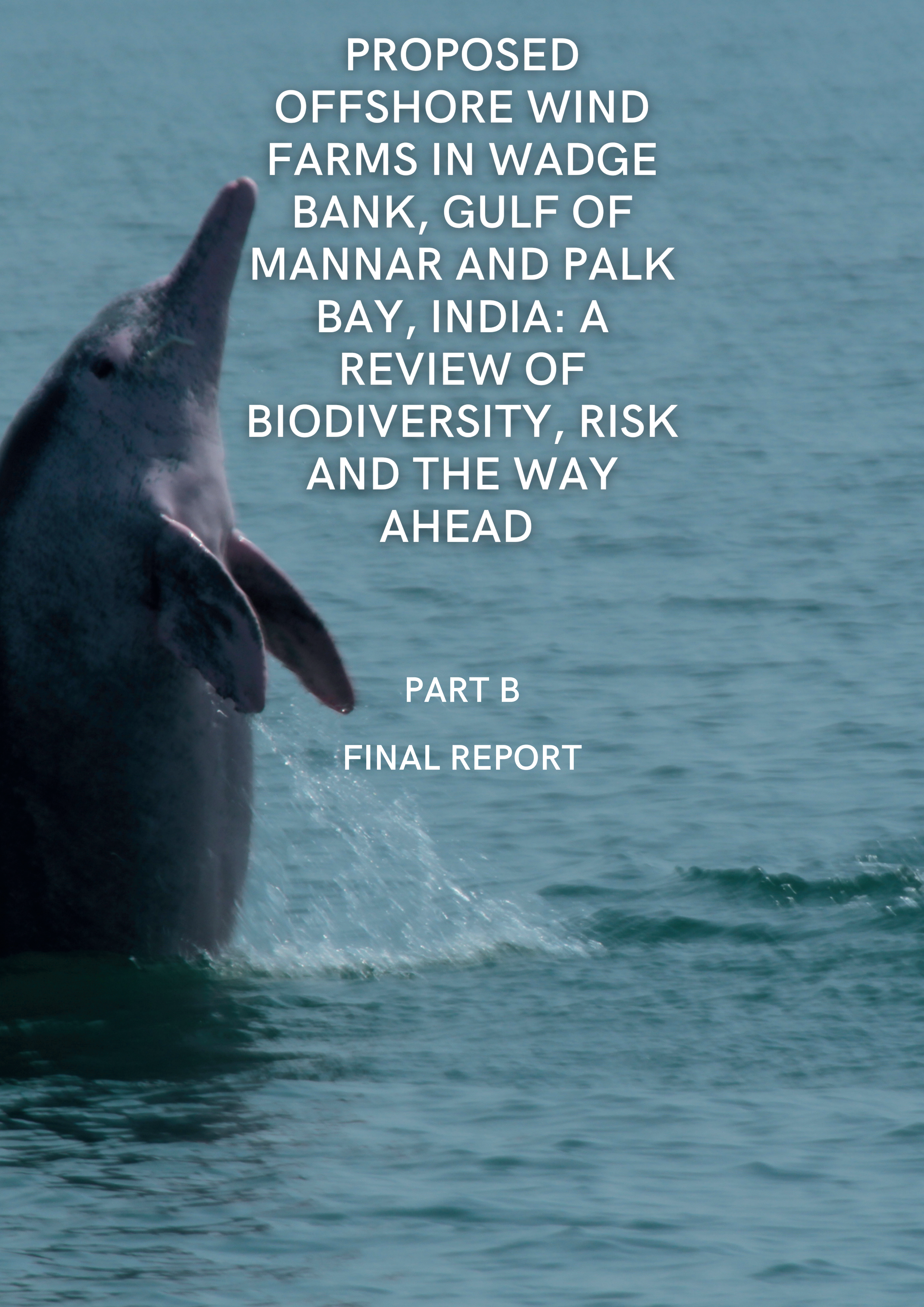

PROPOSED OFFSHORE WIND FARMS IN WADGE BANK, GULF OF MANNAR AND PALK BAY, INDIA: A REVIEW OF BIODIVERSITY, RISK AND THE WAY AHEAD

PART B

FINAL REPORT

JUNE 2025

Proposed offshore wind farms in Wadge Bank, Gulf of Mannar and Palk bay, India: A review of biodiversity, risk and the way ahead

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FINAL REPORT

The Energy Consortium IIT Madras

Danish Energy Agency

Proposed offshore wind farms in Wadge Bank, Gulf of Mannar and Palk bay, India: A review of biodiversity, risk and the way ahead

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DESIGNED BY

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EXECUTIVE SUMMARY

As in other forms of resource extraction and energy production, offshore wind energy too has its share of drawbacks. If designed, adapted and managed for least negative impact on biodiversity and livelihoods, it could prove to be beneficial. Assessing impacts requires robust data sets available on ecosystems, species diversity, spatio-temporal habitat use by the range of marine fauna and on inter-species community interactions.

The proposed offshore wind farms (OWFs) blocks in Tamil Nadu (from Kanyakumari to Palk Bay) are areas within the Wadge Bank, Gulf of Mannar (GoM) and Palk bay. These have one of the richest seagrass ecosystems in the world and support at least 16 seagrass species. Rocky and coralline reefs are present in the area, with fringing and atoll coral reefs around 21 uninhabited islands covering 75.93 km2, and patch reefs occurring in depths of 2 to 15 m. Rocky reefs found from 20m up to 80m, traditionally protected, are found from southern Kerala all around the Cape into the Gulf of Mannar.

These deep water reefs and harbor a rich assemblage of vertebrate and invertebrate life. On the continental shelf in Kanyakumari, is a vast deep sea sand bank called Wadge Bank, starting from 50m gradually up to 200 metres depth that is considered India's most abundant fishery resource and provides livelihood and biodiversity to the region. And at the end of the shelf, is the continental shelf edge, an area of very high productivity and dynamic oceanographic processes, making it a foraging hotspot for a diversity of marine megafauna. Further north in Palk Bay; Pudukkottai, Thanjavur, Thiruvarur and Nagapattinam districts have extensive networks of mangroves and wetlands nearshore that roll into large swaths of seagrass beds.

The proposed project area is known to harbor 24 species of marine mammals (whales, dolphins, porpoises and Dugong), seven species of Bats (four micro chiropterans and three mega chiropterans), five species of marine turtles, and at least 240 species of birds. This information is the minimum collated, based on scanty to almost no research. The near shore areas of the Gulf of Mannar and its 21 islands have been designated as India's first UNESCO recognised Marine Biosphere Reserve. But the entire stretch from the coast of Kanyakumari with its nearshore and offshore rocky coral reefs with a large extended offshore sandbank called Wadge Bank off its coast; and the coasts of Tirunelveli, Tuticorin, Ramanathapuram with its extensive mangroves, mudflats, seagrass beds and coral reefs, make Gulf of Mannar, extremely important for biodiversity and livelihoods of local communities.

Other than the Dugong, other marine mammals reported from the area have not been studied enough to estimate and monitor trends in population size or occupancy. Given that marine mammals play a key role in keeping the nutrient cycles in coastal and offshore waters enriched, this lack of key foundational knowledge is rather disturbing. That the proposed project sites are important foraging and breeding grounds for the endangered dugongs and Arabian Sea humpback whales signifies that extreme caution should be used before altering this ecosystem. Recently, the Government of India notified its first Dugong Conservation Area in Palk Bay. There are also three Important Marine Mammal Area identified by the IUCN Marine Protected Area task Force in the proposed project area.

As for Bats, one of the most important terrestrial mammals on earth to keep forest and agricultural systems genetically diverse and resilient, there are no more than three peer-reviewed papers of which only one paper looks at offshore use of space. Even in the case of turtles, very little ecological work leaves much of their migratory, foraging and breeding patterns in the area still unknown.

In the case of birds using the area, given the extensive citizen science network of birders in India and from abroad that visit India, and the BNHS programs that have been running in Tamil Nadu for several decades have a list of birds. Again, there have been no offshore research projects to mark the paths that migratory birds take in the Gulf of Mannar and Palk Bay, information of vital importance to be known before any OWF can be proposed.

In this report we provide all available knowledge of ecosystems and marine mega fauna for the proposed OWF in Tamil Nadu based on a literature review, but no long-term studies have been carried out here. Filling the gaps in data with intensive studies as recommended by us, would be required for the period ‘Before’ an OWF can be initiated.

This data can then inform aspects of positioning wind farms and managing their construction and operations using the mitigation framework. We recommend a list of research, policy and mitigation actions that need to be carried out before and during every phase of OWF development.

1. INTRODUCTION

India is the third-largest carbon emitter in the world and urgently needs to up its renewable sector, including research for home-grown technology -development - production and supply. The Government of India has set an ambitious target of 175 GW of installed renewable energy capacity with 60 GW of onshore wind and 5 GW of offshore wind. At the same time, Asia including India has a wide range of ecosystems that provide services and resources across the socio-economic spectrum and harbors high biodiversity richness.

Before we can initiate work towards the massive goal of increasing renewable energy, much work needs to be done to collect robust information on the range of ecosystems, their floral and faunal diversity and livelihood services and alternatives in the areas where the projects are proposed. The development needs to be transparent, without harming ecosystems that have both ecological functions and livelihood functions.

Wind farms along coastal stretches and in deeper waters nearshore (where the width of the continental shelf is narrow) have habitats such as deltaic mudflats, beaches, sand dunes, mangroves, seagrass beds, coral reefs and rocky reefs with immense ecological and livelihood function. The macro and micro benthic life supporting nursery grounds for all larger forms of amphibians, fish and crustaceans, which in turn attract and support megafauna such as birds, turtles, sharks, rays, bats, whales, dolphins, dugongs and porpoises. Table 1 describes the range of ecosystems in India and their threatened species based on a 2024 report by UNEP.

Source: Adapted from data available through the IUCN Red List of Threatened Species

RED LIST	Warm-water corals	Saltmarshes	Mangroves	Seagrasses	Cold-water corals
CR Critically Endangered	1	0	1	0	0
EN Endangered	3	0	1	0	0
VU Vulnerable	73	0	0	1	0
NT Near Threatened	107	0	2	0	0
LC Least Concern	170	28	31	14	3
DD Data Deficient	21	0	2	0	0
NE Not Evaluated	0	7	2	0	0
Total:	375	35	39	15	3

Table 1. The table outlines the number of species for each habitat by their global IUCN Red List status, illustrating the number of assessed species known to occur in India (UNEP-WCMC 2024).

As in other forms of resource extraction and energy production, wind energy has its share of drawbacks, but if designed, adapted and managed for least negative impact can prove to be beneficial (Olabi *et.al.* 2023).The construction of onshore and offshore wind farms can cause direct mortality of species, loss and modification of these diverse habitats due to material extraction or transportation related activities such as road construction or port development (Taber *et.al.* 2019, Tolvanen *et.al.* 2023).

The operation and maintenance of facilities can cause habitat fragmentation on land, along with disturbances such as noise pollution both on land and at sea; vibration, shadow flicker and electromagnetic field generation. The impacts therefore of setting up wind farms along coasts and in offshore waters, must include long term monitoring of ecological health, biodiversity assessments and umbrella species monitoring. These impacts need to be reviewed to better inform future design and changes in technology or location to keep biodiversity and ecosystem health as foremost priority.

Impacts of offshore wind farm development on biodiversity

The impacts of offshore wind farms can be divided into Pre-construction, Construction, Operation and Decommissioning (Marine Mammal Commission, USA). The pre-construction phase, if it includes geophysical/seismic surveys for seafloor mapping and site selection, is a proven source of mortality to cetaceans and fish. The actual construction phase would require the repeated exposure and exploitation of nearshore ecosystems such as seagrass beds or wetlands, but would also cause noise and disturbance from pile driving, drilling, excavation with explosives, dredging, cable laying, and continued ship and barge operations.

The actual operation of turbines (offshore and onshore) produce long-duration noise from the vibrations of running blades, while their maintenance offshore would also lead to an increase in vessel traffic, continuing over the entire period of operations. At the time of decommissioning, mechanical cutting and the use of explosives might take place as well.

All these would have impacts of varying degrees on different megafauna such as birds, turtles, marine mammals, large fish and other benthic flora and fauna. In 2021 the IUCN (Bennun et al 2021) summarized the list of 14 negative impacts on biodiversity based on the few studies carried out worldwide. We list these below in Table 2.

Table 2. A list of 14 negative impacts of Offshore wind mills on biodiversity (IUCN 2024)

No	Impact	Phase of OWF
1	Mortality, injury and behavioral effects associated with underwater noise	• Site characterisation • Construction • Operation • Decommissioning
2	Mortality, injury and behavioral effects associated with vessels	• Site characterisation • Construction • Operation • Decommissioning
3	Pollution (dust, light, solid/liquid waste)	• Site characterisation • Construction • Operation • Decommissioning
4	Introduction of invasive alien species	• Site characterisation • Construction • Operation • Decommissioning
5	Associated ecosystem service impacts	• Construction • Operation • Decommissioning
6	Trophic cascades	• Operation
7	Bird and bat mortality from colliding with turbine blades and/or onshore transmission lines	• Operation
8	Seabed habitat loss, degradation and transformation (bottom-fixed turbines)	• Construction • Operation
9	Hydrodynamic change (bottom-fixed turbines)	• Operation

10	Alterations of Habitat (including reef and refuge effects associated with bottom-fixed turbines)	• Construction • Operations
11	Barrier effects or displacement effects due to presence of wind farm (bottom-fixed turbines)	• Operations
12	Electromagnetic fields of subsea power cables behavioral effects	• Operations
13	Bird and bat mortality through electrocution on associated onshore distribution line	• Operation
14	Indirect impact (fisheries, shipping, livelihoods)	• Construction • Operation • Decommissioning

2. PROPOSED OFFSHORE WIND ENERGY, INDIA -TAMIL NADU

The potential for offshore wind farms was assessed by the FOWIND (Facilitating Offshore Wind in India) consortium with NIWE (the National Institute of Wind Energy) as a knowledge partner.

Based on a multi-criteria approach involving assessment of various parameters such as wind resource, bathymetry etc., eight zones each off the coast of Gujarat and Tamil Nadu were identified as potential offshore wind energy zones.

The identified eight zones off the coast of Tamil Nadu and the associated depth profile and seafloor topography are shown in Figure 1a and 1b respectively.

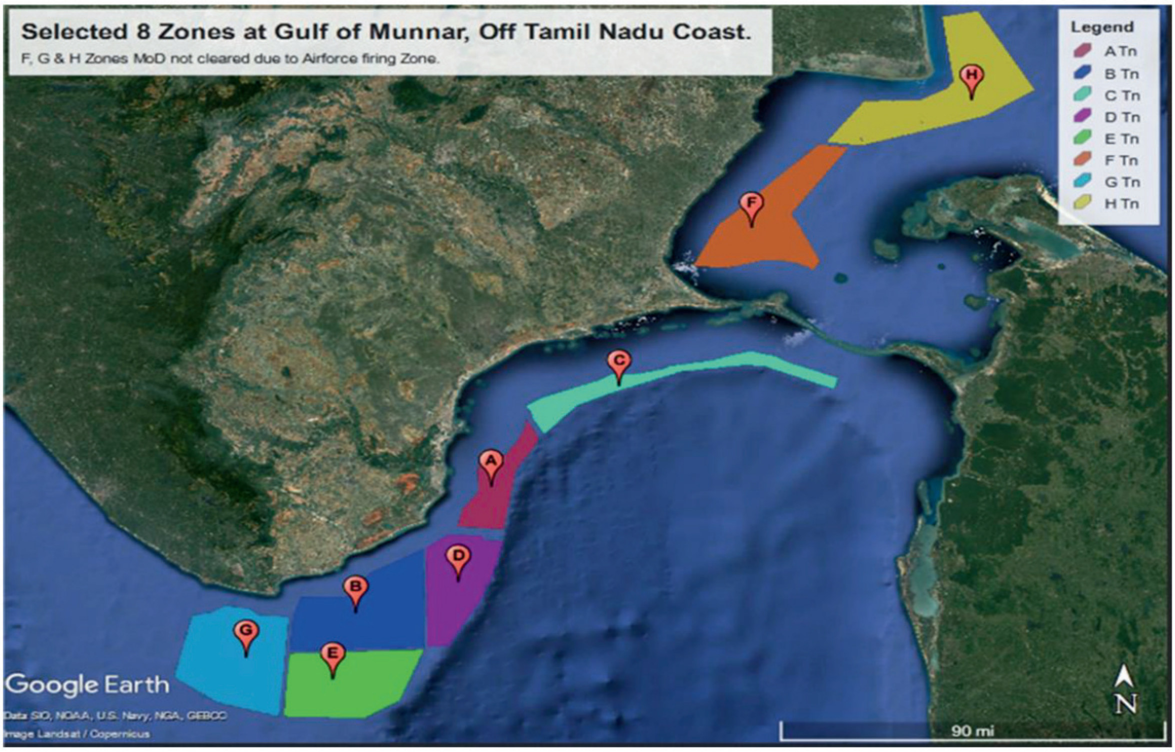


Figure 1a. Proposed area for OWF construction with the preferred sites in blocks 1,2,3 or B or phase I

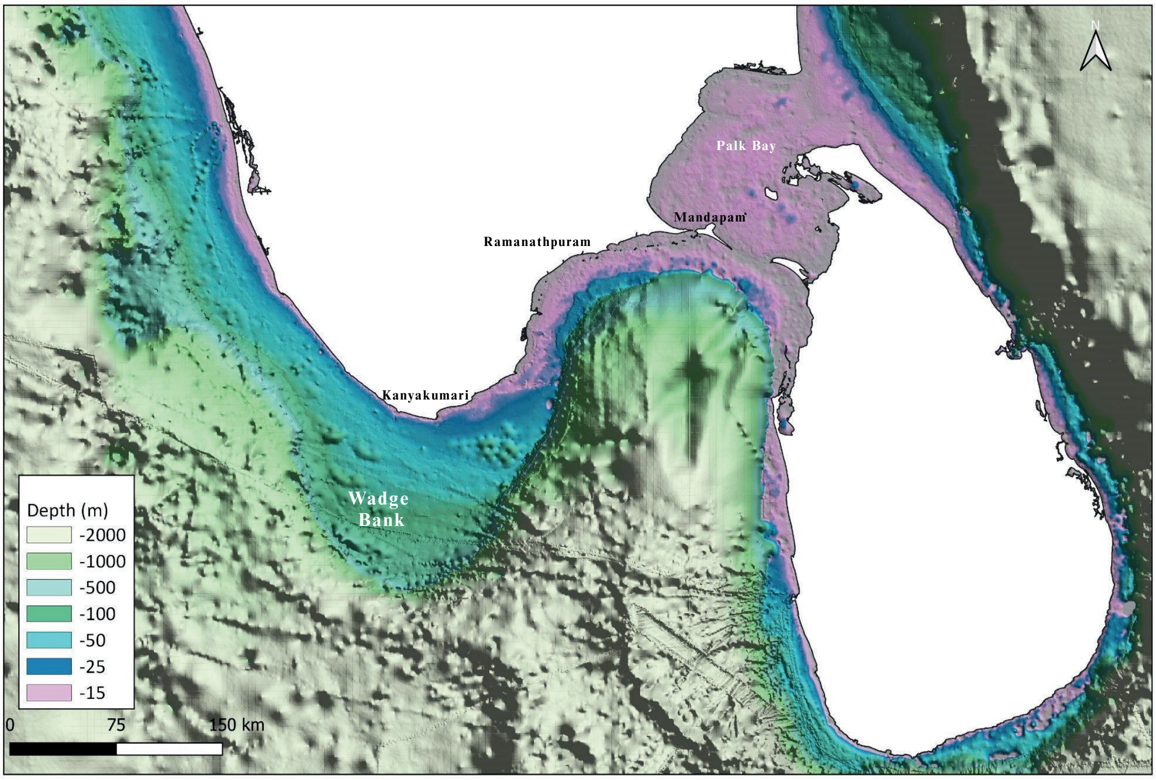


Figure 1b. The sea floor topography and depth profile in the proposed OWF blocks

3. REVIEW PROCESS

This report was produced by collating information from the below sources and synthesizing the same over the spatial extent of the proposed offshore wind energy development project in Tamil Nadu. The types of data sources vary and the amount of information available for the region in terms of diversity, population size, ecology and conservation status are scarce, even though the region is extremely important for biodiversity conservation, fisheries and livelihood. We review the literature available on the different ecologies in the proposed areas and the species of megafauna that use these habitats, to better guide the research and monitoring recommendations for the project site in Tamil Nadu.

- peer-reviewed journal articles and reports
- reports from autonomous agencies working under the the MoEFCC-Government of India
- reports from Non-Profit organisations in India
- citizen science networks and peer-reviewed data platforms such as iNaturalist, MMI (Marine Mammal research and conservation network of India), eBird.
- Reports and databases from international agencies such as UNEP, CMS.

We also provide studies from other areas of the globe where offshore windmills are currently functional to present the impacts the projects can have and to ground our recommendations.

4. ECOSYSTEMS AND BIODIVERSITY OF THE PROPOSED OWF AREA

The regions identified for developing offshore wind energy projects in Tamil Nadu (Palk bay, Gulf of Mannar and the Wadge Bank), harbours a diversity of habitat types - seagrass meadows, marine algae beds, mangroves, coralline reefs, rocky reefs, sand banks and shelf edges and canyons that have a complex seafloor bathymetry within the EEZ. All these along with two monsoons and changing wind and current patterns makes the region extremely biologically productive. Connected to the southeast Arabian sea (SEAS) and the Bay of Bengal, the region is extremely vital oceanographically.

Retnamma *et.al.* 2024 discuss in detail how the shifts in upwellings across seasons between the SEAS and the Bay of Bengal creates a haven for micro and macro fauna. Based on data collated by ENVIS in 2016, 4000 faunal assemblages have been recorded from the Gulf of Mannar including 1147 species of fishes, 856 species of molluscs, 451 species of tunicates, 262 species of coelenterates (117 species of corals), 158 species of arthropods, 153 species of echinoderms and 77 species of sponges.

Key Regulatory Frameworks and Marine Protections applicable to the OWF area

1. Environment Protection Act, 1986
2. Coastal Regulation Zone (CRZ) Notification, 2011
3. Wildlife Protection Act, 1972
4. Territorial Waters, Continental Shelf, Exclusive Economic Zone and Other Maritime Zones Act,1976

India's first Marine Biosphere Reserve was established in the Gulf of Mannar in 1986 and was declared a UNESCO Biosphere Reserve in 1989. It is situated between 78°08-79°30E. and 8°35-9°25N, in an area covering 21 islands from the northernmost Pamban to Tuticorin and is listed under the Ecologically or Biologically Sensitive Marine Areas (EBSA's). This protected area covers approximately 10,500 square kilometres with around 873 km^2 (Seal *et.al.* 2023) of seagrass meadows spreading from Rameswaram to Kanyakumari in Tamil Nadu. Further south is a large gradually deepening Wadge Bank (Figure 1B), considered India's most abundant fishery resource.

The GoM and Palk Bay are one of the most biologically productive and diverse regions in the Northern Indian Ocean it is home to at least 3600 species of plants and animals. The area also constitutes a significant transboundary marine ecosystem spanning the coastal waters of India and Sri Lanka and contains three Important Marine Mammal Area's (IMMA) in the World Atlas of Important Marine Mammal Areas (https://www.marinemammalhabitat.org/factsheets/gulf-mannar-palk-bay) due to its ecological significance, for the presence of dugongs (*Dugong dugong*) and 23 species of cetaceans.

Seagrass meadows

The Gulf of Mannar and Palk Bay are one of the richest seagrass ecosystems (Figure 2) in the world (Thangaradjou and Kannan, 2007; Gangal *et.al.* 2012) and supports at least 14 to 16 seagrass species (Balaji 2018; Geevarghese *et.al.* 2018; Udagedara and Dahanayake 2020; Ponde *et.al.* 2021): *Cymodocea rotundata, C. serrulata; Enhalus acoroides; Halophila beccarii, H. decipiens, H. ovalis, H. major, H. minor, H. ovata, H. stipulacea; Halodule uninervis, H. pinifolia; Syringodium isoetifolium and Thalassia hemprichii*. Of these, *Cymodocea serrulata, Syringodium isoetifolium* and *Thalassia hemprichii* are the dominant species. Seagrass beds just like terrestrial grasslands provide physical stability and buffering to nearshore habitats, and they also have the highest carbon sequestration capacity amongst different ecosystems. Apart from their role in sequestration of carbon they also increase the primary productivity and plankton biomass in the area (Maheswari, 2011; Thangaradjou and Bhatt 2017). The health and protection of the diversity of substrate types and their seagrass beds is hence paramount not only to the Gulf of Mannar- Palk Bay ecosystem but also for India's blue economy goals.

The mapping of seagrass meadows using a standardised robust methodology for the entire area of Palk Bay and Gulf of Mannar is still not available. In the 1960's, the Mandapam area alone was said to have a mean density of sea grass at 558 tons/sq. km and the Gulf of Mannar and Palk Bay had a standing crop of ca 7000 metric tons (Rao *et.al.* 1963; Jagtap, 1966). The present 4125 ha of seagrass beds of Gulf of Mannar have the potential to sequester an annual average of 572.6 mg/C.ha (Thangaradjou and Bhatt,2017). Kaladharan et.al. 2020 estimated that the value of blue carbon stored in seagrass meadows of Gulf of Mannar was 17820 US$ and of Palk Bay was 43,99,682 US$ in 2020.

Balaji 2018 mapped seagrass beds till 10 km from shore in Thanjavur district of Palk Bay and found extensive seagrass covering 12,243 hectares, just in Thanjavur, but no further investigations of its biodiversity richness is available. Studies by Thangaradjou and Bhatt in 2017 on substrate preference show that *Cymodocea sp., Halophila. sp. and Halodule sp.* require clayey and silty substrate whereas *Syringodium isoetifolium* grows well mostly in sandy soils reiterating the relationship between sea grasses and the specific habitat characteristics they require, providing ecological niches for a variety of micro and macro fauna. Seagrass meadows in the Gulf of Mannar are closely associated with extensive coral reefs as is seen around islands like Manoli where faunal communities, particularly fish and invertebrates are known to show seasonal transience between seagrass and reefs; with species migrating to reefs during the monsoon when seagrass beds are disturbed due to heavy wave action (Maheswari *et.al*. 2011). At the same time the seagrass in the area is also highly adapted to shifts and seasonal changes in wind caused by the two monsoon periods with sediment banks formed especially during the north-east monsoons, act as seed banks for new growth of sea grass (Sulochanan et.al.2010).

A study by the Zoological survey of India in 2017 revealed a diversity of 258 species of epibenthic and epibiont species associated with seagrass habitats. They documented 102 mollusc, 90 fish, 44 crustacean, 20 echinoderm species and added four new records of decapods from India (Shrinivaasu *et.al* 2017). Seagrass beds are also very important nursery grounds for sharks and rays and several other fish, and macrofaunal species. Finally, the Gulf of Mannar provides one of the most extensive seagrass habitats for the vulnerable dugong population (see page 28 Schramm *et.al.* 2024) and sea turtles (see page 22) that both feed on seagrass. These areas are especially critical as breeding grounds for turtles and also as feeding grounds for post-nesting females and newly emerged hatchlings. Any changes to the hydrology or sedimentation patterns can quickly have very drastic effects on seagrass beds. There is a lack of a long-term assessment program of floral-faunal communities, to monitor any changes or shifts in the community structure that helps systems to adapt to climate change or other external pressures. This is a huge knowledge gap from the proposed area that needs to be studied before any construction begins.

An increase in human settlements, sedimentation and overharvesting of marine species are some of the dominant threats to this habitat and the rare dugongs. Species like *Halophila becarii* found in the area, are especially sensitive to these changes.

The proposed OWF will lead to increased vessel traffic during the construction phase that can have detrimental impacts on the seagrass beds of GoM and Palk Bay. Anchorage of vessels in seagrass habitats has been known to uproot large swathes of grass which may or may not recruit again in the same area. An increase in sedimentation can bury existing beds.

A significant decrease or degradation in seagrass cover puts at further the risk the remnant population of dugongs.

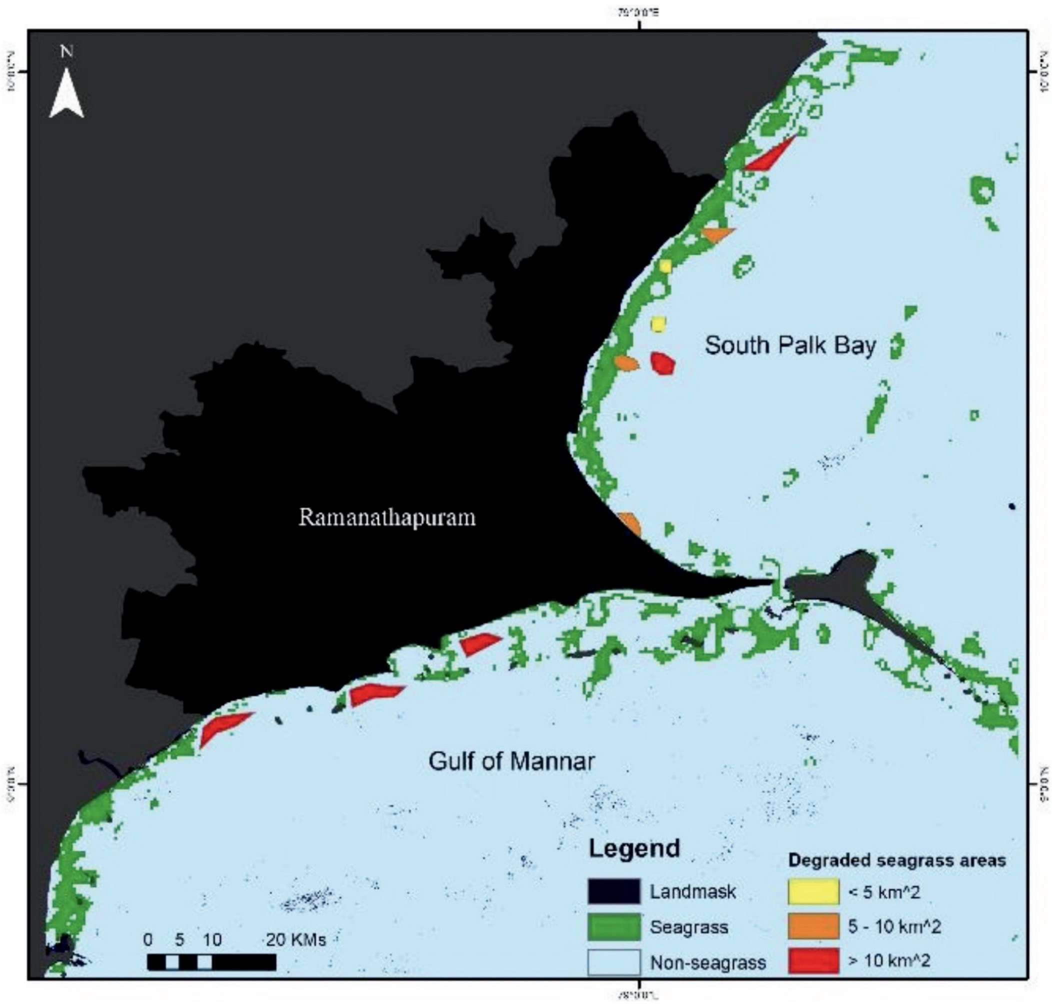


Figure 2. Seagrass map with degraded areas of South Palk Bay and Gulf of Mannar region, Ramanathapuram Wildlife Division, Tamil Nadu. Seal et al 2023, WII

Coral and Rocky Reefs

Coral reefs are considered rain forests of the marine realm. They are a source of food security and livelihood for all coastal communities and serve as important habitats for complex fish and invertebrate communities to thrive together, support assemblages of reef fish, molluscs, echinoderms, crustaceans, algae, and many other species of plants and animals. Reefs also play a significant role in maintaining ecological resilience and stability in the surrounding area and behave as physical defence for coastal habitats.

In the Gulf of Mannar, fringing and atoll coral reefs around the 21 uninhabited islands cover 75.93 km2, with patch reefs occurring in depths of 2 to 9 m, with 1-2 km length patches and as wide as 50m (Patterson *et.al.*,2008). Patterson et al.in 2008 updated the coral species list documented around these islands in the Gulf of Mannar to be 117 species from 40 genera. There are also offshore rocky reef patches found outside the jurisdiction of Gulf of Mannar Marine National Park (GoMMNP) traditionally called 'pars'. Rocky reefs found from 20m up to 60m depth are traditionally protected and form a fringing boundary from southern Kerala all around the Cape into the Gulf of Mannar, making this area astoundingly rich in biodiversity. These are cold water reefs and harbor a rich assemblage of vertebrate and invertebrate life that support source populations of marine invertebrate and fish diversity. Only one such rocky reef has been studied in the proposed OWF area. An assessment of Madapar rocky reef (N 080 37.889 E 780 14.805) located 30km from shore at 19m depth reported 15.25% live coral cover, including eight coral genera mainly consisting of massive and encrusting forms. These include *Porites, Favia, Favites, Goniastrea, Platygyra and Symphyllia, Turbinaria spp., Goniastrea spp., Favia spp., Acanrhastrea spp., Favites spp., Cyphastrea spp. and Symphyllia spp*. Fish from 31 genera and 22 families were documented from this reef, with an average of 418.44±5.75 fish per 50 sqm (Kumar *et.al.* 2017). This study shows the importance of studying offshore regions and their diverse habitats in the area in the future.

Reefs in the Gulf of Mannar are already facing multiple stressors, from overfishing and coral mining to bio-invasion by alien invasive exotic seaweed, harmful practices like trap fishing, bottom trawling, land-based pollution and unsustainable coastal development, coral diseases, along with the larger climate change related sea temperatures causing mass coral bleaching. The OWF could aggravate some of the problems of bio-invasion of invasive flora and fauna and shifting stable community structures.

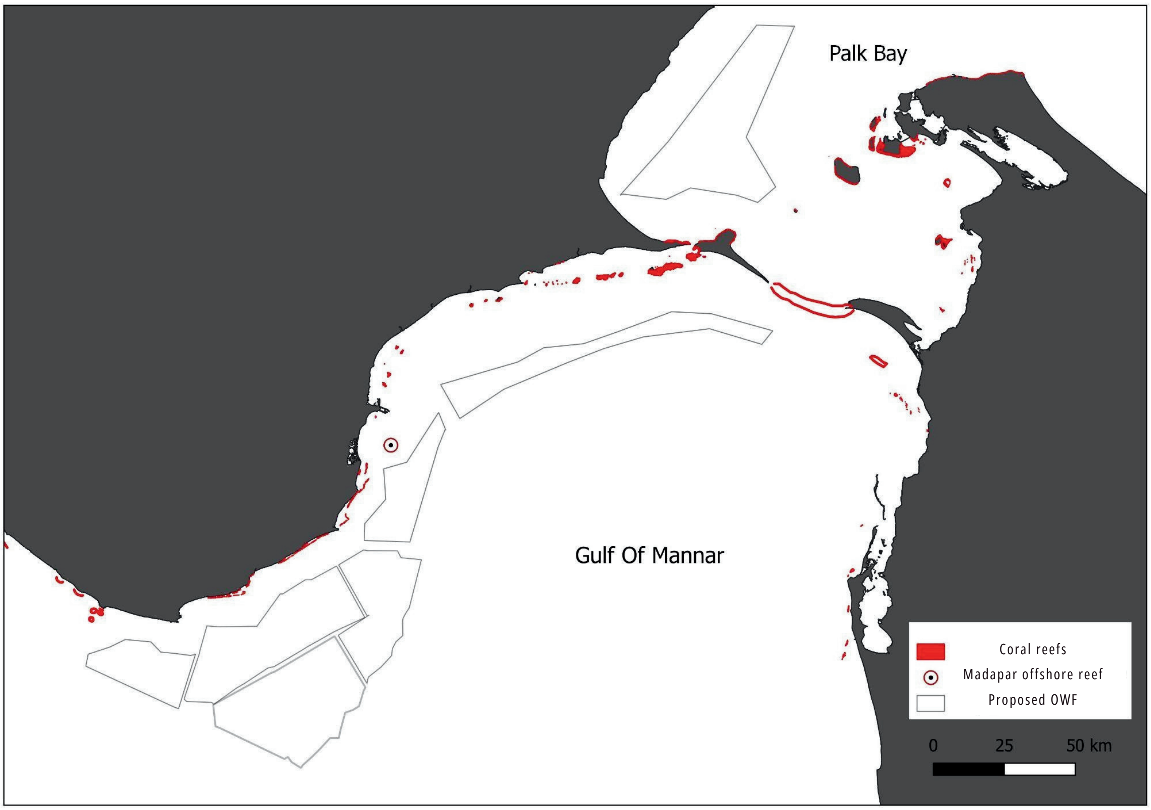


Figure 3. A map of the coralline warm water reefs in the OWF proposed areas and one coldwater offshore reef. The area of the proposed OWF has cold water rocky reefs up to 60m water depth as per traditional knowledge and use by fishers UNEP-WCMC, WorldFish Centre, WRI, TNC (2021).

Mangroves

Mangroves like other ecosystems play vital roles in coastal areas, from providing nursery grounds for fish to breed and supporting faunal assemblages, to sustaining the productivity of the coastal and offshore areas and protecting inland regions during cyclonic events. Mangroves are also responsible for behaving as sinks for pollution while also preventing erosion of coastal areas and hence stopping the ingression of salt water into fresh groundwater aquifers.

A total of 14 species of true mangroves are recorded from the Tamil Nadu coast with eight of them reported from Palk Bay and nine true mangrove species reported from Gulf of Mannar (Vel *et.al.* 2022). Along with these,17 mangrove associates, and 201 flowering plants were reported from the mangrove forests. The mangrove species were *Avicennia marina, Bruguiera cylindrica, Bruguiera gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora apiculata and Rhizophora mucronata belonging to five families with a predominance of Rhizophoraceae*.

In the past, species such as *B. gymnorhizha* and *Acanthus ilicifolius* were also present in Rameshwaram but coastal development of harvesting of mangroves have led to local absence of these species. Importantly, *C. tagal* and *P. acidula* are endemic to the islands in the Gulf of Mannar and are not present in any other mangrove forest of Tamil Nadu.

Mangroves in the area are under threat from an increase in unplanned and unsustainable coastal infrastructural development, release of untreated sewage and industrial effluents, expansion of salt pans, aquaculture and reclamation for residential development. The proposed OWF could exacerbate this situation.

Salt marshes

Salt marsh ecosystems, that are wetlands flooded with salt water from tides are given little importance in South Asia even though they are significant as sheltering and nursing grounds for several important species (Jagtap and Rodrigues 2004). They also provide protection from erosion, and filter water, absorb flood waters, and provide habitats for a diverse range of micro and macro fauna.

Plants like *Suaeda monoica* that grow in salt marshes have evolved to not only tolerate high salinity on land, but they also act as detoxifying agent and absorb heavy metals (such as Cr, Cu, Cd and Zn) from the soil and can be used for restoration (Ayyappan and Ravindran 2014). Other plants such as Salicornia sp. are used as food and medicines.

Tamil Nadu has the second largest salt marsh area in the country at 6108 ha. An integral part of the Gulf of Mannar, salt marshes are found where mangroves have not settled, and flora that has adapted to the saline soil and fluctuating tides such as *Suaeda maritima, Suaeda monica, and Holosacia indicum*.

Often treated as wastelands, salt marshes are highly threatened. Some of the pressures they face are conversion to saltpans and aquaculture ponds, release of solid waste, sewage and industrial pollution, eutrophication, reclamation for building embankments and sea walls, urbanization and infrastructural developments (Jagtap and Rodrigues 2004).

Muttom shores and Wadge Bank

Muttom shoreline and the Wadge Bank submarine plateau are important nursery grounds for fish and other invertebrate life. Extending between Vizhinjam till Chinnamuttom in Kanyakumari and extending offshore 50 miles southwards, it is a 10,000-square-kilometre submarine plateau between latitudes 7°10’N and 8°00'N and longitudes 76°40'E and 78°00'E. The Indian Ocean, the Arabian sea and the Bay of Bengal, meet on the Wadge, with tides creating a rich fishing ground from May to October every year. In the deeper sections of the continental shelf ranging from 50m gradually up to 200 metres depth the sea-bed consists of sand and shell and is rocky in places; rich in biodiversity, it’s considered India’s most abundant fishery resource and a feeding house for the fish. Several rocky reefs also exist in this region with over 200 varieties of rare fish species and more than 60 kinds of aquatic species.

The area is therefore not only extremely important for marine biodiversity but also as fishing grounds, for the indigenous communities of Kanyakumari. Interviews with fishers and videos collected from them show that the large whales and the oceanic dolphins use Wadge bank all through the year, while nearshore waters are used by humpback dolphins and finless porpoises(Page 29-41).

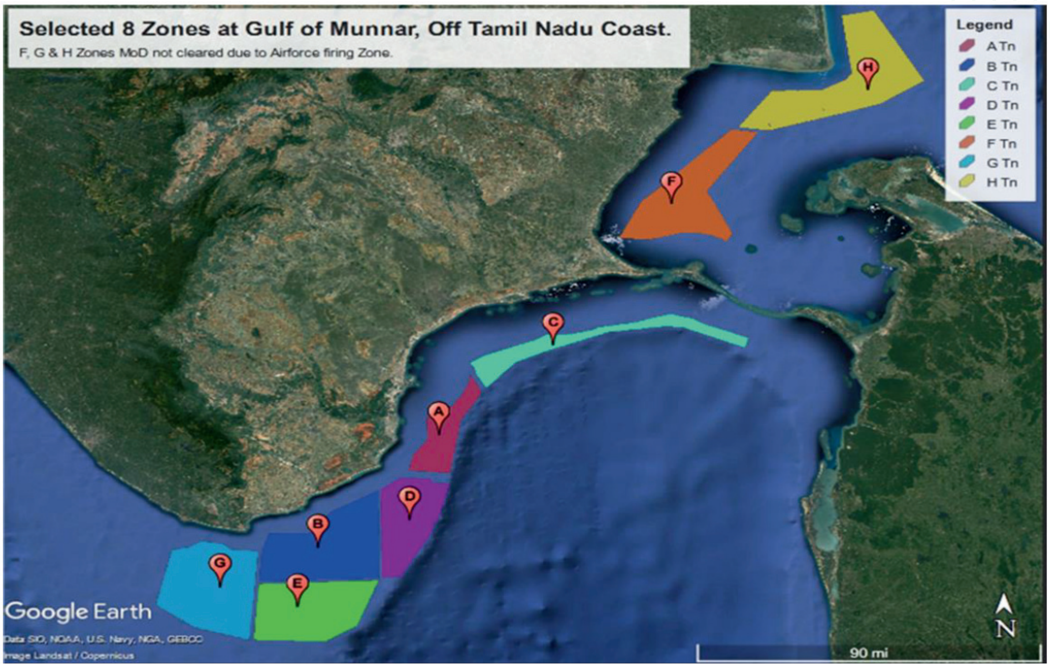


Figure 4. Map showing important fishing grounds within Wadge Bank (Karuppasamy et.al. 2017)

Shelf Edge

As seen in the map of Wadge Bank and in Figure 1b, the topographical margin of the Indian landmass the shelf edge is at the end of the continental shelf, which is the uppermost section of the continental margin. Here the shelf drops steeply into the deeper section of the sea. This margin is important because it is an extremely productive area biologically. Here, offshore underwater currents interact with the topography to cause mixing of cold and warmer surface currents, thus supporting dense filter feeding communities. This in turn makes these areas rich in higher trophic levels such as birds, mammals, sharks and turtles as foraging hotspots (Spitz 2017). All studies of offshore megafauna globally have shown high densities of offshore dolphins and whales and birds in the area where the shelf drops (Kiszka *et.al.* 2007, Cox *et.al.* 2018). In the Bay of Biscay, oceanic processes and bathymetry drive productivity and create diverse habitats for more than 14 species of cetaceans. Hain *et.al.* 1985 show the importance of the shelf edge way back in the 1980's where their surveys over three years, reported 20 species of cetaceans and more than 2500 sightings of cetacean groups. Kiszka *et.al.* 2007 via surveys in the English channel from platform of opportunity show the importance of the shelf edge to cetaceans between 1998 and 2002 had 1008 encounters of 13 identified species. The harbour porpoises were restricted to the shallow waters while common and bottlenose dolphins were distributed over the continental shelf, striped dolphins and pilot whales were sighted in oceanic waters Cuvier's beaked whales and sperm whales were recorded in the deep oceanic waters.

In figure 16, page 41, of this report, cetacean surveys in the EEZ waters by Afsal *et.al.* show the concentration of cetaceans on the shelf edge, underpinning the importance of the continental shelf edge for cetacean conservation. This study clearly shows that bathymetry plays a significant role in the distribution and habitat partitioning of toothed cetaceans. In the proposed OWF region in fact, the shelf edge has reported deep diving species such as sperm whales, dwarf sperm whales, blue whales, humpback whales, pilot whales and some species of beaked whales.

Impacts of the current project on these important ecosystems

In 2024, Danovaro *et.al.* described the impact of floating offshore wind turbines on different habitats based on a set of criteria, response variables and approaches for a reliable impact assessment based on an Ecosystem-based approach. The only reason they could do this, is because they already have data available about the habitats. The analyses supported the "Do No Significant Harm" principle. They examined interactions between potential offshore wind farms with six response variables - i) Vulnerable Marine Ecosystems; ii) critical habitats; iii) migratory routes of large marine vertebrates; iv) habitat-forming species, benthic/pelagic organisms, v) migratory routes of birds/ chiroptera; vi) other human uses leading to cumulative impacts. Lloret et al 2022 did a review of all research that has studied the effects of OWF and floating wind farms on ecosystems and ecosystem function. The review showed that loss or damage of fragile nearshore and inland fragile areas (estuaries, coastal lagoons, large shallow inlets and bays, etc.) due to the building of new terrestrial/ coastal infrastructure, is directly related to loss of biodiversity.

A review of the potential reef effects from offshore wind turbines by Linley *et al.* (2007) suggested largely positive or neutral effects on a variety of species, including mussels and kelp directly attached to the foundations and scour pads; crabs, lobsters, and oysters nearby, and even finfish in the vicinity. Slavik *et.al.* (2019) estimated that up to four tons of mussels could grow on a single turbine foundation. This although may be an example of ecosystem enhancement, erring on the side of caution, such enhancements may lead to an influx in prey species that ultimately may result as an added pressure on the naturally present systems such as seagrass beds or coral reefs.

OWF in the proposed area will alter the access to areas occupied by wind farms thus affecting fisheries and management of fishery resources. The loss of sea floor integrity has also been observed due to the installation and dismantling of pile foundations, cables, and anchors, the scour of the seabed, and the strumming of the cables. Subsea cables that are longer and have higher capacity may increase the extent of electromagnetic fields in the water and impact a great diversity of marine organisms that depend on earth's natural electromagnetic field for navigation. Mooring lines and floating substructures may act as fish aggregation devices and settlement surfaces for invertebrates and algae, thus altering species composition in pelagic communities. When wind farms are built in areas with homogenous sea beds such as Wadge Bank in our case, the installation of foundations and piles may provide space for settlement, shelter and foraging for some species (positive effect) but new, artificial substrates where they did not exist before could favor the colonization by non-indigenous species that are detrimental to local ecology. This may modify food webs and biogeochemical cycling, with the increase of suspension feeders leading to changes in local primary productivity. Finally, the increase in contaminants has also been noticed including organic compounds such as bisphenol A and metals such as aluminum, zinc, and indium from corrosion and biofouling protection measures.

5. MEGAFAUNA

Mega faunal species have large geographic ranges, and transboundary movement in search of food or mates is common and are important indicators of the health of the ecosystem. Scientific monitoring of these groups before and after any alteration to the environment is the basis for future development projects of this nature.

The Gulf of Mannar and Palk bay area where the OWM site has been proposed is used by a large number of marine megafauna including pelagic birds and waders, five species of sea turtles and at least 24 species of marine mammals. We expand upon each of these groups of large fauna in the following sections.

5.1 Marine birds

The Gulf of Mannar is an Important Bird Area (IBA) with about 230-240 species of aquatic and terrestrial birds documented here (IBA, 2003). The list of birds and their conservation priority in the OWF area are also available on the State of India's Birds (SoIB) citizen science database (Figure 5). The full report of the same can be generated from MYNA@State of India's Birds which also provides estimates of which areas have the highest densities of birds. This data was collected not by systematic surveys or bird ringing, but by opportunistic sightings, so is the minimal number of birds using the OWF proposed area. Of these, 26 bird species are endemic to the Indian subcontinent and found nowhere else on the globe.

5.2 Migratory birds

The OWF area is a part of the Central Asian Flyway (CAF) holding important populations of wintering birds along this migratory zone, and is one of the important habitats for coastal birds migrating to the Arctic circle (Byju, 2023). Migratory shorebirds arrive here on their wintering grounds in August and depart by May (Balachandran 1990; Aarif *et.al.* 2021; Shifa 2023, Byju *et.al.* 2024). The island groups in the Gulf of Mannar are also a migratory pathway for birds moving from Sri Lanka towards the Indian mainland, serve as important stop-over sites. According to the State of India's Birds (SioB) biodiversity assessments, four areas have been identified as bird hotspots viz., Hare Island, Dhanushkodi beach and mudflats, Vembar backwaters and Kothandaramar Temple region. According to Balachandran, the area supported more than 50,000 coastal birds (waders, terns and other wading birds) including 13,000 flamingos during 1980s (Balachandran, 1990 and 1995) and it ranks third along the East coast as an important wintering ground for Greater Flamingos *Phoenocopterus ruber*.

Many migrant species occurring on the Indian mainland also occur in Sri Lanka (Rasmussen & Anderton 2005). Jaffna district of Sri Lanka, nearest to the Gulf of Mannar, has 315 species of birds including migratory shorebirds (Birdlife International 2022). Many species migrate annually from the northern autumn-winter to the tropics along the Central Asian-Indian Flyway ending their southward journey on this island (Warakagoda & Siriwardana 2011). Given Gulf of Mannar's proximity to Sri Lanka the IBA here is an important site along the CAF for both migratory water birds and passerines (Zafar & Rahmani 2003).

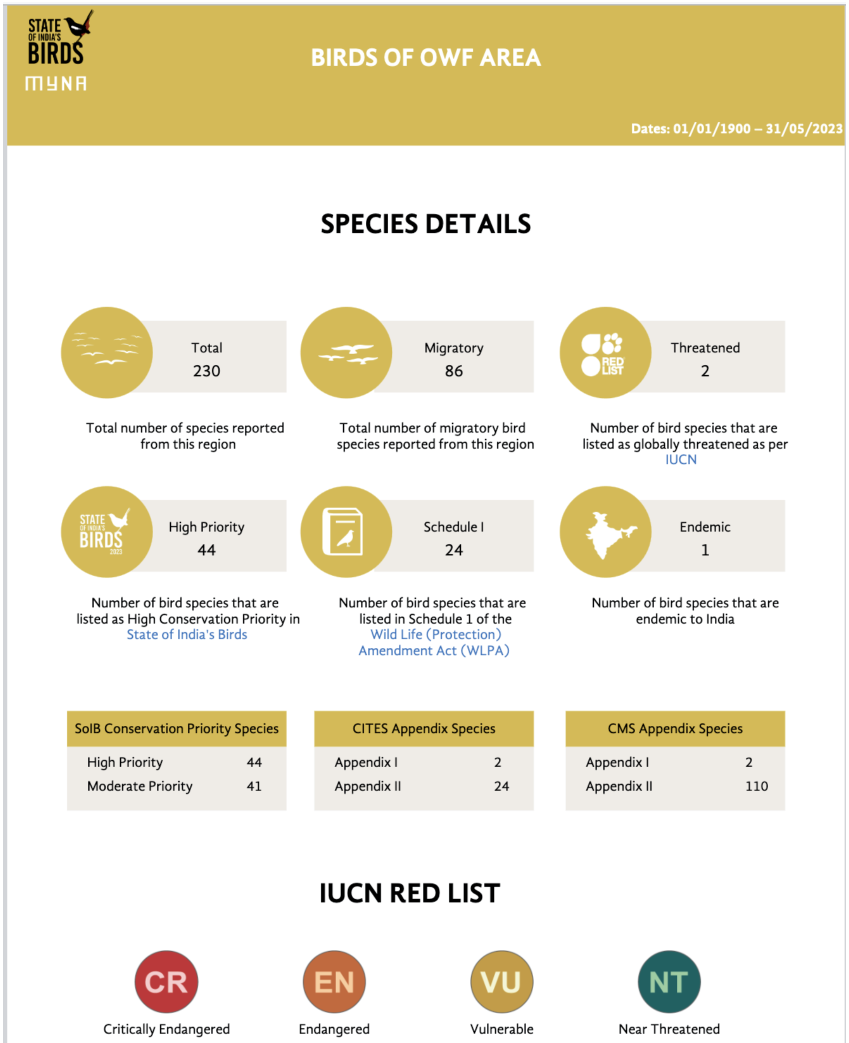
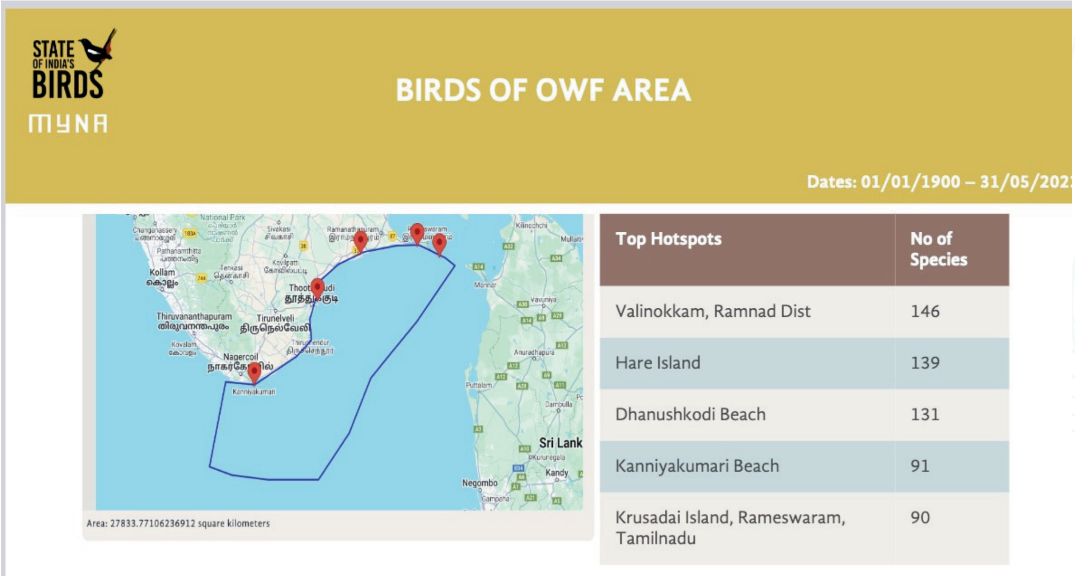


Figure 5. List of birds with their conservation priority documented in the Gulf of Mannar by Citizen science groups, generated from MYNA, State of India's Birds 2024.

Of the 230-240 bird species, 24 species are listed under Schedule 1 of the Indian wildlife (Protection) Act. and 86 are migratory with 44 high priority species. Among the shorebirds, seven Near Threatened species (Bar-tailed Godwit *Limosa lapponica*, Black-tailed Godwit *Limosa limosa*, Red Knot *Calidris canutus*, Curlew Sandpiper *Calidris ferruginea*, Red-necked Stint *Calidris ruficollis*, Eurasian Curlew *Numenius arquata*, and Greater Thick-knee *Esacus recurvirostris*) and one Endangered species (Great Knot *Calidris tenuirostris*) have been recorded.

The populations observed by Balachandran (2012) showed a steadily decreasing trend in the numbers of common waders between 1985-88 and 2007, with most species seeing a reduction of about 80% in their numbers. Changes in land cover of the GoM archipelago is posing to be an important factor affecting migratory patterns in the region. A study between 1969 and 2018 showed that the area cover of 15 out of the 21 islands showed a reduction of 144.15 hectares. In 2020, the Tuticorin group of islands experienced the highest percentage of land cover reduction (78.55%), followed by Keelakarai (43.49%), Vembar (36.21%), and Mandapam (21.84%) groups (Asir *et.al.* 2020). Byju *et.al.* 2023, showed that at least 15 species of migratory birds including the near-threatened Eurasian curlew, that arrive in GoM use alternate agro habitats due to fragmentations of their primary wetland stopover sites in the region.



Top Hotspots	No of Species
Valinokkam, Ramnad Dist	146
Hare Island	139
Dhanushkodi Beach	131
Kanniyakumari Beach	91
Krusadai Island, Rameswaram, Tamilnadu	90

Figure 6: Showing bird assumed density of bird sightings regions within the proposed OWF area (MYNA, State of India's Birds 2024)

Avian Sensitivity Tool (AVISTEP) and assessment for the project area

The AVISTEP tool developed by Birdlife International helps identify areas where renewable energy could impact birds and should therefore be avoided. The tool uses geospatial data collected from multiple regional and global sources to identify areas based on four categories of sensitivity with each 5kmx5km area having a sensitivity score.

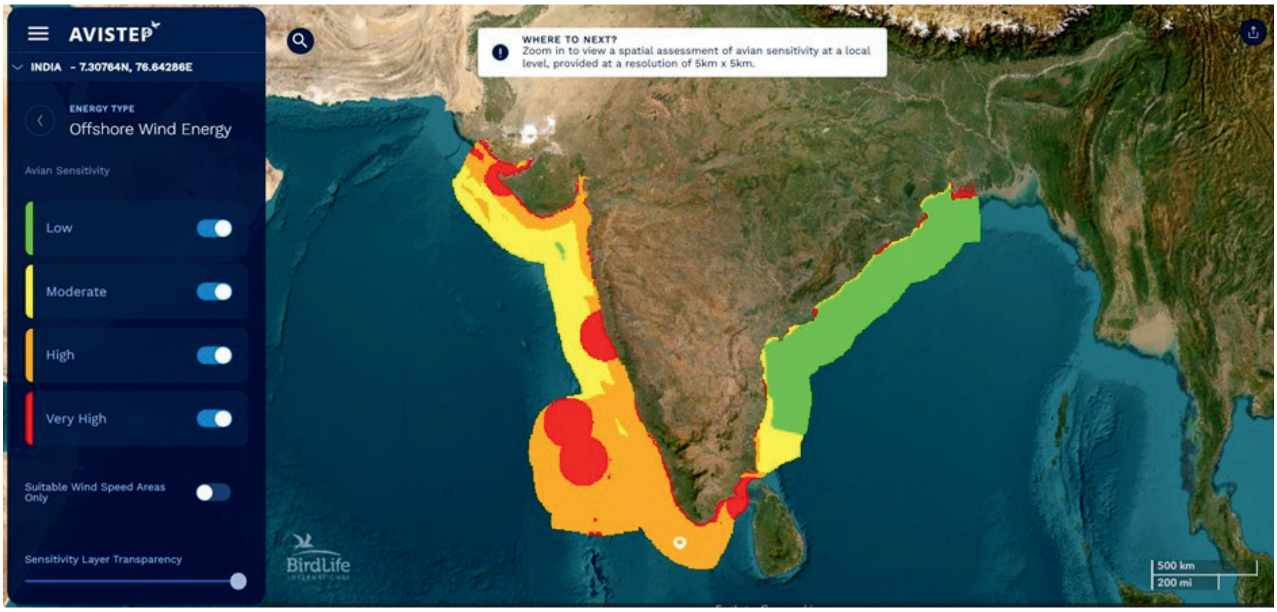


Figure 7. Areas of sensitivity of birds to OWF based on the AVISTEP assessment 2024 (red: very high, Orange: High)

The Sensitivity categories are Low, Moderate, High and Very high. A low sensitivity region is where offshore wind farm development is considered to pose a low risk to bird populations. However, comprehensive site-level assessment is necessary to confirm the absence of significant risk. Similarly, a moderate risk is where OWF development is considered to pose a moderate risk to bird populations. A high sensitivity value is where development is considered to pose a high risk to bird populations (Table 3).

The area may be unsuitable for development and will certainly require mitigation measures. And areas assessed as very highly sensitive are those where development is considered to pose a very high risk to bird populations. For both high and very highly sensitive areas, a comprehensive site-level assessment is necessary to confirm this level of risk.

Sr. No.	Offshore wind energy zone	No. of species	Sensitivity scale	Mean Displacement Risk (%)	Mean Collision Risk (%)
1	A	19	High (100%) and Very High	25 (13-36)	22 (7-54)
2	B	20	High (72%)	24.1 (13-36)	20 (4-54)
3	C	15	Very high (100%)	25 (13-36)	20.2 (7-54)
4	D	19	High (78%) and Very High (100%)	25 (13-36)	22.3 (7-54)
5	E	15	High (59%)	24 (13-36)	20 (7-54)
6	F	15	Very High (100%)	24.5 (13-34)	20 (7-54)
7	G	16	High (61%)	23.3 (13-36)	21 (7-54)

Table 3. Sensitivity of birds to the OWF's in the blocks proposed based on AVISTEP 2024.

Potential impacts on birds and recommendations towards mitigation

Globally, birds are one of the most impacted taxa by operational wind farms, onshore, inland and offshore. Fatalities from collisions into operational turbine blades is a major stressor for bird populations and the height of the turbine, distance between two turbines and the direction of the turbines with respect to the direction of seasonal migration play a major role in the effects of the offshore wind farms on birds.

The height at which birds fly relative to the rotor swept area of turbine blades, is recognized as one of the most important attributes of birds that influences the risk of collision (Furness *et.al*. 2013). Other than collision risk, short-term habitat loss during the construction phase; long-term habitat loss due to disturbance from wind turbine installations and from ship traffic during maintenance; barriers to movement in migration routes; and disconnection of ecological units due to wind farms are the impacts that have been observed in studies abroad (Exo *et.al.* 2003). These impacts must be analysed by gathering information about avoidance responses, energetic consequences of habitat modification and avoidance flight, and demographic sensitivity of key species (Fox *et.al.* 2006).

Avoidance of offshore wind farms is one of the most common behaviors observed in multiple groups of pelagic birds. This has in some places led to a drastic decrease in abundances from the most preferred habitats of those species (Lindeboom *et.al*. 2011;Furness *et.al.* 2013; Reid *et.al.* 2023). In one of the more comprehensive assessments, Garthe *et.al.* 2023 (Table 4) demonstrated how populations of loons showed a decline of 63% within the 10km zone around wind farms and a 20% decline beyond 10km. It has been seen that knowing the flight height of birds in the proposed regions and building turbines shorter than the flight heights can help reduce mortality and avoidance behaviours. Furness *et.al.* 2013, speculate that weather conditions such as cyclones and storms may obscure the wind turbines and lead to collisions. Since GoM faces two turbulent monsoon periods, knowledge of seasonality of species-specific migration is highly recommended. Moreover, in the proposed site, the continuity of the wind farm block A, B, C, D, E and G covering a total area 5460 sq.km, with a parallel to shore length of 259 km is concerning. The minimum distance between two blocks in some cases is as little as 0.9km creating a 'wall' of wind turbine wings. This leaves no buffer for migratory birds to avoid existing farms and take different alternate routes. This array of wind turbines across this length would hamper the flight paths of a major population of birds migrating across the Gulf of Mannar and a critical assessment of flight paths is crucial to map the pathways used by various pelagic and passerine species every season.

Cluster	Offshore wind farms	Number of turbines	Installed power (MW)	Area used (km^2)	Periods (years)		Population change (BACI effect)			
							Within 1 km around OWFs		Within 10 km around OWFs	
					Before	After	Mean	95% CI	Mean	95% CI
Dan Tysk	Dan Tysk	80	288	65.66	2008–2013	2014–2016	−94%	−81%, −98%	−40%	−12%, −59%
Butendiek	Butendiek	80	288	33.12	2009–2014	2015–2017	−99%	−94%, −99.7%	−29%	−8%, −45%
Helgoland	Amrumbank-West, Nordsee-Ost, Meerwind Süd/Ost	208	885.2	108.76	2008–2013	2015–2017	−92%	−84%, −96%	−68%	−57%, −75%
BARD/Austern-grund	Global Tech, BARD 1	160	800	99.35	2005–2010	2014–2016	−46%	+357%, −92%	−66%	−36%, −82%
North of Borkum	Alpha Ventus, Trianel Windpark Borkum, Borkum Riffgrund 1, Gode Wind 1 and 2	227	1154	132.02	2004–2009	2015–2016	−94%	−81%, −98%	−42%	−6%, −64%
All cluster com-bined							−94%	−91%, −96%	−52%	−44%, −58%

Table 4 Garthe *et.al.* 2023 Shows changes in population of loons in different OFW.

5.3 Marine turtles

Five species of sea turtles - the Green sea turtle, Olive ridley, Hawksbill, Loggerhead and the Leatherback sea turtle, have been recorded from Indian waters and all five have been documented in the Gulf of Mannar and Palk bay. The IUCN lists the green sea turtle as Endangered, the hawksbill as Critically Endangered and the rest as Vulnerable. Green sea turtles were abundant in the 1970's but studies show that the population in the area is headed towards a decline due to bycatch in fishing gear and hunting pressure along with habitat degradation (Bhupaty and Sravanan, 2006). Historically targeted for their meat, shells and eggs (Pillai and Thiagarajan,1979) about 3000-4000 individuals were annually hunted between Pamban and Cape Comorin. While the consumption of sea turtle is still common, targeted hunting is now illegal but by-catch in gillnets, drift gillnets and shrimp trawls continue to decimate populations (Rajagopalan *et.al.* 1996; Kannan, 2004, 2008). The five species were introduced to Schedule 1 of the Indian Wildlife act, 1972; that, along with large scale awareness movements by local NGOs has helped reduce to some extent the targeted fishing and consumption (Murugan and Naganathan) of turtles.

The extensive seagrass habitats in the Gulf of Mannar and Palk bay is an important foraging area for these turtles (Richardson *et.al.* 2013; Pillai and Thiagarajan,1979). *Halophila ovalis* and *Thalassia testudinum* species along with the seaweed *Gelidiella acerosa* was documented from the stomach of nine turtles caught at Keelakarai and Vedala (Pillai and Thiagarajan,1979). Sporadic nesting by green, olive ridley, hawksbill and loggerhead turtles also takes place along the beaches of this area. Apart from sporadic records, there is also very little information on space-use and nesting by these turtles although records till the early 2000's show them being exploited for meat (Bhupati and Sravanan, 2002). Hawksbill turtle nests have also been documented from the Manapad region, but very little information exists about how the species uses these waters.

The olive ridleys nest along the coastline between December and April with a peak in February, and in the 1970's, 2500-3000 nests of the species were recorded from the coastline of Tamil Nadu. Studies of tagged Olive ridley turtles from Orissa by Shanker *et.al.* 2001 and Pandav *et.al.* 2001, showed that one satellite tagged individual moved towards Sri Lanka and 20 long distance tags recovered from Sri Lanka & the Gulf of Mannar, most of them were during the breeding season. Indicating that the area is a breeding ground for olive ridleys.

A telemetry study by Richardson *et.al.* 2013 (Figure 8) of ten tagged green sea turtles from southwest Sri Lanka found four post nesting females in the waters of Rameswaram and Dhanushkodi showing that the GoM is important both for post nesting females. No systematic long-term studies are in place to monitor sea turtle ecology in this very important region. A landscape level assessment of population sizes, seasonal movement patterns and nesting behaviour is critical to understand the impact of any future onshore or offshore development projects. Satellite tagging multiple species will particularly inform the space use during breeding, nesting and post nesting periods in the proposed OWF areas.

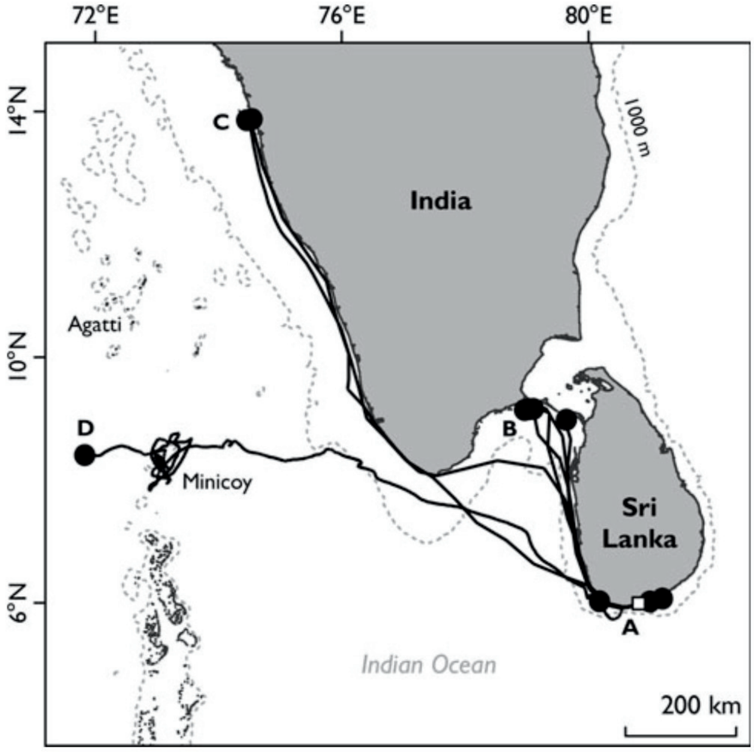


Figure 8: Migrations of the 10 green turtles satellite tagged in this study from Rekawa Sanctuary, SL to southern Sri Lanka , Gulf of Mannar , Karnataka and Lakshadweep Islands (Richardson et.al. 2013)

Potential impacts on turtles and recommendations towards mitigation

There are no known direct impacts of pile driving or the sound levels generated by the pile driving on sea turtles though they may act as a deterrent among pre-nesting females that migrate towards the shores during nesting months. Indirect impacts have been observed due to habitat alteration, with pile driving having a negative relation with zooplankton, jellyfish and benthic molluscs, that are a favoured prey for sea turtles. Habitat alteration events have shown that females may abandon nesting during that or subsequent seasons. Collision risk during the construction period when the influx in vessel traffic increases is the more detrimental aspect for turtles. Especially in the nesting season, when females are inshore, and newborn hatchlings are known to drift with the currents, construction activities may lead to greater mortality events.

Very little work has been done on long term effects of offshore turbines on sea turtles but a number of studies hypothesize the impacts based on the structure and functioning of turbines. A largely stated impact is the change in water column dynamics in the vicinity of the turbines or generation of wakes that change patterns of prey aggregation. The turbines may also increase levels of sedimentation around them, affecting benthic molluscs. Although these disturbances may be restricted to the immediate vicinity of the turbines, the cumulative effect of the entire set up might be substantial and may impact benthic assemblages and turtle prey.

Another poorly documented impact is that of the geomagnetic field generated by the offshore cables and their impacts on the magnetic map of sea turtles which they rely on for making their migratory journeys. A change in the naturally occurring magnetic field has been shown to disorient turtles away from their destinations and a field stronger than the turtles may lead to minor displacements along their routes.

5.4 Bats

Bats are the only true flying mammals under the order chiroptera and the second most diverse among all the orders of mammals, with immense ecological and physiological diversity. There are insectivorous, frugivorous, herbivorous, nectarivorous, and even sanguivorous bats divided into two suborders with 1,232 existing species worldwide, of which over 120 species are reported from Peninsular India and 35 species have been recorded from Tamil Nadu.

Appropriately identified as keystone species, bats keep ecosystems in balance and are excellent ecological indicators of good quality of habitat. Their mobility and movement from roosting sites to foraging sites are often long distances, providing some of the most important ecosystem services for human well-being. Frugivorous, herbivorous and nectarivorous bats conserve forest diversity by dispersing seeds across ecosystems and are responsible for increasing biodiversity. These are also a very important pollinator in agricultural landscapes. Their role is thus key to maintaining genetic variability in forests and crops. Insectivorous bats control and suppress the spread of natural and anthropogenic pathogenic insects and manage pests in both natural and man-made ecosystems, controlling the spread of disease even in crops, thus providing great benefit to human societies. Finally, the guano of these small mammals can provide nutrients and energy to terrestrial and aquatic ecosystems.

In the proposed OWF area, studies done in 1996-1997 in the coastal district of Nagapattinam reported seven species of micropteran bats (Swamidoss *et.al.* 2012). In 2012, a study by Bharathi *et.al*. documented both fruit bats and insectivorous bats roosting on the islands in Gulf of Mannar - these were three microchiropteran bats, *Hipposideros ater* (Dusky leaf nosed bat), *Hipposideros speoris* (Schneider's Leaf nosed bat) and *Megaderma lyra* (Indian false vampire bat) and two megachiropteran bat species *Cynopterus sphinx* (short nosed fruit bat) and *Pteropus giganteus* (Indian Flying fox). *H.speoris* is an insectivorous bat, *M. lyra* is a carnivorous bat while *C.sphinx* and *P.giganteus* are fruit eating bats. The study found a dependency between flora propagation and pest management on the islands - dependencies were observed between *Hipposideros, Megaderma, Cynopterus and Pteropus genus of bats with mangrove spp., Thespesia populnea, Pandanus fascicularis, Tamarindus indica, Zizyphus nummularia, Borassus flabellifer, Syzygium cumnii, Ficus spp., Cordia spp. and Acacia spp*. The bats depended on these plants for fruits, nectar and insect food. No other studies have been done on bats and a huge data gap remains.

Potential impacts on bats and recommendations towards mitigation

Onshore wind turbines are killing nearly a million bats each year in the United States alone due to collisions. Wind turbines onshore or offshore impact bats when the turbines are placed on bat flight lines or migration routes, or near to roosts, foraging areas and swarming sites.

Direct injuries to bats take place due to collision with the turbine blades or because of changes in air pressure around the blades. Indirectly the development of wind farms causes degradation or even loss and fragmentation of their habitats. In depth and long term research on the impacts of offshore wind on bats foraging offshore or migrating across the sea is a high priority in Europe and North America.

The problems of casualties at wind farms is being mitigated by temporarily turning off turbines after detecting a flock of incoming bats; by modifying the installed bright lights on turbines to warn aircraft pilots such that the blinking warning lights are turned on only when an airplane is nearby; and using ultraviolet lights to deter bats.

5.5 Marine Mammals

Twenty four species of marine mammals have been recorded from the Gulf of Mannar and Palk Bay, between India and Sri Lanka (Table 5), including four mysticetes (baleen whales), 19 odontocetes (toothed whales), and one sirenian. Of these, one is Critically Endangered, three are listed as Endangered and four as Vulnerable by the IUCN Red List of Threatened Species. Data from citizen science networks, fisher networks and opportunistic sightings and stranding reports have provided us baseline information on the diversity of this very important group of mammals in the area.

Marine mammal presence in the Gulf of Mannar may be year-round (e.g. dugongs, humpback dolphins, bottlenose dolphins, spinner dolphins, spotted dolphins) or seasonal (e.g. killer whales, humpback whales) and, within a species, may also vary in terms of distance from shore. During winter and spring, migrating Arabian sea humpback whales use the continental shelf within 20 km from shore, while humpback dolphins move nearer to the shore locally in the north - south direction depending on the prey and cold currents, but Dugongs have all year around presence in inshore seagrass beds. Adult dwarf sperm whales with and without calves could be using the area based on sighting and stranding data, as do singing humpback whales and all these reports show that the area is a breeding and calving ground for several endangered species. The review of all reports have been mapped in figures 14, 15 and 16 and are an indicator of the proposed OWF area being used by these species. Regarding OWF's, Madsen *et.al.* 2006 reviewed the existing literature and assessed zones of impact from different noise-generating activities. Pile-driving that generates intense impulses are likely to disrupt important life sustaining behaviors from many kilometers away. The review states that the impact zones from operating wind turbines will depend on the low-frequency hearing-abilities of the species, on sound-propagation conditions, and on the presence of other noise sources such as shipping.

Other than a dedicated program for Dugongs, no other studies or long-term monitoring has taken place for any of the cetaceans (all listed in Schedule 1 and 2 of the WPA 1972). Below we delve into the details of the 24 species of marine mammals that use the proposed OWF project area, their ecology, available information from the region and the threats they already face.

No.	Common Name	Scientific Name	OWF sites	IUCN Conservation Status
01	Blue whale	*Balaenoptera musculus*		EN
02	Bryde's whale	*Balaenoptera spp.*		DD
03	Omura's whale	*Balaenoptera omurai*	SL	DD
04	Arabian sea humpback whale	*Megaptera novaeangliae*		EN
05	Sperm whale	*Physeter macrocephalus*		V
06	Pygmy sperm whale	*Kogia breviceps*		DD
07	Dwarf Sperm whale	*Kogia sima*		DD
08	Cuvier's beaked whale	*Ziphius cavirostris*		DD
09	Killer whale	*Orcinus orca*		DD
10	Short-finned pilot whale	*Globicephala macrorhynchus*		DD
11	Pygmy killer whale	*Feresa attenuata*		DD
12	Melon-headed whale	*Peponocephala electra*		DD
13	False killer whale	*Pseudorca crassidens*		DD
14	Risso's dolphin	*Grampus griseus*		DD
15	Common bottlenose dolphin	*Tursiops truncatus*		DD
16	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*		DD
17	Indian ocean humpback dolphin	*Sousa plumbea*		EN
18	Indo Pacific humpback dolphin	*Sousa chinensis*		V
19	Rough-toothed dolphin	*Steno bredanensis*		DD
20	Spinner dolphin	*Stenella longirostris*		DD
21	Striped dolphin	*Stenella coeruleoalba*		DD
22	Pantropical spotted dolphin	*Stenella attenuata*		DD
23	Indo-Pacific finless porpoise	*Neophocaena phocaenoides*		V
24	Dugong	*Dugong dugon*		V

Table 5. A list of marine mammal species that have been reported from the OWF proposed area. @marinemammals.in and @ Nanayakkara *(pers.comm.),* Sri Lanka.

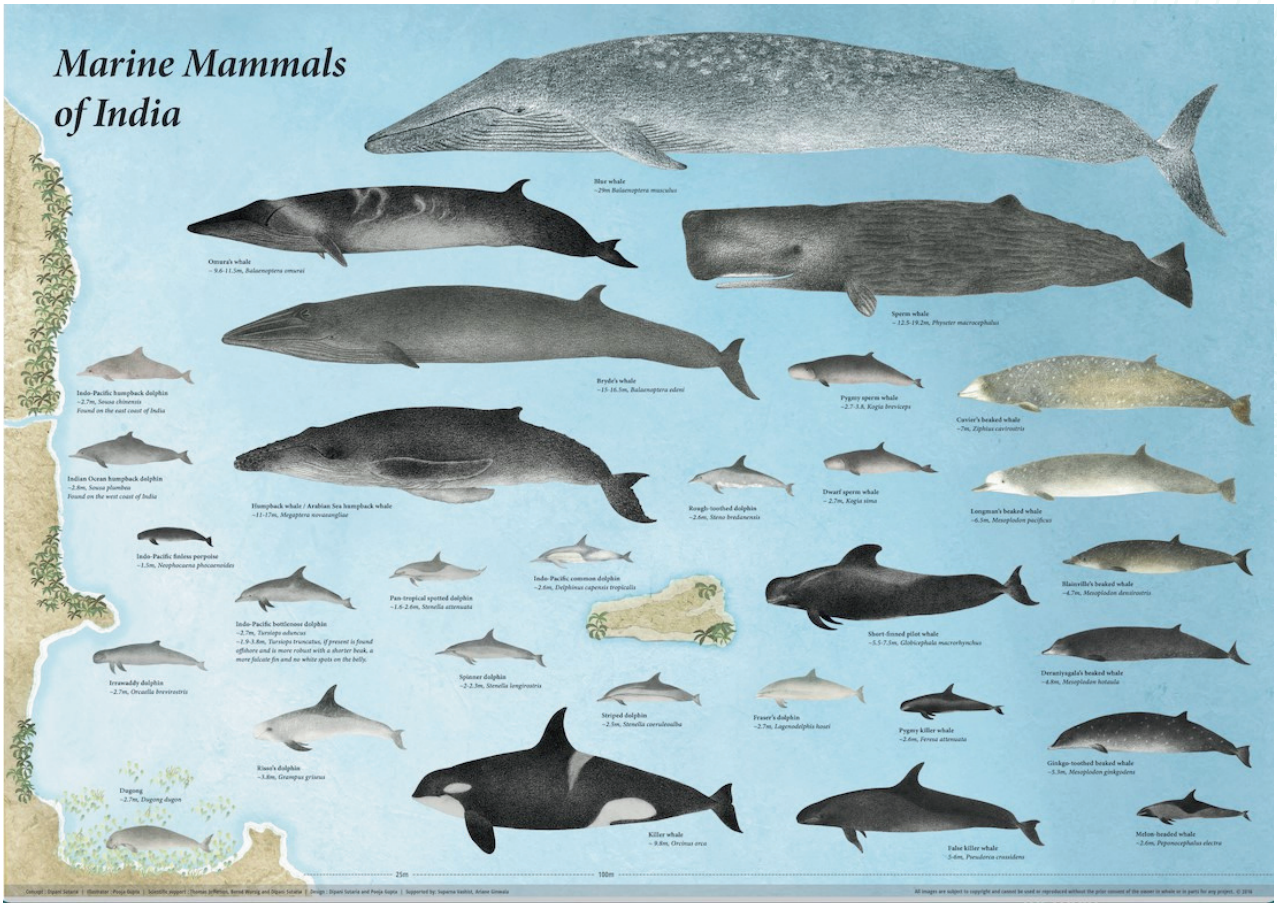


Figure 9. Marine mammal diversity in the waters of the Indian sub-continent, with species depicted in their preferred habitat types, across the depth profile from shore to the deep sea's

Sirenidae

Dugong (*Dugong dugong*)

The transboundary region, shared by India and Sri Lanka, is currently the most important habitat for seagrasses and dugongs in South Asia (Johnson *et.al.* 2023, Schramm *et.al.*2024). Nair and Sivakumar 2013 (Figures 10a,b) show that in the Gulf of Mannar region, the Tuticorin-Tharuvaikulam and Roachamanagar, Dhanushkodi stretches, including the offshore islands, are critical for dugongs.

Johnson et al.'s (2023) exploratory UAV transect surveys in 2022 in a 6.34 km^2 survey area within 3 km from shore, in the Dugong Conservation Reserve of Palk Bay, sighted four Dugongs, showing that the local population is very low in number and requires multiple approaches to conserve, one of the most important being the sustenance of good quality seagrass habitats.

The targeted hunting of Dugongs in the twentieth century suggests that the region had a strong population residing in the seagrass beds. Given their decimation, Dugongs are now listed under Schedule I of the Wildlife (Protection) Act, 1972 and as one of the five Critically Endangered species identified by the MoEFCC for species recovery under the CAMPA scheme.

Dugongs are also one of the 21 species listed as threatened species under the Integrated Development of Wildlife Habitat (IDWH) Programme of India (launched in the 11th plan period 2009) giving the species and its habitat utmost priority for the conservation of species through the National Endangered Species Recovery Plans of the MoEF-CC, India.

Seagrass beds, identified as critical habitat for dugongs such as the one in Gulf of Mannar and Palk Bay have been given protected area status as per the Wildlife (Protection) Act, 1972, and other coastal areas with seagrass meadows are managed under the Environment (Protection) Act, 1986.

The pressures already facing the Dugong population range from local consumption in the past to developmental pressure and habitat degradation and loss from detrimental fishing, oil and gas exploration and shipping related activities.

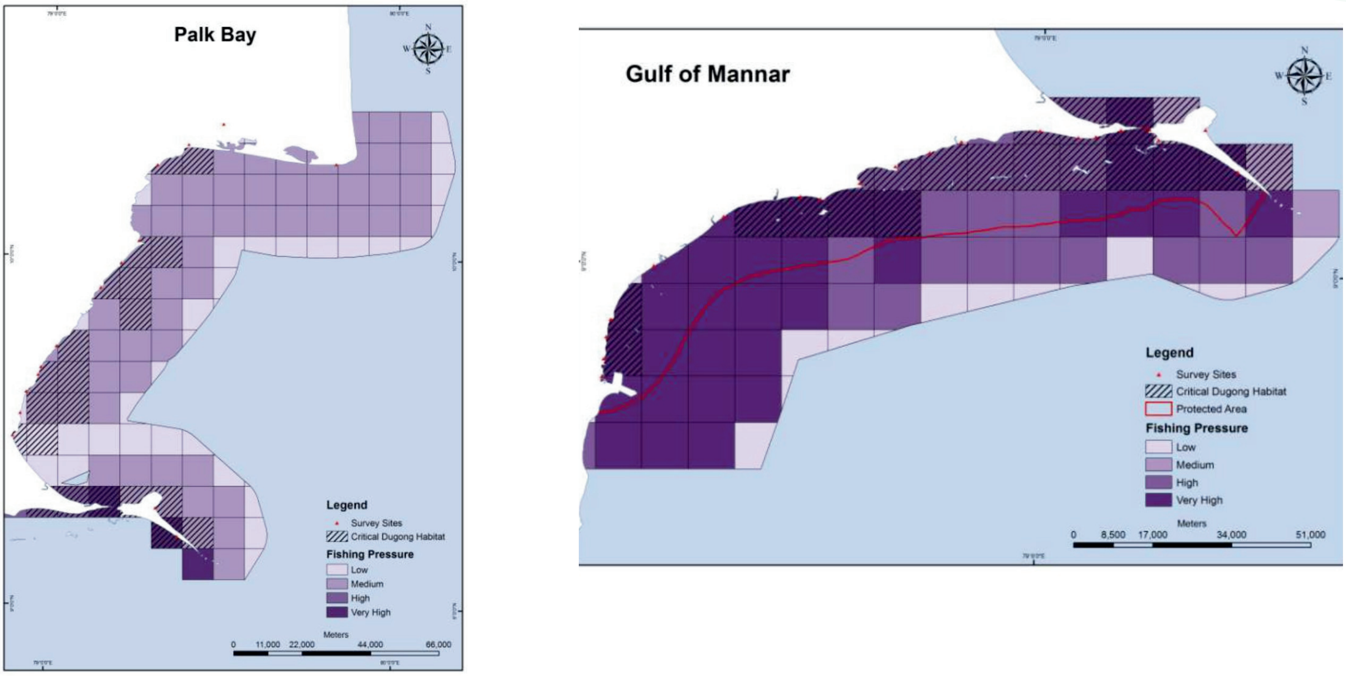


Figure 10. Critical dugong habitat in the a.Gulf of Mannar and b. Palk Bay (Nair and Sivakumar 2013)

Mysticetes (baleen whales)

Bryde’s whale (*Balaenoptera edeni and B. brydei*)

Bryde's whale is a mid-sized baleen whale that inhabits the tropical and subtropical latitudes of the Indian, Pacific and Atlantic oceans. It is known to prefer highly productive areas, and their occurrence is year around, associated with upwelling zones such as the one in the proposed OWF area. It has been commonly documented from the region; being recorded from both Indian and Sri Lankan waters.

The taxonomic status of the Bryde's whale is still uncertain but both *B.brydei* and *B.edeni* are anticipated from the area (Leatherwood, 1984, Ilangakoon 2006; 2012, Devos 2012). Along the coastline of Tamil Nadu, strandings of the species have occurred from areas like Point Calimere, Thootukudi to Ervadi (MMI database, Sudhan *et.al.* 2017, Sutaria *et.al.* 2019). The Sri Lankan coast exhibits two peaks in stranding being observed between August-September and November-December (Ilangakoon 2006). Live sightings of the species have been observed both on the shelf edge and the shallower inshore waters in the Gulf of Mannar (Ilangakoon 2006; Leatherwood, 1984; Figure 12).

Mother-calf pairs have also been regularly sighted in the area, along with observations of foraging by the species (Nanayakkara, Devos, 2012).

Ship strikes have been reported from the region for Bryde's whale mortalities (Nanayakkara and Herath, 2017) and seismic surveys in the Gulf of Mannar have been flagged as a potential threat to all mysticete whales. (Ilangakoon, 2012).

Blue Whale (*Balaenoptera musculus*)

Blue whales are globally endangered and a population of pygmy blue whales (sub species, *B. m. brevicauda*; Figure 11) in the northern Indian ocean shows a year-round presence particularly in the southern seas and Sri Lanka based on stranding and acoustic studies (Stafford, *et.al.* 2011; Figure 12).

Anderson (2012) pointed towards a west-east migration of the species between the Arabian Sea and the Bay of Bengal with animals dispersing from the western Arabian Sea by the end of the south-west monsoon and peak abundances around Sri Lanka occurring between February to March. A higher density of the species around southern Sri Lanka including Wadge bank and Gulf of Mannar (Randage *et.al.* 2014) may be seen in December. Further the presence of mother-calf pairs and observed breeding in this region makes it a very important area for the north Indian ocean population of the species. One of the most vulnerable species to anthropogenic threats, the highly populous shipping route of Colombo on western Sri Lankan coast in southern Gulf of Mannar, also harbours high densities of blue whales (approximately 270 individuals) which has resulted in ship strikes including mortalities of calves (Priyadarshana *et.al.* 2016; De Vos *et.al.* 2016). Ilangakoon (2012) also suggested that the Sri Lankan whale watching industry has led to the displacement of the population from nearshore -feeding grounds to areas in the vicinity of the shipping lanes, further increasing chances of strikes. Being a species that uses low-frequency vocalizations, they are also susceptible to anthropogenic sound sources and disturbances such as those produced by ships and large-scale construction at sea (Ilangakoon 2012; DeVos *et.al.* 2016).

Systematic studies on blue and pygmy blue whales are lacking in Indian waters, but opportunistic sightings and strandings of the species have been frequently observed (MMI database, Kumarran 2012, Sutaria *et.al.* 2017, James and Soundarajan, 1979). Systematic work towards understanding their use of the proposed OWF area is critical.

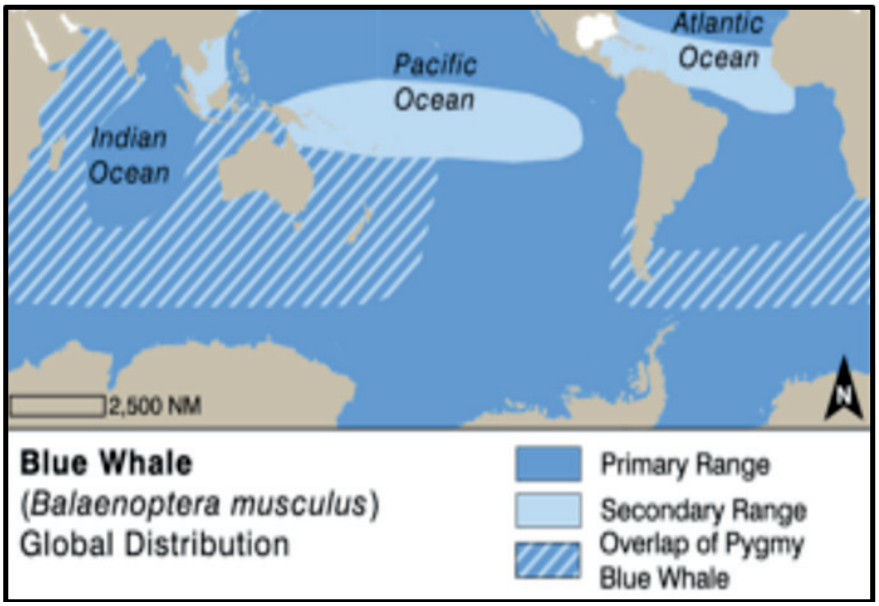


Figure 11. Blue whale global distribution. Adapted by Nina Lisowski from Jefferson, T.A., Webber, M.A. and Pitman, R.L. (2015). "Marine Mammals of the World: A Comprehensive Guide to Their Identification," 2nd ed. Elsevier, San Diego, CA.

Humpback whale (*Megaptera novaeangliae*)

Humpback whales are found in all the major oceanic basins, with temperate populations showing seasonal migration from feeding grounds in temperate waters to calving grounds in tropical waters in the winter. In India, the presence of the small and endangered population of Arabian sea humpback whales, that use the deeper continental shelf in the Arabian sea and around till the Gulf of Mannar was confirmed by Sutaria *et.al.* 2017, 2018. The proposed OWF area might also have migratory humpback whales from the southwest Indian Ocean during December to March and June to October (Anderson *et.al*. 2022). Sightings of the ASHW have been recorded from the nearshore, coastal waters of India and western Sri Lanka, and these also include singing males and females (MMI database, Anderson et.al.2022; Sutaria *et.al*. 2017, Sutaria 2019). Stranding records of the species are also present from the coastlines of both countries in the proposed OWF area (Ilangakoon, 2006, Sutaria *et.al.* 2017, Sutaria 2019). Humpback whales have been hunted across its range till the 1960's and most populations were decimated including this one in the Arabian sea and there is still no evidence of species recovery.

Whitehead (1983) heard humpback whale songs between February and March 1982 and from January to April 1983 (Whitehead 1985), in the Gulf of Mannar (Figure 12, map of baleen whale presence Whitehead 1985). In 2017, a satellite tagged female humpback whale spent close to three months on Wadge Bank and Gulf of Mannar (ESO, Figure 13).

Given that ASHW are already endangered, the risk from ship strikes, entanglement in fishing gear and the effects of the current or changed levels of underwater noise need better evaluation and mitigation to avoid any further threats on this species and similar species in the proposed OWF area.

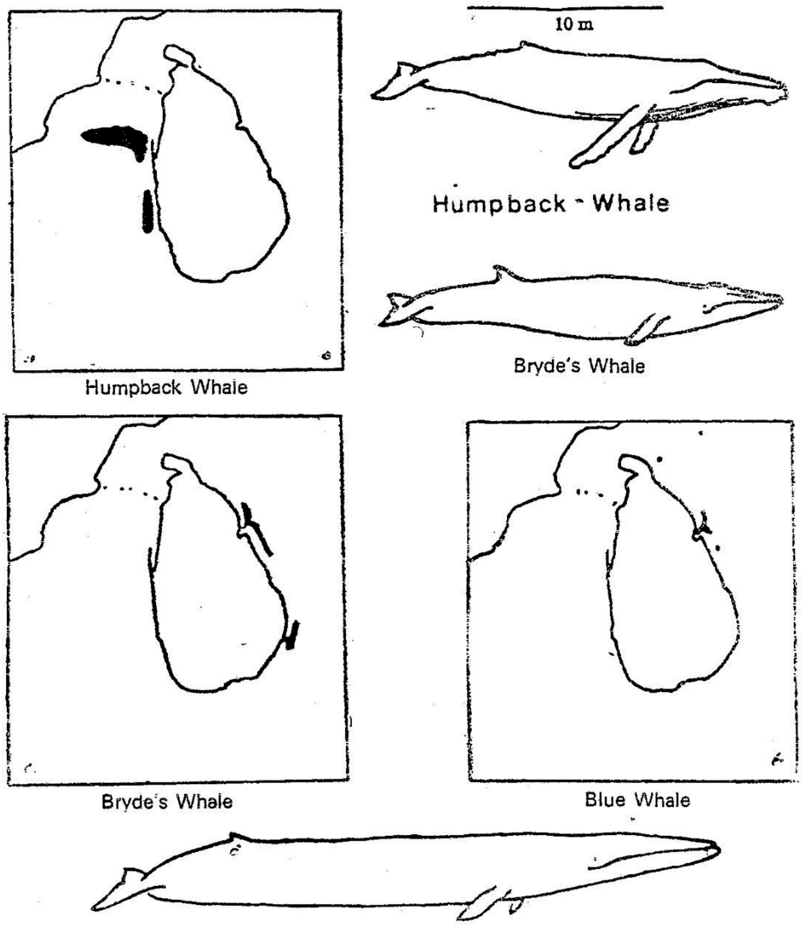


Figure 12. Map of Bryde's, Blue and Humpback whale distribution based on acoustic presence in the Gulf of Mannar in 1982 and 1983 (Whitehead 1983)

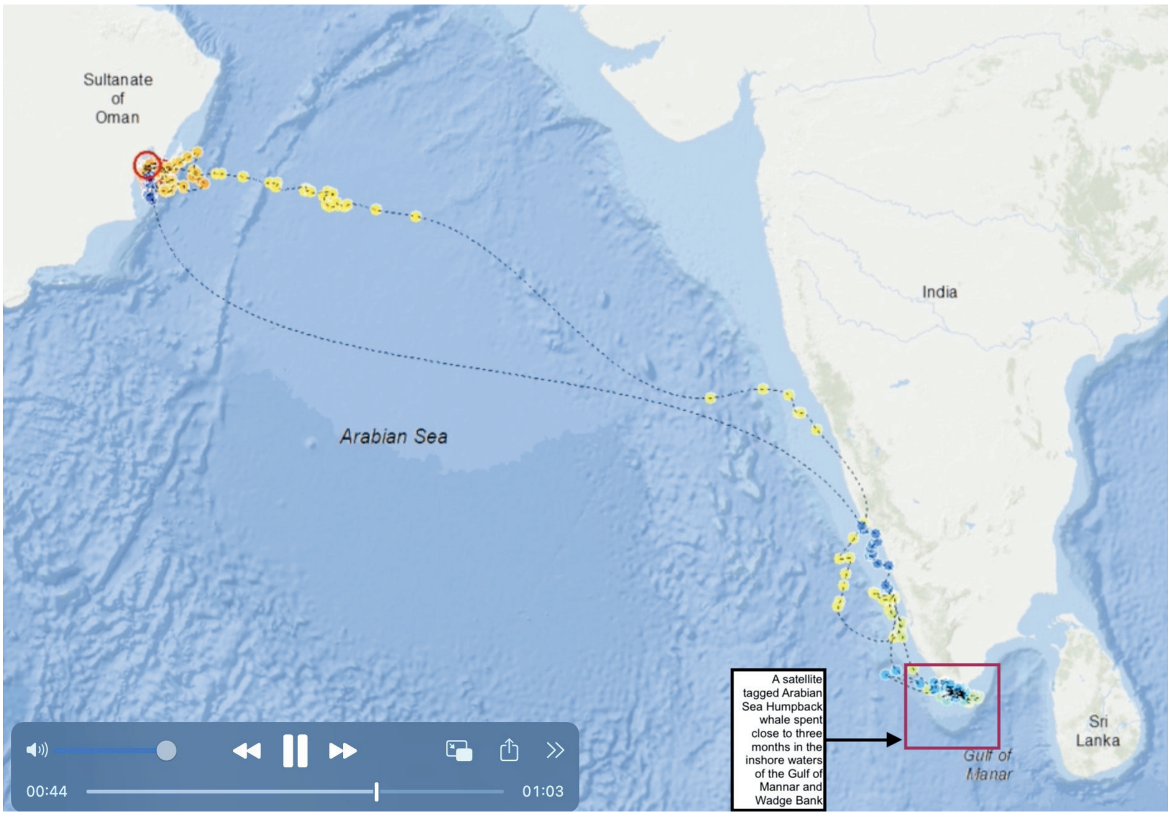


Figure 13. The path of an adult female Arabian sea humpback whale named Lubaan is shown above. Lubaan arrived along the southwest coast of India around day 30 of being satellite tagged off Oman and stayed in the Wadge bank and Gulf of Mannar region for close to 90 days, before returning to Oman waters after being in Indian waters for 110 days. @Environment Society of Oman.

Odontocetes (toothed whales)

Finless porpoises (*Neophocaena phocaenoides*)

The finless porpoise is the only species of porpoise found in south Asia and is an inshore species restricted to coastal waters with a strong preference for sandy-soft bottoms (Jefferson, 2002). Records show the presence of the species in the proposed OWF area along the Tamil Nadu coast and along the west coast of Sri Lanka (Sule *et.al.*2017, Nayanakkara *et.al.* 2017) shows the importance of the contiguous continental shelf between India and Sri Lanka.

Liang *et.al.* 2023 studied the impact of the Jinwan Offshore Wind Farm project in the Pearl River Estuary (PRE) on the resident Indo-Pacific finless porpoise population. A broadband recording system was deployed before and during the construction period, to test how the finless porpoise responded to pile driving activity. The results showed that the porpoises showed avoidance behavior during the pile driving with a significant negative correlation between porpoise detection and pile driving detection. Liang *et.al.* recommend acoustic protection measures in future offshore wind farm developments.

Historically the species has been targeted for meat and have been caught in fixed gill nets and shore seines in coastal zones of the GoM and Palk Bay (Kumarran 2012). Fisheries entanglement and habitat degradation are two of the biggest threats faced by the species. Given its small size and lack of a dorsal fin, studying it via conventional methods has made it difficult to make population assessments. IUCN has assessed a decreasing trend for the species throughout its range; some populations have already disappeared from large areas of countries like Thailand.

Delphinidae

Indian Ocean humpback dolphins (*Sousa plumbea*) and Indo-pacific humpback dolphins (*Sousa chinensis*)

These are two species of cetaceans are found only in nearshore waters within 30m water depth, in their respective geographic ranges. *S. plumbea* is restricted to a range between the tip of south eastern Africa and south India till the Gulf of Mannar; whereas *S.chinensis* is found from Gulf of Mannar (India and northwest Sri Lanka), till Hong Kong, including the Gulf of Thailand and the adjacent land masses. The proposed OWF area hence is the region where speciation of the Sousa complex could have taken place.

The overlap between the two species needs to be assessed using genetic and morphological studies to test the hypothesis that the project area could be harbouring a distinct population or sub-species of Sousa. Our understanding of the two species from the area are from distribution reviews (Sutaria and Jefferson, 2004) and incidents of strandings and opportunistic sightings and surveys along the east coast of India (MMI database).

A higher stranding frequency of the species has been observed from Dhanushkodi and Rameswaram areas. Populations of both species are seeing a declining trend given their coastal habitat which overlaps with fisheries, large scale infrastructure developments including large and small ports and poor water quality.

Range wide mortalities from fishing gear, especially gillnets, is one of the biggest threats to these species (Sutaria *et.al.*2015). Studies from Hong Kong have reported a change in distribution patterns of the species due to increase in vessel traffic and underwater noise levels from high-speed ferries and increase in habitat pressures (Wang *et.al.*2024, Piwetz *et.al.* 2012, Hung 2014).

Huang 2022 studied the impact of a cluster of OWF on a critically endangered subspecies of humpback dolphin (*Sousa chinensis taiwanensis*) in the eastern Taiwan Strait. The OWF were sited in the core habitat of the dolphins and the wakes induced by the foundation were inspected using Landsat imagery. It was found that humpback dolphin sighting rates from boat-based line-transect surveys started decreasing during construction and decreased significantly post construction OWF during the operational phase. This indicated that the dolphins were moving away from the once-important core habitat. The noise and the waves of turbulence generated could lead to acute stress, or impact prey abundance and composition. Masking of fish choruses that are prey for dolphins could also happen from operational noise also disturbing the benthic ecosystem. Huang suggested that future OWFs should avoid the habitats of coastal delphinids.

Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)

The IUCN lists the Indo-Pacific bottlenose dolphin as "Near Threatened" in their Red List of endangered species. This species has been seen caught in the gill net fisheries off Sri Lanka's west coast and in the fisheries on Kerala and Tamil Nadu.

Super pods have been sighted in the offshore northwest waters of India while smaller groups have been reported from Lakshadweep, Andaman Nicobar Islands, and along peninsular India from the southwest coast and all along the east coast of India. They are found around islands, coral reefs and in seagrass and sandy habitats, making the proposed OWF area very conducive for their populations.

The preference for inshore continental shelf habitat makes it very vulnerable to environmental degradation, direct exploitation, and fisheries entanglement.

Studies on bottlenose dolphins have shown that auditory injury can occur within 100m of the pile-driving and behavioural disturbance, defined as modifications in behaviour, can occur up to 50 km away (Bailey *et.al.* 2010). This raises an important issue regarding the evaluation and mitigation of the impact of pile-driving events during construction.

Spinner dolphins (*Stenella longirostris*)

Spinner dolphins have a widespread distribution in offshore tropical waters and often come inshore in large pods. Along the Indian mainland the species is largely found on and off the shelf edge and along the two island groups of Lakshadweep and the Andaman Islands.

In the Gulf of Mannar, the species is common and occasionally strands. In a systematic survey effort across the Indian EEZ, Afsal *et.al.* (2008) recorded the species as the most abundant in terms of number of animals sighted.

Off Sri Lankan the species is most commonly observed in the Bar reef and in offshore sites (Balance and Pitman, 1998; Broker and Ilangakoon, 2008; Ilangakoon, 2008).

Commonly sighted in super pods of 450-1000 animals and also in multispecies associations with species like blue whales, sperm whales, bottlenose dolphins and short finned pilot whales (Ilangakoon, 2012; Broker and Ilangakoon, 2015). This has been hypothesized to maximize foraging opportunities along upwelling zones like the one is the proposed OWF are, such as continental shelf breaks where most of these sightings have been observed. Alling (1986) observed calves between January and March off the edge of Sri lanka. A systematic effort to understand seasonal space-use or breeding periods of the species in the area is very important. Bycatch from gillnets and large sized trawlers has been identified as a threat to the species. The species is also often pursued by dolphin tourism operators and disturbance from tourist boats is an identified threat in the area (Mattingley *et.al.* 2016).

Pantropical spotted dolphins (*Stenella attenuata*)

Pantropical spotted dolphins have a widespread distribution in both inshore and offshore tropical and subtropical waters (IUCN 2024). Just like spinner dolphins, these are a free ranging species which come close to shore following currents of prey fish species.

Along the Indian mainland the species has been reported both from the east coast and the west coast, largely found on the shelf at the 30 plus depth contour, and on the shelf edge, or with tuna shoals that come near shore. They are found in super-pods of 100's of animals consisting of several sub-groups, and often associated with shoals of tuna. The preferred prey for pantropical spotted dolphins decides their diurnal activity and space use, preying on small schooling fish, squid or crustaceans that live in the deep scattering layer. These species descend during the day and rise to the subsurface at dusk and hence the dolphins can be seen often at night foraging. This preference is what makes them associated with various species of tuna, as well as spinner dolphins and other oceanic predators that feed on the same prey. Pantropical spotted dolphin status is unknown and the threats they face are primarily from fishing gear entanglement in tun gill nets, drift gill nets and purse seine fisheries, even in India and Sri Lanka. Data from Sri Lanka of targeted landings of dolphins back in 1990's found 193 spotted dolphins caught in one year showing that their overall numbers are much lower than spinner dolphins.

In the project area, pantropical spotted dolphins have been sighted on Wadge Bank by Afsal *et.al.* 2008 and further east in Sri Lanka. And stranding reports are available for the coast of Tamil Nadu, Kerala and the western Sri Lanka.

Striped dolphin (*Stenella coeruleoalba*)

This is a species of oceanic dolphins found in tropical and temperate waters. Unlike the free ranging spinner dolphin, striped dolphins are almost exclusively found in deeper offshore waters. They feed primarily on pelagic and benthic-pelagic species, in mid waters as deep as 200-700m.

The Indian mainland records few accounts of stranded striped dolphins and even fewer sightings. The TN coast so far shows no record of the species as a sighting or stranding; this is largely a result of a lack of systematic effort.

In her study, Alling (1986) records multiple sightings of the species from the offshore waters of western SL in depths of >1100m. She also records calves between February and April. Balance and Pitman (1998) have also recorded the species from western SL.

The species has been taken by harpoon and gillnet in SL and made up 14% of the total cetaceans brought at fish landing sites between 1985-1988 in SL (Ilangakoon, 1997). Given its preference for offshore habitats, a more dedicated effort in the GoM is required to ascertain its habitat ecology.

Risso's dolphin (*Grampus griseus*)

Risso’s dolphins occur throughout tropical and temperate waters. They are reported using continental slope and oceanic and continental shelf waters, areas where the bottom topography is steep (Jefferson *et.al.* 2024).
Currents and upwellings influence their presence and space use because of which they seem to have a clustered distribution with local resident populations worldwide in offshore areas (Kruse et al. 1999).

It is a common species and estimates based on indices of relative abundance off Sri Lanka from 1980 to 1984 to more recent surveys suggest a possible decline of Risso’s dolphins off Sri Lanka, particularly along the south coast (Anderson 2013).
In India they have been found from both offshore island systems and along the southwest coast and all along the east coast of India, including the Gulf of Mannar.
Threats include bycatch in offshore gillnets, pelagic longlines, and other fishing gear. Like other deep-divers that prey on cephalopods, Risso’s dolphins are at risk from loud anthropogenic sound, such as that generated by military sonar and seismic surveys (Southall *et.al*. 2021).
Given that shelf edges are important habitat for these species, these regions need to be conserved, and all pre-construction geophysical surveys need to be shut down if spinner dolphins are in the vicinity.

Common dolphin (*Delphinus delphis tropicalis*)

Delphinus delphis tropicalis is a subspecies of common dolphins that occurs in the Indo-Pacific where they are found mostly in deeper parts of the continental shelf and generally do not occur around oceanic islands (Jefferson and Van Waerebeek 2002). They also prefer upwelling-modified waters making the proposed OWF area from Kanyakumari to Gulf of Mannar an important habitat for this least studied species of small dolphins.

Common dolphins were a targeted fishery in south India and Sri Lanka and are still by-caught in fishing gear throughout their range.
While the Indian ocean population is not studied, the Black Sea subspecies is classified as Vulnerable, the Mediterranean subpopulation is Endangered (Bearzi 2003, Bearzi *et.al.* 2020), and the Gulf of Corinth subpopulation in Greece, is Critically Endangered (Bearzi *et.al.* 2020).

Prey depletion caused by overfishing, underwater noise and chemical contamination are some of the other threats facing these populations.

Rough-toothed dolphin (*Steno bredanensis*)

Rough-toothed dolphins are oceanic, occurring in deep, usually > 1,000 m waters and can also be found visiting inshore waters of the continental shelf. Usually seen in small groups, mostly ranging from 5 to 15 individuals although large groups of over 100 have also been recorded (IUCN 2024).

In India, they have been sighted off the Lakshadweep islands, Andaman and Nicobar islands, and off the coasts of southwest and southeast India, No abundance estimates for the species are available in the Indian ocean and large parts of their range have not been surveyed.

Their presence in the proposed OWF area just at the shelf edge are highly probable. The threats facing rough toothed dolphins, other than underwater noise, is primarily from target fishery and as bycatch in offshore purse seine fishery, gill nets, drift gill nets and long line fisheries in deep water.

False-killer whale (*Pseudorca crassidens*)

The False killer whale inhabits the tropics and subtropical oceans and is a day feeder and preys on a wide variety of fish and squid including large species like tuna and mahi-mahi.
It is also one of the two other species of cetaceans that feeds on other marine mammals (Bianucci *et.al.* 2022). Multiple records of sightings and strandings point to frequent usage of the proposed OWf area by the species.

Off Sri Lanka the species has been documented via sightings, strandings and by-catch. Multiple historical and recent stranding events have been reported from the project area (MMI database database; Rao *et.al.* 1989; James and Soundarajan 1979, Silas and Pillay 1960).

The species has been observed as individuals and in pods of >10 individuals (MMI database, Ranil pers comm. De Vos 2012) from the region. Stranding and sighting events show year-round presence of the species including calves in the proposed project area (MMI database).

Bycatch and entanglement are a global threat for the species and in the proposed area as well, it has been documented in fishery by-catch in both Indian and Sri Lankan waters (Jayabaskaran and Vivekandan, 2013, Ilangakoon 2000).

Orca (*Orcinus orca*)

Orca are the most widely ranging cetaceans and are found across all latitudes but larger populations of the species are seen in temperate waters. The species has 7 ecotypes across various ocean basins with at least one type anticipated to be a subspecies. The types within the Indian ocean are one of the most under-studied although they have been sighted frequently in coastal and pelagic waters here.

As generalist feeders they forage on a wide variety of species including other marine mammals and mega faunal species. Multiple sightings of the species have been recorded from near Kalpitiya (Sri Lanka) in eastern GoM and off Mirissa in southern Sri Lanka (Ilangakoon *et.al.* 2010; Iangakoon, 2012; Gemmel *et.al.* 2015).
Accounts of Orca feeding on other species such as the sperm whale, blue whale and beaked whales have also been recorded from the area (Gemmel e*t.al.* 2015).

They live in group sizes of 1-8 individuals, and have been recorded with calves from the area. An adult female has also been reported in gill-net by-catch at Negombo (SL) (Ilangakoon *et.al.*, 1990).

Melon-headed whale (*Peponocephala electra*)

The Melon-headed whale is a highly social toothed whale found in tropical and subtropical waters inhabiting deep pelagic waters and is also known to be associated with nearshore features of oceanic islands (IUCN 2024).

Multiple authors record the species from the Gulf of Mannar, Palk Strait area and the Bar Reef Marine Sanctuary in the east (Ilangakoon, 2008; Broker and Ilangakoon, 2008; Devos *et.al.* 2012). Historical data and catch records of the species also show its presence in the region (Blanford, 1891; Devos *et.al.* 2012).

A rare sighting of melon-headed whales associated with sperm whales has also been recorded from the offshore waters of western Sri Lanka (DeVos *et.al.* 2012). Anthropogenic noise, especially those associated with mid-frequency sonar (1-10 khz) and by-catch in drift and purse-seine fisheries are some of the major threats that some resident populations have been known to face (Ilangakoon, 1997; Southall 2021; Jeyabaskaran 2013).

Short-finned pilot whale (*Globicephala macrorhynchus*)

Short-finned pilot whales are found in deep waters over the outer continental shelf or continental slope and are found in tightly associated individuals in small groups. They are deep diving and are adapted to feeding on squid, with reduced tooth counts associated with suction feeding (Werth 2000).

They are known to be both nomadic and resident or at least semi-resident in some parts of their range. Short-finned pilot whales are listed on the IUCN Red List as Data Deficient and the species remains data-poor in much of its range, especially in the Southern Hemisphere.

There is evidence of interaction between Short-finned Pilot Whales and long-line fisheries (Kiszka *et.al.* 2008) based on visual assessment of markings and fisher interviews. Even though they are widely distributed there has been too limited survey effort to estimate population sizes or trends.

In India, they have been reported from the continental shelf off Kerala, and both the Lakshadweep and Andaman Nicobar archipelago's. The proposed OWF site is visited by large pods of pilot whales every year. Three mass strandings of 80-147 individuals have taken place in the area (Alagarswami *et.al.* 1973; Nammalwar *et.al.* 1989, Jeyabaskaran *et.al.* 2018.

Sperm whale (*Physeter macrocephalus*)

Sperm whales are the largest toothed whales found in all ocean basins worldwide, with a preference for deeper waters off the continental edge (depths >1000m), where they feed on deep sea cephalopods, especially deep sea squid and are hence associated with submarine canyons and trenches. Sperm whale populations had been severely decimated to about 67% of their original population due to whaling from the 1700s to the early 1900s. There is no current assessment to quantify if the populations have been recovering since.

Whitehead 1982 reported sperm whale sightings and vocalisations in the deep waters of the shelf edge in the Gulf of Mannar, including a female group of five adults with five calves, showing the importance of this area for this endangered species of deep diving cetacean. Surveys conducted in the northern Indian ocean again recorded sperm whales frequently in the area (Ballance and Pitman, 1998; Afsal *et.al.* 2008). Off the west Sri Lankan coast the species has been frequently documented, in groups as big as 23 individuals, along with females, calves and immature males (Leatherwood and Reeves, 19989; Ilangakoon, 2002, 2006; Ocean Alliance, 2003; De Vos *et.al.* 2012). The marine mammals of India database also report multiple records along the south Tamil Nadu coast including the proposed OWF area. Sperm whales have very sophisticated communication and vocalizing abilities at high frequency (HF) making them susceptible to mortalities due to high frequency sonar noise. Given that sperm whales use continental shelf edge and the canyons of the GoM, and the project area, utmost vigilance in terms of use of pre-construction sonar and geophysical surveys need to be taken and shut down till the species leaves the area.

Dwarf sperm whale *(Kogia sima),* Pygmy sperm whale *(Kogia breviceps)*

Dwarf Sperm whales and Pygmy Sperm whales are closely related and fall under the Kogiidae family. They are highly elusive species inhabiting oceanic waters and the continental and insular slopes in tropical and warmer temperate regions. These are a deep-diving group of animals which are relatively hard to distinguish from each other at sea. Squid and a wide variety of cephalopod species along with fish and mesopelagic crustaceans have been documented from the gut content of stranding cetaceans (Plon and Baird, 2022, Plon, 2023).

In the proposed area, both species have been recorded from the GoM and Palk Bay from both Indian and Sri Lankan waters. Sighting the species is difficult owing to their cryptic nature (Ilangakoon, 2008, 2000, Broker and Ilangakoon, 2008) but a substantial number of individuals have been reported in by-catch, opportunistic hunting and stranding events (Dayaratne and Joseph,1993, Chantrapornsyl, 1991; Ilangakoon *et.al*. 2000; Da Silva, 1987, MMI database).

A detailed assessment to understand space-use of the species in the continental slope bounding the proposed OWF area is particularly critical given that both species occupy niche topographical features in the sea. Kogia has been opportunistically hunted in parts of the northern Indian ocean and has been prone to by-catch in drift gill nets.

It's logging behavior on the surface leaves it vulnerable to ship strikes as well and as is with other species, plastic debris ingestion causing fatality has also been reported in the species. Like Sperm whales, they are extremely vulnerable to high frequency underwater noise.

Ziphiidae (four species of Beaked whales)

Beaked whales are wide-ranging but highly elusive given their nature of making extended deep-dives, making the safety of the deep sea habitats vital for their well-being. They can be found anywhere in waters deeper than 200m but are known to prefer features such as continental slopes, shelf edges and submarine canyons (Azzellino, 2008; Nanayakkara, 2011). Four species of beaked whales, the Cuvier's beaked whale (*Ziphius cavirostris*), the Longman's beaked whale (*Indopacetus pacificus*), the Blainville's beaked whale (*M. densirostris*) and Deraniyagala's beaked whale (*M. hotaula*) have been reported from the proposed OWF area.

The Cuvier's beaked whale is the most common of the four species followed by the Longman's beaked whale while the two Mesoplodons are rare (Dalebout *et.al.* 2012, 2014, Nanayakkara, 2011). Cuvier's beaked whales have been frequently documented from the shelf edge in Bar reef in the Mannar (pers comm Ranil Nanayakkara).

Beaked whales have been targeted as catch by harpooning and are by-caught in fisheries in the region (Anderson *et.al.* 2006; Alling, 1983; Nanayakkara, 2011, Leatherwood and Reeves, 1989; Ilangakoon, 2003, Dayaratne and Joseph, 1993).

A review of known records of sightings, strandings, targeted and by-caught individuals suggest a surge between February to May with a peak in March in the eastern GoM, coinciding with the upwelling period associated with reversal of monsoonal winds in the northern Indian Ocean (Nanayakkara 2011).

Like other deep-diving species, beaked whales too are more vulnerable to anthropogenic sounds especially in the high-frequency ranges and the use of naval sonars in their habitat's vicinity are one of the known causes of mass strandings of these species.

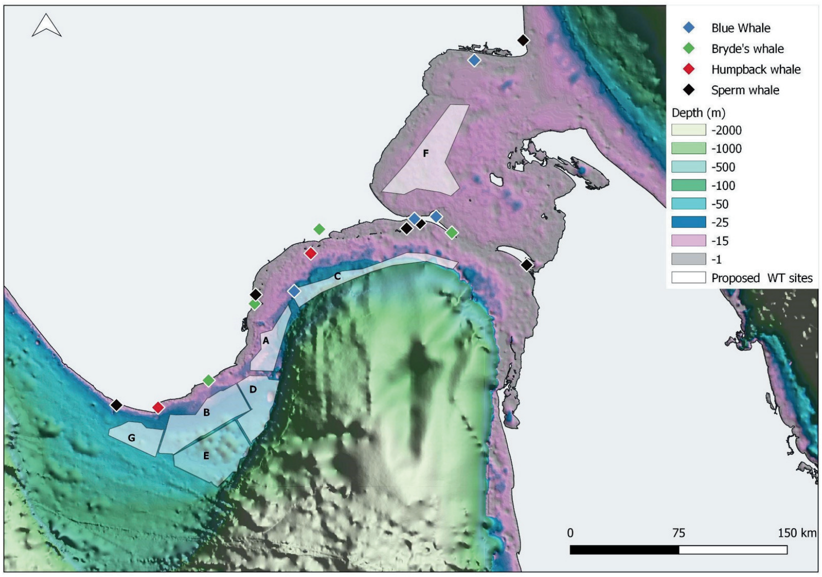


Figure 14. Citizen science reported data mapped for Blue, Bryde's and Humpback whale and the Sperm whale, as an indicator that the OWF area is being used by these species.

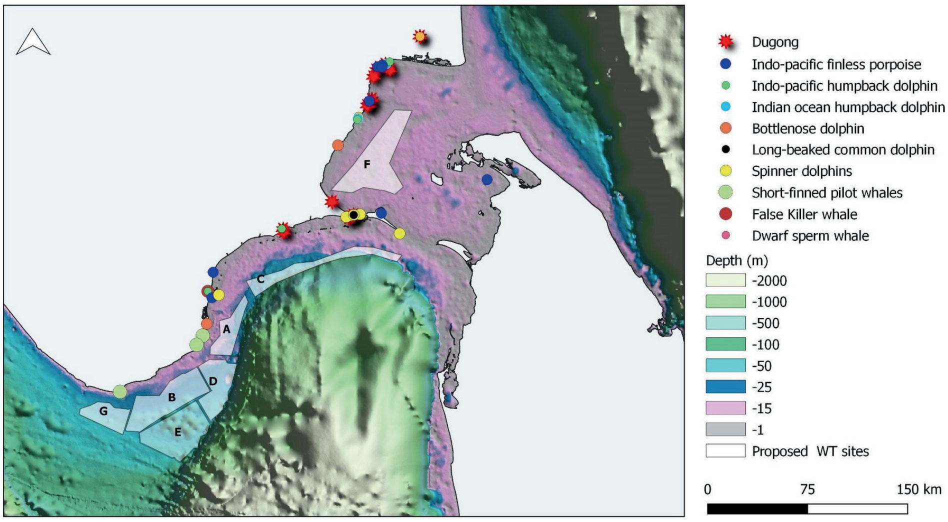


Figure 15. Citizen science data for small, medium and large sized dolphins has been mapped as an indicator that the OWF area is being used by these species.

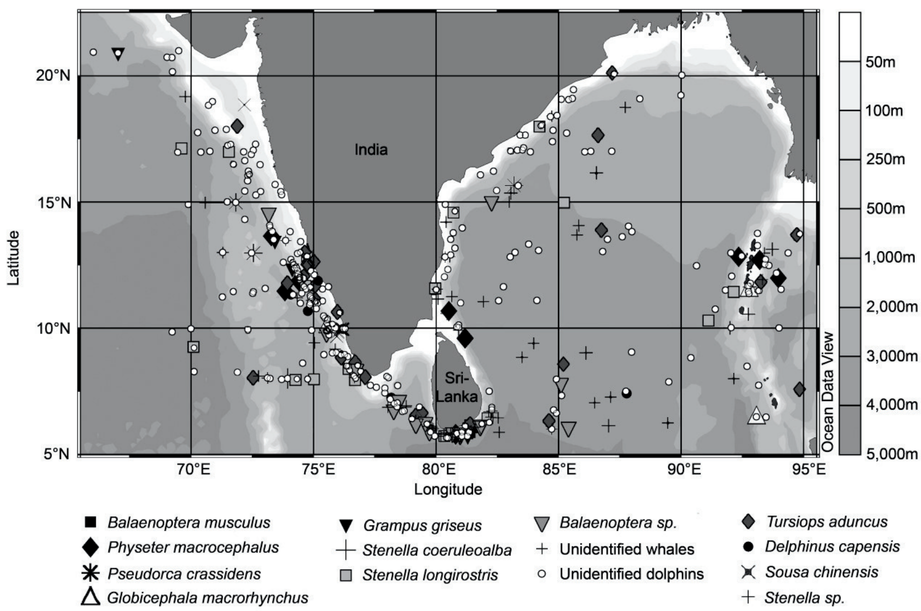


Figure 16. Afsal et al reported sightings in the project area (outside of the GoMBR) in 2003-2007 from dedicated vessel-based surveys showing the important of shelf edges for cetaceans

Species in GoM and Palk Bay	Known Habitat				Habitat Overlap with proposed sites						
	Nearshore (up to 15km from shore)	Continental shelf	Edge	Slope	A	B	C	D	E	F	G
Indian Ocean humpback dolphin	■				■	■		■		■	■
Indo-pacific humpback dolphin	■				■	■		■		■	■
Finless porpoise	■				■	■		■		■	■
Dugong	■				■	■		■		■	■
Indo-pacific bottlenose dolphin	■	■									
Spotted Dolphin			■	■	■		■	■	■		
Spinner dolphin		■	■	■	■	■	■	■	■		■
Striped dolphin			■	■	■	■	■	■	■		■
Risso's dolphin			■	■	■		■	■	■		
Short-finned pilot whale			■	■	■		■	■	■		
Long beaked common dolphin			■	■	■		■	■	■		
Rough-toothed dolphin			■	■	■		■	■	■		
Melon-headed whale			■	■	■		■	■	■		
False-killer whale			■	■	■		■	■	■		
Killer whale	■	■	■	■	■	■	■	■	■	■	■
Bryde's whale	■	■	■	■	■	■	■	■	■	■	■
Humpback whale	■	■	■	■	■	■	■	■	■	■	■
Blue whale	■	■	■	■	■	■	■	■	■	■	■
Beaked whales			■	■	■		■	■	■		
Pygmy sperm whale			■	■							
Dwarf sperm whale			■	■	■		■	■	■		
Sperm whale			■	■	■		■	■	■		

Table 6. Cetacean occurrence overlayed on the different habitat types of the proposed OWF sites in Tami Nadu

6. PHASE-WISE IMPACTS OF OWF ON MARINE MAMMALS

The marine spatial planning report for Tamil Nadu (2022) has stated that critical Dugong areas and their buffer zones and all other important marine mammal areas are 'Negotiable'. We would like to state here that this assessment cannot be accepted, and that marine mammals are most impacted by the construction and operational phases of OWF projects and must be treated with utmost precaution.

In the current proposed areas, construction activities in blocks (A, B, D, F) close to the coast will amplify noise levels underwater and increase frequency of strikes that are detrimental to resident coastal populations of humpback dolphins, finless porpoise and the dugong.

The impacts of pre-construction seafloor studies, construction piling work and operational turbine noise, blade movement and changes in electromagnetic fields all cause impacts on animals that need long term studies to estimate and mitigate.

Pre-Construction

Geophysical survey equipment for offshore wind energy pre-construction surveys include various types of multibeam echo sounders, side-scan sonars, or sub-bottom profilers, all of which produce active sound to map the seafloor.

Just like seismic surveys, used to test the stability of the seafloor and to choose sites for piling construction, these surveys can have detrimental effects on deep diving mammals such as sperm whales and beaked whales, and can also cause displacement of resident populations of humpback dolphins, finless porpoises, bottlenose dolphins and humpback whales.

Acoustic disturbance is also expected from sea floor preparing activities, such as drilling or dredging for piling as well as an intensified vessel traffic (expected for all construction types).

Construction and Operational impacts

Piling noise

The underwater sound levels emitted during offshore pile driving are very high, with received peak-to-peak sound pressure levels exceeding 200 dB re 1 μPa at 100 m and sound exposure levels of single pulses exceeding 180 dB re 1 μPa2s in 100 m from the foundation (ICES 2010). Temporary or permanent damage to the auditory system of marine mammals can take place under such circumstances (Nachtigall *et.al.* 2012, Kastak *et.al.* 2005, Kastelein *et.al*. 2012). Construction phase pile-driving produces multiple pulsed sounds that are loud enough to have a major amplitude at 100–500 Hz. This will essentially acoustically mask all vocalising species, as reverberation, multi-path transmission, and oceanographic factors raise ambient noise levels (Clark *et.al.* 2009; Estabrook *et. al.*, 2016). This is one of the major stressors for marine mammals as it directly affects communication and foraging behaviours of animals and can also potentially cause irreversible physiological damage. A potential consequence of exposure to intense sound is a loss of hearing sensitivity which is reflected in an elevated hearing threshold (i.e. a hearing threshold shift). This effect is called a Temporary Threshold Shift (TTS) if the hearing sensitivity returns to its normal level, or a Permanent Threshold Shift (PTS) if some residual amount of shift remains (Southall *et.al.* 2021).

In smaller odontocetes like the bottlenose dolphins, Bailey *et.al.* 2010 observed that the species was prone to auditory injury when they occurred 100m within pile driving activity; but behavioural disturbances in the population could occur as far as 50km away. Lossenta *et.al.* 2018 showed that the noise from one turbine may elicit reactions for the harbor porpoise, grey seals and bottlenose dolphin at a distance of resp.1 km, 300m and 250m.

The reaction and impact of the activity are elicited variably amongst species and a pre-construction assessment of species presence is critical to understanding effects during and post construction. Harbour porpoise is a species that has been well studied in this context and has Very High Frequency (VHF) frequency vocalizations. The species has in multiple regions shown immediate displacement from pile driving areas (Kraus *et.al.* 2019; Brandt *et.al.* 2016). Reductions in echolocation clicks of harbour porpoises were recorded during construction of offshore wind farms in northern Europe (including pile-driving) with their density decreasing out to distances > 15 km from the OWT site (Tougaard *et.al*. 2005; Carstensen *et.al.* 2006; Brandt *et.al*. 2011). As well as decreased acoustic activity during pile-driving, Tougaard et al. (2003) documented changes in surface behaviour, Tougaard *et.al*. (2003) documented changes in surface behaviour, with more non-directional swimming (presumably associated with feeding) during days where there was no pile-driving than during days where there was. Both these effects were significant at ranges of up to 15 km from the construction site.

The finless porpoise also vocalizes in high frequencies but no study exists about how the species reacts to underwater noise. The finless porpoise, although inshore, has a wider habitat range which may overlap with the shoreward side of the G,B and E blocks. The F block in Palk Bay, is an extensive shallow ground, which may be used by at least three species of coastal cetaceans including finless porpoises and Dugongs. Pile driving could cause disturbances on a larger scale in this block, given its bathymetric profile. An acoustic assessment for species space use is highly recommended before commencing any activity pertaining to the wind farms.

Assessing the impact of OWF on baleen whales is even more challenging given the large ranges they occupy. Pile-driving sounds are impulsive, low frequency and broadband, traveling across large distances of ocean and overlapping with acoustic frequencies that baleen whales depend on for communication. In feeding areas, noise can cause displacement and reduced foraging time, affecting body condition and health. Reduced foraging time could also be caused by direct disturbance of foraging events, or reduced ability to find prey (or direct others to the prey) or because of indirect effects such as changes in prey behavior or abundance due to prey responses to acoustic disturbance (see also Forney *et.al.*, 2017). In species like the Humpback whale, where mother-calf pairs communicate very quietly (probably as an anti-predator strategy) they are likely susceptible to masking (Videsen *et.al*. 2017).

Vessel traffic and noise

Increased vessel traffic during the construction and operations phase can impact marine mammal distribution and movements and raise the risk of strikes. The effects of these vessels will not be limited to offshore sites but will also be felt in coastal areas where a lot of these vessels will either be docked or travel from.

Baleen whales are already a vulnerable group given the intensive ship traffic from the Colombo transshipment port in the area. Nisi *et.al.* 2024 identified the proposed OWF area as a ship-strike whale hotspot (Figure 17) showing the risk that the large whale and offshore cetaceans already face.

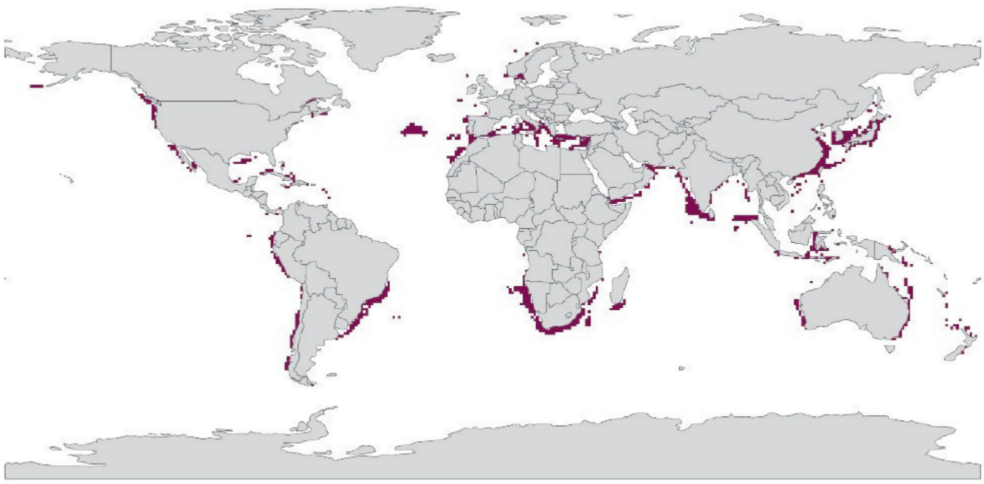


Figure 17. South Tamil Nadu including the proposed OWF area identified as a ship-strike risk hotspot for baleen whales, particularly the endangered blue whale (Nisi et.al. 2024).

Further, the vocalization frequency range of baleen whales and beaked whales overlaps with human generated noise sources such as vessel traffic. Humpback whales have been known to stop singing in areas with vessels within 1100m of individuals. There have also been studies that documented an increase in the amplitude of their vocalizations by 0.8 dB for every 1.0 dB increase in ambient noise, while vocalizing less frequently (Fournet et.al. 2018). Interruption of foraging, socializing and mating behaviours in multiple whale species has been observed in both natural and experimental settings.

A modelling study showed a decrease in the communication range of Bryde's whales in the presence of vessel noise (Clark *et.al.* 2009; Cholewiak *et.al.* 2018). Studies on fecal samples of North Atlantic right whales revealed an increase in the stress hormone cortisol, in populations exposed to high vessel traffic (Rolland *et.al.* 2019).

In beaked whales, off continental shelves, it was seen that in the presence of shipping noise, the horizontal area of foraging as well as successful foraging dives reduced by 50% (Aguilar et.al 2006; Pirotta *et.al.* 2012). In some sperm whales too, reduced vocalizations and a decrease in surface time has been documented in the presence of whale watching boats. In smaller cetaceans, variable impacts from complete displacement to temporary shifts have been observed. Similar to whales, changes in foraging habits and sites were observed.

In the case of Dugongs, vessels pose not only a risk to individual species but are also a threat to seagrass beds. The proposed OWF Block F, is very close to and even overlaps with some seagrass beds. Any intensive vessel movement or even anchorage will damage these seagrass beds and also increases the chances of dugong collisions and mortality. Very few studies have observed the effects of vessel traffic on Dugongs but in other sirenians such as the Florida manatees, vessel strike is responsible for 25% of all mortalities. Further, these species do not seem to react to vessel noise making them even more vulnerable to strikes.

7. DATA GAPS

1. Species diversity and occupancy of all marine megafauna (birds, bats, marine mammals, turtles) in the project area.
2. Spatio-temporal assessment of habitat use by marine mammals, marine turtles, bats and birds use in the project area.
3. Population abundance of different species of marine mammals, bats and turtles in the project area.
4. The effect of different types of unnatural sources of noise such as vessel and turbine noise on both coastal or offshore cetacean assemblages.
5. Status and spatial extent of the different types of ecosystems found in the project area over time - seagrass beds, coral and rocky reefs, mangroves and estuarine deltas.

Matrix of ecosystems, faunal presence and threats

The proposed OWF overlaps various near and offshore habitats (Table 6, Table 7). Most proposed blocks (A, C,D,E,G) have their outermost boundaries over shelf edges. This region of the seafloor is an important transitioning zone between the shelf and the continental slope and is used by deep diving species of marine mammals and turtles. An assessment of how these areas is used in the region is critical as we anticipate that structures right on top of these features may hinder diving and space-use behaviors of certain species. Conversely, the nearshore boundaries of blocks A, B,C,D,G,F, in some cases are very close to shore and may have a direct adverse effect on a number of species, particularly the dugong, finless porpoise and the Humpback dolphins. Because of the broad continental shelf in some areas, the gradient for bathymetry is shallow and ranges of nearshore species might change accordingly. Assessment of these nuances is required before final plans of the OWF can be drawn. Construction and operation of the turbines in such proximity to the shores will increase underwater noise, vessel traffic and be highly impacting for species found in such narrow coastal zones. Appropriate buffers on both the coastal and shelf edge areas are recommended depending on space use patterns of various species.

OWT Block	Ecosystems					Faunal groups						Existing anthropogenic threats		
	Reefs	Mangrove	Sea grass	Wadge Bank	Shelf Edge	Marine mammals			Turtles	Birds	Bats	Colombo port shipping route and high ship densities	Fishing pressure	Habitat fragmentation
						Baleen whales	Near and inshore species	Offshore and deep diving species						
A											DD			
B	DD										DD			
C											DD			
D											DD			
E	DD										DD			
F											DD			
G			DD								DD			
H											DD			

Table 7. Ecosystems, faunal groups and anthropogenic threats overlapping with or in close proximity of the OWF blocks. DD - mostly only opportunistic sightings or stranding leading to problem of data deficiency

8. RECOMMENDATIONS

Assessment and Monitoring (during all phases of the project)

As described in this review, there are large gaps of knowledge about habitat use by various taxa in the proposed OWF. Robust information on species distributions, occupancy, space-use and seasonal patterns of habitat use is critical to be known before effective mitigations can be applied in all the phases of constructing and operating an OWF. Croll *et.al.* 2022, provide a framework for assessing and mitigating the impacts of offshore wind energy development on marine birds that could be used for all fauna. Our primary recommendation is that long term monitoring must be carried out before OWF can be initiated and this information to be used to model any changes in the richness, distribution and space use data for all fauna species. Mitigations would be based in a future date, based on the prospective modelling of threats, if the proposed project is cleared for the location already proposed.

The proposed OWF area covers both offshore and nearshore (Block A, B,C,D,G,F) areas directly overlapping with vulnerable and endangered species of turtles, humpback dolphin, finless porpoise and Dugongs in the nearshore area and with the larger whales and beaked whales in the offshore regions.

Below we recommend a list of methods that can be used to fill the data gaps listed.

1) Ecosystems mapping and quality assessment

- Estimate the extent and status of all ecosystems in the project site using line transect surveys with quadrats on shore and underwater including the use of drones, ROV's and remote sensing data.

- Estimate the flora and fauna present in these ecosystems before the OWF is constructed.

2) Distribution, Diversity, Abundance and Habitat use of marine fauna

- Traditional ecological knowledge of fisher communities in the area to be able to collect
- Multi-disciplinary vessel-based line transect surveys following Distance (Buckland, 2000) based visual sampling can be used for birds, turtles and marine mammals
- Passive acoustic monitoring using static hydrophones for assessing seasonal presence/ absence of marine mammals in different sectors of the area; and towed array surveys for detecting rare and cryptic species and estimating abundance of species difficult to count visually such as finless porpoise and elusive species. of marine mammals. Along with static devices, towed arrays used from a moving vessel will especially be useful for detecting locations of deep diving species over continental slope areas (Blocks, A, C, D, E).
- Radar has been used to assess flight height simultaneously with visual sampling for identification (Thaxter *et.al.* 2015). Recent advances in LiDAR, has in some cases made it possible to estimate flight heights to an accuracy of a 1m (Cook, *et.al;*. 2018). LiDAR is a remote sensing technique that records the three-dimensional location of surfaces by emitting frequent, short-duration laser pulses. Other methods such as GPS tagging with altimetric devices on animals are also available but the accurate analysis of the data has been challenging. These surveys can also be used to map the flight paths of migratory birds. On shore assessments of wintering sites of migratory birds needs to be simultaneously studied around shore and wetland sites.

- For species like the Dugong, both the habitat and population needs to be monitored. Along with TEK, visual distance based boat surveys using drones, aerial surveys using small cessna planes and an underwater assessment of seagrass bed quality using underwater transects or ROV's along with assessing the presence of dugong grazing trails need to be carried out. Passive acoustic devices can be used for data on seasonal presence absence information in different blocks. Recent advances in remote sensing have made it possible for fine scale estimation of seagrass beds and is a cost effective and a largely accurate technique to map changes in seagrass cover and biomass in an area like Palk Bay (Perez *et.al.* 2020; Phinn *et.al.* 2018).
- Shore based surveys of nesting beaches and their quality need to be carried out along with an estimation of nesting turtles and turtle nests using visual distance based sampling on land.
- Distance based estimation of inshore and offshore congregations of mating turtle pairs and nesting using boat based surveys.
- Migratory routes and post-nesting space use of female turtles can be tracked by GPS tagging of nesting females.
- A study of the movement of bats, and their roosting and foraging patterns needs to be carried out in all coastal districts and islands using acoustic recorders on offshore platforms
- Injury and mortality assessment studies by forming a network of local fishers and naturalists who can inform about accidents and stranding events.

3) Measure ambient sound levels both natural and unnatural in the project area

- a) use of static acoustic monitoring devices that can be placed at different distances from shore and from each other to collect data for each block.

4) A threat assessment of existing disturbances such as sewage and contaminant load, infrastructure development, fishing pressure and maritime traffic in all the ecosystems of the proposed OWF area.

The above-mentioned list of assessments is the foundation for a development plan of the scale that has been proposed and the sustainable operations of the same. We recommend using data generated from the above studies to generate spatial maps of species distributions, habitat health and seasonal space use by different fauna, to inform decisions of OWF placement. The above studies must continue during the construction, operations and decommissioning phases of the project to be able to assess any impacts and mitigation measures.

Bergstron *et.al.* 2014 carried out an assessment for different impacts that OWF might bring about based on literature available and found that the decommissioning phase lacked studies. They suggest that for the construction phase, acoustic disturbances and increased sediment dispersal were the primary concerns, and for the operational phase, habitat changes (positive or negative), fisheries exclusion, acoustic disturbance, and electromagnetic fields were the primary concerns across the various projects. OWF based on gravity foundations might lower acoustic impact as they do not involve pile-driving.

Risk Assessment and Mitigation

During the operation of offshore wind farms, it is essential to conduct a risk assessment study by comparing results from before and during operations, based on the data collection methods described above. This is necessary to reduce the probability and magnitude of potential risk events or to avoid these risks completely. Before-After-Control Impact (BACI) (Garthe *et.al.*, 2023) studies or Before After Gradient (BAG) method framework as used by Vigili 2023 need to be utilised out to quantify the effects both outside water and under-water of OWF. In the North Sea for instance, Virgili *et.al.* 2024 already had information from before the windmills had been constructed and operational offshore. They looked at different distances from OWFs to predict intra-annual variability in species distribution and correlated species distribution with the presence of operational OWFs. Their models predicted four patterns of intra-annual variability: with spring having the most abundance of species; followed by winter, both spring and winter, or all year round. They recommended that future OWF constructions be planned in summer and early fall to mitigate impacts on cetaceans, and that offshore areas of northern France and Belgium be avoided to minimise impact on seabirds.

In 2022, Maxwell listed the various floating wind turbine configurations, and studied their potential impacts on marine mammals, seabirds, fishes and benthic ecosystems. The study offered mitigation techniques such as entanglement deterrents or the use of cable and mooring line monitoring technologies. They recommend taut or semi-taut mooring configurations, but request studies and technologies development that cause limited ecological impacts.

Pile driving and vessel traffic: Vibration during the operations phase transmits through the tower into the foundation from where it interacts and gets released into the water as noise. This noise is detected by fish and marine mammals and tends to impact them in varying degrees. The nature of the foundation, the surface area of the foundation, the material used to build the foundation and its internal damping, and the nature of the connection of the foundation to the sea floor will all impact the amount of noise produced and released.

Depending on parameters such as pile diameter, soil structure and blow energy, noise mitigation systems have been tried in Germany (Koschinski and Lüdemann 2013). However, they all have to be applied prior to pile driving or require special technical features on the installation barge. Some methods like bubble curtains, isolation casings, and cofferdams and hydro sound dampers have been suggested but not all these systems have been tested and applied frequently enough to assess their utility or time required for installation.

To avoid vessel strikes marine mega fauna observers need to be trained to spot and identify marine mammals, birds and turtles while construction is underway and based on observer data the speed of boats must be 10 knots or less, in or near the project area to avoid displacing animals or collisions. If cetaceans are spotted too close to the turbines during construction, all operations must stop, till the animals move away.

Seismic airgun surveys, pile driving and sonar cause large amounts of underwater noise that travel tens of kilometers and can disturb or cause auditory injury to marine mammals (Gordon *et.al.* 2003, Bailey *et.al.* 2010). To avoid physiological impacts from piling sounds and to avoid conditions like TTS and PTS in marine mammals, soft start or ramping up practices have been applied across large scale projects. Which basically means to have intervals between hammering so mammals have enough time to leave the area and then to progressively increase the intensity (Furness *et.al.* 2013). It means to start at low sound intensity levels and slowly increase the sound. This may warn and deter mammals from the area before the full noise exposure and reduce chances of injury and mortality (Von Benda-Beckmann *et.al.* 2014). But this response depends on the mammals response of avoidance or curiosity and some mammals can be attracted to low sounds and thus still be injured (Compton *et.al*. 2008). Moreover 'Soft-start' may actually increase the duration and total time that acoustic energy is released into the environment.

9. POLICY

While the effects of one wind farm on a particular wildlife population may be negligible, the aggregate effects of multiple wind farms through space and time will amplify the effects caused by other sectors (Gușatu *et.al.*, 2021).

Policy makers must apply the Precautionary Principle to ensure that the collective pressure of all activities is kept within levels compatible with the preservation of marine ecosystems and the correct ecosystem functioning of the entire network of ecosystems in the project area.

Independent Impact Assessments following ecosystem-based approaches (CBD, 2021) must be carried out to study the potential environmental, social and economic consequences of constructing OWF facilities during all the phases.

Marine and fisheries biologists, social scientists, economists, experts in renewable energy, and leaders of local community members need to be participants in these assessments such that analysis and results are discussed amongst all stakeholders.

Monitoring programs should use different techniques to detect changes in the different components of the marine ecosystem and detailed guidelines for the assessment of cumulative adverse effects, addressing the different taxonomic groups should be put in place.

Data consisting of three years pre-construction phase, two years of the construction phase and three years of the operational phase are needed to build a strong database to show the effects of OWF (BSH, 2013).

10. LITERATURE

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