagrass-Watch
- Status and mapping of seagrass resources in Queensland
- Assessment of primary and secondary productivity of tropical seagrass ecosystems
- Investigations on the macrofauna associated with seagrass meadows
- Great Barrier Reef Water Quality Protection Plan – marine monitoring program: seagrass

Rudi Yoshida

Rudi is a Scientific Assistant with the Queensland Department of Primary Industries & Fisheries. Rudi has over 11 years experience in seagrass related research and monitoring. He is also a core member of Seagrass-Watch HQ, and ensures data submitted is managed and QA/QC protocols applied. He is also responsible for maintenance of the Seagrass-Watch website.

Current Projects

- Seagrass-Watch
- Great Barrier Reef Water Quality Protection Plan – marine monitoring program: seagrass

Agenda

Saturday 17th May 2008

Afternoon	1330 - 1340 *(10min)*	Welcome – *Trischelle Lowry & Len McKenzie*
	1340 – 1400 *(20min)*	Seagrass Biology and Identification – *Len*
	1400 – 1415 *(15min)*	Laboratory exercise: Seagrass Identification – *Len & Rudi Yoshida*
	1415 – 1430 *(15min)*	Seagrass Identification *continued – Len*
	1430 – 1445 *(15min)*	Laboratory exercise: how to prepare a seagrass press specimen – *Len & Rudi*
	1445 - 1530 *(45min)*	Seagrass Ecology and Threats – *Len*
	1530 - 1545 *(15min)*	*Afternoon Tea*
	1545 – 1600 *(15min)*	Seagrass monitoring – *Len*
	1600 - 1630 *(30min)*	Seagrass-Watch: how to sample - *Len*
	1630 - 1715 *(45min)*	Seagrass-Watch: how data is used - *Len*
	1715 – 1730 *(15min)*	*Wrap up for day*

Sunday 18th May 2008

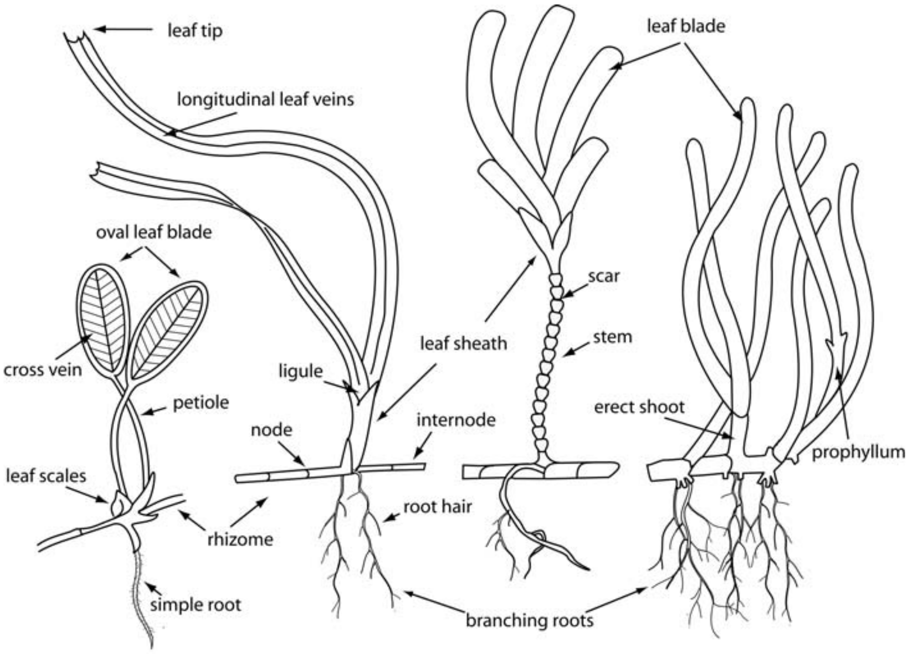
Afternoon	1200 - 1215	Safety briefing & risk assessment – *Trischelle & Len*
	1215 - 1500	**Field exercise:** Seagrass-Watch monitoring - *Len& Rudi* *Where*: Urangan? *What to bring:* • *hat, sunscreen (Slip! Slop! Slap!)* • *dive booties or old shoes that can get wet* • *drink/refreshments* • *Polaroid sunglasses (not essential)* • *enthusiasm* *You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet and muddy!* *Please remember, seagrass meadows are an important resource and are protected by law. We ask that you use discretion when working/walking on them.*
	1500 – 1530	Wrap up *(on foreshore)* • Wash gear • Feedback

Low tide: 1326 0.74m

Background

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

Seagrass are marine flowering plants



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

Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. These names are not consistently applied among countries. Coastal communities would almost certainly recognise the term "turtle grass" as referring to the shallow subtidal and intertidal seagrasses that turtles are associated with.

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

Seagrasses have roots, stems and leaves

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

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

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

Seagrass leaves lack stomata (microscopic pores on the under side of leaves) but have thin cuticle to allow gas and nutrient exchange. They also possess large thin-walled aerenchyma. The aerenchyma are commonly referred to as veins as they carry water and nutrients throughout the plant. Aerenchyma is specialized tissue having a regular arrangement of air spaces, called lacunae, that both provides buoyancy to the leaves and facilitate gas exchange throughout the plant. Leaves have a very thin cuticle, which allows gas and some nutrient diffusion into them from the surrounding water. Veins can be across the leaf blade or run parallel to the leaf edge. Also within the leaves are chloroplasts, which use the suns light to convert carbon dioxide and water into oxygen and sugar (photosynthesis). The sugar and oxygen are then available for use by other living organisms.

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

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

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

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

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

Seagrass pump oxygen into the sediment via their roots

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

Seagrass have flowers, fruits and seeds

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

Pollination occurs in the water

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

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 are more closely related to lilies

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in a least three separate lineages or families. 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.

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

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

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

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

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

Seagrass requirements for growth

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

Seagrasses need plenty of sun and clean water to grow.

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

Seagrasses are physiologically adapted to life in sea 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. A limiting factor for many intertidal seagrasses is osmotic impacts resulting from hypersalinity due to evaporation

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

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

Light availability is the most important factor determining seagrass growth

Seagrasses require between 4.4 - 29% of surface light to grow

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38 degrees Celsius) 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 to 42 degrees Celsius) is the disruption of electron transport activity via inactivation of the

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

Seawater temperatures above 40ºC will stress seagrass. Death occurs at temperatures above 45ºC

Temperature also controls the range of pH and dissolved carbon dioxide (CO2) concentrations in the water column; factors critical in plant survival in the marine environment.

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

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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

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

The availability of nutrients to seagrasses may also be dependent on sediment quality / geochemistry. Bioavailability of nutrients is dependent on particle size and type. For example, clay content influences sediment adsorptive capacity — the more clays the greater the absorptive 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 see floor. Some seagrasses such as *Cymodocea* spp. prefer deeper sediments while others can tolerate a broad range of sediment depths. Colonising seagrasses such as *Halophila* spp. and *Halodule uninervis* are better suited to mobile sediments than larger species. The biogeochemical characteristics of sediment that can affect the nutrient content/binding capacity, organic content and oxygen levels. Seagrasses are unable to grow in sediments of high organic content.

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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

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

Where are seagrasses found?

Seagrasses are found in ocean throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the artic (freezing) regions. Seagrass are mainly found in bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or

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

60 metres. Most species are found in clear shallow inshore areas between mean sea-level and 25 metres depth.

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

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

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

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

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

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

Seagrass plants form small patches that develop into large meadows

How are seagrasses important to the marine ecosystem?

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

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

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

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

Seagrass meadows are a major food source for a number of grazing animals and are considered very productive pastures of the sea. The dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*) mainly feed on seagrass. An adult green turtle eats about two kilograms of seagrass a day while an adult dugong eats about 28 to 40 kilograms a day. Both dugongs and turtles 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* >

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

Halodule uninervis > *Zostera capricorni*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

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

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

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

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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

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.

Valuation of seagrasses

The valuation of ecosystem services is a very controversial topic in today's literature. Ecosystem Services are the processes by which the environment produces resources that we often take for granted. For seagrasses it is services such as clean water, preventing erosion, and habitat for fisheries.

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

The economic values of seagrass meadows are very large, although not always easy to quantify. Seagrass meadows are rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. The average global value of seagrasses for their nutrient cycling services and the raw product they provide has been estimated at 1994 US$ 19,004 ha^{-1} yr^{-1}.

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.

Seagrasses can change due to both natural and human impacts

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

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

What threatens seagrass?

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

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

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

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

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

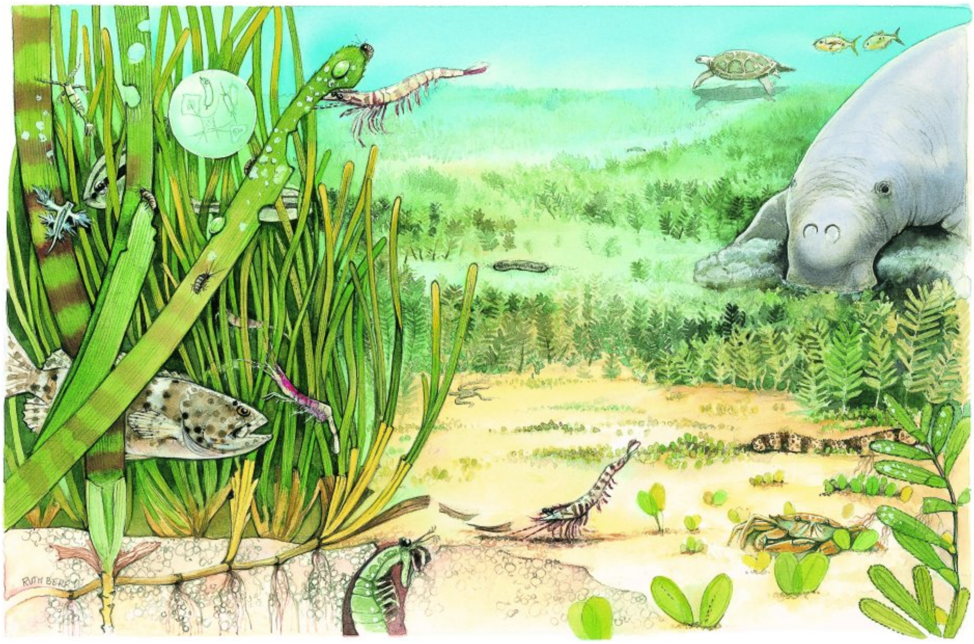
People can also physically damage or destroy seagrass. Coastal development for boat marinas, shipping ports and housing generally occurs on the coast in areas which are sheltered and seagrass like to grow. Seagrass meadows are either removed or buried by these activities. Coastal developments can also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

Coastal development can have a major impact on seagrass meadows

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

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

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



Notes:

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Interesting facts:

Over a billion people live within 50 km of a seagrass meadow. Millions of people obtain their protein from animals that live in seagrasses.

The estimated coverage of seagrasses globally is over 177,000 square kilometres.

A hectare of seagrass absorbs 1.2 kilograms of nutrients per year, equivalent to the treated effluent from 200 people.

In northern Australia, whole seagrass meadows are able to completely replace their leaves (turnover) in around 10 days.

Seagrass meadows sequester 33 grams of carbon per square meter per year, equivalent to the CO_2 emissions from an automobile travelling 2,500 kilometres

One square metre of seagrass can produce up to 10 litres of oxygen per day

In northern Australia, the primary productivity of seagrass meadows is higher than a mangrove forest, a terrestrial forest or grassland.

Seagrasses occupy only 0.1% of the seafloor, yet are responsible for 12% of the organic carbon buried in the ocean, which helps reduce greenhouse gases.

The only endangered marine plant is a species of seagrass (*Halophila johnsonii* in Florida).

There is a single clone of seagrass that is over 6,000 years old (*Posidonia ocea*nica in the Mediterranean Sea).

The deepest growing seagrass (*Halophila decipiens*), 86 metres, is reported from Cargados Carajos Shoals in the Indian Ocean northeast of Mauritius.

Seagrass produce the longest pollen grains on the planet.

Some intertidal species of seagrasses can lose up to 50% per cent of their water content and still survive.

Did you know that Australia has the highest number of seagrass species of any continent in the world?

In Alaska, seagrasses remain frozen and in a dormant state over winter and do not start to grow again until the thaw.

The longest known seagrass 7.3 metres in length has recently been reported from Funakoshi Bay, Japan.

40,000 seeds of *Halodule uninervis* have been found in 1 square metre of mudflat.

In Florida, 80% of the above ground seagrass biomass is consumed by parrot fish.

The anchor from one cruise boat can destroy an area of seagrass the size of a football field!

Notes:

Seagrass in Hervey Bay and the Great Sandy Strait

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

Hervey Bay

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

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

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

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

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

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

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

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

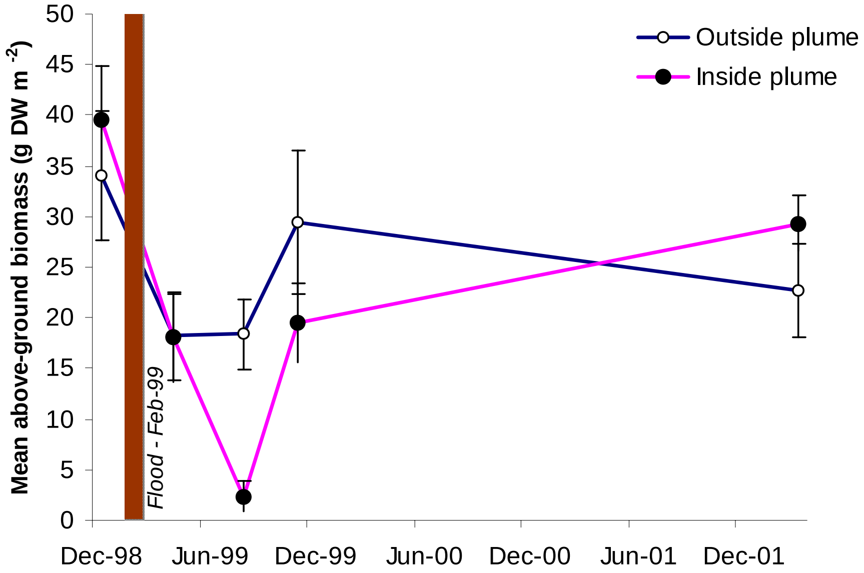

Figure 1. Plot of above-ground seagrass biomass (g DW m-2, all species pooled) from survey sites inside (Impact) and outside (Reference) the area impacted by the Mary River flood plume following flooding in Hervey Bay and the Great Sandy Strait in February 1999. Error bars represent 95% confidence limits.

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

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

Long term monitoring at Seagrass-Watch sites within Booral wetlands by local volunteers, found that initial re-colonisation of seagrass occurred in November 2000, 21 months post-flood. Full recovery of meadows to pre-flood cover values (~20-40%)

occurred August 2002, 30 months post-flood. Monitoring sites also exhibited seasonal tends in abundances with highest cover in November and lowest seagrass cover post-summer from April to June. This typical seasonal response coupled with a trend of increasing seagrass cover indicates a post-flood recovery.

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

Great Sandy Strait.

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

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

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

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

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

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

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

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

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

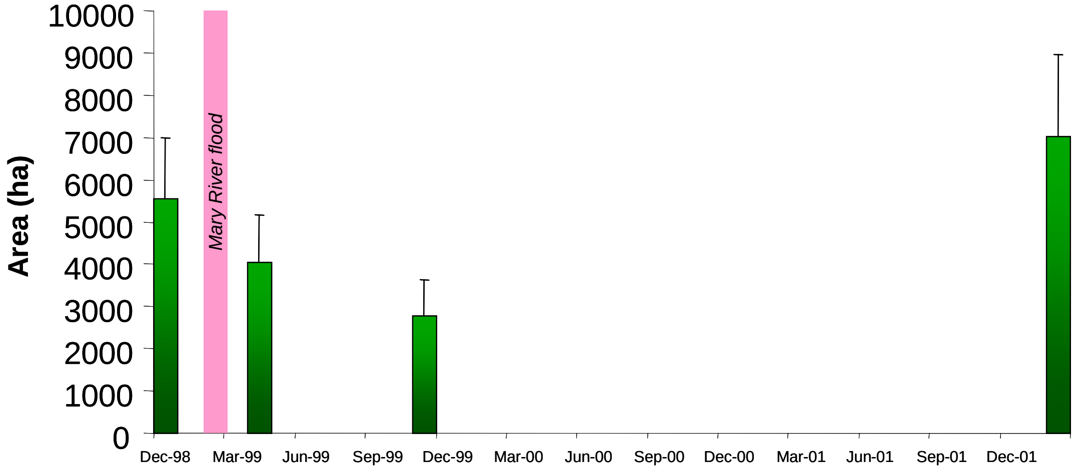

Figure 2. Mean area ±R (estimate of reliability) for seagrass mapped in the Great Sandy Strait pre- and post-flood.

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

Seagrass-Watch

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, 13 sites have been established at 4 different locations in Hervey Bay and 23 sites at 9 locations in the Great Sandy Strait. Sampling frequency at some sites has been reduced from four to three times per year in March/April, July/August and October/November due to access during suitable low spring tides. Two sites (UG1 and UG2) have been integrated in the Reef Plan Marine Monitoring Program. At these sites additional information (eg herbicides, tissue nutrients, sediment nutrients) is collected.

Patterns of seagrass abundance show seasonal and annual differences. Peaks in abundance generally occur during late spring and early summer. The timing of these peaks however can change slightly from year to year. Significant differences in abundance occur between years.

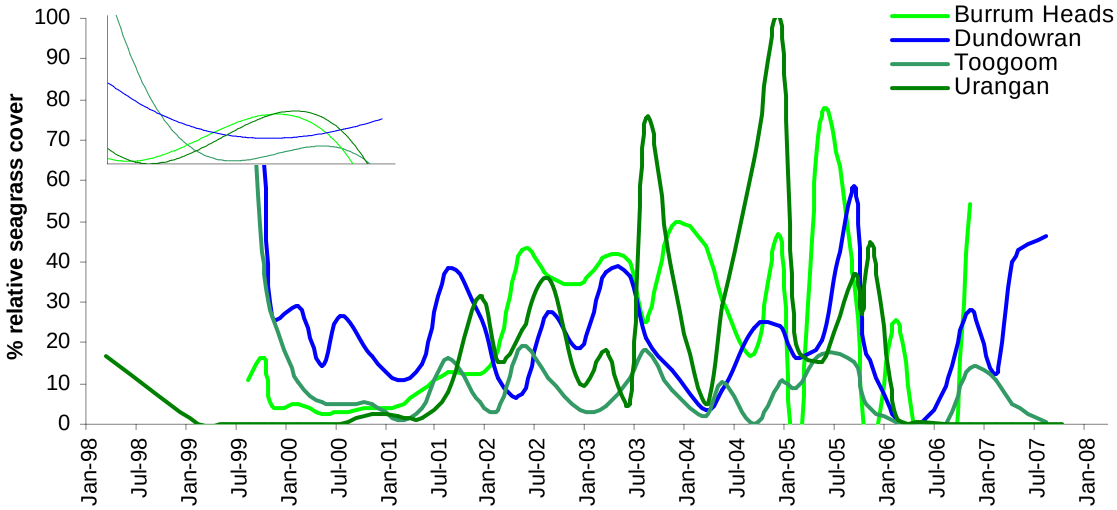

Figure 3. Relative seagrass percentage cover at all Seagrass-Watch monitoring locations in the Hervey Bay region. Percentage cover is relative to 95th percentile of total seagrass percentage cover at each location. Insert graph shows generalised trendline for seagrass cover at each location.

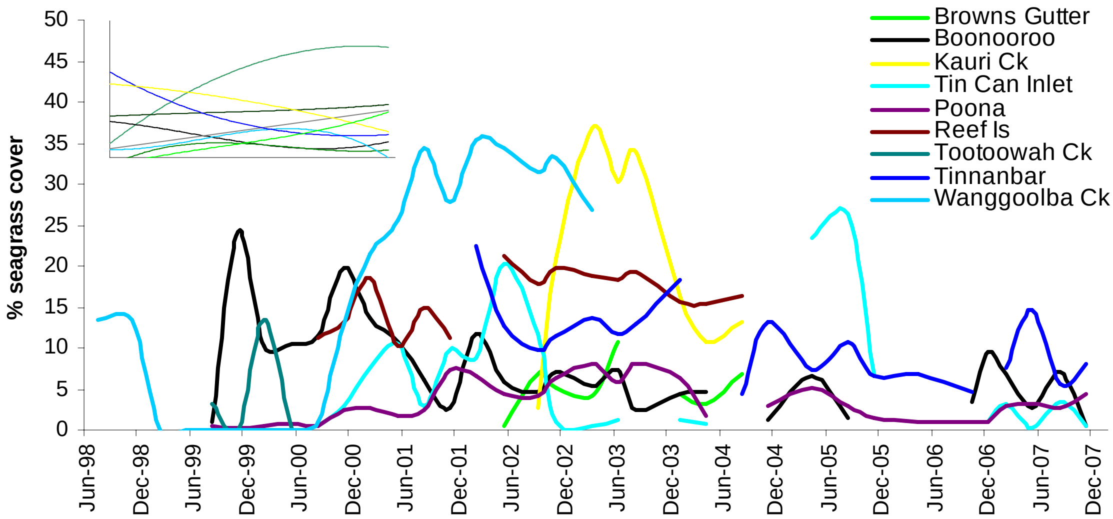

Figure 4. Seagrass percentage cover at all Seagrass-Watch monitoring locations in the Hervey Bay region. Insert graph shows generalised trendline for seagrass cover at each location.

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

Burrum Heads

- Seagrass cover increased at all sites in 2002, however significant declines observed in 2005. In 2006 seagrass abundance was improving, although sites were not examined in 2007. The dominant seagrass species is *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. Species composition varied over the monitoring period due to sediment burial.
- Algae generally low with episodic blooms over late winter and spring.
- Sediment grain size has become coarser over time, possibly aiding water clarity – this coincides with increased seagrass abundance.
- Dugong feeding trails are common and most abundant in May and August.
- Polycheate worms are common but gastropods are 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 (ie less grazing matter and associated faunal prey).

Dundowran

- Seagrass cover has remained low, with significant increases at DD3 in 2007. The dominant seagrass species include *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. Seagrass species composition has remained stable.
- Algae and epiphytes occasional episodic blooms – generally in middle of the year.
- Sediment grain size has become slightly coarser across all sites over the monitoring period.

Toogoom

- Seagrass abundance has not recovered to mid 1999 values. Seagrass is showing some seasonal trends in abundance, with significant increases each spring. The decline in seagrass cover from August 1999 to May 2000 at most intertidal sites between Burrum Heads and Dundowran was due to burial by mobile sediments.
- The dominant seagrass species present include *Halodule uninervis* (narrow leaf morphology) and *Halophila ovalis*. Species composition varied over the monitoring period with losses of both *Z. capricorni* and *H. uninervis* due to sediment burial.
- Algae is generally low with occasional episodic blooms
- Epiphytes increased dramatically in late 2002 and early 2003, however these have now declined.
- Sediment grain size has remained stable with fine sands.

Urangan

- Following a major flood in February 1999, seagrass was absent (0% cover) from August 1999 to May 2000. In July 2000 seedlings of *Zostera capricorni* appeared. Seagrass abundance has recovered significantly. A sudden and dramatic decline in late 2005 was cause for some concern. In late 2007, *Zostera capricorni* seedlings emerged and sparse patches are beginning to develop.
- Algae cover is relatively insignificant at these sites.
- Epiphyte blooms regularly occur at both sites, suggesting acute high nutrient impacts.
- Sediment grain size has changed relatively little over the monitoring period.
- Dugong feeding was absent until late 2001, coinciding with seagrass recovery. Feeding trails are regularly observed across the meadows.
- The high abundance of gastropods may be due to high amounts of mud and organic detrital matter in the sediments.

Booral

- Seagrass abundance has increased significantly since monitoring was initiated in late 2000. Sudden and dramatic declines in 2005 are cause for some concern.
- Episodic algal blooms have occurred in late 2001 and 2002, however the algal abundances subsequently declined early in the new year.
- Epiphyte abundance has continued to increase closely correlating with seagrass abundance.

Brown's Gutter

- Seagrass (*Zostera*) abundance has recovered significantly since early 2000. A dramatic decline in early 2004 caused some concern, however abundance has recovered to “healthy” levels. Generally appears to be seasonal increase in the middle of each year.
- Epiphyte blooms regularly occur at most sites in the middle of the year.
- Sediment grain size has changed relatively little over the monitoring period.
- Polychaete worms and gastropods (including mud whelks) were common.

Boonooroo

- Seagrass abundance at both "impacted" (BN1 & BN2) and "control" (BN3) sites has continued to decline over the monitoring period. Species composition has changed little – with the exception of BN1 which appears to now be dominated by Halodule uninervis rather than Zostera capricorni.
- Algae abundance appears seasonal at it generally increases in the middle of each year.
- Epiphyte abundance – although highly variable has continued to increase (not statistically significantly) over the monitoring period.
- Predominantly composed of fine mud and fine sand with a high organic component. Sediment grain size has remained relatively stable of the monitoring period.
- Dugong feeding trails were found year round, with the most intensive grazing occurred from May to November, coinciding with the nutritional demands of calving from September to December. During this period seasonal forces support high seagrass growth ensuring that losses from grazing are outweighed by tissue production.
- Turtle feeding (cropping) was evident year round.
- 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.

Kauri Creek

- Seagrass abundance has increased over the monitoring period. It was significantly high in 2003, although in early 2004 it declined by more then 50%. Early spring monitoring indicated it was increasing.
- Canopy height is showing a close correlation with seagrass abundance.
- Epiphyte abundance appears highly variable.
- Sediment grain size and seagrass species composition appear stable.
- Polychaete worms and gastropods were common.

Poona

- Seagrass abundance declined dramatically at all sites in early 2004, and have since recovered to 2001 levels. The cause of the peaks in abundance recorded at PN2 in 2002-2003 is unknown. Seagrass composition appears relatively stable across sites.
- Seagrass meadows at Poona were predominantly composed of fine mud and fine sand with a high organic component. Sediment grain size has remained relatively stable at PN1 and PN2, however PN3 appears to have become muddier.
- Dugong feeding trails found year round, with the most intensive grazing occurring 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.

Reef Islands

- Reef Island seagrass meadows appear to be in fairly-good condition. Seagrass abundance fluctuates (either doubling or halving) at times.
- Algal abundance is generally low with the exception being a significant algal bloom at RI1 in late 2003.
- Epiphyte abundance appears seasonal with increases in the later part of the year, with a dramatic decline in the summer months.
- Sediment grain size and species composition relatively stable over monitoring period.
- Dugong feeding trails were found year round, with the most intensive grazing occurred from May to November. 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.

Tin Can Inlet

- Seagrass abundance has remained low at the site adjacent to the Tin Can Bay township (TB1). The sites at Inskip Point in Pelican Bay although peaked in abundance between 2002-2005, have since returned levels similar to when monitoring first established.
- Algal abundance appears to increase seasonally in the winter months and epiphyte abundance is highly variable.
- Polychaete worms and gastropods (including mud whelks) were common. The diversity and abundance of gastropods appears to be dependent on seagrass abundance, most likely due to associated detrital and prey food sources.
- Seagrass meadows at Pelican Bay were predominantly composed of fine mud and fine sand with a high organic component.

Tootoowah Creek

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

Tinnanbar

- Seagrass abundance has decreased over the monitoring period at TN1. Abundacne at other sites generally remains low.
- Algae cover is generally low and epiphyte cover is high and variable.
- Sediment grain size and species composition relatively stable over monitoring period.
- Polychaete worms and gastropods were common.

Wanggoolba & Bennett's Creek

- Seagrass abundance has recovered significantly since it was lost in February 1999, the result of a major flood. Seagrass species composition relatively stable over monitoring period. These sites have not been examined since 2004 and current condition is unknown.
- Canopy height has continued to increase at the site in close correlation with seagrass abundance.
- Algae cover is relatively insignificant at these sites.
- Irregular epiphyte blooms occur at both sites from time to time.
- Sediment grain size appears to be less muddy, with more sand present.
- Dugong feeding was absent until late 2001, coinciding with seagrass recovery. Feeding trails are regularly observed across the meadows.

For more information on monitoring sites and to view latest graphs of data, visit www.seagrasswatch.org


Notes:

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A guide to the identification of seagrasses in Hervey Bay and the Great Sandy Strait

Adapted from *Waycott, M, McMahon, K, Mellors, J., Calladine, A., and Kleine, D (2004) A guide to tropical seagrasses in the Indo-West Pacific. (James Cook University Townsville) 72pp.*

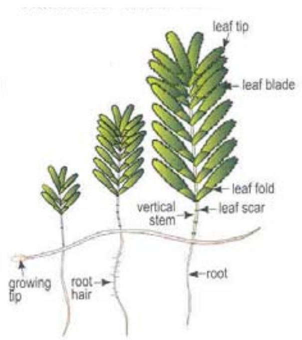
Leaves cylindrical

Syringodium isoetifolium

- Leaf tip pointed
- Leaves contain air cavities
- Inflorescence a "cyme"

Leaves oval to oblong

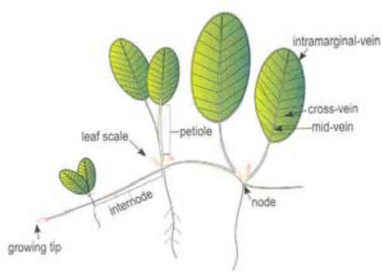
obvious vertical stem with more than 2 leaves



Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated

leaves with petioles, in pairs



Halophila ovalis

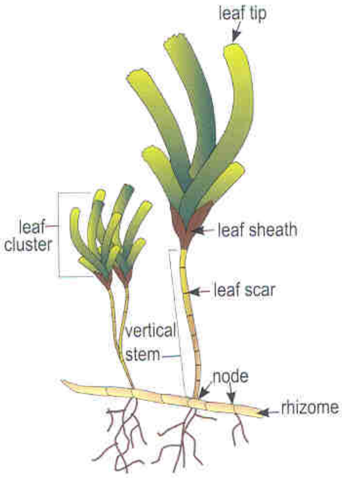
- cross veins more than 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Halophila decipiens

- leaf margins serrated
- fine hairs on both sides of leaf blade
- male & female flowers on same plant

Leaves strap-like

Leaves can arise from vertical stem



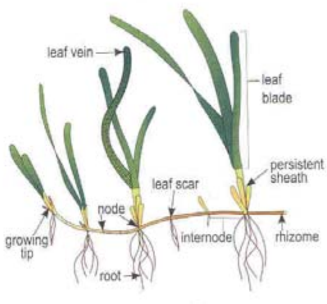
Cymodocea serrulata

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

Halodule uninervis

- Leaf tip tri-dentate or pointed, not rounded
- Leaf with 3 distinct parallel- veins, sheaths fibrous
- Rhizome usually white with small black fibres at the nodes

Leaves always arise directly from rhizome



Zostera muelleri subsp. *capricorni*

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

Monitoring a seagrass meadow

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

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

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

Seagrass-Watch

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

Seagrass-Watch is one of the largest seagrass monitoring programs in the world. Since it's genesis in 1998 in Australia, Seagrass-Watch has now expanded internationally to 20 countries. Monitoring is currently occurring at over 200 sites. To learn more about the program, visit www.seagrasswatch.org .

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

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

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

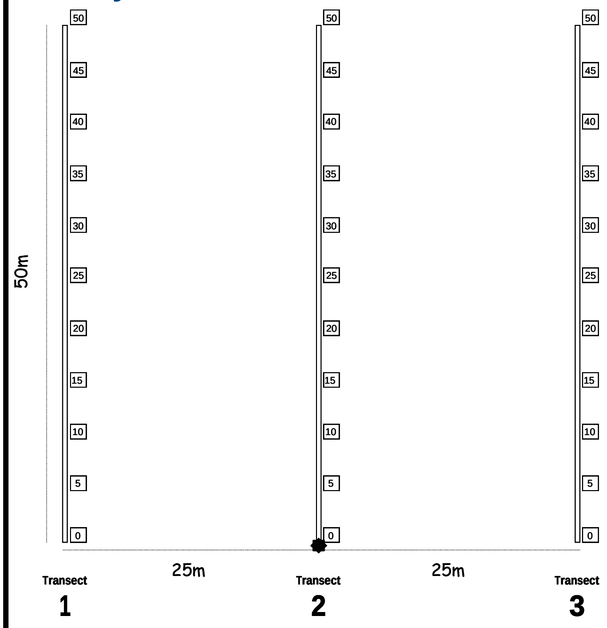
THE GOALS OF THE PROGRAM ARE:

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

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

e.g., PI1225 = Pigeon Is. site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Quarterly sampling

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

Step 1. Take a Photograph of the quadrat

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

Step 2. Describe sediment composition

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

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

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

Step 4. Estimate seagrass percent cover

- Estimate the total % cover of seagrass within the quadrat – use the percent cover photo standards as a guide.

Step 5. Estimate seagrass species composition

- Identify the species of seagrass within the quadrat and determine the percent contribution of each species to the cover. Use seagrass species identification keys provided.

Step 6. Measure canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

At completion of monitoring

Step 1. Check data sheets are filled in fully.

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

Step 2. Remove equipment from site

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

Step 3. Wash & pack gear

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

Step 4. Press any voucher seagrass specimens if collected

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

Step 5. Submit all data

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

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

Managing seagrass resources

Threats to seagrass habitats

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

Management

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

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

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

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

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

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

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

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

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

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

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

References

Aswani, S., Weiant, P. (2004). Scientific evaluation in women's participatory management: monitoring marine invertebrate refugia in the Solomon Islands. *Human Organisation* **63** (3), 301-319.

Bité, J.S., Campbell, S.J., McKenzie, L.J. and Coles, R.G. (2007). Chlorophyll fluorescence measures of seagrasses Halophila ovalis and Zostera capricorni reveal differences in response to experimental shading. *Marine Biology* **152**: 405–414.

Campbell, S.J. and McKenzie, L.J. (2004). Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. *Estuarine, Coastal and Shelf Science* **60**: 477-490.

Coles RG, McKenzie LJ and Campbell SJ. (2003). The seagrasses of eastern Australia. Chapter 11 In: World Atlas of Seagrasses. (EP Green and FT Short eds) Prepared by the UNEP World Conservation Monitoring Centre. (University of California Press, Berkeley. USA). Pp 119-133.

Conacher, C., Thorogood, J. and Boggon, T. (1999). Resurvey of long-term seagrass monitoring sites in the Great Sandy Strait and Tin Can Inlet: February 1999. Unpublished report to the Cooloola Fishermen's Festival Association Inc., Hervey Bay Seafood Festival Associated Inc. and the Heritage Trust. 26 pp.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil RV, Paruelo J, Raskin RG, Sutton P and van der Belt M. (1997). The Value of the world's ecosystem services and natural capital. *Nature* **387**(15): 253-260.

Dredge, M., Kirkman H., and Potter, M. (1977). A Short term Biological Survey. Tin Can Inlet/Great Sandy Strait. Division of Fisheries and Oceanography (CSIRO, Sydney). 29pp

Fisheries Research Consultants (1993). Aerial photographic survey of seagrasses: the Great Sandy Strait and Tin Can Inlet. Report prepared for the Queensland Department of Environment and Heritage.

Fisheries Research Consultants (1994). A re-survey of the seagrasses of the Great Sandy Strait and Tin Can Estuary, November 1993. Report prepared for the Queensland Department of Environment and Heritage. 34.pp.

Gaskell, J. (2003). Engaging science education within diverse cultures. *Curriculum Inquiry.* **33**: 235-249.

George, M., Innes, J., Ross, H. (2004). Managing sea country together: key issues for developing co-operative management for the Great Barrier Reef World Heritage Area. CRC Reef Research Centre Technical Report No 50, CRC Reef Research Centre Ltd, Townsville.

Green EP. and Short FT (Eds) (2003). World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. (University of California Press, Berkeley. USA). 298pp.

Hardin, G. (1968). The tragedy of the commons. *Science, New Series* **162** (3859), 1243-1248.

Johannes, R.E. (2002). The renaissance of community-based marine resource management in Oceania. *Annu. Rev. Ecol. Syst.* **33**: 317-340.

Lee Long WJ, Coles RG, Miller KJ, Vidler KP and Derbyshire KJ (1992). Seagrass beds and juvenile prawn and fish nursery grounds: Water Park Point to Hervey Bay, Queensland. *QDPI Information Series* QI92011. 39pp.

Lee Long WJ, Mellors JE and Coles RG (1993). Seagrasses between Cape York and Hervey Bay, Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**: 19-32.

Lennon, P. and Luck, P. (1990). Seagrass mapping using landsat TM data: a case study in southern Queensland. *Asian Pacific Remote Sensing Journal* **2**:2

Marsh, H. and Lawler, I. (2001) Dugong distribution and abundance in the southern Great Barrier Reef Marine Park and Hervey Bay: Results of an aerial survey in October- December 1999. Report to Great Barrier Reef Marine Park Authority.

McKenzie, L.J. (2000). Seagrass communities of Hervey Bay and the Great Sandy Strait - December 1998. Queensland Department of Primary Industries GIS.

McKenzie, L.J. and Campbell, S.J. (2003). Seagrass resources of the Booral Wetlands and the Great Sandy Strait: February/March 2002. *QDPI Information Series* QI03016 (DPI, Cairns) 28 pp

McKenzie, L.J., Roder, C.A., Roelofs, A.J. and Lee Long W.J. (2000). Post-flood monitoring of seagrsses in Hervey Bay and the Great Sandy Strait, 1999. *QDPI Information Series* No. QI00059, (QDPI, Brisbane) 46 pp.

McKenzie, L.J., Campbell, S.J., Vidler, K.E. & Mellors, J.E. (2007) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources. (Seagrass-Watch HQ, Cairns) 114pp

Middlebrook, R., Williamson, J.E. (2006). Social attitudes towards marine resource management in two Fijian villages. *Ecological Management & Restoration* **7** (2): 144-147.

Preen A.R., Lee Long W.J. and Coles R.G. (1995). Flood and cyclone related loss, and partial recovery, of more than 1000 km2 of seagrasses in Hervey Bay, Queensland, Australia. *Aquatic Botany* **52**:3-17.

Smyth, D., Fitzpatrick, J., Kwan, D. (2006). Towards the development of cultural indicators for marine resource management in Torres Strait. CRC Torres Strait, Townsville. 61 pp.

Turnbull, J. (2004). Explaining complexities of environmental management in developing countries: lessons from the Fiji Islands. *The Geographical Journal* **170** (1), 64–77.

Waycott, M, McMahon, K, Mellors, J., Calladine, A., and Kleine, D (2004) A guide to tropical seagrasses in the Indo-West Pacific. (James Cook University Townsville) 72pp.

Further reading:

Sheppard, J.K., Lawler, I.R. and Marsh, H. (2007). Seagrass as pasture for seacows: Landscape-level dugong habitat evaluation. *Estuarine, Coastal and Shelf Science* **71**: 117-132.

Carruthers TJB, Dennison WC, Longstaff BJ, Waycott M, Abal EG, McKenzie LJ and Lee Long WJ. (2002). Seagrass habitats of northeast Australia: models of key processes and controls. *Bulletin of Marine Science* **71**(3): 1153-1169.

Coles, R. G., McKenzie, L. J., Rasheed, M. A., Mellors, J. E., Taylor, H., Dew, K. McKenna, S., Sankey. T. L., Carter A. B. and Grech A. (2007). Status and Trends of seagrass in the Great Barrier Reef World Heritage Area: Results of monitoring in MTSRF project 1.1.3 Marine and Tropical Sciences Research Facility, Cairns (108 pp).

den Hartog C. (1970). The seagrasses of the world. (North-Holland Publishing, Amsterdam). 293pp.

Green EP and Short FT (Eds) (2003). World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. Uni California Press, Berkeley. USA. 298 pp.

Hemminga M and Duate CM. (2000). Seagrass ecology. United Kingdom: Cambridge University Press.

Kirkman H (1997). Seagrasses of Australia. Australia: State of the Environment .Technical Paper Series (Estuaries and the Sea), Department of the Environment, Canberra.

Lanyon JM, Limpus CJ and Marsh H. (1989). Dugongs and turtles: grazers in the seagrass system. In: Biology of Seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. (AWD Larkum, AJ McComb and SA Shepherd eds). (Elsevier: Amsterdam, New York). pp 610-34.

Larkum AWD, Orth RJ and Duarte CM (2006). Seagrasses: biology, ecology and conservation. Springer, The Netherlands. 691 pp.

Lee Long, W. J., Coles, R. G. & McKenzie, L. J. (2000) Issues for seagrass conservation management in Queensland. *Pacific Conservation Biology* 5, 321-328.

McKenzie LJ, Lee Long WJ, Coles RG and Roder CA. (2000). Seagrass-Watch: Community based monitoring of seagrass resources. Biol. Mar. Medit. 7(2): 393-396.

McMahon, K., Bengston-Nash, S., Mueller, J., Eaglesham, G. and Duke, N. (2003). Relationship between seagrass health and herbicide concentration in Hervey Bay and the Great Sandy Strait. Report to EPA, Queensland Parks and Wildlife, Maryborough. March 2003 (UQ, Brisbane).

McRoy CP and Helfferich C. (1977). Seagrass Ecosystems. Marcel Dekker, New York.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck Jr KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M and Williams SL. (2006). A Global Crisis for Seagrass Ecosystems. BioScience 56 (12): 987-996.

Phillips, R.C, E.G Menez. (1988). Seagrasses. Smithsonian Institution Press, Washington, D.C. 104 pp.

Poiner, I.R., Walker, D.I., and Coles, R.G. (1989). Regional Studies - Seagrass of Tropical Australia. In: Biology of Seagrasses. A.W.D. Larkurn, A-J. McComb and S.A.Shepherd (Eds). Elsevier, Amsterdam, New York; 841 pp.

Short FT and Coles RG. (Eds.) (2001). Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam. 473 pp.

Waycott M, Collier C, McMahon K, Ralph P, McKenzie L, Udy J and Grech A (2007) Vulnerability of seagrasses in the Great Barrier Reef to climate change. In Climate Change and the Great Barrier Reef, eds. Johnson JE and Marshall PA. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia. Part II, Chapter 8, pp 193-235.

We value your suggestions and any comments you may have to improve the Seagrass-Watch program.

Please complete the following statements in your own words

I found the Seagrass-Watch training to be ....

....

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What I enjoyed most about the training was..

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It could have been better if ....

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I did not realize that...

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Now I understand that ....

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In my area the types of seagrasses and habitats include..

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When I go back to my area, I will ....

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Other comments..

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