Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in Cape York Peninsula, Queensland

Yuku-Baja-Muliku Ranger Base, Archer Point, Queensland
24-25 July 2014

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First Published 2014

Disclaimer

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

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The correct citation of this document is

McKenzie, LJ & Yoshida, R.L. (2014). Proceedings of a workshop for monitoring seagrass habitats in Cape York Peninsula. Yuku-Baja-Muliku Ranger Base, Archer Point, Queensland, 24-25 July 2014 (Seagrass-Watch HQ, Cairns). 64pp.

Produced by Seagrass-Watch HQ

Front cover photos (left to right): Archer Point reef flat (Oct09) by Len McKenzie; connected coastal ecosystems (Archer Pt, Oct09); and dugong grazing trails (Archer Pt, Oct09) by Rudi Yoshida.

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We acknowledge the traditional custodians of the lands on which we conduct this workshop and our monitoring.

We pay our respects to ancestors and elders, past, present and future.

Overview

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is funded by the Threatened Species Division, Department of Environment & Heritage Protection (EHP), as part of the Indigenous sea country management project, and supported by the Yuku-Baja-Muliku Corporation and Seagrass-Watch HQ.

This workshop is for experienced participants who plan to lead seagrass monitoring at a site/location or conduct seagrass extension activities. As part of the Level 1 workshop we will:

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

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

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Photo: Fergus Kennedy

Workshop leaders

Len McKenzie

Len is a Principal Researcher with TropWATER (James Cook University) and Seagrass-Watch Program Leader. He is also the Manager of the Reef Rescue Marine Monitoring Program – Inshore Seagrass Monitoring and project leader for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 25 years experience as a researcher on seagrass ecology, assessment and fisheries habitats. This includes experience within Australia and internationally in seagrass research, resource mapping/ assessment and biodiversity. He has provided information on seagrass ecosystems that has been vital in management of seagrass resources of the Great Barrier Reef and at the state, national and international levels. He has also advised on fisheries and coastal resource-use issues for managers, fishing organisations, conservation and community groups. Len is a qualified trainer and assessor (TAE40110). Len is also the Secretary of the World Seagrass Association.

Current Projects

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

Rudi Yoshida

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

Current Projects

- Seagrass-Watch
- Reef Rescue Marine Monitoring Program: inshore seagrass

Agenda - Level 1 (basic)

Thursday 24th July 2014 (Yuku-Baja-Muliku Ranger Base, Archer Point)

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

Friday 25th July 2014 (Yuku-Baja-Muliku Ranger Base, Archer Point)

0930 – 0945 *(15min)*	Seagrass monitoring*
0945 - 1045 *(60min)*	Seagrass-Watch: how to sample*
1045 - 1100 *(15min)*	*Break*
1100 - 1200 *(60min)*	Seagrass-Watch: QAQC & how data is used*
1200 - 1215 *(15min)*	Risk assessment
1215 - 1300 *(45min)*	*Lunch* & relocate to field site
1315 - 1515 *(2hrs)*	**Field exercise:** Seagrass-Watch monitoring

Where: Archer Point (AP1)

What to bring:

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

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

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

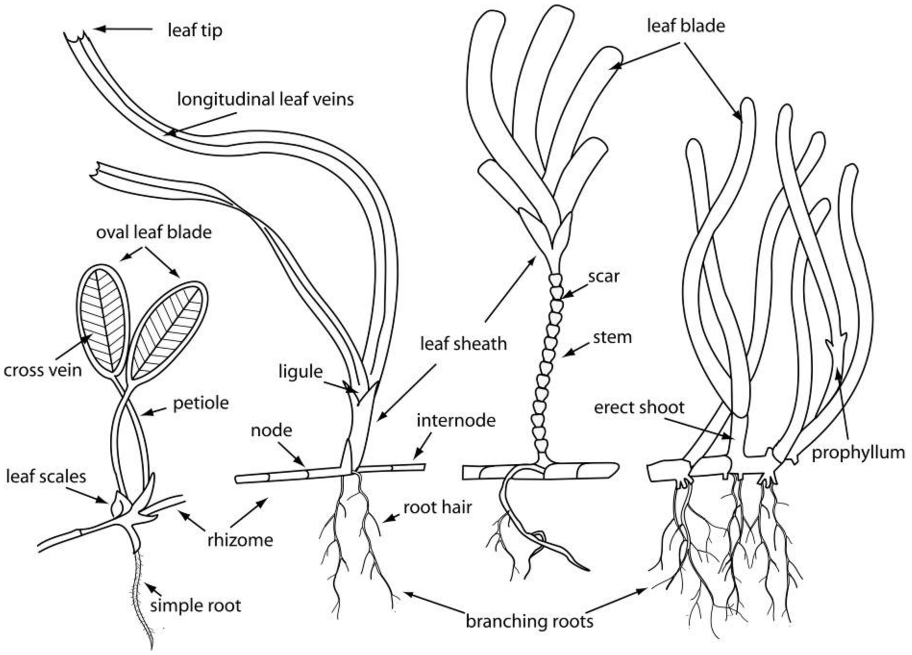
1515 - 1530 *(15min)*	Wrap up

Tide: 1416, 0.4m

Background

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

Seagrass are marine flowering plants



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

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

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

Seagrasses have roots, stems and leaves

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

They are called "seagrass" because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover) shape, a fern shape, a long spaghetti like leaf and a ribbon shape. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea, Thalassia, Thalassodendron, Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as **scars**.

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

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

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

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

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

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

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

Seagrass pump oxygen into the sediment via their roots

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

Seagrass have flowers, fruits and seeds

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

Pollination occurs in the water

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

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

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

Seagrass taxonomy

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

Seagrasses are not true grasses

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in at least 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.

Seagrasses are more closely related to lilies

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 (possibly up to 72) of seagrass. The highest concentration of species occurs in the Indo-West Pacific region.

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

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

Seagrass requirements for growth

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

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

Seagrasses need plenty of sun and clean water to grow.

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

Light availability is the most important factor determining seagrass growth

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

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO_2 concentration. The cause of thermal stress at higher temperatures (38°C to 42°C) is the disruption of electron transport activity via inactivation of the oxygen producing enzymes (proteins) of

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

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

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

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

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

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

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

Where are seagrasses found?

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

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

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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

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

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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

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

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

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 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.

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

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

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

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

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

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

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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

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

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

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

The value of seagrasses

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

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

What causes seagrass areas to change?

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

Seagrasses respond to natural variations in light availability, nutrient and trace element (iron) availability, grazing pressure, disease, weather patterns, and episodic floods and cyclones. The dynamic nature of seagrass meadows in

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

What threatens seagrass?

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

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

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

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

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

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

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

Coastal development can have a major impact on seagrass meadows

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

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

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

Seagrass of Cape York Peninsula

Updated from McKenzie and Yoshida, 2009

Cape York Peninsula (CYP) is the northernmost extremity of Australia, projecting into the Torres Strait between the Gulf of Carpentaria (west) and the Coral Sea (east). From its tip at Cape York it extends southward in Queensland for about 800 km, widening to its base, which spans 650 km from Cairns (east) to the Gilbert River (west). The larger rivers, all emptying into the gulf, are the Wenlock, Archer, Holroyd, Mitchell, Staaten, and Gilbert. Princess Charlotte Bay, in the northeast, is the deepest coastal indentation. The region has a monsoonal climate with distinct wet and dry seasons with mean annual rainfall ranging from 1715 mm (Starke region) to 2159 mm (Lockhart River airport). Most rain falls between December and April. Mean daily air temperatures in the area range between 19.2 – 32.1°C. The prevailing winds are from the south east and persist throughout the year (Earth Tech, 2005).

Cape York Peninsula is an area of exceptional conservation value and has cultural value of great significance to both Indigenous and non-Indigenous communities. The majority of the land is relatively undeveloped, therefore water entering the GBR lagoon is perceived to be of a high quality. Cattle station leases occupy about 52% of the total area, mostly located in central Cape York Peninsula but only around 33% are active leases. Indigenous land comprises about 22%, with a significant area of the West coast being held under Native title and other areas being under native title claim. The remainder is mostly declared as National Park including joint management areas with local traditional owners or under other conservations tenures e.g. nature refuges, conservation areas, wildlife reserves . Mining, agriculture, and commercial and recreational fishing are the major economic activities. All these activities have the potential to expand in this region and with this expansion the risk of increased pollutants.

Although no area on earth is unaffected by human influence, Cape York Peninsula is located in one of the least impacted regions globally (Halpern *et al.*, 2008). Northern Australia is part of the global centre for marine biodiversity. The drivers of anthropogenic change are much less in northern Australia than in the remainder of the Indo-Pacific. Australia as the only developed country in the region has a global responsibility for the conservation of marine biodiversity.

Extensive seagrass meadows are present in the waters surrounding Cape York Peninsula. (Coles *et al.*, 1985; Coles *et al.*, 1987; Lee Long *et al.*, 1993; Coles *et al.*, 1996; Coles *et al.*, 2000; Coles *et al.*, 2001b; Coles *et al.*, 2001a; Coles *et al.*, 2003; Coles *et al.*, 2004). The last broad-scale mapping of the east coast of Cape York occurred in 1984 and the west coast in 1986. More recently, broad scale surveys of intertidal seagrasses in the Gulf of Carpentaria was conducted as part of a larger survey from Kakadu (Northern Territory) to Thursday Island (Torres Strait) (Roelofs *et al.*, 2005). There has also been issued focussed fine scale mapping and monitoring is several locations, eg Weipa, Shelburne, Margaret, Bathurst Bay and Cape Flattery. Mapping across the CYCP has a number of limitations, due to the seasonality (spatial extent of seagrass varies with season), depth of survey extent and difficulties of accurate mapping and precise positioning in marine environments (McKenzie *et al.*, 2001). Initial mapping results from the CYP were first published in 1985. This data was re entered and validated in 2001 and is available in GIS formats (Coles *et al.*, 2001b; Coles *et al.*, 2001a).

Approximately 2,051 km^2 of seagrass meadows have been mapped in CYP in coastal waters down to 10m bMSL (McKenzie *et al.*, 2014). Seagrass meadows have been found from intertidal regions to depths of 60m near Lizard Islands (Coles *et al.*, 2000). These meadows were characterized by high diversity and relatively small total biomass (Lee Long *et al.*, 1993).

Cape York Peninsula's seagrass communities are amongst the richest in the world and are identified as having conservation significance (Earth Tech, 2005). Fifteen seagrass species have been identified in the CYP region: *Enhalus acoroides, Halodule pinifolia, Halodule uninervis,* *Halophila capricorni, Halophila decipiens, Halophila minor, Halophila ovalis, Halophila spinulosa, Halophila tricostata, Cymodocea rotundata, Cymodocea serrulata, Syringodium isoetifolium, Thalassia hemprichii, Thalassodendron ciliatum* and *Zostera muelleri* ssp. *capricorni* (hereafter referred to as *Zostera capricorni)*. Areas notable as species rich include Barrow Point to Murdoch Point (12 species), Flinders Island and Princess Charlotte Bay (9 species), Weymouth Bay, Cape Direction, Murdoch Point - Lookout Point and Bedford Bay - Cape Tribulation (8 species) and Escape River Margaret Bay, Bathurst Bay, Ninian River and Cape Flattery (7 species).

Halodule uninervis and *Halophila ovalis* are the most common species in coastal intertidal areas. *Cymodocea serrulata* and *Syringodium isoetifolium* are found in shallow subtidal areas that are sheltered from the south-east winds in a variety of habitats including estuaries and muddy bays and reef tops (Coles *et al.*, 1987; Lee Long *et al.*, 1993). Subtidal meadows of *Halophila ovalis* and *Halophila spinulosa* are also quite extensive (Lee Long *et al.*, 1993). Species common on coral reef platforms include *Cymodocea rotundata* and *Thalassia hemprichii,* generally around islands and on vegetated cays (Coles *et al.*, 2007). *Enhalus acoroides* is generally found as small isolated patches in sheltered embayments (Shepherd and Womersley, 1981; Coles *et al.*, 2003). Sites that have been revisited since the broadscale surveys in the mid 1980s show that seagrasses generally occurred in similar areas but when surveyed at a finer scale were more extensive (Coles *et al.*, 2007). As the majority of information for Cape York Peninsula comes from broadscale surveys, the area of recorded coastal seagrass for the region is likely to be an underestimate.

Most seagrass meadows are within coastal habitats in the CYP region. The majority of these meadows are in the shallow subtidal waters of large bays sheltered from the prevailing trade winds. In the CYP region there is little land-based influence with few major rivers. These seagrass meadows are also highly productive and provide important nursery grounds for fisheries (Coles *et al.*, 1985). The meadows are also of important to the large dugong population within the region (Marsh and R, 2002). A dominant influence on coastal habitats although small, is terrigenous runoff from seasonal rains, similar to the adjacent estuary habitats (Carruthers *et al.*, 2002). Episodic terrigenous runoff events result in pulses of increased turbidity, nutrients and a zone of reduced salinity in nearshore waters. The inter-tidal upper reaches of the meadows are limited by elevated temperatures and desiccation.

Reef-platform habitats are both subtidal and intertidal and support diverse seagrass assemblages. Approximately 3% of all mapped seagrass meadows in the eastern Cape York region are located on fringing-reefs (Coles *et al.*, 2007). Meadows are known to be found on mid shelf sand reefs (e.g., Corbett Reef (JCU Unpublished Data)) and smaller vegetated cays (e.g., Turtle Island Group), however no detailed mapping has been conducted. On fringing-reefs, physical disturbance from waves and swell and associated sediment movement primarily control seagrass growing in these habitats. Shallow unstable sediment, fluctuating temperature, and variable salinity in intertidal regions characterize these habitats. Sediment movement due to bioturbation and prevalent wave exposure creates an unstable environment where it is difficult for seagrass seedlings to establish or persist.

Seagrasses in deep water (>15m) have been sampled twice, once between 1994 and 1999 (Coles *et al.*, 2009) and again between 2003 and 2006 (Pitcher *et al.*, 2007). The modelled distribution of seagrass species for both time periods shows spatial discontinuities in deep water seagrass meadows along the north-south axis with a low probability of seagrass being present north of Princess Charlotte Bay and extensive seagrass areas in the south of the region extending out from the coast in the Lizard Island region (Coles *et al.*, 2009). *Halophila ovalis, Halophila spinulosa, Halophila tricostata, Halophila decipiens* and *Halophila capricorni* dominated the meadows in both surveys. The deep water comparisons are not true monitoring as they compare modelled distribution rather than actual meadow locations with the potential for unestimated error at small spatial scales. The comparisons for deep water are summarised and discussed in a separate report (De'ath *et al.*, 2007).

The distribution of deepwater seagrasses appears to be mainly influenced by water clarity and a combination of propagule dispersal, nutrient supply, and current stress. Deepwater seagrasses are uncommon north of Princess Charlotte Bay which may be result of the East Australian Current diverging at Princess Charlotte Bay and the far northern section may not receive propagules for colonisation from southern meadows (Coles et al., 2009). Much of this coast is also silica sand and low in rainfall and stream run-off, and it is possible that limited availability of nutrients restricts seagrass growth (Coles *et al.*, 2000).

Based on the mapped seagrass areas, 49% of coastal seagrass meadows on the eastern Cape York region are protected within declared Fish Habitat Areas (Coles *et al.*, 2007). Also on the east coast, approximately 33% of seagrass meadows (excluding deepwater) are covered by the highest levels of protection zones of the GBRWHA (Coles *et al.*, 2007).

A more detailed review of seagrass resources in CYP are presented below heading north from Cedar Bay on the east coast to Cape York and then south to Nassau River on the west coast.

Cedar Bay – Cooktown

There are two major rivers within the region: the Endeavour and the Annan River. Both rivers support commercial, recreational and indigenous fisheries. The Endeavour River is the larger of the two river systems and has a catchment area of approximately 992 km^2. The Annan River is located approximately 5 km south of Cooktown and extends inland from Walker Bay. The Annan River catchment area is approximately 850 km^2 (Hortle and Person, 1990). The Kuku Yalanji bama are the traditional people connected to country between Mowbray River (Port Douglas) and the Annan River.

Broad-scale mapping of the seagrass meadows in the region was conducted between 2-5 February 1985 as the final component of the Cape York to Cairns survey (Coles *et al.*, 1985).

In 2004- 2005, coastal seagrass meadows were remapped from Walsh Bay, south of Archer Point, to Lookout Point, north of Cape Flattery, as part of an EnviroFund project (C. Howley, Pers. Comm.).

Recently seagrasses on reef platforms in close proximity to river mouths (eg Annan River) and the shipping channel have been examined. Preliminary findings from Egret, Cowlishaw and Dawson reefs indicate that substantial seagrass meadows are present, particularly in areas where siltation is not heavy. For example, seagrass meadows dominated by *Halodule uninervis* and *Halophila ovalis* were reported from the NE side of Egret Reef in 2006 (1 - 8m depth). The sediments were fine silt over sand and the average seagrass percent cover was 1-2 % up to 15% (C. Howley, Pers. Comm.).

Archer Point

Intertidal seagrass meadows are located on a fringing reef platform in a protected section of the bay adjacent to Archer Point. Archer Point is monitored as part of the intertidal seagrass component of the Reef Rescue Marine Monitoring Program. The sites are dominated by *Halodule uninervis* and species composition has remained relatively stable over the past 12 months. The overall meadow distribution however, has increased (www.seagrasswatch.org).

Although seagrass cover has followed a seasonal trend over the last couple of years (higher abundance in late spring/early summer), overall the meadow has generally declined in abundance since monitoring was established in 2003. Fortunately, reproductive effort increased in 2007/2008, indicating the potential for the meadow to recover. Epiphyte and macro-algal cover were generally variable but appear to be declining over time (McKenzie *et al.*, 2008).

Nutrient analysis in this coastal fringing reef habitat indicate increasing Nitrogen in the sediments while Phosphate has been declining. Plant tissues indicate a habitat with improving light quality, a relatively small nutrient pool with Phosphate limitation. This is not surprising as the higher calcium carbonate sediments on a reef adsorb the Phosphate making it unavailable to plants for growth. No herbicides were detectable in the sediments at Archer Point in early 2008 (McKenzie *et al.*, 2008).

Walker Bay

Walker Bay is a relatively shallow bay protected from the SE swells by the rocky, mangrove covered, Grave Point and adjacent Draper Patch reef. The Annan River discharges into Walker Bay and is undoubtedly a major influence to the coastal environments and water quality. The predominant land use activities in the Annan River catchment are cattle grazing, timber extraction, aquaculture and agriculture. Although these land uses and practises have changed the nature of the Annan River catchment and tributaries, the system supports diverse habitats and provides an important corridor for the movement of a variety of fish species (Sheppard and Helmke, 1999). The tidal areas of the catchment support extensive marine plant communities including many species of mangrove, saltcouch and seagrasses.

The Cape York Marine Advisory Group (CYMAG) and South Cape York Catchments (SCYC) monitored ambient water quality in the Annan River between July 2002 and May 2009 and reported that river water quality was in good condition with very low contaminant levels (Howley, 2012).

Walker Bay contains a largest subtidal (2-4m deep) meadow which in February 1985 was dominated by *S. isoetifolium* with *C. serrulata/H. uninervis* (wide) (heavily epiphytised) (seagrass cover 80-100%) (Coles *et al.*, 1985; Coles *et al.*, 2001a).

In November-December 2004, the meadows were remapped in greater detail (C. Howley, Pres. Comm.). The meadow was more extensive (approximately 3.5 km^2), with more species present (incl. *Halophila spinulosa*) but similar in abundance. More recently (2007), it appears these meadows experienced a slight shift in species composition, from being dominated in areas by *Syringodium isoetifolium* to *Cymodocea serrulata*. As *Syringodium* is a species well adapted to disturbed environments (eg sediment movement), the species shift may represent a stabilisation of the seabed.

Quarantine Bay to Endeavour River

Between December 2004 – May 2005, coastal seagrass meadows were remapped in Quarantine bay to the mouth of the Endeavour River (C. Howley, Pers. Comm.). Extensive *Halodule uninervis* and *Halophila ovalis* meadows were mapped inshore and extending offshore. A smaller but dense meadow of *Syringodium isoetifolium* / *Halodule uninervis* was also found offshore.

Cooktown and Endeavour River

Cooktown is situated on the Endeavour River and is a 330 km drive north from Cairns. It has numerous natural, cultural and historical attractions for visitors to explore.

The Cape York Marine Advisory Group (CYMAG) and South Cape York Catchments (SCYC) monitored ambient water quality in the Endeavour River between July 2002 and May 2009 and reported that river water quality was in good condition with very low contaminant levels (Howley, 2012).

Results indicate elevated metals and hydrocarbons in sediment adjacent to town stormwater drain and boat slipway site with low levels of herbicides (diuron, simazine, and atrazine) in estuary during 2007 - 2008 wet season. Nutrient levels below the sewerage treatment plant do not appear elevated (Howley, 2012).

Shallow medium density (30-60% cover) *H. ovalis* meadows were mapped on the southern banks near the mouth of the Endeavour River between Racecourse and Chinaman Creeks in February 1985 (Coles *et al.*, 1985; Coles *et al.*, 2001a)

Between 9 November 2004 and 5 May 2005, seagrass meadows were mapped in the lower reaches and mouth of Endeavour River as part of the CYMAG mapping project in the region (C. Howley, Pers. Comm.). Isolated patches of sparse *Halophila ovalis* were present at the mouth of Chinaman Creek. A large meadow covered much of the northern intertidal bank of the river (Leprosy Creek, west of Point Saunders) with dense (50-75% cover) *Zostera capricorni* on the exposed banks and fringed by *Halophila ovalis* meadow (25-50% cover) along the river edge. At the mouth of the Endeavour River are extensive sandbanks. Adjacent to Sach's Spit was a narrow intertidal meadow of *Zostera capricorni* / *Halodule uninervis* fringed by *Halophila ovalis*. A large intertidal meadow of predominately *Halodule uninervis* with some *H. ovalis* was present on the northern portion of Sach's Spit (C. Howley, Pers. Comm.).


Sach's Spit (Endeavour River) seagrass meadow, 2005
courtesy C. Howley

A major dieback of several meadows located near the mouth of the Endeavour river was reported in July 2007. This included the loss the extensive *H. uninervis* mixed meadow from the sands near Sach's Spit, and a significant loss of density and leaf length at the *Zostera capricorni* meadow near Leprosy Creek (C. Howley, Pers. Comm.)). The cause of this dieback is unknown, however the herbicide clopyralid (0.28 mg/kg) was detected in sediments at Leprosy Creek in December 2007 (C. Howley, Pers. Comm.).

COOKTOWN TO CAPE FLATTERY

In this region the coastline includes large bays exposed to SE swells where the seabed is mainly mobile sands. Behind protected headlands the sediment is muddier and more stable. Prevailing wind patterns are typical for this section of the Queensland coast with strong south to south-easterly winds dominating the dry-season months and generally lighter northerly winds prevalent during the wet-season. The only significant coastal meadows are between Cape Bedford and Cape Flattery adjacent to Hopevale.

Broad-scale mapping of the seagrass meadows in the region was conducted on the 2 November 21984 and 2 February 1985 (Coles *et al.*, 1985). No seagrass meadows were found between the Endeavour River mouth and Cape Bedford.

In May 2005, seagrass meadows of *Halodule uninervis* and *Halophila ovalis* fringed much of the sandy bay south of Cape Bedford (C. Howley, Pers. Comm.).

Hope Vale

Hope Vale was established as a Lutheran Mission in 1949. The community covers an area of 110,000 hectares and is a Deed of Grant in Trust (DOGIT) land. Today's population is estimated at 856 (www.atsip.qld.gov.au), includes 13 clan groups with approximately 94% of the total population being of Aboriginal or Torres Strait Islander origin from various clans including the Dhuppi, Nukgal, Binthi, Thitharr, Dharrpa, Ngayumbarr-Ngayumbarr, Dingaal, Ngurrumungu, Thaanil, Gamaay, Ngaatha, Burunga . In addition to these clans, the community is made up of the Kuku Yimidhirr speaking peoples, the Yiidhuwarra (traditional owners of Barrow Point, Flinders Island, and the South Annan), the Bagaarrmugu, Muunthiwarra, Juunjuwaara and Muli peoples plus the Gan Gaarr and Bulgoon peoples to the south, the Kings Plain's Thukuun Warra and the Sunset Yulanji peoples in the Maytown area (www.cypda.com.au/hopevale).

North west of Cape Bedford is Elim Beach which is renowned for its coloured sands and as the original Cape Bedford Mission by the Lutheran Church in 1886 which later became the HopeVale community.

Seagrass meadows between Cape Bedford and Cape Flattery were first surveyed in November 1984. The seagrass meadows in this region are adjacent and slightly north of Morgan River. The meadows are very low cover (<1%) and patchy *H. decipiens* (sand) or *H. decipiens/H. ovalis* (mud/sand) (Coles *et al.*, 1985; Coles *et al.*, 2001a).

In July/August 2007 the region was remapped and extensive seagrass (wupan) meadows of *Halodule uninervis* and *Halophila ovalis* were found across much of the shallow/intertidal sand banks at Elim Beach (C. Howley, Pers. Comm.). These meadows were not reported in 1984 as the banks were not accessible due to the low tides. The meadows north of the Morgan River were also mapped in July 2007, however these were shallower than the 1984 surveys and dominated by *Halodule uninervis* and *Halophila ovalis* (C. Howley, Pers. Comm.).

CAPE FLATTERY REGION (CAPE FLATTERY TO LOOKOUT POINT)

Cape Flattery is a port which encloses an area of approximately 150 km^2 of marine habitat and include over 35 km of coastline. The area has two main creeks, Crystal Creek and Blackwater Creek, in a catchment area of approximately 114 km^2 (Ports Corporation of Queensland, 1995). The regions' climate is tropical and characterised by hot (wet) summers and warm (dry) winters. Prevailing wind patterns are typical for this section of the Queensland coast with strong south to south-easterly winds dominating the dry-season months and generally lighter northerly winds prevalent during the wet-season.

In 2004/05, the Port of Cape Flattery handled 29 ships carrying 1,300,672 tonnes of silica sand (www.pcq.com.au). Silica sand, extracted from the nearby Cape Bedford - Cape Flattery dune-field, is the ports' only export at present. The mine is owned and operated by Cape Flattery Silica Mines Pty Ltd. The silica sand mine is an open cut mine. Mined sand is transported to a processing mill and ultimately to the main export jetty on Cape Flattery via conveyor.

1111 ±200 ha of productive seagrass habitats have been identified between Cape Flattery and Lookout Point (Ayling *et al.*, 1997). Eight species of seagrasses, and three types of seagrass meadow have been identified;

- a predominantly *Halodule/Thalassia* meadow in the sandy intertidal area bordered by the shoreline and fringing coral reef.
- a small isolated high biomass *Cymodocea/Thalassia* meadow at the mouth of Crystal Creek in sand/mud sediment.
- a large *Halodule/Halophila* meadow in muddy sediment offshore from the fringing reef in deeper water.

Halophila ovalis was the most widely distributed species followed by *Halodule uninervis* (wide-leaf) and *Halodule uninervis* (narrow-leaf). *Syringodium isoetifolium* was found only in small isolated patches (Ayling *et al.*, 1997). No seagrass was found deeper than 7.5 m below Mean Sea Level (MSL). *Cymodocea* spp and *Thalassia hemprichii* were only found in shallow areas (<1.6 m below MSL) (Ayling *et al.*, 1997).

Evidence from dugong feeding trails indicates these seagrass meadows are also important feeding habitat for dugong.

Starcke River Region (Lookout Point to Barrow Point)

This is an area recognised for its sizeable dugong populations and associated seagrasses. Seagrasses have been reported along almost the entire coast of this region and from inter-reef waters in the vicinity of the Lizard Island group during a deep-water surveys of seagrasses (Coles *et al.*, 1985; Lee Long *et al.*, 1989; Coles *et al.*, 1996; Coles *et al.*, 2001a).

Coastal seagrass habitats between Lookout Point and Barrow Point were first surveyed in October and November 1984 as part of a study from Cairns to Cape York (Coles *et al.*, 1985; Coles *et al.*, 1987; Coles *et al.*, 2001a). Key seagrass areas along the same coastal region were re-surveyed in the following winter (July 1985). Between 17 - 22 September 1989, seagrass meadows in the area were once again surveyed along the coast and out to 28 m deep as results of dugong aerial surveys suggested the dugong population of the region was large and required an area of seagrass for feeding much larger than that estimated in 1984 (Lee Long *et al.*, 1989; Marsh, 1989).

In 1989, seagrass formed a near continuous seagrass meadow covering approximately 1,500km^2 extending from the coast between Lookout Point to Murdoch Point to depths of 28m (Lee Long *et al.*, 1989). Seagrass cover ranged from dense in shallow water to a patchy and light cover of *Halophila* species in deeper water. Seagrass was also found on every reef platform examined. Deepwater surveys between Cape Weymouth and Cape Tribulation in 1995 confirmed that seagrass meadows were still relatively continuous across the region (Coles *et al.*, 1996).

Eleven species of seagrass have been identified in the region. Seagrass cover is generally greatest, reaching 100%, in sheltered, shallow areas of the nearshore. At depths greater than 10 m in the mid-shelf seagrass cover is generally less than 50%.

From the lee (west) side of Lookout Point, a large *H. ovalis* and *H. spinulosa* meadow was reported extending along the sandy shore, becoming a wide, near-shore meadow of *H. spinulosa*, (80-100% cover) as the seabed becomes more muddy. This seagrass meadow continues three to four nautical miles south-east of the Starcke River (Lee Long *et al.*, 1989). Between the Starcke River and Murdoch Point seagrass is sparse, however between Murdoch Point and Red Point a dense (>50% cover) *H. spinulosa* meadow extends out to the Cole Islets, possibly a consequence of the improved water clarity (Lee Long *et al.*, 1989). Between the Cole Islets and Cape Bowen the seagrass meadows are mostly patchy and composed of *H. ovalis* and *H. uninervis* (10 to 50% cover). Seagrass cover is denser in sheltered shallow waters close to shore. North of Cape Bowen to Barrow Point the meadows are light (<1% cover) and predominately *H. ovalis* and *H. decipiens* on fine mud.

In the deeper waters (10 to 20 m) seagrasses are dominated by *H. ovalis* and *H. spinulosa.* At depths between 15 and 28 m, *H. ovalis* is more common than *H. spinulosa* and bottom cover generally less than 20% (Lee Long *et al.*, 1989).

The reef platforms of Jewell, Parke, Martin, Linnett and Ribbon Reef No 10 were examined in December 1994 as part of a survey of 18 reef-tops between Cape Weymouth and Cape

Tribulation. Meadows of *Halophila ovalis* (<2% cover) and *Thalassia hemprichii* (<1% cover) were reported from the reef-platforms of Parke and Martin Reefs respectively (JCU Unpublished data).

Lizard Island

The Lizard Island group is adjacent to the Starke River region. Price *et al.* (1976) first reported only two species of seagrass (*Cymodocea rotundata* and *Halophila minor*[1]) from the Lizard Island group in their checklist of marine benthic plants. The only other previously reported species for the group was *Thalassia hemprichii* (Nichols and Johns, 1985; Boon, 1986).

In October 1995 McKenzie *et al.*, (1997) mapped 292 ±78ha of intertidal and sub-tidal seagrass in the waters surrounding the Lizard Island Group. Seven seagrass species (1 previously undescribed) were identified in the survey area. *Thalassia hemprichii* was the most commonly encountered species, although it was restricted to the shallow reef-tops. *Halophila ovalis* was the second most commonly encountered species and was found in both intertidal and subtidal areas. Other species found in the survey area included *Halodule uninervis, Halophila spinulosa, Syringodium isoetifolium, Cymodocea serrulata* and *Halophila* sp. *H. ovalis* had the widest depth distribution and occurred at both the shallowest (0.4 m below MSL) and the deepest (4.4 m below MSL) sites where seagrass was found. Mean depths of occurrence for individuals species were mostly <15 m below mean sea level (McKenzie *et al.*, 1997).

A previously undescribed seagrass species, *Halophila* sp., was found in the survey area near Watson's Bay in depths >10 m below MSL. This species was similar to *Halophila capricorni* although several differences were noted. Significant anchor damage (scars) was observed in the seagrass meadows of Watson's Bay. Shallow-water (<10 m) scars showed evidence of recolonisation/recovery, however deep-water (>10 m) scars appeared recent, as there was little evidence of seagrass recovery.

Turtle Group

In November 1992 Derbyshire *et al.*, (1995) conducted a preliminary seagrass survey of reef-top, inshore and deepwater areas between the Turtle Island group and Mid Reef. They reported that seagrass meadows on deepwater and inshore areas were relatively dense, while reef-tops were only sparsely vegetated. Deepwater meadows were predominately *Halophila spinulosa* and *Halophila ovalis*. *Thalassia hemprichii* and *Halophila ovalis* sparsely covered the Mid Reef platform. Nearshore areas were mainly *Cymodocea serrulata* and *Halodule uninervis*.

Derbyshire *et al.*, (1995) established that seagrass meadows in the Turtle Islands group were habitat for commercial prawn species, although deepwater seagrass, despite its vast area, were not as productive as inshore seagrass meadows for commercial prawns. They found that inshore seagrass meadows had juvenile prawn densities several thousand times greater than those from deep water meadows. Their results found that in respect to juvenile prawn habitats, the value of seagrasses was inshore>reef-top>deepwater. The importance also differed for species of prawn, eg. reef-tops were more important for red spot king prawns, deepwater more important for blue endeavour prawns and inshore more important for tiger prawns (the most valuable and sought after species in the fishery) (Derbyshire *et al.*, 1995).

Although the deepwater meadows may not be important juvenile commercial prawn nursery habitat, they are very important feedings areas for the large dugong and turtle populations of the region.

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[1] *Halophila minor* was originally reported as *H. ovata*, but taxonomists now regard *H ovata* in the Indo-western Pacific as only present in the South China Sea and Micronesia (Kuo, J., 2000. Taxonomic notes on *Halophila minor* and *H. ovata*. *Biol. Mar. Medit.* **7**(2): 79-82.).

Miscellaneous reef platforms

Most information on reef platforms of this region are either from the September 1989 surveys (Lee Long *et al.*, 1989) or December 1994 where reef platforms were examined as an addition to deepwater surveys which were being conducted between Cape Weymouth and Cape Tribulation at the time (JCU Unpublished data).

Mid Reef platform has an extensive meadow of *H. ovalis*, with large patches of *T. hemprichii* and *C. rotundata*; Combe Reef platform is covered by light patches of *T. hemprichii, C. rotundata* and *H. ovalis*; Snake Reef has a light cover (<10%) of *T. hemprichii*; the two un-named reefs north of Combe Reef had mostly bare sand and coral rubble platforms but small patches of *H. ovalis* (10% cover) were found on soft, coarse sand on the back reef areas; Martin Reef had very light cover of *T. hemprichii* on sandy patches amongst coral rubble and algae; and Eyrie Reef, has a small area of *H. ovalis* (light cover) in the lee of Eagle Island (Lee Long *et al.*, 1989).

No seagrass was found on the reef-platforms of Davies Reef, Tydeman Reef or an un-named reef (GBRMPA # 14-034) in December 1994 (JCU Unpublished data). However, dense (40-100% cover) seagrass meadows (including *Thalassia hemprichii*, *Zostera capricorni, Halophila ovalis* and *Cymodocea rotundata*) were reported from the reef flat and back reef of Pipon Reef. Meadows of moderate cover (10-30%) *Halophila spinulosa* and *Halophila ovalis* were also reported in the shallow subtidal areas surrounding the bommies of Pipon Reef (JCU Unpublished data).

BARROW POINT TO CAPE MELVILLE

The only seagrass survey conducted in this region was 4th November 1984, when only 22 ground truth sites were examined (Coles *et al.*, 1985; Coles *et al.*, 2001a).

Extensive seagrass meadows were reported within Ninian Bay, which is protected from the SE trades by Barrow Point. The meadow are reported to be predominately *Halophila ovalis/Halophila decipiens/H. uninervis* (narrow) with *C. serrulata* and *S. isoetifolium* (50-80% cover) on coarse sand (Coles *et al.*, 1985; Coles *et al.*, 2001a)

A small but dense (80% cover) meadow dominated by *H. decipiens* with *C. serrulata/H. uninervis* (wide) and *S. isoetifolium* was reported present on the fringing reef north of North Bay Point (Coles *et al.*, 1985; Coles *et al.*, 2001a). Immediately seaward was a large extensive meadow of *C. serrulata* (20% cover) which extended north to Hales Island on the rocky rubble bottom protected from the SE trades by the shallow bank off North Bay Point.

BATHURST BAY & PRINCESS CHARLOTTE BAY

Similar to the region from Cape Melville and Lookout Point, this region has been recognised as an area of importance to the dugong populations of the Great Barrier Reef. As such, conservation park zones (dugong sanctuaries) have been in place in both Bathurst and Princess Charlotte Bays since the mid 1980’s. This zoning protects animals from extractive activities, especially fishing impacts including incidental capture in commercial gill nets (GBRMP Amendment Regulations 2002 (No. 5) 2002 NO. 209). Other significant impacts on the seagrasses in the region are from the adjacent land. The Normanby and North Kennedy Rivers flow into Princess Charlotte Bay (PCB), but no major catchment in Bathurst Bay.

This region was first surveyed during a broadscale survey between 5-7 November 1984 (Coles *et al.*, 1985; Coles *et al.*, 2001a). In May and November 1997 a detailed survey was conducted between Cape Rock (Bathurst Bay) and Port Stewart (PCB) to assess seagrass status in the senescent and growing seasons in response to possible changes in commercial gill netting in the region (Short, 1999). 34,984 hectares of seagrass was mapped in May and 37,345 hectares in November 1997. Most seagrass was within Bathurst Bay and the eastern and northern (surrounding the Cliff Islands) sections of PCB. From May to November there appeared to be a shift of seagrass away from the western side towards the eastern side of PCB. Approximately 75-80% of seagrass meadow area was subtidal, and this changed little between surveys (Short, 1999).

Eleven seagrass species were identified in the region (*Cymodocea serrulata, Cymodocea rotundata, Halodule pinifolia, Halodule uninervis* (thin and wide forms), *Halophila ovalis, Halophila tricostata, Halophila spinulosa, Halophila decipiens, Thalassia hemprichii* and *Syringodium isoetifolium*), however *Cymodocea rotundata* was absent in May 2007. In May the meadows of Bathurst Bay were dominated by either *Halophila decipiens, Cymodocea serrulata, Halophila ovalis, Halodule uninervis* (wide) or *Halophila spinulosa*. In November however there was a shift away from *Halophila decipiens* (Short, 1999).

Mixed *Halophila spinulosa*, *Halodule uninervis* and *Halophila ovalis* meadow, Bathurst Bay May 2007.
Photos: A Roelofs DPI&F

Overall, seagrass distribution was greater in November than May (approximately 2361 ha) and the proportion of meadows with abundance >25% cover was higher (only 4% of the seagrass meadow area had seagrass cover greater than 25% in May compared to 36% in November) (Short, 1999).

Nine seagrass species were found around the Flinders Group of islands, the largest number from a single sampling area reported in the CYP (Coles *et al.*, 1987). Not reported in the 1997 survey was *Halophila tricostata*, which was reported from the shallow waters (4m) of the Flinders Group of islands during the broadscale survey in 1984 (Coles *et al.*, 1987).

Seagrasses were examined at Corbett Reef during a reconnaissance survey in October 1994. Significant seagrass meadows of *Halophila ovalis* and *Thalassia hemprichii* were scattered over the shallow/intertidal sand platform (10-20% cover). Meadows of *Halophila ovalis* occurred along the back edge (<10% cover) and sparse (<1%) meadows of *Thalassia hemprichii* and *Halophila ovalis* were found in the back reef area. In the channels *Halophila spinulosa* and *Halophila ovalis* (10% cover) were also reported (JCU Unpublished data). No detailed mapping has been conducted of any reef-tops in this region.

CLAREMONT POINT TO OLIVE RIVER

This is a large region on the east coast of CYP and includes the narrowest section of the Great Barrier Reef where the outer edge is at its closest point to mainland Queensland. The region contains two large bays (Lloyd Bay and Temple Bay). The most significant settlements in this region include Lockhart River and Portland Roads.

Lockhart River was originally a Mission south of Cape Direction, opened in July 1924 by the Church of England under the Torres Strait Anglican Mission. When the Second World War broke out the Europeans left and the Aboriginal people were told to go back to the bush and fend for themselves. In 1947 the mission was re-established on Quintell Beach in Lloyd Bay, with drastic changes inflicted on how the people should live and behave. In particular, tribal groups were forced to combine into a single community. Administration of Lockhart River mission was transferred to the Queensland Government in May 1967. The government then tried to relocate the people to Bamaga. Refusing to go but in 1971, the people were forced to move away from the traditional area of the coast. No consideration was given to traditional owners of the land and this move resulted in much discontent and friction. On the 29 October 1987, pursuant to section 334 of the Land Act 1962, land was assigned to the Council under the Deed of Grant in Trust (DOGIT) (www.apunipima.org.au).

Coastal seagrass meadows in this region have only been mapped during the broadscale Cape York to Cairns survey in November 1984 (Coles *et al.*, 1985; Coles *et al.*, 2001a). A dense (30-80% cover) and extensive *Halophila spinulosa* with *Halophila ovalis*/*Halodule* spp. meadow and isolated patches *Cymodocea serrulata* were mapped in the shallow waters adjacent to the coast. Smaller and patchy *Halophila* spp./*Halodule uninervis* meadows were scattered along the sandy shallow areas of the coast north to Cape Direction. These meadows were generally low cover (<10%) (Coles *et al.*, 1985; Coles *et al.*, 2001a).

Seagrass in Lloyd Bay was associated with patch reefs or on the lee side of islands and headlands. The meadows were subtidal (3-10m), low cover (<10%) and generally dominated by *Halophila ovalis/H. decipiens/H. uninervis* with *H. spinulosa* (Coles *et al.*, 1985; Coles *et al.*, 2001a)

Immediately north of Lloyd Bay is Cape Weymouth and Restoration Island (significant as the first landfall of Captain William Bligh after he and his companions were forced into the long boat during the mutiny of the "Bounty" near Tahiti). A few kilometres further north is Portland Roads which until the 1980's used to have a large timber wharf used by the allies during World War 2 as a jump off point for the New Guinea campaign. The wharf was more recently blown up by the Navy because of its dilapidated condition. Portland Roads is a safe anchorage used by the fishing fleet and the motherships which supply them with fuel, water and stores, and unload their catch which is returned to Cairns for export.

North of Cape Weymouth the meadows in Weymouth Bay are dense isolated patches, found south of the Pascoe River. In 1984 these meadows were either *H. ovalis/H. uninervis* (wide) with *C. serrulata* or *H. uninervis* (wide)/*S. isoetifolium/H. ovalis* with *H. spinulosa* on mud substrates (Coles *et al.*, 1985; Coles *et al.*, 2001a). den Hartog, (1970) reported *Thalassodendron ciliatum* in the vicinity of Weymouth Bay, however it was not reported in 1984.

Large meadow of light seagrass cover (<10%) occurred in the southern regions of Temple Bay. These meadows were subtidal and dominated by *H. spinulosa* with *H. ovalis/Halodule* spp. Isolated patches of *H. ovalis/H. pinifolia* with *H. spinulosa* occur further north (Coles *et al.*, 1985; Coles *et al.*, 2001a).

Seagrass meadows have also been reported from some of the reef platforms in the region. During a survey in November 1994, seagrass was common on the mid shelf reefs examined. *Thalassia hemprichii* (<5% cover) was present in the lagoon between the isles and on reef flat of Sherrand Reef. On Blanchard Reef, *Thalassia hemprichii* (5% cover) was reported on the sandy reef platform and *Halophila decipiens* (<1%) in 1-10m off back of reef. On the un-named reef south of Ogilvie Reef (GBRMPA #13-077) *Thalassia hemprichii* (<5% cover) was present on the sandy reef platform (JCU Unpublished data).

Seagrass was generally absent from outer barrier reefs (including Tijou Reef, Sand Bank No 7, and the unnamed reefs 12-137 and 13-116), with the exception of Sand Bank No 8 where

Thalassia hemprichii (10% cover) was reported on the back reef and on the reef flat near the cay (JCU Unpublished data).

MARGARET BAY REGION (OLIVE RIVER AND DOUBLE [ETATAPUMA] POINT)

The Margaret Bay region has been described as an area of conservation significance and high wilderness value (Schneiders, 1999). This area contains two large bays, Margaret Bay and Shelburne Bay, as well as two main rivers, a large creek and a number of other unnamed smaller creeks and tributaries. Margaret Bay is north-west of Cape Grenville and approximately 10 km south-east of Shelburne Bay. Large intertidal flats stretch across both bays. The coastal wetland communities within this region are near pristine, and their associated catchments are virtually untouched by human development. The region has critical cultural significance to the Wuthathi people (Sheppard *et al.*, 2002).

Extensive seagrass meadows, which vary from dense (>50% cover) to sparse (<10% cover) occur across Margaret Bay. A large dense seagrass meadow was first identified by Coles *et al.* (1985) at the eastern end of Shelburne Bay during the broadscale survey from Cairns to Cape York in November 1984. Eight species of seagrass were found in these localities (Coles *et al.* 1987).

In August 2001, the fisheries resources of the Margaret Bay region were further investigated as part of declared Fish Habitat Areas (FHAs) in Queensland and to investigate the critical habitats adjacent to the inner shipping route (Sheppard *et al.*, 2002; Rasheed *et al.*, 2005). The survey area extended from Indian Bay (south of Cape Grenville) to Double Point in Shelburne Bay and included the Home Islands, Haggerston Island, Queue Reef, Cockburn Islands and Sunday Island. The fisheries resource assessment of the Margaret Bay region included investigations of marine plants (including seagrass), riparian vegetation and fisheries habitats.

5,623.0 ±843.4 ha of seagrass meadows were mapped in the region in August 2001, which comprised seagrass meadows in Margaret Bay (including Indian Bay) (2441.1 ± 374.2 ha), Shelburne Bay (3069.5 ± 405.9 ha), and the Home Islands (112.4 ± 63.3 ha) sections of the survey. Eight seagrass species were identified: *Cymodocea serrulata, Halodule uninervis, Syringodium isoetifolium, Enhalus acoroides, Halophila decipiens, Halophila ovalis, Halophila spinulosa* and *Thalassia hemprichii* (Sheppard *et al.*, 2002; Rasheed *et al.*, 2005). Seagrass resources in the Margaret Bay region are important in providing nursery habitats to juveniles of commercially important penaeid prawn species and regarded as highly important dugong habitat.

In August 2001 seagrass was found in all sections of the Margaret Bay region, mostly in the sheltered areas of the bays and on reef flats. Seagrass was identified on intertidal sand banks in Shelburne, Margaret and Indian bays, on intertidal reef flats in the Home Islands, and on sand/mud substrates in subtidal areas of western Shelburne Bay, Indian Bay and Margaret Bay. The most extensive cover of seagrass was in Margaret Bay, where seagrass was found in the majority of the subtidal habitat of the bay (Sheppard *et al.*, 2002; Rasheed *et al.*, 2005). Seagrass extended from the upper intertidal zone to 11.7m dbMSL in Margaret Bay, and to 9.0m dbMSL in Shelburne Bay. The seagrass species occurring at greatest depth in the Margaret Bay region were *Halophila spinulosa* and *Halophila decipiens*.

The majority of seagrass meadows (84% of total seagrass area) in the Margaret Bay region were low in seagrass cover (<10% cover) (Sheppard *et al.* 2002). Medium coverage seagrass meadows (10–50% cover) were found only in Margaret Bay and in the Home Islands, and no high coverage meadows (>50% cover) were identified (Sheppard *et al.*, 2002; Rasheed *et al.*, 2005).

The distribution of seagrass meadows in Margaret Bay in 1984 and in 2001 were remarkably similar, suggesting long-term stability in distribution and abundance for these meadows. Most of the differences in total meadow area between 1984 and 2001 may be attributed to different survey methodologies and additional seagrass meadows identified on the intertidal sand flats in Shelburne Bay in August 2001. These meadows were very sparse in above-ground biomass, were dominated by very narrow and small leaved seagrass species (*Halodule uninervis* (narrow leaf form) and *Halophila ovalis*), and were characterised by isolated patches of seagrass interspersed with large areas of unvegetated substrate (Sheppard *et al.*, 2002). Also, *Enhalus acoroides* was identified at locations in Margaret Bay, at Cape Grenville and in the Home Islands but was not found in the region in 1984 (Sheppard *et al.*, 2002).

Double Point to Mount Adolphus Island (Cape York)

The main feature of this region includes the Escape River and Newcastle Bay to the north and the scattered islands and reefs in the very north of the Great Barrier Reef World Heritage Area.

Coastal seagrass meadows in this region have only been mapped during the broadscale Cape York to Cairns survey in November 1984 (Coles *et al.*, 1985; Coles *et al.*, 2001a). Only a few patchy and isolated meadows were found along the sandy coast. They were generally *Halophila* (including *H. decipiens, H. ovalis, H. spinulosa*) and *Halodule uninervis* dominated. Several moderate but patchy meadows were found in the estuary of the Escape River, however very little seagrass was present in Newcastle Bay. In the Escape River mouth the meadows were mainly *H. ovalis* or *H. spinulosa* with *H. uninervis* (wide)/*C. serrulata* on the sand substrate, and *H. ovalis* with *Thalassia/H. uninervis* (wide) on the mud substrates. There were isolated patches of *Enhalus acoroides* on the mud banks.

Deepwater seagrasses were examined across the region in (De'ath *et al.*, 2008; Coles *et al.*, 2009). Deepwater seagrasses are generally sparse north of Princess Charlotte Bay and *H. decipiens* and *H. spinulosa* were reported scattered in the nearshore deepwaters, and in the lee of mid and outer reefs (Coles *et al.*, 2000; De'ath *et al.*, 2008; Coles *et al.*, 2009).

Albany Island to Punsand Bay

Coastal seagrass meadows in this region were first mapped during the broadscale Cape York to Tarrant Point survey in October 1986 (Coles *et al.*, 2001b). Intertidal seagrass meadows between Albany Island and Peak Point (Punsand Bay) were also examined in early April 2005 as part of an atlas on the Prince of Wales and Adolphus shipping channels in the Torres Strait (Rasheed *et al.*, 2006).

Dense (85-100%) meadows of *S. isoetifloium/ H. uninervis* (wide)/ *C. serrulata/ H. spinulosa* with *H. minor/ H. uninervis* (narrow)/ *H. ovalis* were mapped on the shallow sand/shell substrates between Bishop Point and Evans Point (including Shallow/Muddy Bay) in Oct06 (Rasheed *et al.*, 2006). Significant intertidal *Zostera* meadows were located in Somerset Bay in Albany Passage and in Shallow Bay west of Ida Island. An Enhalus acoroides meadow dominated the intertidal banks of Stover Bay in Albany Passage (Rasheed *et al.*, 2006).

In Punsand Bay a subtidal meadow dominated by *Halophila decipens* with *H. minor* was mapped on the sand substrate in 5-6m at the western edge in October 1986 (Coles *et al.*, 2001b). Inshore, a dense (>50% cover) meadow of *Cymodocea serrulata/ Halophila ovalis/Halodule uninervis/Halophila spinulosa* and *Syringodium isoetifolium* was reported in November 1998 (www.seagrasswatch.org/herbarium.html).

NORTH EASTERN GULF OF CARPENTARIA (BAMAGA TO NASSAU RIVER RIVER)

The Gulf of Carpentaria is a large, shallow, muddy marine bay shared between the Northern Territory and Queensland. The area has marked seasonality in temperature, rainfall, salinity and wind regimes. The dominant weather feature is a seasonal summer monsoon with associated northerly winds and rain (November through to March) and a very dry winter period with south-east trade winds (April to September). Seasonal temperatures range from 10 º C in winter (Poiner *et al.*, 1989) to the high 30's in summer. Tidal ranges vary from 2.4 m at Aurukun to 3.6 m at Crab Island in the north (Qld Transport Official Tide Tables and Boating Safety Guide 2002). Temperature, salinity, wind and rainfall show marked seasonality in this region. From June to September (Winter - Spring) winds are predominantly south-easterly, and from November through to April (Summer - Autumn), winds are generally north-western. It is during these months that the most rain falls associated with the monsoon trough.

The region is sparsely populated with the only major indigenous and non-indigenous populations located at Bamaga, Mapoon, Weipa, Napranum, Aurukun, Pormpuraaw, and Kowanyama (Cape York Regional Advisory Group, 1997). The only island in the region is Crab Island in the north (all other islands in the north are within the Torres Strait NRM).

The terrestrial areas of the Northern Gulf region are comprised of extensive areas of woodland (dominated by *Eucalyptus*, some *Acacia*, *Casuarina* and *Melaleuca*), with smaller areas of shrubland and open heath. Major rivers in the Northern Gulf region catchment include the Wenlock R., Jardine R., Archer R., Coen R. and Mitchell. The rivers are typically long and meandering and open on to a flat, dry coastline often with wide tidal wetlands of mangroves and salt-pans. Extensive freshwater wetlands occur along much of the coastline. Large, shallow saline lakes can be found at the Kirke and Love Rivers.

The Northern Gulf coastline is mostly low and open with very few bays. There are three large mangrove lined and protected estuaries at Aurukun, Weipa and Port Musgrave. Coral reefs occur patchily along much of the coastline and there are numerous offshore reefs and shoals. Intertidal sand and mud banks often extend 1-2 km from the coast. Relatively clear water can be found along much of this section of the coastline, especially from Weipa north. The open coastline to the south of Weipa tends to be heavily influenced by wind driven turbidity and wave energy.

The coastline of the eastern gulf is extremely shallow and regularly disturbed by prevailing winds. Sediments throughout the gulf are predominately fine muds, and these are easily resuspended due to the shallow bathymetry resulting in increased turbidity, which restricts seagrass distribution and growth (Coles *et al.*, 2004). Twelve species of seagrass have been found in the eastern Gulf of Carpentaria: *Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis* (wide- & narrow-leaf), *Halodule pinifolia, Syringodium isoetifolium, Enhalus acoroides, Halophila decipiens, Halophila minor, Halophila ovalis, Halophila spinulosa, Halophila tricostata* and *Thalassia hemprichii*.

The intertidal seagrasses of the Gulf of Carpentaria were first surveyed by aerial reconnaissance in October 1982 (Crab Island to Karumba) by CSIRO Division of Fisheries (Poiner *et al.*, 1987b). Following aerial surveys, areas identified as seagrass or unknown were ground truthed using divers. They estimated 18.7 km^2 of seagrass between Crab Island and Tarrant Point. They reported 10 species of seagrass in the eastern Gulf of Carpentaria and seagrass was confined to Crab Island, Port Musgrave, Albatross Bay and Archer Bay.

A more extensive survey of seagrass distribution and abundance in the inlets and bays of the eastern Gulf of Carpentaria ocurred during a broadscale survey between Albany Island and Tarrant Point from 21 October to 7 November, 1986. Approximately 185 km^2 of seagrass was present in 1986 (Coles *et al.*, 2001b).

Roelofs *et al.*, (2005) mapped approximately 93.26km^2 of intertidal meadows along the mainland coast from 19-20 November 2004 using helicopter. Most meadows across the region were aggregated patches, with relatively few continuous meadows. Fringing reef areas, open sandy beaches and less turbid water was reported found north of Aurukun. Extensive intertidal seagrass meadows were found at Aurukun and Weipa.

The extensive intertidal banks along the Gulf of Carpentaria coast have seagrass meadows that are a mixture of *Halodule* and *Halophila* species. *Syringodium isoetifolium* and *Cymodocea serrulata* are common subtidally and *Halophila ovalis* and *Halophila spinulosa* further offshore (Poiner *et al.*, 1989; Coles *et al.*, 2001b). Along the exposed eastern coast of the gulf, seagrasses are generally sparse and restricted to the lee side of islands, protected reef flats, estuaries and protected bays (Coles *et al.*, 2004). Seagrass species dominating meadows adjacent to the mainland coast are often considered to be pioneering or early colonists (*Halophila* and *Halodule* species). Little is know of the seagrass communities in waters greater than 10m depth. Species which are more common in deeper waters (10 metres and deeper) such as *Halophila decipiens* are however present throughout the gulf.

The 2004 intertidal survey (Roelofs *et al.*, 2005) and long - term studies of change in population density and structure which have been carried out associated with port activities in Weipa, Karumba and Kirke River suggest that the distribution of seagrass has remained similar to 1986 but is highly seasonal and declines are associated with flooding during the wet season (Roelofs *et al.*, 2001; Roelofs *et al.*, 2006). These studies suggest considerable interannual variability occurs (Rasheed *et al.*, 2001). Seagrass biomass is generally higher in the wet season than in the dry season. This difference in biomass is opposite to changes measured for seagrasses from the tropical east coast of Queensland (Mellors *et al.*, 1993; McKenzie, 1994; McKenzie *et al.*, 1998; Rasheed, 1999), but similar to seagrass seasonality measured at Karumba in the southern Gulf of Carpentaria (Rasheed *et al.*, 2001).

The following is a detailed review of information about seagrasses in specific regions between Bamaga and the Nassau River.

Bamaga & Jardine River

Seagrass meadows are found scattered along eh coast and on the reef flat of Crab Island. Reef flat communities in this region are dominated by *Thalassia*. Meadows in estuaries and sheltered bays are mostly of the genera *Halodule*, with *Cymodocea* and *Enhalus acoroides* (Coles *et al.*, 2001b).

Skardon

Skardon River was declared a port in February 2002 to service the Skardon River kaolin mine. The port facilities are located upstream on the shallow Skardon River. The Skardon River area includes a diverse range of ecologically important marine habitats such as mangroves, saltpans, rock bars, and marine swamps which are likely to support significant fisheries, estuarine crocodiles and green turtles (Roelofs *et al.*, 2002; Roelofs *et al.*, 2004).

Wet season (April 2002) and Dry season (September 2003) baseline marine habitat resources surveys have been conducted in the Port of Skardon River. An isolated *Halodule uninervis* (narrow form) meadow located approximately 2.4 km north of the port facilities on a sand/mud bank was reported during both surveys, however three sparse subtidal *Halophila decipiens* meadows area within 500 metres of the port facility were only reported during the Dry season (Roelofs *et al.*, 2002; Roelofs *et al.*, 2004).

In December 2006, the marine habitat resources were resurveyed as apart on an ongoing (every 3 years) monitoring program for the Port. Seagrass distribution in December 2006 (9.1ha) (Rasheed, 2007) was more than double that recorded in September 2003 (4.4ha)

(Roelofs *et al.*, 2004). Two moderate *Halophila decipiens* and a light *Halodule uninervis* (narrow) meadows were reported adjacent to the eastern bank of the river and a moderate *Halophila decipiens* meadow was reported adjacent to the western bank (south of the barge landing) (Rasheed, 2007). This was the first time that *Halodule uninervis* was found in the vicinity of the barge landing area. Previously *H. uninervis* had only been found in a nearby branch of the Skardon River (Roelofs *et al.*, 2004)

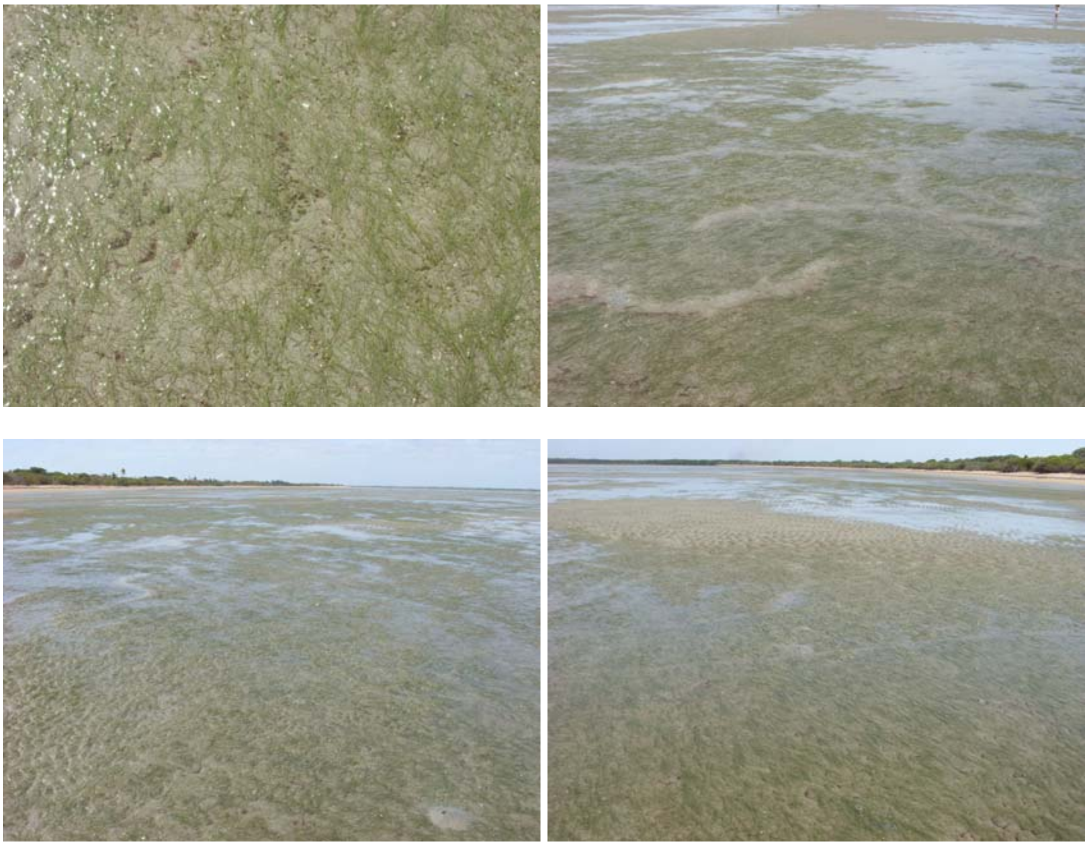
Port Musgrave

Port Musgrave is a shallow, almost enclosed, estuary, forming a bay on the western coast of the Cape York Peninsula. Two major rivers, the Wenlock and the Ducie, to the north and south respectively, discharge into it. The surrounding area is rich in freshwater swamps, while the estuary itself has tidal flats and mangroves. The small Aboriginal community of Mapoon lies on the southern shore of the bay.

Mapoon was declared a Deed of Grant in Trust (DOGIT) in 1998 and is held by a group of nominated trustees. An August 2001 Census stated that 197 persons gave their address of usual residence as Marpuna Community, with about 92 per cent of the total population being of Aboriginal or Torres Strait Islander origin.

Previous studies have identified significant areas of seagrass on the intertidal banks and subtidal waters at Port Musgrave (Coles *et al.*, 2001b). Of particular note, isolated patches of *Halophila tricostata*, a deepwater species and endemic to northern Australia, was found in 3-7m depth off the coast immediately north of Port Musgrave (Coles *et al.*, 2001b).

Meadows of *Halodule uninervis/Halodule pinifolia* and *Halophila ovalis* occur on the intertidal banks. *Enhalus acoroides* occurs in the shallow waters on the seaward edge of the banks, and *Halophila decipiens* is found in the deeper waters. The site is frequented by dugongs as lots of grazing trails have been observed (Christina Howley, Pers. Comm).



Mixed *Halodule uninervis* and *Halophila ovalis* meadow, Port Musgrave August 2008.
Photos: Christina Howley

Weipa

Located on the north-west coast of Cape York Peninsula, the Port of Weipa is principally involved in the export of bauxite. In 2004/05, the port handled 374 ships carrying 15,519,910 tonnes of bauxite, 64,701 tonnes of fuel and 22,052 tonnes of general cargo (www.pcq.com.au). The port is located within Albatross Bay, a large shallow bay fed by four rivers (Pine, Mission, Embley, and Hey). The rivers form an extensive estuarine system with a variety of habitats-including mud flats, seagrass beds, and mangroves- that support significant fisheries resources and populations of seabirds, dugongs, turtles and crocodiles.

Seagrass distribution and species composition was originally documented for Weipa during surveys by CSIRO in 1982 and 1989, during a broadscale survey by QDPI&F in 1986 (Coles *et al.*, 2001b; Coles *et al.*, 2004), and by WBM (1991) and Fisheries Research Consultants (1994) (Dames & Moore, 1995). Collectively, the surveys found up to six seagrass species in meadows located in the Embley, Hey and Mission Rivers and in an area south of Pine River Bay. No seagrasses were mapped in Pine River Bay.

In September 2000, a detailed survey of seagrass meadows in the region mapped 4688 ±418 ha, an area of seagrass larger than in previous surveys of the Port of Weipa; 680 ha in October 1982; 2225 hectares (ha) in October 1986 to 4653 (±422) ha in September 2000 (Poiner *et al.*, 1987a; Coles *et al.*, 2001b; Rasheed *et al.*, 2001; Roelofs *et al.*, 2001). One additional seagrass species, *Syringodium isoetifolium,* was found during the September 2000 survey that was not found previous. *Halophila minor* was not found in the 2000 survey, however Waycott *et al.*, (2004) consider *H. minor* to be part of the *H. ovalis* complex of closely related entities whose leaves are highly plastic especially in relation to blade size, shape, colour, and texture (Waycott *et al.*, 2002).

Since the baseline survey in 2000, annual monitoring has been conducted by the Ports Corporation of Queensland (PCQ) to ensure port activities have a minimal impact on the marine environment with special emphasis on sensitive fisheries habitat, particularly seagrass meadows. Due to the large area of the port, long term monitoring focuses on seagrass meadows located near port and shipping infrastructure and activities *(the Intensive Monitoring Area or IMA*). In August / September each year all seagrass meadows within the IMA are mapped. A selection of “core monitoring meadows” representing the range of seagrass meadow communities in the region are assessed for biomass and species composition. At the time of the IMA survey, an aerial reconnaissance of seagrasses in the greater port limits is conducted with re-mapping of the entire port limits occurring every 3 years (i.e. 2002, 2005 and 2008).

Results of the September 2008 indicated that total seagrass meadow area (3289 ±52 ha) and landscape cover for the greater port limits remained at similar levels to the 2005 survey, however significantly lower than the 2001 and 2002 baselines (Chartrand and Rasheed, 2009). The most significant change within the greater port limits was a change in species diversity in many for the meadows from mixed-species to mono-specific seagrass in 2008.

Nevertheless, monitoring indicates that seagrass habitat in the Port of Weipa were in a moderate condition (Chartrand and Rasheed, 2009). There have been declines in density for a number of meadows compared with the previous eight years of monitoring, particularly for intertidal *Enhalus acoroides* meadows. The observed changes appeared to be partly a response to regional and local climate conditions, however other drivers including anthropogenic factors cannot be discounted. Meadows dominated by *Halodule uninervis* (narrow) had some declines in abundance, however these were generally within the ranges of previous years (Chartrand and Rasheed, 2009).

A survey at the southern reaches of Albatross Bay from the northern end of Boyd Bay to Pera Head in September 2007 reported seagrass occurring as a single continuous meadow of dense

Halodule uninervis (narrow) with *Halophila decipiens* in a coastal strip adjacent to the beach in Boyd Bay (Marine Ecology Consulting, 2007).

Kirke/Love

The Kirke and Love Rivers are located south of the Aboriginal Community of Aurukun. Both rivers have large saline lakes and extensive associated seasonal wetlands. Terrain surrounding the rivers is typically flat, allowing saline tidal influence to extend several kilometres upstream, especially in the dry-season.

Seagrasses in the Love and Kirke rivers were first mapped in October 1986 as part of the broadscale seagrass survey of the Gulf of Carpentaria (Coles *et al.*, 2001b). They recorded the presence of seagrass in the saline lakes of both rivers and identified two species: *Halodule pinifolia* and *Halophila ovalis*.

In August 1999 the seagrasses of the Kirke and Love Rivers were mapped using a helicopter as part of an investigation by the DPI&F on the suitability of the area as a Fish Habitat Area (Rasheed, 2000). No seagrass was found in the Kirke River. Seagrass was confined to six small *Halodule pinifolia* meadows along the edges of shallow intertidal banks in the Love River lake with a total area of 7.614 ± 1.48 hectares (Rasheed, 2000; Sheppard *et al.*, 2000). Rasheed, (2000) however, suggested that the absence of seagrass in August 1999 was due to a prolonged period of freshwater inundation from floods in 1999 and that seagrass are likely to grow in the region when habitat conditions are more optimal for seagrass growth.

A resurvey of the Kirke River region was undertaken during April and September 2001 to examine the presence or absence of seagrass in both wet season and dry season conditions. Seagrass was absent in the Kirke River in April 2001, however two *Halodule pinifolia* meadows with a total area of 22.5 ±1.9 hectares were mapped along the edges of the shallow intertidal banks in the Kirke River lake in September 2001 (Sheppard et al., 2000, Appendix 2).

Cape Keerweer to the Nassau River

No seagrass has been recorded in the coastal area between Cape Keerweer and the Nassua River mouth in the south.

THREATS

The CYP region is an area rich in flora and fauna species. It is highly regarded by the Australian and the international community as one of the least impacted regions globally and deserves the highest amount of environmental protection available. The significance of the region to the cultural and natural heritage of Cape York's indigenous communities cannot be understated. The wilderness areas of the region are crucial to their health, well-being and traditional knowledge. Management of this region will need to be mindful of the traditional habitants.

Mining, agriculture, shipping tourism and commercial and recreational fishing are the major economic activities in CYP. All have potential to expand in this region, however, overall threat level to CYP seagrass habitats is currently low. The low level of urban, agricultural and industrial development means threats are localised to port areas where a greater number of potential harmful activities can occur. Threats at these urban and industrial locations include the potential for increased nutrient runoff, port access dredging operations and port infrastructure development along the foreshore. Most threats to seagrass meadows in this region would be largely climate related, eg cyclones. There is potential for sea level rise, thermal damage to seagrasses, and algae blooms smothering meadows if global climate change predictions become real (Coles *et al.*, 2007).

Nevertheless, the CYP community perceive the greatest threats to their seagrass meadows to be from the passage of large ships during low tides resuspending sediment plumes in their wakes, sediment erosion associated with dirt roads (and improper road construction), erosion in river catchments, disturbance from trawling and oil or chemical spills. Of potential concern would be unchecked increased levels of extractive mining and the development of pastoral areas for horticulture within the region. These activities can greatly increase the amount of sediment/turbidity and pollutants associated with runoff produced after the monsoon rains. Oil spillage from large vessels possibly represents the single biggest point source pollution threat to the Great Barrier Reef in this region (Haynes et al., 2001).

SEAGRASS-WATCH IN THE CAPE YORK NRM REGION

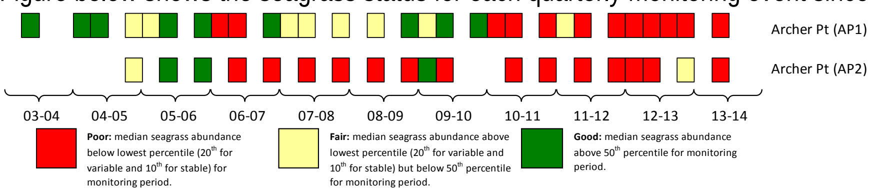
To provide an early warning of change, long-term monitoring has been established at a number of locations across eastern Cape York as part of the Seagrass-Watch, global seagrass assessment and monitoring program (www.seagrasswatch.org) (McKenzie *et al.*, 2000). Establishing a network of monitoring sites in Cape York region provides valuable information on temporal trends in the health status of seagrass meadows in the region and provides a tool for decision-makers in adopting protective measures. The following is a summary of the current status of Seagrass-Watch monitoring in the eastern Cape York region.

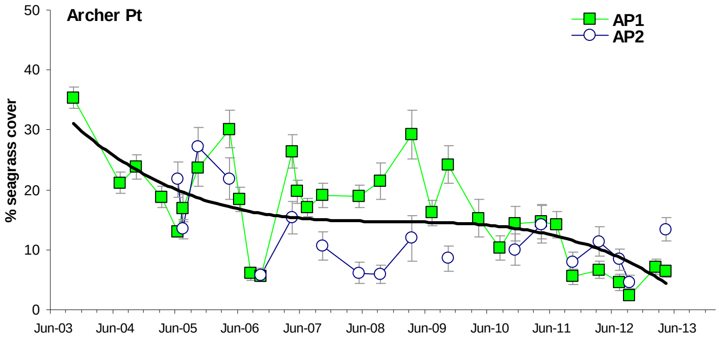
Archer Point

Monitoring: ongoing
Principal watchers: Christina Howley, Jason Carroll, Larissa Hale and Yuku-Baja-Muliku rangers
Occasional and past watchers: John McLaren, Seagrass-Watch HQ
Location: fringing reef flat in protected section of bay, boarded by mangroves, approximately 15km south of Cooktown
Site codes: AP1, AP2
YP1 position: S15.60832 E145.31894 (heading: 125 degrees)
YP2 position: S15.60875 E145.31847 (heading: 125 degrees)
Best tides: <0.5m Cooktown (Port 58940)
Issues: Storm water & land runoff, shipping
Comments: Popular recreational fishing area and turtle feeding grounds.

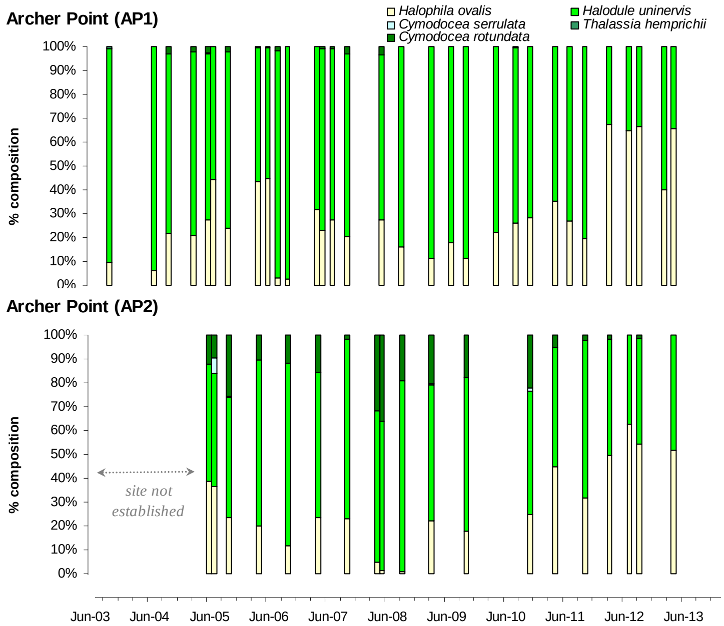
Status (July 2013):

- Seagrass cover long-term average was between 16% in winter (Dry) and 19% in late Dry season.
- Seagrass cover at AP1 has generally followed a seasonal trend with higher abundance in late spring/early summer. However, the seasonal trend is apparent at AP2 as sampling frequency is not quarterly.
- Although the meadow abundance has fluctuated between year, overall their is a declining trend since 2009, reaching lowest levels in 2012.
- Figure below shows the seagrass status for each quarterly monitoring event since October 2003.

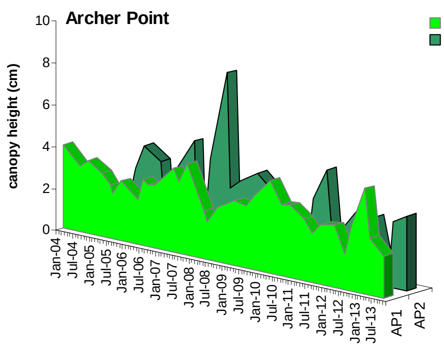




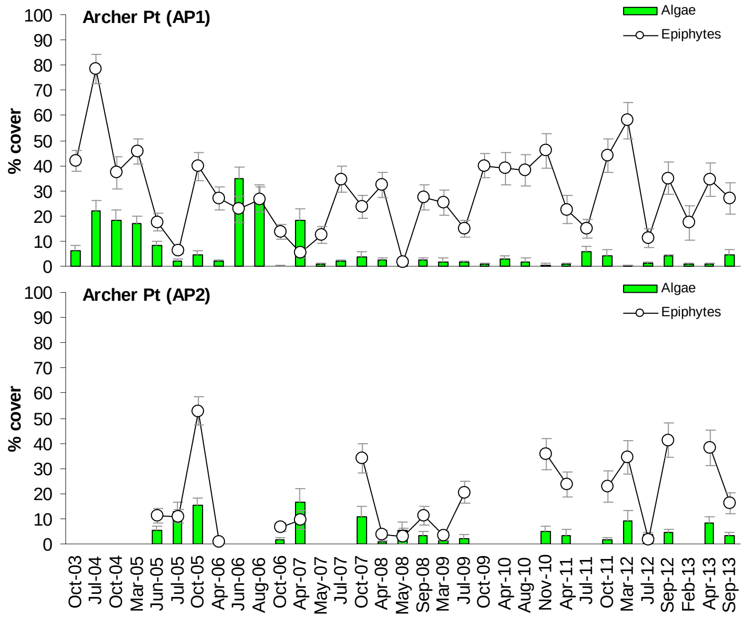
- The sites were dominated by *Halodule uninervis, Halophila ovalis* and *Cymodocea rotundata*
- Although sites are only 50m apart, AP2 has slightly more *Cymodocea* and *Thalassia* present.
- Species composition has varied since sampling began in 2003 with the composition of *Halophila ovalis* increasing since 2010; coinciding with significant losses in abundance. Increased composition of the colonising/ephemeral *Halophila ovalis* indicates high levels of disturbance and subsequent recovery.



- Seagrass canopy height shows a clear season pattern - correlating with abundance of *Halodule uninervis*.
- Canopy height is slightly higher at AP1 than AP2.



- Epiphyte cover on seagrass leaves has fluctuated greatly over the last decade.
- Epiphyte cover has continued to remain high and generally above the GBR long-term average since 2009.
- Macroalgae generally increases in spring/early summer, but has remained well below the GBR long-term average for reef habitats since 2006.

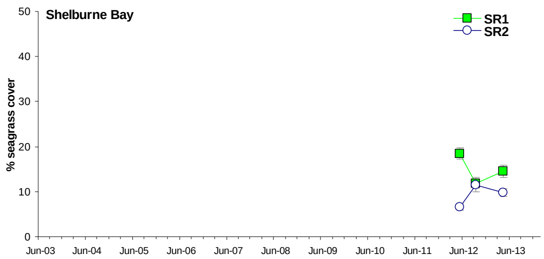


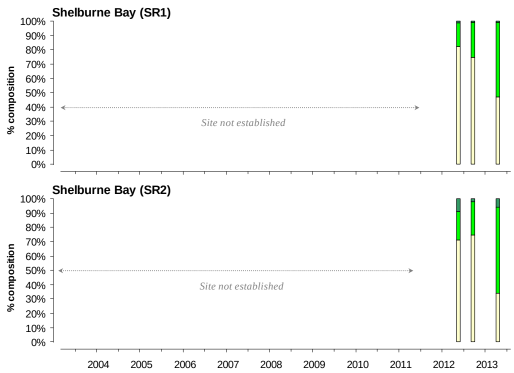
Shelburne Bay

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Location: coastal habitat on land sand banks
Site codes: SR1, SR2
SR1 position: S11.88722 E142.91419 (heading: 0 degrees)
SR2 position: S11.88751 E142.91563 (heading: 0 degrees)
Best tides: <0.7m Leggatt Is (Round Point, Port 58601)
Issues: nil

Status (July 2013):

- Location only established in May 2012
- Three species of seagrass are present at Shelburne Bay: *Halodule uninervis, Halophila ovalis* and *Thalassia hemprichii*
- Dugong grazing trails often observed across meadows.
- Insufficient data to describe long-term trends





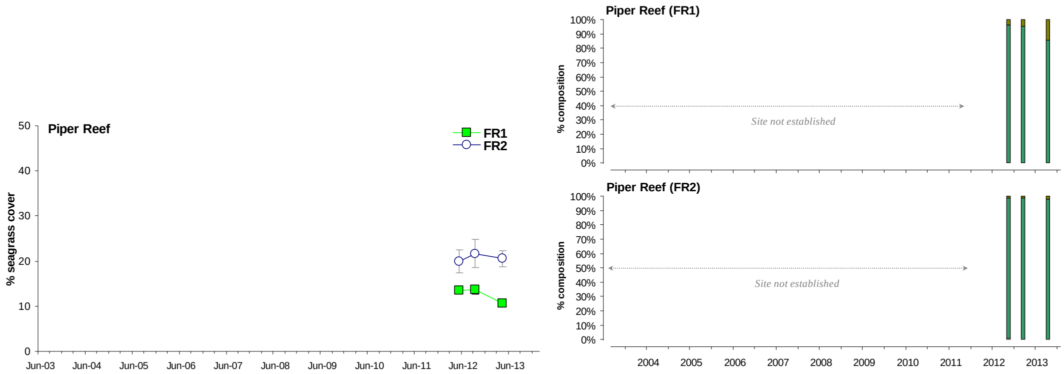
Piper Reef

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Location: on reef platform adjacent to Fisher Island
Site codes: FR1, FR2
FR1 position: S12.25586 E143.23366 (heading: 0 degrees)
FR2 position: S12.25746 E143.23642 (heading: 0 degrees)

Best tides: <0.7m Kay Reef (port 58655)
Issues: shipping

Status (July 2013):

- Location only established in May 2012
- Three species of seagrass are present at Piper Reef: *Thalassia hemprichii, Cymodocea rotundata and Halophila ovalis*.
- Insufficient data to describe long-term trends

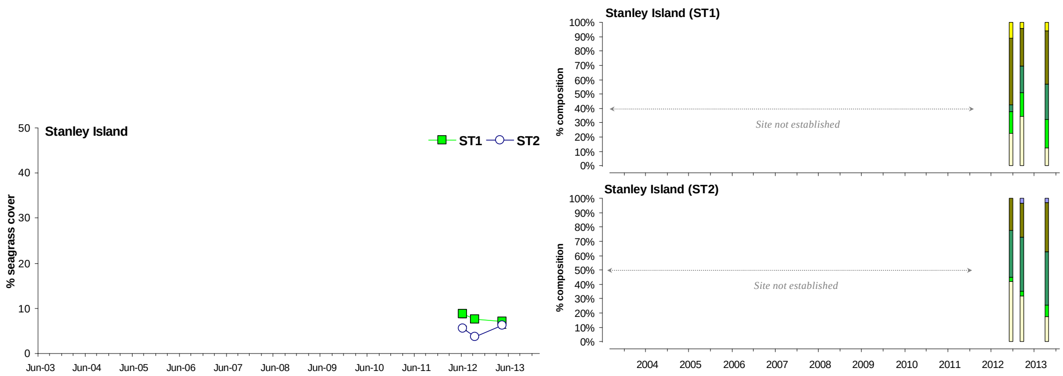


Stanley Island

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Location: fringing reef flat on north east of island
Site codes: ST1, ST 2
ST1 position: S14.14293 E144.24466 (heading: 0 degrees)
ST 2 position: S14.14245 E144.24314 (heading: 0 degrees)
Best tides: <0.7m Flinders Is (Port 58800)
Issues: runoff from Normanby River catchment

Status (July 2013):

- Location only established in June 2012
- Three species of seagrass are present at Stanley Island: *Thalassia hemprichii, Cymodocea rotundata and Halophila ovalis*.
- Insufficient data to describe long-term trends



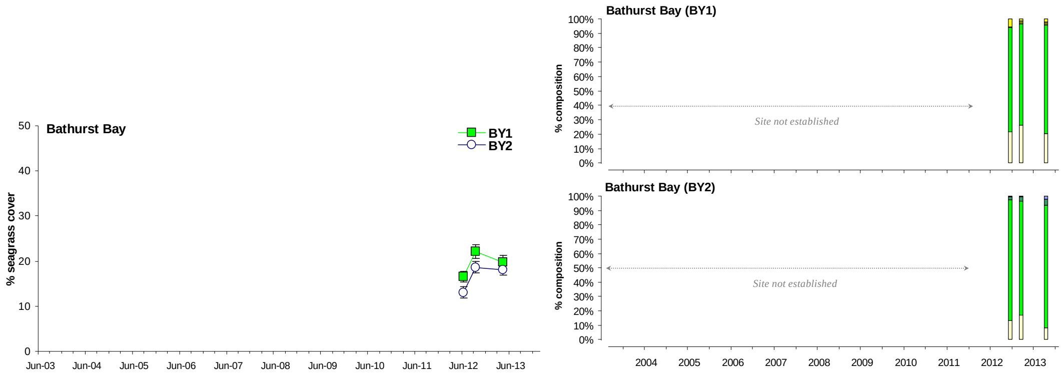
Bathurst Bay

Monitoring: ongoing
Principal watchers: Seagrass-Watch HQ
Location: coastal sandbank in sheltered aby
Site codes: BY1, BY2
BY1 position: S14.26803 E144.23268 (heading: 0 degrees)
BY2 position: S14.26770 E144.23160 (heading: 0 degrees)

Best tides: <0.7m Flinders Is (Port 58800)
Issues: runoff from Normanby River catchment and future coastal development

Status (July 2013):

- Location only established in June 2012
- Five species of seagrass are present at Bathurst Bay: Halodule uninervis, *Halophila ovalis, Thalassia hemprichii, Cymodocea rotundata and Syringodium isoetifolium*.
- Insufficient data to describe long-term trends

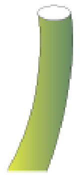


For more information, visit http://www.seagrasswatch.org/cooktown.html

A guide to the identification of Cape York seagrasses

Adapted from *Waycott et al., 2004.*

Leaves cylindrical



cylindrical

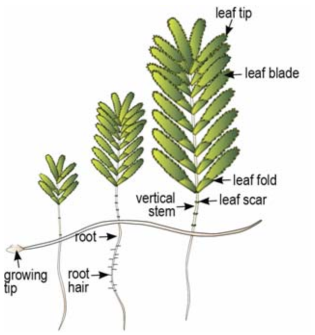
Syringodium isoetifolium

- leaves taper to a point
- leaves contain air cavities
- leaves 7-30cm long

Leaves oval to oblong

oval to oblong

obvious vertical stem with more than 2 leaves



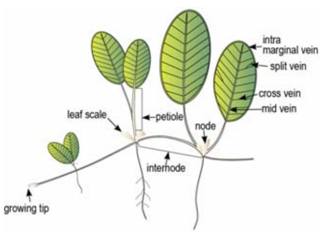
Halophila spinulosa

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

Halophila tricostata

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

leaves with petioles, in pairs



Halophila capricorni

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

Halophila decipiens

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

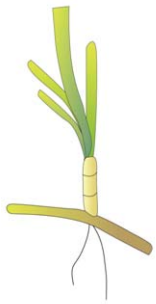
Halophila minor

- less than 8 pairs of cross veins
- leaf 5-15mm long and 3.5-6mm wide
- leaf margins smooth
- no leaf hairs

Halophila ovalis

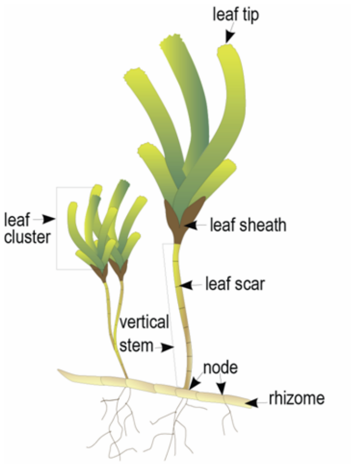
- cross veins 8 or more pairs
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

Leaves strap-like



straplike

Leaves can arise from vertical stem



Cymodocea rotundata

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

Cymodocea serrulata

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

Halodule uninervis

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

Halodule pinifolia

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

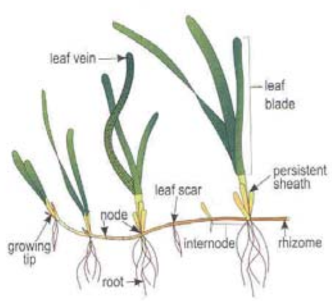
Thalassia hemprichii

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

Thalassodendron ciliatum

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

Leaves always arise directly from rhizome



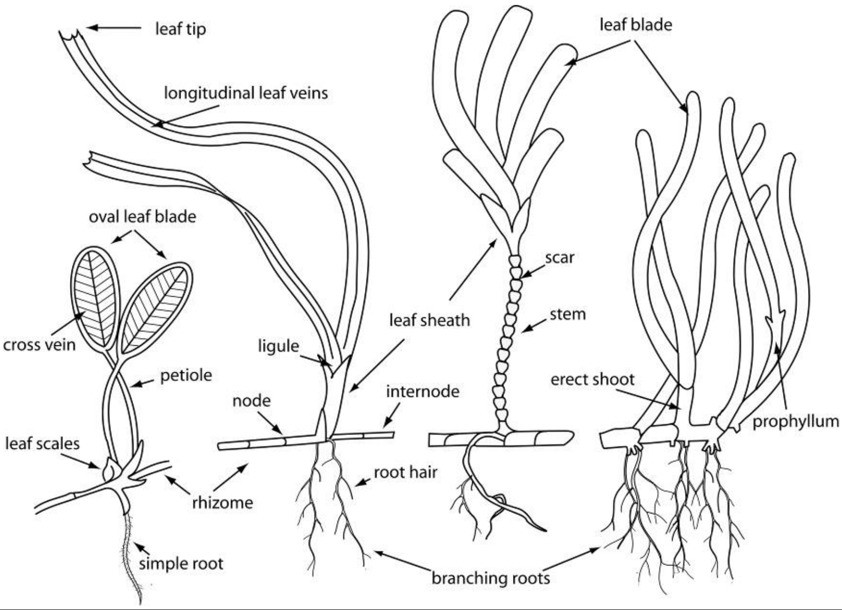
Enhalus acoroides

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

Zostera muelleri subsp. *capricorni*

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

Parts of a seagrass plant



Leaf

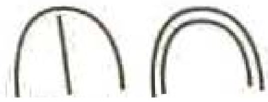
Tip

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

Veins

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

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



Edges

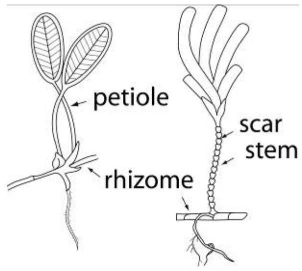
The edges of the leaf can be either serrated, smooth or inrolled

Sheath

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

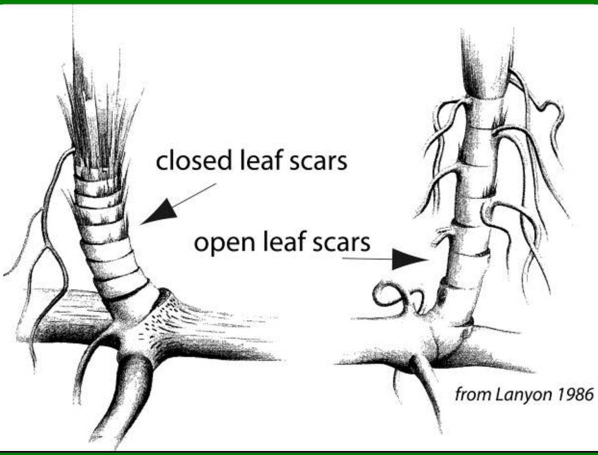
Attachment

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



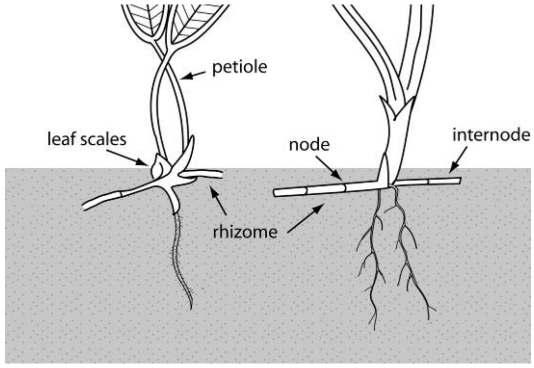
Stem

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



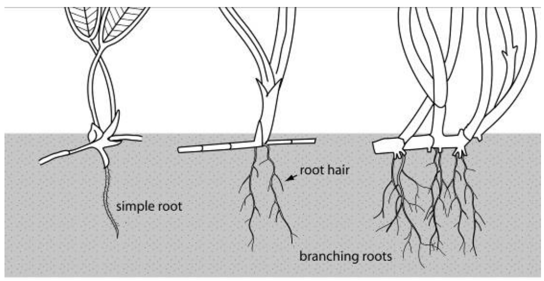
Rhizome

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



Root

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



Notes:

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Monitoring a seagrass meadow

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

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

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

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

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

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

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

Monitoring seagrass

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

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

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

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

Seagrass-Watch

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

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

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

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

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

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

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

Ongoing standardisation of observers is achieved by on-site refreshers of standard percentage covers by all observers prior to monitoring and through *ad hoc* comparisons of data returned from duplicate surveys (e.g. either a site or a transect will be repeated by Seagrass-Watch HQ – preferably the next day and unknown to volunteers). Any discrepancy in these duplicates is used to identify and subsequently mitigate bias. For the most part, uncertainties in percentage cover or species identification are mitigated in the field via direct communication (as at least one experienced/certified observer is always present), or the collection of voucher specimens (to be checked under microscope and pressed in herbarium) and the use of a digital camera to record images (protocol requires at least 27% of quadrats are photographed) for later identification and discussion.

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

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

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

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

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

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

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

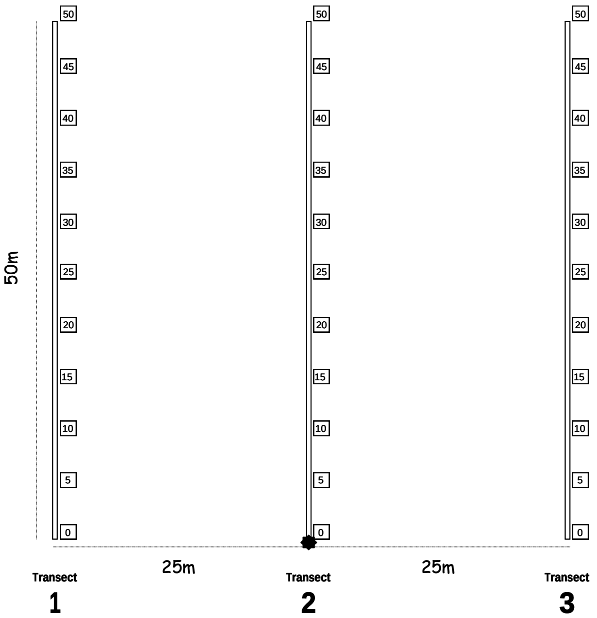
THE GOALS OF THE PROGRAM ARE:

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

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

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

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Each sampling event

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

Step 1. Take a Photograph of the quadrat

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

Step 2. Describe sediment composition

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

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

- Note and count (whole numbers - never use < or > symbols) any features which may be of interest (e.g. gastropods, hermit crabs, turtle feeding) within the comments column.

Step 4. Estimate seagrass percent cover

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

Step 5. Estimate seagrass species composition

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

Step 6. Measure seagrass canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

Step 10. Move to next quadrat

- Repeat steps 1 to 8 for the remaining 32 quadrats

Step 11. At completion of monitoring

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

At completion of monitoring

Step 1. Wash & pack gear

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

Step 2. Press any voucher seagrass specimens if collected

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

Step 3. Submit all data

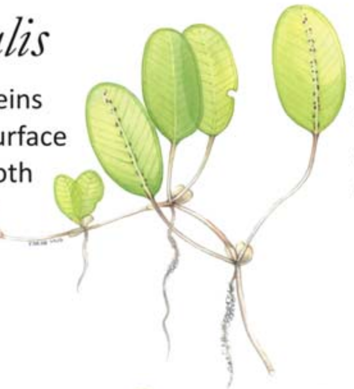
- Data can be entered into the MS-Excel file downloadable from www.seagrasswatch.org. Email completed files to **hq@seagrasswatch.org**
- Mail original datasheets, photos and herbarium sheets

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

SEAGRASS SPECIES CODES

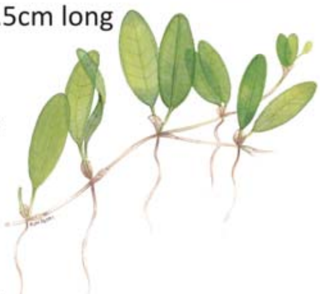
Ho
Halophila ovalis

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



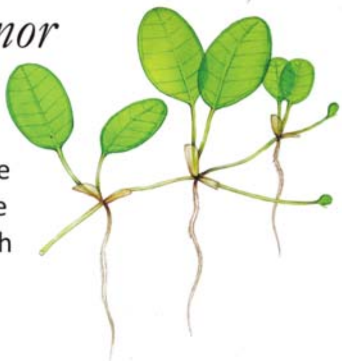
Hd
Halophila decipiens

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



Hm
Halophila minor

- less than 8 pairs of cross veins
- small oval leaf blade less than 5mm wide
- leaf margins smooth
- no leaf hairs



Hu
Halodule uninervis

- flat leaf, 0.25-5mm wide
- trident leaf tip
- 1 central vein
- usually pale rhizome, with clean black leaf scars

Cs
Cymodocea serrulata

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

Hs
Halophila spinulosa

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

Si
Syringodium isoetifolium

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

Zc
Zostera muelleri subsp. *capricorni*

- flat leaf, 2-5mm wide
- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- leaf grows directly from rhizome ie no stem
- rhizome usually brown or yellow in younger parts

SEAGRASS-WATCH MONITORING

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

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

START of transect (GPS reading)
Latitude: 25° 11.2878 ' S **Longitude:** 152° 37.5372 ' E

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: HO	HU	ZC		water	Canopy height (cm)	% Algae cover	% Epi-cover
1 (0m)	Sand	SC x 3 HC x 1		40	30	70			0	5,4,7	5	33
2 (5m)	S	GAS x 3	✓	33	50	50			0	10,7,8	10	18
3 (10m)	mud/sand	worm x 1		18	70	20	10		0	6,8,5	0	48
4 (15m)	m/s	DFT x 1		0					0	0	17	0
5 (20m)	m/s/shell	HC x 3		36	5	90	5		1cm	9,7,5	12	57
6 (25m)	m/s/sh	–	✓	48	100				1cm	NA.	2	96
7 (30m)	Fine Sand	Turtle cropping		0					1.5cm	0	23	0
8 (35m)	FS	SC x 2		0.7		100			2cm	7,7,7	18	31
9 (40m)	s/m	CH x 3		23	96	4			2cm	2,4,6	6	17
10 (45m)	m	Mud whelk x 2 HC x 1	✓	41	2	95	3		2cm	5.5,6 9	3	21
11 (50m)	m/s			16	3	7	90		2cm	7,6,7	38	6

END of transect (GPS reading)
Latitude: 25° 11.2656 ' S **Longitude:** 152° 37.5546 ' E

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

Making a herbarium press specimen

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

Collection

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

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

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

Pressing

Tools

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

Preparation

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

Arrangement

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

Labels

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

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

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

Drying

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

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

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

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

Mounting

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

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

HERBARIA

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

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

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

Understanding sediment

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

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

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

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

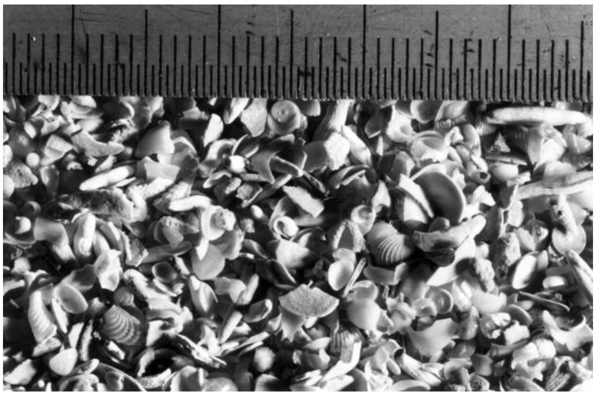
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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

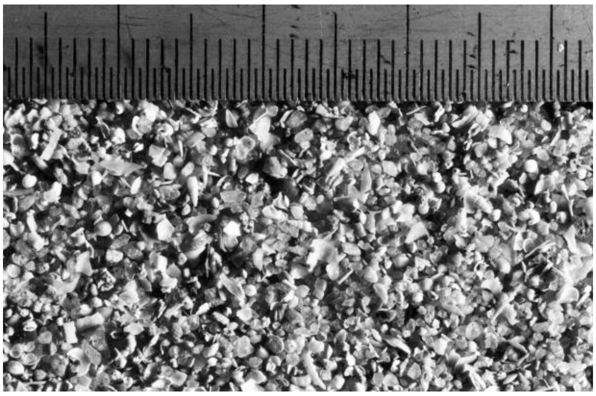
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

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

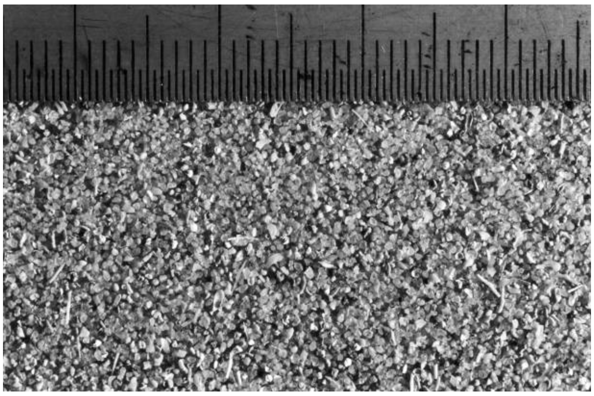
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments McKenzie, 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf.



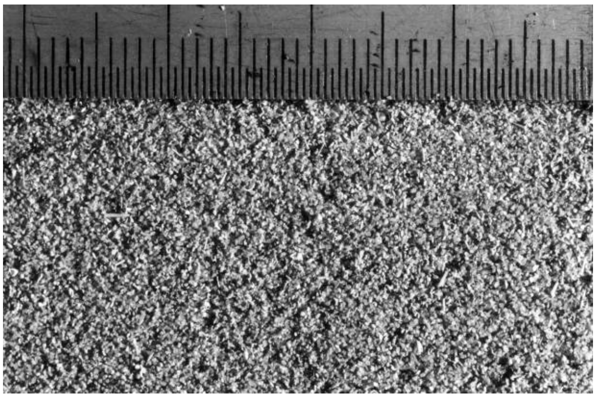
gravel (>2mm)



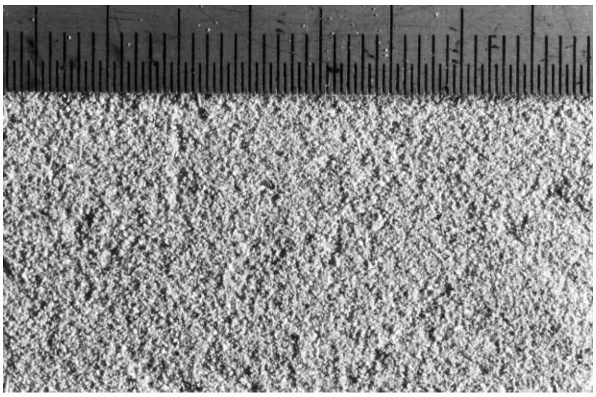
very coarse sand (1 – 2 mm)



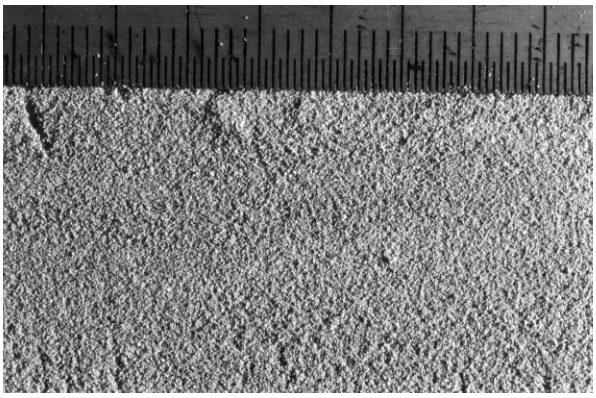
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

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Managing seagrass resources

Threats to seagrass habitats

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

Management

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

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

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

Reactive (on-ground)

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

Prescriptive (legal)

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

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

Non-prescriptive (planning & education)

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

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

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

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

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

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

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

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

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

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

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Useful web links

Seagrass-Watch Official Site www.seagrasswatch.org

Seagrass Adventures Interactive website designed by students from Bentley Park College in Cairns (Australia). Website includes games, puzzles and quizzes for students to learn about seagrass and their importance. www.reef.crc.org.au/seagrass/index.html

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

Seagrass Outreach Partnership Excellent website on seagrass of Florida. Provides some background information on seagrasses and has a great section with educational products and Seagrass Activity Kit for schools. www.flseagrass.org

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

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

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

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

Western Australian Seagrass Webpage Mainly focused on Western Australian research, but provides some general information and links to international seagrass sites. wwwscience.murdoch.edu.au/centres/others/seagrass/

UNEP - World Conservation Monitoring Centre Explains the relationship between coral reefs, mangroves and seagrasses and contains world distribution maps. www.unep-wcmc.org

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