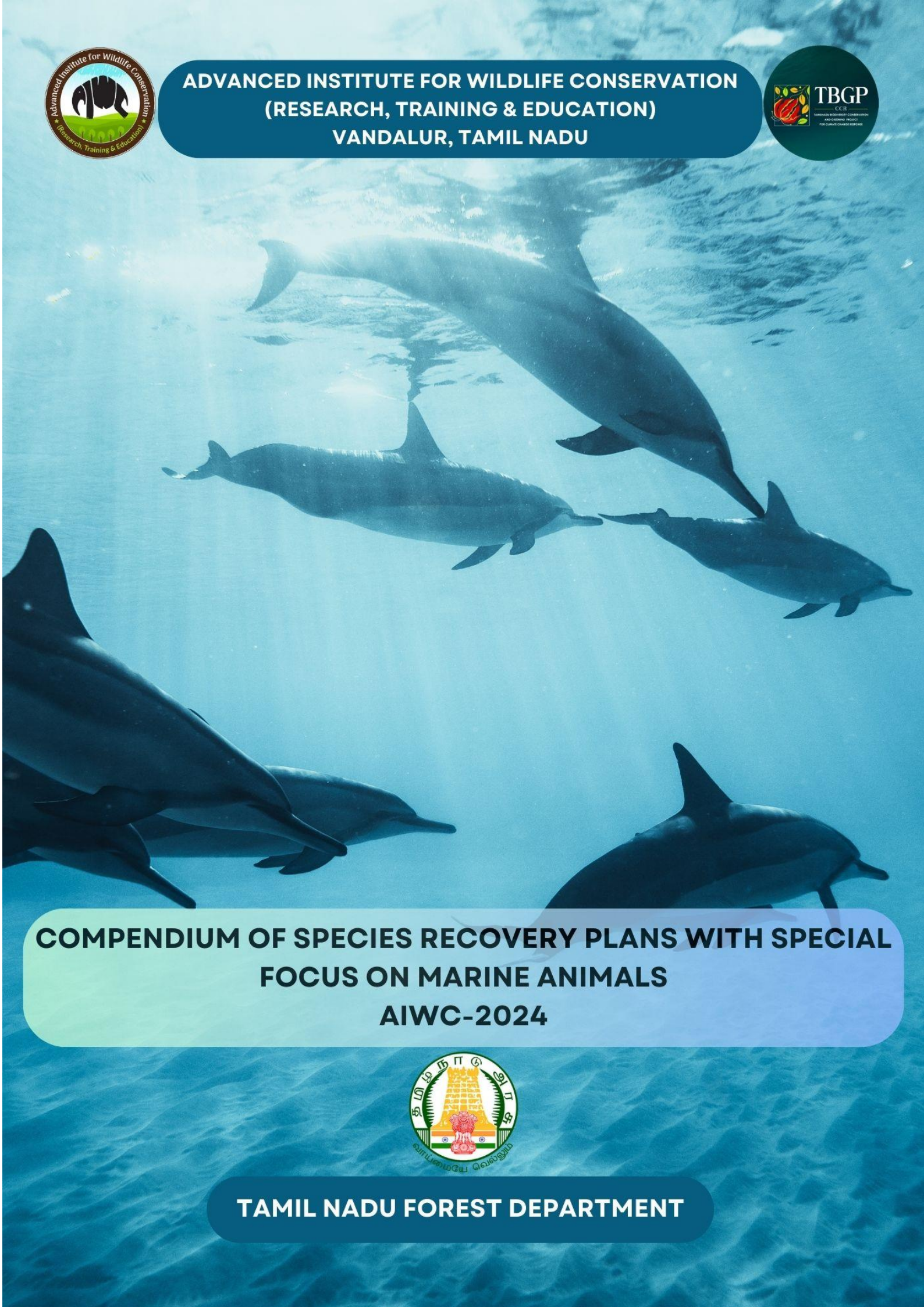




**ADVANCED INSTITUTE FOR WILDLIFE CONSERVATION  
(RESEARCH, TRAINING & EDUCATION)  
VANDALUR, TAMIL NADU**



**COMPENDIUM OF SPECIES RECOVERY PLANS WITH SPECIAL  
FOCUS ON MARINE ANIMALS  
AIWC-2024**



**TAMIL NADU FOREST DEPARTMENT**



**Advanced Institute for Wildlife Conservation**  
(Research, Training & Education)  
Vandalur – 600 048. Tamil Nadu.



**‘COMPENDIUM OF SPECIES RECOVERY PLANS  
WITH SPECIAL FOCUS ON MARINE ANIMALS’**



Tamil Nadu Forest Department

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## **1. Overview**

Marine ecosystems in Tamil Nadu are home to diverse species, many of which face significant threats to their survival and well-being. The challenges posed by activities such as poaching, accidental catch, illegal trade, and habitat degradation have underscored the urgent need for comprehensive and coordinated recovery efforts. In response to these pressing issues, a compendium of recovery plans has been developed to address the conservation of endangered marine species in Tamil Nadu's coastal waters.

This compendium will serve as a consolidated resource, bringing together multiple recovery plans designed to protect and restore populations of critically endangered marine species. These species include the dugong, sea horses, sea cucumbers, dolphins, and sea turtles, each facing unique threats and conservation challenges. By integrating various recovery strategies, this compendium aims to streamline efforts, foster collaboration, and maximize the impact of conservation initiatives across the region.

The overarching goal of this compendium is to provide a comprehensive and integrated approach to marine species recovery in Tamil Nadu. It encompasses species-specific recovery plans that detail each species' threats, proposed conservation measures, habitat protection strategies, stakeholder engagement plans, and long-term sustainability goals. Through a robust monitoring and evaluation framework, the compendium seeks to track progress, assess the effectiveness of conservation measures, and facilitate knowledge sharing among stakeholders.

By uniting stakeholders, sharing best practices, and leveraging collective expertise, this compendium of recovery plans strives to contribute significantly to preserving and recovering marine biodiversity in Tamil Nadu's coastal waters. It represents a concerted effort to address the complex challenges faced by endangered marine species. It underscores the shared responsibility of all stakeholders in safeguarding these invaluable ecosystems for future generations.

## **2. Species recovery plan - Seahorse**

### **Introduction**

Seahorses are unique and fascinating marine creatures belonging to the family Syngnathidae, which also includes pipefish and sea dragons. They have a distinctive appearance characterised by their upright posture, horse-like head, and prehensile tail (Thangaraj & Lipton, 2011). Seahorses have elongated snouts, tubular mouths, and long, slender bodies covered in bony plates instead of scales (Lee, 2014). They come in various colours, including shades of yellow, orange, brown, and black, often with intricate patterns or markings that help camouflage them in their environment (Discover Wildlife – BBC Wildlife Magazine). Seahorses vary in size depending on the species, with some species reaching lengths of only a few centimetres while others can grow up to 35 centimetres (14 inches) or more (Leysen *et al.*, 2011). Despite their small size, seahorses are relatively large compared to other members of the Syngnathidae family (Scales, H. 2010). They are found in shallow coastal waters worldwide, including coral reefs, seagrass beds, mangrove forests, and estuaries (Zhang & Vincent, 2018).

They prefer habitats with plenty of vegetation and shelter, where they can anchor themselves using their prehensile tails and camouflage among the surrounding marine flora (Perera *et al.*, 2017). Seahorses are carnivorous predators that feed primarily on small crustaceans, plankton, and tiny marine organisms (Yip *et al.*, 2015). Unlike most fish, seahorses swim upright, using their dorsal fin to propel them forward and their pectoral fins to steer (Ashley-ross, 2002). Seahorses have limited mobility and are not strong swimmers. They use their elongated snouts to suck prey into their mouths with rapid movements, aided by powerful jaw muscles and a vacuum-like feeding mechanism (Balasubramanian, 2017). They rely on their ability to camouflage and remain motionless to avoid predators (Lee & Kumar, 2019). Seahorses have a unique reproductive strategy. During courtship, females deposit their eggs into the male's pouch, fertilised and nourished until they hatch. Seahorses are known for their elaborate courtship rituals, often involving dancing, colour changes, and intricate displays (Masonjones & Lewis, 2000). Males carry and incubate fertilised eggs in a specialised pouch on their ventral side (Holt *et al.*, 2022).

Many seahorse species face threats due to habitat loss, overfishing, pollution, and the aquarium trade (Pollom *et al.*, 2021). Several seahorse species are listed as vulnerable or endangered by the International Union for Conservation of Nature (IUCN), highlighting the



need for conservation measures to protect their populations and habitats. The seahorse species face significant exploitation along Tamil Nadu due to targeted fishing and increased catches (Salin *et al.*, 2005), (Zhang & Vincent, 2019). This exploitation has led to a decline in their abundance, with the species being more prevalent during the northeast monsoon and less so during summer (Qin *et al.*, 2017). Despite regulatory measures such as bans on targeted fishing, it continues to be caught as by-catch, particularly in the Palk Bay region (Vinod *et al.*, 2015). Studies have indicated seahorse species, highlighting the urgent need for a species recovery plan to protect and restore their population in Tamil Nadu (Vincent *et al.*, 2011).

### **Seahorse distribution**

Research conducted in Tamil Nadu and Kerala has provided insights into the diversity of seahorse species in the region, identifying six distinct species. (*Hippocampus fuscus*, *H. kelloggi*, *H. kuda*, *H. histrix*, *H. mohnikei* and *H. trimaculatus*). Among these, *Hippocampus kuda* emerges as the dominant species in Palk Bay, while *H. trimaculatus* holds sway in the Gulf of Mannar (Lipton & Thangaraj, 2013). However, concerns arise regarding the large-scale exploitation of *H. kuda* along the Palk Bay coast, highlighting the urgent need for conservation efforts (Marichamy *et al.*, 1993). Interestingly, studies indicate a seasonal variation in seahorse abundance, with higher numbers observed during the northeast monsoon in Palk Bay (Murugan *et al.*, 2008).

Despite the historical challenges of targeted fishing activities, there appears to be a positive shift in recent trends. This change is attributed to implementing regulatory measures, such as banning seahorse exports (Lipton & Thangaraj, 2002) and decreasing targeted fishing pressure on seahorse populations. However, ongoing monitoring and conservation efforts remain essential to ensure the long-term sustainability of seahorse populations in these critical habitats.

### **Current status**

Based on the standardized seizure index, the observed illegal wildlife trade during 2015-2021 indicates that 2% of sea horses have been seized globally (UNODC, World Wildlife Crime Report, 2024). Seahorse populations in India, especially along the Tamil Nadu coast, face severe fishing pressure and are at risk (Gopalakrishnan *et al.*, 2020). 70 million seahorses are caught per year. 80 countries are estimated to be affected by international trade in seahorses (Zhang & Vincent, 2019). Between 2015 and 2017, an alarming estimated 13 million seahorses

were caught annually as bycatch in India, with Tamil Nadu experiencing the highest catch and trade (Vaidyanathan & Vincent, 2021). Before the ban on seahorse extraction and trade in 2001, approximately 16.8 million seahorses were caught annually in India (Perry *et al.*, 2020).

Despite the ban, the effectiveness of controlling seahorse bycatch remains questionable, as nonselective fishing methods continue to ensnare large numbers of seahorses (Foster *et al.*, 2019). The seahorse trade persists in Tamil Nadu, where many fishers, despite being aware of the ban, continue to sell seahorses due to their lucrative value (Vaidyanathan *et al.*, 2021).

**Table 1.** List of Sea horse Species (Murugan *et al.*, 2008, Lipton & Thangaraj, 2013)

Sl. No.	Species Name	IUCN Status	Wildlife (Protection) Act, 1972 Schedule	CITES Appendix
1	<i>Hippocampus kuda</i>	Vulnerable	Schedule-I	Appendix II
2	<i>H. trimaculatus</i>	Vulnerable	Schedule I	Appendix II
3	<i>H. histrix</i>	Vulnerable	Schedule I	Appendix II
4	<i>H. fuscus</i>	Data Deficient	Schedule-I	Appendix II
5	<i>H. spinosissimus</i>	Vulnerable	Schedule I	Appendix II
6	<i>H. kelloggi</i>	Vulnerable	Schedule I	Appendix II
7	<i>H. mohnikei</i>	Vulnerable	Schedule I	Appendix II

Seahorse populations in the region undergo seasonal fluctuations and face threats to survival and dispersal due to ongoing fishing pressure and habitat degradation (Pierri *et al.*, 2021). Despite legal protections under the Wildlife (Protection) Act and CITES, seahorse populations in India, particularly in Tamil Nadu, remain critically threatened by continued bycatch and trade (Evanson *et al.*, 2011; Perry *et al.*, 2020).

### Threats / Conservation challenges

**1. Overexploitation:** Seahorses face extensive fishing pressure, with high levels of exploitation on the Coromandel coast (Andhra Pradesh and Tamil Nadu) but are under extensive fishing pressure, with 13 million individuals caught annually. Seahorses face

extensive fishing pressure due to their high demand in traditional medicine, curio trade, and aquariums. Overfishing can lead to population declines and even local extinctions.

**2. Habitat destruction:** Fishing practices, such as bottom trawling and netting, not only catch seahorses but also destroy seagrass beds, coral reefs, and other coastal habitats due to coastal development, pollution, and destructive fishing practices. These practices deprive seahorses of essential shelter, feeding, and breeding habitats, which are crucial for their survival.

**3. Illegal trade:** 75% of seahorse catches and illegal trade occur in Palk Bay in Tamil Nadu. Despite International Protections under CITES (Convention on International Trade in Endangered Species) and National Protection under Schedule I of the Wildlife (Protection) Act, seahorses are still illegally traded for traditional medicines, aquariums, and curiosities, contributing to their population decline.

**4. Incidental bycatch:** Seahorses are often caught unintentionally, such as bycatch in fishing gear such as trawls and nets, leading to mortality rates that can impact their populations, especially in areas with intensive fishing activities.

**5. Fragmentation and connectivity:** Loss of habitat connectivity and fragmentation due to coastal development and habitat destruction can isolate seahorse populations, reducing genetic diversity and increasing their vulnerability to environmental changes and diseases.

**6. Climate change:** Rising sea temperatures, ocean acidification, and changes in currents due to climate change can disrupt seahorse habitats and affect their prey availability, reproduction, and survival.

**7. Need for enhanced enforcement:** Strengthening enforcement agencies and implementing gear limitations to reduce destructive fishing practices are crucial for protecting seahorse populations.

**8. Lack of awareness and conservation efforts:** Limited public awareness about the importance of seahorses and their conservation status, insufficient conservation measures and enforcement of existing regulations pose significant challenges to their protection. Involving local communities in conservation and the effectiveness of bans and conservation projects in curbing seahorse threats remains challenging.

## **International policies/guidelines in Seahorse conservation and management**

1. **Australia:** The Australian Government's Department of Agriculture, Water and the Environment's Threatened Species Protection Division oversees seahorse conservation efforts, including habitat protection and fisheries management measures.
2. **Philippines:** The Philippines' Bureau of Fisheries and Aquatic Resources (BFAR) implements seahorse fishing and trade regulations, including permits and quotas, under the Fisheries Administrative Order (FAO) series.
3. **Indonesia:** Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) focuses on seahorse conservation by developing marine protected areas (MPAs) and community-based management initiatives guided by the National Marine and Fisheries Policy.
4. **Thailand:** Under the Marine and Coastal Resources Conservation Act, Thailand's Department of Marine and Coastal Resources (DMCR) coordinates seahorse conservation efforts, including habitat protection and public awareness campaigns.
5. **China:** Under the Wildlife Protection and Fisheries Law, China's State Oceanic Administration (SOA) oversees seahorse conservation efforts, including trade regulations and enforcement measures.
6. **United States:** The U.S. Fish and Wildlife Service (USFWS) regulates seahorse trade under the Endangered Species Act (ESA) and enforces laws against illegal trafficking through the Lacey Act and the Marine Mammal Protection Act (MMPA).
7. **United Kingdom:** The UK's Marine Management Organization (MMO) coordinates seahorse conservation efforts, including habitat protection and research initiatives, under the Marine and Coastal Access Act.
8. **Vietnam:** Vietnam's Ministry of Agriculture and Rural Development (MARD) works on seahorse conservation through habitat restoration projects and public education programs guided by the Fisheries and Biodiversity Law.
9. **Malaysia:** Malaysia's Department of Fisheries (DOF) implements seahorse fishing and trade regulations under the Fisheries Act to ensure sustainability and conservation.

10. **South Africa:** South Africa's Department of Environment, Forestry and Fisheries (DEFF) oversees seahorse conservation efforts, including habitat protection and research initiatives, under the National Environmental Management: Biodiversity Act.

11. **Bangladesh:** Bangladesh has developed the National Fisheries Policy and the National Plan of Action for Sharks to address marine conservation issues, including seahorse protection.

12. **Pakistan:** Pakistan has established marine protected areas (MPAs) and implemented regulations to regulate fishing activities and protect coastal habitats for seahorse survival.

13. **Myanmar:** Myanmar has developed the National Biodiversity Strategy and Action Plan (NBSAP) and the National Plan of Action for Sharks to address marine conservation issues, including seahorse protection.

14. **India:** India has implemented the National Biodiversity Action Plan (NBAP) and the Coastal Zone Regulation (CZR) Act to address marine conservation issues, including seahorse protection. Indian seahorse populations were moved under Schedule I of the Wildlife (Protection) Act in 2001, and thereby, a ban was imposed on collection or trade. The Government of India has notified 130 Marine Protected Areas (MPAs) across coastal states and islands, and 106 coastal and marine sites have been identified and prioritized as Important Coastal and Marine Biodiversity Areas.

15. **Sri Lanka:** Sri Lanka has developed the National Policy on Biological Diversity and the National Plan of Action for Conservation of Sharks to address broader marine conservation issues, which may indirectly benefit seahorse populations. Additionally, Sri Lanka collaborates with local communities to establish marine protected areas (MPAs) and implement sustainable fisheries management practices that can contribute to seahorse conservation.

### **Comprehensive management plan/guidelines**

With their unique biology and ecological significance, seahorses face numerous threats worldwide, necessitating comprehensive conservation strategies. This plan outlines a multifaceted approach to seahorse conservation, integrating global initiatives with local and regional efforts. By addressing key challenges through habitat protection, sustainable fishing practices, trade regulation, public engagement, research, and policy advocacy, we aim to ensure the long-term viability of seahorse populations.



**1. Habitat protection & restoration:** Preserving and restoring seahorse habitats are fundamental for their survival. Marine protected areas (MPAs) play a crucial role in safeguarding seagrass beds, coral reefs, and mangrove forests—the primary habitats of seahorses. Initiatives such as habitat restoration projects, supported by local governments and NGOs, can rehabilitate degraded areas and enhance habitat resilience. Drawing upon scientific research and community participation, collaborative efforts are essential for adequate habitat protection and restoration (Jones & Schmitz, 2009).

**2. Combating illegal trade:** Illegal trade poses a significant threat to seahorse populations, driven by demand for traditional medicine, curiosities, and the aquarium trade. Combating illegal trade requires stringent enforcement measures, including surveillance, inspections, and offender penalties. Collaboration among law enforcement agencies, governments, and NGOs is vital for disrupting wildlife trafficking networks and dismantling illegal trade operations. International cooperation, facilitated by agreements like CITES, strengthens efforts to combat the illicit trade and protect seahorses from exploitation (Rosen & Smith, 2010).

**3. Enforcement collaboration:** Effective enforcement of seahorse conservation laws relies on collaboration among national, regional, and international enforcement agencies. Sharing intelligence, resources, and expertise enhances enforcement capacity and coordination. Regional cooperation agreements, such as those established by ASEAN countries or regional fisheries management organizations, facilitate cross-border enforcement efforts and strengthen legal frameworks for wildlife protection. By working together, enforcement agencies can deter illegal activities and safeguard seahorse populations (Clarke & McAllister, 2006).

**4. Bycatch mitigation measures:** Reducing bycatch is crucial for seahorse conservation, as incidental capture in fishing gear poses a significant threat to their survival. Implementing measures such as using selective fishing gear, modifying fishing practices, and avoiding areas with high seahorse abundance can minimize accidental capture. Collaborative initiatives between fishers, scientists, and conservationists are essential for developing and implementing effective bycatch reduction strategies tailored to local contexts. Continuous monitoring and adaptive management are necessary to assess the effectiveness of these measures and adjust them as needed (Dudgeon & Arthington, 2006).

**5. Trade curtailment:** Curtailing seahorse trade is critical for preventing overexploitation and ensuring sustainable management. Listing seahorse species under international agreements like

CITES provides legal frameworks for regulating trade and promoting sustainable practices. Implementing permits, quotas, and traceability mechanisms helps monitor and control the trade. National governments, supported by regional and international organizations, play a crucial role in enforcing trade regulations and combating illegal trafficking. Public awareness campaigns can educate consumers about the importance of responsible purchasing practices and the impact of the aquarium trade on seahorse populations (Caro *et al.*, 2022).

**6. Sustainable fishing practices:** Overfishing significantly threatens seahorse populations and their habitats. Promoting sustainable fishing practices is essential for mitigating the impact of overfishing on seahorse populations. Implementing regulations such as fishing quotas, gear restrictions, and seasonal closures helps sustainably manage seahorse fisheries. Engaging with fishing communities to develop and implement bycatch reduction strategies is critical. Supporting alternative livelihoods, such as ecotourism or aquaculture, can alleviate pressure on wild seahorse populations and promote economic sustainability (Hiddink & Jennings, 2017).

**7. Policy advocacy:** Advocating for policies that support seahorse conservation is essential for driving systemic change and promoting sustainable management practices. Critical advocacy strategies include engaging policymakers, providing scientific evidence, and raising awareness about seahorse threats. Collaborating with governments, NGOs, and other stakeholders to develop and implement conservation policies strengthens their effectiveness. National policies and guidelines, informed by scientific research and stakeholder input, provide frameworks for coordinating conservation efforts and allocating resources effectively (Balmford, 2003).

**8. Community engagement:** Local communities are vital in seahorse conservation efforts. Engaging local communities is essential for fostering stewardship and garnering support for seahorse conservation initiatives. Community-based conservation programs, educational outreach, and participatory decision-making processes empower communities to participate actively in conservation efforts. Involving local communities in monitoring and management activities promotes a sense of ownership and responsibility for seahorse conservation. Collaboration with indigenous peoples and regional stakeholders, respecting traditional knowledge and cultural values, enhances the relevance and effectiveness of conservation interventions (Lindsay, 2016; Crowley *et al.*, 2020).

**9. Capacity building:** Building capacity among stakeholders is essential for implementing effective seahorse conservation measures. Training, technical assistance, and resources to conservation practitioners, policymakers, and researchers enhance their skills and knowledge. Collaborating with academic institutions, NGOs, and government agencies to develop capacity-building programs ensures their relevance and sustainability. Investing in capacity building strengthens institutional capacity, fosters collaboration, and empowers stakeholders to address emerging challenges in seahorse conservation (Groom *et al.*, 2006) (Bruckner *et al.*, 2005).

**10. Public awareness:** Raising public awareness about seahorse conservation is critical for mobilizing support and fostering behavior change. Public awareness campaigns, educational outreach, and media engagement initiatives can increase understanding of the importance of seahorses and the threats they face. Targeted messaging, tailored to different audiences, highlights the role of individuals in protecting seahorses and their habitats. Collaborating with media outlets, influencers, and educational institutions amplifies conservation messages and reaches diverse audiences. Public engagement activities, such as citizen science projects or eco-tourism initiatives, allow people to actively contribute to seahorse conservation efforts (Rosa *et al.*, 2012) (Orth, 2023).

**11. Research & monitoring:** Scientific research and monitoring are essential for informing evidence-based conservation strategies and assessing the effectiveness of management measures. Long-term monitoring programs track population trends, habitat changes, and threats to seahorse populations. Collaborative research initiatives involving scientists, governments, NGOs, and local communities generate data on seahorse biology, ecology, and distribution. Research findings contribute to policy development, adaptive management, and public awareness efforts. Investing in research and monitoring builds scientific knowledge and informs conservation actions to ensure the long-term survival of seahorses (Wei *et al.*, 2015) (Aynesworth *et al.*, 2020).

**12. Adaptive management:** Adaptive management approaches allow for flexible and responsive conservation strategies that adapt to changing environmental conditions and emerging threats. Monitoring and evaluating conservation interventions enable stakeholders to assess their effectiveness and make informed decisions. Adaptive management frameworks, informed by scientific research and stakeholder engagement, promote learning, innovation, and resilience in seahorse conservation efforts. Integrating adaptive management principles into

policy development and implementation enhances the effectiveness and sustainability of conservation initiatives (Mace *et al.*, 2012) (Jun *et al.*, 2015).

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### **3. Species Recovery Plan for Sea turtles**

#### **Introduction**

Sea turtles, belonging to the taxonomic order Testudine, are a group of fascinating marine reptiles that inhabit oceans worldwide, and they are commonly recognized for their distinctive appearance and behaviour. Sea turtles have a streamlined body shape adapted for life in the ocean. They typically have a large, oval-shaped shell called a carapace, which covers and protects their body. The colour of their shell varies between species, ranging from shades of green, brown, and black to olive and grey (National Oceanic and Atmospheric Administration, 2022). Their limbs are modified into flippers for swimming through the water with graceful, fluid movements (e Soares, 2018). Sea turtles have a relatively long lifespan, with some individuals living for several decades or up to a century (Heppell *et al.*, 2003). Sea turtles are primarily marine creatures, spending most of their lives in the ocean. They inhabit many aquatic environments, from coastal waters and coral reefs to open ocean habitats (Luschi *et al.*, 2003). Sea turtles are highly migratory and may travel thousands of miles between feeding and nesting grounds (Bowen & Karl, 2007).

While they spend most of their time in the water, sea turtles also rely on coastal beaches for nesting and laying their eggs. Sea turtles have a unique reproductive cycle that involves migrating to coastal beaches to nest and lay their eggs. Female sea turtles return to the same beaches where they were born to lay their eggs, often digging nests in the sand above the high tide line. After laying their eggs, females cover the nest with sand and return to the ocean, leaving the eggs to incubate for several weeks before hatching. Once hatched, baby sea turtles instinctively make their way to the ocean, where they face numerous threats during their early years of life (Wood & Bjorndal, 2000).

With their varied diets, sea turtles play a crucial role in maintaining the health of marine ecosystems. While some species, like the green sea turtle, are herbivorous and feed on seagrasses and algae, others, such as the loggerhead sea turtle, are carnivorous and consume a variety of prey, including crustaceans, molluscs, and jellyfish (Bjorndal, 1997). Their grazing activities are instrumental in the health of seagrass beds and coral reefs, making them an essential part of the marine ecosystem (Alongi, 2020).

Sea turtles are classified as endangered or threatened due to various human-induced threats such as habitat destruction, pollution, climate change, and illegal poaching (Casale, 2010). Conservation efforts are underway worldwide to protect and conserve sea turtle populations and their habitats, including habitat restoration, nesting beach protection, and implementing regulations to reduce threats from fishing activities and marine pollution (Wallace *et al.*, 2010). Public awareness and education are also crucial to sea turtle conservation efforts to promote responsible behaviour and mitigate human impacts on these iconic marine creatures (Seminoff & Shanker, 2008).

Out of seven species, five species of sea turtles, leatherback (*Dermochelys coriacea*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*), found within Indian limits are reported along the Tamil Nadu coast (Bhupathy & Saravanan, 2002). Sea turtles, a group of ancient marine reptiles, face numerous threats to survival, resulting in varied conservation statuses across species (Wallace *et al.*, 2010). Scientific approaches are fundamental in assessing and understanding the current status of sea turtles (Casale, 2008). Through rigorous population assessments, researchers use satellite tracking, genetic analysis, and ecological studies to monitor sea turtle distribution, abundance, and demographic trends (Rivas *et al.*, 2023). These approaches provide invaluable insights into the factors influencing sea turtle populations, including habitat degradation, fisheries bycatch, pollution, climate change, and illegal trade (Komoroske, 2023). By employing scientific methodologies, conservationists can accurately evaluate the health of sea turtle populations, identify priority areas for conservation action, and develop targeted strategies to mitigate threats and ensure the long-term survival of these iconic marine species (Suresh *et al.*, 2023).

### List of Marine Turtle Species in India

Sl. No.	Common name	Scientific name	IUCN	WPA (1972)	CITES
1	Leatherback	<i>Dermochelys coriacea</i>	Vulnerable	Schedule-I	Appendix-I
2	Olive Ridley	<i>Lepidochelys olivacea</i>	Vulnerable	Schedule-I	Appendix-I
3	Loggerhead	<i>Caretta caretta</i>	Vulnerable	Schedule-I	Appendix-I
4	Hawksbill	<i>Eretmochelys imbricata</i>	Critically Endangered	Schedule-I	Appendix-I
5	Green turtle	<i>Chelonia mydas</i>	Endangered	Schedule-I	Appendix-I

## **Current Status**

In Tamil Nadu, located on the southeastern coast of India, sea turtles face numerous threats to survival. Exploitation of turtle products, including meat, eggs, and shells, remains a significant concern despite legal protections. Coastal communities often engage in the consumptive use of turtle products, exacerbating the pressure on sea turtle populations. Habitat degradation due to coastal development, pollution, and erosion poses a serious threat to sea turtles in Tamil Nadu (Riskas *et al*, 2018). Natural disasters, such as the devastating 2004 tsunami, further compound the challenges sea turtles face in the region. The tsunami's destruction of nesting beaches and nesting habitats has had long-lasting impacts on sea turtle populations (Kannan, 2008). Furthermore, the regulatory frameworks for sea turtle conservation in Tamil Nadu are incomplete and require strengthening to protect these vulnerable species effectively (Suganthi, 2002).

Introducing exotic coastal plants (e.g., casuarina) threatens sea turtle nesting habitats and reproductive success. These plants alter the structure and composition of beaches, obstructing access to nesting sites and disrupting turtles nesting behaviour by modifying environmental cues. Furthermore, dense vegetation provides hiding spots for predators, increasing the risk of nest predation. Additionally, changes in microclimate caused by exotic plants may impact the development of turtle embryos within nests, affecting hatching success rates. Overall, the proliferation of non-native vegetation can lead to habitat degradation and loss of biodiversity, exacerbating threats to sea turtles and other coastal wildlife (Sea Turtles of India, 2011).

Given these challenges, urgent action is needed to protect and recover sea turtle populations in Tamil Nadu. Comprehensive conservation efforts must be implemented to address the multiple threats facing sea turtles and ensure their long-term survival. This includes mitigating exploitation, conserving critical habitats, and engaging local communities in conservation efforts (Sridhar, 2005). Only through concerted and scientifically informed action can the decline of sea turtles in Tamil Nadu be reversed and their populations restored (Kuppusamy, 2022).

Climate-resilient turtle hatcheries can protect sea turtle eggs from the adverse effects of climate change, such as rising temperatures, sea level rise, and extreme weather events. A

climate-proof hatchery can ensure the optimal incubation conditions for the eggs and produce healthy and resilient hatchlings that can survive and contribute to the population. 53 such hatcheries across 10 coastal Districts of Tamil Nadu were formed to ensure better survival of Olive Ridley turtle hatchlings. The Forest Department collected 2,58,755 turtle eggs, of which 2,15,778 turtle hatchlings were successfully released on their forever journey in deep oceans.

In July 2013, the government-sanctioned 500 Turtle Excluder Devices (TEDs) to conserve sea turtles. By the 2014-15 period, 20 TEDs had been supplied to fishermen in the Chennai and Nagapattinam Divisions, marking an initial effort to reduce turtle bycatch. In December 2015, the Wild Life Warden of Chennai issued a work order for the fabrication and delivery of 231 stainless steel TEDs, totaling ₹15.66 lakhs under TBGP, distributed across eight districts. These initiatives underscore a proactive approach to mitigate threats to endangered sea turtles from fishing activities. The government's commitment to implementing TEDs reflects a positive stride in sustainable marine conservation, aiming to enhance survival rates and ensure the long-term preservation of these vulnerable marine species.

### **Threats and Conservation Challenges**

- 1. Habitat Loss:** Destruction and degradation of nesting beaches, feeding grounds, and migratory pathways due to coastal development, pollution, and erosion threaten sea turtles' ability to reproduce and find food.
- 2. Climate Change:** Rising temperatures and sea levels impact nesting beaches, altering the sand temperatures and determining the sex of hatchlings. Changes in ocean currents and temperatures can also affect the distribution and abundance of prey species.
- 3. Environmental Pollution:** Marine pollution, including plastic debris, oil spills, and chemical pollutants, poses serious threats to sea turtles. Plastic ingestion can cause intestinal blockages and starvation, while pollution can weaken immune systems and disrupt reproductive hormones. Artificial beach lights can disorient hatchlings, leading them away from the sea and towards roads, buildings, or predators. This increases mortality rates and reduces the number of turtles reaching maturity.



**4. Bycatch:** Accidental capture in fishing gear, known as bycatch, is a significant threat to sea turtles worldwide. Longline, trawl, and gillnet fisheries often unintentionally catch and kill turtles, mainly loggerheads and leatherbacks.

**5. Illegal Trade:** Sea turtles and their eggs are harvested for their meat, shells, and supposed medicinal properties, despite legal protections in many countries. Poaching remains a significant problem, particularly in regions where sea turtles are culturally or economically valuable.

**6. Predation & Invasive Species:** Introduced species like feral pigs and dogs can prey on sea turtle nests and hatchlings. Invasive vegetation can also alter nesting habitats, making them unsuitable for nesting.

**7. Ocean Noise:** Increased noise from shipping, construction, and recreational activities can disrupt sea turtles' communication, navigation, and feeding behaviors, potentially affecting their survival and reproduction.

**8. Exotic Plantations:** Exotic coastal plants seriously threaten sea turtles by altering nesting beaches, obstructing access to nesting sites, and disrupting nesting behavior. These plants increase the risk of predation by providing cover for predators, and they can affect nest incubation conditions, potentially impacting hatching success rates.

### **Management/ Implication plan**

**1. Habitat Restoration:** Coastal activities, development, tourism, and urbanization have led to significant habitat loss in coastal areas worldwide. To address this, a comprehensive management plan should prioritize protecting and restoring coastal habitats. This can include implementing zoning regulations to limit coastal development, establishing marine protected areas (MPAs) to safeguard critical habitats, and promoting sustainable tourism practices (Nayak. S, 2017). For example, the International Union for Conservation of Nature (IUCN) emphasizes integrating conservation efforts with coastal development planning to minimize habitat destruction (Hilty *et al.*, 2020, IUCN). Additionally, community-based initiatives like mangrove restoration projects can help rebuild degraded coastal ecosystems (Keddy, 2023).

**2. Climate Change Mitigation:** Global warming significantly threatens coastal ecosystems, impacting beach nest site temperatures and marine biodiversity (Arora & Phillott, 2023). A comprehensive management plan for climate change mitigation should prioritize reducing greenhouse gas emissions and enhancing coastal resilience (Poloczanska *et al.*, 2009). This can involve implementing nature-based solutions like restoring coastal wetlands to sequester carbon and protect against sea-level rise (Hawkes *et al.*, 2009) & (Barik *et al.*, 2014). Additionally, integrating climate-smart practices into coastal development and land-use planning can help minimize vulnerability to climate change impacts. The Intergovernmental Panel on Climate Change (IPCC) emphasizes the importance of adaptation strategies for coastal areas facing climate-related challenges (IPCC, 2019).

**3. Tackling Environmental Pollution:** Marine pollution, particularly plastic pollution, threatens the health of coastal ecosystems and wildlife. A management plan for tackling environmental pollution should prioritize reducing plastic waste and implementing effective waste management strategies (Verma *et al.*, 2020). This can involve implementing bans on single-use plastics, promoting recycling and waste reduction initiatives, and conducting beach clean-up campaigns. The United Nations Environment Programme (UNEP) highlights the urgent need for global action to address marine pollution and protect marine biodiversity (UNEP, 2009). Conservation strategies entail implementing regular clean-up initiatives, instituting effective waste management systems, and conducting public awareness campaigns to reduce littering and promote responsible waste disposal practices. We can effectively combat environmental pollution and safeguard coastal ecosystems by adopting a multi-sectoral approach and engaging stakeholders at all levels.

**4. Mitigating Light Pollution:** Light pollution disrupts natural ecosystems and affects the behavior of nocturnal species, including sea turtles and shorebirds. A management plan for reducing light pollution should involve implementing lighting ordinances and promoting dark sky-friendly lighting designs in coastal areas. This can help minimize the impacts of artificial light on marine and coastal biodiversity (Karnad *et al.*, 2009), (Rajkhowa, 2014; Silva *et al.*, 2017). The International Dark-Sky Association (IDA) provides guidance on reducing light pollution through responsible lighting practices (IDA, 2020). By raising awareness and advocating for dark sky conservation measures, we can protect nocturnal wildlife and preserve the natural beauty of coastal environments.

**5. Bycatch Mitigation:** Bycatch, the unintentional capture of non-target species in fishing gear, significantly threatens marine biodiversity. A management plan for bycatch mitigation should prioritize the adoption of sustainable fishing practices and the use of bycatch reduction devices (Gilman *et al.*, 2010), (Gilman, 2011; Sachithanandam *et al.*, 2015). This can involve implementing regulations to limit fishing effort in sensitive areas and promoting the use of selective fishing gear (Bourjea *et al.*, 2008). The Food and Agriculture Organization (FAO) emphasizes the importance of reducing bycatch to achieve sustainable fisheries management (FAO Sea Turtle Action Plan, 2008) & (Sacchi, 2021). Fishermen rescue and release 8 Olive Ridley turtles accidentally caught in their fishing nets at Dhanushkodi in Rameshwaram. By promoting collaboration between fishers, scientists, and policymakers, we can develop effective bycatch mitigation strategies and conserve marine species.

**6. Combatting Illegal Trade:** Illegal trade in wildlife and marine resources seriously threatens coastal biodiversity and ecosystems. A management plan for combatting illegal trade should strengthen law enforcement efforts, enhance surveillance and monitoring systems, and promote community involvement in conservation efforts (Chandrasekar & Srinivasan, 2013). (World Wildlife Crime Report, 2024) that illegal wildlife trade during 2015–2021 based on the standardized seizure index indicates 2% of turtles and tortoises are the most affected species, and 4% of turtles and tortoises are seized during this period through various modus operandi. This can involve implementing stricter regulations and penalties for illegal trade activities and engaging local communities as stewards of coastal resources. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) plays a crucial role in regulating international trade to protect endangered species (CITES, 2022). By collaborating with enforcement agencies and raising awareness about the consequences of illegal trade, we can combat this illicit activity and protect coastal biodiversity.

**7. Mitigation of Predator & Invasive Species:** Predation and invasive species can harm native coastal wildlife and ecosystems (Stokes *et al.*, 2024). A management plan for lowering predation and controlling invasive species should prioritize monitoring and early detection efforts, implementing eradication and control measures, and restoring habitats to enhance resilience against invasive species (Heithaus, 2013; Sivakumar *et al.*, 2017). To mitigate this threat, conservation efforts incorporate predator control measures, such as installing exclusion devices and utilizing trained dogs. Moreover, community education initiatives are crucial in raising awareness about safeguarding nests from predation. This can involve targeted invasive

species removal, restoring native vegetation to outcompete invasives, and implementing biosecurity measures to prevent new introductions (Engeman *et al.*, 2019). The Global Invasive Species Database (GISD) provides information and tools for managing invasive species in coastal environments (GISD, 2021). By adopting a proactive approach and investing in invasive species management, we can protect native biodiversity and ecosystem functioning.

**8. Tackling Ocean Noise:** Ocean noise pollution, primarily from human activities such as shipping and construction, can disrupt marine life and interfere with essential behaviors like communication and navigation (Samuel *et al.*, 2005). A management plan for tackling ocean noise should prioritize reducing anthropogenic noise sources, implementing regulations to limit noise emissions in sensitive habitats, and promoting research on the impacts of ocean noise on marine species (Weilgart, 2008). This can involve implementing quiet ship design technologies, establishing quiet zones in key marine habitats, and developing acoustic monitoring programs to assess noise levels over time (Piniak, 2012). The International Quiet Ocean Experiment (IQOE) aims to enhance our understanding of ocean noise and its effects on marine life (IQOE, 2020). By mitigating ocean noise pollution, we can protect marine biodiversity and ensure the health of coastal ecosystems.

**9. Tackling Exotic Plantations by Planting Native Species in the Coastal Areas:** Exotic plantations, particularly invasive species, can outcompete native vegetation and degrade coastal habitats. A management plan for planting native species in coastal areas should prioritize restoring native vegetation to enhance habitat quality and resilience (de Vos *et al.*, 2019) & (Stanford *et al.*, 2020). This can involve conducting invasive species surveys and implementing eradication and control measures to remove exotic plantations and restore native plant communities. It will be the best habitat for the nesting site of marine turtles (Chaudhari *et al.*, 2009), (Korgaonkar, & Sivakumar). The Society for Ecological Restoration (SER) provides guidelines and best practices for restoring native vegetation in coastal ecosystems (SER, 2021). By restoring native plant communities, we can improve habitat suitability for native wildlife and promote ecosystem stability.

**10. Community Engagement:** Community engagement is essential for the success of coastal conservation and management efforts. A management plan for community engagement should prioritize building partnerships with local communities, empowering stakeholders through education and capacity-building initiatives, and integrating traditional knowledge into

decision-making processes (Kale, 2022). This can involve establishing community-based conservation programs, organizing participatory workshops and events, and incorporating local perspectives into coastal planning and management strategies. (Shanker & Manohar Krishnan 2022) provides principles and guidelines for effective community engagement in environmental decision-making. By fostering collaboration and inclusivity, we can empower local communities to become active stewards of coastal ecosystems and ensure the long-term sustainability of conservation efforts.

**11. Awareness Education:** Awareness education promotes public understanding and support for coastal conservation and management. A management plan for awareness education should prioritize developing educational materials and outreach programs to raise awareness about coastal ecosystems, threats, and conservation actions (Hassan *et al.*, 2017) 7 (Smith *et al.*, 2019). This can involve organizing community workshops, producing educational resources such as brochures and videos, and engaging schools and youth groups in environmental education activities (Miller & Meindl 2019). The Environmental Education Alliance of Georgia (EEAG) provides resources and training for educators to integrate environmental education into the curriculum (EEAG, 2021). By fostering environmental literacy and promoting behavior change, we can mobilize public support for coastal conservation and empower individuals to take action to protect coastal ecosystems.

**12. Population Dynamics:** Understanding population dynamics is crucial for effective coastal management and conservation. A comprehensive management plan should incorporate scientific research to monitor population trends, assess the drivers of population change, and develop strategies for sustainable resource management (Chaloupka & Musick 2017). This can involve conducting population surveys, demographic studies, and modeling to predict future population trajectories (Murugan, 2010). By analyzing population dynamics, managers can identify conservation priorities, such as protecting critical habitats and managing harvest levels, to ensure the long-term viability of coastal populations. Climate change also plays a major role in population dynamics trends (Chaloupka *et al.*, 2008). The Population Reference Bureau (PRB) provides resources and data on population dynamics to support evidence-based decision-making (PRB, 2021). By integrating population dynamics research into management practices, we can promote the resilience and sustainability of coastal ecosystems.

**13. Scientific Research:** Scientific research advances our understanding of coastal ecosystems and informs management decisions. A management plan for scientific research should prioritize interdisciplinary studies to address key knowledge gaps, such as ecosystem functioning, species interactions, and ecosystem services (Hamann *et al.*, 2010), (Rees *et al.*, 2018). Satellite tracking can be used to precisely understand its migration pathways and nesting sites (Godley *et al.*, 2008). UAVs are deployed in sea turtle monitoring (Robinson *et al.*, 2023). This can involve conducting field surveys, laboratory experiments, and long-term monitoring programs to collect data on coastal biodiversity and ecosystem health. Collaborative research partnerships between academia, government agencies, and non-profit organizations are essential for fostering innovation and sharing knowledge. The National Oceanic and Atmospheric Administration (NOAA) supports scientific research initiatives to improve coastal management and conservation (NOAA, 2020). Investing in scientific research can enhance our ability to address complex environmental challenges and promote evidence-based decision-making in coastal management.

**14. Genetic Diversity:** Genetic diversity is critical for the resilience and adaptability of coastal species to environmental change (Bowen & Karl 2007). A management plan for genetic diversity should prioritize conserving and restoring genetic variability within populations to enhance their ability to respond to threats such as habitat loss, climate change, and disease (Phillott *et al.*, 2014). This can involve implementing genetic monitoring programs to assess population genetic structure and diversity, establishing protected areas to preserve genetically unique populations, and promoting habitat connectivity to facilitate gene flow (Jensen *et al.*, 2013). The Convention on Biological Diversity (CBD) emphasizes conserving genetic diversity for ecosystem resilience and human well-being (CBD, 2021). By integrating genetic diversity considerations into conservation planning and management strategies, we can safeguard the evolutionary potential of coastal species and ecosystems.

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## **4. Species Recovery Plan for Sea Cucumber**

### **Introduction**

Marine biodiversity, a complex web of species and ecosystems, is under siege. It's not a distant problem but a pressing one that demands immediate attention. The challenges it faces are numerous and severe, necessitating urgent conservation action for its long-term survival. This report provides a stark overview of the current conservation needs and the imminent threats to marine biodiversity.

Habitat destruction and degradation, driven by coastal development, infrastructure projects, and urban runoff pollution, pose significant threats to marine ecosystems (Halpern *et al.*, 2008). Vulnerable habitats such as coral reefs, mangroves, seagrass beds, and estuaries are particularly affected, impacting the diverse species reliant on these areas for food, shelter, and breeding grounds (Lotze *et al.*, 2006).

Overfishing and unsustainable fisheries practices exacerbate these challenges, leading to the decline of fish stocks and disrupting marine food webs through illegal fishing practices and bycatch of non-target species (Worm *et al.*, 2006). Climate change and ocean acidification further compound these issues, with rising sea temperatures, coral bleaching events, and altered ocean currents altering ecosystem dynamics and threatening marine biodiversity (Hoegh-Guldberg & Bruno, 2010).

Pollution from land-based sources, including plastic waste, chemical runoff, and oil spills, contaminates marine environments, while marine debris such as plastic bags and fishing gear poses entanglement and ingestion risks to aquatic species (Jambeck *et al.*, 2015). Invasive species introduced through ballast water discharge and shipping and disease outbreaks exacerbated by habitat degradation contribute to population declines and ecosystem instability (Ruiz *et al.*, 2000; Harvell *et al.*, 2002).

Despite these challenges, inadequate enforcement of conservation laws, limited funding, and insufficient research and monitoring hinder effective conservation measures, highlighting the urgent need for comprehensive and coordinated efforts to protect marine biodiversity (Dayton *et al.*, 1998; Halpern *et al.*, 2008). The sea cucumber, a marine invertebrate with a leathery skin and elongated body, plays a vital role in aquatic ecosystems (Conand *et al.*, 2022). These creatures are sedentary worldwide on the seafloor (James & James, 1994).



Sea cucumbers are consumed in dried and wet forms, where their muscles are cut into strips and boiled. Additionally, they are used in traditional medicine. Globally, 66 species of sea cucumbers are commonly exploited through fishing (Conand *et al.*, 2022). In the Gulf of Mannar area, 27 species have been reported, seven being commercially important (Ram, 2016). However, indiscriminate exploitation for the lucrative trade has led to overexploitation, endangering the species in the wild (Khan *et al.*, 2017).

The government banned sea cucumber fishing in India by listing it under Schedule I of the Wildlife (Protection) Act of 1972 (Patel *et al.*, 2020). While this ban has helped revive sea cucumber populations in the Gulf of Mannar and Palk Bay (Kumar *et al.*, 2020), it has also impacted the livelihoods of thousands of fishermen families involved in sea cucumber fishing (Khan *et al.*, 2017). Sea cucumbers, scientifically known as Holothuroidea, are marine invertebrates belonging to the phylum Echinodermata. They are renowned for their elongated, cucumber-like body shape, from which they derive their common name. These fascinating organisms play vital roles in marine ecosystems, contributing to nutrient recycling, sediment stabilisation, and biodiversity.

The Indian Ocean, which shares the international water boundary with Sri Lanka, is south of Tamil Nadu. The Gulf of Mannar Biosphere Reserve covers 10,500 km<sup>2</sup>, of which approximately 560 km<sup>2</sup> are coral reefs surrounding 21 islands.

Sea cucumbers exhibit a wide range of shapes, sizes, and colours. Some species resemble elongated cylinders, while others have more rounded or flattened bodies. Their skin is covered in tiny, often microscopic, calcareous ossicles or spicules, which provide structural support and protection. Most sea cucumbers possess tube feet, which they use for locomotion and feeding, and specialised tentacles surrounding their mouth, used for feeding and respiration. Depending on the species, sea cucumbers can range in size from a few centimetres to over a meter in length. Sea cucumbers are found in oceans worldwide, inhabiting various marine environments, including coral reefs, rocky shores, sandy sea beds, and deep-sea trenches.

Sea cucumbers are particularly abundant in tropical and subtropical regions but can also be found in temperate and polar waters. They are essential in maintaining ecosystem health and functioning (Conand *et al.*, 2022). They are detritivores, feeding on organic matter and debris found on the seabed. Their feeding activities contribute to nutrient cycling and decomposition

processes. They also help clean and aerate sediments, promoting sediment stability and preventing organic matter accumulation (Purcell *et al.*, 2012).

Sea cucumbers are preyed upon by various marine organisms, serving as an essential food source for species such as fish, crustaceans, and sea turtles. Humans have harvested sea cucumbers for centuries, primarily for their culinary and medicinal properties, in many Asian countries (Conand *et al.*, 2012). In some cultures, they are considered a delicacy and are often dried and reconstituted in soups, stews, and traditional medicines. The commercial exploitation of sea cucumbers has led to overfishing and depletion of populations in some regions, raising concerns about their long-term sustainability.

Many sea cucumber species face threats from overfishing, habitat destruction, pollution, and climate change, resulting in population declines and local extinctions (Conand *et al.*, 2022). Conservation efforts are underway to protect and manage sea cucumber populations sustainably, including establishing protected areas, regulating fishing practices, and implementing trade controls.

### **Current Status**

- ❖ **Protection status:** The laws of India accord all sea cucumber species the highest level of protection.
- ❖ **Wildlife (Protection) Act of India, 1972:** All species are listed in Schedule I of the Act, making their extraction, trade, or any other form of utilisation a punishable offence.
- ❖ **CITES:** Two species of sea cucumber found in Indian waters *Holothuria fuscogilva* and *H. nobilis* are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 2020, which regulates their international trade (TRAFFIC Report, 2022).

### **Threats & Conservation Challenges**

Like many marine organisms, sea cucumbers face numerous conservation challenges and threats. These challenges stem from a variety of human activities and natural factors.

1. **Overexploitation:** Sea cucumbers are harvested extensively for use in traditional medicine, particularly in East Asia. Their high demand has led to overfishing in many regions, causing population declines and local extinctions (Hamel *et al.*, 2012).

2. **Habitat destruction:** Coastal development, pollution, and destructive fishing practices like bottom trawling can damage sea cucumber habitats such as coral reefs, seagrass beds, and sandy substrates (Conand, 2019). Habitat loss reduces the availability of food and shelter for sea cucumbers, affecting their survival.
3. **Illegal trade:** Illegal, unregulated, and unreported (IUU) fishing for sea cucumbers is a significant problem in many parts of the world. This black-market trade undermines conservation efforts and often involves unsustainable harvesting practices (Vásquez & Pauly, 2018).
4. **Climate change:** Rising sea temperatures, ocean acidification, and changes in ocean currents due to climate change can adversely affect sea cucumber populations. These impacts can disrupt reproduction, larval development, and ecosystem health (Purcell *et al.*, 2013).

### **Plan for Sea Cucumber Recovery and Conservation**

**1. Tackling illegal wildlife trade:** Illegal wildlife trade poses a significant threat to biodiversity, including marine species like sea cucumbers. Strengthening law enforcement efforts is essential to combat this illicit activity (Nijman, 2010). Increasing patrols, surveillance, and coordination with relevant authorities are key strategies to disrupt illegal trade networks and apprehend perpetrators (Lee *et al.*, 2017). Implementing stringent penalties for individuals illegally harvesting, trading, and processing sea cucumbers is crucial to deter such activities (Smith *et al.*, 2018). These penalties should be proportionate to the severity of the offence and include fines, imprisonment, and confiscation of assets (UNODC, 2020). Moreover, conducting awareness campaigns targeting consumers is essential to reduce demand for illegally sourced sea cucumbers (Baker *et al.*, 2013). These campaigns can educate the fisherman, local community, and the general public about the ecological importance of sea cucumbers, the consequences of illegal trade, and sustainable alternatives. Addressing both the supply and demand sides of illegal trade, law enforcement efforts, collaboration with other enforcement agencies, and strong continuous monitoring can help curb the illicit exploitation of sea cucumbers and protect marine ecosystems.

**2. Spatial analysis:** Geographic Information System (GIS) and remote sensing technologies are employed to analyse habitat characteristics and map the spatial distribution of sea cucumbers (Smith *et al.*, 2018). GIS allows for integrating various spatial datasets, such as

bathymetry, substrate type, and water quality parameters, to identify potential habitats for sea cucumbers (Jones *et al.*, 2020). Remote sensing data, such as satellite imagery, can detect and map coastal features associated with sea cucumber habitats, such as seagrass beds and coral reefs (Stewart *et al.*, 2019).

**3. Gear, size, and harvesting restrictions:** Regulation in fishing gear used for sea cucumber harvesting to minimise habitat damage and bycatch. Harvest size restrictions are essential for a recovery plan to ensure the sustainable management of sea cucumber populations (Conand *et al.*, 2014). Scientific assessments determine species-specific minimum size limits based on biological characteristics such as growth rates, reproductive maturity, and ecological functions (Purcell *et al.*, 2009). Utilise empirical data from environmental studies and population assessments to establish minimum size thresholds that allow sea cucumbers to reach reproductive maturity before being harvested (Conand *et al.*, 2014). When setting size limits, consider factors such as species vulnerability, habitat requirements, and population dynamics to ensure the long-term sustainability of sea cucumber populations (Hamaguchi *et al.*, 2016).

**4. Seasonal closures:** Seasonal closures in fisheries management have been widely implemented to promote sustainable harvesting and conservation of marine resources (Sumaila *et al.*, 2000). These closures protect vulnerable species during critical life stages, such as reproduction, and allow populations to replenish and maintain healthy levels (Hilborn *et al.*, 2004). Effective monitoring and enforcement of seasonal closures are crucial to ensure compliance and prevent illegal fishing activities (Gutierrez *et al.*, 2011). This requires the collaboration of various stakeholders, including government agencies, local communities, and non-governmental organisations, to enforce regulations and deter violations (Bennett *et al.*, 2019). By incorporating scientific research, community participation, and robust enforcement mechanisms, seasonal closures can contribute significantly to marine ecosystem conservation and sustainable management.

**5. Habitat restoration:** Habitat restoration is crucial in conserving and recovering sea cucumber populations by addressing habitat degradation and loss, significant threats to their survival (Conand *et al.*, 2014). Implementing habitat restoration projects, particularly in degraded areas such as coral reefs and mangrove forests, can enhance sea cucumber habitats and promote population recovery (Toral-Granda *et al.*, 2008). Restoration efforts may include replanting coral fragments, restoring mangrove vegetation, and improving substrate complexity to create suitable habitats for sea cucumbers to thrive (Yap *et al.*, 2020). Engaging

local communities in habitat restoration efforts is essential for the success and sustainability of such projects (Campbell *et al.*, 2019). Providing training and employment opportunities to residents not only empowers them to contribute to conservation efforts but also fosters a sense of ownership and stewardship of their natural resources (Fernandes *et al.*, 2019). By involving communities in habitat restoration initiatives, it is possible to build social resilience, strengthen conservation partnerships, and promote the long-term recovery of sea cucumber populations.

**6. Climate change:** Understanding the impact of climate change on sea cucumber populations is essential for their conservation and management. Research should investigate various aspects, such as changes in sea surface temperatures, ocean acidification, extreme weather events, and their effects on sea cucumber physiology, behaviour, and habitat suitability (Hampton *et al.*, 2017). Additionally, assessing the impacts of pollution, habitat degradation, and anthropogenic disturbances on sea cucumber habitats is crucial. Studies should examine how sedimentation, nutrient runoff, and marine debris affect sea cucumber health and abundance (Khan *et al.*, 2019).

Monitoring environmental parameters, water quality indicators, and ecological variables is essential to quantifying the effects of climate change and pollution on sea cucumbers (Hampton *et al.*, 2018). This involves collecting data on temperature, pH, dissolved oxygen levels, turbidity, and nutrient concentrations in sea cucumber habitats. Furthermore, monitoring population dynamics, reproductive success, and habitat conditions provides insights into the long-term impacts of environmental stressors on sea cucumber populations (Conand *et al.*, 2019).

**7. Ecological and genetic studies:** Ecological and genetic studies play a crucial role in understanding the dynamics of sea cucumber populations and informing conservation efforts. Ecological studies provide insights into population dynamics, reproductive biology, and environmental roles of sea cucumbers within marine ecosystems (Conand, 2021). Researchers can assess the resilience and sustainability of sea cucumber populations by investigating factors such as reproduction rates, growth patterns, and ecological interactions (Purcell *et al.*, 2016).

Genetic studies complement ecological research by examining sea cucumber populations' genetic diversity, connectivity, and resilience (Rashid *et al.*, 2019). Understanding the genetic variability within and between populations helps identify key conservation priorities and management strategies (Zhang *et al.*, 2017). Additionally, genetic analyses shed

light on sea cucumbers' evolutionary processes and adaptive potential in response to environmental changes and anthropogenic pressures (Chen *et al.*, 2018).

By integrating ecological and genetic approaches, researchers can develop comprehensive conservation plans that address ecological and evolutionary aspects of sea cucumber biology. These interdisciplinary studies are essential for safeguarding the long-term viability of sea cucumber populations and maintaining the integrity of marine ecosystems (Hampton *et al.*, 2020).

**8. Enforcement - Monitoring and Evaluation:** Enforcement of wildlife conservation laws is critical for safeguarding biodiversity and combating illegal activities. To enhance enforcement effectiveness, it is essential to bolster enforcement mechanisms through various strategies such as increased patrols, surveillance, and coordination among law enforcement agencies (Smith *et al.*, 2019). This entails deploying patrols in high-risk areas to deter illegal activities, utilising surveillance technologies like cameras and drones to monitor wildlife habitats, and fostering collaboration among agencies involved in wildlife protection and law enforcement (Jones & Hess, 2020).

Regular monitoring and evaluation programs are integral for assessing the impact of enforcement efforts and refining strategies accordingly. By systematically evaluating the effectiveness of management measures, authorities can identify gaps, trends, and areas of improvement in enforcement practices (Dudley *et al.*, 2018). This involves collecting and analysing data on enforcement activities, wildlife populations, and threats to inform evidence-based decision-making. Adjustments to enforcement strategies based on monitoring and evaluation findings enable authorities to adapt to changing circumstances and optimise resource allocation for maximum conservation impact.

**9. Local community participation:** Engaging local communities in decision-making is paramount for effective sea cucumber management and conservation (Tang *et al.*, 2020). Participatory approaches, such as community consultations and stakeholder workshops, facilitate meaningful involvement and foster a sense of ownership among local stakeholders (Ward *et al.*, 2019). By incorporating traditional knowledge and regional perspectives into management plans, authorities can promote greater acceptance and compliance with conservation measures (Gelcich *et al.*, 2018).



Empowering local communities through training and capacity-building programs is essential for promoting sustainable harvesting practices and fostering stewardship of marine resources (Nash *et al.*, 2021). These programs provide communities with the knowledge and skills to monitor sea cucumber populations, implement sustainable harvesting techniques, and contribute to conservation efforts (Berkes, 2018). By investing in the capacity of local stakeholders, authorities can cultivate a sense of responsibility and collective action towards the long-term sustainability of sea cucumber fisheries.

**10. Education and awareness:** Implementing education and awareness campaigns is crucial for promoting sustainable practices and instilling a culture of conservation among various stakeholders involved in sea cucumber fisheries (Jacobsen *et al.*, 2020). These campaigns should target fishers, traders, consumers, and other relevant groups to ensure a broad-reaching impact (Ratner *et al.*, 2017). By disseminating information about the ecological importance of sea cucumbers and the consequences of overexploitation, stakeholders can make informed decisions that support conservation goals (Cinner *et al.*, 2018).

Providing educational materials and organising workshops are effective strategies for raising awareness about sea cucumbers and the threats they face (Fabinyi *et al.*, 2020). Through interactive sessions and hands-on activities, participants can learn about the role of sea cucumbers in marine ecosystems, the benefits of sustainable harvesting practices, and the risks associated with illegal trade (Foale *et al.*, 2018). Empowering stakeholders with knowledge equip them to become advocates for conservation and champions of responsible resource management.

Implementing this comprehensive management plan can promote the conservation and sustainable harvesting of sea cucumbers while addressing threats such as illegal trade, habitat degradation, and overexploitation. Collaboration among government agencies, local communities, NGOs, and international stakeholders is essential for the success of these efforts.

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## **5. Species Recovery Plan for Dolphin**

### **Introduction**

The Indian Ocean is home to diverse dolphin species with unique characteristics. Among these, the Indo-Pacific dolphins stand out with their robust physique, streamlined body shape, and a distinct long, slender beak (Whitehead & Rendell, 2015). Their colouration is a striking dark grey to bluish-grey on the dorsal side, fading into a lighter grey or white on the ventral side, often with speckling or scars. These dolphins can grow up to 2.7 meters (9 feet) in length and weigh around 230 kilograms (500 pounds), with females slightly smaller than males (Mann *et al.*, 2000).

Indian Ocean dolphins are primarily coastal dwellers, commonly found in shallow coastal waters, bays, estuaries, and lagoons. They thrive in the warm waters of the Indian Ocean, particularly along the coasts of eastern Africa, the Arabian Peninsula, the Indian subcontinent, Southeast Asia, and northern Australia. Their diet is diverse, with these opportunistic feeders preying on various fish, cephalopods, and crustaceans (Perrin *et al.*, 2009).

Ocean dolphins use echolocation to locate prey and often hunt in shallow waters with abundant food. They are highly social animals and typically form groups called pods, ranging in size from a few individuals to several dozen. They are known for their acrobatic behavior, including breaching, tail-slapping, and bow-riding (Reeves *et al.*, 2002). There is a complex social structure with individuals forming strong bonds through social interactions such as grooming, play, and cooperative hunting (Connor *et al.*, 2000). Female dolphins tend to remain in the same pod throughout their lives, while males may move between pods (Connor *et al.*, 2000).

Dolphin communication involves vocalizations, including whistles, clicks, and pulsed sounds. These vocalizations are crucial in maintaining social cohesion within the pod and coordinating group activities such as hunting (Janik & Slater, 1998). Dolphins face various threats, including habitat degradation, pollution, entanglement in fishing gear, boat strikes, and disturbance from human activities such as coastal development and maritime traffic (Lusseau *et al.*, 2003). Dolphins are not currently classified as endangered; they face conservation challenges due to human-induced threats and habitat loss. However, local populations may be at risk in areas with more pronounced threats (Hammond *et al.*, 2008).

Dolphin conservation efforts include establishing marine protected areas, regulations to reduce bycatch in fisheries, efforts to mitigate vessel strikes, and public awareness campaigns to promote responsible dolphin-watching practices (Bearzi *et al.*, 2008). Additionally, dolphin ecology and behavior research help inform conservation strategies to protect these charismatic marine mammals and their habitats (Williams *et al.*, 2001).

### Dolphin species

In Indian waters, several species of dolphins inhabit the diverse marine environments. Among them are the Gangetic River Dolphin, scientifically known as *Platanista gangetica*, locally referred to as Susu, which is classified as Endangered according to the IUCN (Braulik *et al.*, 2017). Similarly, the Indus River Dolphin, identified as *Platanista minor* or Bhulan locally, shares the same Endangered status (Braulik *et al.*, 2017). The Irrawaddy Dolphin, known locally as *Orcaella brevirostris* or Sundarbans/Ayeyarwady dolphin, is also endangered (Smith *et al.*, 2017). Moving on to the Humpback Dolphin, scientifically named *Sousa plumbea*, its local name is yet to be determined, and it holds a Vulnerable status according to the IUCN (Jefferson *et al.*, 2017). The Indo-Pacific Bottlenose Dolphin, scientifically identified as *Tursiops aduncus*, and the Common Dolphin, known as *Delphinus delphis*, both lack specific local names and have a Data Deficient status concerning the Indian Ocean subpopulation (Jefferson *et al.*, 2017). Regarding conservation status, these dolphins fall under Schedule I and Schedule II of the Wildlife (Protection) Act, 1972. Moreover, they are included in different appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), all listed in Appendix I or II (CITES, 2022). It's important to note that local names may vary across regions within India, and while the IUCN statuses provided here are global, regional variations may exist.

### List of marine dolphins present in coastal waters of India

Sl. No.	Common Name	Scientific Name	IUCN Status	WPA, 1972 Schedule
1	Indo-Pacific Bottlenose Dolphin	<i>Tursiops aduncus</i>	Near Threatened	Schedule - I
2	Indo-Pacific Humpback Dolphin	<i>Sousa chinensis</i>	Vulnerable	Schedule - I
3	Pantropical Spinner Dolphin	<i>Stenella longirostris</i>	Least Concern	Schedule - I
4	Pantropical Spotted Dolphin	<i>Stenella attenuata</i>	Least Concern	Schedule - I
5	Risso's Dolphin	<i>Grampus griseus</i>	Least Concern	Schedule - I



6	Rough-toothed Dolphin	<i>Steno bredanensis</i>	Least Concern	Schedule - I
7	Short-beaked Saddleback Dolphin/ Common Dolphin	<i>Delphinus delphis</i>	Least Concern	Schedule - I
8	Striped Dolphin	<i>Stenellacoeruleoalba</i>	Least Concern	Schedule - I
9	Indian Ocean humpback dolphin	<i>Sousa plumbea</i>	Endangered	Schedule - II
10	Long-beaked common dolphin	<i>Delphinus capensis</i>	Least Concern	Schedule – II
11	Common bottlenose dolphin	<i>Tursiops truncatus</i>	Least Concern	Schedule - II
12	Irrawaddy Dolphin	<i>Orcaella brevirostris</i>	Endangered	Schedule - I

### Current status

Dolphins are charismatic marine mammals that inhabit Tamil Nadu's coastal waters. They contribute to the region's marine biodiversity and ecosystem dynamics. However, these species face various threats, necessitating a thorough understanding of their current status to guide conservation efforts effectively.

Project Dolphin, launched by the Tamil Nadu government as part of the Government of India's Integrated Development of Wildlife Habitats program, aims to protect and conserve dolphin species in Tamil Nadu's coastal areas. Over nine species of marine dolphins inhabit these waters, and the research focuses on the critical ecosystems within the Gulf of Mannar Biosphere Reserve, a region noted for its diverse marine biodiversity (TN Press release, 2023).

Among the dolphin species found in Tamil Nadu, the Indo-Pacific Humpback Dolphin (*Sousa plumbea*) stands out as an emblematic species. The International Union for Conservation of Nature (IUCN) has classified it as Endangered (Smith *et al.*, 2017). The Indo-Pacific Humpback Dolphin population in Tamil Nadu is vulnerable due to habitat degradation, fishing-related activities, and anthropogenic disturbances along the coastline. The Irrawaddy Dolphin (*Orcaella brevirostris*) is another notable species inhabiting the coastal waters of Tamil Nadu. Classified as Vulnerable by the IUCN (Smith *et al.*, 2017), the Irrawaddy Dolphin faces threats such as habitat loss, pollution, and accidental entanglement in fishing gear, jeopardizing its long-term survival in the region. The Bottlenose Dolphin (*Tursiops truncatus*) is also present in Tamil Nadu's coastal waters. While classified as Least Concern by the IUCN (Reeves *et al.*, 2018), the population of Bottlenose Dolphins in Tamil Nadu is not immune to

anthropogenic pressures, including habitat degradation, pollution, and boat strikes, which could have implications for its conservation status in the future.

The dolphin population in Tamil Nadu, particularly in the coastal waters, is facing significant challenges that threaten its existence. Despite some conservation efforts, the dolphins continue to confront threats such as habitat degradation, pollution, accidental entanglement in fishing gear, and boat strikes. A study by (Kumar *et al.*, 2019) indicates that the dolphin population in Tamil Nadu is under pressure due to anthropogenic activities, with notable declines observed in recent years.

Coastal development and industrial pollution threaten dolphin habitats, affecting their food sources and reproductive success (Ravindran *et al.*, 2017). Furthermore, bycatch in fishing gear remains a persistent threat to dolphin populations along the Tamil Nadu coast (Saravanan *et al.*, 2015). Understanding the current status of these dolphin species in Tamil Nadu is imperative for devising targeted conservation strategies to mitigate threats and ensure their long-term survival in the region's coastal ecosystems.

### **Threats / Conservation challenges**

**1. Habitat Degradation:** Dolphins depend highly on healthy marine and freshwater habitats for feeding, breeding, and resting. Habitat degradation due to coastal development, pollution (including oil spills, chemical contaminants, and marine debris), dredging, and habitat fragmentation pose a significant threat to dolphin populations worldwide.

**2. Overfishing and bycatch:** Dolphins often become unintentional victims of fishing gear such as gillnets, trawls, and longlines, leading to injury or death through entanglement or accidental capture (bycatch). Overfishing of prey species can also indirectly impact dolphin populations by reducing food availability.

**3. Climate change:** Rising sea temperatures, ocean acidification, and changes in ocean currents and prey distribution due to climate change pose significant threats to dolphin populations. These environmental changes can disrupt prey availability, alter habitat suitability, and increase the frequency and intensity of extreme weather events.

**4. Environmental pollution:** Dolphins encounter multiple pollution threats in their aquatic habitats, including chemical contaminants, plastics, oil spills, and, notably, noise pollution. Underwater noise, originating from human activities like shipping and construction, disrupts

essential communication, echolocation, and feeding behaviors. Prolonged exposure to elevated noise levels induces chronic stress, habitat displacement, and reduced reproductive success in dolphins, heightening their vulnerability to predation and other threats. Addressing noise pollution is crucial to mitigate its detrimental impacts on dolphin populations and their habitats.

**5. Collisions with vessels:** Dolphin's risk colliding with vessels, especially in areas with high maritime traffic. Vessel strikes can cause injuries or fatalities, particularly for species that inhabit coastal and estuarine environments or migrate through shipping lanes.

**6. Illegal wildlife trade:** Some dolphin species are targeted for capture and trade for entertainment purposes in dolphinariums or traditional medicines and souvenirs. Illegal trade can devastate wild dolphin populations and tiny and isolated populations.

**7. Lack of legal protection and enforcement:** Inadequate legal protection and enforcement of existing conservation measures, including regulations related to habitat protection, bycatch mitigation, and wildlife trade, undermine efforts to conserve dolphin populations effectively.

**8. Human-wildlife conflict:** Conflicts between dolphins and human activities such as fisheries, aquaculture, and coastal development can lead to negative perceptions of dolphins and result in retaliatory killings, habitat degradation, or displacement of dolphin populations.

**9. Tourism and recreation activities:** They offer opportunities for enjoyment and relaxation, but they also impact the environment, including marine ecosystems and wildlife like dolphins. Dolphin-watching tours, widespread in coastal regions, can provide education and conservation awareness. However, poorly managed tours, such as overcrowding or approaching dolphins too closely, can stress dolphins and alter their natural behaviors. Similarly, direct interactions such as swimming, snorkeling, and diving with dolphins are typical tourist attractions. While enjoyable, these activities can disrupt dolphin behaviors, increase stress, and lead to physical harm or disease transmission between dolphins and humans. Balancing the benefits of tourism with the conservation needs of dolphin populations requires careful management and responsible tourism practices.

### **Management implications**

**1. Habitat restoration and improvement:** A robust habitat restoration and improvement plan must prioritize scientific research, community engagement, and adaptive management. This involves identifying degraded habitats through comprehensive assessments (Magesh, N. S., &

Krishnakumar, 2019), implementing restoration projects such as replanting native vegetation and creating artificial reefs (Robinson, 2006), and monitoring the effectiveness of these initiatives over time. Artificial reefs are planned in the Gulf of Mannar to restore dolphin habitat (Choudhury *et al.*, 2007). Collaboration between government agencies, NGOs, and local communities is crucial for securing funding, implementing restoration projects, and ensuring long-term sustainability (Khan & Varshney 2024).

**2. Bycatch mitigation:** Bycatch mitigation strategies require regulatory measures, technological innovation, and stakeholder collaboration. This includes promoting the use of selective fishing gear (García *et al.*, 2024) & (Thomas *et al.*, 2022), implementing real-time monitoring systems, and establishing no-fishing zones in critical habitats (Prajith, 2022). Educational programs aimed at fishermen and seafood consumers can raise awareness about the importance of bycatch reduction and sustainable fishing practices.

**3. Overfishing:** To address overfishing, management plans should incorporate science-based fisheries management, enforcement of regulations, and stakeholder engagement. Setting catch limits based on stock assessments, implementing seasonal closures, and reducing fishing capacity are crucial steps to prevent overexploitation of marine resources (Curtin, & Prellezo, 2010). Additionally, establishing marine protected areas and promoting alternative livelihoods for affected communities can help alleviate pressure on overfished stocks (Hilborn, & Hilborn, 2019) & (Grip & Blomqvist 2020).

**4. Collisions with vessels:** Effectively managing vessel collisions with marine mammals involves implementing regulations to reduce vessel speed in critical habitats and designating whale-safe shipping lanes (Wells & Fahlman 2024). Utilizing technologies such as acoustic monitoring and real-time vessel tracking can help identify high-risk areas and mitigate the risk of collisions (Schoeman *et al.*, 2020). Collaboration between shipping industries, government agencies, and conservation organizations is essential for developing and implementing vessel collision avoidance measures (Ritter & Panigada 2019) & (Dolman *et al.*, 2006).

**5. Rescue and release standards of Dolphins:** Management methods for dolphin rescue and release should prioritize the welfare of stranded individuals while ensuring the long-term viability of populations (Wells *et al.*, 2022). This includes establishing protocols for assessing the health and behavior of stranded dolphins, providing appropriate medical treatment and

rehabilitation, and conducting post-release monitoring to determine survival and integration into the wild (IUCN Report, 2022). Collaboration between marine mammal rescue organizations, veterinarians, and government agencies is critical for coordinating rescue efforts and enforcing standards for dolphin rehabilitation and release (Conservation Action Plan for the World's Cetaceans - IUCN). 7 Dolphins were rescued and released to the sea at the Gulf of Mannar Biosphere Reserve (TN Press release, 2023).

**6. Tackling illegal wildlife trade:** Combatting illegal wildlife trade requires strengthening law enforcement, enhancing international cooperation, and reducing consumer demand for wildlife products. This includes increasing penalties for wildlife trafficking, improving intelligence gathering and sharing, and raising public awareness about the impacts of illegal wildlife trade (UNODC, 2021) & (Kumar *et al.*, 2021). Collaboration between law enforcement agencies, customs authorities, and conservation organizations is essential for disrupting wildlife trafficking networks and protecting endangered species (UNODC, 2021) & (CITES Summary).

**7. Reduction in environmental pollution:** Management ideas to reduce environmental pollution should prioritize measures to address plastic waste, chemical pollution, and habitat degradation. This includes implementing regulations to limit single-use plastics, promoting recycling and waste management initiatives, and restoring degraded ecosystems (Jambeck *et al.*, 2015) & (Bertolazzi *et al.*, 2024). Public education campaigns and community engagement are crucial for fostering behavior change and promoting sustainable practices to reduce pollution (Narra *et al.*, 2022).

**8. Tackling climate change:** Management strategies to tackle climate change involve mitigating greenhouse gas emissions, enhancing resilience to climate impacts, and transitioning to renewable energy sources (Masson-Delmotte, 2021). This includes implementing policies to reduce carbon emissions, investing in renewable energy infrastructure, and promoting sustainable land-use practices. International cooperation and commitments under the Paris Agreement are essential for achieving global climate targets and minimizing the impacts of climate change on ecosystems and communities (Wernberg *et al.*, 2024).

**9. Reduce human-wildlife conflicts:** Management plans to reduce human-wildlife conflicts should incorporate preventive measures, conflict resolution strategies, and community engagement. This includes implementing barriers and deterrents to prevent wildlife access to

human settlements, developing early warning systems to alert communities of wildlife presence, and compensating for crop damage or livestock loss (Arthington *et al.*, 2016). Collaborative approaches involving local communities, conservation organizations, and government agencies are essential for addressing underlying causes of human-wildlife conflicts and promoting coexistence (Holobinko & Waring 2010; Servais 2020).

**10. Proper maintenance in tourism and recreation activities:** Effective tourism and recreation management requires implementing regulations, monitoring visitor behavior, and promoting sustainable practices. This includes establishing carrying capacity limits, zoning recreational activities to minimize habitat disturbance, and providing education and interpretation programs to raise awareness about environmental conservation (Honey 2008) (Ramsar Site Information Services). Collaboration between tourism operators, conservation NGOs, and government agencies is essential for enforcing regulations and ensuring proper maintenance of tourism infrastructure (Barkin & Bouchez 2002).

**11. Awareness and education:** Developing awareness and education programs is crucial for promoting environmental conservation and sustainable practices. These programs should target various stakeholders, including local communities, fishermen, tourists, and policymakers, to raise awareness about the importance of biodiversity conservation, sustainable resource management, and the impacts of human activities on ecosystems (Malla 2007). Utilizing diverse communication channels such as workshops, educational materials, social media, and community outreach events can help engage a wide audience and foster a culture of environmental stewardship (Guidino *et al.*, 2023).

**12. Capacity building for fishermen:** Capacity-building programs aimed at fishermen are essential for promoting sustainable fishing practices, improving livelihoods, and reducing pressure on marine resources. These programs should provide training on responsible fishing techniques, resource management, and regulation compliance (Umamaheswari *et al.*, 2021). Additionally, providing access to alternative income-generating activities, such as ecotourism or aquaculture, can help reduce dependency on fishing and alleviate poverty in fishing communities (Lobe & Berkes 2004). Collaboration between government agencies, NGOs, and fishing associations is critical for designing and implementing adequate capacity-building initiatives tailored to the needs of local fishing communities (Daw *et al.*, 2012).



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## **6. Species recovery plan for Dugong**

### **Introduction**

The dugong (*Dugong dugon*, Muller 1776) is a charismatic marine mammal that belongs to the Sirenia order and also includes manatees. It is the only living representative of the family Dugongidae, commonly known as the "sea cow," this species resides exclusively in the sea, distinguishing it as the sole existing herbivorous mammal with such habitat preference. (Nair et al., 1975), (Husar, 1975), (Marsh *et al.*, 1999), (Silva & Marsh, 2017) (Hines *et al.*, 2019)

Dugong, found predominantly in the warm coastal waters of the Indo-Pacific region, including regions such as the Gulf of Mannar, Palk Bay, Gulf of Kutch, and the Andaman and Nicobar Islands, the dugong's distribution spans a significant portion of the marine ecosystem (Preen, 2004), (Sivakumar, 2013),

Morphologically, dugongs exhibit a streamlined body equipped with paddle-like flippers and a horizontally flattened tail, enabling efficient movement through their aquatic environment. Their large, muscular lips are adept at grasping and uprooting seagrass, their primary source of nutrition. It measures 2-4 meters long and weighs 300 – 500 kg. (Romero, 2009), (Kumar & Rahul 2024) & (Marsh & Cleguer 2024) Behaviorally, dugongs are often observed in solitary or small group settings, although larger aggregations may form in areas abundant with food resources or during mating seasons (Marsh *et al.*, 1984; Werth & Marshall 2023; Leung *et al.*, 2024). Their ability to hold their breath for extended periods and dive to significant depths facilitates their survival in the marine habitat.

Ecologically, dugongs are known as 'ecosystem engineers' for their vital role in shaping the dynamics of coastal ecosystems, mainly through their feeding habits (Marsh *et al.*, 2011). Since it's an herbivore, its diet mainly consists of seagrasses of the genera *Cymodocea*, *Halophila*, *Thalassia* and *Halodule*. By grazing on seagrass, dugongs contribute to the maintenance of seagrass communities, enhancing overall ecosystem productivity and biodiversity (ABC, 2021), (Prajapati *et al.*, 2021) & (Dewi *et al.*, 2024).

The dugong has been hunted for its meat and oil for thousands of years. Traditional hunting still has great cultural significance in several countries in its modern range. The dugong's current distribution is fragmented, and many populations are believed to be close to extinction. The IUCN lists dugong as a species vulnerable to extinction. At the same time, the Convention on International Trade in Endangered Species (CITES) categorizes to Appendix-I where it

limits or bans the trade of this species or its derived products. In India, it is placed under Schedule I of the Wild Life (Protection) Act, 1972, granting it the highest level of protection (Marsh, Soltzick 2019).

Despite being legally protected in many countries, the leading causes of population decline remain anthropogenic and include fishing-related fatalities, habitat degradation, and hunting. The dugong is especially vulnerable to extinction because of its long lifespan of 70 years or more and slow reproduction rate. (Preen, 1995) (Marsh *et al.*, 2018).

Conserving dugongs holds crucial significance. As a flagship species for conservation efforts, dugongs serve as ecological indicators of marine environment's overall health and integrity. (Kamboj, 2014). Conserving dugong populations involves mitigating threats like habitat loss, entanglement in fishing gear, pollution, and illegal hunting. Through these conservation initiatives, dugongs are safeguarded, and the entire coastal ecosystem is preserved, benefiting numerous other species and human communities dependent on these resources.

## **Current Status**

### **Global status**

Globally, the dugong (*Dugong dugon*) is classified as "Vulnerable" on the IUCN Red List of Threatened Species. The population of dugongs worldwide has been declining, with estimates suggesting a more than 30% decrease over the last 60 years. As of the latest assessments, fewer than 100,000 dugongs are left worldwide. The main threats to dugongs globally include habitat loss and degradation, overfishing of their seagrass food sources, and accidental entanglement in fishing gear. (Marsh *et al.*, 2002), (Preen, 2004) & (Hagihara *et al.*, 2017),

### **In India**

In India, dugongs are primarily found along the Andaman and Nicobar Islands coasts, the Gulf of Mannar, the Gulf of Kutch, and the Palk Bay. According to a report by the Wildlife Institute of India (WII), the dugong population in India is estimated to be around 300 individuals. However, this population is declining due to various threats, including habitat loss, coastal development, pollution, and bycatch in fishing gear (Pandey *et al.*, 2010; Sivakumar, 2013; Hatkar *et al.*, 2023).

## **In Tamil Nadu**

Tamil Nadu, located on the southeastern coast of India, hosts a significant population of dugongs, particularly in the Gulf of Mannar and the Palk Bay. According to a survey conducted by the Tamil Nadu Forest Department, the dugong population in that region is estimated to be around 150 individuals. This population size makes the dugongs in Tamil Nadu particularly vulnerable to threats such as habitat degradation, pollution, and accidental entanglement in fishing gear (Ilangakoon *et al.*, 2008; Newmaster *et al.*, 2011; Anand *et al.*, 2015; Sohom *et al.*, 2023).

### **India's first dugong conservation reserve**

The establishment of the Dugong Conservation Reserve in Palk Bay, announced by Tamil Nadu on September 3, 2021, aims to protect Dugongs and their marine habitats. The reserve covers an area of 448 sq. km across Thanjavur and Pudukkottai Districts. The reserve's establishment signifies a major milestone in global marine conservation efforts (TN, DIPR, Secretariat, 2022).

### **Threats / Conservation challenges**

- 1. Habitat Loss and Degradation:** Dugongs primarily inhabit shallow coastal waters, seagrass beds, and mangrove ecosystems. However, these habitats are threatened by coastal development, dredging, and pollution. Human activities such as land reclamation, port construction, and urban expansion can destroy and degrade critical dugong habitats, leading to habitat loss and fragmentation.
- 2. Overexploitation:** Due to their slow reproductive rates and long lifespans, dugongs are vulnerable to overexploitation. Despite legal protections in many countries, they are often hunted for meat, oil, and other body parts. Overharvesting dugongs for traditional medicine and subsistence purposes, particularly in regions where they are culturally significant, can lead to population declines and local extinctions.
- 3. Hunting:** Hunters target dugongs for their meat, oil, and other body parts, posing a significant threat to survival. Traditional hunting practices, often driven by cultural beliefs and socioeconomic factors, continue to exert pressure on dugong populations, particularly in regions where enforcement of conservation laws is weak.



4. **Vessel strikes:** Dugongs risk collisions with vessels, including boats, ships, and watercraft, especially in areas with high maritime traffic. These collisions can result in injuries or fatalities for dugongs, as they may be struck by propellers or suffer internal injuries from the impact, further endangering already vulnerable populations.

5. **Incidental bycatch:** Dugongs can become unintentionally caught in fishing gear, such as nets, traps, and gillnets intended for other marine species. Incidental bycatch poses a severe threat to dugong populations, particularly in areas where they overlap with commercial fishing activities, leading to injuries, drowning, and death.

6. **Tourism activities:** While tourism can provide economic benefits and opportunities for conservation awareness, unregulated tourism activities can disrupt dugong habitats and behavior. Boat traffic, noise pollution, and habitat disturbance associated with ecotourism can stress dugongs and disrupt their feeding, breeding, and migration patterns, threatening their long-term survival.

7. **Acoustic pollution:** Dugongs rely on sound for communication, navigation, and foraging. However, underwater noise pollution from shipping, construction, and industrial activities can interfere with their ability to communicate and navigate, leading to disorientation, habitat avoidance, and increased vulnerability to predation and other threats.

8. **Environmental pollution:** Dugongs are susceptible to environmental pollution, including chemical pollutants such as heavy metals, pesticides, and oil spills. Pollution from agricultural runoff, industrial discharge, and sewage contamination can degrade water quality and seagrass habitats, exposing dugongs to toxins and contaminants that can affect their health and reproductive success.

9. **Illegal trade:** Dugongs are illegally traded for their meat, oil, and other body parts, despite legal protections under national and international laws. Poaching and illegal trade pose a significant threat to dugong populations, particularly in regions where they are targeted for their perceived medicinal or cultural value, exacerbating existing pressures on their survival.

10. **Coastal developmental activities:** Coastal development projects, such as land reclamation, port construction, and urban expansion, can destroy and degrade dugong habitats, including seagrass beds and mangrove ecosystems. Habitat loss and fragmentation due to coastal development activities can isolate dugong populations, reducing their genetic diversity and increasing their vulnerability to extinction.

**11. Climate change:** Climate change and global warming pose significant threats to dugong populations and their habitats. Rising sea temperatures, ocean acidification, and extreme weather events can disrupt seagrass growth, alter marine ecosystems, and reduce the availability of suitable habitats for dugongs, leading to food shortages and population declines.

**12. Invasive alien species of seagrass/seabed:** Invasive alien species, such as exotic seagrass species, can outcompete native seagrass species, disrupt ecosystem dynamics, and degrade dugong habitats. Introducing invasive species into dugong habitats can lead to habitat loss and fragmentation, reducing food resource availability and threatening dugong populations' survival.

### **Management Implications**

**1. Habitat loss and degradation:** One of the primary management implications for dugong conservation is addressing habitat loss and degradation (Marsh, H, 1988). Bottom trawling was found to be the most severe threat to the seagrass beds. Seagrasses are ecological indicators of water quality and ecosystem (Jagtap *et al.*, 2003; Miththapala, 2008). This involves implementing measures to protect and restore seagrass habitats, which are crucial for dugong survival (Sivakumar and Nair 2013). Management strategies may include establishing marine protected areas (MPAs) encompassing critical dugong habitats, implementing habitat restoration projects, and regulating coastal development to minimize habitat destruction. Additionally, implementing habitat restoration projects, such as replanting seagrass beds, can help reverse the impacts of habitat loss (Edward *et al.*, 2019). These initiatives benefit biodiversity and provide essential ecosystem services, including coastal protection and carbon sequestration (Dodampahala, 2023).

**2. Tackling overexploitation:** Overexploitation of marine resources threatens the sustainability of fisheries and marine ecosystems globally (CMS-Dugong). Addressing this issue requires the implementation of sustainable fisheries management strategies. Science-based catch limits, gear restrictions, and seasonal closures are essential for preventing overfishing and minimizing bycatch (Kasim, 2015). Moreover, promoting ecosystem-based fisheries management approaches / sustainable fisheries management can help maintain marine resources, ensuring ecological balance and preserving marine biodiversity (Infantina *et al.*, 2016).

**3. Gear size management:** Regulating fishing gear size and type is essential for reducing bycatch and minimizing habitat damage in marine ecosystems. Implementing gear restrictions, such as using selective fishing gear or banning destructive methods, can mitigate these impacts. Regular inspections and enforcement of gear regulations are necessary to ensure compliance and prevent illegal practices. Innovations like advanced navigation systems, satellite communication devices, and improved fishing gear have boosted efficiency while minimizing catch and habitat destruction (Mehalakshmi. & Hemanalini 2023; Gunasekaran *et al.*, 2024). Providing incentives for fishermen to adopt sustainable gear practices can promote the adoption of responsible fishing practices, minimize the ecological footprint of fishing activities, and protect marine ecosystems.

**4. Management of vessel strikes/boat traffic regulations:** Managing and regulating vessel strikes are crucial for protecting marine mammals like dugongs (Marsh *et al.*, 2003), (). Implementing rules such as speed limits and vessel routing measures can reduce the risk of collisions in critical habitat areas. Tamil Nadu government has effectively promoted eco-friendly practices among fishers by offering subsidies such as financial aid for acquiring modern fishing equipment and vessels, training programs to enhance skills and knowledge, and incentives for adopting sustainable fishing methods. Technological advancements have also been instrumental in advancing sustainability within the fishing industry (Mehalakshmi & Hemanalini 2023; Medha 2023). Raising awareness among boat operators about the importance of avoiding marine mammals and providing training on collision avoidance techniques are also essential. Installing navigational aids and implementing real-time monitoring systems can further reduce the risk of vessel strikes and protect marine mammal populations (Ilangakoon, 2012).

**5. Bycatch mitigation strategies:** Implementing bycatch reduction measures is crucial for minimizing incidental catch of non-target species (Joshi *et al.*, 2015). Using excluder devices (EDs) and circle hooks can reduce bycatch while maintaining target catches (Briscoe *et al.*, 2014; Nammalwar *et al.*, 2013; Natoli & Al Hameli, 2023). Implementing seasonal closures in bycatch hotspots and engaging fishermen in developing bycatch reduction techniques are also essential. By prioritizing the conservation of non-target species and promoting sustainable fishing practices, we can minimize the ecological impacts of bycatch and support healthy marine ecosystems (Hodgson *et al.*, 2007; Gunasekaran *et al.*, 2024).

**6. Rehabilitation measures:** Implementing rehabilitation measures is crucial for restoring degraded habitats and recovering populations of threatened species. This may involve captive breeding and reintroduction programs, habitat restoration projects, and pollution cleanup efforts (Kashyap *et al.*, 2023), (National Guidelines for the Survey of Cetaceans, Marine Turtles and the Dugong). Engaging local communities in rehabilitation initiatives can foster stewardship and promote long-term conservation efforts. By investing in habitat restoration and species recovery programs and collaborating with stakeholders, we can help restore balance to marine ecosystems and support the recovery of threatened species (Sivakumar, 2013; Sivakumar *et al.*, 2019; Sivakumar *et al.*, 2020; Simeone *et al.*, 2024).

**7. Tourism regulations and guidelines:** Managing tourism activities is essential for minimizing negative impacts on marine ecosystems and wildlife (Birtles *et al.*, 2005). This includes establishing carrying capacity limits, zoning regulations, and promoting responsible tourism practices through education and awareness campaigns (van Veghel 2019). Collaborating with tour operators, local communities, and government agencies is crucial for developing and implementing effective tourism regulations and guidelines. By promoting sustainable tourism practices and minimizing environmental impacts, we can ensure that marine tourism contributes to the conservation of marine ecosystems and supports local livelihoods (Havemann & Smith 2007; Dhandapani 2012; Panyawai & Prathep 2022).

**8. Tackling acoustic pollution:** Reducing acoustic pollution requires mitigating anthropogenic noise from shipping and construction activities on and off shores (Leaper, & Renilson, 2012; Das, 2019). Implementing quiet ship design and routing measures, regulating underwater construction, and establishing marine protected areas can help minimize noise pollution (Gullett, 2022). Researching the effects of underwater noise on marine species is essential for developing effective mitigation strategies. By addressing the sources of acoustic pollution and implementing measures to reduce noise impacts, we can protect marine wildlife and preserve healthy marine ecosystems (Rako-Gospić, & Picciulin, 2023).

**9. Mitigation standards for environmental pollution:** Implementing mitigation standards for environmental pollution involves regulating industrial discharge, sewage runoff, and plastic pollution (Qasim *et al.*, 1988), (Shanmugam *et al.*, 2007), (Zutshi, & Prasad, 2008), (Seth, 2014), (Rajmohan *et al.*, 2019). This includes enforcing pollution control measures, promoting clean technologies, and implementing pollution monitoring programs. Collaboration with industries, local communities, and government agencies is essential for implementing effective

pollution mitigation measures. By addressing environmental pollution and promoting sustainable practices, we can protect marine ecosystems and safeguard human health (Haynes, 2001; Gupta *et al.*, 2005; Vivekanandan *et al.*, 2010; Thushari, & Senevirathna, 2020; Kibria *et al.*, 2023; Sambandam *et al.*, 2024).

**10. Illegal trade control:** Combating illegal wildlife trade requires strengthening law enforcement efforts, enhancing border controls, and increasing penalties for wildlife trafficking offenses (Silas, & Fernando, 1988). Collaboration with international organizations and neighboring countries is essential for disrupting wildlife trafficking networks (Hines *et al.*, 2012; Nijam and Nekaris 2014; Ezekiel, 2018). By addressing illegal trade routes and dismantling trafficking networks, we can protect marine biodiversity and support the conservation of marine ecosystems (Jamadhagni, & Umarhathab, 2022).

**11. Enforcement and monitoring guidelines:** Effective enforcement and monitoring are critical for ensuring compliance with conservation regulations and detecting illegal activities (Marsh *et al.*, 2002). This involves deploying patrols, utilizing surveillance technologies, and strengthening cooperation between law enforcement agencies and local communities. Developing clear guidelines and protocols for monitoring and reporting violations is essential for maintaining accountability and transparency in enforcement efforts (Shawky *et al.*, 2024). Regular training and capacity building for enforcement personnel are also necessary to enhance their ability to detect and respond to illegal activities (Borobia *et al.*, 2023) & (Caddell. R, 2023).

**12. Coastal development guidelines/standards:** Developing coastal development guidelines and standards is essential for managing coastal growth while minimizing environmental impacts (Devaraj 1996; Smith *et al.*, 2023). This includes conducting environmental impact assessments for development projects and establishing setback regulations. Collaboration with developers, policymakers, and local communities is crucial for balancing economic development with environmental conservation goals (Islam, & Tanaka, 2004), (Dugong Status Report- UNEP; Ramesh *et al.*, 2020; Koubrak, 2023). By implementing sustainable coastal development guidelines and standards, we can protect marine ecosystems and ensure the long-term well-being of coastal communities.

**13. Tackling climate change:** Addressing climate change requires mitigation and adaptation strategies (Marsh *et al.*, 2017). This includes reducing emissions through renewable energy

development and implementing adaptation measures such as coastal zone management (Sivakumar, 2013; Hobday *et al.*, 2015, Marsh *et al.*, 2022). Collaboration between governments, NGOs, and local communities is essential for addressing the impacts of climate change on marine ecosystems and coastal communities. By implementing climate change mitigation and adaptation measures, we can protect marine biodiversity and support the long-term health of marine ecosystems (Schumann *et al.*, 2013; Ramesh *et al.*, 2019; Islam, 2024).

**14. Research & monitoring:** Investing in research and monitoring programs is essential for understanding the ecological dynamics of marine ecosystems and guiding conservation efforts. Research efforts such as genetic studies, spatial mapping of seagrass habitats (Seal *et al.*, 2024), and drone monitoring of dugongs and their habitats provide essential data for informing conservation decisions and prioritizing management actions (NEA and UNEP-WCMC, 2024; Bharathi *et al.*, 2014; Dudhat *et al.*, 2022; Cossa *et al.*, 2023; Andriansyah, 2023). Collaboration with research institutions, government agencies, and local communities is crucial for collecting accurate data and implementing evidence-based management strategies. Investing in research and monitoring efforts can improve our understanding of marine ecosystems and support effective conservation and management actions.

**15. Mitigation of invasive alien species in seagrass/sea bed:** Mitigating the spread of invasive alien species in seagrass and seabed habitats requires implementing early detection and rapid response measures (Thangaradjou, & Bhatt, 2018; Vedharajan, *et al.* 2023; Ramesh *et al.*, 2024). This includes conducting regular surveys to identify invasive species and implementing control measures such as manual removal or biological control methods. Restoring native habitat can enhance resilience against invasions and support the recovery of native species (Svarachorn, 2023), (Senthilkumar & Kannan 2008), (Dodampahala, 2023). Collaboration with scientists, conservation organizations, and local communities is essential for effectively managing invasive species and protecting native biodiversity. By prioritizing preventing and controlling invasive species, we can preserve native habitats and support healthy marine ecosystems.

**16. Community engagement in conservation initiatives:** Engaging local communities in conservation initiatives is essential for fostering stewardship and promoting sustainable resource management practices (Venkataraman, 2012). Local communities often possess valuable traditional knowledge and play a critical role in habitat management and stewardship (Bayliss *et al.*, 2015 Nanayakkara *et al.*, 2016). Providing education and training opportunities,



involving communities in decision-making processes, and recognizing traditional ecological knowledge are essential strategies for fostering community engagement (Venkataraman, 2007; Newmaster *et al.*, 2011; Siddiqui *et al.*, 2024; Saravanan, 2020). By empowering local communities to participate in conservation initiatives, we can foster a sense of ownership and responsibility for marine resources, leading to more effective and sustainable conservation outcomes.

**17. Awareness and education:** Raising awareness and educating the public about marine conservation issues is crucial for fostering a culture of environmental stewardship. Many people may be unaware of the threats facing marine ecosystems and the actions they can take to support conservation efforts. Developing outreach programs, organizing workshops and seminars, and utilizing media platforms to disseminate information can help raise awareness about the importance of marine biodiversity and the threats it faces (Saravanan, 2020). Empowering individuals to take action through small lifestyle changes, such as reducing single-use plastics or supporting sustainable seafood choices, can contribute to broader conservation goals. By fostering a sense of responsibility and promoting informed decision-making, we can inspire collective action to protect marine ecosystems for future generations (Hines *et al.*, 2005). Environmental conservation is a top priority for governments, but its local impact depends on public education, awareness, understanding, and engagement (Brisset *et al.*, 2022). Along Tuticorin's coast, villagers have been educated about the importance of marine environments such as corals, seagrasses, and fisheries, stressing the need for conservation for sustainable use (Sheppard *et al.*, 2022). Educated adult women have gained confidence in leading awareness campaigns on environmental conservation within their villages and are key in educating their children about this important cause (Patterson *et al.*, 2009).

**Capacity building for various stakeholders:** Building capacity among stakeholders, including government agencies, non-governmental organizations (NGOs), and local communities, is essential for implementing effective conservation strategies. Capacity-building efforts may include training in monitoring and enforcement techniques, facilitating knowledge exchange and collaboration, and fostering leadership and governance skills (Hines *et al.*, 2005; Gomese *et al.*, 2018; Yuliaty *et al.*, 2021). By investing in capacity-building initiatives, we can enhance the effectiveness and sustainability of marine conservation efforts, ensuring that stakeholders have the skills and resources needed to implement and support conservation actions (Sakthivel *et al.*, 2014) & (Dugong: status report and action plans for countries and

territories. UNEP/Earth print, 2002.). Collaboration between stakeholders is essential for addressing complex conservation challenges and achieving positive conservation outcomes. By building partnerships and fostering a culture of collaboration, we can strengthen the capacity of stakeholders to address marine conservation issues effectively (Sundararaju, 2020), (Tiwary & Bajaj 2022; Shalu *et al.*, 2022).

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