Fulfilling India's Commitment to Seagrass Restoration in accordance with the Kunming-Montreal Global Biodiversity Framework (Target 2)

Introduction

The global ocean has 0.1–0.2% of seagrass cover (Duarte 2002). More than 177,000 km2 is the global seagrass coverage of which 30.61% of the total seagrass species is found across the Indian coast (Sachithanandam et al. 2022). Seagrasses are underground flowering plants (Patro et al. 2017), found in shallow marine waters (Geevarghese et al. 2018) along all the tropical temperate coastlines (Prabhakaran et al. 2021). De Groot et al. (2002) classifies 23 ecosystem services provided by seagrasses, they are one of the most highly productive ecosystems (Koshy et al. 2018), yet one of the most threatened globally. Since 1990's they are declining at a rate of approximately 7% (Koshy et al. 2018). Post industrial revolution 30% of the world's seagrass has been lost (York et al. 2017). Unlike other coastal ecosystems such as mangroves and coral reefs, seagrasses don't gain much attention both in scientific research and coastal management plans (Sachithanandam et al. 2022).

Historic Status of Seagrass Systems in India

Seagrass ecosystems are one of the most poorly studied areas in India and still remains one. Much research needs to be conducted to assess the status at both ecosystem and species level. Since the 1880s seagrass occurrence has been recorded in India and 1959 onwards, literature on seagrass from India is available after it gained attention in the 1950s (Thangaradjou & Bhatt 2018). Particularly in the late 90s and early 2000s, research activities started gaining momentum. Seagrass habitats in India are mainly limited to mudflats and sandy regions, extending from the lower intertidal zone to the depth of 10–15 m along the open shores and lagoons around the islands (Ranith et al. 2024).

Current Status of Seagrass Ecosystems in India

Species Diversity

India's coastal waters host 16 recognized seagrass species across seven genera (Patro et al. 2017; Thangaradjou & Bhatt 2018). Molecular studies, including DNA barcoding and fingerprinting, have largely confirmed the taxonomic distinctness of these species, like separating Halophila ovalis from H. ovata, and even suggest potential for discovering further diversity (Mishra & Apte 2021]; Thangaradjou & Bhatt 2018). Karyomorphological data exists for 11 species (Mishra & Apte 2021). Recent field surveys have expanded regional lists, with Halophila decipiens found in deeper waters (6–12 m) of the Andaman & Nicobar Islands (ANI), making it the 11th species recorded there (Immanuel et al. 2016). Dilipan et al. (2018) states that the most recent species of seagrass is Enhalus. Additionally, the IUCN Red List 'Vulnerable' species, H. beccarii ('Ocean Turf Grass'), was newly documented within a restored mangrove site in Kerala (Prabhakaran et al. 2020; Mishra & Apte 2021).

Table 1. Seagrass species found in India.

	Species	Distribution	Reference	IUCN Red List status
1	*Enhalus acoroides*	Kerala, Tamil Nadu (Gulf of Mannar, Palk Bay)	Geevarghese et al. 2018; Thangaradjou & Bhatt 2018; Short & Waycott 2007	Least Concern
2	*Halophila ovalis*	Gujarat, Goa, Kerala, Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Andhra Pradesh, Odisha, West Bengal, Lakshadweep, Andaman & Nicobar Islands.	Thangaradjou & Bhatt 2018; Short 2007	Least Concern
3	*H. ovata*	Gujarat, Tamil Nadu (Gulf of Mannar, Palk Bay), Andhra Pradesh, Odisha, West Bengal, Lakshadweep, Andaman &Nicobar Islands.	Thangaradjou & Bhatt 2018; Short & Waycott 2007g	Least Concern
4	*H. decipiens*	Maharashtra, Tamil Nadu (Gulf of Mannar, Palk Bay), Lakshadweep and Andaman Islands.	Immanuel et al. 2016; Thangaradjou & Bhatt, 2018; Short et al. 2007f	Least Concern
5	*H. stipulacea*	Tamil Nadu (Gulf of Mannar, Palk Bay) and Andaman Islands.	Thangaradjou & Bhatt 2018; Short et al. 2007h	Least Concern
6	*H. beccarii*	Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Andhra Pradesh, Odisha and West Bengal.	Thangaradjou & Bhatt 2018; Short et al. 2007e	Vulnerable
7	*H. ovalis ramamurthiana*	Tamil Nadu (Palk Bay, other sites), Andhra Pradesh, Odisha.	Geevarghese et al. 2018; Thangaradjou & Bhatt 2018	Not assessed
8	*H. minor*	Odisha and Andaman Islands.	Thangaradjou & Bhatt 2018; Short et al. 2009	Least Concern
9	*Thalassia hemprichii*	Gujarat, Tamil Nadu (Gulf of Mannar, Palk Bay), Lakshadweep, Andaman & Nicobar Islands.	Sachithanandam et al. 2022; Thangaradjou & Bhatt 2018; Short et al. 2007i	Least Concern
10	*Syringodium isoetifolium*	Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Lakshadweep, Andaman & Nicobar Islands.	Thangaradjou & Bhatt 2018; Short et al. 2008b	Least Concern
11	*Cymodocea serrulata*	Gujarat, Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Lakshadweep, Andaman & Nicobar Islands.	Geevarghese et al. 2018; Thangaradjou & Bhatt 2018; Short et al. 2008a	Least Concern
12	*C. rotundata*	Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Lakshadweep, Andaman & Nicobar Islands	Thangaradjou & Bhatt 2018; Short & Waycott 2007a	Least Concern
13	*Halodule pinifolia*	Gujarat, Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Andhra Pradesh, Odisha, West Bengal, Lakshadweep, Andaman & Nicobar Islands.	Sachithanandam et al. 2022; Thangaradjou & Bhatt 2018; Short et al. 2007b	Least Concern

	Species	Distribution	Reference	IUCN Red List status
14	*H. uninervis*	Gujarat, Tamil Nadu (Gulf of Mannar, Palk Bay, other sites), Andhra Pradesh, Odisha, West Bengal, Lakshadweep, Andaman & Nicobar Islands.	Geevarghese et al. 2018a; Sachithanandam et al. 2022; Thangaradjou & Bhatt 2018; Short et al. 2007c	Least Concern
15	*H. wrightii*	Tamil Nadu (Gulf of Mannar, Palk Bay, Other sites), Andhra Pradesh, and West Bengal.	Thangaradjou & Bhatt 2018; (Short et al. 2007d	Least Concern
16	*Rupia maritima*	Gujarat, Tamil Nadu (Gulf of Mannar) and Odisha.	Thangaradjou & Bhatt 2018	No mention as seagrass on internet/ IUCN website

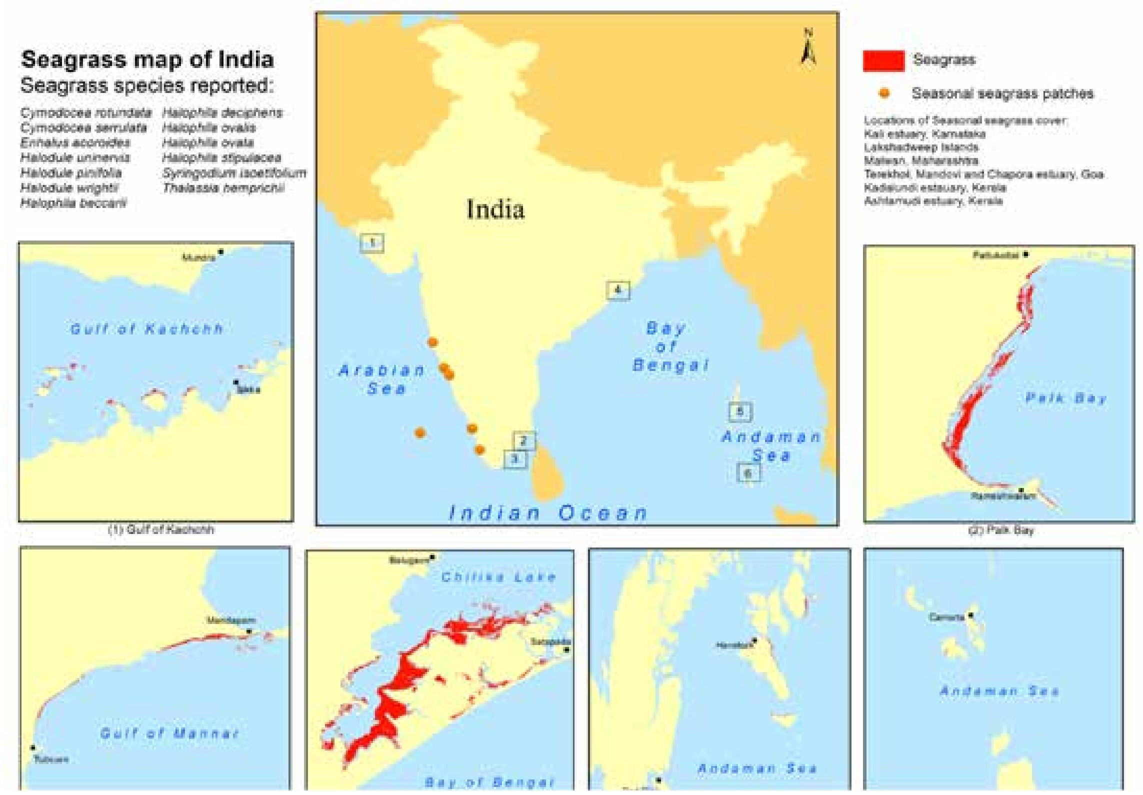

Image source: Map of Seagrass Distribution patterns in India (Geevarghese et al. 2018).

National Extent & Distribution

The most comprehensive recent national estimate suggests India's total seagrass cover spans 516.59 km2 (Geevarghese et al. 2018). This figure was derived using Landsat 8 OLI satellite data, crucially applying standardized atmospheric and water column corrections for improved mapping accuracy (Geevarghese et al. 2018). Seagrass distribution is concentrated in several key regions:

- Map of Seagrass Distribution patterns in India (TNGCC 2024).
- Palk Bay and Gulf of Mannar (Tamil Nadu): Holding approximately 77% of the national total (398.81 km2), this area boasts the highest species diversity (up to 14 species) (Patro et al. 2017; Geevarghese et al. 2018; Thangaradjou & Bhatt 2018).

Chilika Lake (Odisha): Significant area estimated at 85.47 km2 (pre-monsoon), known for seasonal variations and hosting 8 species (Geevarghese et al. 2018; Thangaradjou & Bhatt 2018).

Gulf of Kachchh (Gujarat): Supports 16.99 km2 of seagrass, with 8 species recorded (Geevarghese et al. 2018; Thangaradjou & Bhatt 2018).

Andaman & Nicobar Islands (ANI): Estimates vary; 14.6 km2 mapped comprehensively (Geevarghese et al. 2018), though other studies suggest up to 29.43 km2 (Nobi et al. 2013). Hosts 12+ species (Savurirajan et al. 2015; Immanuel et al. 2016; Thangaradjou & Bhatt 2018).

Lakshadweep Islands: Shows a marked decline, with only 0.72 km2 mapped recently in two key islands (Geevarghese et al. 2018). Hosts 10 species (Thangaradjou & Bhatt 2018).

West Coast Patchiness: Smaller, often seasonal patches, particularly of H. beccarii, occur in estuaries and mangrove areas of Kerala, Karnataka, Goa, and Maharashtra (Arunachalam & Nair 1988; Patro et al. 2017; Prabhakaran et al. 2020; Mishra & Apte 2021).

Ecological Characteristics

Indian seagrasses inhabit diverse coastal habitats from intertidal zones to subtidal depths (~15–20 m), growing on substrates like mud, silt, sand, and coral debris (Arunachalam & Nair 1988; Immanuel et al. 2016; Patro et al. 2017; Geevarghese et al. 2018). Their growth is influenced by temperature (24–34.5 OC), salinity (18–39 ppt, wider for estuarine species), pH (6–8.9), light availability (affected by turbidity), and nutrient levels (Govindsamy & Arulpriya 2011; Thangaradjou & Bhatt 2018; Mishra & Apte 2021). Biomass typically peaks post-monsoon (Govindsamy & Arulpriya 2011). These highly productive meadows support rich biodiversity (>1250 associated species reported), cycle nutrients, sequester significant carbon (Blue Carbon), stabilize sediments, and attenuate waves (Prabhakaran et al. 2013; Patro et al. 2017; Thangaradjou & Bhatt 2018; Sachithanandam et al. 2022). Concerns exist regarding heavy metal contamination (e.g., Cadmium in Lakshadweep) (Thangaradjou et al. 2013; Thangaradjou & Bhatt 2018). Home to ~750 fish species, 121 other threatened species, although there has been no exclusive study on the flora and fauna associated with seagrasses in India, 1250 number of species it supposedly is in association with (Duarte et al. 2025).

Trends & Evidence of Degradation

A consistent theme is the decline and degradation of India's seagrass ecosystems due to multiple stressors (Koshy et al. 2018; Mishra & Apte 2021). Global decline has been 1–2% in the past century and nearly 5% of species of seagrass are currently listed as endangered (Duarte et al. 2025). Quantified Losses: Losses have been documented in several regions: Lakshadweep (73 ha lost 2000–2008, with significant further decline suggested) (Nobi & Thangaradjou 2012; Geevarghese et al. 2018); ANI (catastrophic 1619 ha loss post 2004 tsunami, plus 32–68% loss in specific bays after Cyclone Lehar 2013) (Nobi et al. 2013; Sachithanandam et al. 2022); Palk Bay/GoM (historical declines of 9–28% reported in specific studies/periods) (Thangaradjou & Bhatt 2018); and decline of the vulnerable H. beccarii, especially on the west coast (Mishra & Apte 2021).

Major Threats

Anthropogenic Factors: Key human-induced pressures include coastal development (dredging, construction leading to habitat loss, and turbidity), pollution (Zhang et al. 2023) (nutrient enrichment from sewage/agriculture/aquaculture causing eutrophication and algal blooms; industrial contaminants; solid waste), and destructive fishing practices (bottom trawling, damaging gear like push nets/shore seines, anchoring) (Govindsamy & Arulpriya 2011; Patro et al. 2017; Koshy et al. 2018; Ramesh et al. 2018; Mishra & Apte 2021; Sachithanandam et al. 2022). Major anthropogenic threats stated by the global forum being the degradation caused by oil spills and excessive tourism activities (GSERWIO 2019).

Natural/Climatic Factors: Natural and climate-related threats include extreme weather events like cyclones and tsunamis causing severe physical damage and sedimentation (Nobi et al. 2013; Sachithanandam et al. 2022); tectonic events causing land uplift (ANI post-tsunami) (Nobi et al. 2013; Patro et al. 2017); climate change impacts (sea-level rise, warming, acidification, increased storminess) (Ramesh et al. 2018); and biological pressures such as intense grazing by protected Green Turtles in Lakshadweep (Koshy et al. 2018; Ramesh et al. 2018).

India currently employs several legislative and policy tools that provide a framework for seagrass conservation, aligning with national goals (like the NBSAP) and contributing towards global targets like the Kunming-Montreal GBF Target 2.

Existing Legal Protections

Seagrass meadows are designated as Ecologically Sensitive Areas (CRZ-IA) under the Coastal Regulation Zone (CRZ) Notification (2011), which restricts most new development activities within these zones. Mapping under CRZ provides a legal basis for spatial protection (Patro et al. 2017; Ramesh et al. 2018; Mishra & Apte 2021).
The Wildlife (Protection) Act, 1972 offers indirect protection through the establishment of Marine Protected Areas (MPAs) (like Gulf of Mannar Marine National Park) that encompass significant seagrass habitats, and by legally protecting associated endangered species like the Dugong (Schedule I) (Patro et al. 2017; Ramesh et al. 2018).

Pollution impacting seagrass is addressed through the Water (Prevention and Control of Pollution) Act, 1974 and rules under the Environment (Protection) Act, 1986 concerning effluent standards. The Coastal Aquaculture Authority Act, 2005 includes provisions for managing aquaculture waste (Ramesh et al. 2018).

Destructive fishing practices can be regulated under State Marine Fishing Regulation Acts (MFRAs) (Ramesh et al. 2018).

The Biodiversity Act, 2002, provides mechanisms like declaring Biodiversity Heritage Sites (BHS) and establishing local Biodiversity Management Committees (BMCs), which can be leveraged for seagrass conservation (Ramesh et al. 2018).

Policy Recognition

The National Policy on Marine Fisheries (NPMF), 2017 explicitly recognizes the ecological importance of seagrasses and the need to protect them from anthropogenic impacts (Ramesh et al. 2018; Mishra & Apte 2021).

Mapping and Monitoring Efforts

A national-level geospatial assessment using standardized remote sensing techniques has provided a crucial baseline estimate of seagrass extent (516.59 km2) (Geevarghese et al. 2018). Community-based monitoring initiatives like Seagrass-Watch exist in some areas (Patro et al. 2017).

Restoration Examples

While large-scale restoration is limited, successful natural recovery observed in Chilika Lagoon after hydrological interventions demonstrates potential when stressors are removed (Koshy et al. 2018). The colonization of restored mangrove areas by H. beccarii also indicates recovery potential (Prabhakaran et al. 2020). Geospatial techniques have been used to identify potential restoration sites based on past cover (Nobi et al. 2013). GSERWIO 2020 provides general considerations for seagrass restoration, elaborate restoration methods, restoration site identification, a restoration protocol, monitoring & management plan precise directions, methods of seagrass restoration, site identification, selection criteria, stakeholder engagement, community participation, multidisciplinary approach, spacing- planting units, time frame, monitoring & evaluation techniques, indicators have been provided through actual documentation, and case studies from Mozambique. ('GSERWIO.pdf',n.d.)

Current Initiatives

In Odisha, IIT-Bhubaneswar with Enhancing Climate Resilience of India's Coastal Communities (ECRICC) Project (supported by Green Climate Fund (GCF) implemented in partnership with the Ministry of Environment, Forest and Climate Change (MoEF&CC) and the government of Odisha) aims at ecosystem-based restoration of seagrass through scientific research and community engagement (Statesman News 2025).

A report on Strengthening Coastal Resilience and the Economy – Tamil Nadu (TN-SHORE) for "Enhancing the Coastal Community's Adaptive Capacity to Climate Change Impacts by means of Protecting and Restoring Kariyachalli Island and the surrounding Coral and Seagrass Habitats in Gulf of Mannar, Tamil Nadu" by Department of Ocean Engineering, IIT Madras, a Tamil Nadu government initiative supported by World Bank, says to restore ecological services by rehabilitation of seagrass as a climate adaptation strategy. During this project three acres of degraded seagrass bed to be restored in 17 seagrass sites (DOE, IIT Madras Report 2025).

In the states of Andhra Pradesh, Maharashtra, and Odisha, Ministry of Environment, Forest and Climate Change (MOEF&CC) has initiated project on "enhancing climate resilience of India's coastal communities" supported by Global Climate Fund (GCF), which aims to work for climate resilience of coastal communities by protecting and restoring 24 natural ecosystems, one being seagrass (Press release, 2022).

Developing Participatory (involving local fishermen communities), Eco-friendly and Low-cost Seagrass restoration method (2016 - 2022) in Palk Bay and Gulf of Mannar by OMCAR in collaboration with PANORAMA foundation. ('Developing Participatory, Eco-friendly and Low-cost Seagrass restoration method (2016 - 2022) | PANORAMA',n.d.)

Strategies

Achieving significant restoration and ensuring the long-term health of India's seagrass meadows requires dedicated future actions that are built upon existing frameworks, and the following strategies aim to align with national biodiversity goals (NBSAP) and international commitments like the Kunming-Montreal Global Biodiversity Framework (GBF), particularly focusing on restoring 30% of degraded ecosystems by 2030, as included in Target 2:

- The goal to restore 30% of degraded coastal ecosystems by 2030 directly applies to India's seagrass meadows, where significant losses and degradation have been documented (Nobi & Thangaradjou 2012; Nobi et al. 2013; Paulose 2013; Thangaradjou & Bhatt 2018; Sachithanandam et al. 2022). Future strategies must focus on identifying these degraded areas and implementing effective restoration to meet this target.
- NBSAP doesn't have any exclusive provision for the seagrass conservation/restoration mentioned under National Biodiversity Targets and Monitoring Framework (MoEFCC 2024). Definition and integration of actionable relevant to India to fulfil the KMGBF Target 2 include:

Action 1: Prioritize Restoration Sites

Future efforts require a systematic national inventory and assessment to identify and quantify degraded seagrass areas suitable for restoration, based on factors like documented historical loss (e.g., ANI, Lakshadweep), ecological significance, feasibility, and the potential to manage threats effectively (Nobi et al. 2013; Koshy et al. 2018; Thangaradjou & Bhatt 2018; Sachithanandam et al. 2022). Geospatial suitability modeling can aid this process (Nobi et al. 2013). Assessment and inclusion of seagrass ecosystems of India on IUCN Red List for ecosystems is the need of the hour since no seagrass ecosystems have been assessed. ('IUCN Ecosystems',n.d.)

Action 2: Implement Effective Restoration

Meeting the 30% target necessitates active restoration interventions. This involves researching, standardizing, and scaling up cost-effective techniques like transplantation of shoots/rhizomes, or potentially seed-based methods, tailored to Indian species and conditions. Careful site selection, use of appropriate & genetically diverse donor populations, and facilitating natural recovery by removing stressors are crucial for success (Nobi et al. 2013; Koshy et al. 2018; Thangaradjou & Bhatt 2018; Prabhakaran et al. 2020). Following the restorative continuum provided by the SER and the general/specific restoration guidelines of the KM-GBF Target 2 necessitates immediate action. (Delivering restoration outcomes for biodiversity and human well-being 2024).

Action 3: Threat Mitigation

Restoration success is fundamentally linked to reducing ongoing pressures. Future strategies must emphasize rigorous enforcement of existing environmental laws (CRZ Notification, Water Act, EPA rules, MFRAs) to curb impacts from unmanaged coastal development, pollution (sewage, industrial, agricultural, aquaculture), and destructive fishing practices (trawling, damaging gear, anchoring) (Ramesh et al. 2018; Mishra & Apte 2021). Ecosystem-based approaches are needed to resolve conflicts, such as managing turtle grazing impacts in Lakshadweep while respecting conservation laws (Koshy et al. 2018; Ramesh et al. 2018).

Action 4: Strengthen Science and Monitoring

Addressing knowledge gaps is critical. Future research should prioritize restoration ecology, population dynamics, climate change impacts, resilience studies, genetic connectivity, and the economic valuation of seagrass ecosystem services (Koshy et al. 2018; Thangaradjou & Bhatt 2018; Mishra & Apte 2021). Building National Information System for Environmental Restoration (SNIRA), which will be an integrated platform for consolidated information about all the existing restoration projects in the country. SNIRA will have integrated datasets from projects using diverse restoration approaches, like ecological restoration and rehabilitation, implemented by government and non-government agencies, academic institutions, civil society, indigenous groups, and local communities, promoting transparency, collaboration, and ultimately sharing the best practices, errors made and lessons learned. Inclusion of advanced technological methods like remote sensing, GIS & drone based monitoring ,and photo/videographic records (Delivering restoration outcomes for biodiversity and human well-being 2024).

Establishing systematic, regular, and standardized national monitoring programs using consistent remote sensing and field verification protocols is essential to track trends and evaluate interventions (Geevarghese et al. 2018; Koshy et al. 2018; Thangaradjou & Bhatt 2018).

Action 5: Enhance Policy and Governance

A primary future direction is the finalization and dedicated implementation of the recommended comprehensive National Plan of Action for seagrass conservation and management. Seagrass conservation needs further integration into broader coastal management frameworks like ICZM and MPA planning, and securing dedicated funding for research, monitoring, enforcement, and restoration is imperative (Koshy et al. 2018; Ramesh et al. 2018).

Action 6: Community Engagement

Long-term success relies on involving local communities. Future strategies should actively utilize platforms like Biodiversity Management Committees (BMCs) and community monitoring programs (e.g., Seagrass-Watch), incorporating traditional knowledge and building local stewardship. Increasing public and policymaker awareness about the value of seagrass ecosystems is also crucial (Newmaster et al. 2011; Patro et al. 2017; Koshy et al. 2018; Ramesh et al. 2018; Mishra & Apte 2021).

Success Indicators

The success of restoration of seagrass is low (globally 30% success) and cost of restoration is high (Van Der Heide et al. 2007). Short-term monitoring program doesn't give clear picture of successful restoration so long-term monitoring should be done to identify the success of restoration, e.g., seagrass restoration near Tampa Bay, Florida long-term monitoring showed seagrass recovery was slow during first three years and rapid recovery from fourth year (McSkimming et al. 2016). Assessment of increased water quality (Tomasko et al. 2018), area, habitat quality (shoot density) (Fonseca et al. 2000), species richness (McSkimming et al. 2016), and net change of seagrass population (shoot recruitment v/s mortality) (Short & Duarte 2001) using economic tools to compute replacement ratio (it is based on injured seagrass bed recovering themselves intrinsically in comparison to restoration efficacy) (e.g., using Habitat Equivalency Analysis (HBA)) (Fonseca et al. 2000) will help determine success of seagrass recovery.

Categories:

- Species-specific monitoring indicators-
- Survival rates: Percentage (%) of the numbers of individual transplants that survived.
- Aerial coverage: Surface area (in m2) covered per planting unit should be recorded until coalescence.
- Shoot Density: Shoot density count.
- Braun Blanquet Score can be used to assess the success of restoration efforts in terms of species diversity, density and abundance (Bell et al. 2008).

Conclusion

Based on the data provided above, we can conclude that an ecosystem-based recovery plan is of utmost requirement. Conservation of flagship species like Dugongs and Turtles are important, but conservation of seagrass is equally or more important since these are fodder/habitat for those species. Region wise and species-based seagrass studies are a necessity at the moment, since very little data is available in terms of quantitative threat assessment, considering the temporal aspects of seagrass system deterioration. Even the IUCN Red List has little to no data on threat assessment in the Indian context. The strategies section above reflects the immediate actionable. These actionable are a must for the achievement of the KM-GBF(T2) goals for a better future for seagrasses and dependent species.

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