Gillnet tuna fisheries in the Coastal waters of India: intensity and spatial spread of the fisheries with implications of non-target and sensitive species interactions.

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Abstract:

Artisanal large mesh pelagic drift gillnet fisheries accounts for nearly 34% of the Indian Ocean tuna catches. India is one of the major coastal countries employing gillnets for harvesting tuna and tuna like fishes. Cooccurrence of non-tuna species including endangered threatened and protected species is universal in this fishery although the rates of incidence varies with the fishing area, time and intensity of fishing. The study aimed at updating the dynamics of large mesh pelagic gillnet fisheries of northwest coast of India through skipper supplied data for the period of 2011 to 2022 together with analysis of the landing data of large mesh pelagic gillnets of India obtained by the ICAR-CMFRI through the multistage, stratified random sampling survey protocols for the corresponding period. The study reveals the patterns of landing by the gear across the four regions of India's coast over the seasons and the pattern of catches in the observed gillnetters during the period. Tunas are the major group caught in this gear followed by other large pelagics like seer fishes, leather jackets, billfishes etc. Sensitive bycatches like sharks, turtles and cetaceans are lesser compared to other gillnet fisheries in the region.

Introduction:

Pelagic gillnet is the major tuna fishing gear (33%) in the entire Indian Ocean followed by purse seines (26%) (Miller *et al*., 2017) and contributes nearly 53% of the artisanal nominal catches reported to the Indian Ocean Tuna Commission (IOTC 2017). Fuel efficiency of the gillnet fishing (Northridge, 1991) and lower cost of operation aided the rapid expansion of the gillnet fleet in the region (IOTC, 2017). Tuna fishing in India is of artisanal nature, with the total annual landing of 1.09 lakh tonnes in 2022 (FRAEED, CMFRI, 2023). Tuna forms nearly 40% of the large pelagics landed in India followed by barracudas, seer fishes and queen fishes. These four groups constituted nearly 85 percentage of the large pelagic landing and neritic tunas constitute a major part of the tuna landing (65%) (CMFRI 2021). This indicates the coastal nature of the large pelagic fishery in India.

Gillnet fisheries of India is classified into non-motorised, motorised, and mechanised sub-sectors, based on size of the vessel and method of propulsion. According to mesh size, gillnets are categorised as small (<45 mm), medium (between 45 and 70 mm) and large (>70 mm) mesh (DAHDF, 2005). The mechanized gillnet sub-sector comprises of wooden, FRP or steel vessels powered with 24 to 280 hp inboard diesel engines targeting tuna, seer, sailfish, and shark using large mesh gillnets and undertake multiday trips extending 15 to 45 days (Thomas *et al*., 2020). Along the north-west coast of India, fishing for coastal tunas occurs principally on the shelf area as evident from the dominance of neritic tunas (70%) in the landings from Gujarat (Ghosh *et al*., 2010). The gillnets contributed nearly 77% of the tuna landings (CMFRI, 2017) and the operations are made using medium or large mesh gillnets operated from smaller sized, open type canoes (9-12m OAL) propelled by outboard motors or by larger, decked crafts (16-17m OAL), propelled with inboard engines (Polara *et al*., 2014).

The paper attempts to detail the spread of gillnet tuna fisheries and the species composition of large mesh gillnet fisheries across the four major regions of India *viz*. the Northwest, Southwest, Northeast and Southeast coast besides detailing on the dynamics of large mesh gillnet fisheries in the Northwest coast of India with skipper-based data collected from three large mesh gillnet fishing crafts operated basing Gujarat.

Materials and Methods:

Monthly and annual landing data collected by the Fisheries Resources Assessment Division of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) and maintained at the National Marine Fishery Data Centre (NMFDC); Kochi was used for studying the performance of the Mechanized Gillnet fishery during the 12-year period from 2011-2022. The ICAR-CMFRI collects fish landing data along the coast of India following national-level sample survey through a multi-stage (two-stage) stratified random sampling protocol. The survey using this acclaimed and FAO-approved sampling design of late has been carried through online data collection application- Fish Catch Survey and Analysis (FCSA) (Mini *et al*., 2023) enabling a real-time, high-resolution data on fish landing in India. The data has been analysed for pan India species composition in large mesh gillnet fisheries as well as the species composition in four regions Northwest, Southwest, Northeast and Southeast (Fig.1) using the computer programme MS Excel.

The spatially explicit data on large mesh gillnet fisheries in the Northwest coast was collected using specially designed and pre-tested logsheets provided to three medium-size commercial multiday gillnetters (16mOAL) operating basing Veraval, Gujarat. Veraval is the major fishing harbour for large-mesh gillnetter-based fishing in the region. The logsheet was designed to gather maximum information on fishing grounds, time and duration of operation, number of hauls, size-wise catch, and species composition. The schedule had fields to note the date, Global Positioning System (GPS) points for shooting and hauling the net, species composition as well as for number of fishes under the size class small (<40 cm), medium (40-60cm) and large (>60cm) for the listed species which included the sensitive bycatch like the whales, turtles, and dolphins. The fishermen of selected gillnetters were provided with the logsheets before every voyage and the filled in schedules were collected back after the fishing voyage. Relative accuracy of the position data was checked for the correctness using Google Earth and the outliers found were omitted from the database. Accuracy of the data were also ascertained through port-based observations and periodic consultation with the participating fishermen. Data schedules for 1156 fishing operations were collected during the study period (January 2011 to December 2022) covering all fishing months. Marine fishing is customarily prohibited in the state during June-August, coinciding with the south-west monsoon and the efforts are absent or very meagre in these days. The data collected has been analysed for percentage composition using the computer programme MS Excel. Fishing points aggregated formed grid cells and the intensity of each cell is determined based on normalized catch. The Excel charting tools such as the 2-D Heatmap are utilized to visually represent the spatial distribution of fish abundance. Interpretation of the resulting map allows for identifying areas with higher fishing point density, aiding in understanding fishing patterns and potential hotspots.

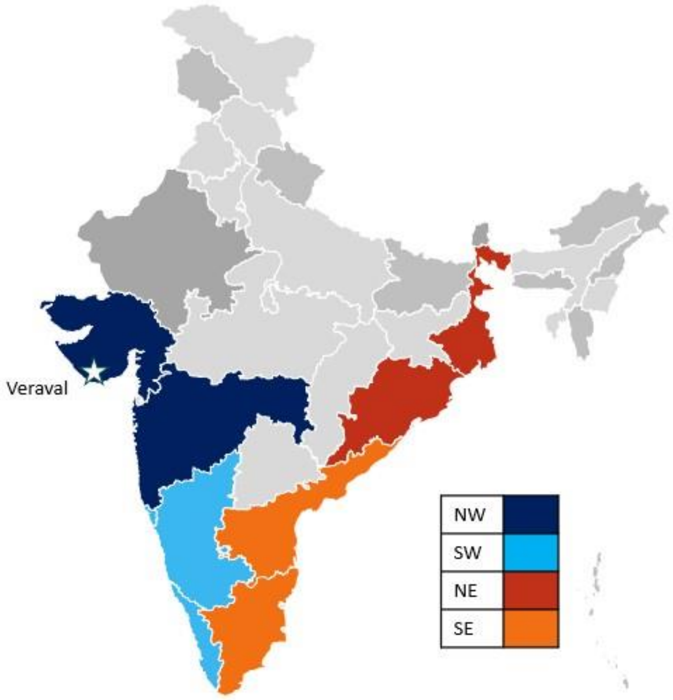

Fig. 1 Map of India showing the four coastal regions (The Veraval fishing port is highlighted).

Results:

In the last twelve years since 2011, the large mesh gillnet catches mainly comprised of oceanic tuna (skipjack and yellowfin), neritic tuna (kawakawa, longtail and bullet tuna), seer fishes (Spanish mackerel and spotted seer) and other non-tuna fishes (queen fishes, rainbow runner, mahimahi, billfishes, leather jackets, barracuda etc). Oceanic tuna catches exhibited a wide fluctuation in landing with peaks in 2016 and 2018-2019 (Fig.2). Although gillnetting is a predominant fishing practice in India, the use of large mesh pelagic gillnetting is limited mainly to the Northwest and the Southeast coast of India as evident from the landing data (Fig.3). The major species/groups landed are the skipjack tuna, yellowfin tuna, narrow barred Spanish mackerel, billfishes, kawakawa, spotted seer, longtail tuna, leather jackets and bullet tuna in the order of dominance (Fig.4).

The target or the dominant species varies from region to region. In the Southeast coast, the major region where the gillnet catches are the highest among the four regions, skipjack is the predominant catch forming 50.4% of the large pelagic catch followed by yellowfin tuna (18.8%) and bill fishes (13.5) (Fig. 5). The oceanic resources constituted nearly 83% of the landing. Neritic resources formed the catch are kawakawa (7.4%), bullet tuna (4.7%), narrow barred Spanish mackerel (2.5%) etc. However, neritic resources dominated the catches in the Northwest coast (Fig.6). Longtail tuna (23%), narrow barred Spanish mackerel (20.2%), spotted seer (12.3%), kawakawa (12.1%), leather jackets (8.1%) and bullet tuna (3%) forming nearly 79% of the landing. Yellowfin (7.9%), billfish (5.2) and skipjack 4.3%) forms the oceanic resources here. The northeast and southwest constituted 9% each to the large mesh gillnet catch. However, the species dominant in the southwest coast was oceanic resources (73%) like yellowfin tuna (29%), billfishes (23.8%) and skipjack (20%) (Fig.7) and that in the northeast coast was predominantly neritic resources like spotted seer (47.7), leather jackets (39.9%), kawakawa (6.5%) etc. (Fig.8).

Target catch in gillnet varies with season in all the regions (Fig.9). Oceanic tuna was generally higher in the summer months than other months while the neritic tuna catches are higher in the post monsoon and winter months. In the southeast region, where the gillnet forms a sizeable gear harvesting large pelagics, there is a dominance of oceanic resources like skipjack, yellowfin, and billfishes in all the seasons indicating a targeted gillnet fishing for oceanic resources here (Fig.10). In the northwest coast, the other major region for the gillnet fisheries, neritic species dominate the catches in gillnet in most of the months especially in post monsoon and winter months (Fig.11). The oceanic resources form catches in winter and summer months.

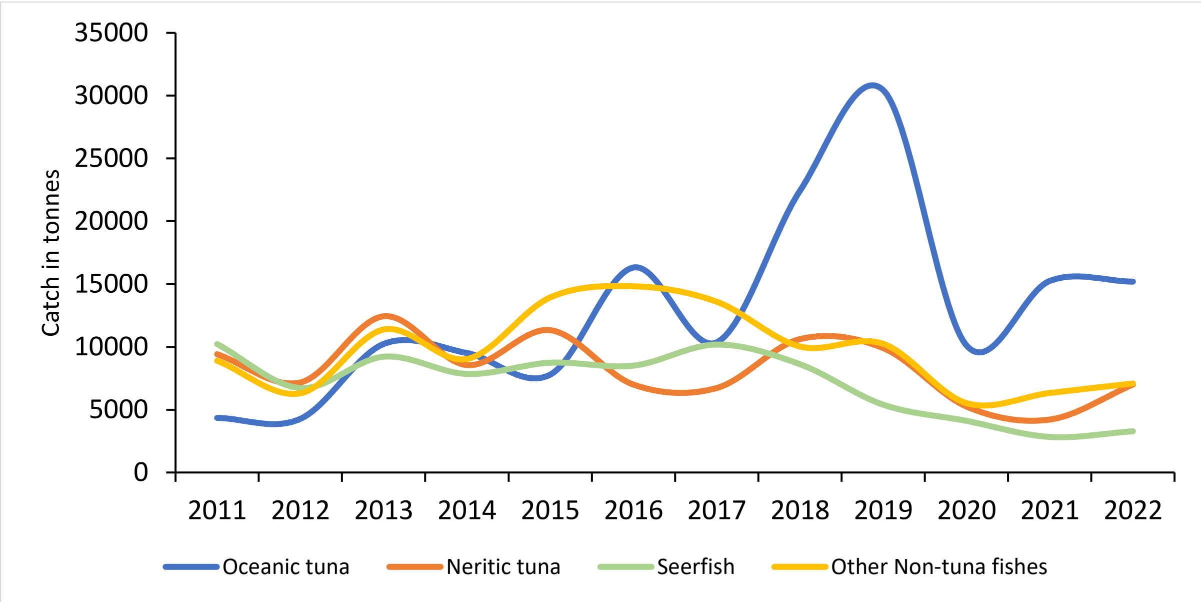

Fig. 2. Annual variation of tuna and non-target catches from gillnet catch along Indian coast during 2011-2022.

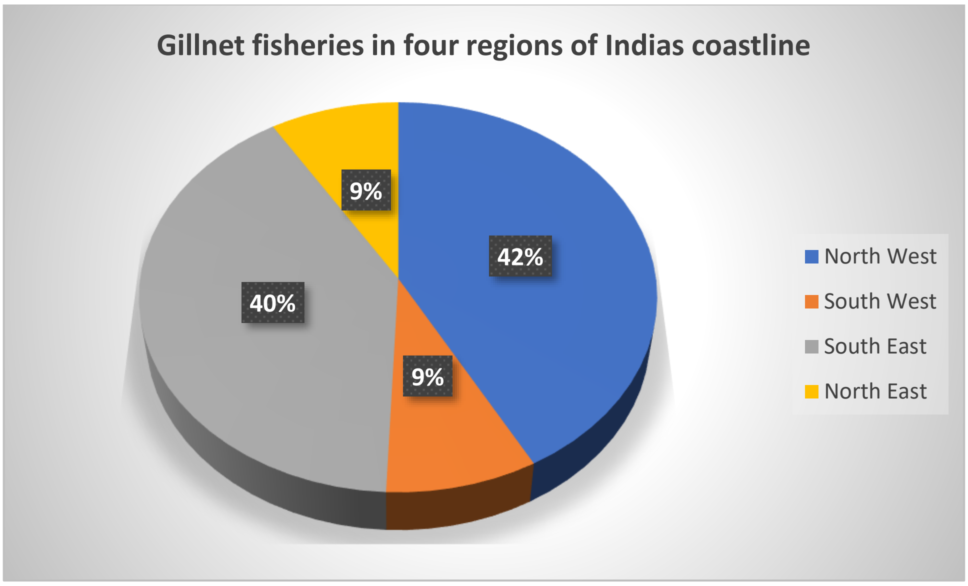

Figure 3 Contribution of four regions of India (mainland) in gillnet fisheries

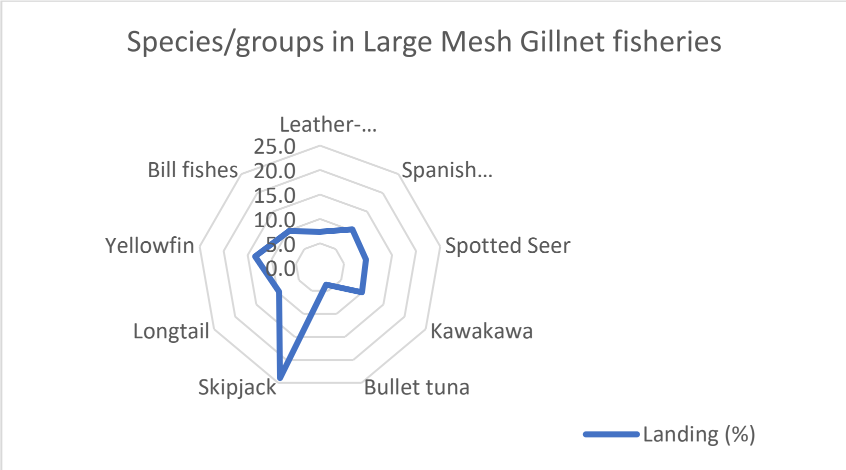

Figure 4 Major species/groups in large mesh gillnet fisheries in India

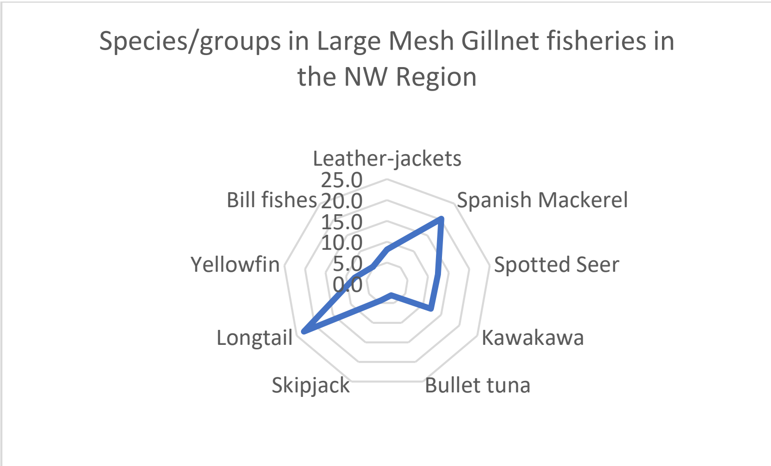

Figure 5 Major species/groups in gillnet fisheries in the Northwest region

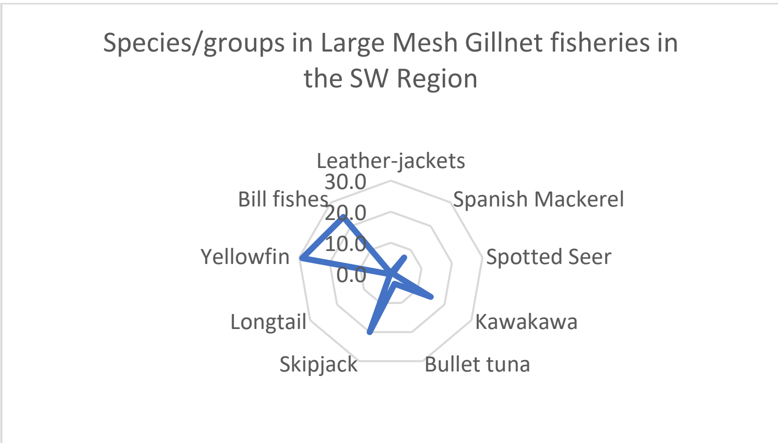

Fig. 6 Major species/groups in large mesh gillnet fisheries in the southwest region

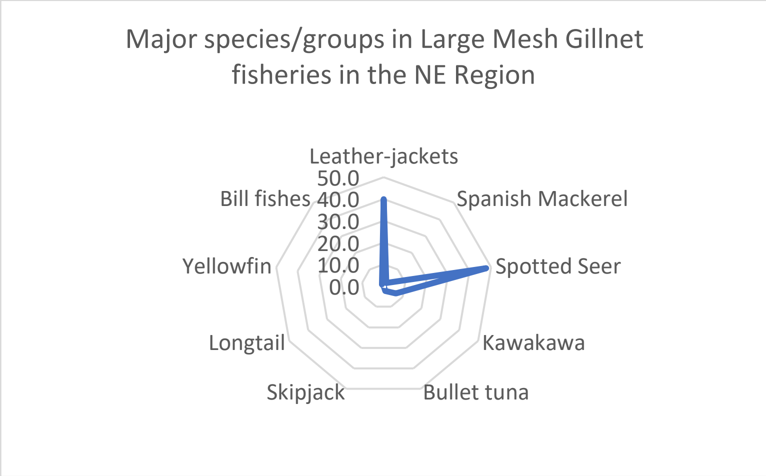

Fig. 7 Major species/groups in large mesh gillnet fisheries in the Northeast region

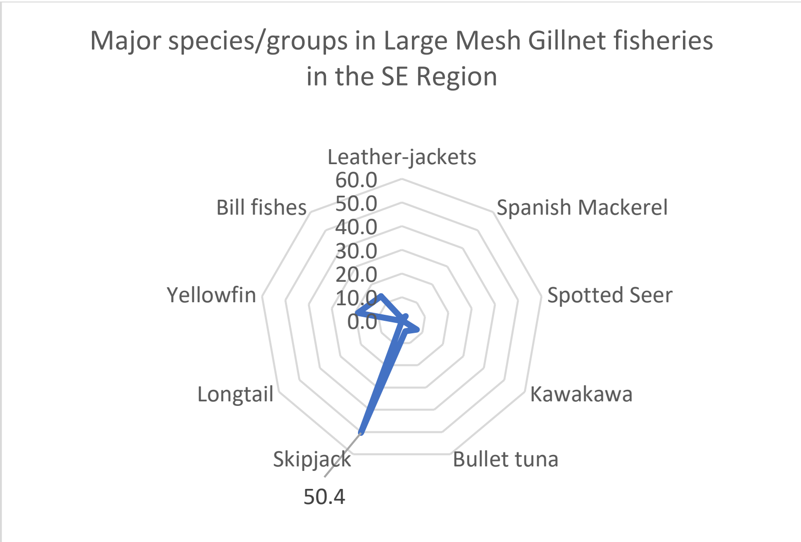

Fig. 8 Major species/groups in in large mesh gillnet fisheries int he southeast region

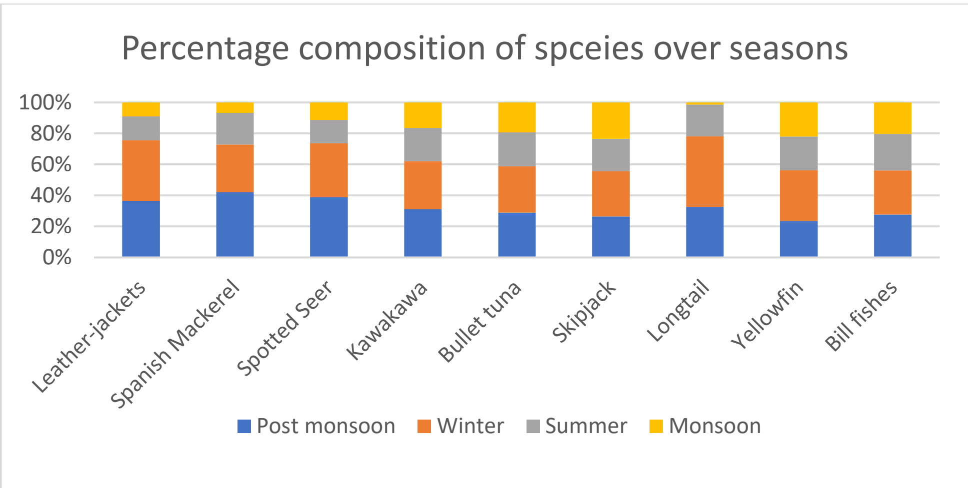

Fig. 9 Percentage composition of species in the large mesh gillnet fishery over the seasons

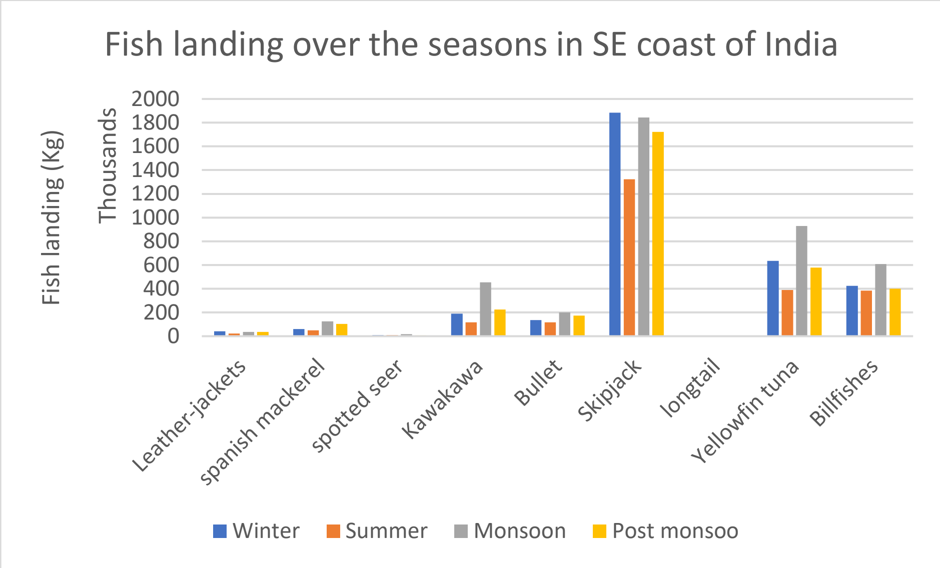

Fig. 10 Seasonality of fish landing by large mesh gillnet fishery in the southeast coast of India

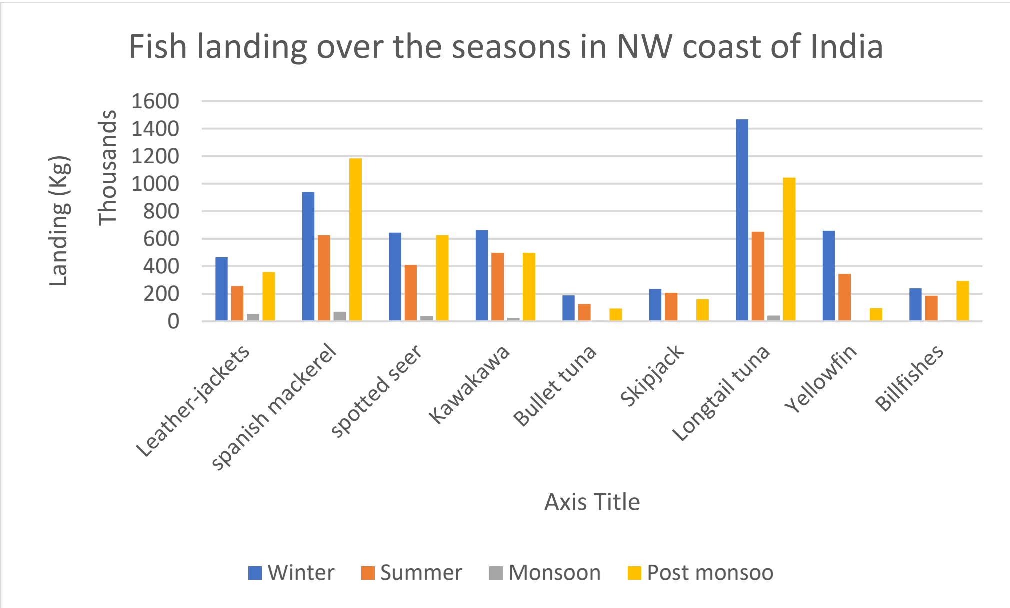

Fig. 11 Seasonality of fish landing by large mesh gillnet fishery in the Northwest coast of India

Species composition of large mesh gillnet fishery off the northwest coast.

In the skipper-based survey of three large mesh gillnet fishing vessels during January 2011 to December 2022 basing Veraval, Gujarat, 1156 observations were taken spread across all the months of the year except June and July, the peak southwest monsoon. At least forty-five species and a total of 160,163 animals were recorded, including six species of tuna, two species of seer fish, three billfish species, cobia, dolphinfish, seven shark species, seven species of other fishes, and two species of sea turtles. Catch compositions are summarized by fleet in Table 1. Among them, tuna species, including longtail (19.6%), kawakawa (19.2%), skipjack (4.3%), and yellowfin (1.5%) comprised >61.5% of the total catch. Spanish mackerel (6.4%), spotted seer (6.0%), dolphinfish (4.7%), Unicorn leatherjacket (3.7%), and cobia (1.7%) were the major species in the high value bycatch. All low value bycatch species comprised 7.6%, shark species comprised 0.28% and ETP species comprised 0.22%.

Table: Numbers and Percentage of species caught by gillnet operated in NWCI.

Major group	Species/minor group	No.	Percentage
	Skipjack	6889	4.30
	Yellowfin	2496	1.56
Oceanic tuna		**9385**	**5.86**
	Longtail	31522	19.68
	Kawakawa	30840	19.26
	Axius	36258	22.64
Neritic tuna		**98620**	**61.57**
	King seer	9704	6.06
	Spanish mackerel	10302	6.43
Seerfish		**20006**	**12.49**
	Cobia	2873	1.79
	Dolphin fish	7620	4.76
	Sailfish	519	0.32
	Marlin	185	0.12
	Hilsa	113	0.07
	Barracuda	989	0.62
	Catfish	600	0.37
	Queenfish	3	0.00
	Unicorn leatherjacket	5951	3.72
	Silver pomfret	184	0.11
	Black pomfret	143	0.09
	LVB	12174	7.60
Other Non-tuna fishes		**31354**	**19.58**
	Shark	431	0.27
	Spine tail mobula	13	0.01
	Manta ray	8	0.00
Elasmobranchs		**452**	**0.28**
	Whale shark	11	0.01
	Turtle	205	0.13
	Dolphin	130	0.08
ETP		**346**	**0.22**
Total		**160163**	**100.00**

Temporal changes

The monthly fluctuations in catch observed through skipper-based observations provide valuable insights into tuna abundance pattern over time and space. These fluctuations are particularly evident from September to November, with a minor peak occurring in February (Fig. 12). A similar pattern is observed in non-tuna species. Contrarily, the abundance of ETP species showed a distinct rise during February and March, with recorded numbers ranging from 57 to 58 individuals. Shark catch exhibited its highest numbers in August (110 no.) and October (124 no.).

Analyzing the all-India landing from tuna gillnetters spanning from 2011 to 2022 reveals consistent trends with the skipper-based observations (Fig.2). Tuna landings, encompassing both neritic and oceanic species, demonstrated peaks during January to March (2187-2799 tons) and again from August to October (1927-1999 tons). Although there were limited numbers of ETP species and elasmobranchs, the existing data were inadequate to make a reliable monthly comparison of their abundance with tuna.

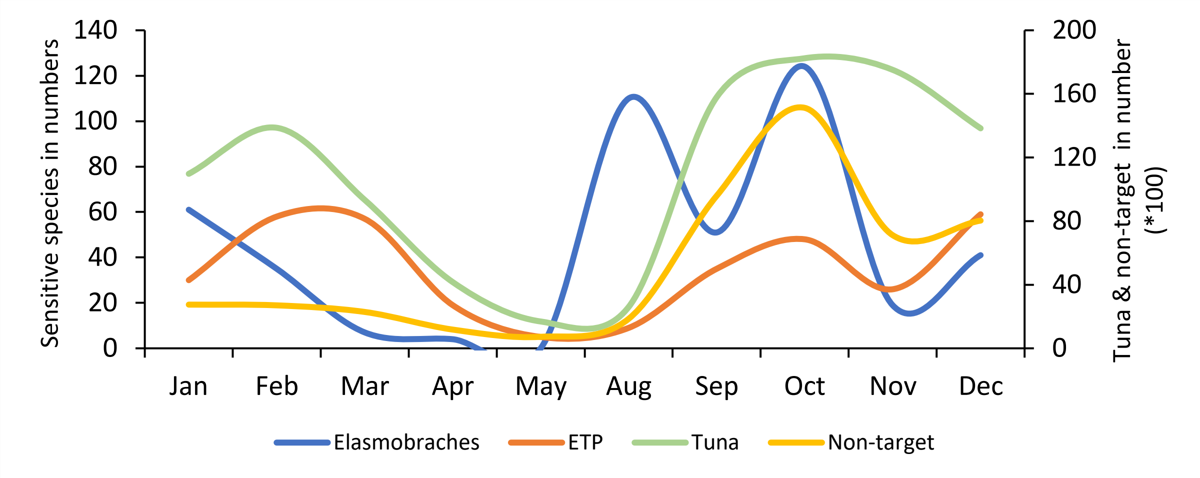

Fig. 12. Monthly variation of tuna and non-target catches from gillnet-based skipper observed data in NWCI.

The tuna landings from gillnetters in Indian waters reveals a declining trend after its peak in 2019, as depicted in Figure 1. This trend of decline is reflected in the observations made by skippers, as depicted in Figure 13. Tuna landings exhibited a notable surge, approximately 1.5 to 2 times, during 2018-19, primarily attributed to an increase in oceanic tuna such as yellowfin and skipjack. The skipper-based observations unveiled a consistent alignment in catch patterns between tuna and non-tuna target species throughout the study duration. Nevertheless, there was an increase in the occurrence of elasmobranchs during periods marked by reduced tuna catches, specifically in the years 2015, 2019, and 2022. Interestingly, there were no recorded elasmobranch incidents during the years 2017-18 and 2020.

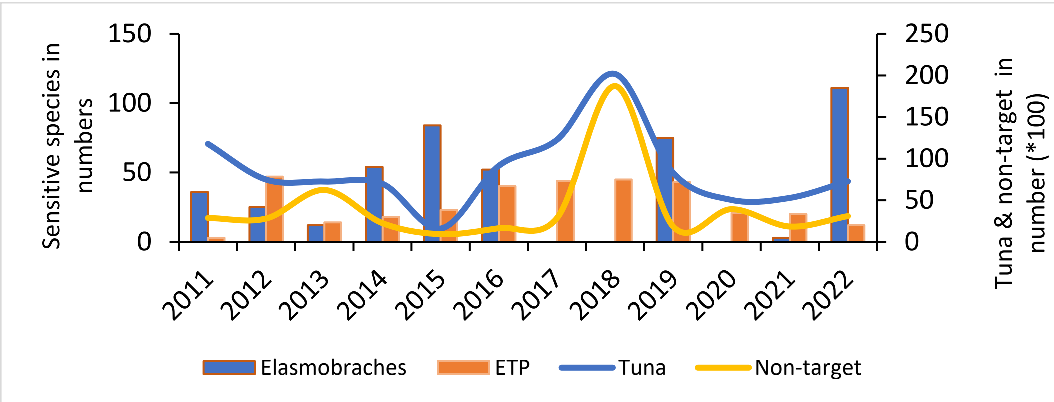

Fig. 13. Annual variation of tuna and non-target catches from gillnet-based skipper observed data in NWCI.

Spatial distributions

The spatial distribution maps depicted in Figure 14, distinctly illustrate variations in the areas of peak abundance of tuna and ecologically sensitive species. Oceanic tuna incidence points are in relatively deeper areas while the neritic tunas are closer to the shore. Elasmobranch incidence points were also nearer to the shore in the south Saurashtra peninsula. Turtle, dolphin, and whale sharks were the ETP species occurred. Dolphin incidence points were more in t the deeper areas while the turtles occurred more in the inshore areas (30-100m depth). These discrepancies in spatial distribution offer valuable insights for the development of spatial management strategies, particularly pertaining to the establishment of non-fishing zones. This approach becomes especially pertinent to the ETP hotspot, as it is designed to address the unintentional entanglement of ETP species in gillnet fisheries.

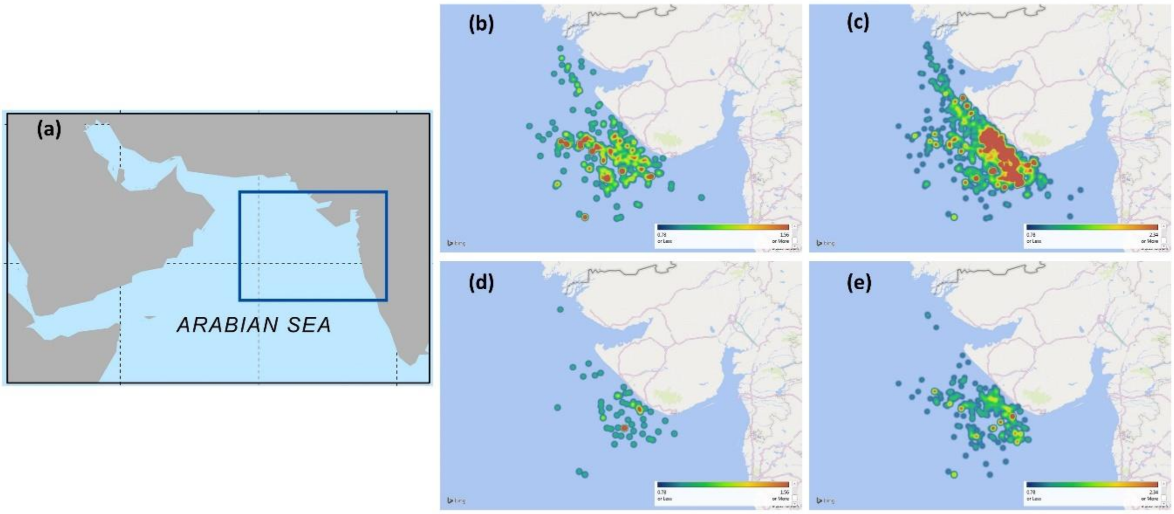

Fig. 14. Spatial distribution of tuna and sensitive species from the gillnet in the NWCI, (a) northwest coast of India, (b) oceanic tuna, (c) neritic tuna, (d) elasmobranch and (e) ETP species.

Discussions and conclusion:

Small scale fisheries in the Indian Ocean region have landed 1,90,000 tonnes of non-tuna species for 1,40,000 tonnes of tuna caught annually in the recent years (Gillet, 2011). Though globally artisanal fisheries play an important role in food security, livelihood, and national economies in many coastal nations (FAO, 2017), it brings about large uncertainties in data collection, undermining the scientific processes and the effectiveness of conservation and management measures (CMM) built on it (IOTC- 2017a).

Gillnet is a very widely used gear in the fisheries sector of India. The target species varies according to the mesh size, the vertical position of setting the net and the area of fishing. Large mesh gillnets when set at the surface catches large pelagics like tunas, billfises, seerfishes, mahimai etc. while when it is set at bottom, the catches are bottom fishes like the snappers, croakers, breams, sharks etc. The decision of use of gear depends on the local resources, skill of the fishermen and the market demand for the catches. Although a passive, size selective fishing gear, gillnets are not species selective. Incidence of non-target resource are part of this gear.

The pelagic, large mesh gillnet fisheries in India mainly targets the tunas and neritic or oceanic tunas form the major target depending upon the region. The continental shelf is wider towards north in both east and west coast of India. This influences the catch composition in the pelagic large mesh gillnet fisheries as the neritic species dominate the catches in the northern region and oceanic species dominate the catches in the southern regions. The non-tuna fishes caught in this gear are all high value fishes and are retained. The composition of non-tuna species is almost similar in all the regions of India although the dominance varies from region to region. Fishing intensity varies from quarter to quarter over a year. Post monsoon months and the winter are the major season for the tuna fishing although the oceanic species occur more during the winter and summer months.

Skipper based survey of pelagic large mesh gillnet fisheries in the northwest coast revealed the dynamics of the gillnet fishery more closely. The survey results corroborate with the landing data collected by the ICAR-CMFRI and maintained at the National Marine Fishery Data Centre. The neritic species, longtail tuna dominated the catch followed by kawakawa. The non-tuna species recorded are all high value species and are retained. The low value by catch like the trigger fishes, sucker fish, moon fish etc. formed around 7.5% was also retained and sold for fish meal or for domestic consumption. Sharks formed only 0.28% of the catch and the ETP species together formed 0.22% of the total number of fishes caught in 1156 fishing operations. There is marginal increase in the incidence of turtle and dolphin in the gillnet catches compared to that reported by Mohammed koya *et. al*., 2018 during the study period 2011-2016.

The incidence of non-target resources, especially the sensitive resources like the cetaceans and turtles depend on the abundance of such resources in the fishing area and the intensity of the gillnet fishery. The study reveals the abundance areas for the cetaceans and turtles in the northwest coast. All the non-tuna fishes caught were also landed, and like in many small-scale fisheries (Gillet, 2011), discards were particularly low and did not form a major problem which requires an immediate focussed management attention, except for species that are over- exploited, threatened or protected.

Similar study in the southeast region of India would have given clearer picture of interaction of non-tuna species in the gillnet including the incidence of ETP species. As the oceanic species dominate the catches in the gillnet fisheries in the southeast, indicating operation of the gear in the oceanic areas, the catch rates of incidental catches are likely to be lesser compared to the northwest coast. Mohammed koya *et al*., 2018 indicated that the incidence of ETP species is negatively correlated with the depth of fishing, the occurrence of ETP species, especially turtles is also likely to be lesser compared to northwest.

The pelagic large mesh gillnet fishery of India will need to adopt measures to reduce the incidence of cetaceans and turtles in the gear while fishing for tunas. Measures like subsurface setting (Moazzam *et al*., 2016 (Hembree & Harwood, 1987; Dayaratne & de Silva (1991)) or use of pingers. The first study conducted in India during 2019-20 with coastal gillnets operated off Cochin using dolphin pinger (Fishtek Marine, 70 KHz) showed that gillnet units without pingers were 2.3 times more prone to dolphin attack than pinger assisted gillnet units (Thomas *et al*., 2022). Reduction of net profile (narrower nets) is an effective and economically viable solution for reducing turtle interactions (Gilman *et al*., 2010). Visual mitigation measures like attachment of shark shaped silhouettes, illuminating portions of the net using green light, sticks and light emitting diode lamps etc had shown reduction in number of turtles caught in gillnets (Wang *et al*. 2009; Wang *et al*., 2013; Ortiz *et al*., 2016).

Information on the catch composition of gillnet fisheries at higher resolution is needed from all the region of India to clearly understand the dynamics of the fisheries in order to devise pragmatic measures to reduce the ecological impacts of gillnet fisheries. Meanwhile research needs to focus on devising viable measures to reduce the occurrence of sensitive species like the cetaceans, certain shark species and turtles in the pelagic large mesh gillnet fisheries of the region.

References:

Anderson, Charles A and Herrera, Miguel and Ilangakoon, Anoukchika D and Koya, Mohammed and Moazzam Khan, Muhammad and Mustika, Putu L and Sutaria, Dipani N (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. Endangered Species Research, 41. pp. 39-53.

CMFRI. 2017. Annual Report 2016-17, Central Marine Fisheries Research Institute, Kochi. 292p

CMFRI. 2021. Annual Report 2020, Central Marine Fisheries Research Institute, Kochi. 292p

Dayaratne, P and de Silva, J. (1991) Drift gillnet fishery in Sri Lanka. IPTP Col Vol Work Docs. 4: 230-234

FRAEED, CMFRI, 2023. Marine Fish Landings in India-2022. Technical Report, CMFRI Booklet Series No. 31/2023. ICAR-Central Marine Fisheries Research Institute, Kochi

Ghosh Subhadeep, N.G.K. Pillai and H.K. Dhokia. 2010. Fishery, population characteristics and yield estimates of coastal tunas at Veraval. Indian J. Fish., 57(2) 7-13.

Gilman, E., Gearhart, J., Price, B., Eckert, S., Milliken, H., Wang, J. and Ishizaki, A. (2010) Mitigating Sea turtle by-catch in coastal passive net fisheries. Fish Fish. 11(1): 57-88

Hembree, D. and Harwood, M. B. (1987) Pelagic gillnet modification trials in northern Australian seas. Rep. Int. Whal. Comm. 37: 369-373

IOTC. 2017. Description of tuna gillnet capacity and bycatch in the IOTC Convention Area

Miller K.I., Nadheeh I, Jauharee AR, Anderson R.C., Adam M.S. 2017. Bycatch in the Maldivian pole-and-line tuna fishery. PLoS ONE 12(5): e0177391.

Mini, K G and Sathianandan, T V and Kuriakose, Somy and Augustine, Sindhu K and Manu, V K, Manjeesh, R, Sijo Paul, Jayasankar, J., Varghese, Eldho and Gopalakrishnan, A (2023). Fish Catch Survey and Analysis – An online application for deriving measures and indicators for fish stock assessment. Fisheries Research, 267. pp. 1-10. ISSN 0165-7836

Moazzam, M., Muhammad Wasim Khan, and Rab Nawaz 2016. Bycatch of Commercially Important Species of the Tuna Gillnet Fisheries of Pakistan. In the IOTC Working Party on Ecosystems and Bycatch (WPEB) Seychelles, IOTC–2016–WPEB12-40

Mohammed Koya, K and Rohit, Prathibha and Vase, Vinay Kumar and Abdul Azeez, P (2018) Non-target species interactions in tuna fisheries and its implications in fisheries management: Case of large-mesh gillnet fisheries along the north-west coast of India. Journal of the Marine Biological Association of India, 60 (1). pp. 18-26.

Northridge S.P., 1991. Drift net fisheries and their impacts on non-target species: a world review. FAO Fisheries Technical Paper, No. 320, Rome, FAO. 1991. 115p

Ortiz, N., Jeffrey C. M., John W., Alfaro-Shigueto, J., Sergio, P., Jimenez, A., Tania S., Swimmer, Y., Felipe, C., and Brendan J. G. (2016) Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. Mar. Ecol. Prog. Ser. 545: 251-259

Thomas, Saly N., K. M. Sandhya and Leela Edwin Incidental Catch of Marine Mammals and Turtles in Gillnets: Indian Scenario. Fishery Technology 59 (2022): 1 – 18.

Wang, J., Fisler, S. and Swimmer, Y. (2009) Developing visual deterrents to reduce sea turtle bycatch: testing shark shapes and net illumination. In: Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries (Gilman, E., Ed.). IUCN, Western Pacific Regional Fishery Management Council, Southeast Asian Fisheries Development Center, Indian Ocean South-East Asian Marine Turtle MoU, U.S. National Marine Fisheries Service, Southeast Fisheries Science Center, Gland, Switzerland; Honolulu, Bangkok, and Pascagoula, USA, pp 49–50. ISBN: 1-934061-40-9
