SEAGRASS-WATCH

Guidelines for Monitoring Seagrass Habitats in the Torres Strait

Thursday Island
4th -8th March 2009

Jane Mellors & Len McKenzie
Seagrass-Watch HQ
Department of Primary Industries & Fisheries, Queensland

Seagrass-Watch

Queensland Government
Department of Primary Industries and Fisheries

Tagai College

Torres Strait Regional Authority

First Published 2009

Disclaimer

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

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

The correct citation of this document is
Mellors, JE and McKenzie, L.J. (2009). Seagrass-Watch: Guidelines for Monitoring Seagrass Habitats. Proceedings of a workshop held on Thursday Island, Torres Strait. March 4-8, 2009 (Seagrass-Watch, Townsville: 58pp)

Produced by Seagrass-Watch HQ, DPI&F Townsville

Front Cover Artwork Jared Turner

Enquires with regard to these proceedings should be directed to:
Jane Mellors
Seagrass-Watch Scientist
DPI&F North Office,
PO Box1085
Townsville, QLD 4810 Australia

Table of Contents

Overview

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

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

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

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

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

Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assessing 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. Protection of the valuable seagrass meadows along our coasts, requires everyone to 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 being hosted by the TSRA's Land & Sea Management Unit, Tagai College, Seagrass-Watch HQ, and the Queensland Department of Primary Industries and Fisheries as a key component in the delivery of the Seagrass Monitoring Project funded under the Torres Strait Caring for our Country Regional Investment Strategy (RIS) 2008-09).

Workshop Participants will

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

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

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

or visit

www.seagrasswatch.org

Workshop Presenter

Jane Mellors

- Jane is a Fisheries Biologist with the Queensland Department of Primary Industries & Fisheries. Jane has over 20 years experience in seagrass related research and monitoring. She is the project Leader for the Seagrass-Watch component of the Seagrass Monitoring Project funded under the Torres Strait Caring for our Country Regional Investment Strategy. Jane is a specialist in tropical seagrass eco-physiology, seagrass taxonomy and geochemistry of marine sediments pertaining to seagrass meadow communities. Jane completed her Doctorate (Dept TESAG, James Cook University) on sediment and nutrient dynamics in coastal intertidal seagrass meadows of north eastern Australia of North Queensland. She is a co-author of *A guide to tropical seagrasses of the Indo-west Pacific* and Treasurer f the World Seagrass Association Inc.

Current Projects

- Torres Strait Seagrass Monitoring Project
- Seagrass-Watch

Agenda

Wednesday March 4, 2009 - Workshop

Morning	8:30 - 8:50*(20min)*	Finalise registration
	8:50 - 9:00 *(10mins)*	Acknowledgments and Welcome – *Jane Mellors and Pearson Wigness*
	9:00 – 9:15 *(15mins)*	Introduction to Workshop and Seagrass-Watch
	9:15 - 9:45 *(30mins)*	Seagrass Biology and Identification –
	9:45 - 10:15 *(30mins)*	*Activity 1: Identifying Seagrass*
	10:15 – 10:25 (*10mins)*	How to prepare a seagrass press specimen
	10:25 – 10:45(*15mins*)	*Activity 2: Pressing seagrass*
	10:45 – 11:00*(20mins)*	*Morning Tea*
	11:00-12:00 *(60mins)*	Seagrass Ecology, Threats and Management
	12:00 -12:15 *(15min)*	Seagrass Monitoring
	12:15 – 13:00 *(45min)*	Seagrass-Watch Techniques
Afternoon	13:00 – 13:30 *(30 mins)*	Lunch
	13:30 – 13:45 *(45min)*	*Activity 3 Mock Seagrass-Watch*
	13:45 -14:30 *(45mins)*	Seagrass-Watch data
	14:30 – 15:00 *(30mins)*	Basic GPS Use
	15:00 – 16:00 *(60mins)*	*Activity 4 Using the GPS*
	16:00 – 16:15 *(15mins)*	Safety Briefing and Risk Assessment
	16:15 – 16:45 *(45mins)*	Workshop Wrap-up and Close

Thursday March 5, 2009 – Wongai Beach HI1

Afternoon	14:40 MacDonald's ferry Wongai Beach – Horn Island	Seagrass Monitoring – Wongai Beach, HI. *Those travelling from TI will catch 2:50pm Macdonald's Ferry.* We will start monitoring at about 3:20pm. Low tide is at 4:56pm (0.6m)

Friday March 6, 2009 – Corner Beach HD1

Afternoon	15:15 –Rosehill Boat Ramp Corner Beach , Hammond I.	Seagrass Monitoring – Hammond Island. *We will leave Rosehill Boat Ramp at 3:30 pm* Walk to Corner Beach start monitoring around 4:00pm. Low tide at 5:21pm (0.5m)

Saturday March 7, 2009 – Front Beach TI2

Afternoon	16:30 – Gazebo Front Beach	Seagrass Monitoring - Front Beach meet at Gazebo 4:30pm. Low tide is at 5:53pm (0.4m)

Sunday March 8, 2009 – Back Beach/Battery Point TI1

Afternoon	16:45 – Crocodile sign Battery Point	Seagrass Monitoring - Back Beach/Battery Point. Meet at crocodile sign near mangroves at 4:45pm. Low tide is at 6:28 (0.5m)

Background

Seagrasses are unique amongst the flowering plants as they have evolved to live in the sea. They belong to a group of plants known as angiosperms (flowering plants). The name seagrass probably originated because many types of seagrass look like grasses and form meadows that resemble grasslands. However they are not true grasses, but are rather more closely related to the lily family.

MORPHOLOGY

There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle) shape, a fern shape, a long spaghetti like leaf and a ribbon shape. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea, Thalassia, Thalassodendron, Halodule* and *Zostera*. Spaghetti-like seagrass is called *Syringodium.*

Paddle

Halophila ovalis,

Fern

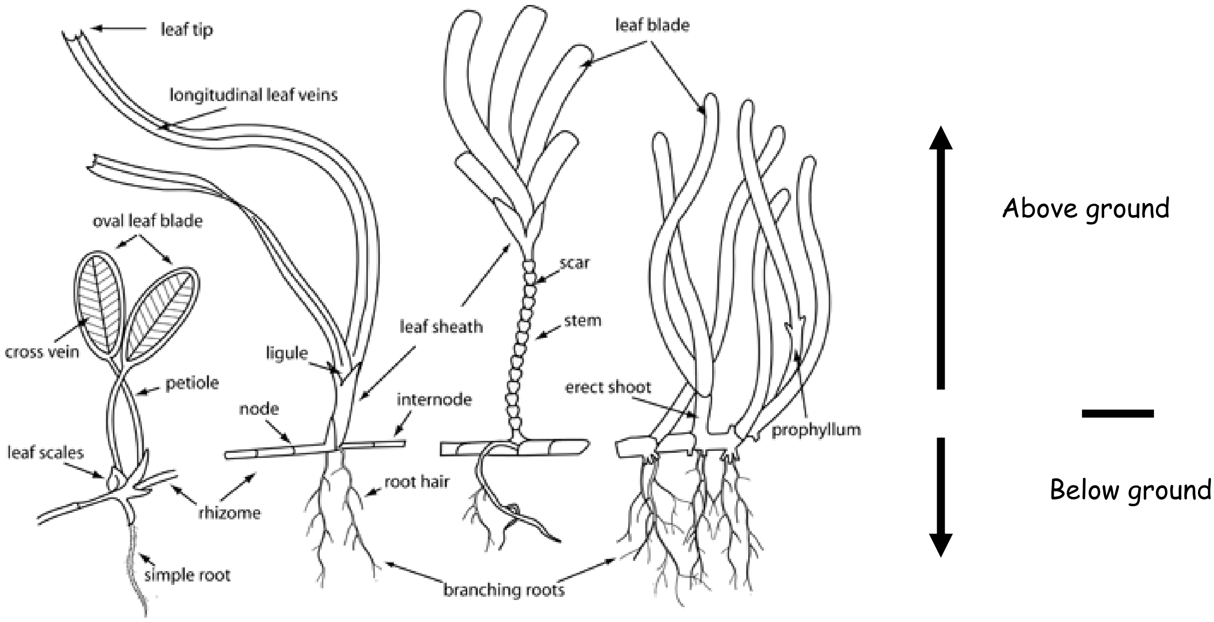
Halophila spinulosa

Spaghetti

Syringodium isoetofolium

Ribbon

Cymodocea serrulata



Composite illustration demonstrating morphological features used to identify seagrass types.

Like terrestrial (land living) plants, a seagrass can be divided into its **veins** (conducting tissue that transports food, nutrients and water around the plant) stem, and roots.

All seagrasses are **rhizomatous** in habit. This means that they posses **rhizomes,** an underground horizontal stem that produces roots and has shoots that develop into new plants.

The vertical stem is the upright axis of the plant from which leaves arise. The remnants of leaf attachment are seen as scars. The rhizome (horizontal stem) of the seagrass plant, is usually buried in the 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.

The roots anchor the plant into the sediment and absorb nutrients. Since seagrasses live in water, the roots do not play a significant role in water uptake. Growing in water though does present a problem in terms of obtaining oxygen and seagrasses have overcome this by developing air channels in the leaves and stems. Seagrasses living in nutrient poor sediments, can absorb nutrients directly from the water column, through their leaves.

The growing tips or **meristems** continuously produce new plant tissue and are located at the tips of the rhizomes. The base of a leaf has a sheath which protects young leaves. A **prophyllum** is a single leaf growing immediately from the horizontal rhizome instead of from an erect shoot. This feature is unique to the genus Zostera.

Some species of *Halophila* have the leaf divided into a **petiole** (stalk) and leaf blade. A **ligule** is a short **membranous** (thin, pliable, often translucent tissue) flap on the upper inner side of the leaf that separates the leaf blade from the sheath found in only some seagrass types , such as *Cymodocea, Halodule, Syringodium, Thalassodendron, Zostera).*

REPRODUCTION

Seagrasses reproduce by increasing rhizomes and producing more stems and leaves (vegetative/ clonal growth). Seagrass can also introduce new plants into the meadow by reproducing sexually as they have reproductive parts such as flowers and fruits. Most seagrasses have separate male and female plants.

Halophila female flower

Halophila male flower

Enhalus male flowers

Enhalus female flowers

Since they live covered in water for either part or all of their lives, they have mostly adopted means of underwater pollination. 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).

Once the female plant is pollinated it becomes a fruit. The seed within the fruit then germinate into seedlings.

Fruits

Thalassia hemprichii

Enhalus acorides

Halophila ovalis

Halodule uninervis ***Thalassia hemprichii*** ***Enhalus acoroides***

Seeds

DISTRIBUTION

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the artic (freezing) regions.

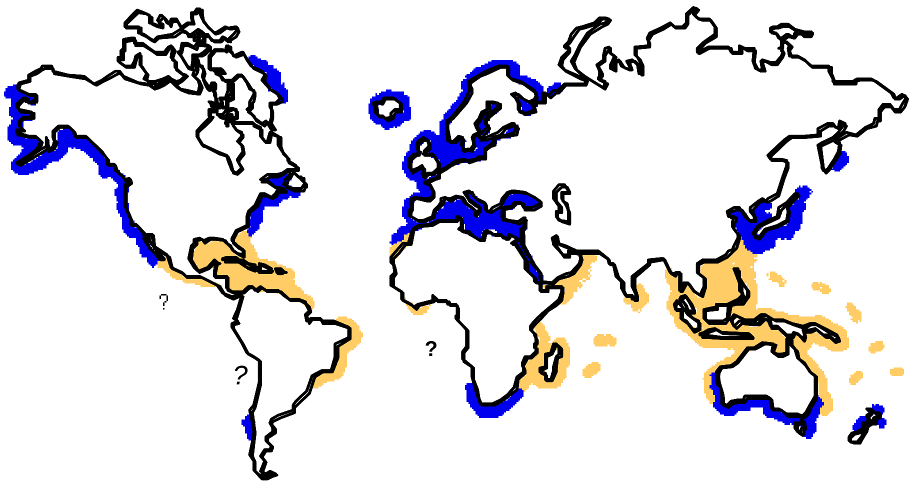
Seagrass are mainly found in bays, estuaries and coastal waters from the mid-**intertidal** (shallow) region down to depths of 50 or 60 metres (**subtidal**). Most species are found in clear shallow inshore areas between mean sea-level (**MSL**) and 25 metres depth. The depth range of seagrass is most likely to be controlled at its deepest edge by the availability of light to allow for **photosynthesis** (the ability plants have to use the energy of sunlight to convert carbon dioxide and water into sugars and oxygen). At its shallower edge, distributions are controlled by exposure at low tide, wave action and associated **turbidity** (muddy) and low **salinity** (containing salt) from fresh water inflow.

Shallow sub-tidal and intertidal species distributions are better recorded than seagrasses in water greater than 10 m below MSL. Surveying deeper water seagrass is time consuming and expensive and it is likely that areas of deepwater seagrass are still to be located.

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

Seagrass plants form small patches that develop into large continuous meadows. These meadows may consist of one (**monospecific**) or many species (**mulitspecific**). As many as thirteen species have been recorded present within one meadow in the Phillipines!

There is now a broad understanding of the range of species and where these species are found. Areas less well known include the southeast Pacific reefs and islands, South America, the southern Atlantic, and the west African coast.



Global seagrass distribution: tropical and temperate

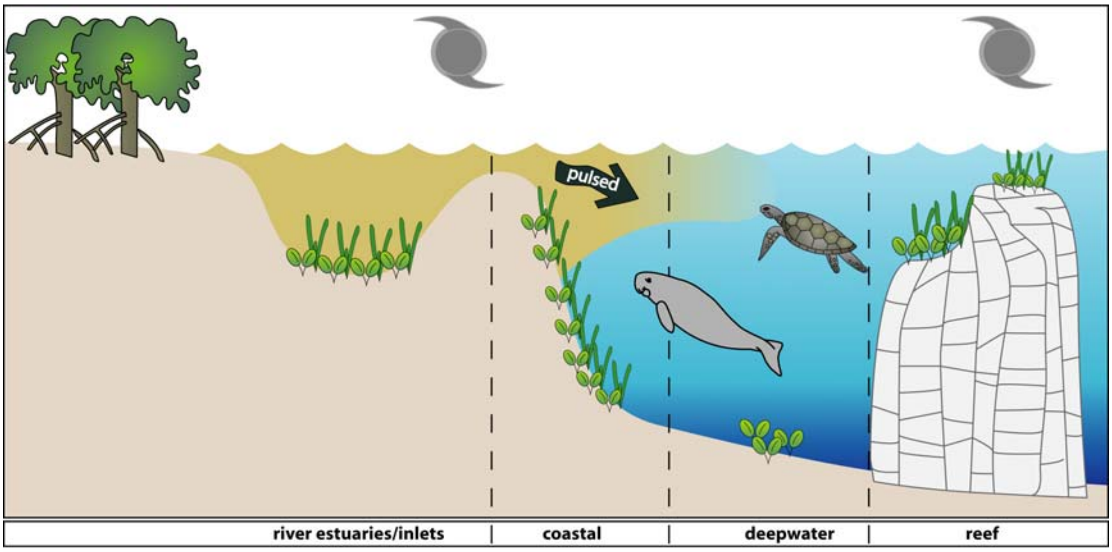
The stresses and limitations to seagrasses in the tropics are generally different to those in temperate or subarctic regions. These stressors (e.g temperature) limit the type (**species**) and amount (**density**) of seagrass present.

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 (Amesbury and Francis 1988).

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

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

Tropical seagrasses occupy a variety of habitats. Four generalized habitats have been described for seagrasses in north east Australia



Conceptual diagram of the four seagrass habitats for North East Australia
Adapted from Carruthers et al. 2002

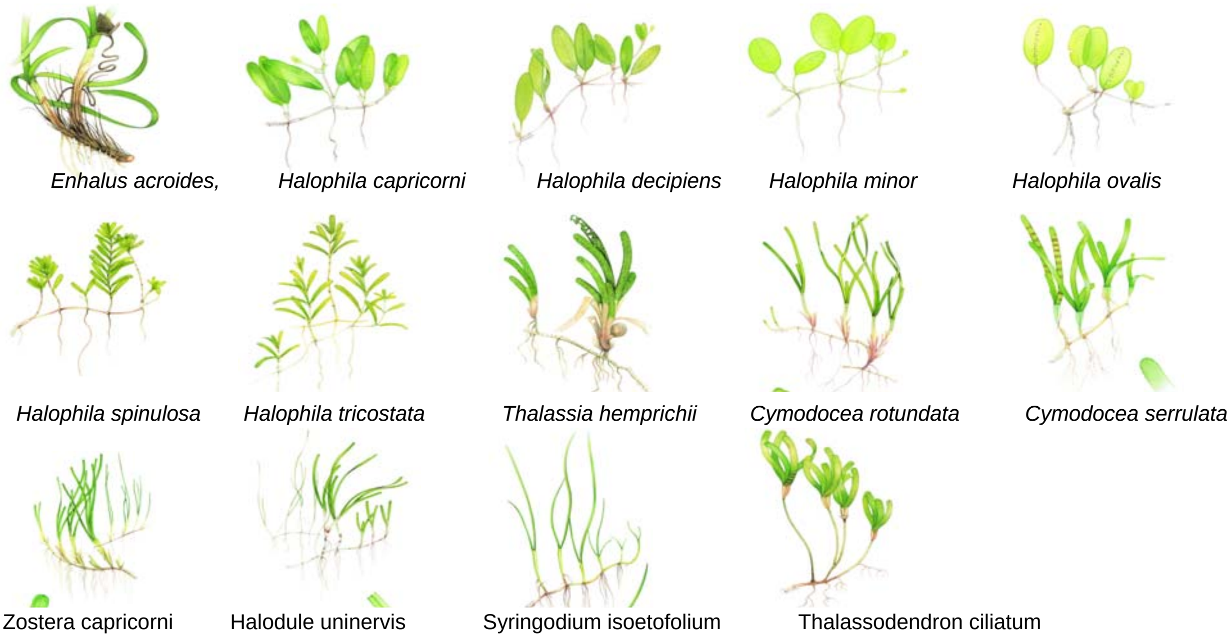
Inshore seagrass communities occur in river estuaries and are dominated by species of seagrasses that can tolerate changes in salinity and light availability. Coastal habitats can be intertidal or subtidal and are affected by rapid increases in run-off with heavy rain or cyclone events. Increasing the distance from the coast, decreases the impacts from run-off so light is able to penetrate through the clear waters allowing seagrass to grow in deepwater. Deep water seagrasses are found in the Torres Strait, within the Great Barrier Reef Lagoon, extending south to the Capricorn Bunker Group. Away from the influences of river plumes coral reefs develop and seagrasses can be associated with them. Reef seagrass communities may be intertidal or subtidal.

TAXONOMY

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.

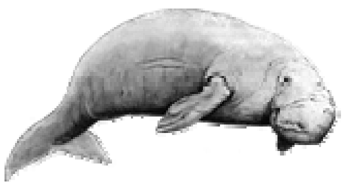
Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in a least three separate lineage. Each lineage is a separate group and are known botanically as a **family**. Each seagrass family contains several **genera** which are groups of species that are closely related.

There are relatively few species of seagrass globally (about 60) and these are grouped into just 13 Genera and 5 Families. The highest concentration of species occurs in the Indo-West Pacific region. Around thirty species are found in Australia, with approximately 14 species in Queensland waters.



Species found in Queensland waters

Several common names are applied to seagrass species, such as turtle grass, eelgrass and shoal grass. These names are not consistently applied among countries and in any case are not commonly used in northern Australia. We are not aware of any name for seagrass species used consistently through sea country. However coastal communities would almost certainly recognise the term "dugong grass" as referring to the shallow subtidal and intertidal seagrasses.

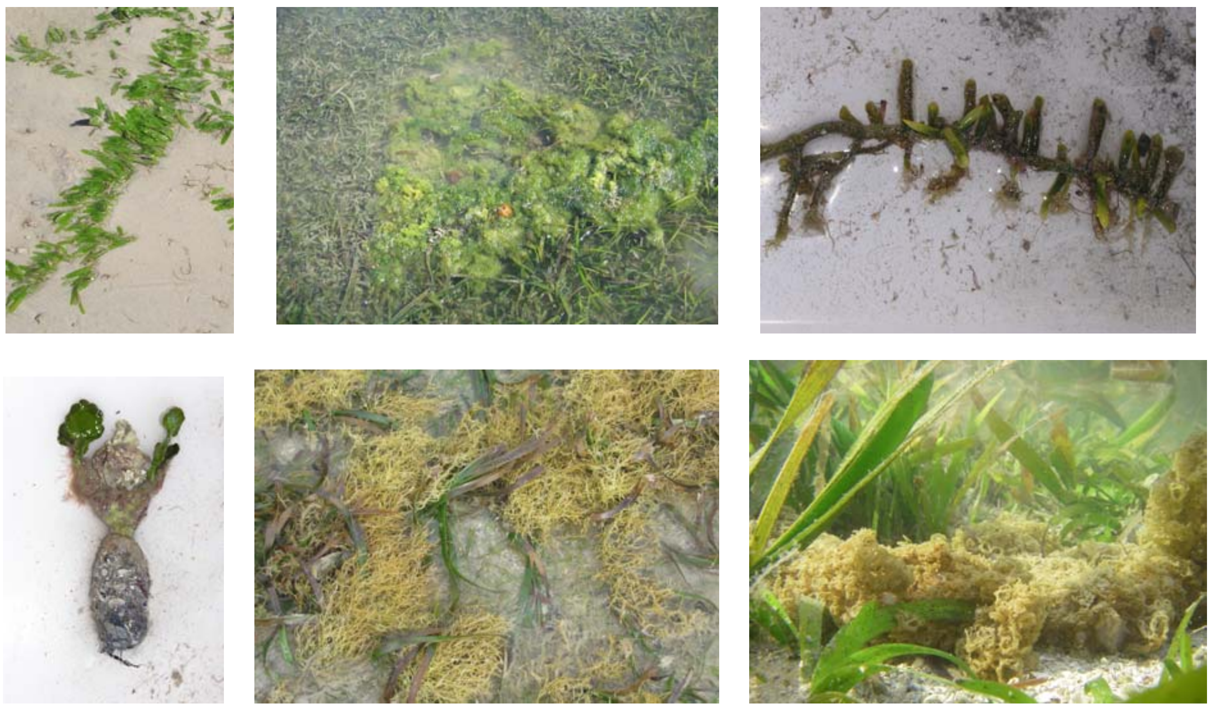


Seagrasses are not seaweed. Seaweed is a common name for algae.

Seagrass versus Algae

Algae are plants that also colonised the sea and are often confused with seagrasses, however, they are more primitive than seagrasses. In contrast to seagrasses, algae do not have a true root system (they have holdfasts) and do not have veins that carry nutrients or water around the plant. Algae also use a different method to reproduce. Algae have spores and do not flower or produce fruit, while seagrasses have seeds and fruit

Seagrass	***Marine Algae***
Complex root structure to anchor plant in the sediment, and extract nutrients and minerals	*Simple holdfast to anchor to hard substrate such as rocks or shells*
Photosynthesis restricted to cells in leaves	*Photosynthesis undertaken by all cells*
Transport minerals and nutrients in aerenchyma and the lacunae (veins)	*Uptake of minerals and nutrients from water column via diffusion*
Reproduction via flowers, fruits and seeds	*Reproduction via spores*



Different types of algae

Notes:

A guide to the identification of Torres Strait Seagrasses

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

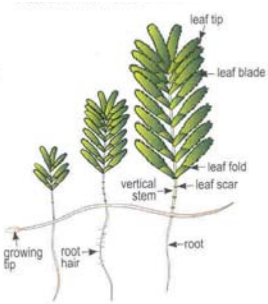
Leaves cylindrical

Syringodium isoetifolium

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

Leaves oval to oblong

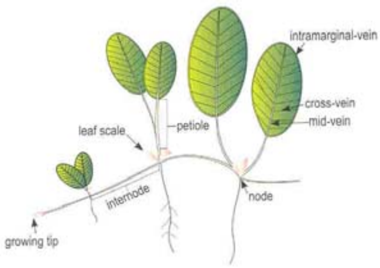
obvious vertical stem with more than 2 leaves



Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated

leaves with petioles, in pairs



Halophila ovalis

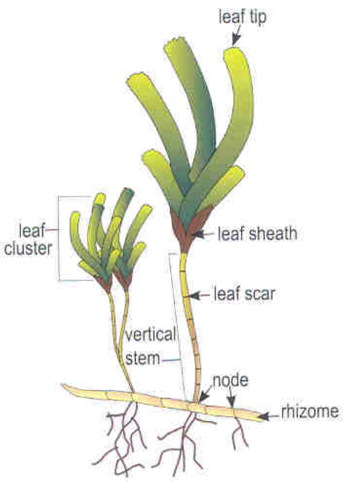
- cross veins more than 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Halophila decipiens

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

Leaves strap-like

Leaves can arise from vertical stem



Thalassia hemprichii

- Leaf with obvious red flecks, 1-2mm long
- Leaf tip rounded may be slightly serrated
- Leaf often distinctly curved
- Distant scars on rhizome

Cymodocea serrulata

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

Cymodocea rotundata

- Leaf tip rounded with smooth edge
- Leaf sheath not obviously flattened
- Leaf sheath scars continuous around upright stem

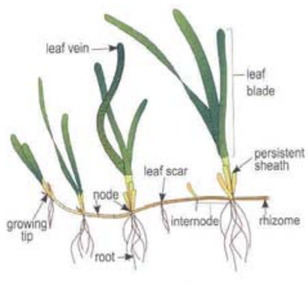
Halodule uninervis

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

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
- inrolled edges of leaves
- long, black bristles protruding from thick rhizome

Zostera capricorni

- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- rhizome usually brown or yellow in younger parts

ECOLOGY

The study of the relationships between living organisms and their interactions with their natural or developed environment

Seagrass meadows are one of the most productive and dynamic ecosystems globally. Seagrasses provide coastal zones with a number of **ecosystem services.**

Ecosystem Services are the processes by which the environment produces resources that we often take for granted. Seagrasses provide services such as clean water, fishing grounds, wave protection, oxygen production and protection against coastal erosion

Seagrasses are sometimes labelled 'ecological engineers' because they have the ability to influence their physical, chemical and biological environments. Their leaves slow down water-currents increasing sedimentation, and their seagrass roots and rhizomes stabilize the seabed.

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 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 live in seagrass meadows as juveniles. Shellfish such as some oysters and pearl shell may be more likely to settle and survive where there is seagrass. Juvenile and adult sandcrabs and flathead are just two species which spend most of their lives in seagrass meadows, where there is not only food but also protection from strong tidal currents and predators. Larger predatory animals such as herons, cormorants, sharks, barramundi, salmon, crocodiles, etc, are also attracted to the seagrass meadows by the schools of forage fish which seek shelter there.

Seagrasses create a habitat complexity, that when compared with unvegetated areas, provide 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.

Seagrass meadows are a major food source for a number of grazing animals. The dugong (Dugong dugon) and the green turtle (Chelonia mydas) mainly feed on seagrass. An adult green turtle eats about two kilograms of seagrass a day while an adult dugong eats about 28 to 40 kilograms a day. Both dugongs and turtles select seagrass species for food which are high nitrogen, high starch and low fibre. The order of seagrass species preference for dugongs is Halophila ovalis > Halodule uninervis > Zostera capricorni.

It was originally thought that few species other than the dugong and turtle feed directly on seagrass leaves (partly because of their low nutritional content), but scientific reviews and improved working methods have shown that seagrass **herbivory** (eating plants) is a highly important link in the food chain. It has now been documented that hundreds of species feed on seagrasses worldwide, including, fish, geese, swans, sea urchins and crabs.

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.

Besides these obvious services, seagrass meadows also act as a buffer or filter for terrestrial run-off into the marine environment. The rhizomes and roots of the seagrasses bind sediments on the substrate, where nutrients are recycled by microorganisms back into the marine ecosystem. Seagrasses can absorb nitrogen and phosphorus, from coastal run-off. This leads to improved water quality for other marine habitats, as excess nutrients, can start algal blooms that impair water quality. They also improve water quality by pumping oxygen into the water column while storing carbon within the meadow.

The economic value of seagrass meadow can be calculated based on the type and amount of ecosystem services that it can provide. These valuations can be quite controversial and difficult to quantify. Seagrass meadows have been rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. The average global value of seagrasses for their nutrient cycling services and the raw product they provide has been estimated at 1994 US$19,004 $ha^{-1}yr^{-1}$.

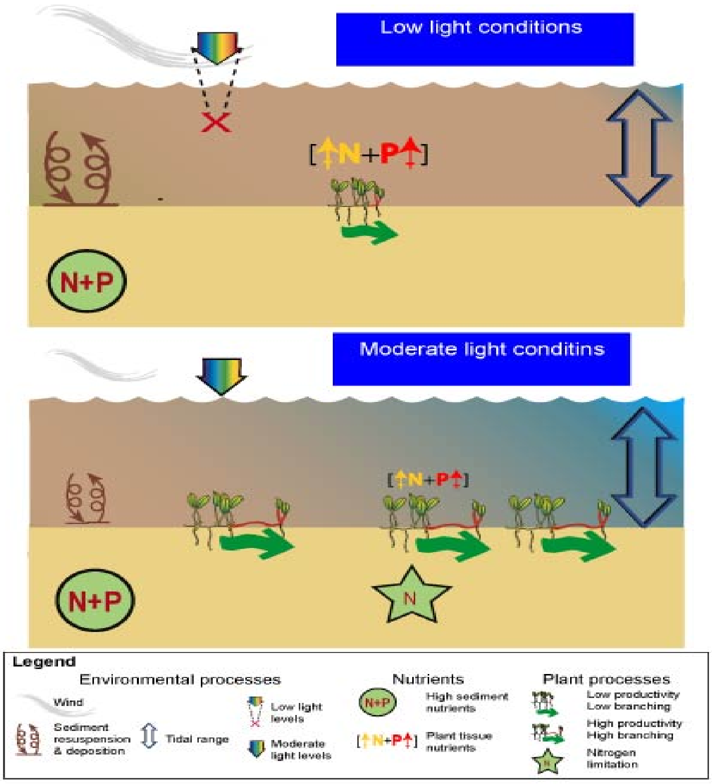
REQUIREMENTS FOR GROWTH

Seagrasses require light, nutrients, inorganic carbon, suitable substrate and **hydrodynamic** (properties of water: currents and wave action) regimes, tolerable salinity; temperature and pH to survive.

Light

Seagrasses, being plants, need light for photosynthesis. Light availability is the most dominant overriding factor in seagrass growth. Seagrasses have high minimum light requirements, because of living under water and supporting roots and rhizomes that lay buried in the sediment and do not contribute to photosynthesis.

Light availability can be affected many things: cloud cover, daylength, and clarity (clearness of water). Water clarity can be modified by wind strength, depth of water, resuspension of sediments and sediment plumes caused by terrestrial run-off after rain events. Too much light can also be damaging to seagrasses as it causes the parts of the plant that photosynthesise to shut down. This is can be a problem for seagrasses that inhabit intertidal areas. UV exposure can also have significant impacts on seagrasses as it burns them.



Conceptual diagram of seagrass growth under different light regimes

Nutrients

Seagrasses require two key nutrients, nitrogen and phosphorous, for growth. Seagrass growth In the coastal regions, appears to be primarily limited by nitrogen. The demand for nutrients by seagrasses appears to be seasonally dependent. The demand for nutrients during the growing season is high, however during the senescent season nutrients tend to be stored within the plant.

The availability of nutrients to seagrasses is dependent on the biogeochemistry of the sediment. Bioavailability of nutrients is dependent on particle size and **mineralogy** (type). For example, clay content influences sediment adsorptive capacity — the more clays the greater the absorptive capacity. Calcium carbonate is another mineral complex which binds up phosphorus, limiting its bioavailability. As calcium carbonate is major component of the sediments associated with reefs, some reef top seagrass meadows may be phosphorus limited.

Seagrasses also require inorganic carbon for growth. They absorb inorganic carbon at the leaf surface via two pathways which are species-specific. Some species use bicarbonate ($HCO3^-$) as an inorganic carbon source (*Halophila ovalis, Cymodocea rotundata, Syringodium isoetifolium* and *Thalassia*), whereas others use enzymes to make CO2 available as the inorganic carbon source (*Enhalus acoroides, Halodule, Cymodocea serrulata*).

Sediment

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 the Cymodoceas. prefer deeper sediments while others can tolerate a broad range of sediment depths. Colonising seagrasses such as the Halophilas. and Halodule uninervis are better suited to mobile sediments than larger species.

The biogeochemical characteristics of sediment can affect the nutrient content, organic content and oxygen levels. Seagrasses are unable to grow in sediments of high organic content, as they tend to be **anoxic** (without oxygen).

Hydrology

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). They can influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

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 from the water column.

Salinity

In contrast to land plants, some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or **hypersaline** (very salty). 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 along estuaries. A limiting factor for many intertidal seagrasses is **osmotic** (the flow of a liquid through a membrane) impacts resulting from hypersalinity due to evaporation

Temperature

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As water temperatures increase (up to 38 degrees Celsius) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO_2 concentration.

Temperatures of 38 to 42 degrees Celsius cause the cells responsible for photosynthesis to shut down and many plant proteins are simply destroyed resulting in plant death.

Temperature related impacts can result from high water temperatures or overexposure to warm air; It is seen at the meadow scale by patches of burnt looking seagrass. This symptom can also be caused by **desiccation** (lack of water) in intertidal meadows due to long exposure times and drying from wind.

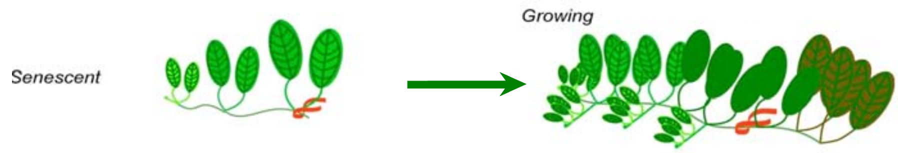
Various combinations of these parameters will permit, encourage or eliminate seagrass from a specific location all together or perhaps just temporarily due to changes in these parameters caused by changes in the seasons.

SEASONALITY

Seagrass meadows vary seasonally and between years. Fluctuations in biomass, growth rates, flowering and fruit production occur as a result of seasonal changes in carbon balance, light and temperature. The seasonal pattern of temperate seagrasses shows a strong increase in spring, a peak in the summer and a subsequent decline in autumn. In Australia, temperate and subtropical seagrasses also follow this pattern of biomass change

In tropical Queensland, seagrass abundance appears to peak either late in the dry-season (October - November), or just after the wet season, as plants take advantage of the extra nutrients being delivered from terrestrial run off. They are at a minimum in the early dry (south-easterly season (June- August).

One species that shows quite dramatic seasonal changes is *Halophila tricostata* (a deepwater seagrass). This seagrass is an annual and changes in the area and biomass of these species between summer and winter seasons can be dramatic. *H. tricostata* which can form extensive subtidal meadows in the waters of the Great Barrier Reef is absent in autumn and winter months and re-establishes from its seed bank when sea temperatures rise to 26-28ºC.



Seasonal changes in growth for Halophila ovalis

THREATS

Seagrass meadows are fragile ecosystems. Approximately 54% of seagrass meadows globally, have lost part of their distribution. Documented losses in seagrass meadows globally since 1980 are equivalent to two football fields per hour. The dynamic nature of seagrass meadows in response to natural environmental variation complicates the identification of changes caused by humans

Loss of seagrasses has been reported from most parts of the world, sometimes from natural causes, e.g., high energy storms, or "wasting disease". More commonly, loss has resulted from human activities, e.g., as a consequence of **eutrophication** (excess nutrients in the system) or land reclamation and changes in land use. **Anthropogenic** (caused by humans) impacts on seagrass meadows are continuing to destroy or degrade these coastal ecosystems and decrease their yield of natural resources.

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 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** (rich in dissolved nutrients).

Oil and trace metal contamination can exert direct toxic effects on seagrass species. Seagrasses are able to **bioaccumulate** (the toxin is added at a rate higher than originally present in the environment) the trace metals and this has implications for grazers such as dugongs and turtles. .

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 seagrasses 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. Rubbish and litter can physically and chemically damage seagrass meadows and the animals that live within them.

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

One of the other significant impacts to seagrass is climate change. The major vulnerability of seagrass to climate change is loss of seagrass in the coastal zone, particularly near river mouths and in shallow areas. The greatest impact is expected to result from elevated temperatures, particularly in shallower habitats, effecting seagrass distribution and reproduction. 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. These events are expected to cause a shift to more **ephemeral** (short-lived) species and those with lower minimum light requirements.

LOCAL EYES, GLOBAL WISE

It is important to document seagrass species diversity and distribution locally and identify areas requiring conservation measures before significant meadows and species of seagrass are lost. Determining the extent of these areas and their ecosystem values coastal zone managers will have detailed information to aid them in their planning and development decisions.

Knowledge of regional and global seagrass distributions are still too limited and general for broad scale protection and management. Information gathered from activities such as Seagrass-Watch is needed to minimize future impacts on seagrass habitat worldwide. With global electronic communication it is now possible to begin the process of assembling both formally published and unpublished notes on the distribution of the world's seagrasses with the eventual aim of providing a global "report card" on the distribution and status of seagrass.

With well-recorded events of seagrass loss from many coastal environments it is important to map and record the distribution of not only the location of existing seagrass meadows but also areas of past and potential seagrass habitats. Such areas are generally shallow, sheltered coastal waters with suitable bottom type and other environmental conditions for seagrass growth.

Spatial and temporal changes in seagrass abundance and species composition must be measured and interpreted with respect to prevailing environmental conditions. These may need to be measured seasonally, monthly, or weekly, depending on the nature of their variability, and the aims of the study. Physical parameters important to seagrass growth and survival include light (turbidity, depth), sediment type and chemistry, and nutrient levels. Detailed studies of changes in community structure of seagrasses are essential to understand the role of these communities and the effects of disturbance on their composition, structure and rate of recovery.

Notes:

Monitoring

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. Environmental monitoring programs should ideally be designed to a) quantify the causes of change; b) examine and assess acceptable ranges of change for the particular site; and c)to measure levels of impacts.

Environment monitoring programs provide coastal managers with information and assist them to make decisions with greater confidence.

SEAGRASS MONITORING

Seagrass meadows are often at the downstream end of catchments, receiving runoff from a range of agricultural, urban and industrial land-uses.

Several parameters are important for the persistence of healthy seagrass meadows. They are sediment quality; water quality (temperature, salinity, clarity); current and hydrodynamic processes; and species interactions (e.g., epiphytes and grazers).Factors that can affect these parameters 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 shades seagrasses, also reducing photosynthetic capacity;
- increased sedimentation can smother seagrass or interfere with photosynthesis;
- herbicides can kill seagrass and some chemicals (e.g., pesticides) can kill associated fish, crabs and shellfish;
- 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.

Because seagrasses generally respond in a typical manner this allows them to be measured and monitored as an indicator of environmental health.

Seagrasses make good bioindicators of environmental health because they have a) widespread distribution; b) an important ecological role; c) are **sessile** (don't move around) plants (individuals, populations and communities); d) show measurable and timely responses to impacts and e) are integrative of environmental conditions

SEAGRASS-WATCH

A simple method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses 50m by 50m 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 community based seagrass monitoring program in the world. Since it's genesis in 1998 in Australia, Seagrass-Watch has expanded to the Indo and western Pacific, with volunteers in Micronesia, Palau, Japan, Philippines, Malaysia, Indonesia, Papua New Guinea, Solomon Islands and Fiji. Monitoring is now occurring at approximately 150 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 and sustainability. Most participants are associated with established local community groups, schools, universities & research institutions, government (local & state) or non-government organisations.

Seagrass-Watch integrates with existing education, government, non-government and scientific programs to raise public awareness of these important marine ecosystems 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 sustainability and the information collected is used to assist the management of coastal environments and to prevent significant areas and species being lost. Seagrass-Watch is also a component of the Global Seagrass Monitoring Network.

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, the community, government and researchers have to work together in partnership

THE GOALS OF THE PROGRAM ARE:

- To educate the wider community on the importance of seagrass resources
- To raise community awareness of coastal management issues
- To develop community participation and ownership
- To build the capacity of local communities in the use of standardised scientific methodologies
- To conduct long-term & broad-scale monitoring of seagrass & coastal habitats, and
- To provide an early warning system of coastal environment changes for management.

Notes:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

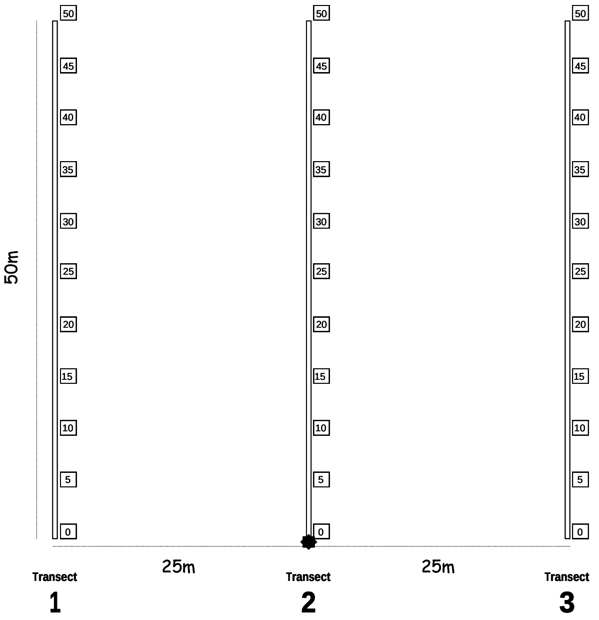
....

....

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

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

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Quarterly sampling

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

Step 1. Take a Photograph of the quadrat

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

Step 2. Describe sediment composition

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

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

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

Step 4. Estimate seagrass percent cover

- Estimate the total % cover of seagrass within the quadrat – use the percent cover photo standards (calibration sheets) as your guide.

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). Use seagrass species identification keys provided.

Step 6. Measure canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

At completion of monitoring

Step 1. Check data sheets are filled in fully.

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

Step 2. Remove equipment from site

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

Step 3. Wash & pack gear

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

Step 4. Press any voucher seagrass specimens if collected

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

Step 5. Submit all data

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

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

Seagrasses of Torres Strait

Torres Strait has some of the most extensive seagrass meadows in northern Australia (Coles et al. 2003) They are acknowledged as an invaluable resource for sustaining populations of dugong, turtle, fish, prawns, beche de mer and tropical rock lobster that support their local economies (Marsh et al. 2004; Green 2006). They are an important component of coastal fisheries productivity, as they function as nursery grounds for many commercially important species. They play an important role in maintaining coastal water quality and clarity. The loss of seagrass habitat due to a variety of factors whether manmade or natural would lead to a loss of a food source and nursery areas of species reliant on seagrass meadows. Torres Strait island communities strongly rely on coastal marine habitats for subsistence as well as strong cultural and spiritual links to these environments

Approximately 60 seagrass species are found worldwide, grouped into 13 genera and 5 families (Short and Coles 2001). Torres Strait contains the highest number of seagrass species in the western Pacific, and is included in a diversity “hotspot” for seagrass species which encompasses Sulawesi, Papua New Guinea, Borneo and Malaysia, (Mukai 1993). Of the 14 species that are recorded for Queensland waters, 13 of them are found in the Torres Strait. They are:

- Family **Cymodoceaceae**
  - *Cymodocea rotundata*
  - *Cymodocea serrulata*
  - *Halodule uninervis* (wide- & narrow-leaf)
  - *Syringodium isoetifolium*
  - *Thalassodendron ciliatum*
- Family **Hydrocharitaceae**
  - *Enhalus acoroides*
  - *Halophila decipiens*
  - *Halophila minor*
  - *Halophila ovalis*
  - *Halophila spinulosa*
  - *Halophila tricostata*
  - *Thalassia hemprichii*
- Family **Zosteraceae**
  - *Zostera muelleri* ssp*. capricorni (*aka *Zostera capricorni)*

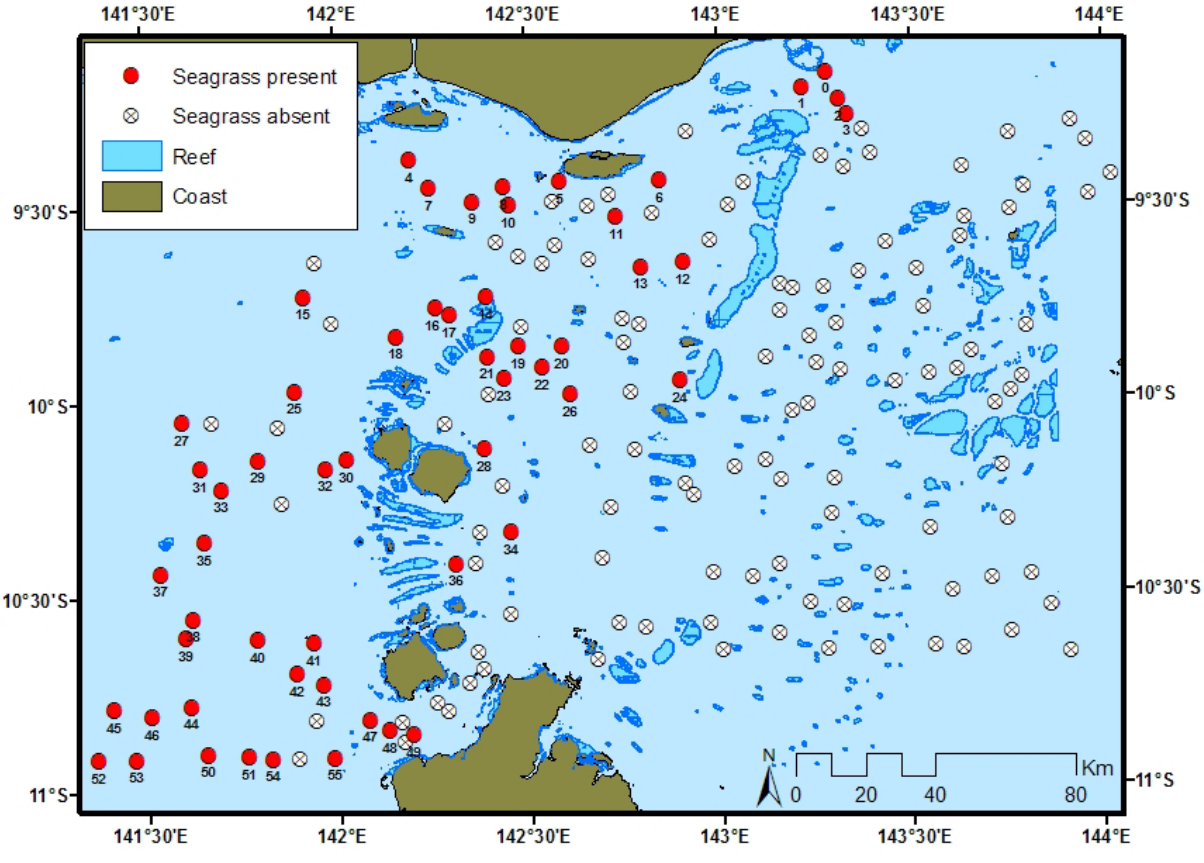
DISTRIBUTION OF TORRES STRAIT SEAGRASSES

Surveys of the open waters of Torres Strait have estimated 13,425 km^2 of seagrass habitat. Seagrass communities occur across the open sea floor, on reef flats and sub-tidally adjacent to continental islands. Seagrass biomass and shoot density is greatest in shallow bays (<7m), foreshore/ intertidal areas landward of the reef crest of fringing reefs of continental islands and on reef tops. *Enhalus acoroides (a species common throughout the Torres Strait)* is generally restricted to shallow subtidal and intertidal regions associated wit the continental islands.

Subtidal meadows displayed a clear east-west partitioning thought to be related to increased turbidity and a change in sediment from coarse sediment in the west to fine sediment in the east. These meadows were populated by sparsely distributed *Halophila* or mixed species (*Halodule, Thalassia* and *Syringodium*) communities. Lush *Halophila ovalis* and *Halophila spinulosa* communities are also found in the deep waters (>25m) of the south-western Torres Strait. Subtidal meadows are common west of the Warrior Reefs and generally absent east of the Warrior Reefs (SOE 2007).

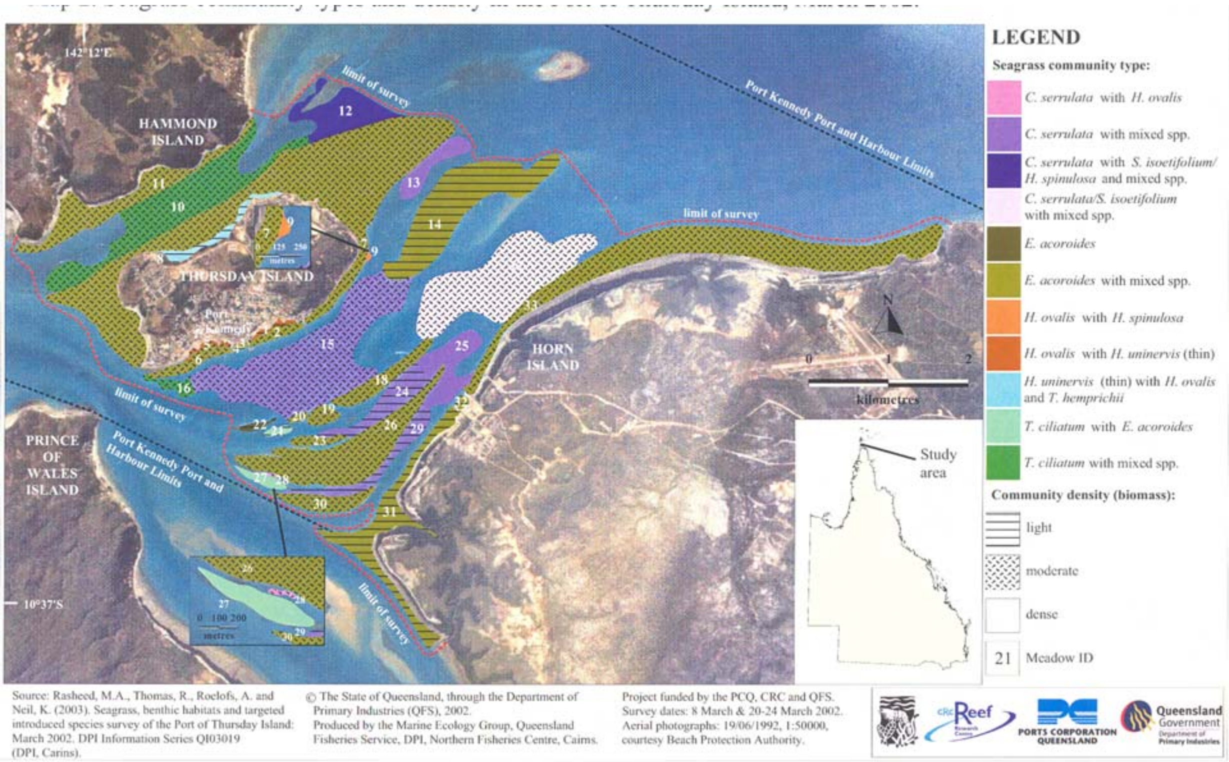
The Warrior Reefs have extensive seagrass-covered reef flats. A number of species co-occur on these flats; most commonly *Halodule uninervis, Thalassodendron ciliatum, Cymodocea rotundata*, and *Thalassia hemprichii*.. These reef platform habitats are also important as nursery grounds for commercial juvenile penaeid prawns (Turnbull and Mellors 1990)

Intertidal seagrass habitat occurred throughout the Torres Strait survey and was mapped over an area of 4179 ± 144 ha (Table 4; Maps 3-12). Of the 19 intertidal island and reef areas surveyed, 14 were found to have a seagrass community present. Despite the fact that seagrasses covered such a large area of the intertidal regions surveyed, it comprised the lowest overall cover in proportion to the other habitat types (Figure 2). Percent cover for the majority of intertidal seagrass meadows was generally very low (0-10%), with the remaining meadows having a low (10-30%) cover of seagrass (Maps 3 & 4). Five species were identified in five distinct community types and fourteen meadows (Figure 3; Table 4; Maps 5-12). Seagrass communities were dominated by *Thalassia hemprichii,* with many meadows having a mix of species present. (Table 4). The meadows identified were typically comprised of aggregated patches and tended to extend to the outer edges of the intertidal regions surveyed. It is important to note that seagrasses may have a much larger extent than reported here, as subtidal areas were not surveyed.



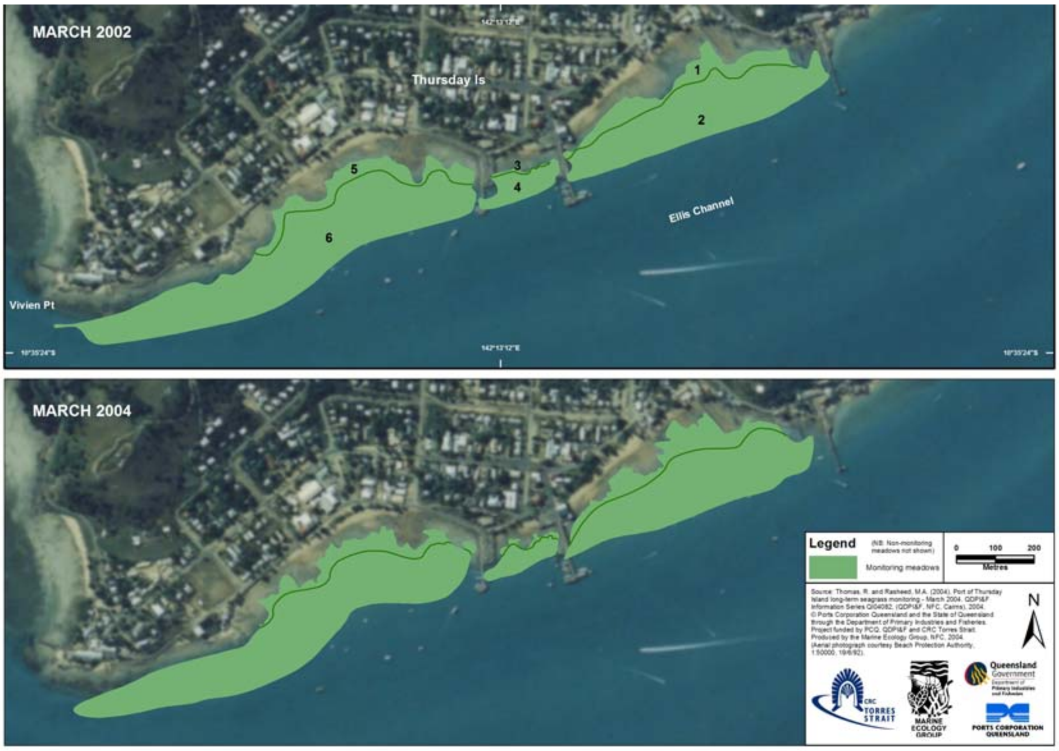
Distribution map of seagrass from areas surveyed

Seagrass meadows have been found to occur in close proximity to the port facilities at Thursday Island. A fine-scale baseline survey of seagrass habitats conducted in March 2002 identified seagrass as the dominant benthic habitat with 11 species, covering over 1500 ha (Rasheed *et al.*, 2003). Extensive intertidal banks of *Enhalus acoroides* are found along the foreshores of Thursday, Horn and Hammond Islands and on the reef platforms around Madge and Holmes reefs. Subtidal meadows dominated by *C. serrulata* or *C. serrulata/S. isoetifolium* occur in Ellis Channel between Thursday and Horn Islands. The channel between Thursday and Hammond Islands is almost entirely occupied by a subtidal *T. ciliatum* dominated meadow (Rasheed *et al.*, 2003).



Seagrass community types and density in the Port of Thursday Island, March 2002

A second survey of a nine representative meadows in the Port was conducted in 2004. This survey found no apparent anthropogenic impacts from port operations or developments had influenced seagrass growth at Thursday Island since March 2002. (Thomas & Rasheed, 2004).Significant increases in seagrass biomass were recorded for four of the nine monitoring meadows since the March 2002 baseline survey.



Thursday Island foreshore meadows in 2002 and 2004

Besides mapping the distribution of seagrass; nutritional profiling of sub tidal seagrasses has been undertaken. This type of mapping may be of use in managing and protecting the ecological, economic and cultural values of the subtidal seagrass meadows and the associated traditional fisheries of the Torres Strait.

Starch and nitrogen within plant tissue are the best indicators of habitat nutritional quality. *H. ovalis* was the most nutritious of the four commonly encountered sub-tidal seagrass species in the Torres Strait, with high nitrogen, starch and digestibility and low fibre levels. Sub-tidal nitrogen and starch distributions in the Torres Strait were concentrated where *H. ovalis* was prevalent, particularly around the south-west and north-central regions. The nutritional superiority of *H. ovalis* coupled with its broad geographic and depth distribution make it an important seagrass species for marine herbivores foraging sub-tidally in the Torres Strait. *H. ovalis* is consistently present in dugong stomach content samples and in the seagrass meadows dugongs target.

S. isoetifolium had considerably less starch content (particularly with increasing depth) and digestibility than *H. ovalis*, it had slightly higher nitrogen content and lower fibre and lignin levels. Given its similar geographic range to *H. ovalis*, *S. isoetifolium* may also constitute an important food resource. *S. isoetifolium* is a larger plant than *H. ovalis*. It also forms denser meadows and has higher total biomass in the Torres Strait than *H. ovalis* (Long and Poiner, 1997). Food seagrasses that occur in concentrated patches will presumably increase the foraging efficiency of a grazing herbivore by reducing search costs and maximising intake rates for grazing effort. *S. isoetifolium* provides less nutritional energy than *H. ovalis* on a plant level, however its morphology, patch characteristics and prevalence (total availability) may enhance its dietary value to a foraging dugong.

Defining, designating and managing areas of seagrass habitat based on their nutritional value and where dugongs are know to forage may assist in the sustainable management of this traditional fishery. Two such sites present themselves based on these factors. The south-western site coincides with the Dugong Sanctuary established in 1985 where hunting is prohibited (Commonwealth of Australia 2003). The second site (north-central) is already recognized as an area of consistently high importance as dugong habitat based on visual surveys in 1987, 1991, 1996 and 2001.

THREATS TO TORRES STRAIT SEAGRASSES

Widespread die back of seagrasses has been reported in the past in the central and northern regions of the Torres Strait. More than 1400 square kilometres of seagrass was lost between 1989 and 1993. There is anecdotal evidence of earlier dieback incidents in the 1970's (Long *et al*. 1997). It is possible this is a natural cyclical event but that has not yet been determined.

The seagrasses of this region may be impacted by a number of activities, including: storm run-off during the wet season; migrating sand waves, trampling; boat traffic; small scale infra structure works; shipping and port activities/accidents; anchoring; careening of vessels; introduced marine pests, and climate change.

Despite the remote location of the Torres Strait region, increasing pollution, most notably marine debris, threatens the viability of the wildlife and in turn, the way of life for the local communities. Marine debris poses a threat to local fishery resources, wildlife and habitat, as well as human health and safety. Although the impact of marine debris on wildlife is relatively well known, the impacts on seagrass meadows that support these animals is largely unknown.

Shipping accidents in Torres Strait pose a serious risk to commercial and Indigenous fishing and the habitats that these activities rely on. The Torres Strait region has a high rate of shipping incidents compared to other shipping passages. Queensland Transport has identified the two major shipping lanes of the Torres Strait, The Prince of Wales channel and the Great North East channel, as areas of high risk from shipping accidents with heightened consequences to surrounding habitats.

For example the Torres Strait prawn fishery alone generated in excess of $74 million dollars in 2003 / 2004 (Australian Fisheries Management Authority, 2006). The extensive seagrass habitats located around the Great North East channel provides vital nursery habitats for juvenile prawns associated with the fishery.

There have been at least 19 separate accidents since 1970, seventeen of which were ship groundings on reefs, with the remaining two being discharge accidents while docked at the Port of Thursday Island (Queensland Transport and the Great Barrier Reef Marine Park Authority, 2000). Of these 19 accidents, four caused large quantities of oil and fuel to be spilt into the sea (John Wright, Maritime Safety Queensland, 2006).

Many ecologically, economically and traditionally valuable intertidal marine habitats such as seagrasses, algae, mangroves and coral reefs line are adjacent to these shipping lanes. These habitats are vulnerable to oil and fuel spills, particularly when they occur in intertidal areas.

Other identified impacts that are slightly more insidious and more difficult to counter are natural seagrass die-back, marine pests and global warming. It has been recognized that these factors could impact on local seagrass meadows leading to a loss of a food source and nursery areas of species reliant on seagrass meadows

Despite Islander reliance on these habitats, there exists no mechanism other than anecdotal, in which local communities can report on its condition for use in decision making for the protection of seagrass ecosystems. Monitoring the distribution and abundance of seagrass meadows was recognised as a high priority (TSSAC 2006). The ability to predict the consequences of any disturbance on different seagrass habitats requires ongoing collection of monitoring information that is relevant for making management decisions

Regular detailed monitoring in this region started in March 2004 when Seagrass-Watch was established with the backing of Torres Strait CRC and ongoing support from Tagai College and TSRA Land and Sea Management Unit, (www.seagrasswatch.org).

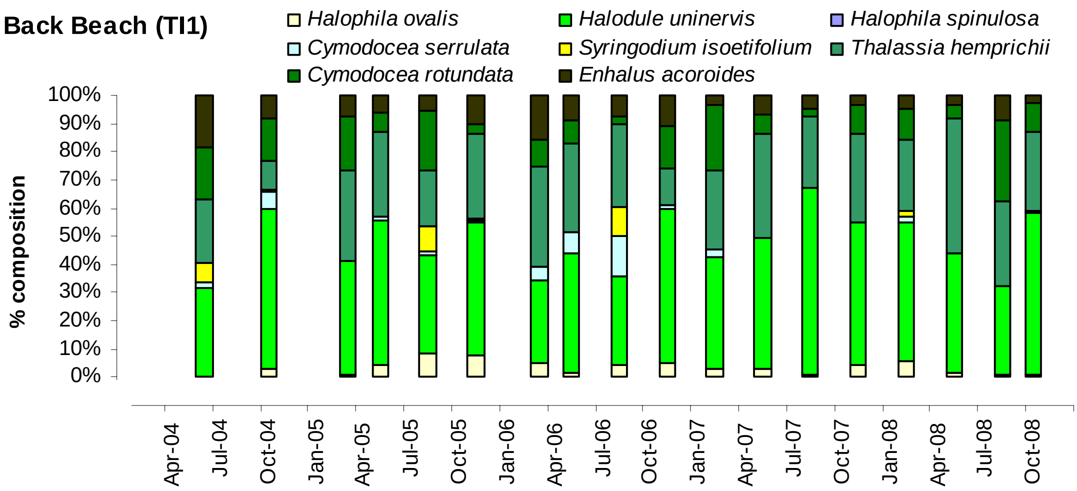
TORRES STRAIT SEAGRASS-WATCH SITES

Back Beach/Battery Point (TI1)

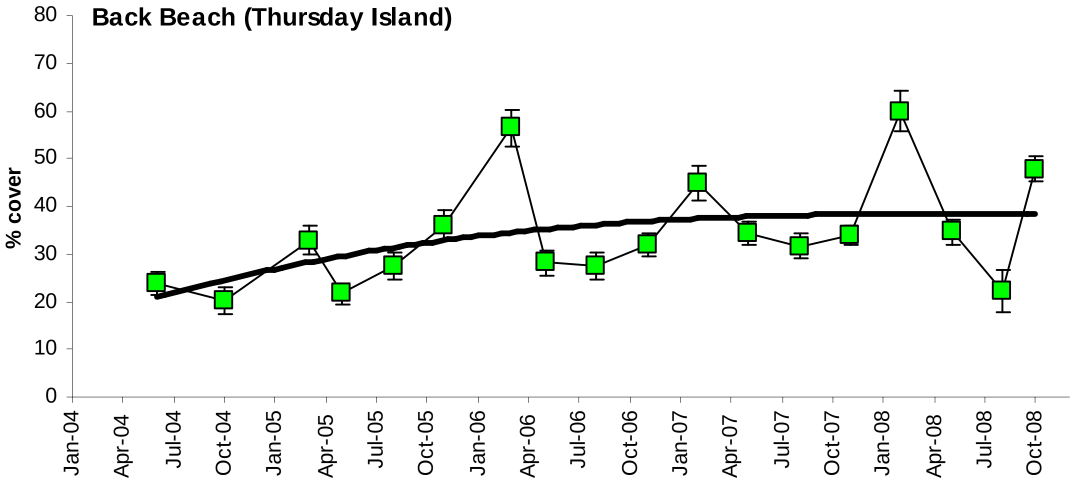
The seagrass meadow at Back Beach (Thursday Island) is an extensive intertidal fringing reef top meadow. On its landward edge it is fringed by mangroves which are used as a roost for a flying fox colony.

Species diversity at Back Beach is high, as 8 species have been identified, including *Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium* and *Halophila spinulosa.* As many as seven species can co-occur in one quadrat

Species composition appears to fluctuate seasonally, driven by changes in *Halodule uninervis* and *Cymodocea rotundata*.



Seagrass abundance appears to have increased gradually since monitoring was established. Seagrass appears to be showing a fairly typical seasonal pattern of abundance (higher in late summer than mid year) and was higher in 2008 than previous years

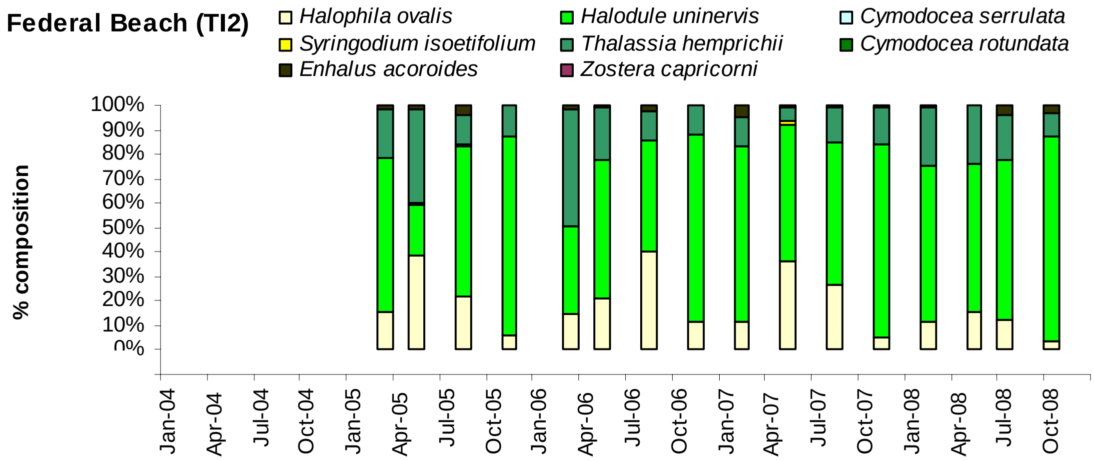


Octopus, crabs and large molluscs flourish at this location demonstrating the notion of seagrass meadows as habitats of great biodiversity. *Enhalus* flowers and fruits are also a common sight at this location.

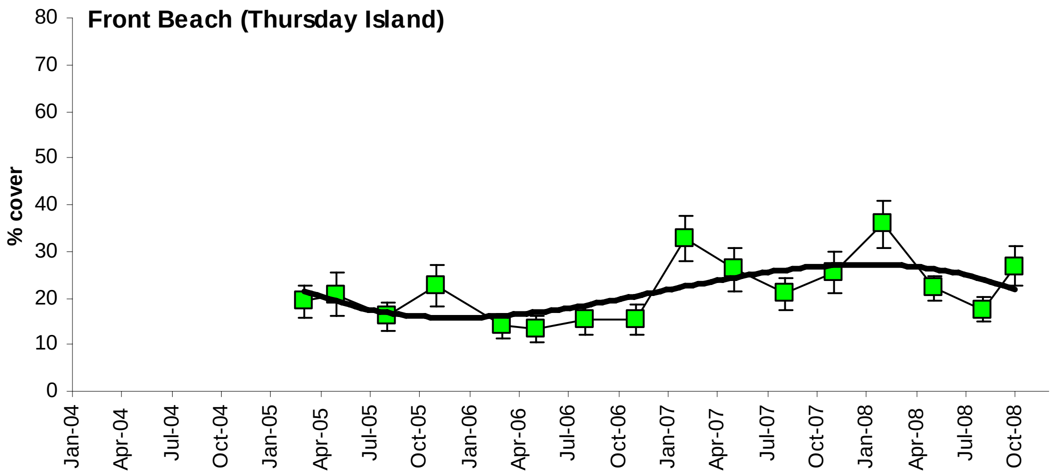
Front/Federal Beach (TI2)

This is a highly disturbed meadow due to its location at the receiving end of many storm water drains on Thursday Island. During the wet season the storm water drains deliver large quantities of freshwater and sediment to this meadow. The meadow overall is quite patchy, though species diversity is moderate. The upper intertidal zone is occupied by *Halodule uninervis* and *Halophila ovalis*. Traversing the meadow seawards, *Enhalus acoroides*, *Thalassia hemprichii* and *Cymodocea serrulata* become more abundant.

Within the Seagrass-Watch site, seagrass cover is sparse, with *Halodule uninervis* being the most abundant species present inshore with *Enhalus* and *Thalassia* occurring in the seaward quadrats. Species composition appears to fluctuate seasonally, driven by changes in *Halodule uninervis* and *Halophila ovalis.*



Seagrass appears to be showing a fairly typical seasonal pattern of abundance (higher in late summer than mid year) and was higher in 2008 than previous years. In general cover is low relative to the other sites being monitored. The frequency of disturbance is relatively high at this site and may explain the persistent low seagrass cover. The site is in the direct path of a large storm water drain and we have observed large amounts of sediment arriving on the site and burying the seagrass. Also, it's proximity to the main harbour results in frequent physical damage from vessel careening, scarring and anchoring. Seagrass abundance appears to have increased gradually since monitoring was established.

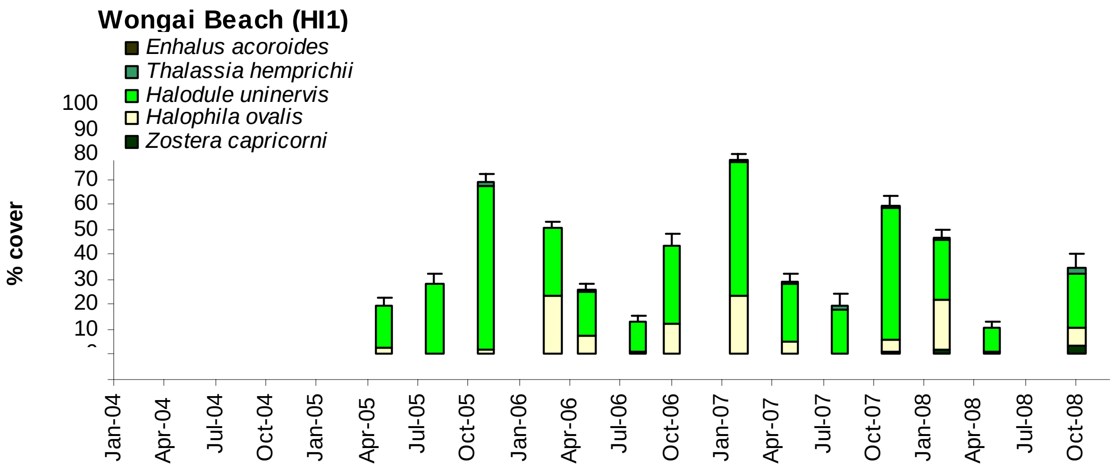


Hermit crabs, and snails are recorded regularly in this meadow with the occasional sighting of sand dollars and heart urchins.

Wongai Beach (HI1)

The meadow at Wongai Beach (Horn Island) is similar to the meadow at Front Beach Thursday Island, in that it has *Halodule uninervis* and *Halophila ovalis* occupying the landward edge of the meadow and *Enhalus acoroides* and *Thalassia hemprichii* seaward. However that is where all similarities end. HI1 has an extremely muddy substrate and in comparison has higher densities of seagrass and seeds. *Zostera capricorni* has also been noted at this site close to transect 3.

Species diversity is lower than Thursday Island sites as only 5 species have been reported: Enhalus acoroides, Thalassia hemprichii, Halodule uninervis, Halophila ovalis and Zostera capricorni. In last 12-18 months, the species composition appears to fluctuate seasonally, due to changes in *Halodule uninervis* and *Halophila ovalis.*



Seagrass abundance appears to have fluctuated greatly since monitoring was established. It does appear to be showing a fairly typical seasonal pattern of abundance (higher in spring/summer than mid year). Abundances were higher in 2007 than previous years or 2008.

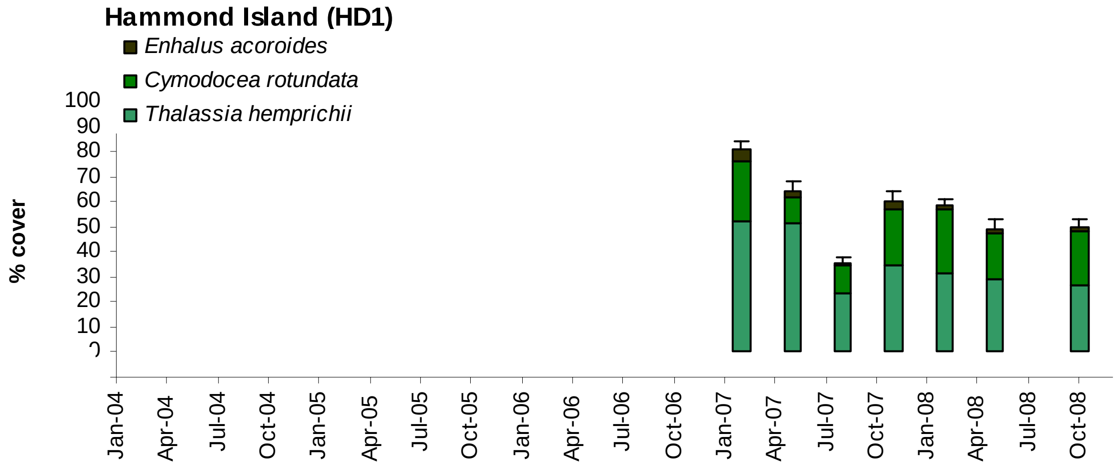
The decline in seagrass cover during 2008 can be attributed to the seaward migration of the landward edge of the meadow, possibly a result of impacts from the construction occurring along the foreshore.

During one monitoring trip, large numbers of small sea hares were observed on the site demonstrating the meadow's function as a nursery area.

.

Corner Beach, Hammond Island HD1

The meadow at Corner Beach is a multispecies meadow. The lower intertidal area of the meadow is dominated by a band of *Halodule uninervis* (narrow leaf). The Seagrass-Watch site is located further out in the multispecific band.



Within the Segrass-Watch site species diversity is low with only three species, *Enhalus acroides, Cymodocea rotundata* and *Thalassia hemprichii* being recorded. In last 12-18 months, the composition species composition appears to have remained stable.

Seagrass abundance appears to have decreased gradually since monitoring was established. The first year of monitoring did show some seasonal signal with minimum abundance occurring in the winter months. This was unable to be supported by a lack of sampling in August 2008 and the fact that the dataset for this site is limited.

.

Macro algae, sponges and mud crabs are commonly found within this reef top meadow

TORRES STRAIT SEAGRASS-WATCH SUMMATION

Monitoring of these sites has established that eight seagrass species inhabit this area. Variation in seagrass cover occurred inter-annually as well as intra-annually. Preliminary evidence from this monitoring data indicates that drivers for seagrass variability were climate related.

Generally seagrass abundance increased during the north-west monsoon (*Kuki)*, possibly a consequence of elevated nutrients, lower tidal exposure times, less wind and higher air temperatures. Most of the annual rainfall (95%) occurs during this time (Mulrennan and Hanssen 1994). Downstream flow from terrestrial habitats occurs with rainfall, bringing nutrients to the near shore environments. Seagrass meadows respond to this by increasing in cover, suggesting that these meadows may be nutrient limited. Decreased wind speeds also lessen turbidity and plants will be able to photosynthesize for longer periods.

Low seagrass abundance coincided with the presence of greater winds and longer periods of exposure at low tides during the south-east trade wind season (*Sager)*. This wind season is characterised by strong persistent winds with speeds up to 37km/hour and rough seas for two thirds of the time. Strong winds lead to an increase in turbidity due to re-suspension of sediments and thereby limiting the light reaching the seagrass canopy. Coupled with desiccation caused by long periods of exposure as low tides occur in the middle to early afternoon during this time of year, these are factors that restrict growth of intertidal seagrasses

This is preliminary evidence that drivers for seagrass variability are related to changes in climate. It is therefore important to maintain this monitoring in light of global warming which is predicting greater changes in climate. Information from Torres Strait is provided to Seagrass-Watch as part of a statewide and global monitoring initiative to ensure a broad comprehensive data stream on seagrass condition and trends. Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assess the human impacts which have the potential to destroy or degrade these coastal ecosystems and decrease their yield of natural resources (McKenzie et al. 2006b).

Notes:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Managing seagrass resources

Seagrasses do not exist in nature as a separate ecological component from other marine plants or habitats 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 origin in the protection of wider ecological systems or are designed to protect the overall biodiversity of the marine environment.

Coastal management decision making is complex, and much of the information on approaches and methods exist 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. Inter-country 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. Torres Strait Islanders 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. Many of these systems, have undergone considerable change since Torres Strait became part of Queensland in 1881 and there is a general feeling among modern day islanders that efforts should be made towards cultural revitalisation of those aspects of traditional *Ailan Kastom* that still exist (TSRA 2006).

Marine resource management in Torres Strait should therefore attempt to achieve the following interrelated objectives: *a*) monitor the wellbeing (distribution, health and sustainability) of culturally significant species (dugong, marine turtles, fish, molluscs),and environments (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 that are robust to challenge planning applications
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 of any areas that are of special value to the ecosystems that support coastal fisheries and inshore productivity. It is also important that this information is readily available to decision makers in Governments and traditional owners in a form that can be easily understood.

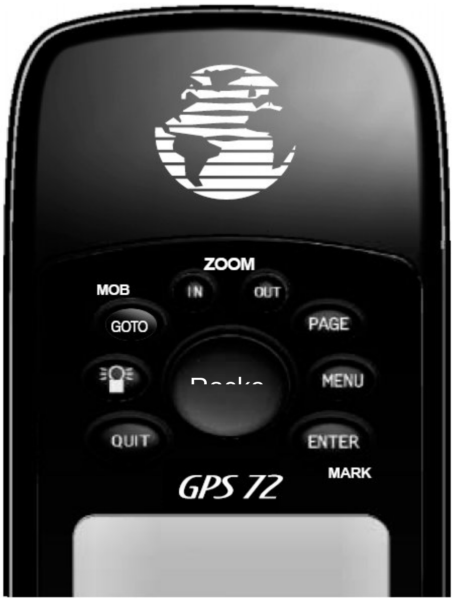
A combination of modern *"western"* science and indigenous knowledge can then be brought together within a co-management framework for the successful management of these resources. (Johannes 2002; Aswani & Weiant 2004; Turnbull 2004; Middlebrook and Williamson 2006; Gaskell 2003, George et al. 2004).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

Using the GARMIN GPS 72

For locating your site or mapping the edge of your meadow.

TURN GPS RECEIVER ON.

Hold down the Red button for 2 seconds. Wait a few seconds and the GPS unit will begin to track available satellites. Make sure to hold the GPS in a vertical position (top to the GPS pointing to the sky) for best reception of satellite signals.

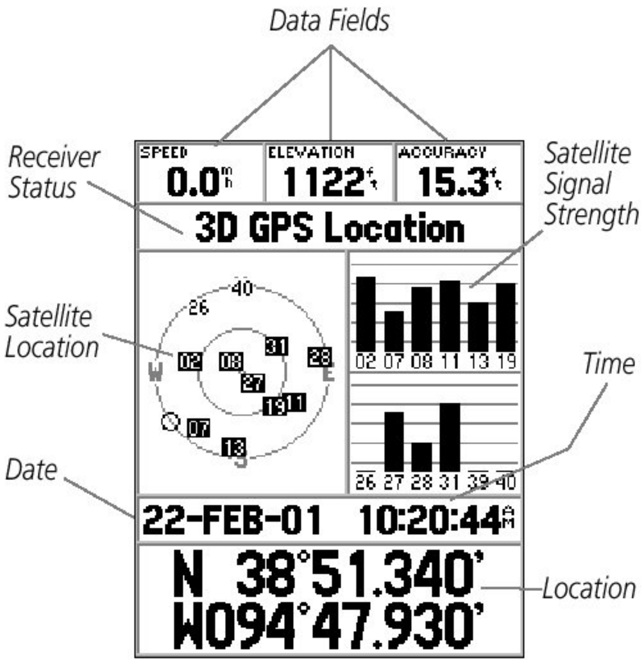


Using the Interface Keys on the GPS

- **IN & OUT** keys – used on the Map Page to zoom in and out.
- **GOTO/MOB** key – used to begin or stop navigation to a waypoint.
- **PAGE** key – used to cycle through the five main display pages in sequence.
- **POWER** key – used to turn the GPS on or off by holding the button down for 2 seconds.
- **MENU** key – used to display a variety of GPS options which can be altered to suit usage. Press the Menu key twice to access the Main Menu.
- **QUIT** key – used to cycle in reverse to the Page key. Also used to cancel operation in progress.
- **ENTER/MARK** key – used to activate or confirm a selection. To record a Waypoint, press and hold down the ENTER/MARK key.
- **ROCKER** key – used to move up/down and left/right to access and change menu options, and for data entry. The ROCKER key is always used to scroll through the different menu options and the ENTER key is used to activate or confirm the selection.

TRACKING SATELLITES.

Continue to press the PAGE key until the GPS Information Page appear (the Information Page looks like the diagram just below). When the GPS receiver is tracking enough satellites (minimum four), the GPS Information appears.



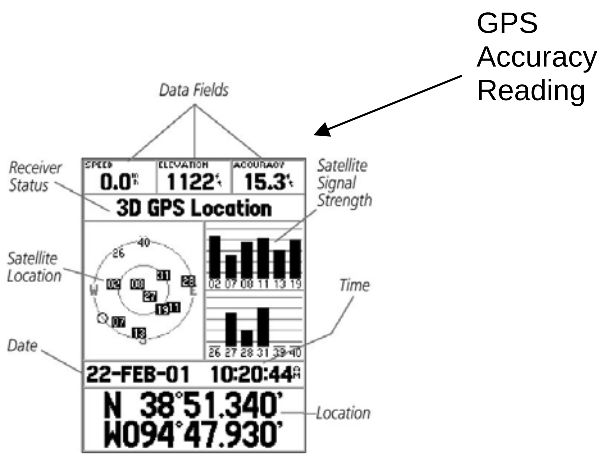
GPS Information Page

Receiver is now ready to record Waypoints. It is recommended that there are at least four satellites are present and have a strong signal when marking the waypoints. The more satellites available the better the accuracy.

MARK LOCATION AS WAYPOINTS

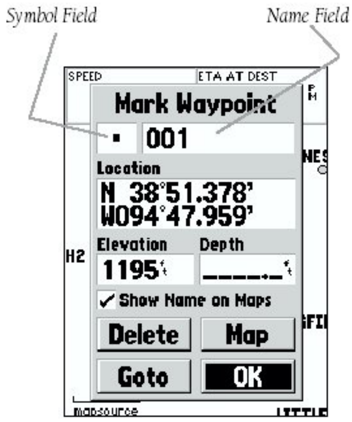
Mark Waypoints are stored as point locations.

To record Waypoints, it is best to be in the Information Page (continue to press the PAGE button until the Information page appears). Before you record a Waypoint, you must look at the accuracy reading on the GPS Information Page. An acceptable accuracy should be less than 5 metres (<5 m)



GPS Information Page

Step 1. Press and hold the **ENTER** key. The following screen appears:



Mark Waypoint Page

To save the waypoint without any changes, press **ENTER** on the OK button to save the waypoint.

Step 2. You can choose to rename the waypoint number to another name by using the ROCKER key to highlight the Name field, then press ENTER.

Step 3. Use the ROCKER key as an Alpha-numeric key selection to type in the new waypoint name. Press the ENTER key to accept the name.

Step 4. You can choose to delete the waypoint by highlighting 'DELETE?', press ENTER and then highlight the 'Yes' prompt and press ENTER again to confirm.

USE THE GOTO OPTION TO GET TO A LOCATION.

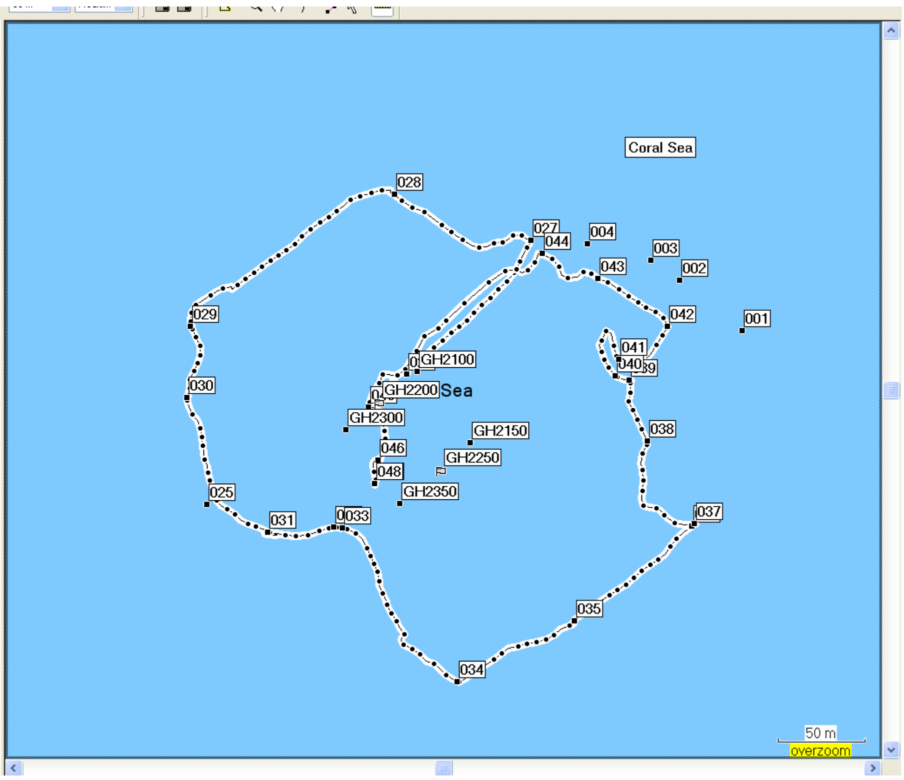
- Press the GOTO key.
- Highlight the "Waypoint" then press the ENTER key.
- Use the ROCKER key to highlight the waypoint you want to go to, press the ENTER key.
- Press the PAGE key until you get to the Map Page to see where you are (use the IN or OUT key to zoom in or out). Press the PAGE key until you get to the Compass Page to see where you need to be heading to get to the waypoint.

USING GLOBAL POSITIONING SYSTEM (GPS) TO MAP THE MEADOW EDGE/BOUNDARY

The meadow boundary is mapped by recording (or marking) a series of waypoints along the edge of the meadow from which a line representing the meadow boundary can then be drawn..

To map the boundary you should:

- Walk along the meadow edge, stopping to record (mark) waypoints on your GPS approximately every 10 steps or where there is a change in direction of the meadow boundary.
- Alternatively, you can use the "track" feature if the meadow boundary is clear.
- Only record a waypoint when you are sure you are on the edge of the meadow. For meadows where the edge is patchy you may have to do some reconnaissance to make sure you are at the edge of the seagrass meadow before recording a waypoint.
- Keep in mind that others will be using the points that you record on the GPS to draw a line (*"join the dots"*) that represents the meadow boundary, so it is better to have too many points than too few.
- Stand still for approximately 10 seconds on a point before recording (marking) a waypoint. It is good to keep checking the accuracy (in the top right of the screen) to ensure the point is as accurate as possible (generally less than 5m).
- As waypoints are labelled by sequential numbers, ensure you record the label of the first and last waypoint. If you make an error, either delete the waypoint or note the erroneous waypoint. .
- At the conclusion of the sampling trip the waypoints you record should be downloaded onto your computer



References

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

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

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

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

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

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

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

Long B, Skewes, T, Thomas, M, Isdale, P, Pitcher, R, and Poiner I, (1997). Torres Strait Seagrass Dieback. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Brisbane, Australia. 24pp.

Long B.G and Poiner I.R (1997). The Seagrass Communities of Torres Strait, Northern Australia.. Final report to TSFSAC 26. CSIRO Division of Marine Research, Cleveland, Brisbane, Australia. 49pp.

McKenzie et al. (2001b)

McKenzie LJ, Campbell SJ, Roder CA (2001). Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers. (QFS, NFC, Cairns) 94pp.

McKenzie LJ. (1994). Seasonal changes in biomass and shoot characteristics of a *Zostera capricorni* Aschers. dominant meadow in Cairns harbour, northern Queensland. *Australian Journal of Marine and Freshwater Research* **45**: 1337-52.

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

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

Taylor, H., Rasheed, M., McKenna, S., Sankey, T. & Chartrand, K. (2008).Critical Marine Habitats & Marine Debris in the Great North East Channel, Torres Strait – Poruma to Ugar Islands – 2008 Atlas. QDPI&F Information Series Northern Fisheries Centre, Cairns, 47pp.

Thomas, R. and Rasheed, M.A. (2004). Port of Thursday Island long-term seagrass monitoring - March 2004. QDPI&F Information Series QI04082. (Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, Cairns), 22 pp.

Torres Strait Regional Authority (TSRA), 2006. Welcome to the TSRA. http://www.tsra.gov.au/

Turnbull, C and Mellors J (1990). Settlement of juvenile Penaeus esculentus (Haswell 1978) on nursery grounds in the Torres Strait. In Torres Strait prawn project: A Review of Research 1986-88, J.E Mellors ed, Queensland Department of Primary Industries QI90018 29 – 38.

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

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

www.seagraswatch.org

www.unep.org

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. http://wsa.seagrassonline.org/

Seagrass Outreach Partnership Excellent website on seagrass of Florida. Provides some background information on seagrases 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 Authoirty. Includes a great collection of resources about the animals, plants, habitats and features of the Great Barrier Reef. Also iIncludes an on-line encyclopaedia, colour images and videos for educational use, a range of free teaching resources and activities. www.reefed.edu.au/home/

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

Puzzlemaker This is a great site where you can create and print customized word search, criss-cross, math puzzles, and more using your own word lists for free. puzzlemaker.discoveryeducation.com

Notes:

Notes:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Notes: