Incidence of pregnant endangered devil rays (Elasmobranchii: Mobulidae) from the Gulf of Mannar and Palk Bay, southeast coast of India

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Out of the nine valid extant mobulid species confirmed globally, seven have been reported in India. All mobulids are vulnerable due to anthropogenic pressure, i.e. commercial fisheries, for their gill plates, which are traded on the international market. Information on their reproductive biology including, the seasons of mating, pupping, and nursery grounds are still largely unknown from Indian waters. The present study reports the occurrence of pregnant endangered devil rays, longhorned pygmy devil ray *Mobula eregoodoo*, oceanic manta ray *Mobula birostris* and Bentfin devil ray *Mobula thurstoni* in Indian waters, off the southeast coast. All three species were observed to have a single pup each. Our observations of mobulid catch from 2020 to 2022 indicates a predictable occurrence of pregnant devil rays either for feeding or for pupping (July to November), with a peak during November in the Gulf of Mannar and Palk Bay. The size-at-birth was in the order of 33.3 cm disc width (DW), 125.8 cm DW and 40.5–60.5 cm DW for *M. eregoodoo*, *M. birostris* and *M. thurstoni* respectively. *Mobula thurstoni* chiefly consumed needle squid and *Acetes* spp., while the gut contents of the other two species were completely digested. The observations on *M. thurstoni* suggests a pupping/nursery/feeding ground off the Gulf of Mannar, probably assist to develop area-based management interventions.

Keywords: Conservation, mobulidae, pupping ground, reproductive biology, spatial management.

THE manta and devil rays are presently placed under a monotypic genus *Mobula* based on certain morphological characters such as shape and position of spiracle, phylogenetic analysis and genetic evidences[1–4]. Currently, there are nine extant valid species of *Mobula* confirmed globally[5] out of which seven species have been reported from the Indian Ocean. These species include, *Mobula birostris* (oceanic manta ray), *Mobula alfredi* (reef manta ray), *Mobula mobular* (spinetail/giant devil ray), *Mobula tarapacana* (sicklefin devil ray), *Mobula thurstoni* (bentfin devil ray), *Mobula kuhlii* (shortfin pygmy devil ray) and *Mobula eregoodoo* (longhorned pygmy devil ray)[6,7]. Mobulids are pelagic elasmobranchs that occupy the second level of the marine trophic system as filter feeders, serving as important consumers[8,9]. However, they are highly vulnerable to overexploitation due to their conservative life history traits such as slow growth, late maturation (5–15 years), prolonged gestation period (12–15 months) and inter-birth intervals (2–7 years), minimum litter size (one pup per litter), low population growth rates, etc.[7,10–12]. Larger size, slow movement and predictable assemblage of devil rays in specific location for feeding, courtship, breeding and cleaning increase the likelihood of targeted fishing[8,9,13,14]. Moreover, the international trade of dried gill rakers has intensified the anthropogenic pressure on mobulids, leading to targeted or bycatch fishing by artisanal and commercial fishing gears[15–17]. To address these threats with the exception of *M. alfredi* (vulnerable), all other mobulids are categorised as Endangered in the IUCN Red List of Threatened Species.

The Gulf of Mannar (GoM) and Palk Bay (PB) are two distinct eco-regions located in the south eastern coast of India between maritime state of Tamil Nadu and the west coast of Sri Lanka. PB extends from Tiruvarur district to Dhanushkodi in Ramanathapuram district, while the GoM encompasses the area from Dhanushkodi in the Ramanathapuram district to Kanyakumari in the Kanyakumari district. The major landings in both regions are brought by mechanised single day trawlers, which account for 59.3% of the landings, followed by motorised gillnets at 32.49% (ICAR-CMFRI[18]). Since both crafts types set out and make landing within 24 h, the entire catch is undoubtedly from these eco-regions[19]. Mobulids are occasionally landed by both types of fishing fleets in GoM and PB[20–23].

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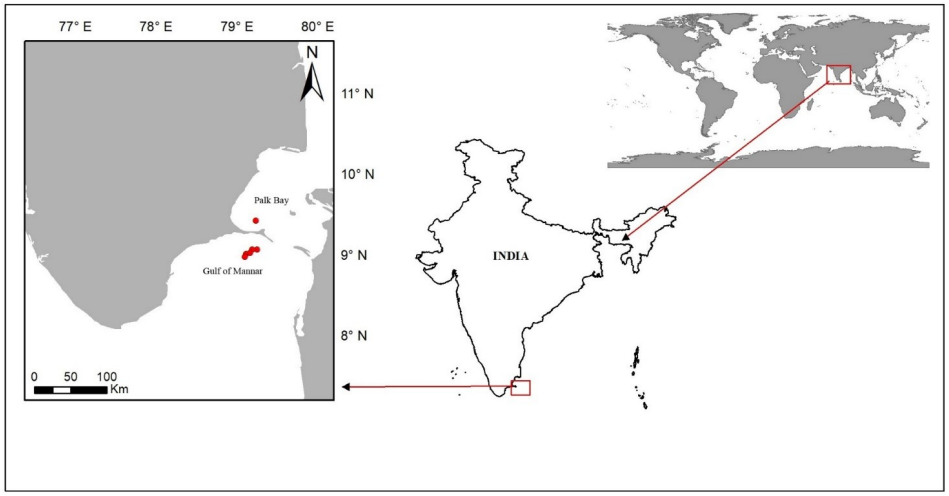

Figure 1. Fishing ground of mobulids in the Pamban vicinity of Gulf of Mannar (GOM) and Palk Bay (PB).

The present work is of the first reporting of the occurrence of pregnant females of three endangered devil rays, *Mobula eregoodoo* (Cantor, 1849), *Mobula thurstoni* (Lloyd, 1908) and *Mobula birostris* (Walbaum, 1792) observed at GoM and PB. Since no earlier reports on pregnant mobulids exist from India, this makes it a first report of its kind from the country as well.

Materials and methods

The study was carried out at Pamban, a meeting place of GoM and PB. Observations on *Mobula thurstoni* and *Mobula eregoodoo* were made during weekly sampling visits to Pamban Therkuvadi fish landing centres (PTFLC) (9.27865379N, 79.20521981E), located to the south of Pamban between 2020 and 2022. These two species were landed by mechanised single day trawlers. The mechanised single day fishing trawlers landing their catch at PTFLC operate in an area between Dhanushkodi and Keelakarai of Ramanathapuram district, Tamil Nadu and the fishing ground is located at a distance of 28–35 km away from the Pamban coast. Fishing happens only during alternative days in a week and Saturday is a fishing holiday in the study area[19].

The data on *Mobula birostris*, landed by a motorised drift gillnetter was collected from Pamban Lighthouse fish landing centre (PLFLC) (9.28488889N, 79.21577778E), situated in the northern premise of Pamban. The single day motorised gillnetters operating along northern side of the Pamban region, fish at a distance of 5–14 km from coast. The data on *M. birostris* and *M. eregoodoo* were collected from single specimens. The fishing grounds of devil rays in the Pamban vicinity of GoM and PB is shown in Figure 1.

All the three species of devil rays were identified using FAO Guide[24]. The length measurements of devil rays were taken using a graduated measuring tape (1 mm) and weights recorded using digital weighing balance (0.1 g accuracy). The gut and reproductive organs were obtained from dry fish units in the vicinity of the landing centres where the animals were processed for marketing. The gut contents and reproductive status[25] were examined and assessed in the laboratory of Mandapam Regional Centre of ICAR-CMFRI.

Results

The regular sampling in the GoM and PB recorded several batoids (rays, wedge fishes and guitar fishes) rather than sharks. Bamboo shark *Chiloscyllium griseum* was the only abundant shark available to the coastal waters of Pamban. Around 38 batoid species belonging to families Dasyatidae, Rhinobatidae, Mobulidae, Rhinopteridae, Aetobatidae, Rhinidae Glaucostegidae, Gymnuridae and Myliobatidae were encountered. The landings of mobulids were observed only in some months. The species composition of mobulids in the area is presented in Figure 2. *Mobula thurstoni* was the most dominant species forming 37% landings followed by *M. mobular* (34%). The landings of *M. eregoodoo* and *M. tarapacana* were quite meagre. Only a single specimen of *M. tarapacana* was observed during that study and since it was not a pregnant animal, the details not been included in the results of this study. Occurrence of *M. thurstoni* was more in the area between July and September. *Mobula eregoodo* and *M. birostris* were observed in the commercial landings during November only. No individuals of *M. alfredi* were noticed in the study area during the observation period.

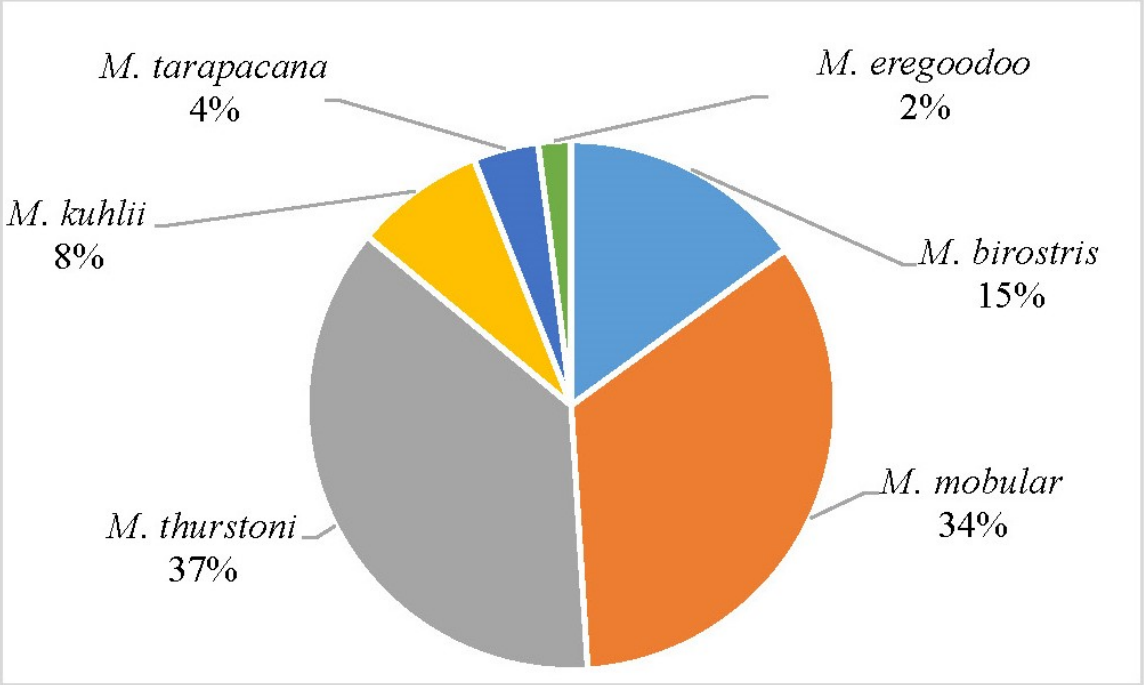

Figure 2. Species composition of mobulids in PB and GoM.

On 15 November 2016, a single day mechanised fish trawler at PTFLC landed a pregnant female *M. eregoodoo* (Figure 3*a*). The devil ray was 125 cm DW in size and weighed 28.5 kg. The morphometrics of pregnant fish is presented in Table 1 and the details of pups in Table 2.

The length of *M. birostris* 46% of its DW, while that of *M. thurstoni* accounted for 42%. In contrast, the total length of *M. eregoodoo* was 50% of its DW. The sub terminal mouths of *M. eregoodoo* and *M. thurstoni* measured 10.5% and 11% of their DW respectively, whereas the broad mouth of *M. birostris* was 18% of its DW. The disc width of pups of *M. eregoodoo*, *M. thurstoni*, and *M. birostris* represented 27%, 30% and 22% of the DW of their respective mother fishes.

A total of 31 females of *M. thurstoni* examined with sizes ranging from 73.5 to 194 cm DW were either individuals with full-term embryos (1 per female) or had recently given birth as evidenced by their post-partum state (developed extended trophonemata in the uteri). The male to female ratio was 1 : 0.5. Approximately 75% of the female *M. thurstoni* landing comprised of pregnant individuals. The mother and pup are shown in Figure 3*b* and *d*.

A *M. birostris* measuring 567 cm DW (896 kg weight) was caught in a drift gillnet (locally known as *Kattavalai*) with a mesh size of 60 mm on 23 November 2022 (Figure 3*c*). The gear had a length and width of 180 and 5.5 m respectively. The gillnet was operated from a 13.5 m OAL (Overall Length) inboard motorised fibre glass boat fitted with 20 hp engine. This fish was caught at depth of 15 m approximately 13 km away from coast. Since the fish was too heavy to weigh as a whole, it was cut into pieces, and the weight of individual pieces was added to obtain the total weight. The animal had a single pup, which was retained whole. The pup was male and weighed 30 kg (Figure 3*e*).

The gut contents of *M. eregoodoo* and *M. birostris* were found to be fully digested making it difficult to identify major food items. On the other hand, the stomach of *M. thurstoni* was found with 75–98% needle squid along with small proportions of *Acetes* spp., bigeye scad (*Selar crumenophthalmus*), and redtail scad (*Decapterus kurroides*) in an undigested state.

Discussion

The occurrence of the long-horned devil ray, *Mobula eregoodoo*, in GoM has been confirmed for the first time, despite no record of this species being landed in India in the last 50 years[26]. Records of *M. eregoodoo* are limited, likely due to misidentification with the short-horned devil ray, *Mobula kuhlii*, as well as population depletion. Occurrence of a single *M. eregoodoo* was documented in 2020 from Sri Lanka, a neighbouring country that shares the GoM and PB with India[27]. This observation further underscores the rarity of the species within the region. According to reports from East Australia, male and female longhorned

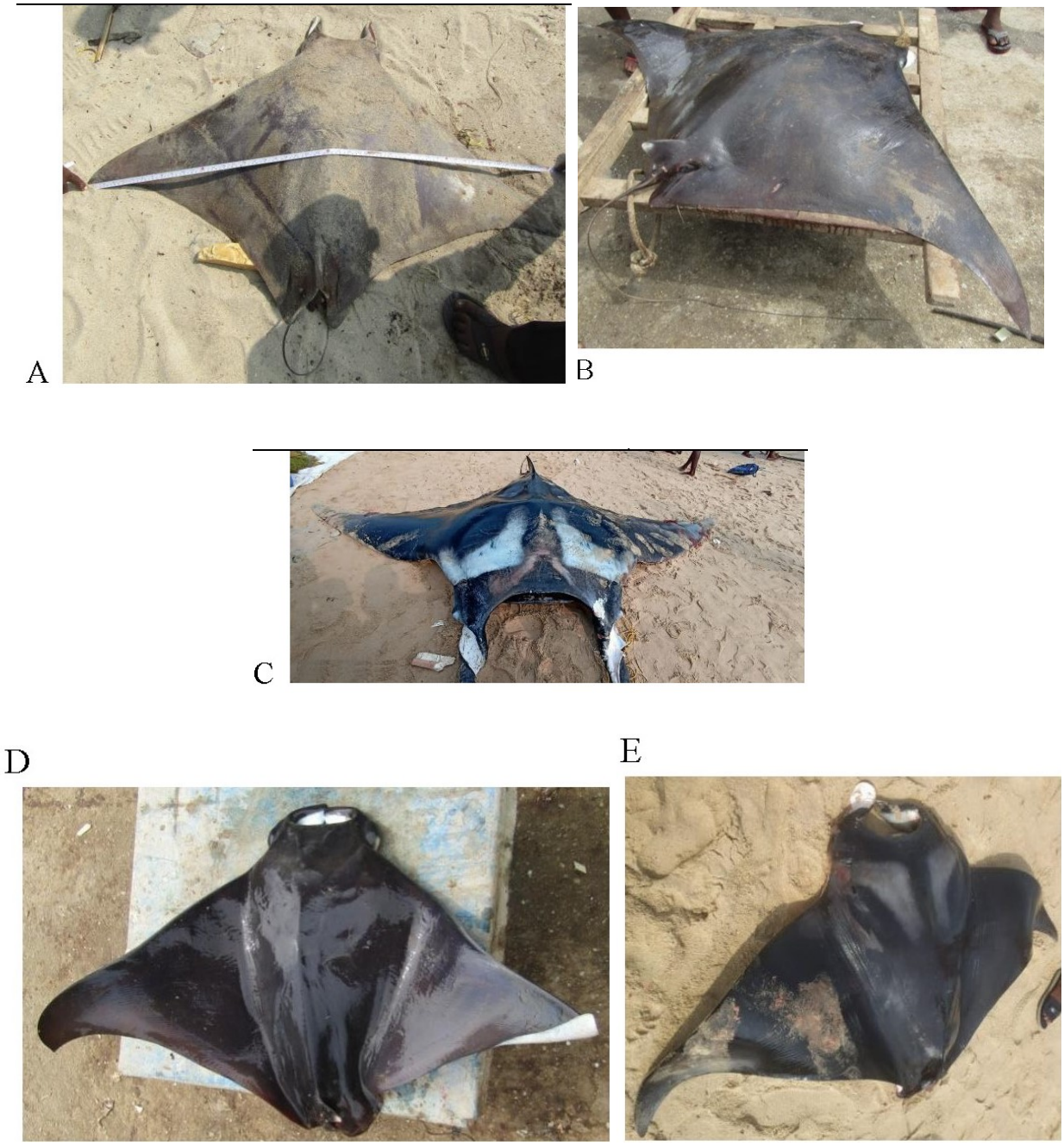

Figure 3. Pregnant devil rays and pups. *a*, *Mobula eregoodoo*; *b*, *Mobula thurstoni*; *c*, *Mobula birostris*; *d*, Female pup of *Mobula thusrstoni*; *e*, Male pup of *Mobula birostris*.

pigmy devil ray mature at 99 and 92.5 cm DW respectively. The size at birth or the size of near-term embryo from eastern Australia falls between 34.7 and 42.3 cm DW[10].

Although the *Mobula thurstoni* is reported to have a global distribution[28] the information about this species from India is limited to very few studies[29]. Among the devil rays landed in the PTFLC, *M. thurstoni* is the most dominant followed by *M. mobular*. The size at maturity of *M. thurstoni* was estimated at 150 cm DW for males from Indonesia[25] and 163.6 cm DW for females from Philippines[11]. Majority of the *M. thurstoni* (70%) reported in this study fall within this range. The size of pups in the present study is slightly smaller than previous reports, 65–85 cm DW[11,28]. *M. thurstoni* appears to give birth in this area between July and September. The observations indicate the presence of females of *M. thurstoni* at

Table 1. Morphometric measurements of pregnant mobulids

Species	*Mobula eregoodoo*	*Mobula thurstoni*	*Mobula birostris*
Location	(GoM)	(GoM)	(PB)
Weight (kg)	28.5	49.5	900
Disc width	125	176	567
Disc length	62.4	74.5	260.8
Tail length	31.3	68.3	266.6
Total length	93.7	142.8	527.4
Length of pelvic fin	14.5	15.7	43.1
Breadth of pelvic fin	7.3	7.8	36.9
Eye diameter	3.4	4.2	11.3
Snout length	5.5	7.6	37.8
Inter orbital space	26.2	34	138.9
Length of cephalic horn	15.4	17	63.5
Breadth of cephalic horn	3.5	4.6	28.9
Distance between cephalic horns	11.5	16.8	86.1
Mouth width	13.2	19.4	101.5
Distance from 1st gill to snout tip	11	14.9	36.5
Distance from 2nd gill to snout tip	13.6	19.1	49.4
Distance from 3rd gill to snout tip	16.7	21.4	62.6
Distance from 4th gill to snout tip	19.8	27.0	75.6
Distance from 5th gill to snout tip	22.4	30.1	83.4
Space between 1st gillpair	13.6	20.6	65.2
Space between 2nd gillpair	11.3	19.3	56.1
Space between 3rd gillpair	10.3	18.8	50.6
Space between 4th gillpair	8.7	17.9	41.9
Space between 5th gillpair	7.4	15.1	34.4
Length of 1st gill slit	6.1	5.4	60
Length of 2nd gill slit	5.2	6.2	62.6
Length of 3rd gill slit	4.8	7.3	62.6
Length of 4th gill slit	3.5	6.6	57.4
Length of 5th gill slit	2.6	6.1	47
Distance between 1st and 2nd gills	3.9	5.5	69.1
Distance between 2nd and 3rd gills	3.5	4.8	50.6
Distance between 3rd and 4th gills	3.1	4.8	46.3
Distance between 4th and 5th gills	2.2	4.2	29.9

several phases of their gestation period in the study region, thereby suggesting that the study region could possibly be a breeding ground for the species.

The size at maturity at which 50% (DW_{50}) of *Mobula birostris* in the Western Pacific and Mozambique varies between 318.9–400 cm DW for males and 413–448 cm DW for females[11,13]. The DW_{50} of male *M. birostris* in Sri Lanka[27], Philippines[11] and Indonesia[25] was found to be between 375 and 386 cm DW. *Mobula birostris* reported in the present study, 567 cm DW is much larger than all these ranges. The size of young one in the present study was 127.5 cm DW, which is smaller than previous report (200 cm DW)[11].

In India unlike some other countries, the discard of mobulids at sea is almost nil since the entire elasmobranch species caught would fetch some value in the domestic market. The filter plates of *Mobula eregoodoo* are remarkably distinct from those of other *Mobula* species, featuring four (rarely five) ascending lobes marking the fewest within the genus. The terminal lobes are uniquely elongated and leaf-shaped, ending in a pointed cusp, more pronounced than in any other *Mobula*. Additionally, small size of the species may reduce its market value, as smaller gill plates command significantly lower prices[30]. Therefore, its distinctive gill-plate structure may pose additional obstacles for commercialisation, potentially offering this species some protection from targeted fishing[26].

Mobulids are known to form aggregations, ranging from a few individuals to thousands, for various purposes, including mating, pupping, nursery grounds[31], feeding[32],

Table 2. Details of pregnant female and pups of devil rays

Species	DW of pregnant fish (cm)	DW of pup (cm)	Weight of pup (kg)	Sex of pup	Litter size
Mobula eregoodoo	125	33.3	1.06	Female	1
Mobula thurstoni	170–176	40.5–60.5	0.85–2.5	Female	1
Mobula birostris	567	125.8	30	Male	1

cleaning[33] and predator avoidance[34]. Notable aggregation sites, such as the Revillagigedo Archipelago (a UNESCO World Heritage Site in Mexico) and Hanifaru Bay Marine Protected Area in the Maldives, are spatially managed to support conservation efforts[35]. Conservation measures include regulations for the number of boats and interactions, especially during key reproductive times to prevent disturbance to this threatened species either by tourism or by fishing[35]. The prevalence of the zooplankton *Euphausia diomedeae* in the Bohol Sea during November to May likely supports a mechanism facilitating the coexistence of mobulid species[9]. This observation on *mobula* aggregations, highlights the need for spatio-temporal management strategies for mobulids in the region. Growing fishing pressure on mobulids by the artisanal sector along Sri Lankan coast, a neighbouring country which shares both GoM and PB with India, has led to massive decline in mobulids over a period of 10 years from 2010 (ref. 27). India has taken several steps towards conserving devil rays, by including *Mobula birostris* and *M. alfredi* under Schedule I and *M. tarapacana* under Schedule II of the Indian Wildlife Protection Act which prohibits capture of these species. Despite these conservation measures, much more needs to be done to conserve the devil rays including implementation of the provisions outlined by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Migratory Species (CMS), and the Indian Ocean Tuna Commission (IOTC) to the extent permitted by national laws. These measures are necessary for the effective management and conservation of mobulid species, whose value-added products cater to international markets.

The present study provides valuable insights into potential pupping grounds for devil rays. These findings could serve as crucial inputs for the development of future spatial management plans aimed at the conservation of these species. The findings of this study, including data on pregnant *Mobula* species, their spatial and seasonal distributions, and the implications of international obligations mentioned above can be effectively communicated to fishers either directly or via relevant line departments. This information could facilitate the release of live individuals incidentally captured in fishing gear, contributing to an on-site conservation strategy aligned with stakeholder engagement.

This study reports the landing of three pregnant endangered devil rays in Indian waters, specifically off the southeast coast. The catch data suggests a predictable pupping season in the GoM and PB. However, the mating, pupping, and nursery grounds of devil rays remain poorly understood. The landing of *M. thurstoni* by mechanised trawlers in the GoM suggests their coexistence with other small pelagics and squids, likely for feeding purposes. An examination of the gut contents of the *M. thurstoni* from GoM reveals that they may be opportunistic feeders, consuming small pelagic fish along with *acetes*. Alternatively, these rays might frequent the area specifically to feed on squids and small pelagics, as indicated by the similarity between their gut contents and other species landed alongside them. The young individuals found may represent full-term or near-term embryos.

Conclusion

This study provides critical insights into the pupping seasons and pupping grounds of *M. birostris* and *M. eregoodoo* and highlights aggregations of *M. thurstoni* in two ecologically significant regions – Palk Bay and the Gulf of Mannar. The findings offer valuable reference material for developing spatial management and conservation efforts for these endangered species. The study further emphasises the importance of long-term data collection from large-scale commercial fisheries, combined with environmental monitoring, to improve understanding of the habitat preferences of devil rays in offshore areas along the southeast coast of India.

Data availability statement: The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Conflict of interest: The authors declare that they have no conflict of interest.

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