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CREDIT SEMINAR:
IMPORTANCE OF SEAGRASS ECOSYSTEM

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IMPORTANCE OF SEAGRASS ECOSYSTEM

Introduction:

The seagrass ecosystem is defined as a unit of biological organization comprised of interacting biotic and abiotic components. Seagrass are not truly grasses. They belong to three families of monocotyledonous plants, but are called seagrass since they usually form extensive underwater meadows, which resemble fields of terrestrial grasses. In almost all cases, seagrass communities are multispecific in the tropics, but tend to be unispecific in many parts of the temperate zones. Seagrass are found along most coastlines of all continents. They appear to be excluded generally north of the Arctic Circle and south of the Antarctic Circle because of ice scouring.

Seagrass are marine flowering plants capable of completing their life cycle when they are submerged in sea water. Seagrass ecosystem is one of the most widespread coastal vegetation types when compared to coral and mangrove ecosystems. Seagrass meadows are valuable habitats that provide important ecological and economic services worldwide. They are an important food source for mega herbivores such as green turtles, dugongs and manatees, and provide critical habitat for many animals, including commercially and recreationally important fishery species. A variety of medicines and chemicals are prepared from seagrass and their associates. 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.

They are unique in that they are:

1) Usually totally submerged in the water,
2) They possess a root system with stems buried within a soft substrate,
3) They have vegetative and sexual reproduction, and,
4) Have flowers fertilized by waterborne pollen.

Requirements for development:

- Salt or brackish water is absolutely necessary.
- They need enough light for photosynthesis.
- When the water becomes too turbid (sediment suspension), the plants and their dependant organisms can be destroyed. For an optimal growth, the plants need clear water.
- They need a soft substrate such as mud or sand, but some species can also grow on rocky sediments and corals.
- The most suitable place is a gently sloping coast, with little or no tidal currents or strong waves.
- Nutrients such as nitrogen and phosphorus are necessary for seagrass growth.

**Biology of seagrass:**

Seagrass have developed unique ecological, physiological, and morphological adaptations to a completely submersed existence, including internal gas transport, epidermal chloroplasts, submarine pollination, and marine dispersal. Seagrass belong to a group of plants called monocotyledons that include grasses, lilies and palms. Seagrass have leaves, roots and veins, and produce flowers and seeds. They are able to grow under submerged conditions. They are called hydrophytes. For this reason, the tissues of the seagrass consist of aerenchyma. Through this aerenchyma, air can be provided to the submerged parts of the plants. Another adaptation to these conditions is that the seagrasses have an epidermis with chloroplasts. Chloroplasts in their tissues use the sun's energy to convert carbon dioxide and water into sugar and oxygen for growth through the process of photosynthesis. Veins transport nutrients and water throughout the plant, and have little air pockets called lacunae that help keep the leaves buoyant and exchange...
oxygen and carbon dioxide throughout the plant. Like other flowering plants, their roots can absorb nutrients. They are resistant to erosion by waves and tidal currents. This is due to the well developed rhizomes and numerous, fleshy roots that anchor into the substrate.

**Taxonomic classification:**

**Kingdom:** Plantae  
**Division:** Magnoliophyta (Angiosperms)  
**Class:** Liliopsida  
**Sub class:** Alismatidae  
**Order:** Potamogetonales  
**Family:** Cymodoceaceae, Posidoniaceae, Potamogetonaceae, Ruppiaceae, Zosteraceae  
**Order:** Alismatales  
**Family:** Hydrocharitaceae

**Identification of seagrass:**

**Key distinguishing factors:**

**Leaf**
- Shape
- Tip morphology
- Vein pattern
- Smooth or serrated edge
- Sheath type
- Attachment type (rhizome or stem)

![Tip morphology of leaves](image)
Sheath type
- Size and thickness
- Presence of root hairs

Where found
- Location (geographical and depth)
- Substrate type

Rhizome
- Morphology

Stem
- Closed or open leaf scars

Distribution of seagrasses – In World:

Seagrass are widely distributed and comprises of <0.02% of the Angiosperm flora, represented by sixty odd species but occur in all the coastal areas of the world except the polar regions because of ice scouring. Globally over 177,000 km² of seagrass cover were estimated occupying 0.1 – 0.4 % of ocean floor. Seagrass are assigned mainly to six families encompassing 14 genera of Angiosperms and are often separated into tropical and temperate genera, with 7 genera each with 72
species. In tropical seas, genera such as *Cymodocea, Enhalus, Halodule, Halophila, Syringodium, Thalassia* and *Thalassodendron* are represented. However, some species of these genera are also found in temperate regions, whereas species of *Amphibolis, Heterozostera, Phyllospadix, Posidonia, Pseudalthenia* and *Zostera* are usually restricted only to temperate seas.

**Distribution of seagrasses – In India:**

Indian seagrass habitats are mainly limited to mud flats and sandy regions. The country possesses an abundant seagrass cover stretching over 360 sqkm. (172.5 sqkm in Palk Bay and 85.5 sqkm in Gulf of Mannar). Seagrass flora of India is represented by 6 genera and 13 species, out of which the Gulf of Mannar and Palk Bay harbour the maximum number of species followed by Andaman and Nicobar and Lakshadweep islands. Many seagrass species live in depths of 3 to 9 feet (1 to 3 meters), but the deepest growing seagrass (*Halophila decipiens*) has been found at depths of 190 feet (58 meters). In India, the seagrasses in the marine habitats are dominated by *Thalassia hemprichii, Cymodocea spp., Halodule uninervis* and *Halophila ovalis*. Seagrass species of India are placed under two families such as Hydrocharitaceae and Potamogetanaceae.

**Family : Hydrocharitaceae**

*Enhalus acoroides* (Broadblade seagrass)
*Halophila ovalis* (Spoon grass)
*Halophila ovata*
*Halophila stipulacea* (Broadleaf seagrass)
*Halophila beccari* (Turf grass)
*Halophila decipiens* (Paddle grass)
*Thalassia hemprichii*

**Family : Potamogetanaceae**

*Cymodocea rotundata* (Smooth ribbon grass)
*Cymodocea serrulata* (Serrated ribbongrass)
*Halodule uninervis* (Narrow leaf seagrass)
*Halodule pinifolia* (Needle grass)
*Halodule wrightii* (Shoal grass)
*Syringodium isoetifolium* (Roundleaf seagrass)
Family: Cymodoceaceae

*Thalassodendron ciliatum* (Sickle leaved seagrass)

**Enhalus acoroides** (Broadblade seagrass):

It has dark green long linear grass like leaves 1.0-1.5 cm wide, 50-170 cm long. Common in shallow intertidal areas with sandy and muddy substrata but can extend down to 6 m depth. Rhizomes are thick with long black bristles and cord like roots. It is the only seagrass species which forms aerial surface pollination. *Enhalus* with long strap like leaves form good wave breakers and extensive beds give some protection to shorelines exposed to strong waves.

**Halophila ovalis** (Spoon grass):

*H. ovalis* is a small herbaceous plant. The leaves are ovate in outline and found in pairs with 8 or more cross veins, appearing on stems that emerge from rhizome beneath the sand. The roots get up to 80 cm long and are covered in fine root hairs. It is also connected by a series of interconnecting rhizomes as in grasses. This seagrass has one of the widest salinity tolerances. It is found from shallow subtidal areas to the deepest waters where seagrasses can be found, 30 m and deeper. It can tolerate areas with freshwater runoff and thus lower salinity, as well as hyper saline waters. It is one of the favourite food of *Dugong*.

**Halophila ovata**:

*H. ovata* is fast growing and pioneering seagrass. It is found in a variety of habitats, including sand and sandy mud bottoms and is often found in exposed areas. Reproduction is mainly vegetative. Plants are separated as male and female. Fleshy, unbranched (rarely branched) rhizomes, unbranched solitary roots at the nodes up to 6 cm long, with root hairs. Leaves, paired at each node, lamina transparent, oblong, glabrous with 4-24 mm long petiole, entire margin, cross-veins 3-9 pairs, sub-opposite or alternate, merging with intramarginal nerves. Fruits, ovoid with 20 seeds. Seeds, globose, beaked at both the ends, white when young and brown when mature.

**Halophila stipulacea** (Broadleaf seagrass):

Plants are dioecious with male and female flowers produced at each leaf node. Rhizomes are creeping, branched and fleshy, and roots appear solitary at each node of the rhizome, unbranched and thick with dense soft root hairs. Pairs of leaves are distributed on petioles along a rhizome, rooted in the sand. Leaves from
3-8 mm wide, obovate, not narrowing at base, thin and hairy; margin spinulose. Petiole 3-15 mm long.

**Halophila beccarii** (Turf grass):

*H. beccarii* is found in the upper intertidal zone and grows on mud or muddy sand substrates in estuarine and coastal areas. This species is fast growing with large seed production. It is a colonizing species. It flowers year round and has annual and perennial populations in Malaysia and Bangladesh. In India, it acts as a pioneer species in the succession process leading to mangrove formation.

**Halophila decipiens** (Paddle grass):

*H. decipiens* is monoecious, has serrate leaf tips and hairs on both sides of its leaves. It is typically found on coarse sediments, sand and muddy bottoms. It is a deep water species but also found in shallow water under docks and in turbid areas. *H. Decipiens* can grow in areas with high sedimentation. Female flowers produce approximately 30 seeds. In the Indo-Pacific region it is found even up to a depth of 58 m.

**Thalassia hemprichii**:

*T. hemprichii* is purely a marine form, not seen in backwaters and estuaries, plants occur in tidal and subtidal zones, in black muddy and loose sandy soils. Male and female plants are separate, perennial with creeping rhizome; rhizome with scales and scale scars; shoot erect, covered by 2-6 old decayed leaves, 3-7 leaves in each shoot, measuring up to 10 - 40 cm in length and 1.2 cm in width, leaf blade linear, sometimes leaf tips show some serration.

**Cymodocea rotundata** (Smooth ribbon grass):

*C. rotundata* occurs in clear water, and often in the high intertidal zone. It has separate male and female plants, rhizomes creeping, branched, jointed; roots single at each node, branched, 2-4 mm thick; shoots erect, up to 31 cm long, each shoot bearing 3-4 leaves with persistent leaf scars.

**Cymodocea serrulata** (Serrated ribbongrass):

*Cymodocea serrulata* has separate male and female plants. It has creeping rhizome with scales and scale scars; shoot erect, with 2-6 leaves, shoot covered by old decayed leaves*C. serrulata* has linear strap-like leaves of 5-9mm wide with serrated leaf tip. Leaf sheath is broadly triangular with a narrow base. Leaf scars do
not form a continuous ring around the stem. Mostly found on shallow subtidal reef flats and sand banks.

**Halodule uninervis** (Narrow leaf seagrass):

*Halodule uninervis* is a sublittoral seagrass found from the mid-intertidal to a depth of 20 m. Its characteristic features include: shoots up to 30 cm long and erect, having 2-4 leaves in each branch, leaf linear, narrowed at base with sheath. They have trident leaf tip with 1 central longitudinal vein. Rhizome usually pale ivory, with clean black leaf scars. It can form dense meadows at some sites or is patchy and intermixed with other seagrass species, and frequently observed on back reefs in association with larger algae. It is one of favoured foods of the Dugong and often heavily grazed.

**Halodule pinifolia** (Needle grass):

*H. pinifolia* have separate male and female plants, with rhizomes slender and branched, roots creeping, formed at each node. It generally grows on sandy to muddy soils along the coasts, mangrove creeks, coral platforms, etc. they have fine, delicate leaves up to 20 cm long with 1 central vein and the black central vein splits into two at the rounded leaf tip. Usually pale rhizome, with clean black leaf scars and found on intertidal sand banks.

**Halodule wrightii** (Shoal grass):

*Halodule wrightii* has a disjunct global and predominantly tropical distribution. It is typically found on sandy to muddy bottoms and can be found in mixed seagrass species beds. This is dioecious plant with creeping rhizome, branched, often moniliferous; internodes up to 2.6 cm long with 1-7 roots at each node; roots up to 13 cm long, unbranched. It has 5-12 cm long leaves, lamina linear, narrowed at base, covered; leaf margin entire, nerves ending in lateral teeth at the leaf tip, teeth bidentate.

**Syringodium isoetifolium** (Roundleaf seagrass):

*Syringodium isoetifolium* leaves are tubular, narrowed at base and pointed at the apex. They are herbaceous plants; rhizomes creeping, shoots erect, branched, bearing 2-3 leaves; rhizomes and shoots have scars; rhizomes produce branched roots at each node. It generally grows well on coral flats, but also grows on sandy to muddy bottoms up to 15 m depth.
**Thalassodendron ciliatum (Sickle leaved seagrass):**

It is a fast growing species. Leaves are linear and falcate, 10–15 cm long. Leaf margins are almost entire with serrations visible towards the tip.

**Morphological adaptation:**

- They are physiologically adapted to seawater.
- They are able to grow under submerged conditions. They are called hydrophytes. For this reason, the tissues of the seagrasses consist of aerenchyma. Through this aerenchyma, air can be provided to the submerged parts of the plants. Another adaptation to these conditions is that the seagrasses have an epidermis with chloroplasts. This is exceptional because the other higher plants lack chloroplasts. Above this epidermis, a very thin cuticle is present. This provides the uptake of nutrients through the whole leaf surface. Stomata’s are absent. Little transport is needed because the nutrient uptake is carried out by the whole leaf surface. Therefore, the vascular bundles are strongly reduced.
- They are resistant to erosion by waves and tidal currents. This is due to the well developed rhizomes and numerous, fleshy roots that anchor into the substrate. The supple leaves are better resistant to water movement than stiff leaves.
- The pollination is provided by the water. The pollen is released from the flowers in gelatinous clumps that are carried by water currents to the pistils (female reproductive organ). They also have seed dispersal.

**Growth and Reproduction:**

Seagrasses grow both vertically and horizontally their blades reach upwards and their roots down and sideways to capture sunlight and nutrients from the water and sediment. They reproduce by two methods:

- Asexual clonal growth and
- Sexual reproduction.
Asexual clonal growth:

Similar to grasses on land, seagrass shoots are connected underground by a network of large root-like structures called rhizomes. The rhizomes can spread under the sediment and send up new shoots. When this happens, many stems within the same meadow can actually be part of the same plant and will have the same genetic code which is why it is called clonal growth.

Sexual reproduction:

Seagrasses reproduce sexually like terrestrial grasses, but pollination for seagrasses is completed with the help of water. Male seagrass flowers release pollen from structures called stamens into the water as clumps. The clumps are moved by currents until they land on the pistil of a female flower and fertilization takes place. There is also evidence that small invertebrates, such as amphipods (tiny shrimp-like crustaceans) and polychaetes (marine worms), feed on the pollen of one seagrass (Thalassa testudinum), which could help to fertilize the flowers in a way similar to how insects pollinate flowers on land. Self-pollination happens in some grass species, which can reduce genetic variation. Just like land grasses, fertilized seagrass flowers develop seeds. Seagrass seeds are neutrally buoyant and can float many miles before they settle onto the soft seafloor and germinate to form a new plant. A few seagrass species such as the surfgrass Phylospadix can settle and live on rocky shores. Animals that eat seagrass seeds including fish and turtles may incidentally aid with their dispersal and germination if the seeds pass through their digestive tracks and remain viable.
**Structural components of seagrass ecosystem:**

Structure consists of three major subcomponents that are interrelated: 1) floristic and faunistic composition; 2) arrangement of the organisms in space and time; and, 3) interrelationships within the community and with the abiotic environment.

The spatial arrangement of seagrasses displays a number of characteristic patterns that can be divided into vertical, horizontal, and three-dimensional. Vertical patterns are characterized by zonation and stratification. Horizontal patterns may be observed over geographic distances or may be due to differences in bottom configuration or prevailing hydrodynamic conditions. The three dimensional pattern is the way in which the species fill up the available space. This is probably the structural characteristic most decisive for the function of the community.

**A. Shelter:**

The structural function of seagrasses is a result of the morphology of the seagrass plants. The seagrass plants possess an extensive underground rhizome/root system with erect shoots with bundles of leaves, which extend into the water column. As a result, they create a highly structured ecosystem from a relatively unstructured one.

Seagrasses receive material and energy inputs from the sun and surrounding ecosystems, such as riverine, marsh, and mangrove and offshore coral reefs (in the tropics), and tend to internalize their energy and material production. They export excess material in the form of dissolved and particulate detritus. Seagrass ecosystems can be extremely complex with high levels of biodiversity which function through herbivore as well as detritus food webs. Seagrass beds are spatially positioned between the inshore mangroves and marshes and the offshore coral reefs, and/or open waters. Thus, a great variety of animals are permanent residents or find temporary shelter within the canopy at some time during the day or night or during seasonal movement at some part of their life cycle. There are seasonal finfish and shellfish that shelter and feed within the seagrasses during their migratory movements. There are also a great number of juvenile fish species which migrate from the inshore mangrove/marsh habitats inshore to the seagrass beds and refuge and feed before migrating offshore to deeper or deep waters.

The reasons for this sheltering function:
Seagrass form a dense submerged meadow and increase the available substrate surface for epiphytic algae and fauna;

Resulting currents and waves;

Mineral and organic particles sink to the bottom in the less turbulent water, creating relatively clear water; and

The leaf mass reduces excessive illumination in the daytime which facilitates the refuge effect for prey species.

B. Food and Feeding Pathways and Biodiversity:

The photosynthetically fixed energy from the seagrasses may follow two different pathways:

1) Direct grazing by organisms on the living seagrass, or,

2) The utilization of the detritus produced from decaying seagrass material, primarily leaves.

The export of seagrass material either inshore or offshore allows for further distribution of energy away from its original source and helps to fuel other ecosystems.

Of the two pathways, the detrital pathway is overwhelmingly the most important within the seagrass ecosystem. In this pathway, bacteria form the basis of the food web. As they age, leaves release both particulate and dissolved carbon and organic matter, which the bacteria assimilate and transform into bacterial matter. The bacteria are consumed by a host of small organisms, which are then eaten by another larger group of organisms, and so on. Detrital food webs are long and complex, and lead to commercially and recreationally important food animals. Direct or herbivore food webs are shorter, with perhaps two to three links. A relatively small number of animals feed directly on the plants, e.g., manatees in Florida and dugongs in the Indo-Pacific, a wide variety of waterfowl in the temperate zones, and green turtles, and a limited number of fish and sea urchins in the tropics. In the Arabian Gulf, the valuable pearl oyster finds shelter and food in the extensive seagrass beds.

The high biodiversity was the result of the high productivity of the seagrasses coupled with the physical stabilization, which the plants exert on their physical environment. The three dimensional space created in the water column by the seagrasses is also a decisive factor in the high biodiversity.
Functional components of seagrass ecosystem:

There are three major functional components:

- The rate of energy flow through the system, including primary and secondary production and respiration;
- The rate of material or nutrient cycling within the system, including decomposition; and,
- The degree of biological or ecological regulation in the ecosystem, including the regulation of organisms by the environment and vice versa.

A. Rate of Nutrient Cycling:

The production of detritus and promotion of sedimentation by the seagrass leaves provide organic matter for nutrient cycling. Epiphytic algae on the leaves fix nitrogen, thus adding to the nutrient pool of the region. Seagrasses assimilate nutrients from the sediments, transporting them through the plant and releasing them into the water column through the leaves, thus acting as a nutrient pump from the sediment. Seagrass blades, epiphytes, and macroalgae also pick up water column nutrients.

Decomposition rates of the various plant and animal substances show great variation from almost no decomposition to instant decomposition. These rates determine whether nutrients will be returned quickly to the system or held in reserve. These rates could also influence the relative predominance of feeding types in a system (particulate feeders, grazers, etc.). If detritus is removed by suspension or deposit feeders, nutrient relationships in the sediment will be altered. On the other hand, if grazers are numerous, a significant amount of energy will be transported away from the system. In an intact, relatively dense seagrass bed, the leaves act as a baffle for wave and current action. This baffling effect effectively reduces water motion within the leaf canopy, allowing incoming and resident particulate matter to settle to the bottom and remain there. This allows water within the seagrass bed to be clearer than water over unvegetated sediments, thus improving water quality for resident plants and animals.

B. Rate of Energy Flow:

The physical stability, reduced mixing of different water masses, and shelter provided by the complex seagrass structure provides the basis for a highly productive ecosystem. The ability of seagrasses to exert a major influence on the
marine seascape is due in large part to their extremely rapid growth and high net productivity. Leaves grow at rates typically 5 mm/day, but growth rates of over 10 m/day are not uncommon under favorable circumstances. Primary production is the most essential function of the seagrass ecosystem. Production rates are remarkably high. Production rates for tropical species vary from 280 gC m$^{-2}$ yr$^{-1}$ to 825 gC m$^{-2}$ yr$^{-1}$, while the temperate seagrass species vary between 180 gC m$^{-2}$ yr$^{-1}$ to 400-800 gC m$^{-2}$ yr$^{-1}$.

C. Biological Regulation:
Species composition affects biological regulation. Blue green bacteria on or in the plant or substrate fix nitrogen for seagrass or epiphyte use. Owing to the high rate of use, nitrogen is considered a rate limiting factor in the seagrass ecosystem. Seagrass density and biomass variations on spatial and temporal scales are reflections of the nitrogen pool. These parameters in turn affect sediment accretion and stabilization, water clarity (which affects primary production), and further nutrient cycling. Features of the abiotic environment, viz., daily and annual ranges in temperature and salinity, wave activity, and tidal currents, regulate species composition and productivity values. In a holistic sense, at least one major ecosystem property emerges when the system is intact, e.g., the nursery function of a seagrass meadow. The vast interplay of structural and functional characteristics results in a dense, stable environment that forms refuge and shelter as well as food for a myriad of organisms.

Fauna of seagrass ecosystem:
Many species of algae and microalgae (such as diatoms), bacteria and invertebrates grow as “epiphytes” directly on living seagrass leaves. Small invertebrates (like crabs and shrimp and other types of crustaceans), small fish and juveniles of larger fish species, sponges, clams, polychaete worms and sea anemones many types of fish, sharks, turtles, marine mammals (dugongs and manatees), mollusks (octopus, squid, cuttlefish, snails, bivalves), crustaceans (shrimp, crabs, copepods, isopods and amphipods), etc. are the inhabitants of seagrass ecosystem.

Ecological role:
Seagrass beds are important coastal habitats along tropical, temperate and subarctic coasts, supporting the production of living marine resources. Seagrasses
support complex food webs by virtue of both their physical structure and primary production and are best known for their role as breeding grounds and nurseries for important finfish and shellfish populations. The plants filter suspended sediments and nutrients from coastal waters, stabilize sediments and act as dampers to wave action. Seagrasses are the basis of an important detrital food chain. Worldwide, seagrasses rank with mangroves and coral reefs as some of the most productive coastal habitats. Additionally, strong linkages exist between seagrasses and these habitats, making loss of seagrass habitat a contributing factor in the degradation of the world's oceans.

1) **Stabilization**

Ocean bottom areas that are devoid of seagrass are vulnerable to intense wave action from currents and storms. The extensive root system in seagrasses, which extends both vertically and horizontally, helps stabilize the sea bottom in a manner similar to the way land grasses prevent soil erosion. With no seagrasses to diminish the force of the currents along the bottom, beaches, businesses, and homes can be subject to greater damage from storms.

2) **Modification of the physical environment**

Seagrasses are known as the "lungs of the sea" because one square meter of seagrass can generate 10 liters of oxygen every day through photosynthesis. In nutrient poor regions, the seagrass plants themselves help nutrient cycling by taking up nutrients from the soil and releasing them into the water through their leaves, acting as a nutrient pump.

3) **Ecosystem support**

Seagrasses provide food, shelter, and essential nursery areas to commercial and recreational fishery species and to countless invertebrates living in seagrass communities. Some fish, such as seahorses and lizardfish, can be found in seagrasses throughout the year, while other fish remain in seagrass beds during certain life stages.

4) **Food**

Some organisms, including the endangered dugongs and sea turtles graze directly on seagrass leaves others use seagrass indirectly to provide nutrients. Dolphins are often found feeding on organisms that live in seagrass areas. Detritus from bacterial decomposition of dead seagrass plants provides food for worms, sea
cucumbers, crabs, and filter feeders such as anemones and ascidians. Further decomposition releases nutrients (such as nitrogen and phosphorus), which, when dissolved in water, are reabsorbed by seagrasses and phytoplankton. The epiphytic organisms growing on the surface of the seagrass blades provide other sources of food. Some epiphytic bacteria can extract nitrogen from the environment and make it available to larger animals. Small invertebrate mesograzers, such as crustaceans and snails, feed on epiphytes, and in doing so can help keep the seagrass clean, acting as mutualistic partners (or housekeepers) that promote seagrass growth.

5) Nursery areas

The relative safety of seagrass meadows provides a suitable environment for juvenile fish and invertebrates to conceal themselves from predators. Seagrass leaves are also suitable for the attachment of larvae and eggs, including those of the gastropods and bivalves. Much of recreationally and commercially important marine life can be found in seagrass meadows during at least one early life stage.

6) Habitat

While seagrasses provide shelter for juvenile and small adult fish from larger predators, many infaunal organisms (animals living in soft sea bottom sediments) also live within seagrass meadows. Species such as clams, worms, crabs, and echinoderms, like starfishes, sea cucumbers, and sea urchins, use the buffering capabilities of seagrasses to provide a refuge from strong currents. The dense network of roots established by seagrasses also helps prevent predators from digging through the substratum to find infaunal prey organisms. Seagrass leaves provide a place of anchor for seaweeds and for filter-feeding animals like bryozoans, sponges, and forams.

7) Water Quality

Seagrass assist in trapping fine sediments and particles that are suspended in the water column, which increases water clarity. When a sea floor area lacks seagrass communities, the sediments are more frequently stirred by wind and waves, decreasing water clarity, affecting marine animal behavior, and generally decreasing the recreational quality of coastal areas. Seagrasses also work to filter nutrients that come from land-based industrial discharge and storm water runoff before these nutrients are washed out to sea and to other sensitive habitats such as coral reefs.
8) Economics

Although seagrass is not a commodity that is directly cultivated, its economic value can be measured through other industries, such as commercial and recreational fisheries which rely on this habitat to survive. Since most of the fishery species spend at least part of their life cycle within seagrass communities, seagrasses are vital to the survival of these fishing industries.

Blue Carbon:

Seagrasses are capable of capturing and storing a large amount of carbon from the atmosphere. Similar to how trees take carbon from the air to build their trunks, seagrasses take carbon from the water to build their leaves and roots. As parts of the seagrass plants and associated organisms die and decay, they can collect on the seafloor and become buried, trapped in the sediment. It has been estimated that in this way the world’s seagrass meadows can capture 27.4 million tons of carbon each year. The carbon stored in sediments from coastal ecosystems including seagrass meadows, mangrove forests and salt marshes is known as "blue carbon" because it is stored in the sea. Atmospheric carbon is captured by coastal mangroves, seagrasses and salt marshes at a rate five times faster than tropical forests.

Ecosystem connectivity:

Seagrass beds are beneficial to adjacent ecosystems like coral reef and mangrove ecosystems. Mangroves, reefs and seagrasses often have a synergistic relationship, based on connectivity, which exerts a stabilising effect on the environment. Seagrasses and mangroves stabilise sediments, slow water movements and trap heavy metals and nutrient rich runoff, thus improving the water quality for corals and fish communities. Seagrasses and mangroves filter freshwater discharges from land, maintaining necessary water clarity for coral reef growth. The link between mangrove and seagrass areas and fisheries production is based on the well-established perception that these habitats serve as nursery areas for fisheries species. Many studies in various parts of the world suggest that these habitats provide a sheltered environment, protection from predators, supply abundant and diverse food and physically intercept and concentrate planktonic larvae. Coral reefs, in turn, buffer ocean currents and waves to create a suitable environment for seagrasses and mangroves. Mangroves also enhance the biomass of coral reef fish.
species. It has been shown that seagrass meadows are important intermediate nursery habitats between mangroves and reefs that increase young fish survival.

**Human uses:**

1) **Seagrass as food**
In India, the local fishers are said to consume *Cymodocea* spp. (it taste like sugar cane) and seeds of *Enhalus*. People in Japan prepare salads with seagrasses and even candies are made from the leaves. In Indonesia, fishermen sometimes use the rhizome of *Enhalus acoroides* as an emergency food source, while the seeds of this seagrass, are eaten by local children as snacks between meals. The seeds are also eaten by fishermen and others in Thailand, Malaysia and the Philippines.

2) **Insulation:**
Dried seagrass material was commonly used as housing insulation, until well into this century. Its thermal and sound-proofing properties derived largely from the air spaces which occur in mats of seagrass material. One of the major beneficial properties of seagrass as insulation was that it was non-flammable, because of its high silicon content. The material was also used to sound-proof radio studios in USA and the UK.

3) **Roofing thatch:**
Seagrass material was popularly used to thatch roofs in rural coastal areas in Europe and the UK. Its use dates from the seventeenth century (and possibly before), and was used as a substitute for straw. The major advantages of seagrass were that it was slow to rot, and was flea-proof. Presumably its poor combustion properties were also an advantage.

4) **Binding soil:**
Seagrass material was extensively used to bind clay and soil in embankments; for example, in the dikes of the Netherlands. This use has found a translation into modern times, with seagrass drift being used to produce mulch applied to sand dunes to help with stabilization. It appears to form an erosion resistant mat, suitable for seed germination in sand dune rehabilitation programmes, and has been used in Australia.

5) **Stuffing and packaging:**
*Zostera marina* has found use as a substitute for horse hair in Europe and the USA, as a material for stuffing pillows, mattresses and upholstery. The crab industry in
Chesapeake Bay used seagrass as a packing material for exporting crabs from the region. Seagrass fibre was used to fill leaks in ships hulls in the seventeenth century.

**Medicinal uses of seagrass:**

Paste from leaves of *C. rotundata* used to treat wounds. Paste from leaves *C. serrulata* used to treat wounds. *E. acroides* rhizome and root juices consumed raw to treat seasickness, rhizome (peeled of skin) consumed fresh with cup of seawater to treat heart conditions and low blood pressure, rhizomes consumed fresh to ease indigestion and hangover. Paste of fresh leaves used to treat many kinds of skin diseases. Seeds, which taste like almonds, are eaten by people or fed to goats and sheep. A handful of leaves of *H. ovalis* is toasted with three drops of sesame oil and consumed for three days to treat iron deficiency. A leaf paste is mixed with turmeric and applied to cure various skin ailments, including burns and boils. A handful of leaves *H. ovata* is toasted with three drops of sesame oil and consumed for three days to treat iron deficiency. A leaf paste is mixed with turmeric and applied to cure various skin ailments, including burns and boils. Fresh leaf juice *S. isoetifolium* consumed to ease acid reflux. Dried rhizome powder of *T. hemprichii* consumed to treat mental disorders. The same powder mixed with coconut oil and applied on wounds.

**Threats to the seagrass ecosystem:**

The declining population of seagrasses is a worldwide trend. This can be the cause of several natural and human disturbances. Over the last 2 decades, the estimated loss from direct and indirect human impacts amounts to 18% of the documented seagrass area. But this is a small fraction of the actual numbers, because many losses remain unreported. In their turn, seagrass loss leads to a loss of the associated functions and services in the coastal zone. Natural disturbances that are most commonly responsible for seagrass loss include hurricanes, earthquakes, disease, and grazing by herbivores. Human activities most affecting seagrasses are those which alter water quality or clarity: nutrient and sediment loading from runoff and sewage disposal, dredging and filling, pollution, upland development, and certain fishing practices.

**Natural disturbances:**

Geological events such as (1) tectonic plate movement causing coastal uplift or subsidence, (2) coastal erosion from oceanic waves and currents, and (3) volcanic
eruption, can impact or eliminate seagrasses. In addition, meteorological events, including heavy and prolonged rains, increased wind velocity (e.g. winter storms, hurricanes, cyclones) and seasonal sea-ice formation and retreat, can result in a loss of seagrass cover or a change in seagrass species assemblage. Finally, biological interactions, such as grazing, sediment turnover and disease, can disrupt seagrasses at scales from individual leaves to whole ecosystems.

**Anthropogenic threats:**

Humans impact seagrass ecosystems both through direct proximal impacts, affecting seagrass meadows locally, and indirect impacts that may affect seagrass meadows far away from the sources of the disturbance. Proximal impacts include mechanical damage and damage created by the construction and maintenance of infrastructures in the coastal zone, as well as effects of eutrophication, siltation, coastal engineering and aquaculture. Indirect impacts include those from global anthropogenic changes, such as global warming, sea level rise, CO2 and UV increase, and anthropogenic impacts on marine biodiversity, such as the large scale modification of the marine food web through fisheries.

Worldwide, anthropogenic nutrient over enrichment of coastal waters is the factor responsible for much of the reported seagrass decline. The primary cause of nutrient enrichment in estuarine and coastal waters is anthropogenic loading from coastal watersheds. In general, pristine estuaries and coastal seas are nitrogen limited and nitrogen inputs from point and nonpoint sources causes eutrophication. Increased nutrient loading is widely acknowledged to alter the structure and function of coastal ecosystems. In addition to nutrient inputs from land, increased nutrient inputs are also occurring in coastal areas adjacent to industrialized regions of the world through direct atmospheric deposition of nitrogen, providing additional nutrients that can only be reduced at the source.

Poor land use practices also result in increased soil erosion and the delivery of vast quantities of sediment into coastal waters. Removal of terrestrial vegetation leads to erosion and transport of sediments through rivers and streams to estuaries and coastal waters where the suspended particles create turbidity that reduces water clarity and increase sedimentation above levels tolerable to seagrass.

Direct impacts from human activity include: i) fishing and aquaculture, ii) introduced exotic species, iii) boating and anchoring, and iv) habitat alteration
(dredging, reclamation and coastal construction). Fishing methods such as dredging and trawling may significantly affect seagrasses by direct removal. Aquaculture has been shown to produce major environmental impacts, particularly due to shading, eutrophication and sediment deterioration through excess organic inputs. The introduction of exotic marine organisms, from accidental release, vessel ballast water, hull fouling and aquaculture, remains an area of concern. Direct boat propeller damage to seagrass communities in shallow areas with heavy boat traffic. Boat anchoring and boat moorings leaves scars in seagrass communities. Docks and piers shade shoreline seagrass, an effect that may fragment the habitat. Boating may also be associated with organic inputs in areas where boats do not have holding tanks. The development of the coastline, particularly related to increased population pressure, leads to alteration and fragmentation of habitats available for seagrasses in coastal waters. Coastal development, construction of ports, marinas and groynes, is usually localized to centers of population. Housing developments impact coastal water quality, and the number of houses in a watershed has been directly correlated to rate of seagrass loss. Dredging and reclamation of marine environments, either for extraction of sediments or as part of coastal engineering or construction, can remove seagrasses. Filling of shallow coastal areas, known as reclamation, can directly eliminate seagrass habitat and results in hardening of the shoreline, which further eliminates productive seagrass habitat. Dredging removes seagrass habitat as well as the underlying sediment, leaving bare sand at greater depth, resulting in changes to the biological, chemical and physical habitat values that seagrasses support. Beach replenishment may impact adjacent seagrasses by delivering sediment that may shade or bury the seagrasses. Beach nourishment can also impact seagrasses growing in areas where sediments are collected, often at depths < 30m. Removal of fish can also lead to seagrass death by disrupting important components of the food web. When large predators are removed, intermediate predators can become more abundant, and they in turn cause the decline of the smaller organisms that keep the blades of the seagrasses clean. Tourism also imparts more stress on the flexible seagrass ecosystem leading to seagrass loss.

Global warming is the more concern nowadays and it also affects the seagrass ecosystem by increased temperature. Temperature affects how enzymes and metabolism work, influencing how organisms grow. Rising water temperatures tend to increase rates of seagrass respiration (using up oxygen) faster than rates of
photosynthesis (producing oxygen), which makes them more susceptible to grazing by herbivores. Increased temperature also increases seagrass light requirements, influences how quickly seagrasses can take up nutrients in their environment, and can make seagrasses more susceptible to disease.

The widespread loss of seagrasses is largely a consequence of the rapid growth in human activities and transformation of the coastal zone, with the resulting direct and indirect impacts on seagrasses. Global population growth is concentrated in the coastal zone, which also harbors a disproportionate fraction of the world’s wealth. Indeed, some industries linked to the marine environment, such as tourism, maritime transport and aquaculture is rapidly growing. Consequently, human activity in the coastal zone is likely to continue to increase, with a potential for even greater impacts on seagrasses.

**Conservation and management:**

In a 2011 assessment, nearly one quarter of all seagrass species for which information was adequate to judge were threatened (endangered or vulnerable) or near threatened using the International Union for the Conservation of Nature (IUCN) Red List criteria. There is no international legislation for seagrasses, and so protection typically occurs by local and regional agencies. The most common approach to conserving seagrass ecosystems is to reduce common threats to them (e.g. pollution, damage by boats), for example through local regulations. Restoring seagrass ecosystems can include harvesting and transplanting seagrass plants and subsequent management and monitoring of restored sites. For complete protection of biodiversity their linkage systems also has to be protected. Three generalized approaches are used to protect seagrasses or manage impacts on seagrass: reactive, prescriptive and nonprescriptive. 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,. Nonprescriptive approaches range from codes of practice, local agreements, planning processes to education.
There are also attempts to rebuild and restore seagrass beds, often by planting seeds or seedlings grown in aquaria, or transplanting adult seagrasses from other healthy meadows. Some of the most successful restoration stories come from the Chesapeake Bay and coastal Virginia in the Eastern United States where, through 2014, the Virginia Institute of Marine Science has seeded 456 acres with 7.65 million seagrass seeds. As of 2015, the seagrass *Zostera marina* has increased from these seeded plots to cover 6,195 acres. Seagrass restoration in Tampa Bay, Florida, has also experienced important success including improvements in water quality and the associated fish community. For restoration to work, it is critical that the causes of the original decline in seagrasses have been eliminated.

**Conservation status in India:**

In India, Seagrass habitats are largely ignored from the educational, research and management points of view. There are no adaptive management strategies, public education plans or conservation measures in place for seagrass ecosystems in India. However researchers are involved in estimating changes in the coverage area and biomass of the seagrass ecosystem. SDMRI, Thoothukudi has proposed some of the conservation and management measures for seagrass ecosystem. They are;

**Protection**

- Survey and mapping
- Restriction on boat anchoring
- Restriction on destructive fishing practices like trawling, shore seine and push net operation
- Regulation of coastal development activities on a scientific basis

**Management**

- Regular survey and assessment of seagrass beds and associated resources to update the status
- Regulation of fishing activities
- Monitoring of seagrass beds, associated resources and threats
- Preparation of monitoring protocol
Rehabilitation
- Rehabilitation of degraded seagrass area using native species with appropriate low tech methods.
- Protection of seagrass and associated faunal & floral diversity
- Monitoring of rehabilitated areas
- Community involvement in rehabilitation and monitoring

Pollution control
- Regulation of industrial effluent discharges
- Regulation of land based domestic sewage discharges.
- Regulation of fishing harbor activities
- Regulation of coastal developmental activities
- Regulation of aquaculture and slat pan waste discharges

Socio-economic development through community participation
- Skill development programmes to local community
- Training in Eco-friendly fishing practices
- Regular surveys to be conducted on the socioeconomics of the local people
- Viable and site additional livelihood options to seagrass dependent coastal community
- Formation of village level conservation and management committees

Awareness building
- Local workshop to create awareness among coastal community
- Publication of brochures, posters and education materials to make aware all stakeholders including conservation managers, administrators, judiciary, political leaders etc.
- Awareness creation through electronic media.

Environmental Monitoring
- Monitoring of environmental parameters (Water and Sediment Quality) in seagrass bed areas
- Monitoring of pollution level

Capacity building
- Training of management staff
• Capacity building of local research institutions for assessment, and monitoring
• Capacity building of local community in seagrass rehabilitation

**Legislative and administrative measures**

• Steps to provide appropriate conservation status to seagrass bed areas in Palk Bay and Gulf of Mannar

**Conclusion:**

There is a need for rehabilitation of the abundant seagrass meadows in India. As the coastal population grows with a marked increase in dependence on marine and coastal resources, the ecosystem must be restored for valuable nurseries for commercially important organisms, to serve our own needs and the needs of some of the poorest communities in India. As such comprehensive research must be conducted, to make policies for conserving valuable ecosystems.
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