

SEAGRASS SYLLABUS

A TRAINING MANUAL FOR RESOURCE MANAGERS



WORLD  SEAGRASS ASSOCIATION

CONSERVATION
INTERNATIONAL





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INTRODUCTION

Purpose of this manual

This manual is intended to be a supplement to the “seagrass training course”. Both the manual and the course are tailored to build capacity amongst resource managers, practitioners, rangers, volunteers, etc to address the need for and approaches to managing seagrasses systems. The manual, used during capacity building training, provides key information to increase understanding of seagrass ecosystems and the important services they provide. The manual can be used as a training guide and serves as a take-home reference. As the training course has been so far only piloted in tropical countries, this manual makes reference to tropical species for the most part, however it can be easily modified to temperate seagrass systems.

The manual is intended to provide a concise learning experience and a quick reference guide in the field. It is tailored to provide general information about seagrass ecosystems in support of inclusive management frameworks, also for Marine Protected Areas (hereafter MPA or MPAs). The information included complements capacity building focused on the monitoring and management of other marine ecosystems such as coral reefs and mangrove forests and is designed to support the development and completion of local, joint and regional coastal management plans.

The manual highlights the importance of seagrass habitats and how maintaining the resources they provide can support local economies, municipal fisheries and local livelihoods. Enhancing the knowledge of managers and other stakeholders means enhancing local capacity to understand and solve problems and increases the ability to be able to communicate problems and solutions to third parties promoting awareness, education and engagement both among governing authorities and local communities.

Who is this manual for?

This manual is designed for MPA practitioners, managers, government officials, decision-makers and any other stakeholders that manage seagrass resources. It can be read by a range of people from different backgrounds but it is designed for people who would like to integrate the knowledge and lessons learned in the training modules into the development of management plans from local to regional scales.

The sections of the manual – modules – are designed assuming minimal or no prior knowledge of seagrass systems beyond local knowledge and expertise as resource users or managers, therefore basic information on seagrass ecology and biology is included.

General introduction to seagrasses

Seagrasses are a group of around 60 species of flowering plants that live submerged in shallow marine and estuarine environments. They are found on all of the worlds continents except Antarctica and cover around 0.1-0.2 per cent of the global ocean. In many places they cover large areas of the seafloor where they are often referred to as seagrass beds or seagrass meadows.

Seagrass meadows are valuable habitats that provide important ecological and economic services worldwide. They provide critical habitat for diverse groups of other marine organisms, including more than 360 species of fish, and are an important source of food for numerous charismatic animals including turtles, dugongs and seahorses. Seagrasses play an important role in fisheries production as well as sediment stabilisation and protection from coastal erosion, making them one of the most important coastal marine ecosystems for humans. Seagrass meadows also represent an important cultural resource with many traditional ways of life intricately associated with them for food, recreation, and spiritual fulfilment.

Seagrass meadows support adjacent habitats (through flows of organisms and physical resources), including salt marshes, mangrove forests and coral reefs, so monitoring changes in seagrass meadows (and their associated animals) can provide an indication of coastal ecosystem health and be used to improve our capacity to predict changes to other resources on which coastal communities depend.

Global trends in seagrass ecosystems

It is well acknowledged that the majority of the world's coral reefs are at risk from anthropogenic (human) activities. Less well acknowledged are the global threats to seagrass meadows. Seagrass meadows are experiencing rates of loss that may be as high as seven per cent of their total global area per year, which equates to losing up to two football fields every hour. In total, 29 percent of the known global coverage of seagrasses has already disappeared and they are now considered one of the most threatened marine habitats. The loss of seagrass meadows is largely due to increasing human populations and associated destructive activities in coastal regions. This degradation of habitats and associated resources will result in severe ecological and economic losses. Concern for seagrass ecosystems is therefore essential to a comprehensive approach to integrated coastal management.

Seagrasses and Marine Protected Areas

As seagrass are often neglected compared to other coastal ecosystems (for example coral reefs), it is important to increase awareness and management programs while enabling legal frameworks to protect and conserve seagrasses and to monitor and restore the marine environment globally. The need for effective local management is most urgent in developing tropical regions where the capacity to implement conservation policies is limited. To protect these resources from current and future threats, marine protected areas (MPAs) are being established worldwide as they are recognised globally as valid management tools. However, to effectively conserve and restore marine ecosystems, MPA managers need to ensure that appropriate and representative habitats are protected, and local stakeholders need to understand the relative importance of these habitats. To achieve these management goals, there is a need to increase the knowledge of MPA practitioners on the value and role of seagrass ecosystems in the coastal marine environment. As managers and resource users become more aware of specific issues, they can implement targeted management practices and implement awareness campaigns for other stakeholders, including local resource users and tourists.

Learning objectives

This manual aims to develop understanding of seagrasses and the critical role that they play in the marine environment to ensure that the services they provide to our oceans and societies can be maintained for future generations. The key learning objectives of the manual are:

1. To increase and strengthen the protection of seagrasses by sharing knowledge of seagrass ecosystems and their role in the environment
2. To build awareness of the threats to seagrass ecosystems
3. To provide tools for monitoring and managing seagrass ecosystems
4. To identify and prioritise local communication needs and develop appropriate communication tools

To meet these objectives, the manual brings together a comprehensive curriculum on why seagrasses are important, how they can be monitored and managed, and how their management can support coastal ecosystems in the face of a changing global environment. Basic information is provided within ten simple modules along with lists of where further detailed information can be found. Each module has its own specific objectives, information to support the objectives and activities to reflect on your learning within the module.

MODULE 1

WHAT ARE SEAGRASSES? BASIC NOTIONS OF THEIR BIOLOGY AND ECOLOGY

Module Objectives

- To develop a basic understanding of the biology and ecology of seagrass plants and ecosystems
- To identify key environmental parameters that support and shape seagrass communities

What are seagrasses?

Seagrasses are highly productive underwater systems of flowering marine plants (angiosperms) that grow fully submerged and rooted in estuarine and marine environments. Angiosperms are plants that produce flowers, fruits and seeds. Pollen from male flowers is dispersed to female flowers by tidal water flow. There are approximately 60 species of seagrass, with 24 species found in the tropical Indo-Pacific region. Species composition and density in a given seagrass meadow depends largely on water depth, the type of material making up the coastal substrate from which the seagrass grows, the ability for light to reach the leaves, and the salinity of the water. Forming beds of one or more species (seagrass meadows), seagrasses create important habitat for other marine organisms and have a direct effect on physical processes in the environment.

Where are seagrasses found?

Seagrasses grow widely in coastal zones throughout the world, from temperate regions such as the United Kingdom to tropical regions such as the Indo-Pacific

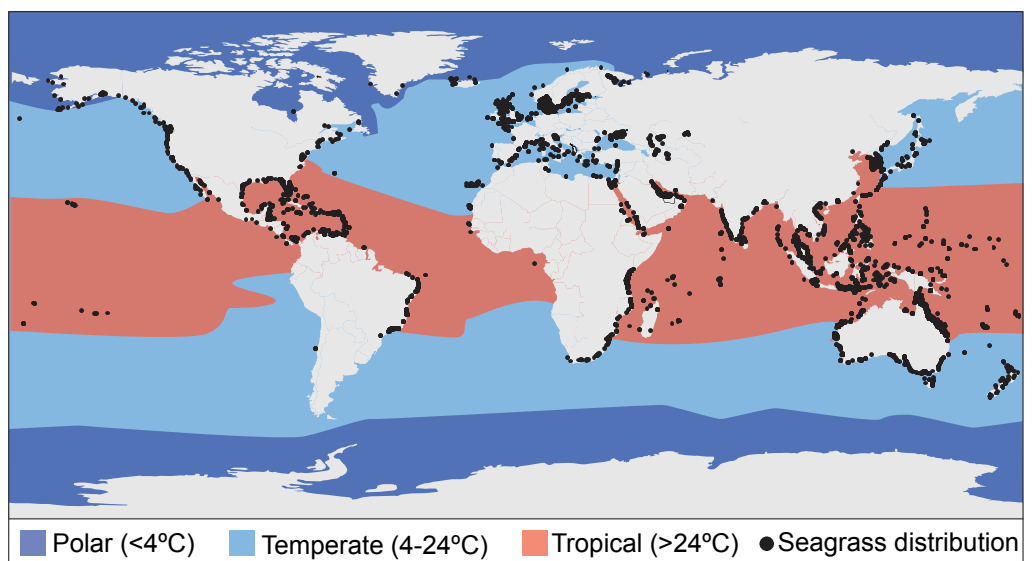


Figure 1.1: Where in the world are seagrasses? (From Orth et al 2006)

Did you know...

...that Darwin's grandfather, Erasmus Darwin, published a poem about seagrass in 1798?



Seagrasses grow in the part of the marine environment that is most heavily affected by humans including river estuaries (where fresh water from rivers meets the salt water of the sea), shallow coastal areas and coral reefs. Some seagrasses live in offshore waters up to 60 metres deep but most are found inshore at depths of no more than 25 metres. In tropical regions seagrasses are often connected to mangrove and coral reef habitats and play an important role in keeping all three systems and their associated plants and animals healthy and functional.

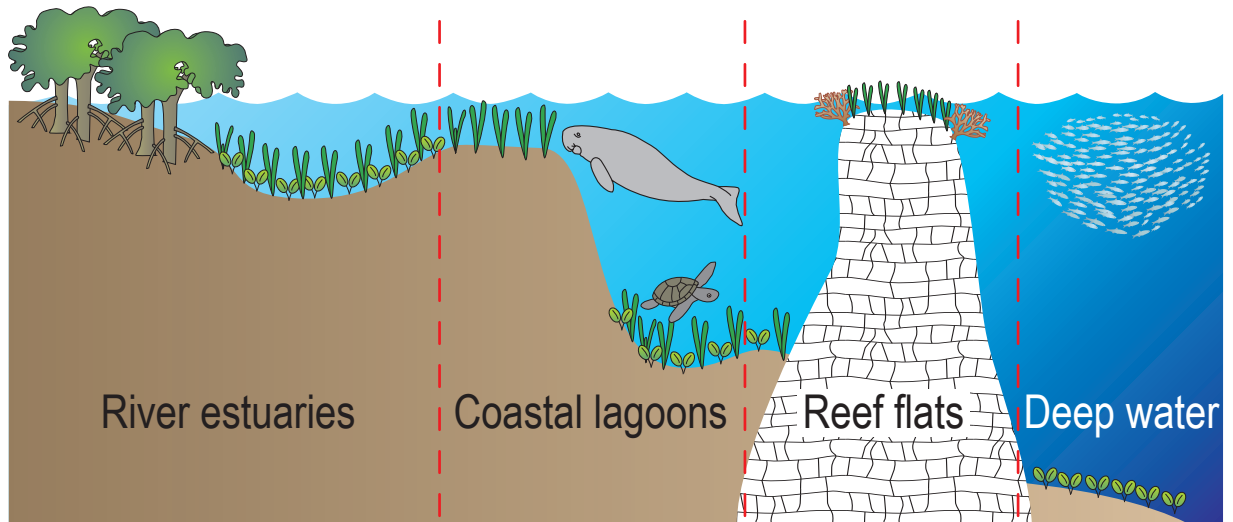


Figure 1.2: Where are seagrass meadows found?

The seagrass plant

Seagrasses range in size and shape from the strap-like *Enhalus acroides* and *Zostera caulescens* that can grow to more than 4m long; to the small (2-3 cm) and rounded *Halophila decipiens*.



Enhalus acroides



Halophila decipiens

Seagrasses have similar organs and tissues to other flowering plants with distinctive above and below sediment parts. Below the sediment, parts include roots for anchoring and rhizomes or stems for mechanical support. Above the sediment, in the water column, parts include shoots and leaves. The leaves usually have a basal sheath to protect developing leaves and an extended leaf blade to produce food using photosynthesis.

Seagrasses are not the same as marine algae

Some of the major differences are outlined below:

Seagrass

- Complex rhizome and root structure to anchor to substrate and extracts nutrients
- Photosynthesis takes place only in leaf cells
- Reproduces via underwater pollination, and has flowers, fruits and seeds
- Internal vascular system

Marine Algae

- Simple root structure anchors to rocks or shells
- Photosynthesis takes place in all algae cells
- Reproduces by way of spores
- No internal vascular system

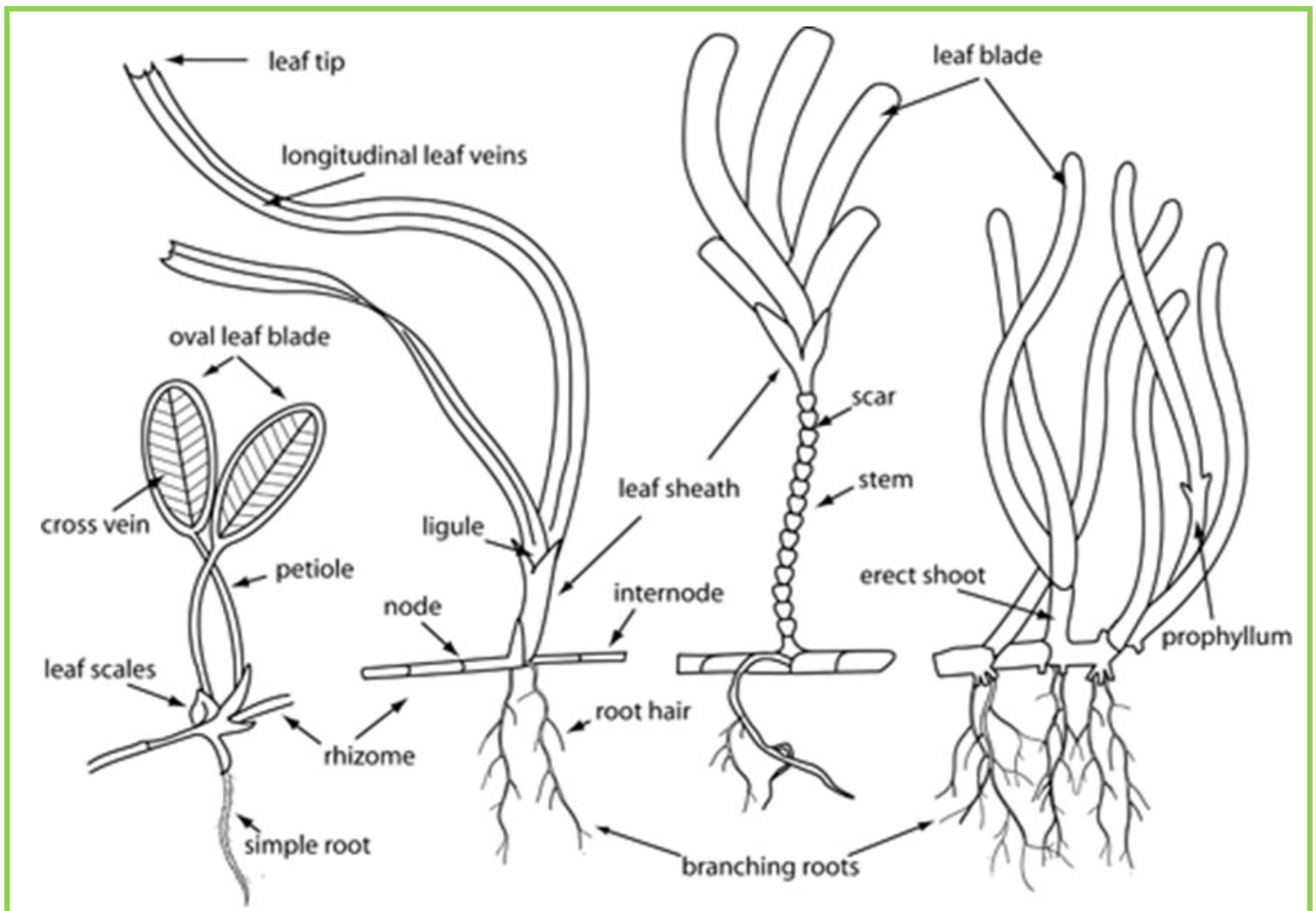


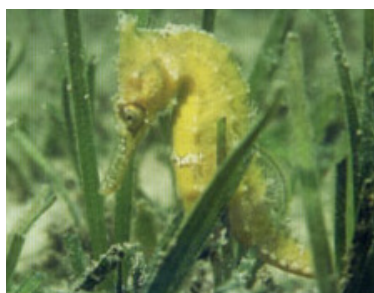
Figure 1.3: Parts of a seagrass plant

What keeps seagrasses healthy?

- Seagrass needs light to produce food
 - The availability of light determines the depth and location of seagrass species
- Sediments provide nutrients for growth and substrate for anchorage
- Seagrasses grow best at different temperatures in different regions
 - temperatures higher than 43°C may harm tropical seagrasses
 - temperature also controls seagrass reproduction
- Nutrients, such as nitrogen and phosphorous, are necessary for seagrass growth
- Salinity helps determine the species of seagrass within a community and affects growth, reproduction and survival
- Some Physical Disturbance is needed to maintain community structure and open up new space for colonization
 - strong physical disturbance (from storms or boat anchors for example) can uproot or destroy seagrass plants



Seagrass is the primary food source for green sea turtles



Seagrass is the primary habitat for sea horses



Sea star in *E. acoroides* meadow

The ecological role of seagrass beds

Seagrass beds are important because:

- They provide food for macrograzers (e.g. sea turtles) and micrograzers (e.g. sea urchins)
- They provide refuges and nurseries for larvae and juveniles of many fish species (e.g. groupers, snappers, barracudas, yellow grunts)
- They reduce coastal erosion, filter water, and trap sediment
- They produce oxygen and take up carbon dioxide

Food and shelter

- Juvenile fish and prawns mature in seagrass beds
- Lobsters, crabs, and seahorses also live in seagrasses, as do important molluscs such as clams and conch
- Marine herbivores, like dugongs, rely on seagrass as their primary food source, a healthy dugong can eat up to 40kg wet weight of sea grass per day
- Seagrasses are also an important part of green sea turtle diets, turtles eat around 2kg wet weight of sea grass each day
- Coastal waterfowl, such as ducks, geese, and swans eat seagrass too

Sediment and water clarity

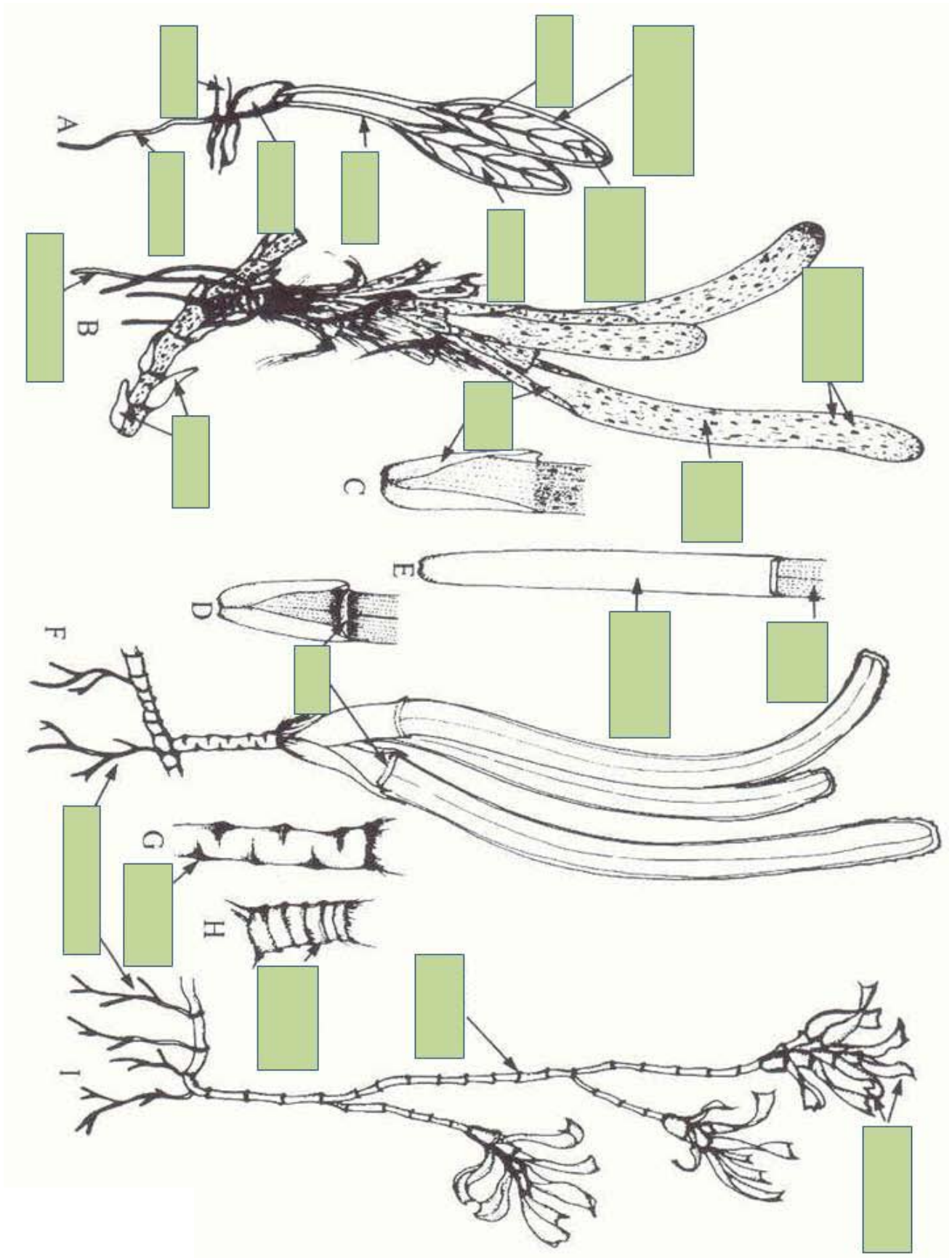
- Seagrass leaves trap sediment particles, improving water clarity
- Seagrass roots also stabilize sediments, keeping the water clear
- Seagrass root structure keeps coastal erosion under control

Oxygen and carbon dioxide

- Seagrass takes up carbon dioxide during the process of photosynthesis and converts it to food for the plant
- As a result of this process, seagrasses release oxygen that other marine creatures use
- Oxygen is the major gas that seagrasses pump into sediments, keeping them aerated

ACTIVITY: SEAGRASS MORPHOLOGY DIAGRAM

IDENTIFY SEAGRASS PLANT PARTS BY FILLING IN THE BLANKS



(For answers see Appendix 2)

MODULE 2


KEY SEAGRASS SPECIES AND HOW TO IDENTIFY THEM

Module Objectives

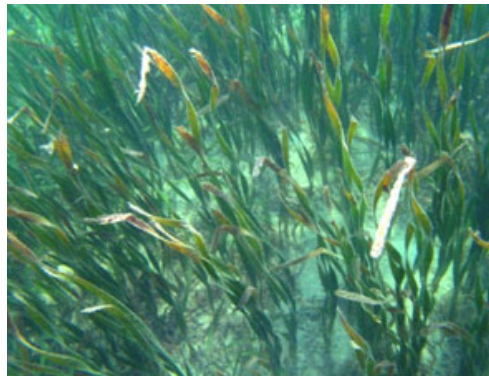
- To learn how to identify some key species of seagrass
- To learn how to use taxonomic keys and field guides for the identification of species

Species diversity

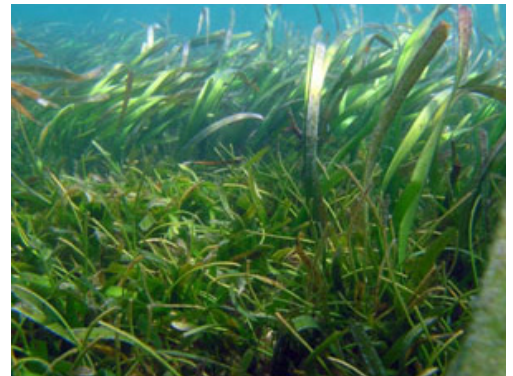
Seagrass diversity is low compared to terrestrial plants. Their associated flora and fauna account for most of the seagrass meadow biodiversity. Seagrasses can be found in meadows containing a single species (monospecific) or a number of different species (multi-species). Seagrasses form an ecological group rather than a distinct taxonomic group which means that various seagrass families do not necessary have to be closely related.



Did you know...
...that seagrass produces the longest pollen grains on the planet?



Example of a monospecific seagrass bed (*Enhalus acoroides*)



Example of a multi-species seagrass bed (*Enhalus acoroides*, *Thalassia hemprichii*, *Syringodium filiforme*)

Classification of seagrass species

Classification System

Kingdom
Phylum/Division
Class
Subclass
Order
Family
Genus
Species

Based on best available information (<http://www.SeagrassWatch.org>)

Division: Magnoliophyta (angiosperms)

Class: Liliopsida (monocots)

Subclass: Alismatidae (basal side of monocots; primitive; typically aquatic)

Order: Alismatales

Family: Hydrocharitaceae

Order: Potamogetonales

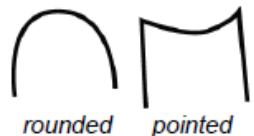
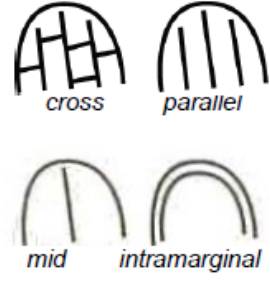


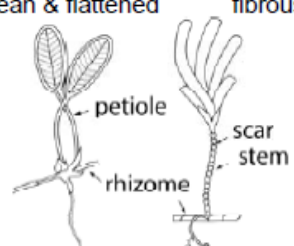
Family: Cymodoceaceae; Posidoniaceae; Zosteriaceae

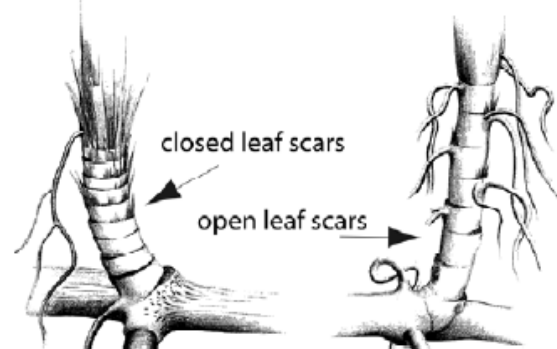
Potamogetonaceae; Ruppiaceae; Zannichelliaceae

Most seagrasses belong within two families: Hydrocharitaceae and Posidoniaceae and only three families consist exclusively of seagrasses: Zosteraceae, Cymodoceaceae and Posidoniaceae. Around 50% of species are found within just three genera: *Halophila*, *Zostera* and *Posidonia*.

Key distinguishing features

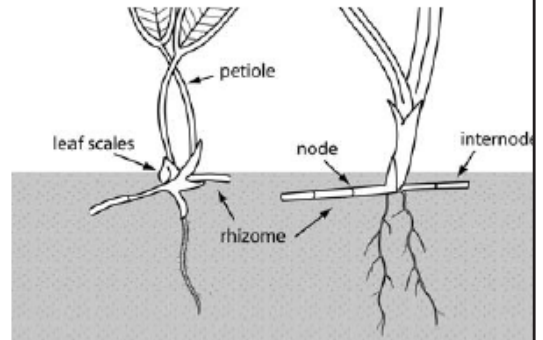
Leaf	Root
<ul style="list-style-type: none"> – shape – tip morphology – vein pattern – smooth or serrated edge – sheath type – attachment type (rhizome or stem) 	<ul style="list-style-type: none"> – Size and thickness – Presence of root hairs
Rhizome	Stem
<ul style="list-style-type: none"> – morphology 	<ul style="list-style-type: none"> – Closed or open leaf scars

Leaf		
Tip	Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.	 <p>rounded pointed</p>
Veins	Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for identification. <ul style="list-style-type: none"> • cross-vein: perpendicular to the length of the leaf • parallel-vein: along the length of the leaf • mid-vein: prominent central vein • intramarginal-vein: around inside edge of leaf 	 <p>cross parallel</p> <p>mid intramarginal</p>
Edges	The edges of the leaf can be either serrated, smooth or inrolled	 <p>serrated smooth inrolled</p>
Sheath	A modification of the leaf base that protects the newly developing tissue. The sheath can entirely circle the vertical stem or rhizome (continuous) or not (non-continuous); fully or partly cover the developing leaves and be flattened or rounded. Once the leaf has died, persistent sheaths may remain as fibres or bristles.	 <p>clean & flattened fibrous</p>
Attachment	The leaf can attach directly to the rhizome, where the base of the leaf clasps the rhizome, or from a vertical stem or stalk (petiole) e.g. <i>Halophila ovalis</i> .	 <p>petiole scar stem</p> <p>rhizome</p>

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

Rhizome

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



Root

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

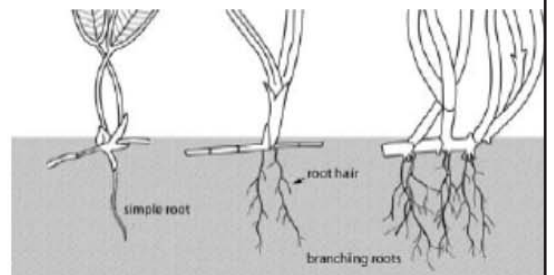


Figure 2.1: Key distinguishing features from Lanyon 1986 (adapted from Waycott et al. 2004)

Guide to the identification of some common tropical seagrass species

Leaves cylindrical



cylindrical

Syringodium isoetifolium

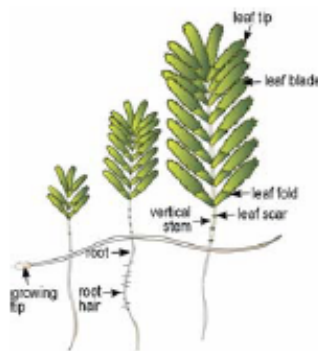
- narrow spaghetti-like leaves, 1-2mm diameter
- leaf tip pointed
- leaves contain air cavities
- inflorescence a "cyme"

Leaves oval to oblong



oval to oblong

obvious vertical stem with more than 2 leaves



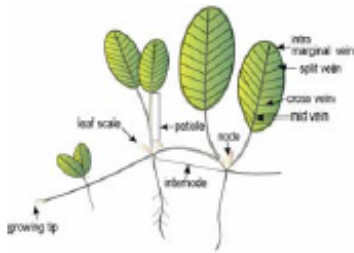
Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated
- shoots can be up to 15cm long
- 10-20 pairs of leaves per shoot
- leaf 15-20mm long and 3-5mm wide
- thin rhizomes

Halophila beccarii

- leaves arranged in clusters of 5-10, at a node on vertical stem
- short vertical stem between clusters
- leaf clusters do not lie flat
- leaves elongate, with mid-vein and no obvious cross-veins
- leaf margin finely serrated

leaves with petioles, in pairs



Halophila ovalis

- cross veins more than 8 pairs
- leaf margins smooth
- no leaf hairs
- leaf 5-20mm long

- fine hairs on both sides of leaf blade
- leaves are usually longer than wide

Halophila minor

- leaf less than 5mm wide
- cross veins up to 8 pairs

Halophila decipiens

- leaf margins serrated

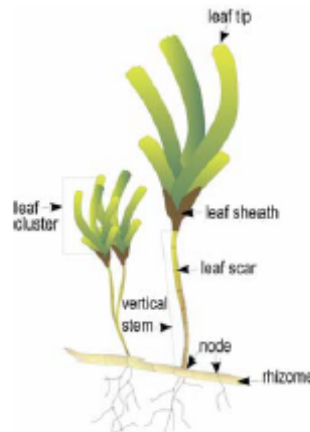
- leaf margins smooth
- no leaf hairs

Leaves strap-like

Leaves can arise from vertical stem



strap-like



Thalassia hemprichii

- ribbon-like, curved leaves 10-40cm long
- short red/black bars of tannin cells, 1-2mm long, in leaf blade
- leaf tip rounded may be slightly serrated
- 10-17 longitudinal leaf veins
- thick rhizome (up to 5mm) with conspicuous scars

Cymodocea rotundata

- leaf tip rounded with smooth edge
- leaf sheath not obviously flattened, fibrous
- 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
- narrow leaf blades 0.25-5mm wide
- rhizome usually pale ivory, with small black fibres at the nodes

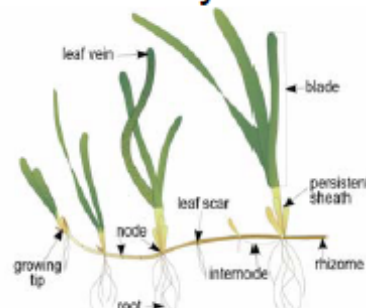
Halodule pinifolia

- leaf tip 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

Leaves always arise directly from rhizome



Enhalus acoroides

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

Figure 2.2: Guide to the identification of some common tropical seagrass species (modified from Waycott et al. 2004)

CLASSROOM ACTIVITY: SEAGRASS IDENTIFICATION

Identify to species level the following 4 seagrasses (for answers see appendix 2)



1

- Very long ribbon-like leaves 30-150 cm long
- Leaves with in rolled leaf margins
- Thick rhizome with long black bristles and cord-like roots
- Found on shallow/intertidal sand/mud banks (often adjacent to mangrove forests)



2

- Short black bars of tannin cells in leaf blade
- Thick rhizome with scars between shoots
- Hooked/curved shaped leaves
- Leaves 10-40 cm long
- Common on shallow reef flats



3

- Oval shaped leaves in pairs
- 8 or more cross veins
- No hairs on leaf surface
- Preferred dugong food
- Common early colonising species
- Found from intertidal to subtidal depths



4

- Cylindrical in cross section (spaghetti like)
- Leaf tip tapers to a point
- Leaves 7-30 cm long
- Found on shallow subtidal reef flats and sand banks

MODULE 3

SEAGRASS ECOSYSTEMS AND THE SERVICES THEY PROVIDE

Module Objectives

- To learn the basic definition of ecosystem services
- To identify the different categories of ecosystem services
- To identify the services that seagrasses provide to coastal societies
- To be aware of the services provided by other marine habitats

What are ecosystem services?

Ecosystem Services are critical for human well being. They can be defined as:

“The benefits that humans derive, directly or indirectly, from ecological functions”
(Costanza 1997)

“The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life” (Daily 1997).

Ecosystem services are made up of provisioning, regulating, cultural and supporting services.

Provisioning Services	Regulating Services	Cultural Services	Supporting services
Products obtained from ecosystems e.g. fisheries nursery and feeding grounds	Benefits obtained from regulation of ecosystem processes e.g. coastal protection (buffer against erosion and sediment stabilisation)	Nonmaterial benefits obtained from ecosystems e.g. aesthetic, spiritual and recreational values	Services necessary for the production of all other ecosystem services

(adapted from Millennium Ecosystem Assessment 2005)

What ecosystem services do seagrasses provide?

Seagrass beds provide many benefits for wildlife, people and the planet, from the provision of food and shelter to environmental regulatory processes. Many coastal communities depend on marine resources for food and livelihoods so seagrass ecosystems are critical contributors to wellbeing and the economy in coastal societies worldwide. Important ecological and economic roles of seagrasses include:

- producing large quantities of organic material that supports complex food webs;
- providing physical shelter for faunal species and nursery grounds for commercially important faunal species (fish, crabs and molluscs);
- filtering nutrients and sediments accumulating and recycling organic and inorganic materials;
- stabilising sediments whilst producing large quantities of organic carbon, thus they have an important role in the food web;
- protecting coastlines from storms;
- acting as a biological indicator (bioindicator) of environmental health
- oxygenation of water and sediments.

Did you know...

...that Seagrass has been used as fuel, upholstery, feed for poultry and to thatch roofs in several places in the world?



Seagrasses represent good bioindicators of marine and coastal health due to their:

- widespread distribution
- important ecological role
- sessile nature
- measurable and timely responses to environmental conditions and impacts (e.g. dredging, pollution, temperature, sediment resuspension, salinity)

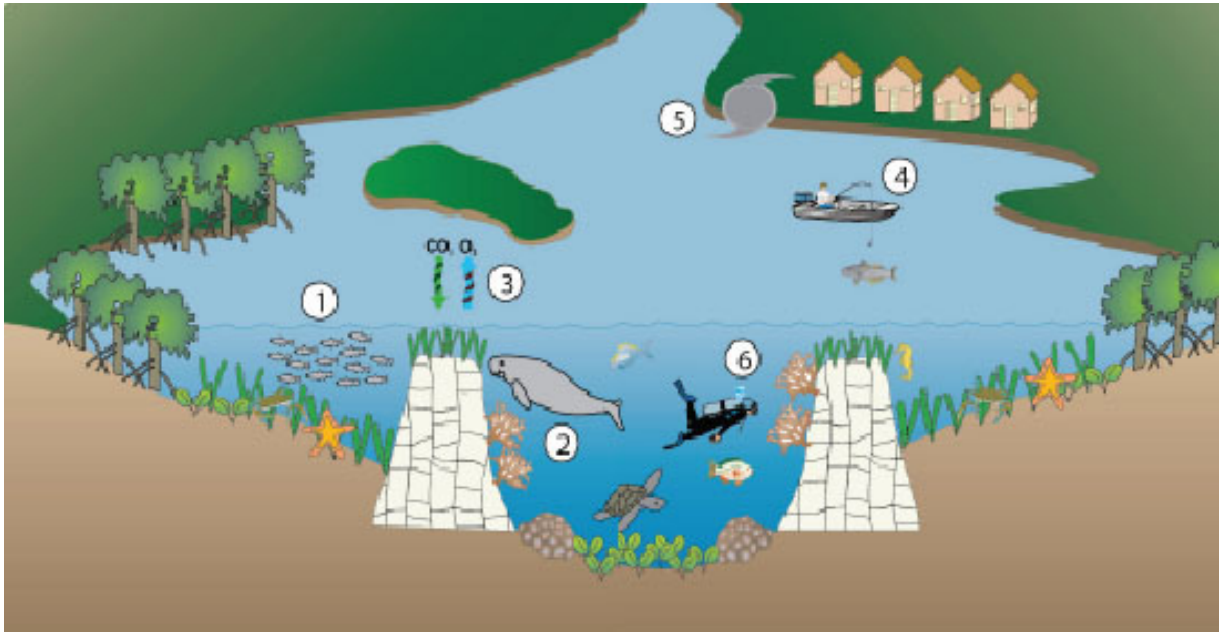


Figure 3.1: Ecosystem services of seagrasses

<p><i>Nursery and Habitat</i></p> <ul style="list-style-type: none"> • Juvenile fish find shelter and grow up in seagrasses. After maturation they move out to populate coral reefs and the open ocean • Seagrasses also serve as habitat for crabs, shrimp, mussels and octopus 	<p><i>Fishing grounds for coastal communities</i></p> <ul style="list-style-type: none"> • Fish that mature in seagrass beds provide food and income for local communities • Crabs, shrimps, scallops and mussels living in seagrass beds also provide food and income
<p><i>Food for grazers</i></p> <ul style="list-style-type: none"> • Seagrasses are an important food source for large herbivores such as dugongs and turtles • Invertebrates like lobsters, crabs and sea urchins also rely on seagrass for food 	<p><i>Coastal protection</i></p> <ul style="list-style-type: none"> • Seagrass roots stabilise sediments and so reduce coastal erosion. This protects coastal infrastructure and homes from storms and floods
<p><i>Primary productivity</i></p> <ul style="list-style-type: none"> • During photosynthesis seagrass takes up carbon dioxide (CO²) and converts it to food for the plant. As they grow they release oxygen (O²) into the water which supports other marine life • Seagrasses recycle nutrients to nourish plants and animals 	<p><i>Water filtration</i></p> <ul style="list-style-type: none"> • Seagrass leaves trap sediment particles that cloud the water. Seagrasses are also good indicators of water quality and can be used to assess the overall health of marine ecosystems • Filtration keeps the water clear for coral reefs, which support fisheries and attract the tourism that often sustains local economies

What services do other marine habitats provide?

	Mangrove Forests	Coral Reefs	Seagrass Beds
Carbon sequestration	✓		✓
Coastal defence	✓	✓	✓
Building materials	✓	✓	
Fisheries	✓	✓	✓
Tourism	✓	✓	✓

The economic value of seagrass

Economic valuation assesses the goods and services provided by an ecosystem which contribute to the wellbeing of human life. By attributing a dollar value to natural resources, the benefits of conservation and some of the unforeseen “costs” of mismanagement can be realised.

Many of the ecosystem services that seagrasses provide have high economic importance, not least the provision of critical habitat for many commercially and recreationally important fish species. They are an important resource base for rural human populations contributing significantly to human welfare through the provision of fishing grounds, bait collection grounds, substrate for seaweed cultivation, traditional medicines and food as well as the social and cultural services and aesthetic value that they provide. Seagrasses and algae beds combined have an estimated value in terms of ecosystem goods and services of US\$ 19,004 ha⁻¹ yr⁻¹ or globally US\$ 3,801 billion yr⁻¹ (Costanza et al. 1997). However, once again, seagrasses and these associated ecosystem services and economic values are under direct threat from anthropogenic impacts.

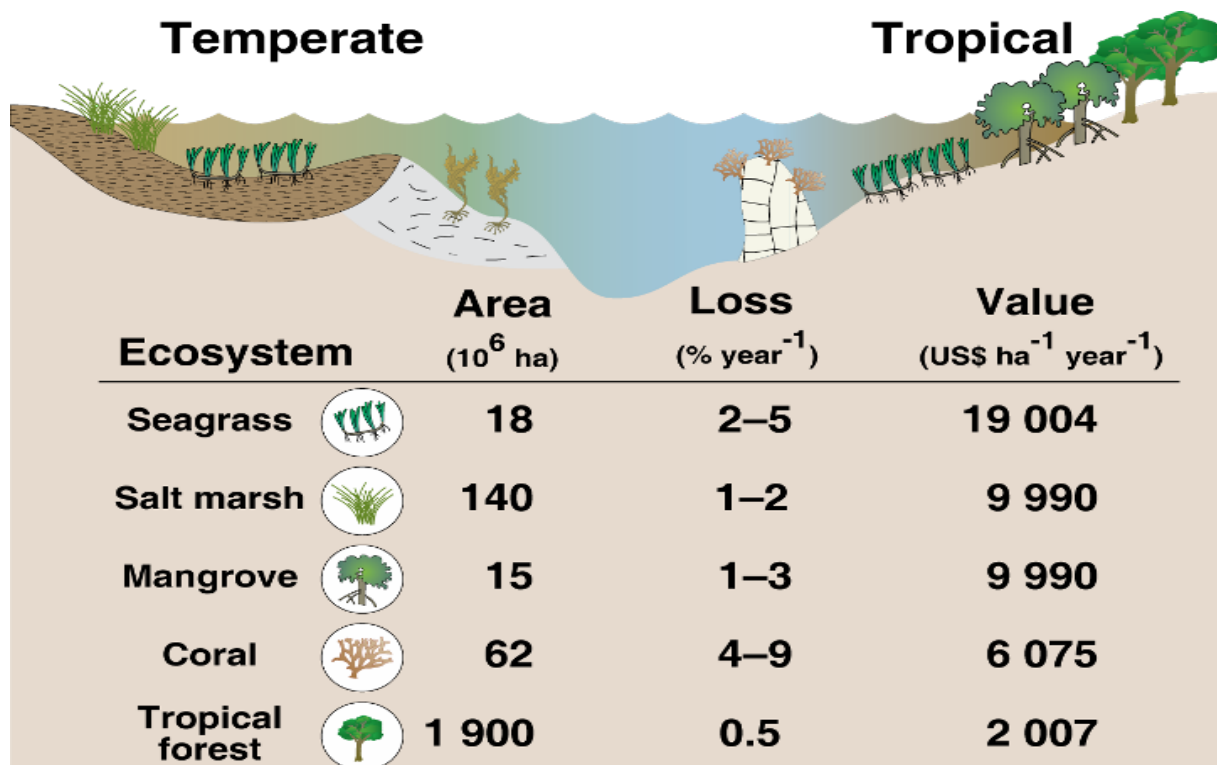


Figure 3.2: the value of temperate and tropical seagrass (from Duarte 2008)

ACTIVITY: WHAT DO YOU SEE AS THE IMPORTANT SERVICES THAT SEAGRASSES PROVIDE IN YOUR REGION?

Discuss the important services

List what you think are the top five services provided by seagrass that are important in your region.

1.

2.

3.

4.

5.

Discuss why these services are important and compare your list with other groups.

NOTES

MODULE 4

ECOSYSTEM FLOWS AND HABITAT CONNECTIVITY

Module Objectives

- To understand the dynamic flows within seagrass ecosystems
- To understand the important links and flows between seagrasses and other coastal marine ecosystems

Flows within seagrass ecosystems

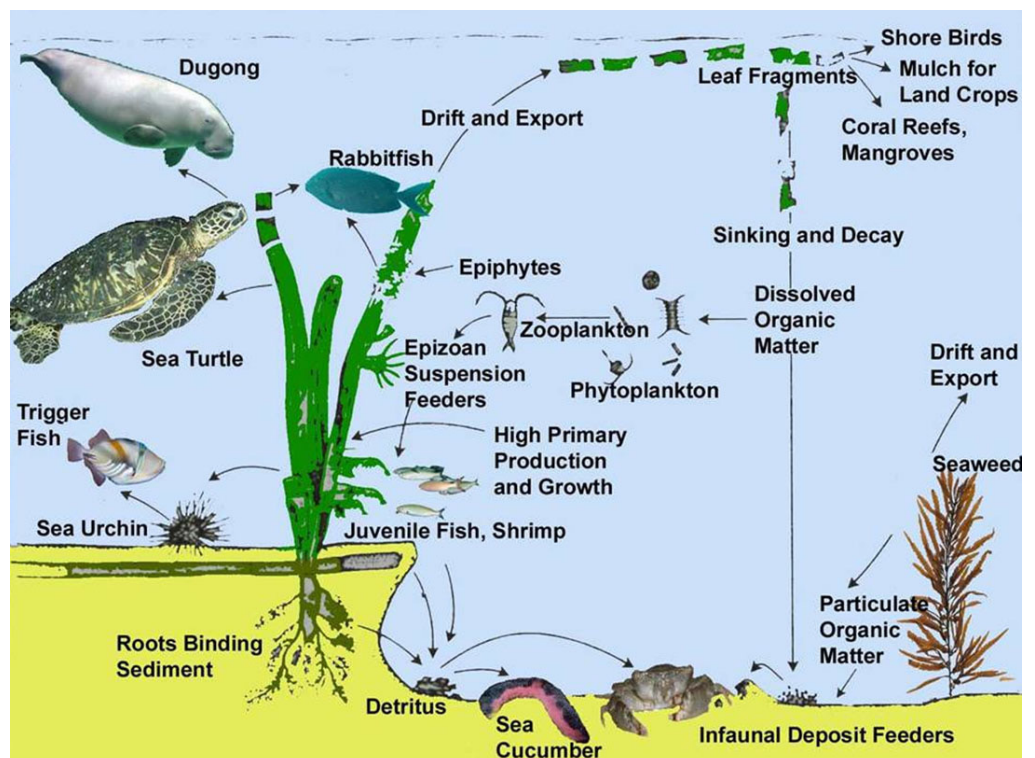


Figure 4.1: Flows within seagrass ecosystems (Source: Unsworth 2007, adapted from Fortes 1990)

Habitat connectivity

Much of the connectivity (how one habitat is connected to or reliant on another habitat) in tropical coastal ecosystems depends on intact and healthy non-coral habitats such as seagrass meadows. These non-coral habitats are particularly important for the maintenance and regeneration of fish populations.

Seagrasses are connected to other ecosystems in the following ways, with resultant benefits:

- Fish and other marine creatures depend on different habitats for different things (see diagrams below)
- Seagrass beds provide habitat for juvenile fish that populate coral reefs and the open ocean after they reach maturity
- Seagrasses filter sediments and contaminants, keeping the water clear for coral reef growth so seagrasses benefit coral reefs, which in turn helps humans too because:
 - Coral reefs maintain healthy fish populations for local and commercial fishermen

Did you know...

...that decomposing pieces of seagrass, or detritus, drift downward and provide nutrients for creatures in deep ocean canyons?

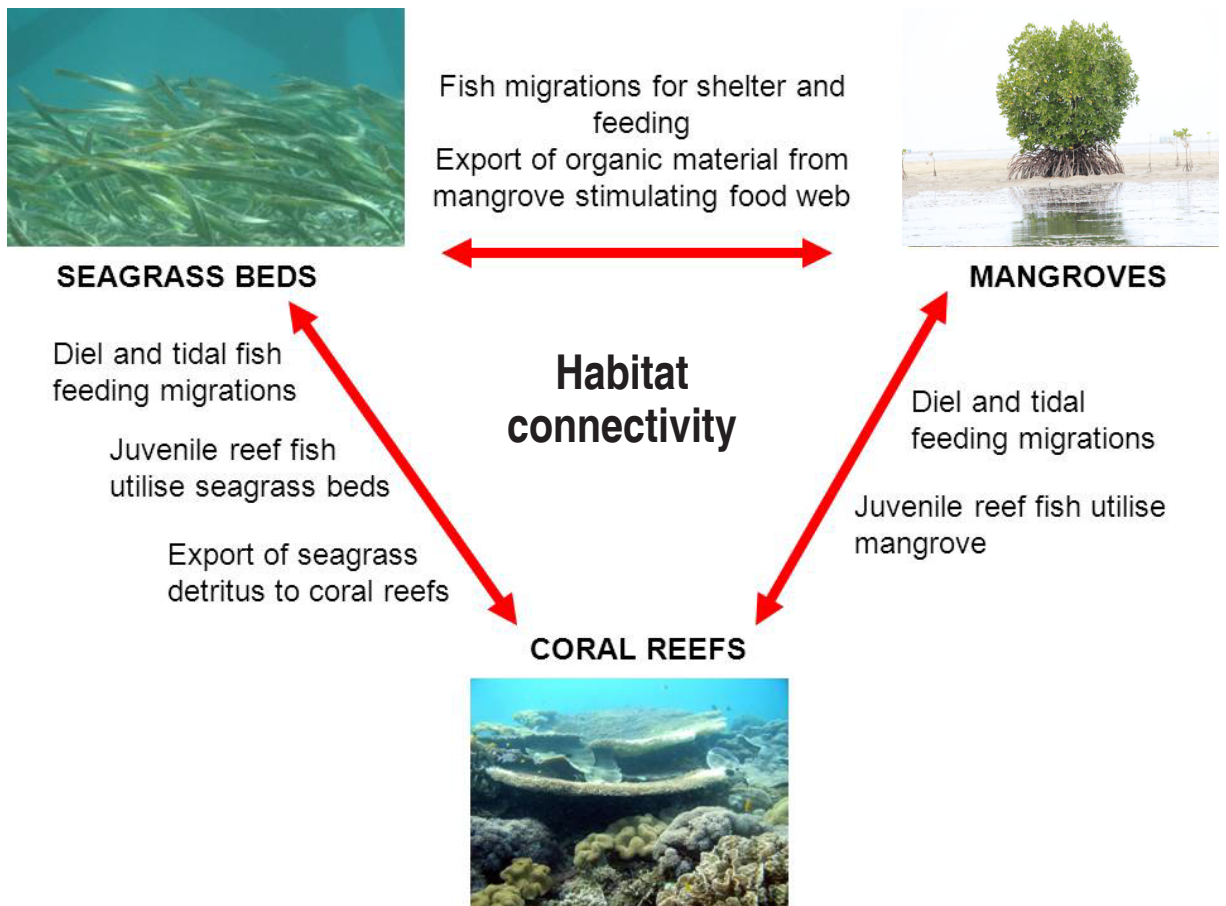
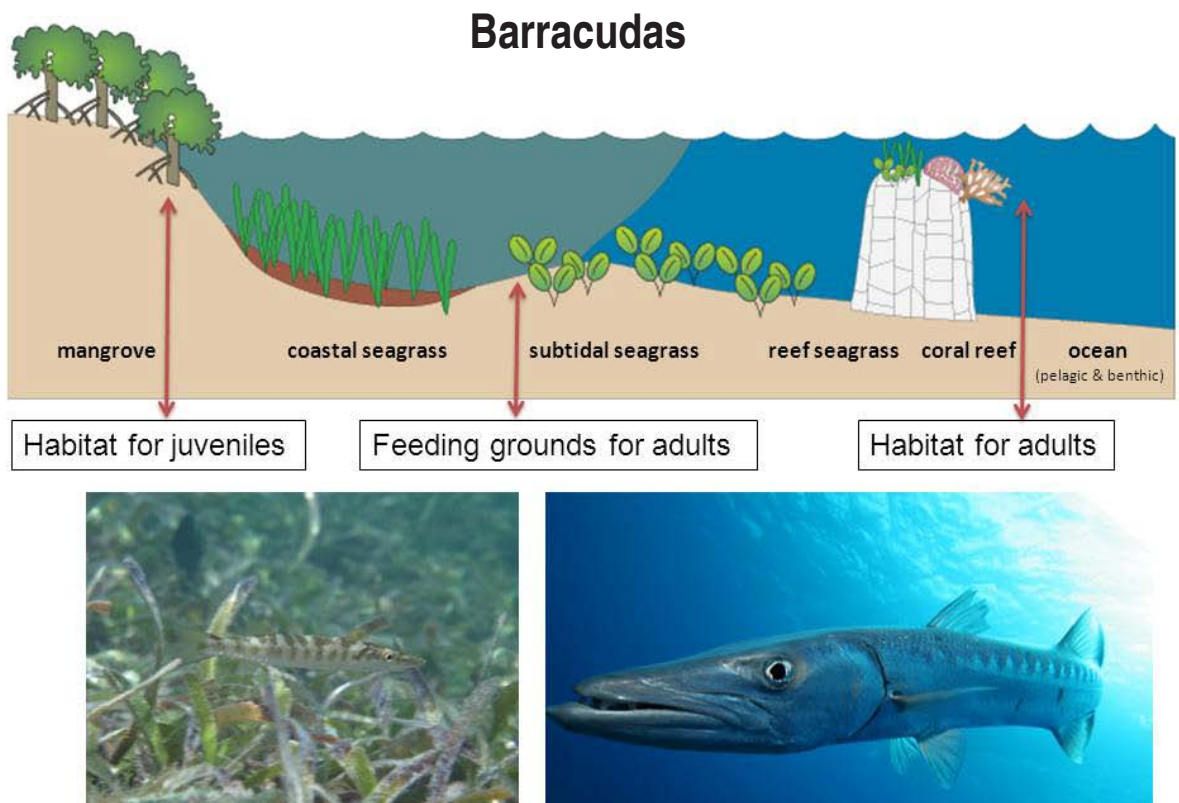
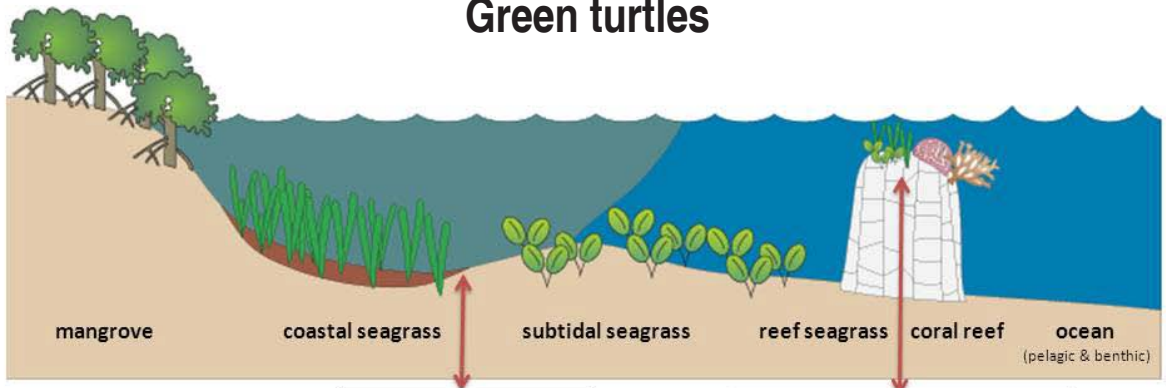


Figure 4.2: Habitat connectivity (From Unsworth 2007)

Marine creatures depend on different habitats for different things:



Green turtles

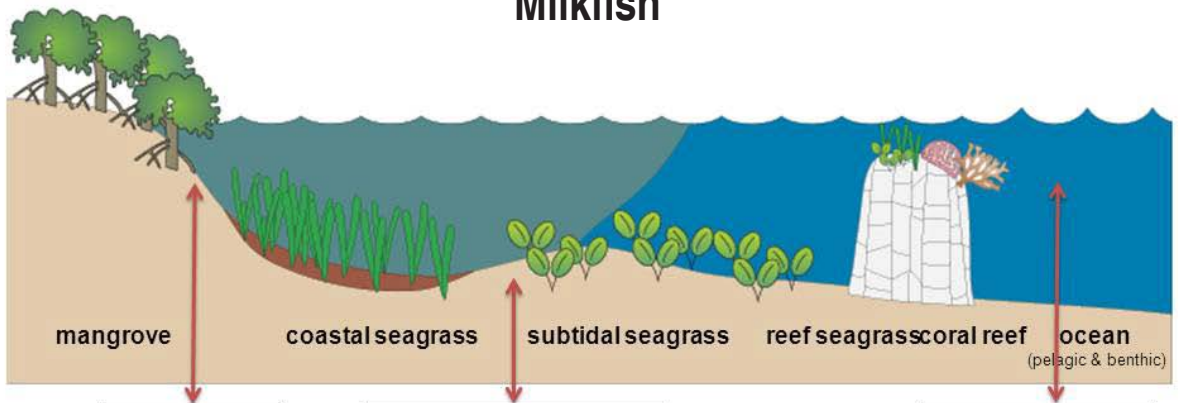


Feeding grounds

Resting grounds/refugia



Milkfish



Habitat for fry

Habitat for fry/juveniles

Habitat for adults

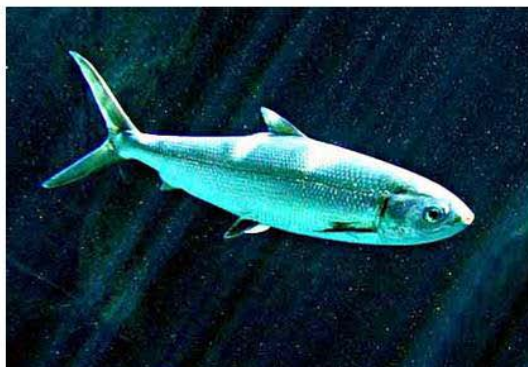


Figure 4.3: different organism depend on seagrass at different stages of their lifespan.

Seagrasses and coral reefs

The diagram (above) shows some of the interactions between seagrass meadows and coral reefs, and the support that seagrass meadows provide directly and indirectly to food production.

Seagrasses and mangrove forests

Mangroves act as coastal bio-filters. If this function is lost, there will be detrimental consequences for seagrasses including:

- Reduced water quality
- Increased nutrient load
- Increased pollution loading
- Increased freshwater input

When designing marine protected areas (MPAs) it is essential that you protect all habitats as they are connected and depend on each other.

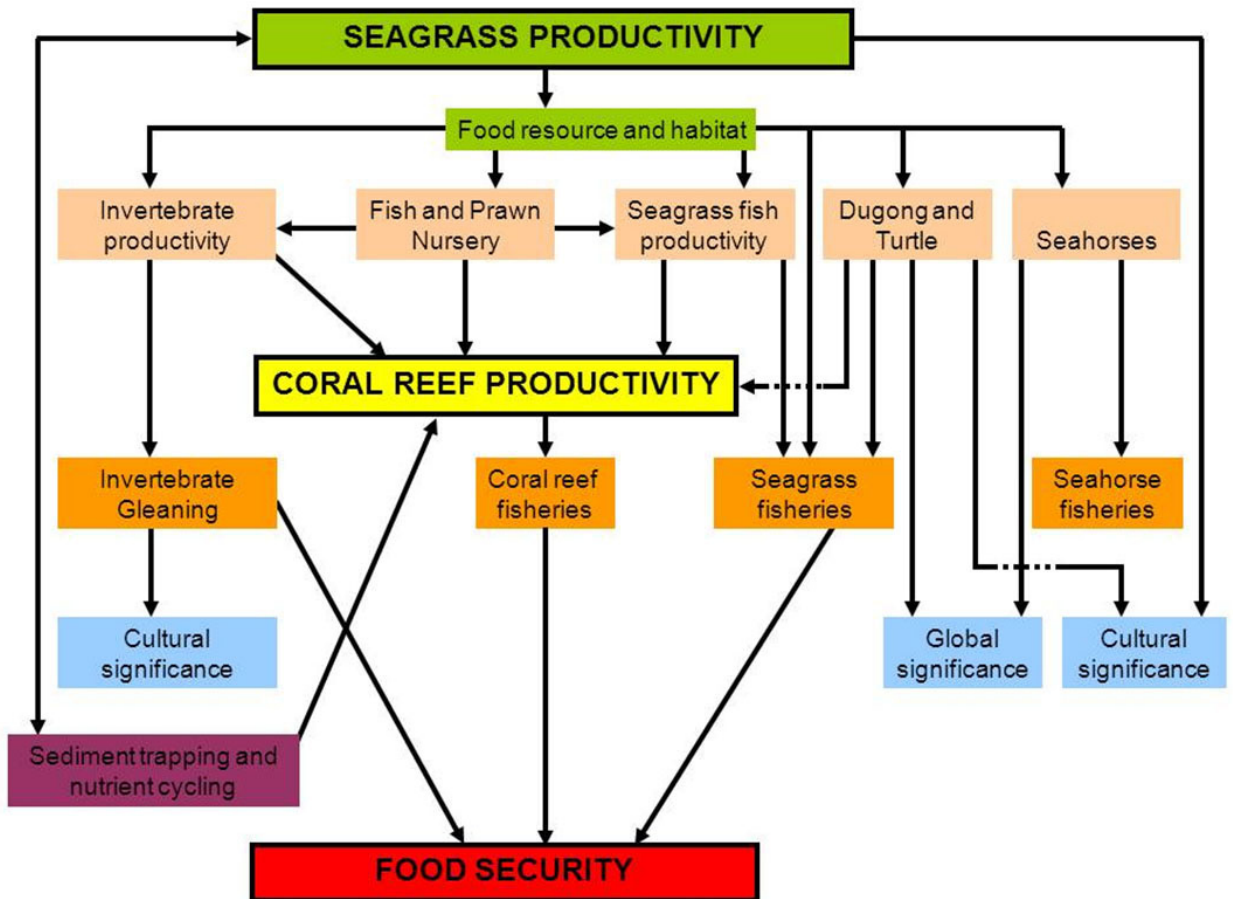
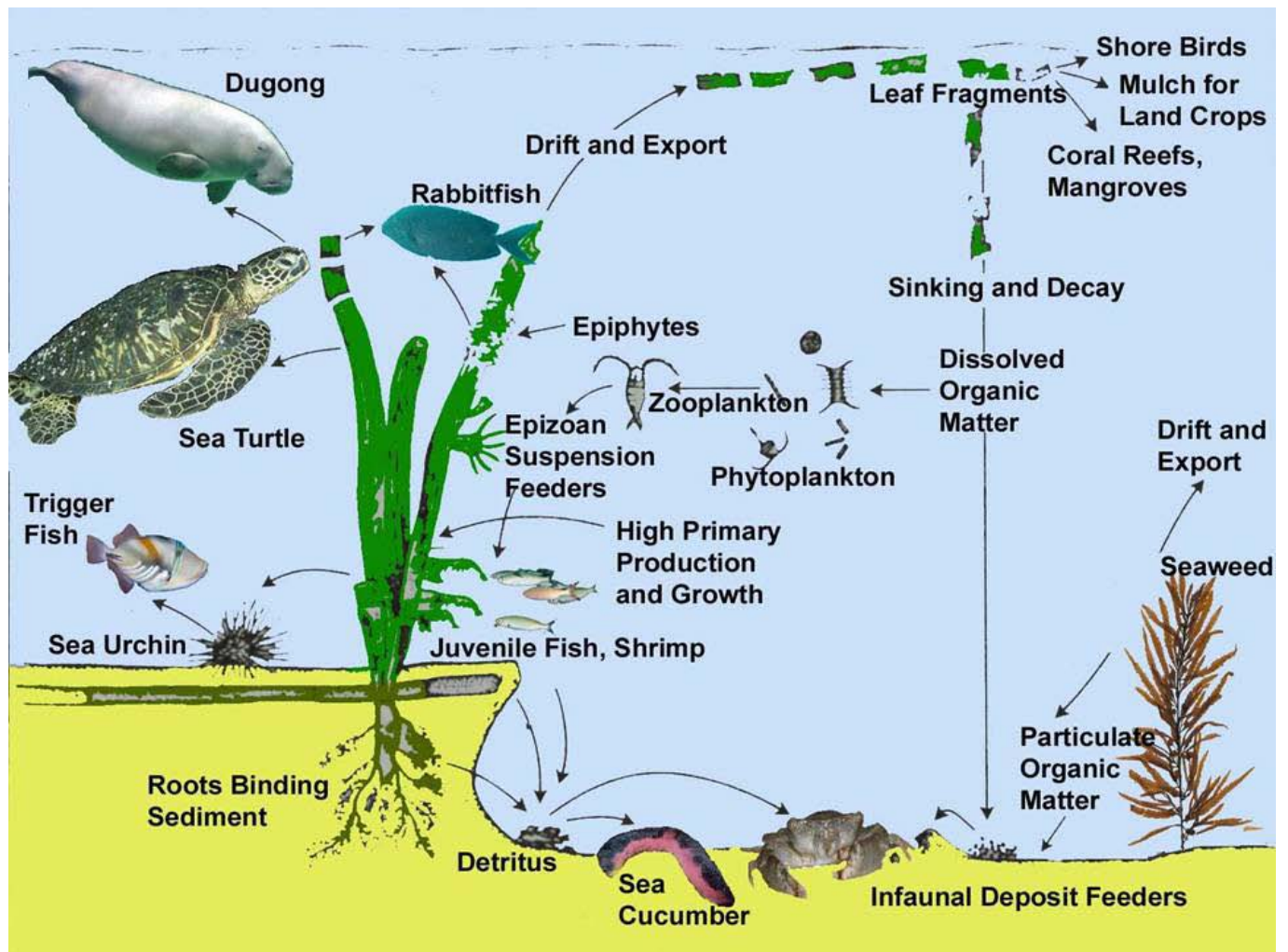


Figure 4.4: Connectivity between seagrass and coral habitats (From Unsworth and Cullen 2010)

ACTIVITY: SEAGRASS ECOSYSTEMS

IDENTIFY FLOWS ACROSS AND BETWEEN COASTAL HABITATS BY FILLING IN THE BLANKS



MODULE 5

FISH AND OTHER COMMERCIAL SPECIES ASSOCIATED WITH SEAGRASSES

Module Objective

- To understand which fish and other species are associated with seagrass beds and how seagrasses play an important role in supporting coastal fisheries, providing nursery habitat and protection for commercially important species

Seagrasses support many commercially-important marine species in both vertebrate and invertebrate fisheries. In the records available, seagrass beds can support fishery production as high as 30mt/km²/yr, which is equivalent to the productivity of tropical agricultural systems.

A range of values have been calculated for seagrass meadows throughout the world based upon a number of different goods or services. One of the most straight forward values to be placed upon a seagrass meadow is that of its exploitable (or exploited) fisheries. This has yielded results from a variety of locations with values ranging from US\$47 ha⁻¹yr⁻¹ to more than US\$3500 ha⁻¹yr⁻¹.

The most common organisms that are commercially harvested from seagrass beds in the Indo-Pacific are

- sea urchins
- sea cucumbers
- rabbitfishes (Siganidae)
- emperor (Lethrinidae)
- crabs and prawns
- shellfish

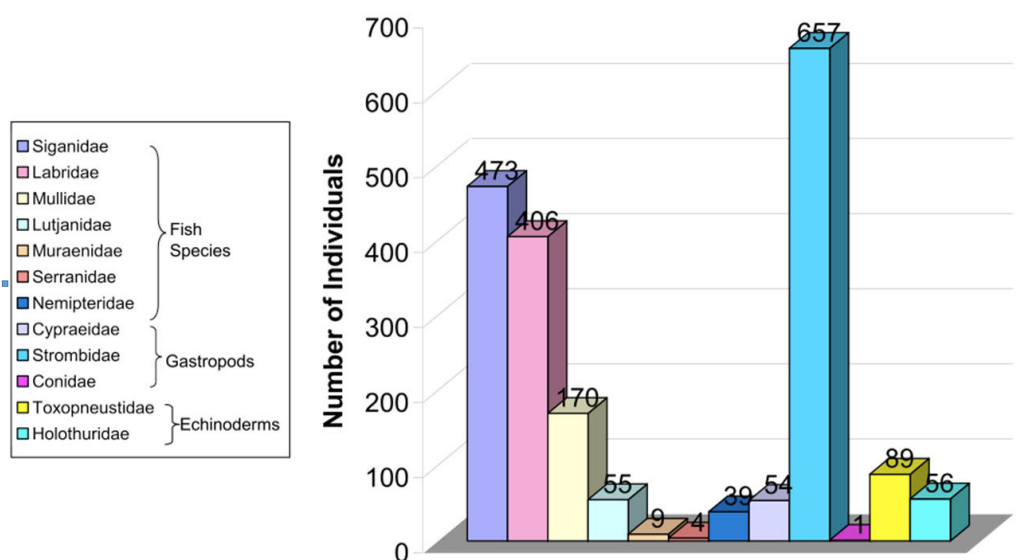


Figure 5.1: Most commonly harvested seagrass organisms (from Harvey et al., unpublished data)

Vertebrate fishery

The seagrass vertebrate fishery catch commonly includes species from Lethrinidae, Siganidae, and Scaridae, which are families known to migrate between coral reef, mangrove and seagrass areas (Unsworth et al. 2008). As shown in our graph, Siganids (rabbitfish) are the most harvested fish family in the Indo-Pacific and within this family the most abundant commercially important fish species is commonly *Siganus fuscescens*.

Many charismatic fish species are also harvested for the ornamental trade with the common seahorse *Hippocampus kuda* the most popular ornamental fish species found in the seagrass beds.



Seagrass provides habitats for a variety of fish, some of which are of high commercial value

Invertebrate fishery

When intertidal seagrass meadows (particularly reef associated seagrass) become exposed during low tide, they become the focus for local community fishing activity. Gleaning exists as an economic, recreational, cultural, social, community, and family activity. The seagrass invertebrate fishery is also of high commercial value. In the Indo-Pacific, many seagrass invertebrate fisheries are in decline with the sea cucumber (e.g., *Stichopus chloronotus*, *Holothuria scabra*, and *Holothuria atra*) fishery a major concern. Based on what little data is available on trade from export and import, Asia and the Pacific are by far the top producing areas with catches in the order of 20-40,000 tonnes per year. The northern hemisphere is estimated at around 9,000 tonnes a year. They are largely multi-species fisheries. In all tropical regions overexploitation results from commercial and subsistence activity, and is confounded in many areas by the widespread curio trade for shells from genera such as the Strombidae, Muricidae, and Volutidae. Sea urchins are commonly harvested in the seagrass beds where important protein is obtained from consuming the gonad. Invertebrate fisheries represent a vital and accessible source of protein, hence food security for local communities.



Seagrass provides habitats for a variety of invertebrates, some of which are of high commercial value

Did you know...

...that some fish, like the pinfish, pretend to be a seagrass leaf to avoid being eaten by other fish?

SEAGRASS TRAINING ASSESSMENT 1

20 MULTIPLE CHOICE QUESTIONS (20 MINUTES)

- At what depths do you mostly find seagrasses?
 - between mean sea-level and 25m
 - down to approximately 60m
 - from highest astronomical tide to 25m
- What is the main distinguishing characteristic of angiosperms?
 - plants which grow from spores
 - plants that produce flowers, fruits and seeds
 - plants which grow asexually
- What characteristic of seagrass is absent in algae?
 - internal vascular system
 - chloroplasts
 - holdfasts
- How is pollen from male flowers mainly dispersed to female flowers?
 - air currents
 - tidal currents
 - butterfly fish
- What is the role of veins in seagrass plants?
 - to provide architecture to leaves
 - to transport water, nutrients and photosynthetic products
 - to stabilise sediments
- What is the function of seagrass roots?
 - to anchor the plants and absorb nutrients
 - to bind sediments
 - to photosynthesize
- What is the pattern for cross-veins in the leaf blade?
 - along the length of the leaf
 - around the length of the leaf
 - perpendicular to the length of the leaf
- What is a sheath?
 - a modified stem
 - fibres or bristles that persist once the rhizome has died
 - a modification of the leaf base that protects newly developing tissue
- What are leaf scars?
 - marks left by propellers
 - marks from broken rhizomes
 - remnants of leaf attachment
- Which seagrass species has cylindrical leaves, with pointed tips and contains air cavities?
 - Halodule uninervis*
 - Thalassodendron ciliatum*
 - Syringodium isoetifolium*
- Which species has leaves which arise from a vertical stem and have a tri-dentate tip?
 - Halodule uninervis*
 - Halophila tricostata*
 - Halodule pinifolia*
- Which species has flat, strap-like leaves, 2-4mm wide that can be slightly curved?
 - Thalassia hemprichii*
 - Cymodocea serrulata*
 - Ruppia maritima*
- What is a distinguishing characteristic of *Halophila ovalis*?
 - oval shaped leaves in pairs
 - cross veins less than 8 pairs
 - leaves have hairs and smooth margins
 - all of the above
- Which seagrass species has leaves with in-rolled edges and long black bristles which arise directly from the rhizome?
 - Halodule uninervis*
 - Halophila spinulosa*
 - Enhalus acoroides*
- What role(s) do(es) seagrass beds play in fishery production (commercially important fish and invertebrates)?
 - as feeding ground
 - as nursery ground
 - as feeding and nursery grounds
- What is the most abundant commercially important fish species in the seagrass beds?
 - Siganus spinus*
 - Siganus fuscescens*
 - Siganus punctatus*
- In the records available, seagrass beds can support fishery production as high as ?
 - 30mt/km²/yr
 - 20mt/km²/yr
 - 8mt/mo
- What are the most common organisms that are commercially harvested in the seagrass beds?
 - Sea urchins, sea cucumbers, rabbit fishes, crabs and shellfish
 - Sea urchins, sea cucumbers and rabbit fishes
 - Sea cucumbers, rabbit fishes, crabs and shellfish
- What family is harvested in the seagrass beds for its gonad?
 - sea star
 - sea horse
 - sea urchin
- What species is most popular ornamental fish species found in the seagrass beds?
 - Napoleon wrasse (*Cheilinus undulatus*)
 - Pipefish (*Syngnathoides biaculeatus*)
 - Seahorse (*Hippocampus kuda*)

MODULE 6

THREATS TO SEAGRASSES

Module Objective

- To understand the specific threats to seagrass ecosystems, with focus on human-induced threats, their cause and effect and how to reduce the impacts

Direct anthropogenic impacts on seagrass include:

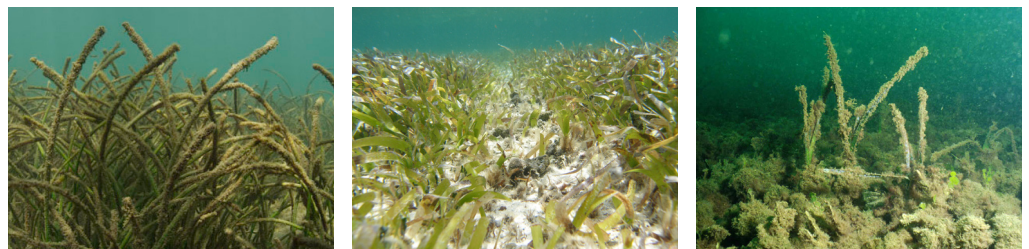
- discharge of agricultural, industrial and domestic waste and the associated reduction of water quality, increased sedimentation and nutrient loading
- dredging and other mechanical damage
- overexploitation of seagrass fauna
- development of infrastructure like marinas, ports, breakwaters, etc.

Threats to seagrasses also include those related to global climate change

- increases in sea surface temperatures
- sea level rise
- frequency and intensity of storms

The environmental effects of excess nutrients or sediments are the most common and significant causes of seagrass decline. Elevated nutrients can lead to algal blooms and epiphyte growth. Epiphytes are plants that grow on the surface of other plants and if there are too many of them, they can smother leaves and prevent light reaching the seagrass.

The direct influence of other organisms (e.g. urchin overgrazing, and disease) has also led to large-scale losses as well as the direct mechanical damage from trampling and anchors.



High nutrient inputs from run offs, boat propellers and excessive sediment loads have irreversible effects on seagrass meadows

The destruction of seagrass has wide ranging consequences including:

- reduction of detritus production, which changes the fish community and alters the food web
- beach erosion due to the loss of the binding grasses
- loss of structural and biological diversity
- reduction of water quality which impacts reefs, algal systems, and potentially tourism activities

Many seagrass-associated species, including commercially important fish species are also threatened or vulnerable to extinction. Impacts on seagrass also threaten ecosystems that rely on them, like coral reefs and mangroves.

Did you know...

...that in the Mediterranean region it is forbidden to have fish farms near or over seagrass beds?

Seagrasses are being lost at a rate of 9% per year globally. 29% of all the known global seagrass area has already disappeared.

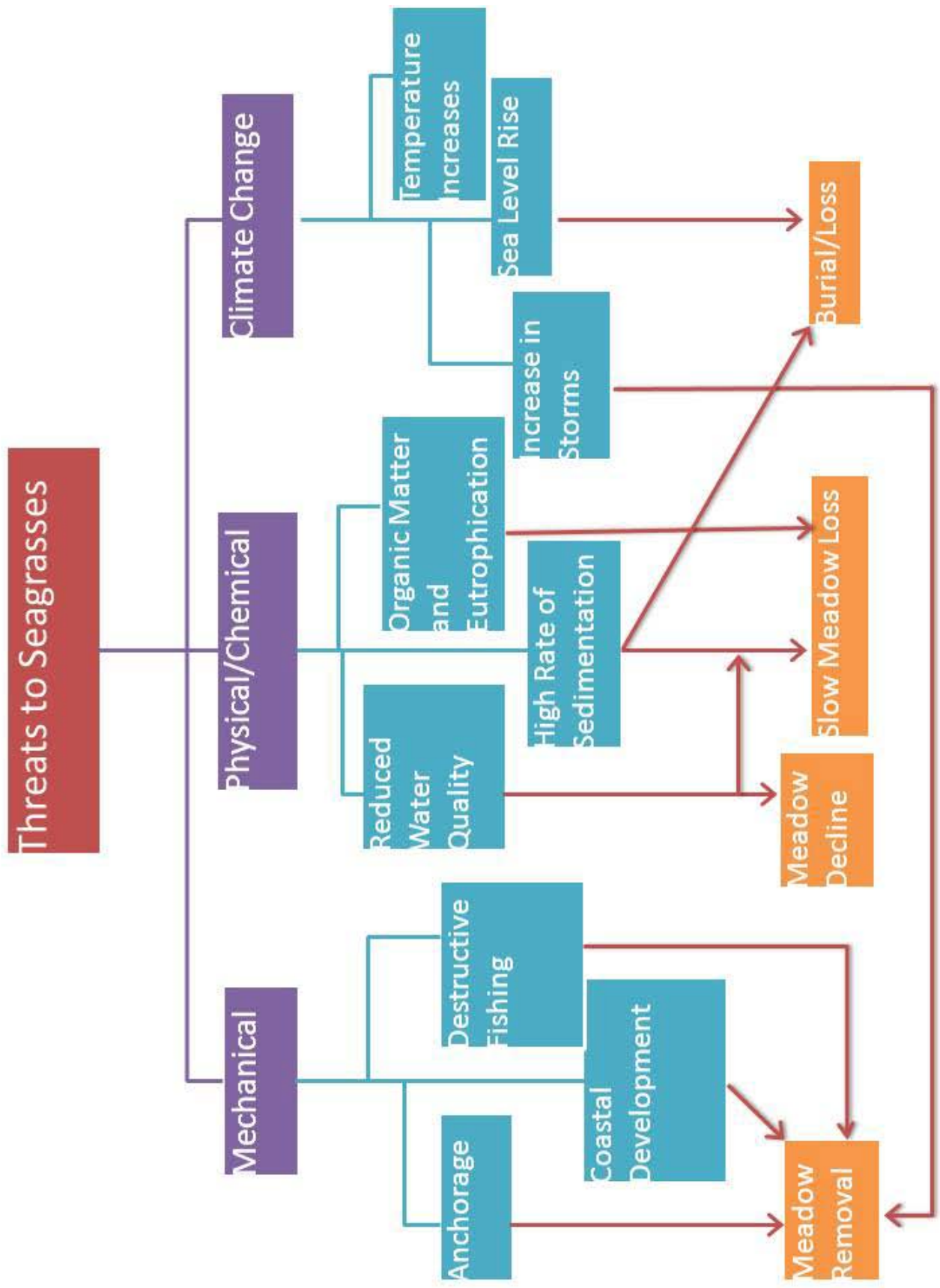


Figure 6.1: Threats to seagrasses, root causes and effects.

Threats to seagrasses and associated management actions

Threats and their Impacts on Seagrass	Action Recommendations
<p>Coastal development</p> <ul style="list-style-type: none"> • physically uproots and destroys seagrass • construction and infrastructure along the coast remove seagrasses, and increase runoff, sedimentation, and pollution affecting seagrasses and fisheries • increases erosion • oil from boats is toxic to seagrass and can hinder growth 	<p>Enforce existing and implement new requirements and zoning codes for sustainable coastal development</p>
<p>Land reclamation</p> <ul style="list-style-type: none"> • removes mangroves and other coastal vegetation which filter sediment • too much sediment hinders seagrass growth by blocking the light needed for photosynthesis 	<p>Protect and restore damaged coastal waters and shorelines</p>
<p>Destructive fishing practices (e.g. use of push-nets, algae collection, anchor damage)</p> <ul style="list-style-type: none"> • causes physical damage to seagrasses • disturb communities of marine creatures that live in seagrass beds • if seagrass beds are lost or fragmented fish and other invertebrates disappear 	<p>Establish marine protected areas that limit or ban fishing to rebuild healthy marine ecosystems Implement regulations that restrict destructive fishing methods (e.g. beach seines and bomb fishing)</p>
<p>Fish farming</p> <ul style="list-style-type: none"> • practices contribute organic waste and chemicals that directly harm seagrass • escaped fish and their diseases threaten marine life in seagrass beds 	<p>Promote sustainable aquaculture practices that minimise impacts (e.g. low density fish pens) Establish fish farms away from seagrass beds and coral reefs</p>
<p>Excess nutrients from sewage, aquaculture and farming cause algal blooms that restrict sunlight and use up oxygen</p>	<p>Educate fishermen and farmers about practices to minimise impacts on seagrass beds</p>
<p>Land run-off</p> <ul style="list-style-type: none"> • from deforestation, mining and agriculture • increases the amount of pollutants in the water (e.g. pesticides and mine tailings) that are toxic to seagrasses • increases sediments 	<p>Restore mangrove forests to prevent siltation and excessive run-off. This will improve water quality to support seagrass growth</p>
<p>Solid waste disposal</p> <ul style="list-style-type: none"> • covers the plants and animals dependent on seagrasses, smothering and killing them 	<p>Encourage waste management solutions to address improper disposal. Promote reusing, reducing and recycling!</p>
<p>Lack of awareness of the importance of seagrass</p> <ul style="list-style-type: none"> • by local communities, managers and government officials • makes it harder to pass new laws and enforce existing ones 	<p>Conduct outreach programmes for communities, governments and tourists to help them get involved</p>
<p>Lack of tools and information</p> <ul style="list-style-type: none"> • managers and policy makers need tools and information to implement and enforce conservation measures 	<p>Hold training sessions for coastal managers to improve monitoring skills and develop effective management options</p>

ACTIVITY: IDENTIFYING THREATS TO SEAGRASSES

WHAT ARE THE KEY THREATS IN YOUR REGION?

Discuss the threats to seagrasses in your region

List what you think are the top five threats in your region

1.

2.

3.

4.

5.

Discuss why these threats are important and how you could implement appropriate management strategies to reduce the impacts

NOTES

MODULE 7

SEAGRASSES AND CLIMATE CHANGE

Module Objectives

- To develop a basic understanding about the mechanics of climate change and seagrass adaptation
- To understand the cause and effect relationships between human activities and climate change
- To understand how climate change will affect seagrass ecosystems and their resources

What is climate change?

Climate change is a long-term change (i.e. over more than 30 years) in the statistical distribution of weather patterns over time and across the globe. Climate change also includes the more generally known “global warming” or “anthropogenic global warming”, which is the increase in the average temperature of Earth’s near-surface air and oceans since the mid-20th century and its projected continuation. Most of the observed temperature increase since the middle of the 20th century has been caused by increasing concentrations of greenhouse gases, which result from human activities such as the burning of fossil fuels and deforestation.

Vulnerability of seagrasses to climate change

Vulnerability to climate change can be defined as the degree to which a system is susceptible to changes.

Seagrasses are most vulnerable to the effects of climate change through associated:

- Increased ocean temperature
- Sea level rise
- Increased frequency and intensity of storms and floods

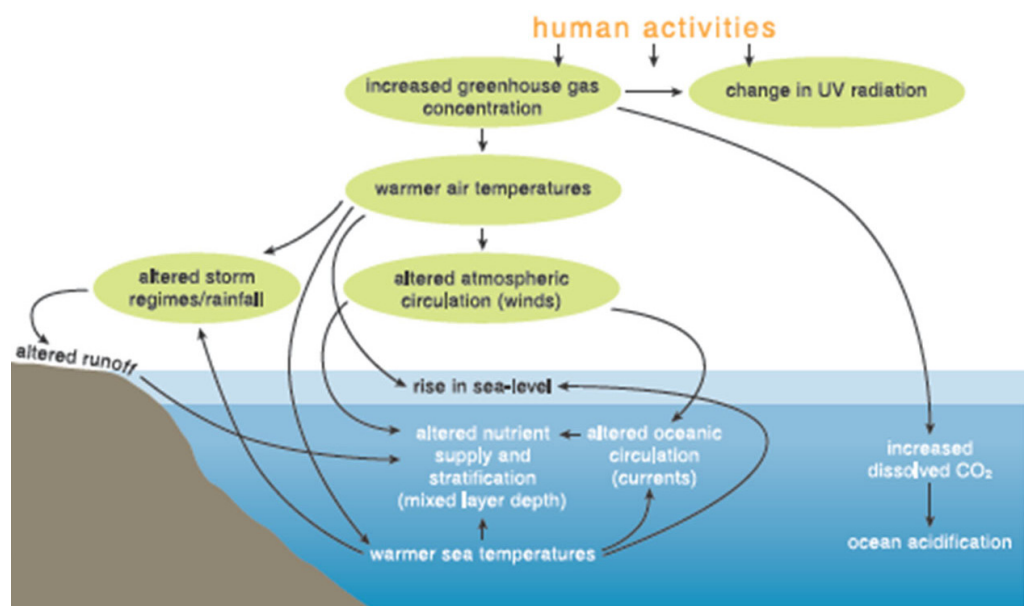


Figure 7.1: How does global warming affect our oceans?

Did you know...

...that the high pH generated by seagrass photosynthesis can counteract the effect of ocean acidification for organisms that live within the meadow?



Direct impacts of climate change

	IMPACT	EFFECT ON SEAGRASS	MANAGEMENT ACTION
Sea level rise	Coastline will be inundated causing coastline erosion and habitat loss	Mangrove habitat will be lost increasing sediment resuspension in the water column that affects water quality for shallow and deep seagrass beds	Maintain and restore mangrove areas that act as buffer for sediment and nutrient runoff
	Erosional processes and habitat loss may increase sediment resuspension	Erosion causes resuspension and burial of seagrasses in shallow water, also elevated nutrient inputs can trigger algal bloom or increase in epiphyte cover	Protect natural buffers against coastal erosion, improve management of catchment runoff and sewage outfalls
	Greater water depth will limit light availability for shallow and deep seagrass beds	While habitat might become more available for seagrass, coastal development restricts available range	Promote climate-smart coastal development that minimise environmental impacts and maintains coastal resilience
Increase in storms and typhoons	Impact on sediment movement (erosion and deposition), turbulent water motion and storm surge	Erosion causes resuspension and burial of seagrasses in shallow water, also large nutrient inputs can trigger nutrient pollution, epiphyte cover, etc.	Reduce seagrass habitat fragmentation that increases vulnerability to erosional processes; improve risk management plans
	Associated flooding will increase runoff from watersheds and agricultural lands	The major impacts of flooding and river flood plumes are expected to be salinity fluctuations and the introduction of sediments and nutrients	Improve catchment management processes and reduce deforestation to reduce sediment, nutrient and pesticide runoff
Increase in ocean temperature	Higher desiccation from hotter air, and high salinity as water evaporates faster, higher solar radiation	Species will desiccate faster, high stress and potential death; increase in respiration which reduces growth, potential photoinhibition	Mitigate fossil fuel emission that are responsible for global warming; maintain ecosystem resilience
	Temperature controls reproduction and photosynthesis, loss of diversity	Stress to reproduction, growth and other temp controlled processes. Loss of species at temperature threshold restricts and reduces species distributional range	Improve understanding of temperature threshold for seagrasses; maintain genetic diversity
	Species more adapted to thermal stress might become more abundant, loss of ecosystem services	Loss of species in shallow beds, shifts to more tolerant, fast growing species, potential competition with invasive species	Minimise human impacts to reduce stress and increase seagrass capacity to cope with environmental changes; control and monitor invasive species and interaction with seagrasses

Potential indirect impacts of climate change

Community/cascade effects

- Shifts in fish communities caused by higher ocean temperature could result in
 - New invasive/alien species
 - Species aggregation
- Ocean acidification will affect corals and other shell-building organisms (i.e. bivalves and crustaceans)
 - Species removal

Physical effects

- Rising sea level will affect mangroves/salt marshes
 - changes in sediment dynamics
 - as a result of these conditions seagrasses may experience additional cascade effects, which can cause phase shifts (i.e. seagrass to macroalgae) and loss of habitat connectivity

Ocean acidification

As a result of ocean acidification, seagrass may have increased growth rates and biomass, however, this may not counteract the negative consequences of other impacts associated with climate change

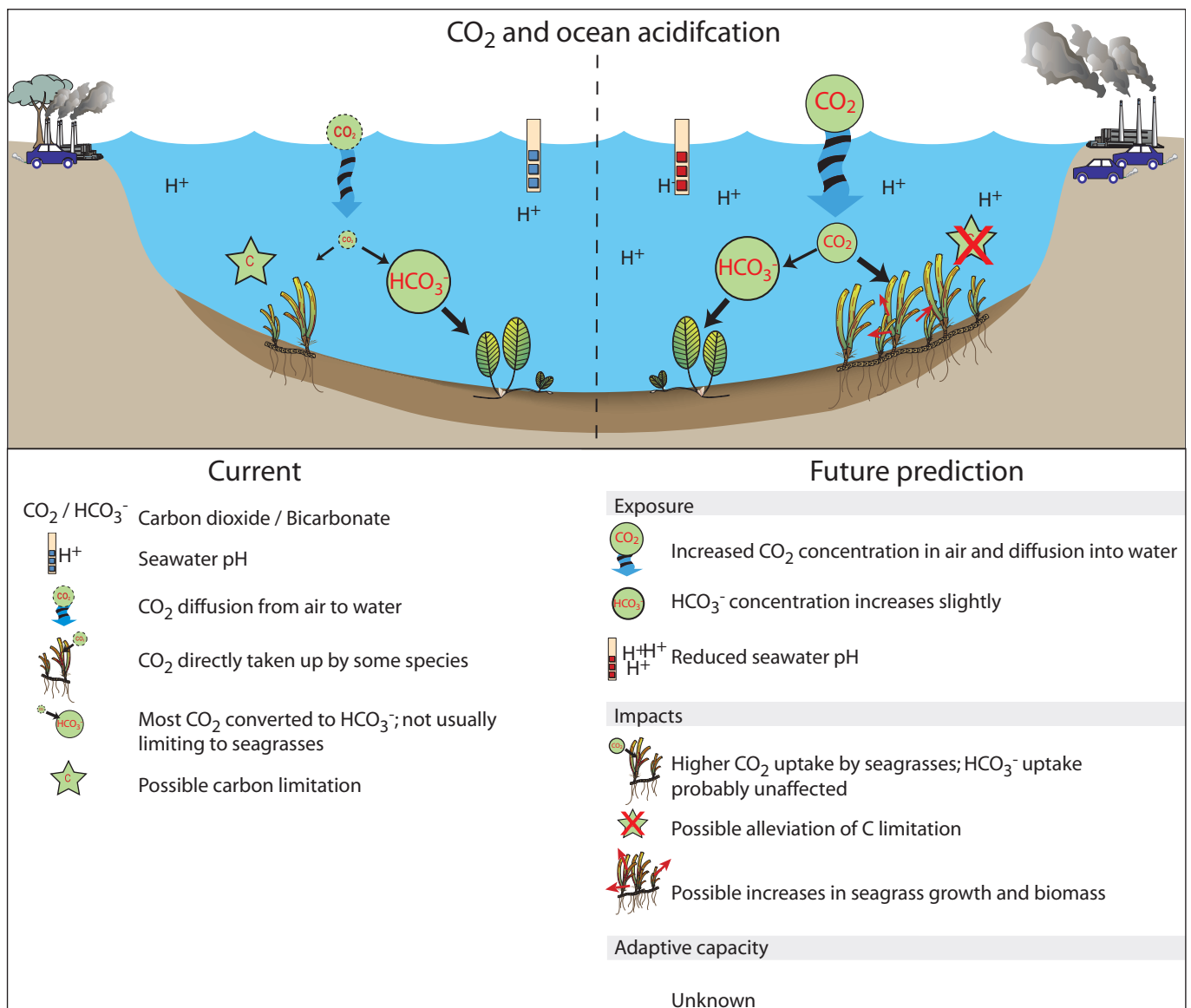


Figure 7.2: To reduce the impacts of climate change on seagrasses we need to reduce threats, maintain resilience, for example by establishing protected areas (from Waycott et al. 2007)

MODULE 8

WHY AND HOW TO MANAGE SEAGRASSES

Module Objectives

- To understand why we need to manage seagrasses
- To learn management strategies that take into account the ecology of seagrass ecosystems and the needs of local people

Why manage seagrass?

Why should we reduce human impacts on seagrasses?

- To keep fish stocks healthy for food and commerce
- To protect the coast from storms and erosion
- To maintain habitat, feeding ground, and migration routes for marine and coastal species
- To support tourist attractions
- To maintain all of the ecosystem services outlined in module 3
- To maintain the economic flows that result from a healthy seagrass ecosystem and coastal environment

Who are the key stakeholders?

Key stakeholders might include:

- Local communities, including school groups, fishermen, residents
- All resource users (e.g. fishermen, divers, farmers)
- Local business operators
- Managers and government officials
- Tourists

Management approaches

Many management actions to protect seagrass have their genesis in the protection of wider ecological systems or are designed to protect the overall biodiversity of the marine environment. Approaches to protection of seagrass tend to be location-specific or at least national-specific (as there is no international legislation specific for seagrass) and depend to a large extent on the legal tools available and the cultural approach of the community. Three generalized approaches are used to protect seagrasses or manage impacts on seagrass: reactive, prescriptive and non-prescriptive. 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 practices on adjacent land. Prescriptive or legal approaches can range from local to state-wide laws. Legal approaches can provide general protection, that is all seagrasses have some level of protection, or specific protection as in a Marine Park or Marine Reserve. Non-prescriptive approaches range from codes of practice, local agreements, planning processes to education.

(adapted from Seagrass-Watch Handbook)

Did you know...

...that one in five seagrass species is now listed as Endangered, Vulnerable, or Near Threatened, having a heightened risk of extinction under the IUCN Red List Criteria?



Threat	Solution
Pollution	Institute waste management programs
Sewage Outfall	Create sewage treatment plants
Runoff	Reforest and rehabilitate upstream areas
Aquaculture	Regulate fish-farming operations
Destructive Fishing Practices	Require sustainable fishing methods
Coastal Development	Change zoning laws
Anchor Damage	Implement fixed moorings for boats
Dredging	Water quality monitoring and thresholds

How can you help?

Efforts are underway to educate the public about the benefits and values of seagrasses so that we can help to protect them. 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; avoid anchoring on seagrass beds as one small anchor can remove up to 1m² of seagrass; support marine conservation initiatives; learn about special marine habitats and volunteer to monitor their health.

We need to establish more Marine Protected Areas to address many of the threats seagrass face. Increased awareness and education is essential to inform managers and local communities about the importance of seagrasses. When managing specific threats to seagrasses you should understand the effects of your chosen actions, evaluate possible management options, and take appropriate action. We need to establish more Marine Protected Areas to address many of the threats seagrass face. Increased awareness and education is essential to inform managers and local communities about the importance of seagrasses. When managing specific threats to seagrasses you should understand the effects of your chosen actions, evaluate possible management options, and take appropriate action.

ACTIVITY: DO SEAGRASSES NEED TO BE MANAGED IN YOUR REGION?

- Discuss why seagrasses need to be managed in your region
- Discuss what the potential impacts of management action will be on key stakeholders
- Discuss how seagrasses can be included in MPA management plans for your region taking into account the needs and aspirations of local people
- Think about how you can encourage local support for management actions

NOTES

MODULE 9

SEAGRASS MONITORING

Module Objectives

- To develop a basic understanding of the need for monitoring seagrass ecosystems
- To understand the resources and skills needed for monitoring seagrasses
- To learn a basic monitoring protocol and put it into practice in the field

Why monitor seagrasses?

Monitoring is the repeated observation of a system, usually to detect change. Monitoring is a valuable tool for improving management practices by allowing resource managers to know if resource condition is stable, changing, improving or declining. It allows the detection of changes and subsequent design of appropriate management strategies. Early detection of change allows coastal management agencies to adjust their management practices and/or take remedial action sooner for a greater chance of successful results. Seagrasses are also considered good marine sentinels and biological indicators. This is because they respond to both natural and anthropogenic alterations and are able to register changes in environmental variables. Monitoring of seagrass ecosystems can also be used as a way of engaging local communities in marine conservation.

Monitoring programs should be designed:

- to quantify causes of change;
- to examine and assess acceptable ranges of change for a particular site;
- to measure level of impact;
- to guide conservation or management actions;
- reflect the training of the available staff and/or volunteers

Everyone must work together to protect our valuable seagrasses

What parameters can we measure?

Deciding what to measure in a seagrass meadow depends on why the group or management authority wants to monitor. In practice most monitoring programmes follow the SeagrassWatch protocol as this is designed to observe a range of different types of impact or change in a seagrass meadow. Occasionally some managers may want to add additional parameters due to specific issues at a given location. In such circumstances the programme will require additional resources and expertise to support monitoring. Parameters included in the standard SeagrassWatch protocol can be measured without the need for expensive equipment, extensive training or laboratory analysis.

Within (and in addition to) the SeagrassWatch protocol there are four different types of parameters that can be measured:

Habitat quality parameters

- Seagrass meadow area (size of meadow in hectares)
- Seagrass percentage cover
- Seagrass species composition

Tip:
when there are two or more species present, always start your estimations with the least dominant

Tip:
measure at least 3 leaves of
the dominant strap-like species
in each quadrat to determine
canopy height

- Canopy height
- Macro-algae percentage cover
- Epiphyte percentage cover on seagrass shoots
- Sediment type (sediment size)
- Dugong/turtle activity
- Invertebrate abundance and activity

Resilience parameters (i.e. measuring how well the seagrass might recover if it is damaged)

- Seed bank and reproductive structure (seed bank size reflects a simple measure of the capacity of a seagrass meadow to recover following large scale impacts)
- Fruits and Flowers (this requires laboratory work and additional detailed training)

Bioindicators (i.e. using seagrass to measure the condition of the marine environment)

- Macro algal abundance and epiphyte cover (increases in the abundance of epiphytes and sometimes macro algae are stimulated by nutrient loading)
- Chemical analysis of seagrass leaf tissue for nutrient ratios (N:P, C:N, C:P) (this again requires laboratory work and further detailed training)
 - C:P values <500 may indicate nutrient rich habitats
 - N:P levels of 25-30 indicate seagrass to be nutrient replete (saturated), <25 indicates N-limitation and >30 indicates P-limitation

Environmental change parameters (i.e. measuring how physical conditions might change)

- Water temperature
- Changes in sediment type and size
- Light availability (this requires additional equipment and further detailed training)
- Sedimentation (this again requires laboratory work and further detailed training)

Applying the Seagrass-Watch protocol

SeagrassWatch is a global monitoring programme with a standard protocol for seagrass ecosystems. The main objectives of SeagrassWatch 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

The approach offers an opportunity to learn and practice a technique that can be easily implemented. More than 25 countries participate in the programme globally and monitoring occurs at more than 270 sites. Seagrass Watch has an accepted quality assurance and control method in place to ensure that the programme is producing data of high quality, which reassures data users (e.g. coastal management agencies) that they can use the data to make informed decisions with confidence. Other seagrass monitoring programmes exist and are used in different locations (e.g. SeagrassNet, SeaSearch). These programmes may be similar to SeagrassWatch or they may have been designed for location specific monitoring.



Did you know...

...that seagrass are often referred to as coastal canaries? This comes from the bird, the canary, traditionally used by miners to detect danger!

Seagrass-Watch supports on-ground (reactive), legal (prescriptive), planning and educational (non-prescriptive) approaches to seagrass protection



What skills are needed to monitor seagrasses?

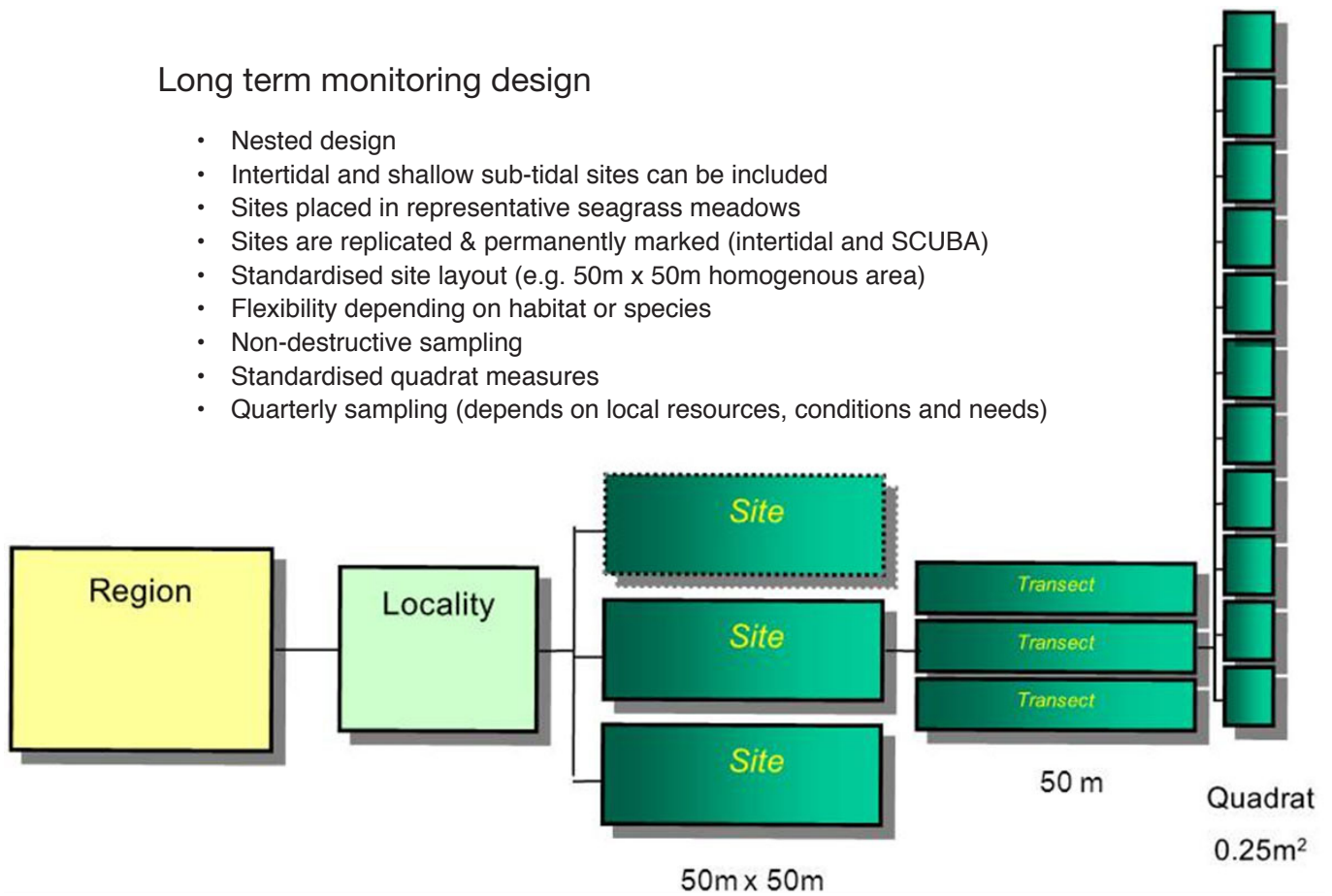
- Participants in Seagrass Watch range in age from 18 to 72 and represent a diverse cross-section of the community including tradespeople, school teachers, Indigenous communities, engineers, fishers, divers, retirees, students and scientists. No prior knowledge or specific skills are needed
- Seagrass Watch methods were developed to be rigorous but simple and easy to use
- After 6-9 hours of training, participants can produce reliable data
- Training includes both formal and informal approaches

What equipment is needed to monitor seagrasses?

- Crate for samples
- Trays for sorting samples
- Clip boards
- Mask and Snorkel (for when seagrass submerged)
- Underwater paper /waterproof slate
- Notebooks/pens
- Camera
- Mesh bags
- GPS and batteries
- Identification kits/guides
- Seagrass Watch protocol
- Quadrats/ Transect line

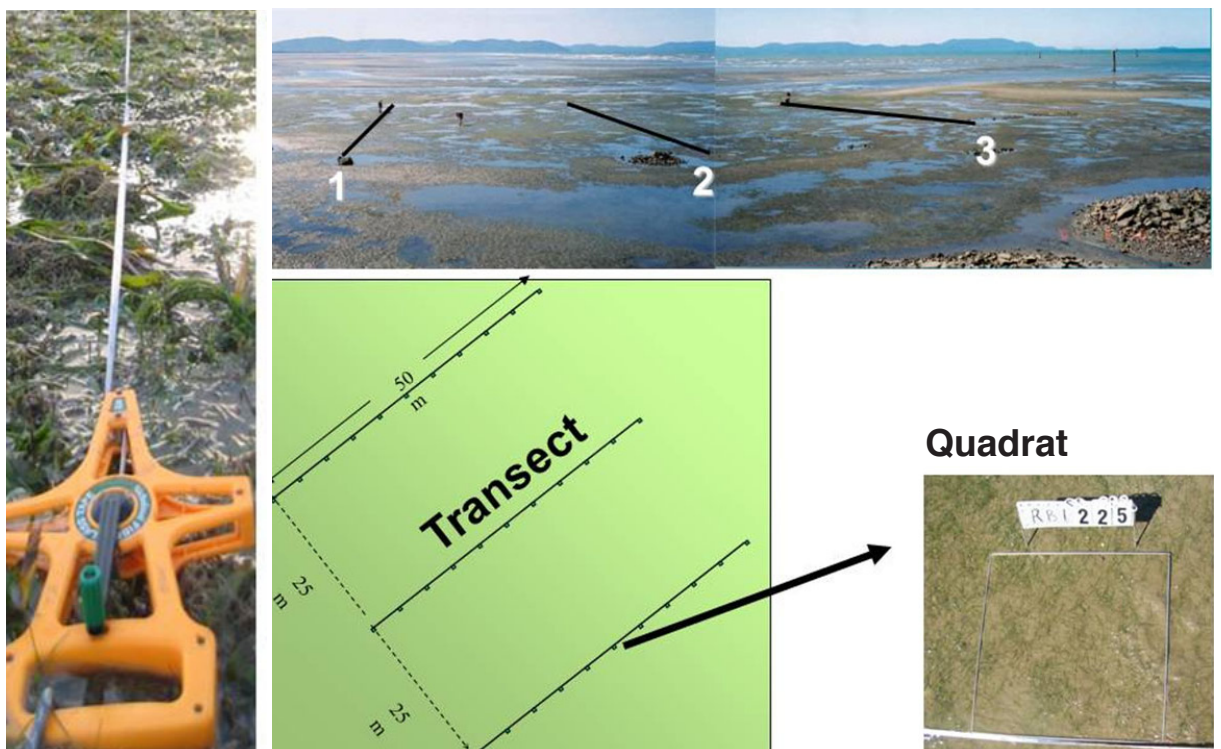
Long term monitoring design

- Nested design
- Intertidal and shallow sub-tidal sites can be included
- Sites placed in representative seagrass meadows
- Sites are replicated & permanently marked (intertidal and SCUBA)
- Standardised site layout (e.g. 50m x 50m homogenous area)
- Flexibility depending on habitat or species
- Non-destructive sampling
- Standardised quadrat measures
- Quarterly sampling (depends on local resources, conditions and needs)



Outline of the SeagrassWatch Method

- A standard intertidal site will measure 50m x 50m
- Within that site three 50m transects will be permanently marked
- Along each transect 11 quadrats will be included. A quadrat is the standard unit, usually square, which is used for estimating seagrass
- A total of 33 quadrats will be sampled in a standard intertidal site



Quadrat parameters measured

- Seagrass percentage cover
- Species composition
- Canopy height
- Algal % cover
- % epiphyte cover
- Sediment description
- Invertebrate abundance
- Other comments (e.g. water depth)
- Quadrat photograph taken (if available) at 5m, 25m and 45m along each transect
- Seed bank measured from core

Quality assurance and control

- Representative site selection – measurements actually represent the whole population at the time an observation was made
- Sites permanently marked – ensures data can be compared between periods of time
- Methods simple and easy to use – ensure completeness (amount of useable data originally planned to collect, versus how much collected)
- Scientific training ensures precision among repeated measurements and that measures are close to a true or standardised value
- Calibration sheets ensure:
 - precision among repeated measurements,
 - measures close to a true or standardised value,
 - consistency between observers, and
 - data is comparable between sample locations or periods of time
- Photographic records ensures measures are accurate
- Voucher specimens ensure species identifications are accurate
- Data error notifications ensure:
 - monitors (observers) are aware of any errors
 - provides an opportunity to clarify or correct data
 - highlights if additional/refresher training is required



FIELD ACTIVITY: FOLLOWING THE SEAGRASS WATCH MONITORING PROTOCOL

If you would like full details of the Seagrass Watch programme or you would like to register to join the Seagrass Watch programme, visit www.seagrasswatch.org.

If you are interested in organising a Seagrass Watch training workshop, please contact the Seagrass Watch coordinator (contact details available at the end of this manual).

MODULE 10

COMMUNICATION AND OUTREACH

Module Objectives

- To learn how to communicate the importance of seagrass and the need for management
- To learn how to design a communication plan, working with different audiences and stakeholders
- To learn how to engage stakeholders, particularly local communities
- To learn how to conduct campaigns with local communities, schools, or other groups to increase awareness

Why communicate?

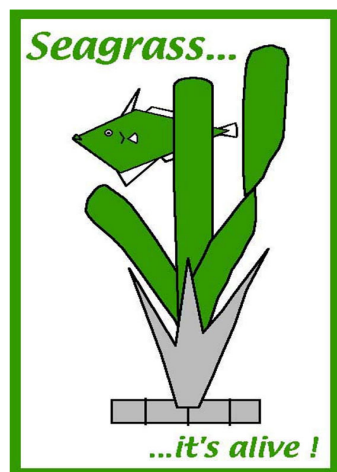
- To build awareness of the importance of seagrass and threats they face
- To prompt protection and restoration through regulation and community stewardship

Who should we communicate with?

Who is our target audience?

All key stakeholders including:

- Resource users (e.g. fishermen)
- Local communities
- Local business operators
- Managers and government officials
- Tourists



Communication methods

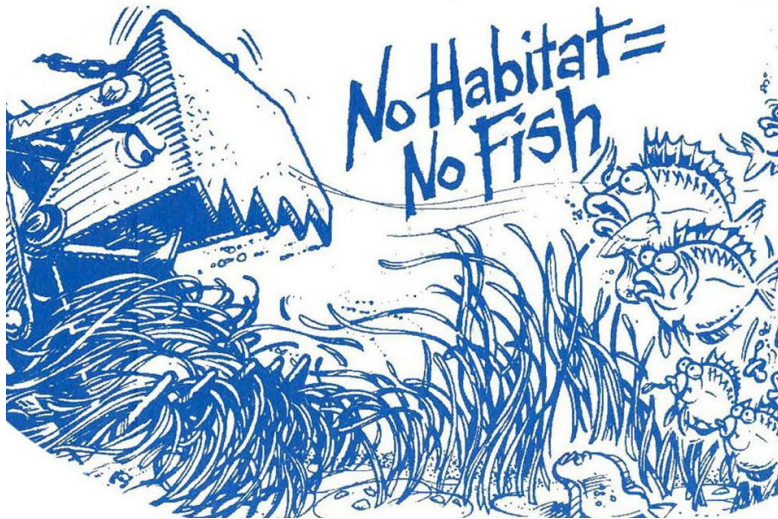
- Meetings and Group Discussions
- Films and Presentations
- Hands-on Training (Seagrass Watch!)
- Signs and Posters
- Brochures and Newsletters

Slogans can be a useful tool for communication and to help your audience remember important facts:

Did you know...

...that each seagrass has a latin name, a common English name and a local name in thousands of languages and dialects around the world?





Seagrass is an important Ecosystem, Always Govern Resources And Save Seagrass!

Community engagement

Increased awareness and education is essential to inform managers and local communities about the importance of seagrasses, people care about what they understand. Communities can be engaged through formal education and training programmes using the methods outlined, or by taking part in initiatives such as Seagrass Watch where they can make an active contribution to seagrass conservation.

Community and stakeholder engagement can be used to encourage the inclusion of seagrasses into management plans and enable legal mechanisms for their protection



Children reading about MPAs in the Philippines

ACTIVITY: COMMUNICATION STRATEGY DEVELOPMENT.

Identify the issue to be communicated; identify the target audience; develop effective messages (for example “no habitat, no fish”); design products that can be used to deliver your message.

SEAGRASS TRAINING ASSESSMENT 2:

28 MULTIPLE CHOICE QUESTIONS (20 MINUTES)

21. How much seagrass can a dugong eat in a day?
- up to 20kg wet weight
 - up to 40kg wet weight
 - up to 100kg wet weight
22. How much seagrass (wet weight) does a turtle eat in a day?
- up to 20 kg
 - approximately 10 kg
 - approximately 2 kg
23. What is the major gas that seagrasses pump into sediments?
- carbon dioxide
 - oxygen
 - nitrogen
24. Complete this sentence "Monitoring is the repeated observation of a system, usually to"
- determine health
 - detect change
 - involve stakeholders
25. Why do seagrasses make good bioindicators of environmental health?
- widespread distribution
 - important ecological role
 - sessile plants
 - show measurable and timely responses to impacts
 - response to environmental conditions
 - all of the above
26. What is the name of the standard unit, usually square, which is used for estimating seagrass?
- quadrant
 - quadratic
 - quadrat
27. How many quadrats are sampled in a standard intertidal site?
- 33
 - 30
 - 11
28. When must photos be taken along a transect?
- every 10m
 - 5m, 30m & 45m
 - 5m, 25m & 45m
29. How many leaves of the dominant strap like species are measured per quadrat to determine canopy height?
- at least 3 (ignoring longest 20%)
 - at least 5 (including longest 20%)
 - at least 1 (ignoring longest 50%)
30. When determining species composition for two or more species, always start with...?
- the most dominant
 - the least dominant
 - the tallest
31. What are epiphytes?
- animals living on the surface of plants
 - plants growing on the surface of other plants
 - the tips/ends of leaves
32. How does Seagrass-Watch ensure data can be compared between periods of time?
- recording start and end times
 - sites permanently marked
 - names of all observers recorded
33. How does Seagrass-Watch ensure percentage covers are close to a true or standardised value?
- calibration sheets
 - sites permanently marked
 - sampling during low spring tides
34. How does Seagrass-Watch ensure measures are accurate?
- photographic records (27% quadrats)
 - data notifications
 - refresher workshops
35. How does Seagrass-Watch ensure observers are aware of errors and provide opportunity to clarify or correct data?
- data error notifications
 - E-bulletins
 - newsletter
36. How do seagrasses help stop beach erosion?
- reduce tidal exposure
 - rhizomes & roots stabilise sediments
 - resuspending of sediments

37. How does seagrass help stop land-based pollution?
- filters nutrients
 - buffers sediment
 - filters chemicals
 - all of the above
38. Types of physical disturbance which can damage seagrass include?
- dredging
 - bait & clam digging
 - anchors & propellers
 - all of the above
39. Catchment runoff can damage seagrasses by?
- elevating nutrients
 - reducing available light
 - releasing herbicides
 - all of the above
40. How will elevated sea temperatures from climate change impact seagrass?
- possible species shift in distribution
 - shift in timing of flowering and seed production
 - increased respiration, reduced photosynthesis
 - all of the above
41. What are Ecosystem services?
- conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life
 - the benefits that human derived, directly or indirectly, from ecological functions
 - critical for human wellbeing
 - all of the above
42. Vulnerability to climate change can be defined as
- the degree to which a system responds to changes
 - the degree to which a system is susceptible to changes
 - the ability of a system to change
43. Which of the following is not an ecosystem service that seagrass provide?
- Reduce coastal erosion
 - nursery grounds for fish
 - provide material for charcoal
 - provide food for sea turtles
44. How can we reduce the impacts of climate change on seagrasses?
- Increase use of boats instead of cars
 - reduce threats, maintain resilience, establish protected areas
 - Do nothing
45. When designing MPAs you should
- Protect coral reefs and mangroves so don't need to protect seagrass
 - Protect coral reefs and seagrass so don't need to protect mangroves
 - Protect all habitats as they are connected and depend on each other
46. Climate change might increase storm frequency and intensity, this will impact seagrasses through
- increase in wave energy that can disrupt/uproot seagrasses
 - increase rainfall that cause nutrient runoffs
 - impact mangroves that act as a buffer for coastal sediments, limiting light availability
 - all of the above
47. When managing specific threats to seagrasses you should
- Understand the effects on seagrasses and address it promptly
 - Understand the effects but wait for a while
 - Understand the effects, evaluate possible management options, and take action
48. What are the approaches Seagrass-Watch supports for the protection/conservation of seagrass?
- reactive (on-ground)
 - prescriptive (legal)
 - non-prescriptive (planning & education)
 - all of the above

ADDITIONAL SEAGRASS RESOURCES

Bibliography, key references and useful websites

Journal Papers

- Costanza R, d'Arge R, deGroot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, vandenBelt M, 1997. The value of the world's ecosystem services and natural capital. *Nature*, volume 387, pages 253-260
- Daily, 1997. What are ecosystem services? *American Association for the Advancement of Science: Engaging Science, Sustaining Society, AAAS Annual Meeting and Science Innovation Exposition*, volume 163
- Duarte, 2002. The future of seagrass meadows. *Environmental Conservation*, volume 29, pages 192-206
- Duarte CM, Dennison WC, Orth RJ, Carruthers TJB, 2008. The charisma of coastal ecosystems: Addressing the imbalance. *Estuaries and Coasts*, volume 31, issue 2, pages 233-238
- Fortes, 1990. Seagrasses: a resource unknown in the ASEAN region. Page 46 in *ICLARM Education Series 5*, International Centre for Aquatic Living Resources, Manila, Philippines.
- MEA 2005. Millennium Ecosystem Assessment. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DCMA.
- Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, Williams SL, 2006. A global crisis for seagrass ecosystems. *Bioscience*, volume 56, issue 12, pages 987-996
- Unsworth, 2007. Aspects of the ecology of Indo-Pacific seagrass systems. PhD thesis, University of Essex, U.K
- Unsworth and Cullen 2010. Recognising the Necessity for Seagrass Conservation. *Conservation Letters*, Volume 3, number 2, pages 63-73.
- Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Short FT, Williams SL, 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Science USA*, Volume 106, pages 12377-12381
- Waycott M, Collier C, McMahon K, Ralph P, McKenzie L, Udy J, Grech A (2007) Vulnerability of seagrasses in the GBR to climate change. In 'Assessing Climate Change Vulnerability of the Great Barrier Reef'. (Eds J Johnson and P Marshall). (GBRMPA: Townsville)

Books

- *Seagrass Ecology*. Hemminga and Duarte, 2000. Published by Cambridge University Press
- *Seagrasses: Biology, Ecology and Conservation*. Larkum, Orth, and Duarte, 2006. Published by Springer
- *SeagrassWatch: manual for mapping and monitoring seagrass resources by community (citizen) volunteers*. 2nd Edition. McKenzie, Campbell and Roder 2003. Department of Primary Industries, Queensland.
- Short, F. T. and R. G. Coles. eds. 2001. *Global Seagrass Research Methods* Amsterdam Elsevier.
- *The Ecology of the Indonesian Seas: Part II*. Tomascik, Mah, Nontji and Moosa, 1997. Periplus Editions (HK) Ltd
- 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.
- *World Atlas of Seagrasses*. Green and Short, 2003. Published in association with UNEP-WCMC by the University of California Press

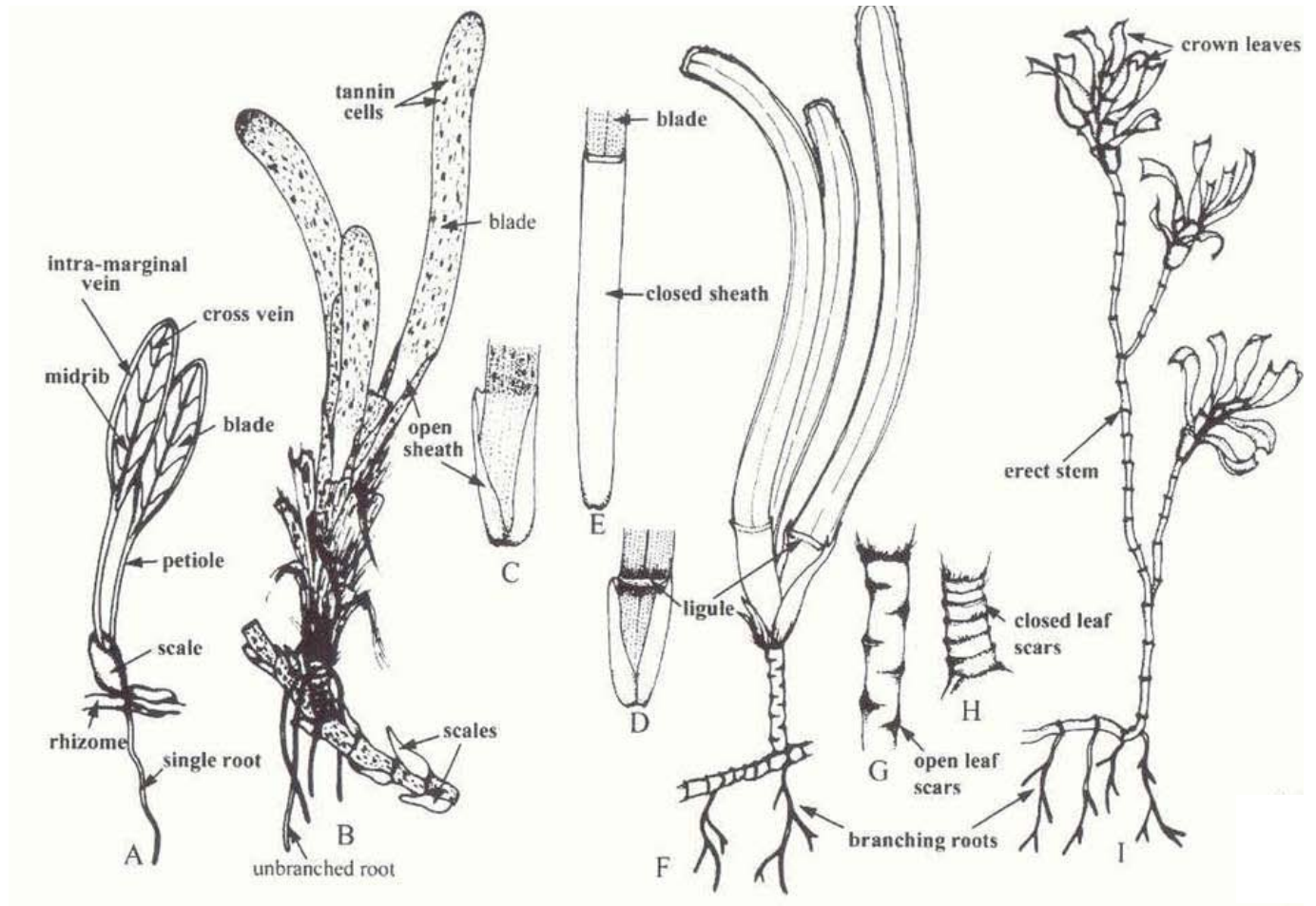
Useful websites

- World Seagrass Association: <http://www.worldseagrass.org/>
- Seagrass-Watch: <http://www.seagrasswatch.org/home.html>
- Global Seagrass Monitoring Network: <http://www.seagrassnet.org>
- ECU Center for Marine Ecosystem Research: <http://www.worldseagrass.org/>
- University of Maryland COSEE: http://www1.coseecoastaltrends.net/modules/seagrass/get_started/
- Florida International University Seagrass Ecosystems Research Laboratory: <http://www2.fiu.edu/~seagrass/>

APPENDIX 1

Answers

Module 1: Seagrass morphology



Module 2

- *Enhalus acoroides*
- *Thalassia hemprichii*
- *Halophila ovalis*
- *Syringodium isoetifolium*

APPENDIX 2

Answers

Seagrass Training Assessment 1

1. At what depths do you mostly find seagrasses?
 - a. between mean sea-level and 25m
2. What is the main distinguishing characteristic of angiosperms?
 - b. plants that produce flowers, fruits and seeds
3. What characteristic of seagrass is absent in algae?
 - a. internal vascular system
4. How is pollen from male flowers mainly dispersed to female flowers?
 - b. tidal currents
5. What is the role of veins in seagrass plants?
 - b. to transport water, nutrients and photosynthetic products
6. What is the function of seagrass roots?
 - a. to anchor the plants and absorb nutrients
7. What is the pattern for cross-veins in the leaf blade?
 - c. perpendicular to the length of the leaf
8. What is a sheath?
 - c. a modification of the leaf base that protects newly developing tissue
9. What are leaf scars?
 - c. remnants of leaf attachment
10. Which seagrass species has cylindrical leaves, with pointed tips and contains air cavities?
 - c. *Syringodium isoetifolium*
11. Which species has leaves which arise from vertical stem and have a tri-dentate tip?
 - a. *Halodule uninervis*
12. Which species has flat, strap-like leaves, 2-4mm wide that can be slightly curved?
 - a. *Thalassia hemprichii*
13. What is a distinguishing characteristic of *Halophila ovalis*?
 - a. oval shaped leaves in pairs
14. Which seagrass species has leaves with in-rolled edges and long black bristles which arise directly from the rhizome?
 - c. *Enhalus acoroides*
15. What role(s) do(es) seagrass beds play in fishery production (commercially important fish and invertebrates)?
 - c. as feeding and nursery grounds
16. What is the most abundant commercially important fish species in the seagrass beds?
 - b. *Siganus fuscescens*
17. In the records available, seagrass beds can support fishery production as high as _____.
 - a. 30mt/km²/yr
18. What are the most common organisms that are commercially harvested in the seagrass beds?
 - a. Sea urchins, sea cucumbers, rabbit fishes, crabs and shellfish
19. What best species of sea urchin harvested in the seagrass beds for its gonad?
 - c. sea urchin
20. What species is most popular ornamental fish species found in the seagrass beds?
 - c. *Hippocampus kuda*

APPENDIX 3

Answers

Seagrass Training Assessment 2

21. How much seagrass can a dugong eat in a day?
b. up to 40kg wet weight
22. How much seagrass (wet weight) does a turtle eat in a day?
c. approximately 2 kg
23. What is the major gas that seagrasses pump into sediments?
b. oxygen
24. Complete this sentence "Monitoring is the repeated observation of a system, usually to"
b. detect change
25. Why do seagrasses make good bioindicators of environmental health?
f. all of the above
26. What is the name of the standard unit, usually square, which is used for estimating seagrass?
c. Quadrat
27. How many quadrats are sampled in a standard intertidal site?
a. 33
28. When must photos be taken along a transect?
c. 5m, 25m & 45m
29. How many leaves of the dominant strap like species are measured per quadrat to determine canopy height?
a. at least 3 (ignoring longest 20%)
30. When determining species composition for two or more species, always start with...?
b. the least dominant
31. What are epiphytes?
b. plants growing on the surface of other plants
32. How does Seagrass-Watch ensure data can be compared between periods of time?
b. sites permanently marked
33. How does Seagrass-Watch ensure percentage covers are close to a true or standardised value?
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36. How do seagrasses help stop beach erosion?
b. rhizomes & roots stabilise sediments
37. How does seagrass help stop land based pollution?
d. all of the above
38. Types of physical disturbance which can damage seagrass include..
d. all of the above
39. Catchment runoff can damage seagrasses by?
d. all of the above
40. How will elevated sea temperatures from climate change impact seagrass?
d. all of the above
41. What are Ecosystem services?
d. all of the above
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b. the degree to which a system is susceptible to changes
43. Which of the following is not an ecosystem service that seagrass provide?
c. provide material for charcoal
44. How can we reduce the impacts of climate change on seagrasses?
b. reduce threats, maintain resilience, establish protected areas
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c. Protect all habitats as they are connected and depend on each other
46. Climate change might increase storm frequency and intensity, this will impact seagrasses through
d. all of the above
47. When managing specific threats to seagrasses you should
c. Understand the effects, evaluate possible management options, and take action
48. What are the approaches Seagrass-Watch supports for the protection/conservation of seagrass?
d. all of the above

GLOSSARY

A

Aerobic: Living or occurring only in the presence of oxygen

Algae: Non-vascular plants that grow submerged in marine or freshwater environments.

Algal bloom: The sudden growth of algae in an aquatic ecosystem. They can occur naturally in spring or summer when production exceeds consumption by aquatic herbivores, or can be the result of nutrient enrichment of waters due to pollution. Algal blooms are a characteristic symptom of eutrophication.

Anaerobic: A descriptive term for a process, such as fermentation, that can proceed only in the absence of oxygen, or a living thing that can survive only in the absence of oxygen.

Anoxic: Without oxygen.

Anthropogenic: Derived from or associated with human activity, often used to describe environmental contamination: or disruption resulting from human activities.

B

Benthic: Of or relating to the sea bottom.

Biodiversity: A description of the variety, abundance and distribution of living organisms within a defined ecosystem or habitat.

Bivalves: The class of mollusks that are laterally compressed and covered with two shells, or valves; clams, mussels, scallops.

Blade: The leaf of grasses or similar plants; the broad flat part of a leaf.

C

Climate change: A long-term change in the statistical distribution of weather patterns over periods ranging from decades to millions of years.

Clone: To reproduce or propagate asexually; a group of genetically identical plants all produced by vegetative propagation from a single parent.

Community: A group of interdependent organisms inhabiting the same region and interacting with each other.

Crustaceans: Any of various predominantly aquatic arthropods including lobsters, crabs, shrimps, and barnacles, characteristically having a segmented body, a chitinous exoskeleton, and paired, jointed limbs.

D

Desiccation: Dryness resulting from the removal of water.

Detrivore: An organism that feeds on detritus, or decomposing plant and animal material.

Distribution: The geographic occurrence or range of an organism.

Disturbance: A temporary change in average environmental conditions that causes a pronounced change in ecosystem structure that lasts longer than the change in the environment. Disturbances may be natural or anthropogenic.

E

Echinoderms: Any of numerous marine invertebrates of the phylum Echinodermata. Characteristics include being radially symmetrical, having an internal calcareous skeleton and often covered with spines. They include the starfishes, sea urchins, sand dollars, and brittle stars.

Ecology: The scientific study of the relationships between plants, animals, and their environment.

Ecosystem: An ecological community together with its environment, functioning as a unit.

Elgrass: The temperate seagrass *Zostera marina* which is the dominant seagrass from Canada to the Carolinas, northern latitudes on the eastern Atlantic coast of Europe and the Pacific ocean.

Epibenthic: Relating to the area on top of the sea floor. Epibenthic organisms may be freely moving or sessile (permanently attached to a surface).

Epiphytes: Organisms that live on the surface of plants and seaweeds.

Erosion: The group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface. The principal agents are gravity, running water, near-shore waves, ice (mostly glaciers), and wind.

Estuary: A partially enclosed coastal body of water, having an open connection with the ocean, where freshwater from inland is mixed with saltwater from the sea.

Euphotic: The photic zone; the uppermost layer of a body of water that receives sufficient light for photosynthesis and the growth of green plants.

Eutrophication: An environmental condition where excess nutrients, in the form of nitrogen or phosphorus, are introduced into a water body leading to increase growth of micro- and macroalgae.

F

Food chain: A succession of organisms in an ecological community that constitutes a continuation of food energy from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.

Food web: A community of organisms where there are several interrelated food chains.

Forage: The act of looking or searching for food.

G

Gastropods: The class of mollusks that includes snails, nudibranchs, and slugs.

Gene pool: The collective genetic information contained within a population of sexually reproducing organisms.

Genetic diversity: The variety of genetic materials within a single species of organism that permit the organism to adapt to changes in the environment.

Genotype: The genetic makeup of an organism or a set of organisms.

Geomorphology: The study of the shape and form of the landscape, and how the nature of landforms relates to their origin, development, and change over time.

Global warming: An increase in the average temperature of the earth's atmosphere, believed by most scientists to be the result of an enhancement of the greenhouse effect caused by air pollution.

Greenhouse effect: The natural phenomenon in which gases such as carbon dioxide, water vapor, and methane in the earth's atmosphere trap solar radiation. Most scientists believe that the greenhouse effect has been enhanced due to air pollution, resulting in global climate change.

H

Herbivore: An animal that feeds primarily on plants.

Holdfast: A structure in seaweeds or other algae that anchors the thallus to a substrate (e.g. rocks, other plants, shells). The holdfast may be root-like or discoid and sucker-like.

Hypothesis: A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.

Hypoxic: The amount of dissolved oxygen in the water is reduced to a level significantly lower than its theoretical maximum resulting in induced stress in aquatic organisms due to lack of oxygen for normal metabolism.

I

Infauna: Those aquatic organisms that exist buried in the sediment as opposed to those that live at the sediment surface or in the water column.

Inflorescence: A flowering structure that consists of more than a single flower; the time and process of budding and unfolding of blossoms.

Introduced species: Species that have been inadvertently or intentionally brought into a new region by the activities of humans. An introduced species may not be considered invasive.

Invasive species: An introduced species that has spread widely throughout the new location and causes harm by altering ecological relationships among native species. Common invasive species traits include fast growth, rapid reproduction, high dispersal ability, phenotypic plasticity, tolerance of a wide range of environmental conditions, ability to live off of a wide range of food types, single parent reproduction (especially in plants), and, commonly, association with humans.

Intertidal: The region or zone between the limits of high and low tides.

M

Macroalgae: A classification of algae that are defined according to the size of the plant where the body of the plant is large enough to be observable to the eye.

Meadow: A tract of land where grass or grass-like vegetation grows and is the dominant form of plant life.

Microalgae: A classification of algae that are defined according to the size of the plant where the body of the plant is small enough that it requires magnification to observe.

Mollusk: Any of numerous chiefly marine invertebrates of the phylum Mollusca, typically having a soft unsegmented body, a mantle, and a protective calcareous shell, including snails (gastropods), clams (bivalves), squid and octopus (cephalopods).

N

Native species: A species that has a long history of living in a particular region.

Nursery grounds: Habitats used by juveniles for food and protection from predators and physical stresses.

O

Omnivore: An animal whose normal diet includes both plants and animals.

Ocean acidification: The name given to the ongoing decrease in the pH of the Earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere

P

Pelagic: In the water column; the open water above the sea floor.

Phenotype: The observable physical or biochemical characteristics of an organism, as determined by both genetic makeup and environmental influences.

Phenotypic plasticity: The ability to alter one's growth form to suit current conditions; the ability of a genotype to change its phenotype in response to changes in the environment.

Photosynthesis: The process in which green plants and certain other organisms utilize the energy of sunlight to manufacture carbohydrates from carbon dioxide and water in the presence of chlorophyll, usually producing oxygen as a byproduct.

Phylogeny: A pattern of evolutionary relationships among organisms.

Physical stresses: Abiotic (heat, water loss, wave impacts) as opposed to biotic (competition, predation) stresses.

Phytoplankton: Single-celled microalgae that are found suspended in the water column and provide the first step most marine food chains.

Plankton: The collection of small or microscopic organisms, including algae and protozoans, that float or drift in great numbers in fresh or salt water, especially at or near the surface, and serve as food for fish and other larger organisms.

Plasticity: Expression of a trait that is not fixed and varies with the environment.

Pollination: The transfer of pollen (male sex cells) from the anther (male) to the stigma (female) of a plant for fertilization.

Population: A group of organisms of the same species populating a given area.

Predator: An organism that lives by preying on other organisms.

Primary production: The production of biological organic compounds from inorganic materials through photosynthesis or chemosynthesis; the fixing of inorganic carbon from an outside energy source, usually solar energy.

Propagule: Generic term for the seeds, spores, and larvae used by plants, algae and animals to reproduce themselves. Usually produced sexually.

Q

Quadrat: Any of a group of small rectangular plots arranged for close study of the distribution of plants or animals in that area. We use this term when referring to our PVC frames which we use for monitoring purposes in our eelgrass beds to determine the shoot density and algal percent cover of a given area (ex. 0.25m²).

R

Resilience: the time required for an ecosystem to return to an equilibrium or steady-state following a perturbation

Rhizome: A horizontal, usually underground stem that often sends out roots and shoots from its nodes.

Roots: The usually underground portion of a plant that lacks buds, leaves, or nodes and serves as support, draws minerals and water from the surrounding soil, and sometimes stores food.

S

Salinity: A measurement of the amount of salt that is dissolved in water and is normally reported in parts per thousand (ppt). Normal seawater has a salinity of 30-35 ppt.

Scavengers: Animals that consume already dead organic life-forms. Scavengers are useful to the ecosystem by feeding on and therefore breaking down dead animal and plant remains.

Seagrasses: Rooted vascular plants of terrestrial origin that have adapted to life submerged in the sea. Seagrasses provide coastal zones with a number of ecological goods and ecological services, for instance fishing grounds, wave protection, oxygen production and protection against coastal erosion.

Sediment: Any material having a geological origin and comprised of small particles.: The size of the individual particles determines the description of the sediment and it can range from fine clay to coarse gravel.

Sedimentation: The accumulation or deposition of sediment. In a seagrass bed, sedimentation occurs due to the ability of seagrasses to dampen wave energy causing particulates from the water column to settle as well as sediments moving across the sea floor to become trapped. The opposite of erosion.

Seed bank: The supply of propagules that are present and will germinate if an opportunity to do so occurs.

Seedling: A young plant that is grown from a seed.

Sheath: In plants, the protective covering at the base of a blade or stalk that covers the stem; an enveloping structure or covering enclosing an animal or plant organ or part.

Shellfish: A common term for clams, mussels, scallops, shrimps, lobsters; commercially harvested marine organisms other than fishes.

Shoot: One of two primary sections of a plant; the other is the root. The shoot refers to what is generally the upper portion of a plant, and consists of stems, leaves, flowers, and fruits.

Species: A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding and sharing unique characteristics.

Stipe: A supportive structure in seaweeds that may be stem-like. This structure is particularly common in brown algae such as kelp.

Stress/stressor: A perturbation applied to a system (a) which is foreign to that system or (b) is natural to that system but applied at an excessive level. In marine ecosystems, stressors are often anthropogenic, resulting from coastal development (e.g. excess nutrients/contaminants like nitrogen and phosphorus, overfishing, invasive species, increased temperature, etc. When multiple stressors occur, they can interact and intensify, altering predictability within that system, and therefore resulting in difficulty for restoration and management strategies.

T

Taxonomy: The classification of organisms in an ordered system that indicates natural relationships.

Thallus: A primitive type of vegetative plant body undifferentiated into stem, root, or leaf. The term is mainly used in non-vascular plants e.g. algae.

Tolerance: The power or capacity of an organism to survive unfavorable environmental conditions.

Turbidity: A cloudiness or haziness of water caused by sediment or foreign particles being stirred up or suspended.

V

Vegetative reproduction: The ability of plants to reproduce without sexual reproduction, by producing new plants from existing vegetative structures; asexual reproduction.

W

Water column: The water mass lying above the benthic (seafloor) habitat; the open water where planktonic and pelagic organisms live.

Wrack: Floating plant material (often containing seeds) that is carried away by winds and currents onto shorelines.

Z

Zooplankton: Plankton that consists of animals, including small crustaceans, fish larvae, corals, rotifers, sea anemones and jellyfish.

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Conservation International (CI)

Mission

Building upon a strong foundation of science, partnership and field demonstration, CI empowers societies to responsibly and sustainably care for nature, our global biodiversity, for the well-being of humanity.

Vision

We imagine a healthy prosperous world in which societies are forever committed to caring for and valuing nature, our global biodiversity, for the long-term benefit of people and all life on Earth.

