Seagrass Educators Handbook

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This handbook provides educators with information on what seagrasses are, their plant morphology and anatomy, where they can be found, and how they survive and reproduce in salt water. Information on seagrass habitat and its function, such as sediment stabilisation, food web and nursery areas is provided. Conservation and management options for seagrass habitats are also discussed.

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

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 assist 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 helps transport within water. *Halophila* and *Thalassia* have spherical pollen grains, but they remain joined together in long chains, giving the same effect as having elongated, filamentous pollen grains.

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

Seagrass taxonomy

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

Seagrasses are not true grasses

Seagrasses are more closely related to lilies

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

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

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

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

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

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.

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 are physiologically adapted to life in sea water

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

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

Seawater temperatures above 40ºC will stress seagrass. Death occurs at temperatures above 45ºC electron transport activity via inactivation of the oxygen producing enzymes (proteins) of photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

Temperature also controls the range of 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

Tidal currents are important for pollination and exchange of gases from the water to the plant by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

Where are seagrasses found?

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

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

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

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

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

Seagrasses survive in the intertidal zone with most extensive meadows occurring on soft substrates like sand and mud

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

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

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

Seagrass plants form small patches that develop into large meadows

How are seagrasses important to the marine ecosystem?

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

Seagrasses are important habitat and feeding grounds for marine organisms.

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

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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

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

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

Seagrass meadows are a major food source for a number of grazing animals and are considered very productive pastures of the sea. The dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*) mainly feed on seagrass. An adult green turtle eats about two kilograms of seagrass a day while an adult dugong eats about 28 to 40 kilograms a day. 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* > *Halodule uninervis* > *Zostera capricorni*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

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

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

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

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

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

Seagrass rhizomes and roots bind sediments on the substrate and help prevent erosion

Seagrasses slow water flow, allowing suspended material to settle on the bottom and increase water clarity

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

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

Interactions with mangroves and coral reefs

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

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

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

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

Valuation of seagrasses

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

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}.

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

What causes seagrass areas to change?

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

Seagrasses can change due to both natural and human impacts

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

What threatens seagrass?

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

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

Some losses are natural due to storms and herbivores, however most losses are the result of human activities. Human pollution has contributed most to seagrass declines around the world.
The most widespread and pervasive cause of seagrass decline is a

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

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

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

Coastal development can have a major impact on seagrass meadows

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

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

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

Monitoring

We can see if seagrass meadows are healthy by watching them over time – this is called monitoring. Seagrasses are also an excellent indicator of marine ecosystem health, and are considered as "coastal canaries" due to their widespread distribution, important ecological role, sessile nature, and the fact that they are integrative of environmental conditions and show measurable and timely responses to impacts

Monitoring is the repeated observation of a system, usually to detect change

Seagrasses are an excellent indicator of marine ecosystem health

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.

Monitoring seagrasses can enable early detection of impacts and facilitate management to prevent further losses

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 is a global seagrass monitoring program which measures seagrass health and makes us aware of any damage or loss. Participants include local residents, schools, tertiary academic institutions, non-government organisations and government agencies/departments. 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.

Seagrass-Watch is a global seagrass monitoring program which measures seagrass health and makes us aware of any damage or loss

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

Responsive management based on adequate information will help to prevent further significant areas and species of seagrass from being lost 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.

Protecting seagrasses and managing threats

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. Approaches to protecting seagrass tend to be location specific or at least nation specific (there is no international legislation directly for seagrasses) and depend to a large extent on the tools available in law and in the cultural approach of the community. There are three generalised approaches that are used to protect seagrasses or manage impacts on seagrasses: reactive, prescriptive and non-prescriptive.

Management actions to protect seagrasses are designed to protect the overall biodiversity of the marine environment.

Reactive approaches are direct on-ground actions, such as relocating the damaging activity or limiting damaging processes, such as excessive bottom trawling, pollution, cyanide fishing or poor farming practice on adjacent land.

The three generalised approaches used to protect seagrasses or manage impacts on seagrasses include reactive , prescriptive (legal) and non-prescriptive (planning processes or education)

Prescriptive or legal approaches can range from local to state-wide laws. For example, in the state of Queensland (Australia) seagrasses and other marine plants are protected under the Queensland Fisheries Act 1994. Legal approaches can provide general protection, that is all seagrasses have some level of protection, or specific protection as in a Marine Park or in an area designated as having values important to protect.

In Queensland (Australia) seagrasses and other marine plants are protected under the Queensland Fisheries Act 1994

Non-prescriptive or broad based approaches range from codes of practice, local agreements, planning processes to education.

While a "legal" prescriptive approach works well in some instances in Australia it may not be appropriate in other countries. Different approaches may be more suitable in some countries and districts than others.

How can you help?

Many efforts are underway to educate the public about the benefits of seagrass and how they can help to protect seagrass. There are many ways you can help: don't litter; be aware when applying fertilizers and pesticides, as excess amounts can wash down gutters and drains to the sea; when boating, slow down and avoid shallow areas; support marine conservation initiatives; learn about these special marine habitats and volunteer to monitor their health by joining Seagrass-Watch. For more information visit: www.seagrasswatch.org

You can help stop the damage to seagrasses by changing many things you do, being aware and helping to monitor

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 metre per year, equivalent to the CO_2 emissions from an automobile traveling 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 johnson*ii in Florida).

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

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

Seagrass produce the longest pollen grains on the planet.

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

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

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

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

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

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

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

Suggested activities:

Classroom:

1. Work through the Seagrass-Watch Activity Book

The activity book can be useful to teach students about the structure of seagrasses and the variety of forms. It can also be used as a basis to discuss the importance of seagrasses and the types of ecosystem services they provide.

2. Food webs

To help illustrate seagrass food webs (pages 12 - 13 of activity book) ask the students to prepare cards illustrating a range of plant and animal groups found in seagrass meadows. Focus on the interdependence of living things (students can prepare their own cards from a list of species provided). Each card represents one plant or animal group/species. On the back of each card, write information on what the organism "eats", and what eats it. Nominate one student to be the Sun and give that student a ball of wool or string.

Students identify one plant species that gets energy directly from the Sun. The ball is passed first to that student and then to one that holds the card of a small herbivore. From there, the ball is passed to a student holding the card illustrating a species that eats the small herbivore, and so on until it reaches the end of the food chain (a top predator). Repeat the process always starting from the Sun. Each series of connections from the Sun to a top predator is an example of a food chain. Continue making food chains until each student is holding the string (or wool) at least once. The matrix of connections made by the string is an example of a food web.

3. Impacts on seagrasses & food webs

Talk with students about the threats to seagrasses and forms of pollution in coastal areas. Also discuss the effects of "invisible" pollution on seagrass meadows such as sewage and fertilisers in rainwater runoff, or siltation from dredging and land reclamation works. Take one or more possible events that might impact on the area and apply it to the food web. For example, a flood could affect water quality, which in turn could impact on marine plants and herbivores such as dugongs.

One way to demonstrate the impacts of various activities on seagrasses is to use the food web in the previous exercise. This time, when the food web is in place, have the students directly affected by the impact/threat squat down and gently pull on their string(s) so those that are connected to them feel the tension. Discuss what might happen to the food web as a result of a major flood.

Repeat the activity using different scenarios such as:

- An oil spill
  Oil can smother seagrass and be toxic to the animals which live within the meadow.
- The dumping of rubbish, including toxic waste
  Many chemicals used in industry are poisonous to animals and humans. Even in small quantities some toxic chemicals may result in serious water pollution. A great deal of this pollution finds its way into the sea through stormwater drains.
- Some other scenario suggested by the students.

Discuss the impact these threats have on the environment and in particular how pollution would affect seagrass meadows and their inhabitants.

Field:

1. Conduct a Seagrass-Watch monitoring event.
   Duration: 2-3 hours

   You can only conduct this exercise during the low spring tides, so you will need to check your local tide tables and choose an appropriate date and time before you venture out.

   You will also need to ensure you have a seagrass meadow which is larger than 50m by 50m. It is recommended that you conduct a site visit prior to the day of the exercise so you will be familiar with the surrounding and help plan the exercise.

   To assist with planning, it is recommend you first contact Seagrass-Watch HQ hq@seagrasswatch.org. You will find additional information on the exercise at http://www.seagrasswatch.org/monitoring.html

   Materials you will need:
   - 3x 50 metre measuring tapes
   - 6x 50cm plastic tent pegs
   - 1x compass
   - 3x 50cm x 50cm quadrats
   - 1x Magnifying glass
   - 3x Monitoring datasheets
   - 3x Clipboard, pencils & 30 cm ruler
   - 1x Camera
   - 1x Quadrat photo labeller
   - 3x Percent cover standards and Seagrass identification sheets http://www.seagrasswatch.org/guides.html

   For instructions on how to set up a site and how to collect seagrass data, see pages 18-19 of this booklet.

2. Seagrass pressing

   If students have access to beaches near a seagrass area they may be able to find seagrass that has been washed ashore. Seagrass can be found at the waters edge, this will only need a little pressing between layers of newspaper under some heavy books (e.g. phone books). Instructions for pressing fresh seagrass are as follows.

   Materials you will need:
   - fresh seagrass
   - a tray
   - clean white paper (photocopy paper is OK)
   - Cardboard (the type with internal corrugations is best)
   - old newspaper
   - heavy books

     - When collecting seagrass, ensure that you have all the plant parts including the rhizomes and roots. Only take a small sample, you only 2 or 3 complete shoots.
     - The seagrass sample should be placed inside a labelled plastic bag with seawater. Don't let the sample dry or over heat as the plant will discolour.
     - Seagrass should be pressed as soon as possible after collection. If it is going to be more than 2 hours before you press the seagrass then you should refrigerate to prevent any decomposition. Do not refrigerate longer than 2 days, press the

sample as soon as possible.

- Wash the seagrass sample in clean water and carefully remove any debris, epiphytes or sediment particles.
- Layout specimen on a clean sheet of white paper, spreading leaves and roots to make each part of the specimen distinct.
- Write a label including where the sample was collected, date collected, who collected it. Place the label in the lower right hand corner of paper.
- Place another clean sheet of paper over the seagrass, and place within several sheets of newspaper.
- Place the assemblage of specimen/paper within two sheets of cardboard and then place between some heavy books.
- 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.
- Correctly pressed and preserved seagrass specimens are invaluable for future reference material. If stored properly, the specimens will provide a record that not only supports data and published reports, but increases in value over time.

3. Play the "Turtle Troubles" game

Green sea turtles live in nearly all the oceans of the world and feed on seagrass. The only time they leave the sea is during nesting periods. It is during these nesting periods that the turtles and their offspring are the most vulnerable. Female sea turtles dig deep holes on beaches within which they lay and bury their eggs. Sometimes the females make repeated nesting visits in one season. Once the eggs are buried, the female returns to the sea or seeks new nest sites. The eggs are on their own for nearly two months. If the eggs survive predatory ghost crabs, feral pigs and humans - the sea turtles hatch, dig their way upward through the sand, and promptly head toward the sea.

The hatchlings journey across the beach is typically accompanied by predatory crabs, gulls and birds. Once hatched, only about one to five percent of the turtles survive the first year. In the sea, the turtles must mature for nearly a decade before returning to nesting sites as a natural part of their life cycle. Biologists are uncertain how long sea turtles reproduce and live. They are preyed upon by fish, tiger sharks, and humans.

Humans can impact green sea turtles in many ways. 4 wheel drives destroy nests and break the eggs buried in the sand. Entanglement in discarded fishing gear kills many sea turtles each year. More damaging, given the scope of the impact, is coastal development (private homes, hotels, etc.). This may create a barricade that prevents the turtles from reaching their traditional nesting sites and eliminates many nest sites. Loss of seagrass meadows, the primary food for green sea turtles, can be devastating to populations.

The major purpose of this activity is for students to become familiar with some of the limiting factors affecting the survival of sea turtles as well as the role of human beings in contributing to the endangerment of other species.

Materials you will need:

- 20 to 30m length of rope;
- two jump ropes or hula hoops;
- one paper bag per student;
- several sheets of self adhesive address labels (eg Avery Standard 7163)
- write/print on each label the name of a predator or limiting factor;
- poker chips;
- dried beans.

Nest Zone: the place where the eggs are laid and hatch. This is the zone to which the surviving turtles will return in ten years. This is where the baby turtles hatch and begin their journey to the sea.

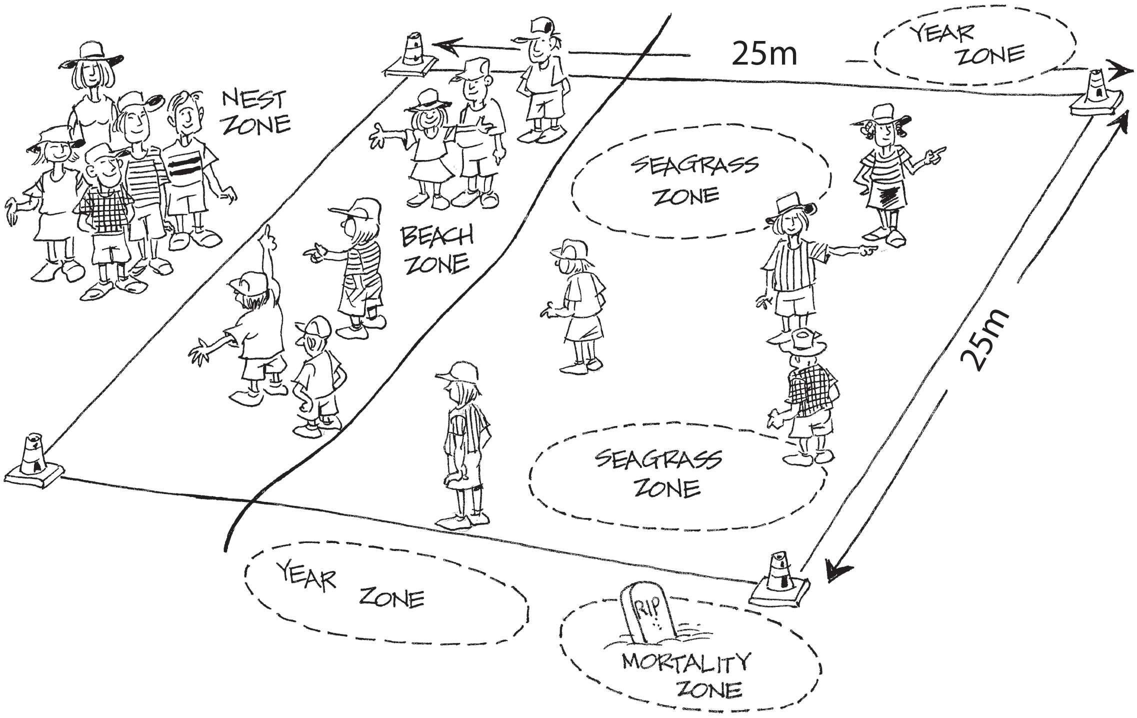
Beach Zone: the zone the hatchlings must cross to get to the sea. It is a place of high predation and other limiting factors.

Sea Zone: the area where the turtles must mature for a period of ten years before returning to nest.

Year Zones: the two zones that the turtles must visit to get the year cards necessary to "mature" to ten years of age. One card is awarded for each one-way trip between the zones. During the trip between the zones the turtles are vulnerable to predators and other limiting factors. Turtles are safe from other limiting factors when they are inside either year zone.

Seagrass Zones: places where the turtles are safe until they reach four years of age. At that age they are too large to hide from predators.

How to play:
1. Set up the activity areas as shown.



2. Give each student a bag and divide the class into two groups.

Group 1 - TURTLES. Each student counts out 50 beans to place in his or her bag. Beans represent turtles. Each bag of beans represents the turtles that hatch from a single nest.

Group 2 - LIMITING FACTORS. Divide this group into two smaller groups, on-land and in the sea.

- On-land: predators (e.g., pigs, ghost crabs, and gulls) and limiting factors from human activities (e.g., 4 wheel drives, human egg collectors, shoreline development)
- In-sea: predators (e.g., sharks) and limiting factors from human activities

(e.g., entanglement in fishing gear, hunting by humans)

- Give each student a label that indicates what kind of limiting factor each one represents. Attach these labels to students' clothing.

3. Walk the class through the activity and explain these rules:

    A. Turtles must hatch, cross the beach and spend 10 years in the open sea. The time in the ocean is simulated by the turtles running between the year zones. They pick up one poker chip at a year zone and then run to the other year zone to pick up another poker ship. Each chip represents two years of successful ocean survival. After collecting five poker chips, turtles return to the nesting area to reproduce.
    B. Turtles try to avoid limiting factors and predators. If tagged by a limiting factor, a turtle stops, counts out ten beans and places those ten beans in the limiting factor's bag.
    C. The seagrass areas are turtle safety zones where limiting factors cannot tag them. The teacher may set a time limit for how long a turtle may rest in a seagrass zone.
    D. Limiting factors must obey the following rules:
        - They cannot tag the same turtle twice in a zone.
        - They cannot tag turtles that are counting out beans to another limiting factor.
        - They must stay at least four steps away from any turtle that is transferring beans to another limiting factor.
    E. Any turtle that loses all 50 beans is dead. It must go to the beach and become a coastal development. If the coastal developments (sitting side by side) eventually block the access to the nesting beach, the remaining turtles die without reproducing and starting the next cycle.
    F. The activity ends when all turtles are either dead or have returned to the nest area.

4. Review the rules two times to make sure the students understand their roles and the procedures. Become endangered sea turtles and limiting factors and conduct the activity!

5. After completing the activity, encourage the students to discuss the results. It is likely that some students will be disturbed by the high mortality of the turtles and will benefit from the realization that there are groups actively trying to diminish human contributions to such high mortality. However, it is also important to emphasize that natural limiting factors are built into the scheme of things. If all sea turtle eggs survived, there might well be an overabundance of these creatures. Many animals produce more young than will survive, serving as food for other species as a part of nature's dynamic balance. Ask the students to briefly describe the life cycle of sea turtles.

Turtle game courtesy Western Regional Environmental Education Council.

Suggested further reading

www.seagrasswatch.org

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

Coles RG, McKenzie LJ, Rasheed MA, Mellors JE, Taylor H, Dew K, McKenna S, Sankey TL, Carter AB and Grech A. (2007). Status and Trends of seagrass in the Great Barrier Reef World Heritage Area: Results of monitoring in MTSRF project 1.1.3 Marine and Tropical Sciences Research Facility, Cairns. 108 pp.

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

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.

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, Campbell SJ, Vidler KE and Mellors JE. (2007) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources. Seagrass-Watch HQ, Cairns. 114 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 RC and Menez EG. (1988). Seagrasses. Smithsonian Institution Press, Washington, D.C. 104 pp.

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

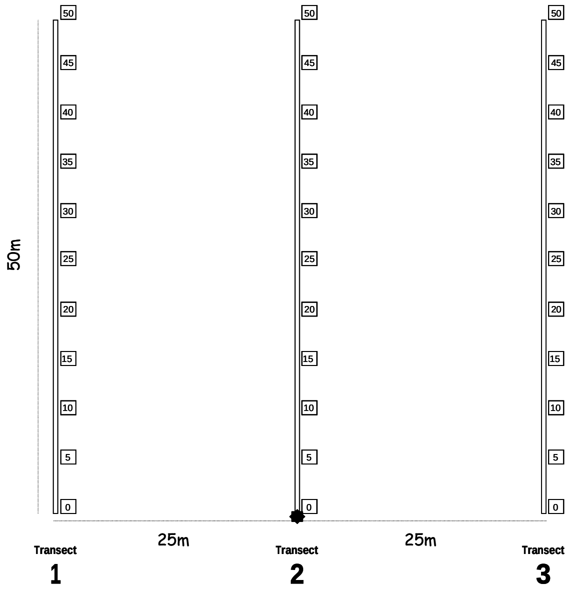
Waycott M, Collier C, McMahon K, Ralph P, McKenzie L, Udy J and Grech A (2007) Vulnerability of seagrasses in the Great Barrier Reef to climate change. *In* Climate Change and the Great Barrier Reef, eds. Johnson JE and Marshall PA. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office,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

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. 72 pp.

Seagrass-Watch Monitoring Summary

The following is a step-by-step summary of the most popular protocol used in Seagrass-Watch for monitoring intertidal seagrass habitats (see www.seagrasswatch.org). You can only conduct this exercise during the low spring tides, so make sure you check the tides before you venture out.

Site layout



Quadrat code = site + transect+quadrat
e.g., PN1225 = Poona site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

- Assess the risks before monitoring - check weather, tides, time of day, etc.
- Use your instincts - if you do not feel safe then abandon sampling.
- Do not put yourself or others at risk.
- Wear appropriate clothing and footwear.
- Be sun-smart.
- Adult supervision is required for students
- 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 measuring tapes*
- ❑ *6x 50cm plastic tent pegs*
- ❑ *1x compass*
- ❑ *3x standard (50cm x 50cm) quadrats*
- ❑ *3x Magnifying glass*
- ❑ *3x Monitoring datasheets*
- ❑ *3x Clipboard, pencils & 30 cm ruler*
- ❑ *1x Camera & film*
- ❑ *1x Quadrat photo labeller*
- ❑ *3x Percent cover standard sheet*
- ❑ *3x Seagrass identification sheets*

How to sample

Choose an area within a fairly uniform section of the meadow which 50m by 50m. Lay out the three 50 transects parallel to each other, 25m apart and perpendicular to shore (see site layout above). Divide the students into three groups (with a teacher or adult to supervise each group) and assign each group to a transect. Measures of seagrass a taken from within 50cm x 50 cm quadrats which are placed every 5 metres along each transect (starting at 0 m and ending at 50m. Quadrats are place beside the tape measure and fall seaward from the 5m interval. Within each of the quadrats placed for sampling, complete the following steps:

Step 1. Take a Photograph of the quadrat

- Photographs are 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 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 (e.g., number of shellfish, sea cucumbers, sea urchins, evidence of turtle feeding).

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 maco-algae in the quadrat. Maco-algae are seaweeds that are not attached to seagrass blades but may overlie the seagrass. Use "Algal percentage cover photo guide".

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 assisting.

Step 2. Remove equipment from site

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

Useful web links

Seagrass-Watch Official Site www.seagrasswatch.org

Seagrass Adventures

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

World Seagrass Association

A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses.
www.worldseagrass.org

Seagrass Outreach Partnership

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

Seagrass forum

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

Reef Guardians and ReefEd

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

Integration and Application Network (IAN)

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

Reef Base

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

Western Australian Seagrass Webpage

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

UNEP - World Conservation Monitoring Centre

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

Puzzlemaker

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