Seagrass-Watch

Proceedings of a Workshop for Mapping and Monitoring Seagrass Habitats in North East Arnhem Land, Northern Territory

18th – 20th October 2008

Len McKenzie

Seagrass-Watch HQ

Northern Territory Government

BATCHELOR INSTITUTE OF INDIGENOUS TERTIARY EDUCATION

First Published 2008

Disclaimer

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

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

The correct citation of this document is

McKenzie, LJ (2008). Seagrass-Watch: Proceedings of a Workshop for Mapping and Monitoring Seagrass Habitats in North East Arnhem Land, Northern Territory, 18–20 October 2008. (Seagrass-Watch HQ, Cairns). 49pp.

Produced by Seagrass-Watch HQ

Front cover illustration: Len McKenzie

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

Table of Contents

Overview

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

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

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

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

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

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

The goals of the Seagrass-Watch program are:

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

This workshop is hosted by the Dhimurru Aboriginal Corporation, local coordination by Neil Smit and Vanessa Walsh, and supported by the Dhimurru Aboriginal Corporation, the Northern Territory Department of Natural Resources, Environment, The Arts and Sport, Park and Wildlife Commission Northern Territory, Bachelor Institute of Indigenous Tertiary Education and Seagrass-Watch HQ. As part of this workshop we will

- *learn seagrass taxonomy*
- *discuss the present knowledge of seagrass ecology,*
- *discuss the threats to seagrasses*
- *learn techniques for monitoring seagrass resources*
- *learn techniques for mapping seagrass resources, and*
- *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 mapping and 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 leader

Len McKenzie

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

Current Projects

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

Agenda

Saturday 18th October 2008

Morning	830 - 840 *(10min)*	Welcome
	840 - 900 *(20min)*	Seagrass Biology and Identification
	900 - 930 *(30min)*	**Classroom activity:** Seagrass Identification
	930 - 1000 *(30min)*	Seagrass Identification *continued*
	1000 - 1015 *(15min)*	**Classroom activity:** how to prepare a seagrass press specimen
	1030 - 1100	*Break*
	1100 - 1215 *(85min)*	Seagrass Ecology and Threats
Afternoon	1215 - 1330	*Lunch*
	1330 – 1345 *(15min)*	Seagrass monitoring
	1345 – 1430 *(45min)*	Seagrass-Watch: how to sample
	1530 – 1730 *(2hrs)*	**Field activity:** Seagrass-Watch monitoring
		Low tide: 0.2m 1712hrs (0.7m at 1520hrs)

Sunday 19th October 2008

Afternoon	1300 – 1320 *(20min)*	Seagrass Mapping Pt 1
	1320 – 1350 *(30min)*	Seagrass Mapping Pt 2
	1430 – 1700 *(2.5hrs)*	**Field activity:** Seagrass Mapping
		Low tide: 0.22m 1754hrs (0.7m at 1600hrs)

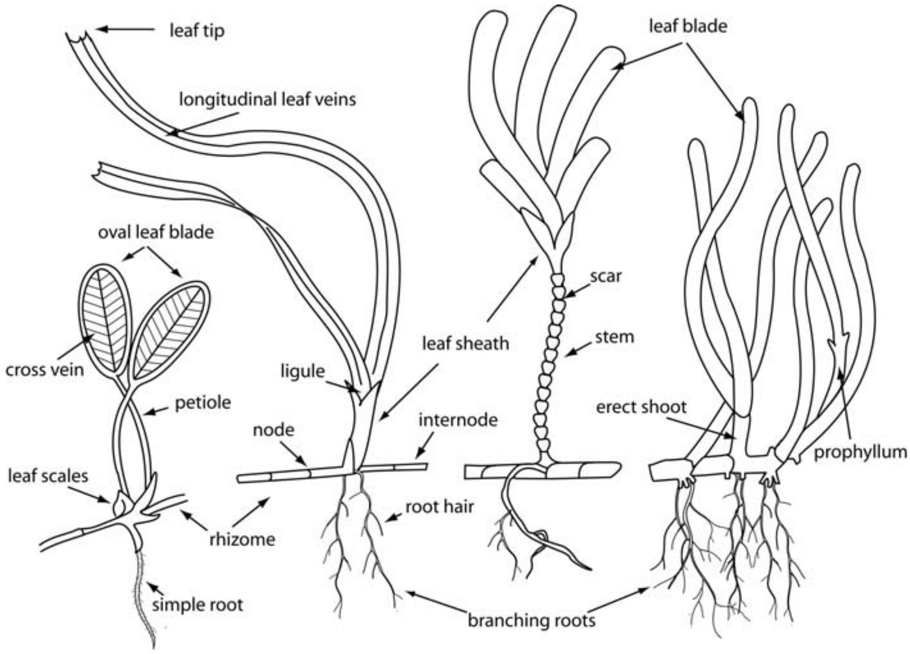
Monday 20th October 2008

Morning	945 – 1000 *(15min)*	Seagrass-Watch refrehser
	1000 – 1045 *(45min)*	**Classroom activity:** Data entry & interpretation
	1045 – 1115	*Break*
	1115 – 1215 *(60min)*	Seagrass-Watch: how data is used
Afternoon	1215 - 1330	*Lunch*
	1330 – 1400 *(30min)*	Seagrass Mapping Pt 3
	1400 – 1430 *(30min)*	Seagrass Management
	1430 - 1500 *(30min)*	Open discussion & Close

Background

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

Seagrass are marine flowering plants



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

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

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

Seagrasses have roots, stems and leaves

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

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

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

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

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

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

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

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

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

Seagrass pump oxygen into the sediment via their roots

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

Seagrass have flowers, fruits and seeds

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

Pollination occurs in the water

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

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

Seagrass taxonomy

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

Seagrasses are not true grasses

Seagrasses are more closely related to lilies

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in a least three separate lineages or families. Thus, seagrasses are not a taxonomically unified group but a ‘biological’ or ‘ecological’ group. The evolutionary adaptations required for survival in the marine environment have led to convergence (similarity) in morphology.

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

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

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

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

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

Seagrass requirements for growth

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

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. A limiting factor for many intertidal seagrasses is osmotic impacts resulting from hypersalinity due to evaporation

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

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

Light availability is the most important factor determining seagrass growth

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

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

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

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

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

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

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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

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

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

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

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

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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

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

Where are seagrasses found?

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

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

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

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.

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

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.

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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

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

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

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

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

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

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

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.

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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 help remove harmful nutrient and sediment pollution from coastal waters

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.

Interactions with mangroves and coral reefs

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

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.

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

Valuation of seagrasses

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

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

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

What causes seagrass areas to change?

Tropical seagrass meadows vary seasonally and between years, and the potential for widespread seagrass loss has been well documented.

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

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

Seagrasses can change due to both natural and human impacts

What threatens seagrass?

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

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, 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.

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

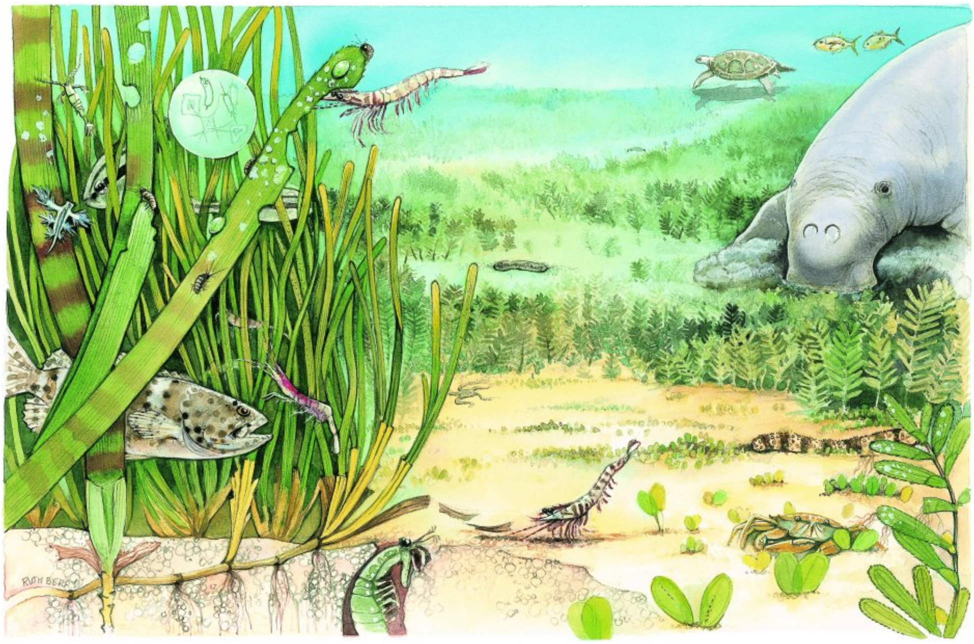
People can also physically damage or destroy seagrass. Coastal development for boat marinas, shipping ports and housing generally occurs on the coast in areas which are sheltered and seagrass like to grow. Seagrass meadows are either removed or buried by these activities. Coastal developments can also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

Coastal development can have a major impact on seagrass meadows

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

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

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



Notes:

....

....

....

....

....

....

....

....

Interesting facts:

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

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

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

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

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

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

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

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

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

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

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

Seagrass produce the longest pollen grains on the planet.

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

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

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

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

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

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

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

Notes:

Seagrass of North East Arnhem Land, Northern Territory

Arnhem Land consists of the eastern half of the large peninsula that forms the northernmost portion of the Northern Territory. The region, with a total area of about 95,900 km^2, consists of a ruggedly dissected plateau and associated lowlands. The coast of Arnhem Land extends from Van Diemen Gulf and the Cobourg Peninsula eastward to Gove Peninsula, the Gulf of Carpentaria south east to the Roper River, and Groote Eylandt. The climate is characterised by a tropical monsoon with a distinct wet season starting in November/December and lasting for approximately four months followed by a dry season. Cyclonic activity is low to moderate (Ferns 1999).

Although no area on earth is unaffected by human influence, Arnhem Land 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 mostly 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.

Local indigenous people hold much of the biological knowledge of Arnhem Land. Very little marine research has been conducted and consequently there is very little known about the distribution and abundance of marine flora and fauna, including seagrasses along the Arnhem Land coastline (Butler & Jernakoff 1999; Coles *et al.* 2004)). Much of the information has been based on anecdotal evidence from the 1970s (Williams *et al.* 2000; Green & Short 2003), surveys from fixed wing aircraft in the 1980s (Poiner *et al*. 1987), and a recent survey of intertidal seagrass meadows by helicopter in November 2004 (Roelofs *et al.* 2005).

Seagrass has been reported in the past from Nhulunbuy (*Halophila decipiens*) and along the north coast of the Tiwi Islands. Ten seagrass species have been reported from the waters surrounding Arnhem Land (Poiner *et al*. 1987; Roelofs *et al.* 2005): *Cymodocea serrulata, Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halophila decipiens, Halophila ovalis, Halophila spinulosa, Syringodium isoetifolium, Thalassia hemprichii* and *Thalassodendron ciliatum*. *H. uninervis* and *H. ovalis* are by far the most common on the open sand and mud flats. *T. hemprichii* and *T. ciliatum* are often found on reef platforms and around rocky islands. *E. acoroides* often occurs in sheltered bays.

Goulburn Islands - Castlereagh Bay

This region encompasses the western coastline of northern Arnhem Land and lies within the western part of the Arnhem-Wessel marine bioregion (ANZECC 1998). The Goulburn-Castlereagh Bay region has a diverse coastline. Between Goulburn Islands and Maningrida the dominant landforms are undulating sand and lateritic plains with sandy beaches and low rocky headlands with mangrove lined saline mudflats in the more protected bays and estuaries. East of Maningrida, coastal landforms are dominated by floodplains and mangroves with extensive tidal mud and sand flats. Off the coast there are a number of islands: North and South Goulburn islands; Entrance Island in the mouth of the Liverpool estuary; Mooroonga Island and the Crocodile Islands, which lie north-east of Millingimbi.

In this region the coastal waters are shallow and have a tidal range of 2 5 m (Heap et al. 2004). Currents (0.5 – 1.0 knots) are generally westerly during the Dry but during the Wet they are weak and have no constant direction (Heap et al. 2004). Wave energy is generally low except during short periods during storm and cyclonic activity in the Wet and transition periods between the Wet and Dry (Davies 1986). Water clarity varies within the region: estuaries, protected bays in the west and near coastal waters in the east are naturally turbid, whereas the rocky platform and sandy areas in the west and offshore waters across the region including around the offshore islands (eg Goulburn's, Crocodile and Mooroonga islands) have low turbidity.

Roelofs *et al*. (2005) mapped 6,694ha of intertidal seagrass meadows in this region. Approximately half of the meadows mapped were classified as aggregated patches. Intertidal seagrass communities in this region were concentrated around the Goulburn Islands, Maningrida and Milingimbi (Roelofs *et al*.2005).

Six seagrass species have been identified from this region: *Enhalus acoroides, Halodule uninervis, Halophila decipiens, Halophila ovalis, Thalassia hemprichii* and *Thalassodendron ciliatum*.

The Goulburn Islands seagrasses were typical of tropical reefal seagrass communities and were comprised of *Thalassia, Thalassodendron* and *Enhalus* species (Roelofs *et al.* 2005). The sheltered regions near the Maningrida and Milingimbi communities supported extensive *Halophila* dominated meadows. Isolated and aggregated seagrass patches were the dominant cover type for this region (Roelofs *et al.* 2005). The large open bays in the region (Boucuat, Castlereagh, Buckingham and Arnhem Bays) were almost devoid of intertidal seagrass meadows, with only small isolated meadows found in Castlereagh and Boucaut Bays (Roelofs *et al.* 2005).

Melville Bay

Melville Bay is a large embayment adjacent to Nhulunbuy (pop. 3500), the second largest population in the Northern Territory (Gardner 1991). Melville Bay is approximately 170 km^2 in area, and fringed by mangroves, with several coarse sandy beaches and some rocky shores. There are small rocky islands and headlands in the northern part of the bay. The water in the Bay is shallow, rarely more than 15m in depth and mostly less than 10m. The tidal range is 4m and on most low spring tides some of the shallow arms of the Bay dry out. The substrate over most of the Bay is fine mud and silts, typically anoxic, and seagrasses are present but patchy in distribution (Foster *et al.* 1968; Hanley 1996). Seagrasses are largely *Halophila* spp. although several other species are reported (Hanley 1996). Approximately 10.8 km^2 of intertidal flats occur within the bay (http://dbforms.ga.gov.au/pls/www/npm.ozest.show_mm?pBlobno=9037) and it is likely that seagrass habitats cover some proportion of these.

Along the northern side of Melville Bay, is the Gove peninsula where the Nabalco alumina refinery is located. The Nabalco bauxite mine at Nhulunbuy lies inland and the ore is transported by conveyor to the Gove peninsula. There have been a number of reports examining Nabalco's operations and potential environmental impacts on the region (Noller 1991; Peerzada *et al.* 1990a, 1990b; Peerzada & Dickinson 1989; McConchie 1991; Hanley 1993a). Concerns have included the level of sulphur emissions from the Steam Power Station stacks, the discharge of heated seawater into the Bay, occasional spills of caustic soda into the Bay (Noller 1991), and heavy metal contamination of oysters in Melville Bay.

Apart from the possible impact of Nabalco operations on the Bay there are several other sources of concern. A barge landing facility and a fuel depot for prawn trawlers are located on the southern side of a low, narrow peninsula dividing Melville Bay from the sea. Further east along this peninsula lies the recreational yacht club in Inverell Bay. The sediments of the small embayments on the southern side of the peninsula are fine mud and silts and are highly anoxic. This is a depositional environment with poor circulation, particularly since the construction of a causeway during World War II has halted movement of seawater through the northern end of Drimmie Arm (Hanley 1996). Careful assessment and the development of a management plan for the area has been recommended (Hanley 1996).

Western Gulf of Carpentaria (Gove to Roper 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 and a very dry winter period with south-east trade winds. Seasonal temperatures range from 10 º C in winter (Poiner *et al.* 1989) to the high 30's in summer. Tidal ranges are around 0.5m at Groote Eylandt.

Two broad scale surveys have been conducted of the western Gulf of Carpentaria coast. This is a complex coastline with few river inputs, and is consequently less muddy than the southern Gulf. In November 1983 (Poiner *et al.* 1987) mapped 440km^2 of seagrass meadows between Limmen Bight River and Gove. Significant areas of seagrass occured at Groote Eylandt (Poiner *et al.* 1987). Roelofs *et al.* (2005) mapped approximately 59km^2 of intertidal meadows along the mainland coast. The differences between the surveys are possibly a result of different survey methods used and/or because of physical damage by tropical storms and cyclones for which the region is prone.

Eight seagrass species have been identified in this region: *Cymodocea serrulata, Cymodocea rotundata, Enhalus acoroides, Halodule uninervis, Halophila ovalis, Halophila spinulosa, Syringodium isoetifolium,* and *Thalassia hemprichii* (Poiner *et al.* 1987; Roelofs *et al.* 2005).

Open-coastline communities were the major intertidal meadow types mapped in this region and they were dominated by monospecific stands of *H. ovalis* and *H. uninervis* intertidally, and *C. serrulata* and *S. isoetifoliurn* subtidally (Poiner *et al.* 1987; Roelofs *et al.* 2005). Mixed-species meadows of *C. serrulata, T. hemprichii* and *S. isoetifolium* occurred on reef flats, some small sheltered embayments were dominated by *E. acoroides*, and *H. ovalis* and *H. spinulosa* sometimes occurred in river-mouth areas (Poiner *et al.* 1987).

In areas surveyed in 2004, seagrass communities were concentrated in the Caledon and Blue Mud Bay regions in the north and Numbulwar in the south (Roelofs *et al.* 2005). Most meadows with aggregated seagrass patches and they supported abundant dugong and turtle populations, particularly in Caledon Bay and from Limmen Bight to the Sir Edward Pellew Island Group (Roelofs *et al.* 2005).

For more information, visit www.seagrasswatch.org

Notes:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

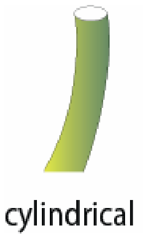
....

....

A guide to the identification of seagrasses in North East Arnhem Land, Northern Territory

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.*

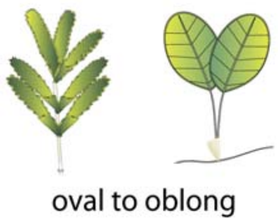
Leaves cylindrical



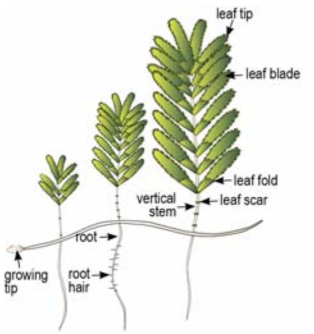
Syringodium isoetifolium

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

Leaves oval to oblong



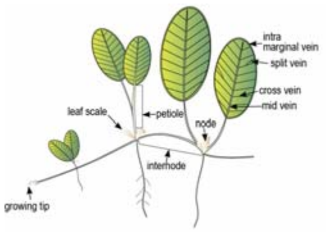
obvious vertical stem with more than 2 leaves



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

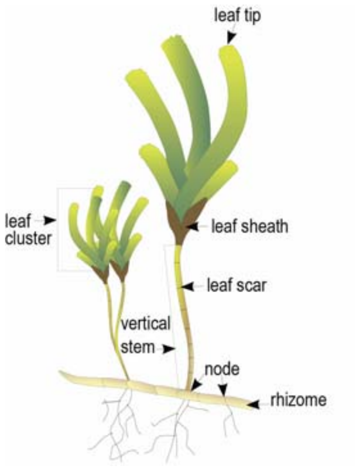
Halophila decipiens

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

Leaves strap-like

straplike

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 rotundata

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

Cymodocea serrulata

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

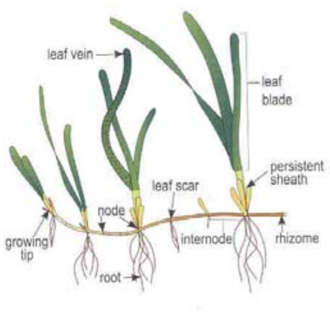
Halodule uninervis

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

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

Monitoring a seagrass meadow

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

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

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

Seagrass-Watch

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

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

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

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

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

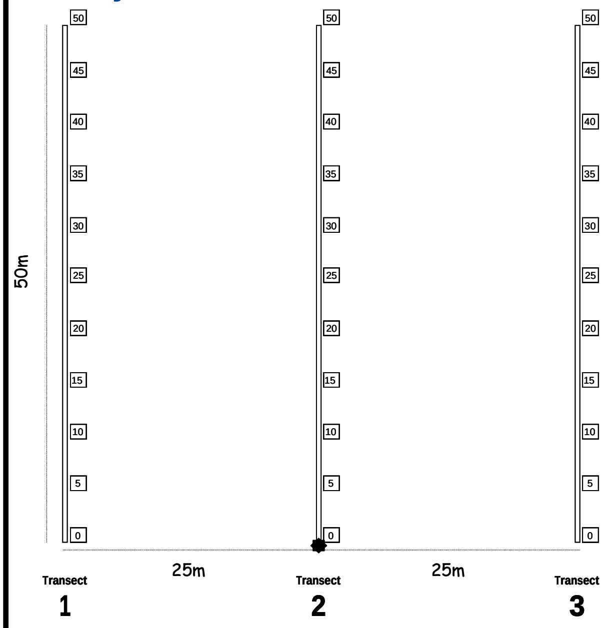
THE GOALS OF THE PROGRAM ARE:

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

Seagrass-Watch Protocols

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

Site layout



Quadrat code = site + transect+quadrat

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

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Quarterly sampling

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

Step 1. Take a Photograph of the quadrat

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

Step 2. Describe sediment composition

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

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

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

Step 4. Estimate seagrass percent cover

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

Step 5. Estimate seagrass species composition

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

Step 6. Measure canopy height

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

Step 7. Estimate algae percent cover

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

Step 8. Estimate epiphyte percent cover

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

Step 9. Take a voucher seagrass specimen if required

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

At completion of monitoring

Step 1. Check data sheets are filled in fully.

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

Step 2. Remove equipment from site

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

Step 3. Wash & pack gear

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

Step 4. Press any voucher seagrass specimens if collected

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

Step 5. Submit all data

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

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

Seagrass mapping

Seagrass-Watch activities initially map the distribution of seagrass meadows at a locality or in a region to better understand the seagrass resources of an area. Mapping is often limited to the accessible intertidal seagrasses, although in some cases subtidal seagrass meadows can be included.

The most important information that is required for management of seagrass resources is their distribution, ie. a map. It would be inappropriate to set up a monitoring program if the most basic information is unavailable - that is, whether seagrass is present or absent.

When planning a mapping task, there are several issues that need to be considered, including:

Scale

Mapping requires different approaches depending on whether survey area is relative to a region (tens of kilometres), locality (tens of metres to kilometres) or to a specific site (metres to tens of metres). Scale includes aspects both of extent and resolution. In both broad and large scale approaches, the intensity of sampling will be low (low resolution), with a statistical sampling design that allows the results to be extrapolated from a few observations to the extent of the study area. For finer scale examinations of seagrass meadows, the sampling intensity required can be high with greater precision (high resolution). Scale also influences what is possible with a limited set of financial and human resources. The financial, technical, and human resources available to conduct the study is also a consideration.

Accuracy

Determining the level of detail required when mapping an area also depends on the level of accuracy required for the final map product. Errors that can occur in the field directly influence the quality of the data. It is important to document these. GPS is a quick method for position fixing during mapping and reduces point errors to <3m in most cases. It is important for the observer to be as close as possible to the GPS aerial receiver to minimise position fix error.

Choosing a Survey/Mapping strategy

The selection of a mapping scale represents a compromise between two components. One is the maximum amount of detail required to capture the necessary information about a resource. The other is the logistical resource available to capture that level of detail over a given area. Generally, an area can be mapped using a grid pattern or a combination of transects and spots. When mapping a region of relatively homogenous coastline between 10 and 100 km long, we recommend that transects should be no further than 500-1000 m apart. For regions between 1 and 10 km, we recommend transects 100-500 m apart and for localities less than 1 km, we recommend 50-100 m apart. This however may change depending on the complexity of the regional coastline, i.e., more complex, then more transects required.

To assist with choosing a mapping strategy, it is a good idea to conduct a reconnaissance survey. An initial visual (reconnaissance) survey of the region/area will give you an idea as to the amount of variation or patchiness there is within the seagrass meadow. This will influence how to space your ground truthing sites.

When mapping, ground truthing observations need to be taken at regular intervals (usually 50 to 100m apart). The location of each observation is referred to a point, and the intervals they are taken at may vary depending on the topography.

When ground truthing a point, there are a variety of techniques that can be used depending on resources available and water depth (free dives, grabs, remote video, etc). First the position of a point must be recorded, preferably using a GPS. Otherwise use a handheld compass to determine the bearing, triangulating to at least 3 permanent landmarks or marker established as reference points. A point can vary in size depending on the extent of the region being mapped. In most cases a point can be defined as an area encompassing a 5m radius. Although only one observation (sample) is necessary at a ground truth point, we recommend replicate samples spread within the point (possible 3 observations) to ensure the point is well represented.

Observations recorded at a point should ideally include some measure of abundance (at least a visual estimate of biomass or % cover) and species composition. Also record the depth of each point (this can be later converted to depth below mean sea level) and other characteristics such as a description of the sediment type (eg. shell grit, rock, gravel, coarse sand, sand, fine sand or mud), or distance from other habitats (reefs or mangroves).

For details on the necessary materials & equipment and the general field procedure for mapping a seagrass meadow, please see Chapter 4 of the Seagrass-Watch manual (www.seagrasswatch.org/manuals.html).

Creating the map

The simplest way to map the distribution of seagrasses is to draw the meadows on a paper marine chart from the GPS positions of the ground truth sites. The problem with this type of mapping is that the final map is in a format that does not allow manipulation and transformation. The layout of a paper map is permanent, which makes it difficult for future seagrass mapping studies to be compared, queried and analysed. If resources are available, we recommend that the data be transferred to a digital format and a Geographic Information System (GIS) be used. A detailed description of using and mapping with GIS is beyond the scope of this manual, and we recommend consulting with a scientist experienced in mapping and reading McKenzie *et al.* (2001b).

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.

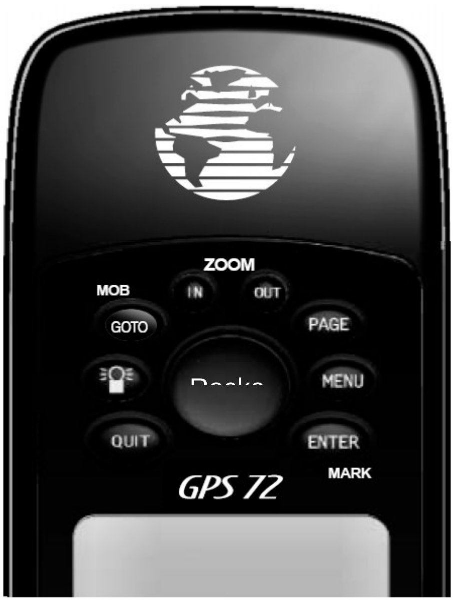
To map the boundary you should:

- 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 may 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 a 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 (see later section)

Using the GARMIN GPS 72

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.

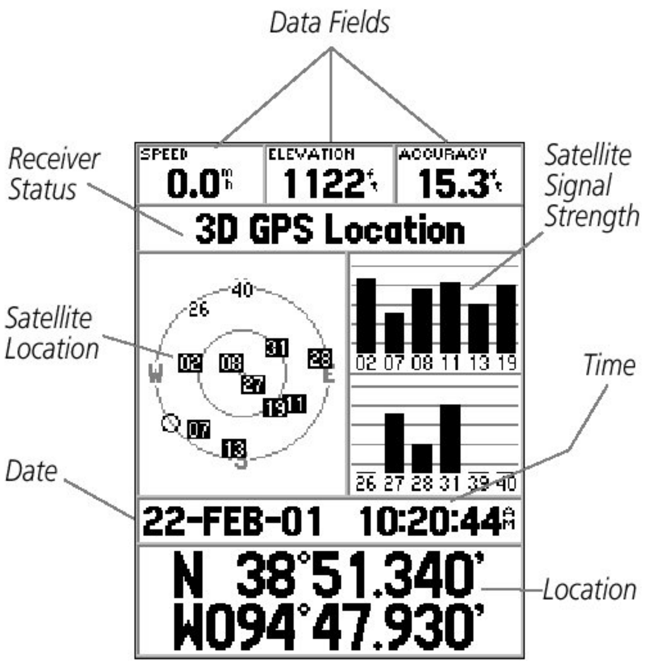


Using the Interface Keys on the GPS

- **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.

Before any waypoints are to be collected, you must check that the GPS settings are correct. The settings are in the Main Menu.

Setting up the correct properties in the Main Menu

- To get to the Main Menu you must press the **Menu** key twice.
- Scroll down to highlight "Setup" and press **Enter**.
  1. You must use the **ROCKER** key and move to the appropriate field and use the **ENTER** key to activate the field.
  2. Then use the **ROCKER** key (to move up/down and left/right) to access the appropriate setting and use the **ENTER** key to confirm selection.
  3. Once changes are made, use the **QUIT** to exit each of the option or menu.
- Scroll across to the "Time" tab and change to the Time settings.

Time Setup

Time Format : 24 Hour

Time Zone : Other

UTC Offset: +10:00

- Scroll across to the "Location" tab and change to the Time settings.

Units Setup

Elevation : Meters

Distance and Speed: Metric

Temperature: Celsius

- Scroll across to the "Location" tab and change to the Time settings.

Location Setup

Location Format : hddd.ddddd

MAP DATUM : WGS84

- Scroll across to the "Interface" tab and change to the Time settings.

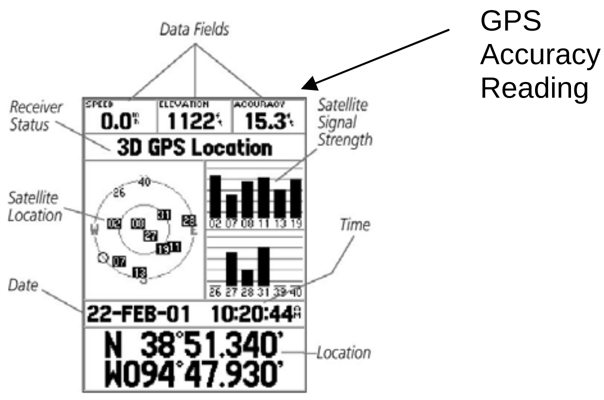
Interface Setup

Serial Data Format: Garmin

Mark Location as Waypoints

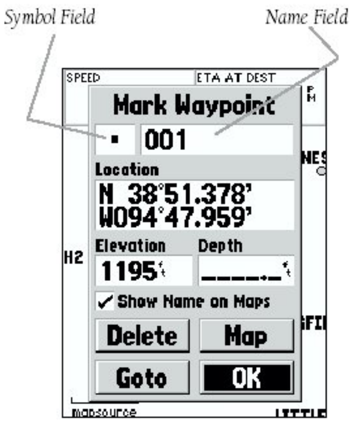
Mark Waypoints are stored as point locations.

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 15 metres (<15 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.

Installing the program MAPSOURCE to download information from your GPS to your computer

Step 1: Installing MapSource

Before installing MapSource, all programs should be closed.

1. Put CD into the CD Drive (Place the CD in with CD labels facing up)
2. If the MapSource setup menu does not appear automatically, Go to **Windows Explorer** (Select Start, Programs, Windows Explorer)
   - Double Click on CD Drive (This could either be D: or E: drive on your computer)
   - Double click on "**Setup.exe**" (To startup the setup program [about 70kb])
     - i. Click **Next** (To say OK to the Welcome Page)
     - ii. Click **Yes** (To accept License Agreement)
     - iii. Click **No** (When ask to check GPS)
     - iv. Click **No** (To confirm not checking the GPS)
     - v. Click **Next** (To select typical install)
     - vi. Click **Finish** (To complete installation)

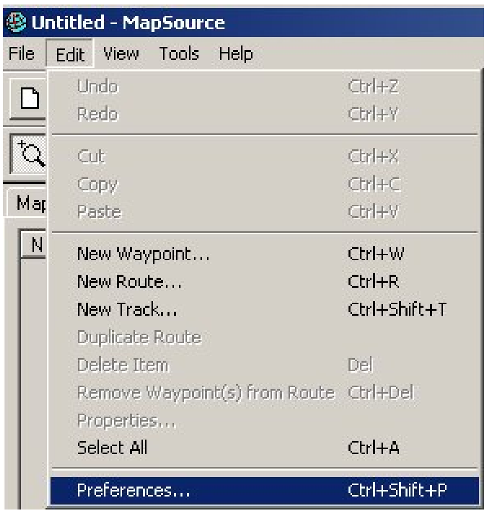
Step 2: Installing Updated files for Mapsource

1. While the **CD** is still in the CD drive,
3. Go to **Windows Explorer** (Select Start, Programs, Windows Explorer)
2. Double Click on CD Drive (This could either be D: or E: drive on your computer)
3. Double Click the **Mapsource Upgrade** folder (You will see a MapSource_680.exe file)
4. Double Click on the file **mapsource_680.exe** (This will startup the setup program to MapSource)
5. Click **Next** (To choose English language)
6. Click **Next** (To accept MapSource Version 6.8)
7. Click **Yes** (To accept License Agreement)
8. Click **Finish** (To complete installation)
9. Eject CD and take disc out

Step 3: Setting the correct Properties for MapSource

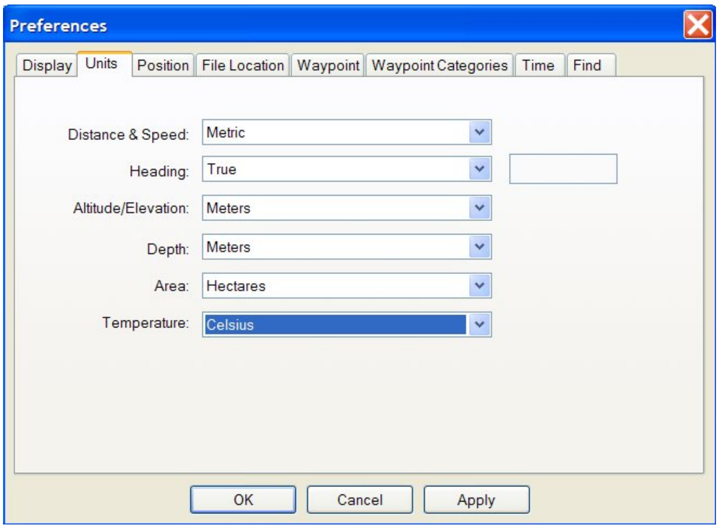
Before using MapSource you must set up some map properties to view the data.

1. Start MapSource (Click the MapSource Icon on the desktop)
2. Go to the **Edit** menu and select **Preferences**



3. The Preferences window will appear.

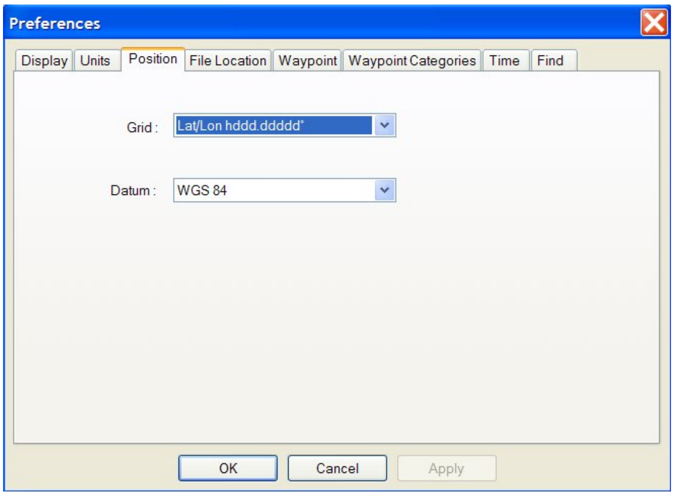
Go to the **Units** tab



You must set the following properties:

- Distance & Speed Metric
- Heading True
- Altitude/Elevation Meters
- Depth Meters
- Area Hectares
- Temperature Celsius

4. Go to the **Position** tab



You must set the following properties:

- Grid Lat/Lon hddd.ddddd
- Datum WGS 84

5. Click OK to finish.

6. MapSource is now correctly set up for use.

Downloading information from your GPS using the MapSource program

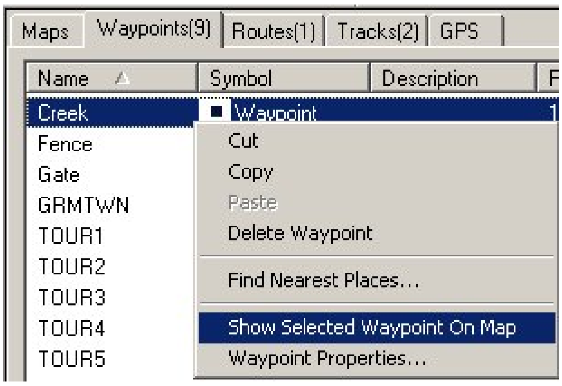
Step 1: Downloading GPS data using MapSource (download software)

1. Start MapSource (Double click on the MapSource Icon) or (start, programs, MapSource, MapSource)
2. Plug the Garmin serial cable from your GPS unit to the communications port on your computer.
3. On the GPS unit, make sure that the Garmin interface is set to "**GARMIN**" on the GPS 72. To Check this, go to the "Setup menu", select "Interface", select "GARMIN".
4. In the MapSource program, go to the **Transfer** menu and select "**Receive from Device..**". The following menu will appear.

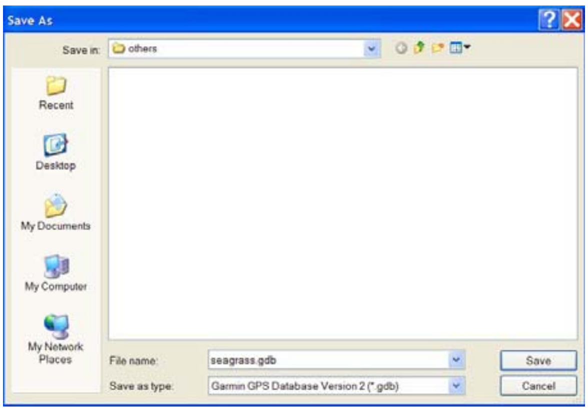
5. Click on the **Receive** button.
6. The GPS data will begin to download to the MapSource software. Click OK after data is successfully opened.

Saving GPS data in MapSource

1. To Check the GPS data that has just been downloaded, click on the "Waypoints" tab (the full list of all waypoints are listed).
2. To view the waypoints on the MapSource map area, right click on any of the waypoints (a context menu will appear) and select "**Show Selected Waypoint On Map**". The waypoint will be shown on the map



3. You must always save the GPS data that has been downloaded to MapSource. To save the GPS data in MapSource, Click on "**File**" menu, then select "**Save**". A "Save As" window will appear. Browse to the directory where you want to save the file in and type in a file name. Click "Save" and the MapSource file is save (this file contains all the GPS data).



The advantages for saving the GPS data are:

- GPS data will not be lost when the data is save in a MapSource file (*.mps) to your PC.
- The GPS data on the GPS unit can be deleted. The GPS unit will have the maximum memory space available for any further data capture use.
- Once the GPS data is saved as a MapSource file, the data can always be uploaded back onto the GPS unit.

Notes:

Managing seagrass resources

Threats to seagrass habitats

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

Management

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

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

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

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

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

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

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

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

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

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

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

References

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

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

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

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

Coles, R, Smit, N, McKenzie, L, Roelofs, A, Haywood, M & Kenyon, R (2004). Seagrasses. In: National Oceans Office. Description of Key Species Groups in the Northern Planning Area. National Oceans Office, Hobart, Australia. pp9-22.

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

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

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

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

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

Foster, D.N., Stone, P.B. & Nelson, R.C. 1968, Gove, N.T. Harbour feasibility studies, Report no.102., Water Research Laboratory, University of NSW.

Gardner, P.M. 1991, Northern Territory Statistical Summary 1991, Australian Bureau of Statistics, Northern Territory Office.

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

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

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

Halpern, BS., Walbridge, S., Selkoe, KA., Kappel, CV., Micheli, F., D’Agrosa, C., Bruno, JF., Casey, KS., Ebert, C., Fox, HE., Fujita, R., Heinemann, D., Lenihan, HS., Madin, EMP., Perry, MT., Selig, ER., Spalding, M., Steneck, R. and Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science* **319**: 948-952

Hanley, J.R. 1993a, `Melville Bay Environmental Study: Report on the Benthic Invertebrates Survey, July 1991 and March 1992', Marine Ecology Technical Report 93/1, 75 pp., and supplement (species list), Marine Ecology Unit, Museum and Art gallery of the Northern Territory.

Hanley R. (1996). Issues in the Northern Territory Marine Environment. In (LP Zann and D Sutton, Eds) State of the Marine Environment Report for Australia: State and Territory Issues - Technical Annex 3. Department of the Environment, Sport and Territories, Canberra (1996). ISBN 0 642 23012 9 (http://www.environment.gov.au/coasts/publications/somer/annex3/nt.html)

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

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

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

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

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

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

McConchie, D.M. 1991, Progress Notes on the Melville Bay Marine Study, Northern Territory, November, 1991, Report to Nabalco.

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

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

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

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

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

Noller, B.N. 1991, Assessment of Trace Element Levels at Melville Bay, Gove Peninsula, Northern Territory, Environmental Technical Report 91/1, Mines Environment Directorate, Northern Territory Department of Mines and Energy, Darwin.

Peerzada, N. & Dickinson, C. 1989, `Metals in Oysters from the Arnhem Land Coast, Northern Territory, Australia, Marine Pollution Bulletin, vol. 20 (3), pp. 144-145.

Peerzada, N., Eastbrook, C. & Guinea, M. 1990a, `Heavy Metal Concentration in Telescopium from Darwin Harbour, N.T., Australia', Marine Pollution Bulletin, vol. 21 (6), pp. 307-308.

Peerzada, N., McMorrow, L., Skiliros, S., Guinea, M. & Ryan, P. 1990b, `Distribution of Heavy Metals in Gove Harbour', The Science of the Total Environment, vol. 92, pp. 1-12.

Poiner, IR, Staples, DJ & Kenyon, R (1987). Seagrass communities of the Gulf of Carpentaria, Australia. Australian Journal of Marine and Freshwater Research 38: 121-131.

Poiner, IR, Walker, DI & Coles, RG (1989). Regional studies - seagrasses of tropical Australia. In: Larkum, AWD, McComb, AJ & Shepherd, SA (Eds). Biology of Seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. Elsevier, New York: 279-296.

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

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

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

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

Further reading:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Please complete the following statements in your own words

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

....

....

What I enjoyed most about the training was..

....

....

It could have been better if ....

....

....

I did not realize that...

....

....

Now I understand that ....

....

....

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

....

....

....

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

..

..

..

Other comments..

..

..

..

..

..

..

..

..

..

..

..

..

..

..

..

..