



## Seagrass Ecosystems and Their Ecological Roles: The Green Foundation of Coastal Seas

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Seagrasses are submerged flowering plants that form highly productive meadows in shallow marine and estuarine environments. Although they resemble terrestrial grasses, they are specialized vascular plants capable of completing their entire life cycle underwater. Seagrass meadows provide food, shelter and nursery grounds for fishes, crustaceans, molluscs, echinoderms and many other organisms, while also supporting grazers such as dugongs and green turtles. Their extensive leaves, rhizomes and roots slow water movement, stabilize sediments, improve water clarity and contribute to long-term carbon storage. In India, important meadows occur in the Gulf of Mannar, Palk Bay, Lakshadweep, Andaman and Nicobar Islands, Gulf of Kachchh and smaller coastal habitats. Indian research has documented their biodiversity, fisheries importance and blue-carbon value, but seagrass habitats continue to face pressure from destructive fishing, dredging, coastal construction, pollution, sedimentation, aquaculture and climatic disturbances. Protecting these habitats therefore requires ecological monitoring, better coastal planning, responsible fishing, community participation and restoration wherever feasible.

**Keywords:** seagrass, seagrass meadow, coastal ecosystem, nursery habitat, blue carbon, biodiversity, India, conservation

### Introduction

Seagrasses are submerged marine flowering plants that form dense vegetative communities in shallow coastal waters. They are not true grasses, but their long, narrow leaves and meadow-forming habit give them a grass-like appearance. Unlike most terrestrial flowering plants, seagrasses complete their life cycle while fully submerged in saline water. They are rooted in soft sediments, with leaves above the sediment surface and interconnected rhizomes and roots below it. This combination of above-ground foliage and below-ground networks allows seagrass meadows to function as both living habitat and physical stabilizers of the seafloor (Thangaradjou and Bhatt, 2018). Seagrasses occur in tropical and temperate seas and are generally associated with shallow, clear waters where sufficient light reaches the seabed. The depth to which they grow varies among species and local environmental conditions. Light availability, water temperature, salinity, sediment characteristics, hydrodynamics and nutrient conditions influence the distribution and productivity of individual meadows. Once established, seagrasses can themselves modify their surroundings by slowing near-bottom currents, trapping particles and organic matter, and creating a more structurally complex habitat for associated organisms. India possesses important seagrass resources distributed along both its eastern and western coasts and around its island territories. The Gulf of Mannar and Palk Bay on the southeast coast are especially well known for extensive meadows, while significant habitats are also present in the Andaman and Nicobar Islands, Lakshadweep and

the Gulf of Kachchh (Thangaradjou and Bhatt, 2018). Earlier Indian assessments commonly reported 14 species, whereas later taxonomic reviews have recognized 16 species in Indian waters; the difference reflects continuing taxonomic work and refinement of species identification (Thangaradjou and Bhatt, 2018). Seagrass ecosystems are closely linked with coral reefs, mangroves, sandy bottoms and other coastal habitats. In the Gulf of Mannar and Palk Bay, seagrass beds support diverse associated fish and invertebrate communities and are important to local fisheries and conservation of threatened marine fauna (Jeyabaskaran et al., 2018). Their importance is therefore much greater than the small area they occupy relative to the ocean as a whole.



**Figure 1. Seagrass meadow showing the submerged, grass-like vegetation that forms a structured coastal habitat.**

### **What Makes Seagrasses Special?**

Seagrasses are true vascular plants adapted to permanent submergence in seawater. Their leaves perform photosynthesis underwater, while rhizomes and roots anchor the plants in sediment and facilitate the development of interconnected meadow patches. Vegetative reproduction through rhizome growth can rapidly increase local cover, biomass and meadow continuity, while sexual reproduction through flowers and seeds contributes to dispersal and genetic diversity. The large below-ground component of a meadow is particularly important because roots and rhizomes bind sediment and form long-lived organic-matter stores. The physical setting is critical. Light is often the major factor determining the maximum depth of a meadow, whereas sediment grain size, temperature and salinity influence which species can persist. Seagrasses can tolerate a range of conditions, but prolonged extreme temperatures, sudden freshwater inputs, high turbidity and physical disturbance can reduce photosynthetic performance and cause meadow loss. Stable sediments and moderate hydrodynamic conditions favour establishment because excessive wave and current energy can uproot plants before a stable root-rhizome network develops.



Figure 2. *Halophila decipiens*, an example of a small-leaved seagrass species

### Seagrass Diversity and Distribution in India

Indian seagrass habitats are concentrated in a few major regions rather than being uniformly distributed along the coastline. The Gulf of Mannar and Palk Bay support some of the country's most extensive and species-rich meadows. CMFRI literature identifies the southeast coast, especially the Gulf of Mannar and Palk Bay, as a major centre of seagrass diversity, with additional important habitats in Lakshadweep and the Andaman and Nicobar Islands (Thangaradjou et al., 2008; Jeyabaskaran et al., 2018). Recent national reviews place the overall Indian seagrass cover at roughly 500–517 km<sup>2</sup>, while recognizing that estimates change with mapping methods and taxonomic treatment (Thangaradjou and Bhatt, 2018; Kaladharan et al., 2020). Species composition varies among regions. *Halophila*, *Halodule*, *Cymodocea*, *Enhalus*, *Thalassia* and *Syringodium* are among the important genera reported from Indian coastal waters. *Halophila beccarii* has a broad distribution in Indian coastal habitats, while *Cymodocea serrulata* is an important component of several island meadows. The Gulf of Mannar and Palk Bay are particularly significant because their meadows provide feeding grounds and habitat for numerous fishes, invertebrates and threatened megafauna, including dugongs and green turtles.



Figure 3. Seagrass habitat associated with other coastal environments, illustrating the close ecological connection among seagrass, reef and sedimentary habitats.

### Structure, Biomass and Reproduction

A typical seagrass meadow has three closely connected structural components: leaves, rhizomes and roots. Leaves form the visible canopy and intercept light, while rhizomes

spread horizontally through the sediment and produce new shoots. Roots anchor the plant and help bind sediment. Because a substantial proportion of plant biomass occurs below the sediment surface, measurements of meadow condition should consider both above-ground shoots and below-ground biomass. Seagrasses reproduce both sexually and vegetatively. Flowering and seed production permit dispersal to new areas and contribute to genetic variability, whereas vegetative expansion allows established meadows to occupy space rapidly. This combination helps seagrasses persist under suitable environmental conditions, but recovery after severe physical disturbance may still be slow because recolonization depends on the availability of surviving rhizomes, seeds or nearby donor meadows.

## **Ecological Roles of Seagrass Meadows**

### **1. Food and Energy Flow**

Seagrasses contribute directly and indirectly to coastal food webs. Herbivores such as dugongs and green turtles can graze on living leaves, while many other organisms feed on epiphytes and small animals associated with the meadow. When leaves die, their organic material enters detrital food pathways. Bacterial decomposition and subsequent nutrient recycling support worms, crustaceans, echinoderms and filter-feeding organisms and return nutrients to the coastal system.

### **2. Habitat and Nursery Grounds**

The three-dimensional structure created by leaves, roots and rhizomes provides shelter from predators and water movement. Juvenile fishes and invertebrates can use seagrass beds as nursery habitats, while eggs and larvae may attach to vegetation. Seagrass-associated fauna includes fishes, molluscs, crustaceans, echinoderms and numerous smaller organisms. In India, the ecological importance of seagrass beds is closely connected with fisheries and the survival of species that depend on these habitats (Jeyabaskaran et al., 2018).

### **3. Stabilization of Sediments and Coastal Protection**

The roots and rhizomes bind the seabed, while the above-ground canopy reduces near-bottom water velocity. This can decrease sediment resuspension and help maintain a more stable substrate. Where seagrasses are lost, sediments may become more exposed to wave and current action, potentially increasing turbidity and coastal erosion. Thus, seagrass meadows can act as natural coastal infrastructure alongside mangroves, coral reefs and other habitats.

### **4. Water Quality Improvement**

Seagrass leaves and meadow structure slow water movement and encourage fine particles to settle. This can improve water clarity and reduce the movement of suspended sediments. Seagrasses can also intercept and retain nutrients and particulate material entering coastal waters. However, their filtering capacity has limits, and excessive nutrient enrichment or chronic pollution can itself promote algal growth and reduce the light available to seagrasses.

### **5. Blue Carbon Storage**

Seagrass meadows are recognized as blue-carbon ecosystems because they capture carbon through photosynthesis and store organic carbon in plant biomass and, importantly, in sediments. The dense below-ground root-rhizome system and accumulation of organic-rich sediment allow carbon to remain stored over long periods. Indian measurements from the Gulf of Mannar and Palk Bay have demonstrated substantial sedimentary blue-carbon stocks, highlighting the climate relevance of conserving these habitats (Kaladharan et al., 2020).

### **6. Links with Mangroves and Coral Reefs**

Seagrass meadows often occur between or near mangroves and coral reefs and can function as ecological transition zones. Organisms associated with one habitat may feed or shelter in another, creating connected coastal food webs. Maintaining these habitat linkages is therefore important because conservation of an isolated patch may provide less ecological benefit than protection of the broader coastal seascape.



**Figure 4. Seagrass plants and meadow structure provide habitat and nursery space for associated coastal fauna**

### Economic and Social Importance

Seagrasses are not generally harvested as a conventional crop, but their economic value is expressed through the ecosystem services they support. Fisheries benefit from nursery habitat, feeding grounds and shelter for commercially important organisms. Nature-based tourism and wildlife viewing can also depend on healthy coastal habitats. In communities surrounding the Gulf of Mannar and Palk Bay, the condition of seagrass meadows is therefore closely linked with marine biodiversity and fishing livelihoods (Jeyabaskaran et al., 2018). Seagrasses also have potential biomedical importance. The presentation notes reports of biological metabolites and antimicrobial activity from Indian seagrasses such as *Halodule pinifolia* and *Cymodocea rotundata*. Such observations are useful research leads, but the medicinal potential of individual compounds requires laboratory validation, toxicological assessment and clinical evidence before therapeutic claims can be made.



**Figure 5. Seagrass species associated with Indian coastal habitats.**

### Major Threats to Seagrass Ecosystems

Despite their ecological value, seagrass meadows are exposed to multiple pressures. In Indian waters, destructive and intensive fishing, trawling, boat activity, coastal construction,

dredging, reclamation, aquaculture and agricultural or urban runoff can physically damage plants or reduce water quality. Excessive sedimentation and nutrient enrichment are particularly important because they increase turbidity and can restrict the light needed for photosynthesis. Indian reviews have emphasized that seagrass conservation must address both direct physical damage and changes in the wider coastal watershed (Thangaradjou and Bhatt, 2018; Jeyabaskaran et al., 2018). Natural disturbances also influence seagrass dynamics. Cyclones, storms, unusual freshwater inputs, grazing, disease and other disturbances can remove biomass or alter meadow structure. Climate change may intensify some of these pressures through warming, sea-level change, altered storm regimes and changes in coastal water quality. The important point is that natural disturbance and human pressure can interact: a meadow weakened by chronic pollution or physical disturbance may have less capacity to recover after a major storm.

### Conservation and Management

Seagrass conservation should begin with accurate mapping and repeated monitoring. Changes in meadow area, shoot density, species composition, canopy condition, sediment characteristics and associated fauna can provide early warning of degradation. Indian research has highlighted the need for better spatial coverage and long-term monitoring, particularly outside the best-studied areas (Thangaradjou and Bhatt, 2018). Protection also requires management of activities outside the meadow itself. Better control of destructive fishing practices, careful planning of dredging and coastal construction, reduction of land-based pollution, protection of nursery grounds and maintenance of habitat connectivity can reduce pressure. Community participation is equally important because fishers and coastal residents are often the people who observe changes in meadow condition first. Awareness programmes, citizen monitoring and locally appropriate conservation rules can strengthen formal management. Restoration may be considered where natural recovery is unlikely, but planting should not replace protection of existing healthy meadows. Restoration success depends on suitable environmental conditions, donor material, planting method, hydrodynamics and long-term protection from the disturbance that caused the original decline. International initiatives such as Seagrass-Watch demonstrate how scientists and trained community members can work together to document changes in seagrass condition, while Indian programmes can adapt similar monitoring approaches to local needs.



**Figure 6. Seagrass-associated habitat illustrating the importance of maintaining healthy coastal meadow structure**

## Seagrass Conservation: A Shared Responsibility

Seagrasses may occupy a relatively small fraction of the seabed, but their ecological influence is much larger than their area suggests. They connect primary production, fisheries, sediment stability, carbon storage and biodiversity conservation in one habitat. For India, conserving the Gulf of Mannar and Palk Bay meadows, island seagrass habitats and smaller coastal patches should be treated as part of integrated coastal management rather than as isolated vegetation patches. Successful conservation will require cooperation among researchers, fishers, local communities, government agencies, protected-area managers and coastal planners. Regular monitoring, responsible fishing, reduction of pollution and physical disturbance, public awareness and scientifically designed restoration can together improve the resilience of seagrass ecosystems.

## Conclusion

Seagrass meadows are among the most valuable yet comparatively underappreciated coastal ecosystems. Their leaves, roots and rhizomes provide food, nursery habitat, sediment stabilization, water-quality benefits and long-term carbon storage, while supporting complex communities of fishes and invertebrates and threatened species such as dugongs and sea turtles. India possesses important seagrass resources, particularly in the Gulf of Mannar, Palk Bay, Lakshadweep, Andaman and Nicobar Islands and Gulf of Kachchh. Protecting these meadows is therefore important not only for biodiversity but also for fisheries, coastal resilience and climate-related ecosystem services. The future of seagrass conservation depends on combining sound science with practical management and meaningful participation of coastal communities.

## References

1. Jeyabaskaran, R., Jayasankar, J., Ambrose, T.V., Valsalan, K.C.V., Divya, N.D., Raji, N., Vysakhan, P., John, S., Prema, D., Kaladharan, P. and Kripa, V. (2018). Conservation of seagrass beds with special reference to associated species and fishery resources. *Journal of the Marine Biological Association of India*, 60(1): 62–70.
2. Kaladharan, P., Zacharia, P.U., Thirumalaiselvan, S., Anasu Koya, A., Lavanya, R. and Batcha, S.M.S. (2020). Blue carbon stock of the seagrass meadows of Gulf of Mannar and Palk Bay off Coromandel Coast, south India. *Indian Journal of Fisheries*, 67(4): 149–153. <https://doi.org/10.21077/ijf.2020.67.4.98101-18>.
3. Patro, S., Krishnan, P., Samuel, V.D., Purvaja, R. and Ramesh, R. (2018). Seagrass and salt marsh ecosystems in South Asia: An overview of diversity, distribution, threats and conservation status. In: *Wetland Science: Perspectives From South Asia*. Springer, pp. 87–104.
4. Thangaradjou, T., Sridhar, R., Kumar, S.S. and Kannan, L. (2008). Seagrass resource assessment in the Mandapam coast of the Gulf of Mannar Biosphere Reserve, India. *Applied Ecology and Environmental Research*, 6(1): 139–146.
5. Thangaradjou, T. and Bhatt, J.R. (2018). Status of seagrass ecosystems in India. *Ocean & Coastal Management*, 159: 7–15. <https://doi.org/10.1016/j.ocecoaman.2017.11.025>.
6. Thirumalaiselvan, S., Rajkumar, M., Vinothkumar, R., Remya, L. and Batcha, S.M.S. (2020). Seagrass, seaweed and mangrove ecosystem of Gulf of Mannar and Palk Bay region. In: *Course Manual on Marine Fisheries & Mariculture*. ICAR-Central Marine Fisheries Research Institute, Mandapam, pp. 129–141.
7. Waycott, M., McMahon, K., Mellors, J., Calladine, A. and Kleine, D. (2004). *A Guide to Tropical Seagrasses of the Indo-West Pacific*. James Cook University, Townsville, Queensland, 72 pp.
8. Jagtap, T.G. and Rodrigues, R.S. (2004). Distribution and abundance of seagrasses along the Indian coast. Related Indian coastal biodiversity literature.