# 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

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## *Abstract*

Occurrence of non-target, associated and dependent species is a feature of tuna gillnet fisheries world-over, posing a great concern for fisheries management. Predominance of small-scale or artisanal fisheries in the region compounds the concern due to the uncertainty in data. There is dearth of information on the catches and the non-target species interaction in the tuna gillnets fisheries in India, especially from the north-west coast, where gillnet is the predominant gear targeting the tuna. We collected spatially explicit catch data with voluntary participation of fishermen from Veraval, Gujarat and quantified the species wise catches over space and time for 567 fishing operations spread across six years (2011-2016). Species composition, seasonal variation, nature and level of interrelationship in catch incidences, similarities among different groups of resources *etc*. were ascertained using various statistical tests like the Kruskal-Wallis rank test, Pearson's correlation and principal component analysis (PCA). The study reveals spatial expanse of gillnet fisheries of Gujarat and their major fishing grounds together with variations in catches of different groups over space and time. Nature and strength of interaction of sensitive species like turtles and dolphins as well as the unicorn leatherjacket, an emerging catch in the gillnet tuna fisheries was ascertained and GIS maps depicting the areas of copious presence of these groups are presented. Management implications of such interactions as well as the potential of involving fishermen to gather spatially explicit fishery data, paving way for their active involvement in fisheries governance are discussed. The study can be replicated at national level to enhance the understanding on the gillnet fisheries to bring in pragmatic interventions to sustain the fisheries.
**Keywords**: Bycatch, unicorn leatherjacket, turtle, dolphin, spatio-temporal distribution

## *Introduction*

Tunas are one of the highly valuable marine resource groups having an annual catch of 7.7million tonnes, constituting nearly 9% of the total global fish catch (FAO, 2016). Gillnet is the major tuna fishing gear (33%) in the entire Indian Ocean followed by purse seines (26%) (Miller *et al*., 2017), contributing nearly 53% of the artisanal nominal catches reported to the Indian Ocean Tuna Commission (IOTC 2017a). The 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, 2017a). India ranks fourth in neritic tuna production among the nations in the IOTC area (IOTC, 2017b). Tuna fishing in India is of artisanal nature, with the total annual landing of 0.92 lakh tonnes in 2016. The catch is predominated by neritic tunas comprising 64% of total tuna catch (CMFRI, 2017). 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 operation is made either 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).

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). Non-reporting of catches by the fishermen and lack of observer programmes are the main reasons for the dearth of information on bycatch and discards in large-mesh gillnets fisheries in India. Smaller size of the crafts, longer duration of fishing, higher cost involved and non-cooperation of the fishers could have been the deterrents for implementing the observer programmes on board Indian vessels. However, fishermen have a wealth of information on the fishing grounds and catch rates over space and time gained through years of fishing experience and could be sourced suitably. The fishermen generally take note of the geographical coordinates where they get higher catches for future revisits. Such information on spatially referenced fishing grounds can be collected from fishers through active cooperation and adequate empowerment of fishermen at very low costs. Spatially referenced information thus collected would provide information on a) bycatch and discards in the gillnet fisheries (IOTC- 2017c), b) spatial and temporal patterns of the small scale fishery and c) an idea on the movement of the target and bycatch species in the fishing grounds, which are basic research information required for planning management of pelagic resources and identifying marine protected areas (Kaplan, 2014). The present study aims to understand the spatio-temporal variations in the non-targeted species incidence and species interactions in the eastern Arabian Sea off the north-west coast of India.

## *Materials and Method*

### Data collection

Customized log sheets in local language were provided to three selected large-mesh gillnetters at Veraval (20º54’10”N; 70º22’26”E), the most important fishing harbour in Gujarat for large-mesh gillnetters. The log sheet was designed to be simple and user friendly to gather maximum spatio-temporal information on fishing with least inconvenience to the fishers. Date and time of operations, GPS position of shooting and hauling the net, details of catch (approximate weight) including species composition *etc* were collected. Large-mesh gillnetters carry out multiday fishing generally for 3-7 days in a voyage and use gillnets made of multifilament nylon (polyamide) nets of over 2500 m with mesh size of 140 mm. The fishermen set the net once in a day at dusk and haul it back at dawn the following day with a soak time of nearly ten hours. The fishermen were provided log sheets before the commencement of every voyage and the filled-in log sheets were collected back on completion of the fishing voyage. The data on the log sheets were collected every month from January 2011 to December 2016, except during southwest monsoon (June, July & August) when fishing was customarily prohibited in the state.

The collected information was digitized in to a database. Relative accuracy of the fishing positions were checked by overlaying the points to a satellite image base map. The composition of landed catch was noted by observation on arrival of the fishing vessel at port. The fishermen were also consulted periodically during which the catch information and fishing points were ratified and outliers if any were removed. Data sheets for 567 fishing operations were collected during the study period.

## Data Analysis

Kruskal-Wallis H test, a non-parametric test of variance, was used to analyse species composition and seasonal variations. Nature and strength of interrelationship between major catch and the by-catch fishery resources as well as their level of dependency on each other were studied by correlation analysis using Pearson's correlation. The Principle component analysis (PCA) was used to reduce the complexity of data sets without losing information (Ragno *et al*., 2007) and to find groups and sets of variables with similar properties. For the statistical analysis and plotting of data, R ver. R.3.5.0 (R, 2014) was used.

GeoMedia Professional 2014 and its extensions were used to create georeferenced maps for the abundance and disribution of different groups/species. Interpolations were made using inverse distance weighted (IDW) interpolations, which allowed a value at unsampled locations to be estimated from sparsely sampled data points (Rivoirard *et al.* 2000). Analyses were performed to create different maps depicting the extent of the gillnet fishery in the region with major regions of incidence for non-target resources and Endangered, Threatened and Protected species (ETPs). Co-occurrence of non-tuna species, leatherjackets and ETPs with the oceanic and neritic tunas was analysed using Pearson correlation analysis. As the leatherjackets constituted considerable share of gillnet catch, exhibiting specific pattern in area and time of abundance, the group was analysed separately from other non-tuna fishes.

## *Results*

The fishing points of the observed gillnetters were spread all across the continental shelf areas along Gujarat and to the adjacent oceanic region between 18$^{o}$N and 23$^{o}$N latitudes at depths ranging from 14 m to over 3000 m (Fig. 1). Majority of the effort was expended on the shelves off the Saurashtra coast between 20$^{o}$N and 22$^{o}$N latitudes at 50-100m depth zone and only 17% was made in the oceanic areas *i.e*., beyond the continental shelf break after around 200m depth contour (Fig.1). Fishing in the oceanic areas was mainly during late winter (February) and summer months (March-May).

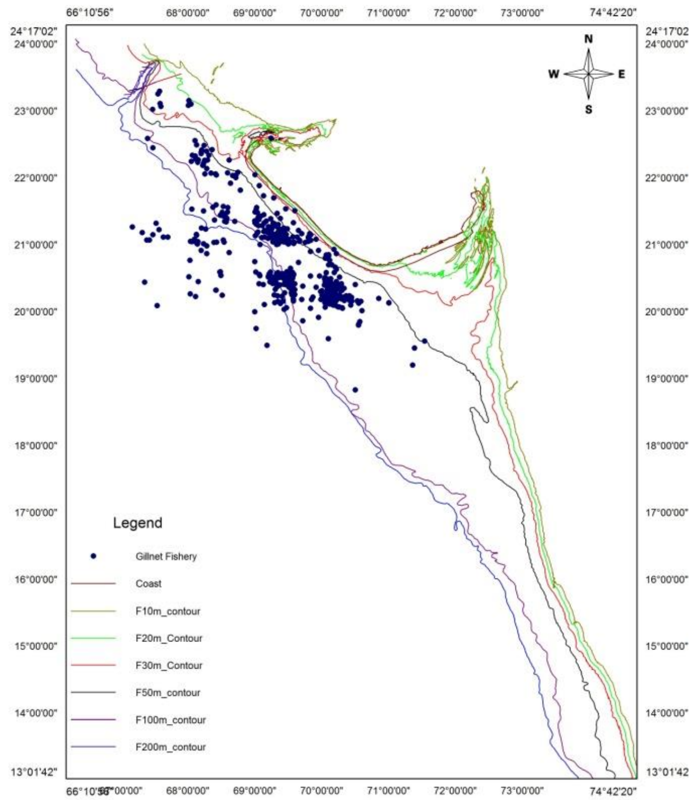


Figure 1. Spread of fishing points of the observed gillnetters (2011-16)

## Catch Composition and its variations over the year

The gillnet catch covered 16 taxa comprising of commercially important species such as tunas (oceanic tunas - Skipjack (*Katsuwonus* pelamis) and Yellowfin (*Thunnus albacares*) and neritic tunas – Longtail (*Thunnus tonggol*), Kawakawa (*Euthynnus affinis*) and Frigate (*Auxis thazard*)), Cobia (*Rachycentron canandum*), Mahimahi (*Coryphaenus hippurus*), leatherjacket (*Aluterus monoceros*), billfishes, seerfishes and queenfishes. Low value bycatch (LVB) comprised clupeoids (wolf herrings, shads *etc.*), needlefishes, flying fishes, triggerfishes, remoras, moonfish, eels *etc*. and ETPs consisted of turtles and dolphins. The tunas constituted 64.62% of the gillnet catch followed by non-tuna fishes (35.26%). The ETP species constituted only 0.12% of the total catch. Neritic tuna formed nearly 92% of the total tuna catch (Table 1). Though non-tuna fishes ranged from zero to 100% in different fishing operations, it constituted only up to 30% of the catch in most (60%) of the fishing operations (Fig. 2). Longtail tuna constituted 24.3 percentage of the total catch in gillnets followed by Kawakawa (21.6%), leatherjackets (16.26%), frigate tunas (13.57%), Mahimahi (4%) *etc*. The oceanic tunas (Yellowfin and Skipjack) formed 8% with their catch limiting to the winter and summer months.

Species composition of ten fishing operations with a high percentage of longtail tuna in catch is depicted in Fig.3. Kawakawa and frigate tunas were the dominant catch in these operations besides leatherjackets, seerfishes and oceanic tunas in smaller quantities. Unicorn leatherjackets and filefishes constituted major catch in gillnets during winter months. There was exclusivity in abundance of unicorn leatherjackets visible from the analysis of composition of ten fishing operations wherein the species constituted the major catch (Fig. 4). The species formed nearly 73% of the catch in these operations with no or minimal catch of other fishes including Longtail tuna (except for one operation). LVB was the only category that formed a considerable part of catch in these operations along with stray numbers of Kawakawa and frigate tunas. LVB ranged from 0 to 670 numbers with an average contribution of 5.58%.Though some of these resources like needlefishes, wolf herrings, eels *etc.* fetch some value and are used for local consumption, and much of the LVB goes for preparation of fish meal, especially when the quality is deteriorated. Season wise analysis indicated that majority of LVB were landed during winter months followed by post-monsoon. The LVB landing was minimal during summer months when the operations by gillnets were more in the oceanic areas indicating the coastal nature of most of the LVBs.

Mahimahi, Cobia, leatherbacks, leatherjackets *etc*. that formed considerable portion of catch in gillnets do have a high commercial value though they are considered as a bycatch in IOTC parlance. There were no discards in the gillnet fishery other than the release of legally prohibited species like turtles and dolphins that are accidentally caught. The ETP species recorded during the study included turtles and dolphins. Whale shark, a protected species common in Gujarat waters was not reported throughout the study period so was the case of birds of any kind. Out of 567 fishing operations, 30 dolphins occurred in 22 fishing operations (4%) and 65 turtles were observed in 56 operations (10%) with a catch rate of 0.05 and 0.11 respectively. The maximum number of dolphins that occurred in any fishing operation was two and that for turtles were three. Dolphin incidence in gillnet was more during summer months and least during the post monsoon months while turtle incidence was less during summer months and more in post monsoon months (Fig. 5). The spatial pattern of occurrence of dolphins and turtles in the catches is given in Fig.6. Turtle and dolphin incidence points were distinctly limited between 20$^{o}$00N and 21$^{o}$30'N which falls off central Saurashtra region. Turtles occurred in all depth zones with the abundance being more between 30m and 100m depth contours while dolphins occurred at deeper waters close to 100m and beyond 200m depth contours.

Table 1: Composition of catch in the large-mesh gillnet fishery

| **Major Groups** | **Species/Minor Group** | **Catch(Nos.)** | **Percentage of Total** |
|---|---|---:|---:|
| | Skipjack | 3001 | 3.84 |
| | Yellowfin | 1047 | 1.34 |
| Oceanic Tuna | | 4048 | 5.17 |
| | Longtail | 19006 | 24.29 |
| | Kawakawa | 16898 | 21.60 |
| | Frigate tuna | 10614 | 13.57 |
| Neritic Tuna | | 46518 | 59.45 |
| **TUNA** | | **50566** | **64.62** |
| | Cobia | 1573 | 2.01 |
| | Mahimahi | 3150 | 4.03 |
| | Spanish Mackerel | 1959 | 2.50 |
| | King seer | 2931 | 3.75 |
| | Leatherback | 153 | 0.20 |

| | | | |
|---|---|---|---|
| | Shark | 412 | 0.53 |
| | Billfishes | 321 | 0.41 |
| | leatherjacket | 12723 | 16.26 |
| | LVB | 4364 | 5.58 |
| **NON-TUNA Fishes** | | **27586** | **35.26** |
| | Turtle | 65 | 0.08 |
| | Dolphin | 30 | 0.04 |
| **ETP** | | **95** | **0.12** |
| TOTAL | | 78247 | 100.00 |

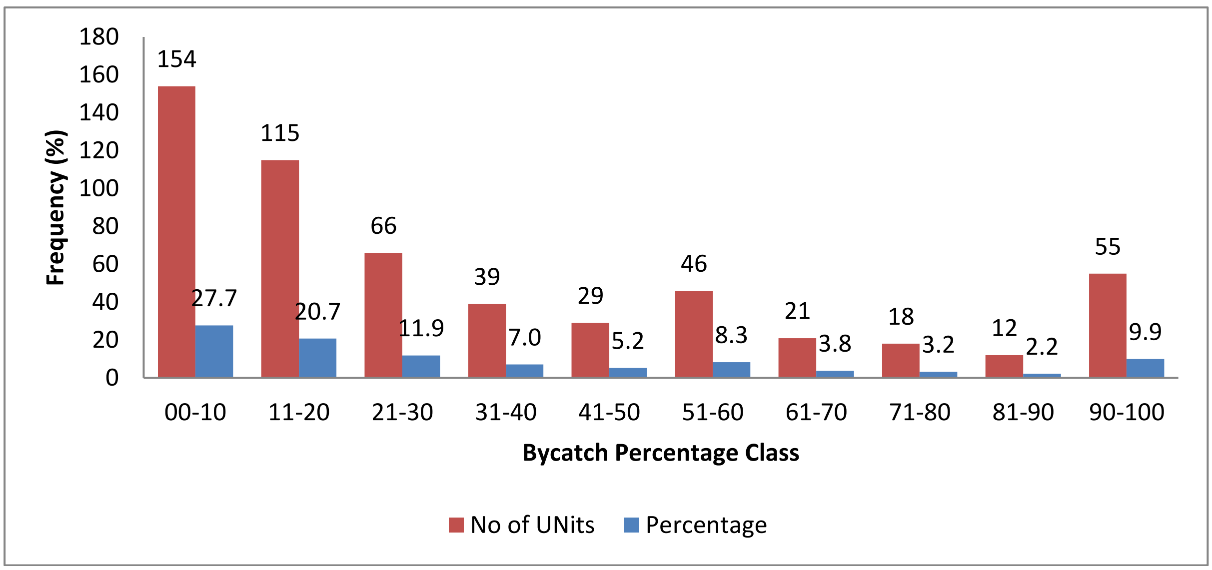


Figure 2. Frequency chart of incidence rate of non-tuna species in gillnet catches

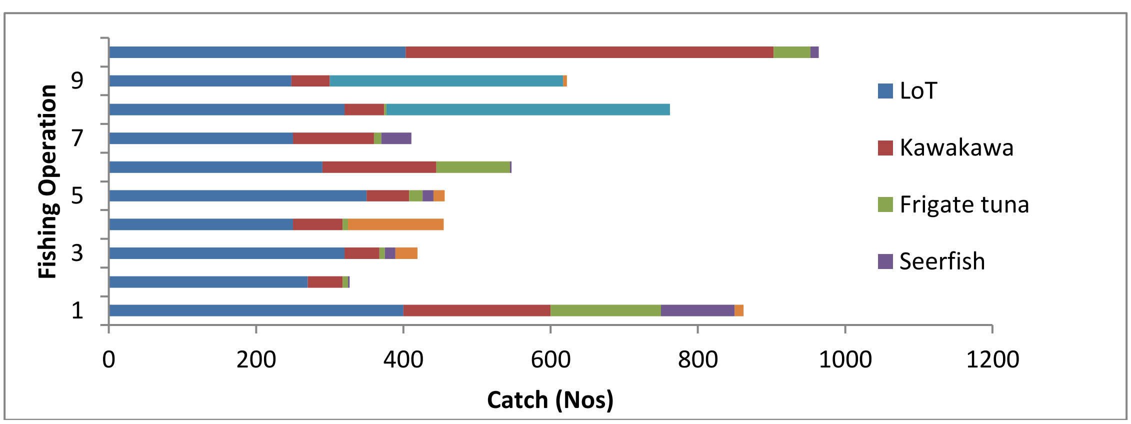


Figure 3. Major resources co-occurred in ten gillnet operations where the longtail tuna dominated the catches.

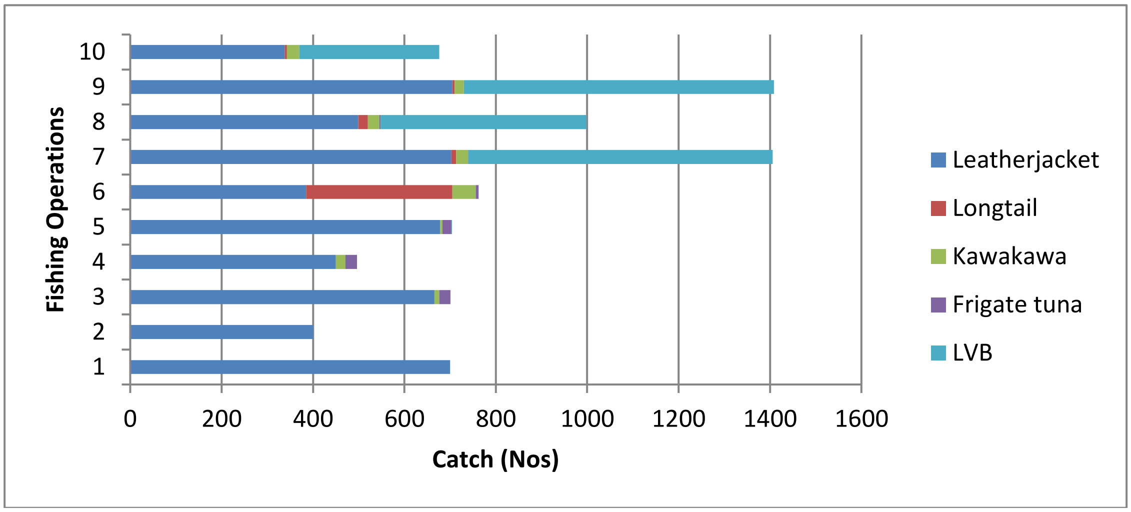


Figure 4: Major resources co-occurred in ten gillnet operations where leatherjackets dominated the catches.

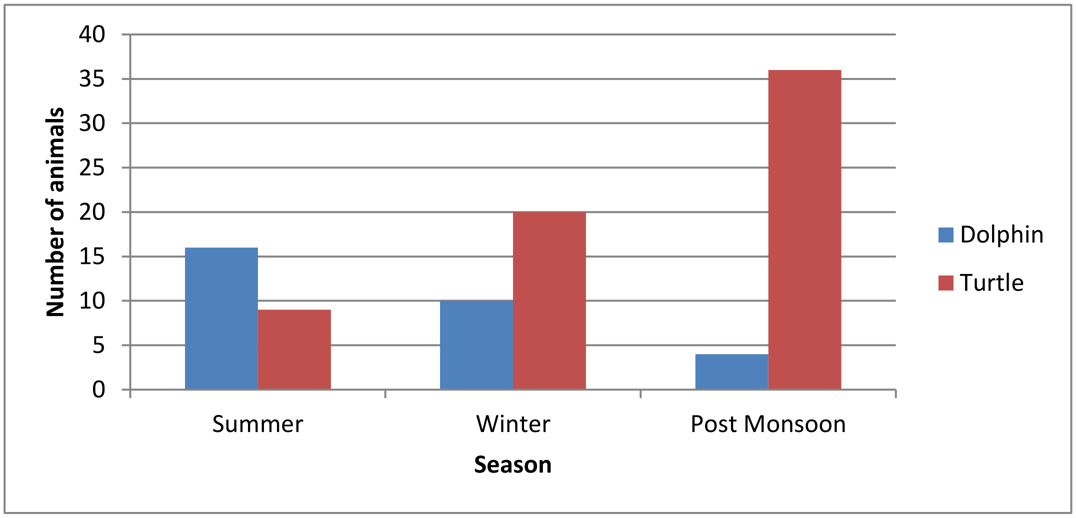


Figure 5. Seasonal variations in ETP catches in gillnet operations.

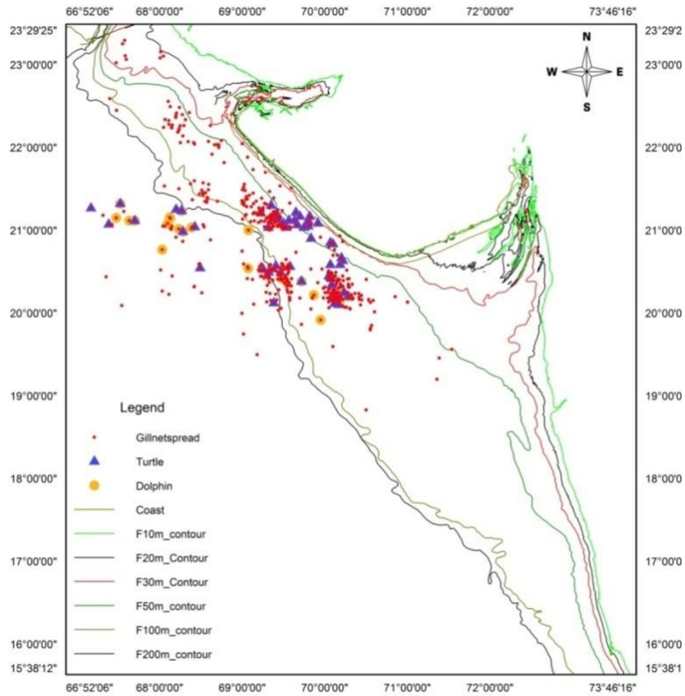


Figure 6. Spatial points of incidence of ETP species in gillnet fishing off Gujarat

**Relationship of tuna catches with non-tuna and ETP species**

Correlation studies of the catch rates revealed that the oceanic tuna catches had a positive relationship with neritic tuna and non-tuna species and negative correlation with leatherjackets and ETPs. The correlation was significant only with the neritic tuna species ($p < 0.01$) (Table 2). Neritic tuna was positively correlated with the non-tuna species and negatively correlated with leatherjackets and ETPs. However, the correlations were not significant ($p$ >0.05). The catch of leatherjackets exhibited a significant positive correlation with non-tuna species ($p$ value<0.000) (Fig 7). The non-tuna catch had positive correlation with oceanic tuna, neritic tuna and the leatherjackets and had negative correlation with the ETPs. The ETPs had negative correlation with all the other categories and in no case, the correlation was significant.

Table 2 Correlation matrix of different catch groups

| | Oceanic tuna catch | Neritic tuna catch | Leatherjacket catch | Non Tuna catch |
|---|---|---|---|---|
| Neritic tuna catch (r) | **0.13*** | | | |
| *p value* | **0.002** | | | |
| Leatherjacket catch (r) | -0.056 | -0.041 | | |
| *p value* | 0.189 | 0.332 | | |
| Non Tuna catch (r) | 0.022 | 0.066 | **0.426**** | |
| *p value* | 0.610 | 0.121 | **0.000** | |
| ETP Species catch (r) | -0.041 | -0.016 | -0.021 | -0.081 |

| | | | | |
|---|---|---|---|---|
| *p value* | 0.342 | 0.703 | 0.628 | 0.057 |

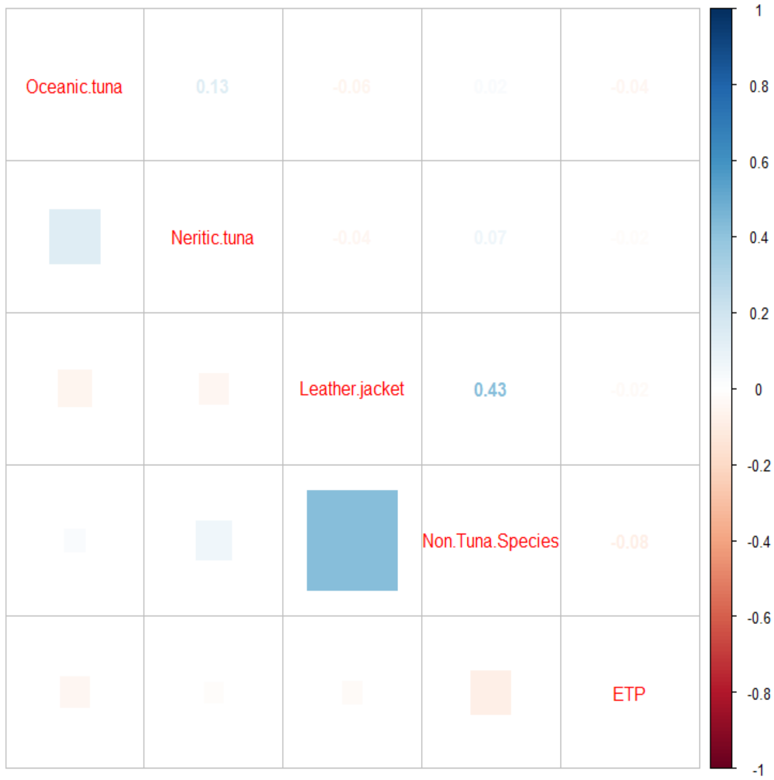


Figure 7. Correlation analysis of catches of different groups in gillnets. Colour coding is provided alongside. (The colour intensity and size of the box represents the strength of the correlation)

## Principal Component Analysis

The first three principal components in the PCA analysis together explained 72% of the total variations with 28.8%, 23.1% and 19.6% of variance respectively. PC1 accounted for 28.8% of the total variance with high positive loading for oceanic tunas and ETP species; higher negative loadings for leatherjackets and other non-tuna species and lower negative loadings for neritic tuna species. The oceanic and neritic tuna species showed negative loading in the case of PC 2 with 23.1% of the total variance. (Table3; Fig. 8).

Table 3: Eigen analysis of the Correlation Matrix

| Variable | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| Oceanic | **0.021** | **-0.682** | -0.046 | 0.726 | -0.069 |
| Neritic | -0.038 | **-0.657** | **-0.348** | -0.652 | -0.142 |
| Leather | **-0.689** | **0.158** | -0.119 | 0.095 | -0.690 |
| Non Tuna | **-0.703** | -0.076 | -0.086 | 0.011 | 0.701 |
| ETP | **0.167** | **0.267** | **-0.925** | 0.196 | 0.081 |

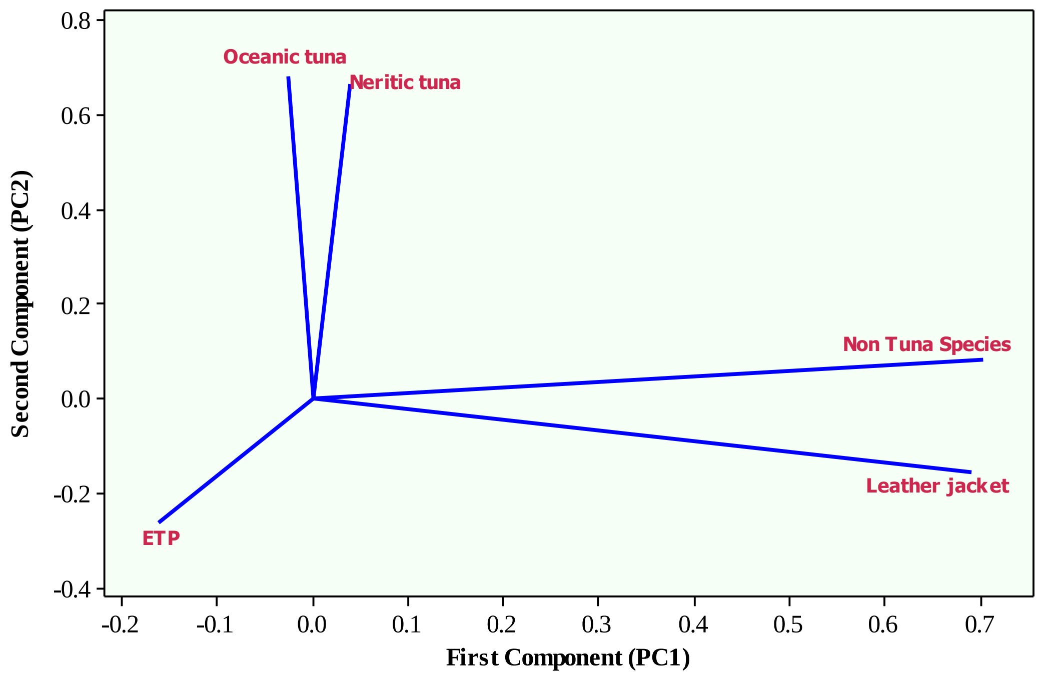


Figure 8. Results of the PCA Analysis

## Variations in catch rates of different groups across seasons and depth zones

The catch quantity (Fig. 9) and composition (Fig. 10) varied considerably over the seasons with the catch being higher during post monsoon and winter months. Number of fishing operations in each season also varied greatly with majority of operations being made during post monsoon and winter months. The summer months had the lower number of fishing operations. Catch and catch rate of different categories of non-tuna species also varied at different depth zones. Number of fishing operations in each depth zone varied greatly with very low (n=10) number of operations at 0-30m and 201-300m depth zones. The number of fishing operations were highest in 51-100 m depth zone (n=357) followed by >300m (n=83), 101-200m (n=60) and 31-50m (n=31).

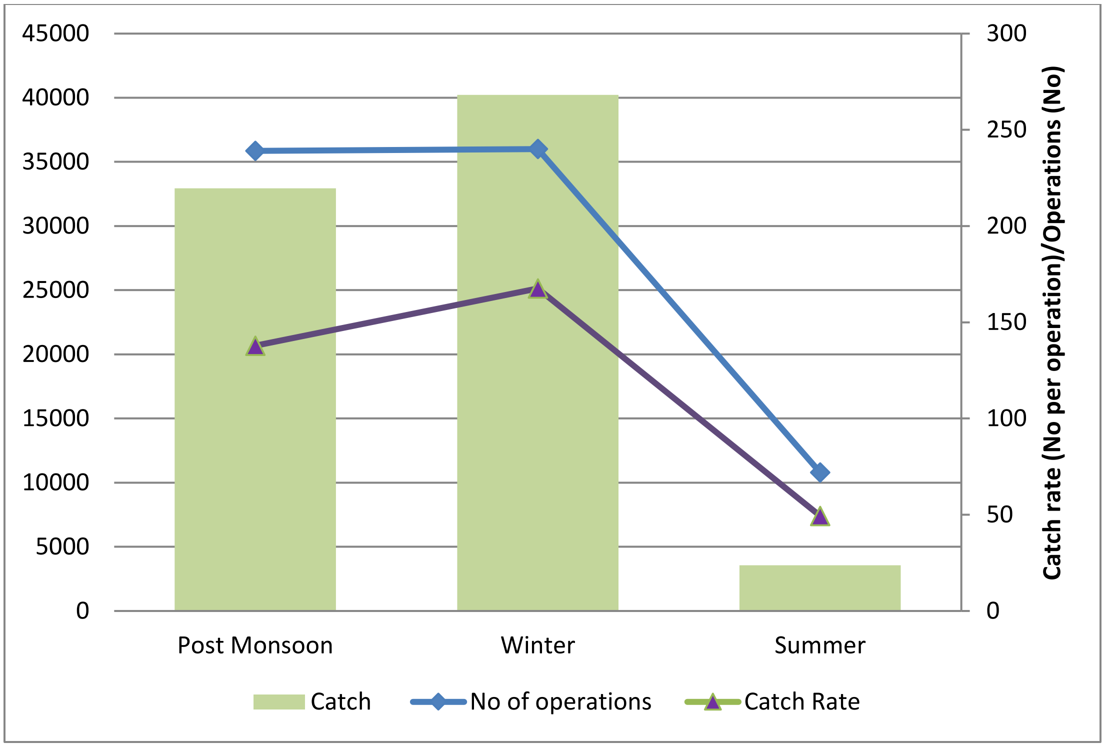


Figure 9. Season-wise trends in average catch and effort of the gillnet fisheries (average of 2011-16)

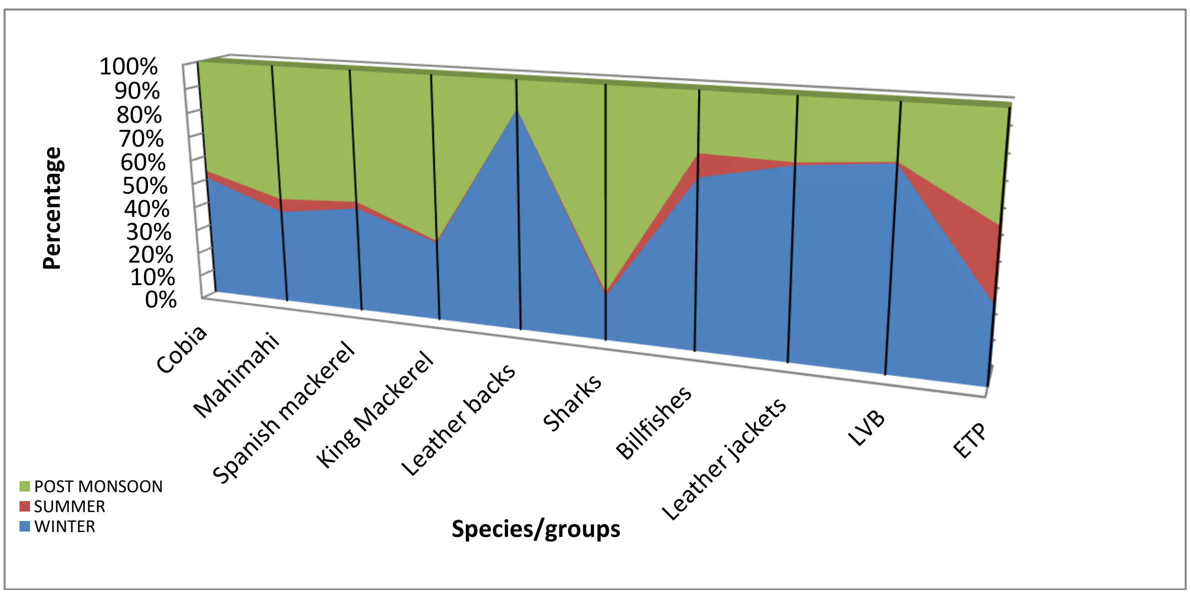


Figure 10. Seasonal variations in the species composition of large-mesh gillnet catches (average of 2011-16)

**Unicorn Leatherjackets:**

The leatherjacket catches depicted a very clear statistically significant seasonal pattern ($p < 0.01$). Winter season ranked the highest (295) above the average (276) indicating the catch rate is much high during these months followed by post monsoon season (Fig. 11). The catches of leatherjackets in gillnets were not influenced significantly ($p > 0.10$) by the depth of the fishing area. However, this fish did not occur at depths below 30m and rarely occurred at depths below 50m and above 300m. The depths 51-100, 101-200 and 201-300 ranked higher than the average indicating the catch rates were higher at these depths with the highest catch rate obtained at depths 201-300m. Dot plot indicated that the most preferred depth zone of the leatherjacket was 51-100m followed by 101-200m (Fig. 11). Incidence of leatherjackets at deeper areas (>100m) is seen more during the winter months. The GIS map (Fig.12) indicated that the shelf area south of Saurashtra coast between 50 and 100m depth contour has been the most productive ground for the leatherjackets with another minor congregation off Porbandar.

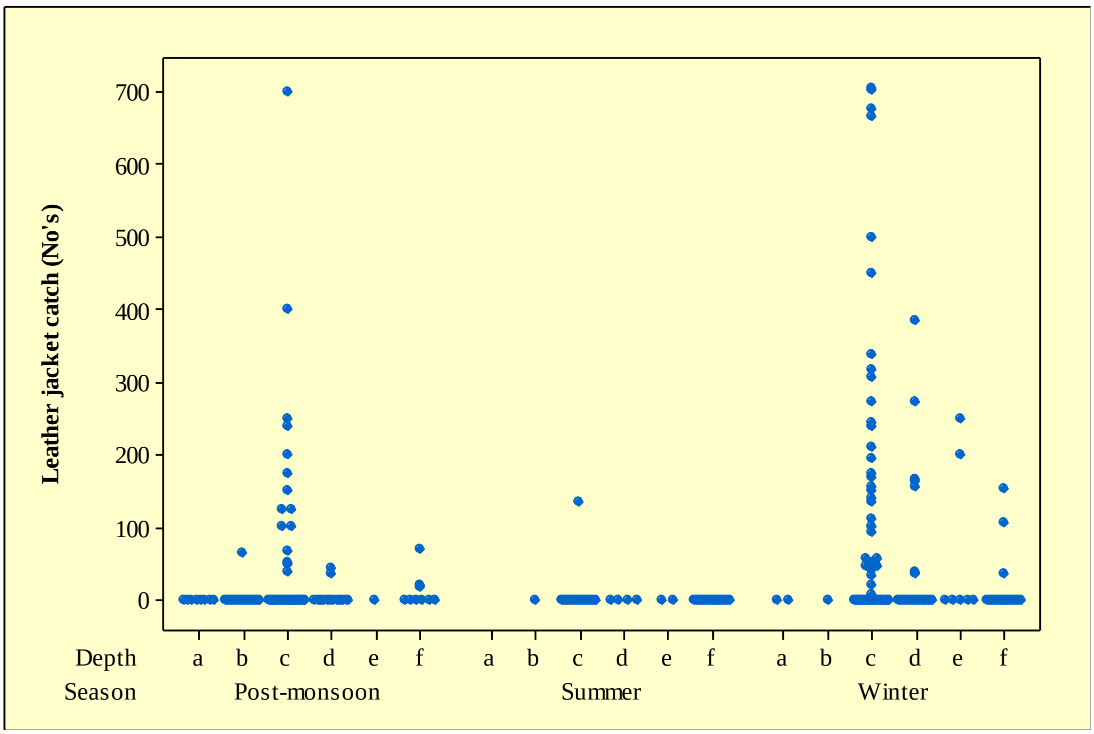


Figure 11. Dot plot of leatherjacket catches in gillnet across the seasons and depths (a=, 30m, b=31-50m, c=51-100m, d=101-200m, e=201-300m and f=>300m)

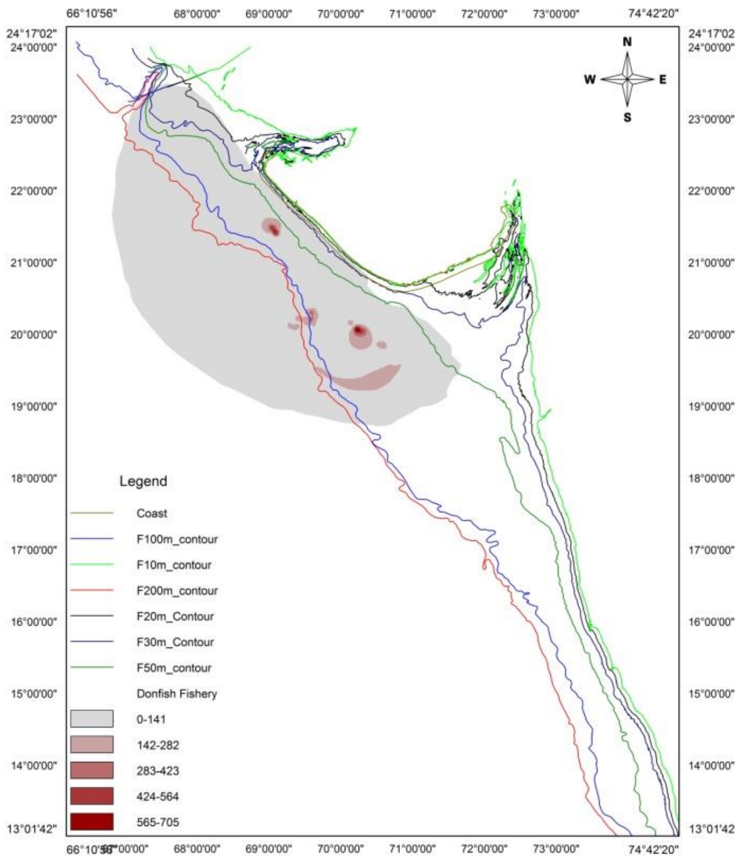


Figure 12. Areas of abundance of unicorn leatherjacket filefish off Gujarat coast

**Other non-tuna species:**

Incidence of non-tuna species in the large-mesh gillnet fishery had clear seasonal pattern (*P* value = 0.000 with the catch rate being highest during post monsoon followed by winter and the summer remained distinctly lower than the average. Most of the non-tuna resources like the Cobia, Mahimahi, Spanish mackerel and King mackerel had almost similar seasonality (Fig. 10) while the leatherbacks and billfishes were caught more during winter; the sharks were caught more during post-monsoon months. Occurrence of non-tuna species in gillnets was significantly ($p < 0.01$) influenced by the depth. Ranks in respect of depths; 31-50 (322), 51-100 (291) and 201-300 (286) were above the overall average (276) while depths <30m, 101-200 and >300m were lesser than the average. Non-tuna fishes occurred more at depths of 31-50 m and 51-100 m (Fig. 13). The dot plot indicated that higher catch rates of non-tuna species occurred during winter months; similarly the incidence of this group in the oceanic areas (>300m).

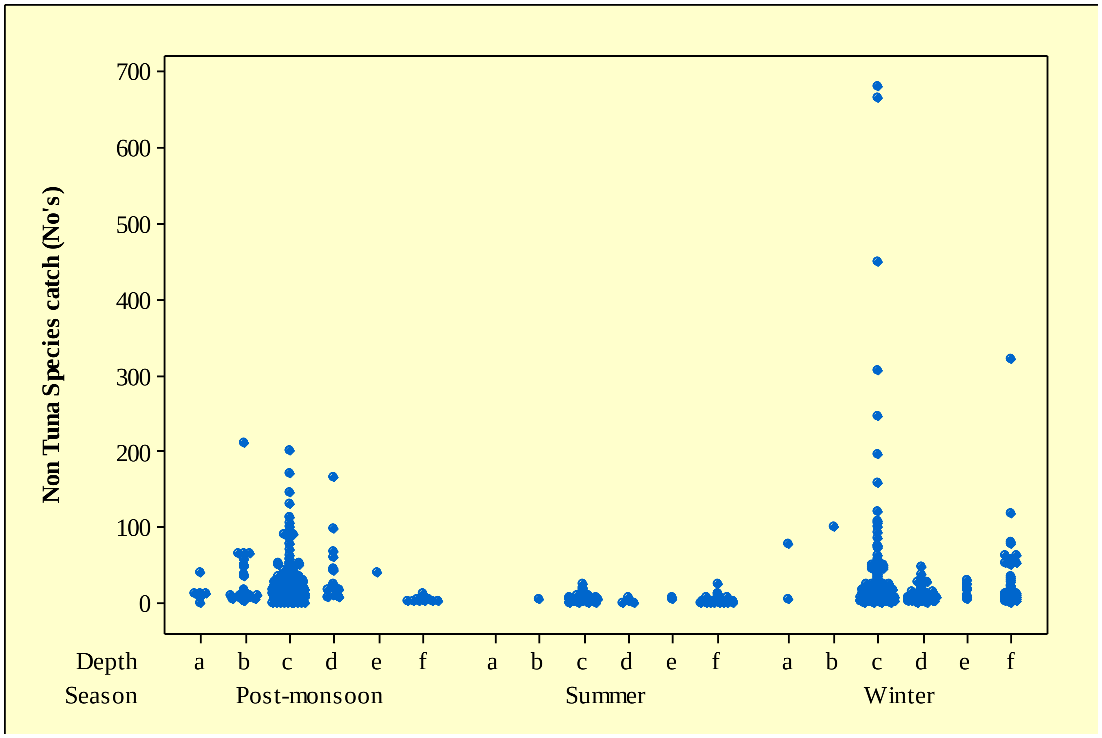


Figure 2.Dot plot of non-tuna species catches in gillnet across the seasons and depths (a=, 30m, b=31-50m, c=51-100m, d=101-200m, e=201-300m and f=>300m)

### Endangered, Threatened and Protected Species

Incidence of ETP species in the gillnet operations varied from 0 to 3 numbers per operation. There was significant ($p < 0.05$) variations in incidence of ETPs in gillnet operations over the seasons observed, with higher values and rate of incidence during summer months was much above the average (Fig.14). Turtle incidence was more in post-monsoon months while the dolphins occurred more during summer months (Fig.5). Depth had significant ($p < 0.05$) influence on the occurrence of ETP species in gillnet. Depths of 31-50m, 201-300m, >300m had values higher than the average (Fig. 14). Dot plot indicated higher number of ETPs (three numbers) in operations during winter and summer months, especially at oceanic areas (>200m).

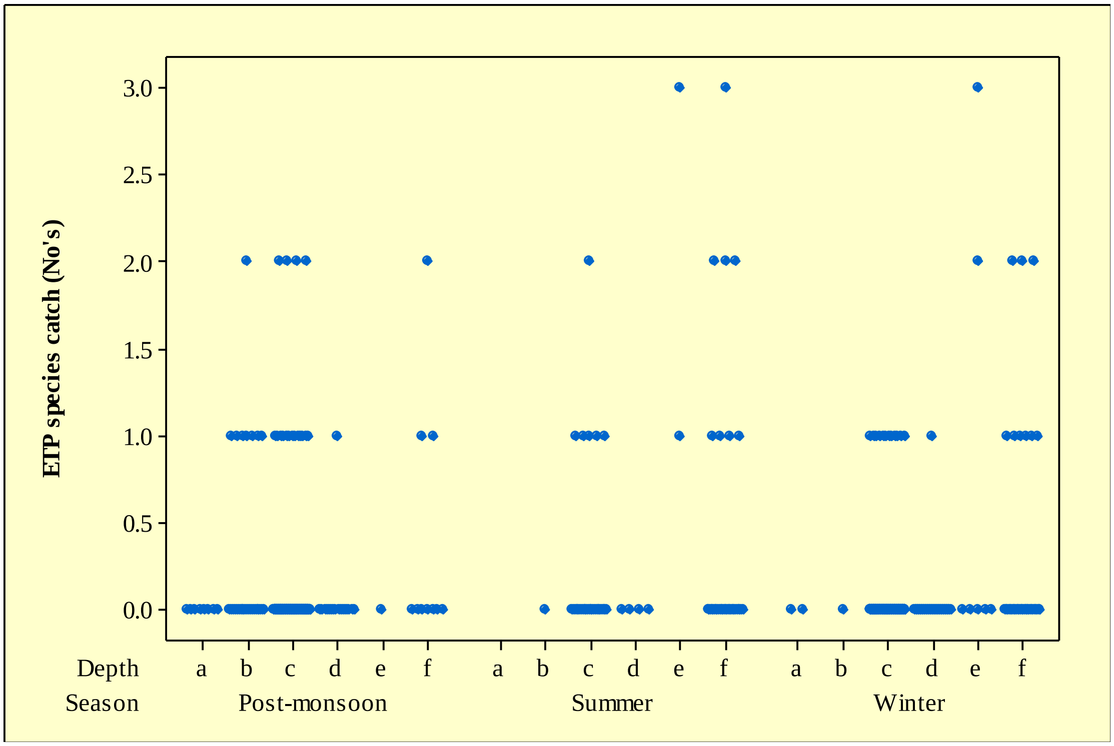


Figure 3.Dot plot of ETP species catches in gillnet across the seasons and depths (a=, 30m, b=31-50m, c=51-100m, d=101-200m, e=201-300m and f=>300m)

## Discussion

The study indicates that the principal catch of the large-mesh gillnet fishery in this region are the tunas, especially the neritic tunas. Dominance of neritic tunas, especially the longtail tuna in the gillnet fisheries along the north-west coast of India have been established by many authors (Abdussamad *et al*. 2012 and Ghosh *et al.*, 2010). Moazzam *et al*. (2012) also reported a similar (60% tunas and 40% other resources) composition of catch in the gillnet fishery in Pakistan waters. Co-occurrence of different non-tuna species and protected species like turtles and dolphins with tunas in the north-eastern Arabian Sea off the north-west coast of India is being reported for the first time. Gillnet, though a passive gear, confronts the issues of non-target fishes, accidental catches of turtles, cetaceans and birds in every region (Gillet, 2011). The catch composition of a fishing gear varies depending on the area or the habitat where it is operated and the season of operation. Large percentage of the effort expended by gillnet fishery was on the shelf areas and hence the composition is skewed towards neritic species. 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.

Mahimahi, Indo-pacific king mackerel, Narrow-barred spanish mackerel and Cobia were the major non-tuna species, besides shark, billfishes and leatherbacks in the gillnet catch. Most of these large pelagic resources have been categorised as apex predators (Vivekandan *et al.*, 2009) and their diets overlap (Yunkai *et al*., 2016) which could be the reason for their co-occurrence. Moazzam *et al*. (2012) observed talang queen fish and narrow barred Spanish mackerel to be dominant bony fishes in the neritic waters of Pakistan while sailfishes and marlins dominated in oceanic areas. Stock of the Mahimahi, the major non-tuna fish caught, though not assessed in the Indian Ocean (Rubio and Restrepo, 2015), is in good state along the southwest coast of India (Benjamin and Kurup, 2012) and the species is highly resilient (Froese and Pauly, 2018). Stock of narrow-barred Spanish mackerel is overfished and subject to overfishing while the state of Indo-pacific king mackerel are not known and a precautionary management measure is deemed needed (IOTC, 2018). Stocks of Indo-pacific sailfish and blue marlin, the major billfish species caught in the region are not overfished and subject to overfishing while the black marlin is overfished and subject to overfishing as per the latest assessment (IOTC, 2018), however, the catch is much low in the gillnet fishery off Gujarat as the fishing is limited to the neritic areas.

There was notably low incidence of sharks (1.5% of total non-tuna catches) in the gillnet catch in the area studied contrary to the findings of Moazzam *et al*., 2012 from Pakistan waters (23% of the bycatch) and Shaifar (2012) from Iranian gillnet fisheries (18% of the bycatch). There are limited reports on the species composition of sharks in the gillnet fisheries off Gujarat in recent years though sharks like *Scoliodon laticaudus*, *Rhizoprionodon acutus*, *Carcharhinus limbatus*, *Carcharhinus amblyrhincoides*, *Carcharhinus maclotii*, *Carcharhinus dussumierii*, *Carcharhinus longimanus*, *Sphyrna lewinii*, *Alopias pelagicus*, *Isurus oxyrhinchus* and *Galeocerdo cuvier etc*. occur in stray numbers in large mesh gillnets (Per. Communication Swatipriyanka Sen, 2018). In the neighbouring Pakistan waters, thresher shark (*A. superciliosus*) and silky shark (*C. falsiformis*) in the neritic areas and threshers *(A. superciliosus*) and mako (*I.oxyrinchus*) in the oceanic areas were the major shark species caught in gillnets (Moazzam *et al*., 2012). Dominance of sharks and rays over other groups in gillnet fisheries in late 70's and 80's as reported by Kasim and Khan (1986) and Said Koya and Vivekanandan, (1992) were due to targeted fishing for demersal resources like sharks, croakers, threadfins, pomfrets, *etc*. using large mesh bottom set gillnets (180-215mm) in those days. Evolution of gillnet fisheries from demersal to a more resilient pelagic realm is visible from the increase in mesh size of surface drift gillnet from 85mm in 1979-80 (Kasim and Khan, 1986) to 140mm in later years (Polara *et al*., 2014); and the expansion of fishing areas to beyond 50m depth zones; resulting in increased landing of large pelagics like tuna.

Unicorn leatherjacket, *Aluterus monoceros* occurred in considerably large quantities especially during the winter months. The fish started occurring in gillnets in commercial scale since 2008 prior to which it formed catch in stray numbers (Ghosh *et al*., 2011). Results of the present study ratify the fishermen's perception that large scale occurrence of unicorn leatherjacket in gillnet indicates poorer abundance of longtail tuna. However, exclusivity of this resource with other fishes needs to be studied more closely for different interactions of the species, especially the ecological interactions. Emergence of this fishery need to be looked from market point of view too as the species has earned a good export market recently, indicating possibility of targeted exploitation of this resource. Though the species is reef associated and known to occur at depths up to 80m (Froese and Pauly, 2018), 120m (Dianne, 2018) and 150m (Robertson and Tassell, 2015), the capture of this species by gillnets in oceanic areas could have been resultant to fishing near the debris as this species is reported to associate with flotsam (Robertson and Tassell, 2015; Dianne, 2018). Higher catch rates of the species in oceanic areas also indicate fishing nearer to aggregations.

Interaction with fishing gear is considered one of the most serious threats to sea turtles (FAO 2010 and Wallace *et al*., 2011). Turtles have been reported to occur in gillnet fisheries targeting tunas in most of the regions. Iran and Pakistan, two important tuna fishing nations in the northern Arabian Sea have also reported turtle interactions (Shaifar, 2012 and Muazzam and Nawaz, 2014). Number of turtle entanglement reported (10%) in the study is much lower compared to the reports from neighbouring Pakistan waters, where 1-2 green turtles and 3-8 Olive ridleys were reported to be encountered in every fishing trip (Moazzam and Nawaz, 2014). Gillnet fishing fleet of Pakistan is larger (10-30m OAL) as compared to the Indian fleet and undertake voyage up to 90 days and fish in grounds as far as 400 miles from the base station (Moazzam, 2012). On the other hand, the gillnet fishing fleet of Gujarat comprises of boats of size upto 16m LOA (Polara *et al*., 2014) and operate mainly on the shelves extended up to nearly 300 nm with a voyage duration lasting for 7 days. Further, the size of the net used in India is around 4000 to 5000 m (gillnet length of 2500 m as reported by Polara *et al*., 2014 may be an underestimate) whereas the size of the gillnets used in Pakistani fleet extends up to 11,000m (Moazzam and Nawaz, 2014). Low incidence of turtles in gillnets of Gujarat can therefore be attributed to the smaller scale of fishing. Gujarat coast is known for nesting of turtles with the Green turtle (*Chelonia mydas*) (68%) dominating the reported nesting observations. Beaches in Kutch, Jamnagar, Porbander and Junagadh (erstwhile) districts is the preferred places in the state (Sunderraj *et al*., 2013), which partly explains the congregation of the turtle incidence points to the coastal areas of central Saurashtra.

Gillnet has been reported to be the primary gear responsible for cetacean mortality worldwide (MRAG, 2012; Anderson, 2014). Dolphins often get enmeshed in gillnets while predating on entangled fish (Romanov *et al.*, 2014). Anderson (2014) has reported on the common cetaceans occurring in the Indian Ocean while Moazzam (2013) has reported mortalities of several species of cetaceans. Kumaran (2012) and Anderson (2014) cited the large mesh gillnetting as potential threat to small cetaceans. Yousuf *et al.* (2009) estimated the dolphin bycatch along the coasts of India to be to the tune of 9000 to 10000 numbers per year. However, the dolphin bycatch in the gillnet fisheries in the present study is much lower compared to the available reports globally. The study reveals that a dolphin occurred in the gillnet catch once in nearly 25 operations against mortality of 1-4 dolphins in each fishing operation reported from Pakistan waters (Moazzam, 2013). Lower frequencies of occurrence of dolphins in the major fishing grounds for gillnet fisheries (*i.e*. the areas between 50 to 100m depth contours), lower number of fishing operations in summer months when the dolphin incidence are more in the region and smaller scale of operation as explained in the previous paragraph may be the reasons for considerably lower incidence of dolphins in the fisheries off Gujarat.

The fishermen in the present study reported that the turtles when entangled were live in most cases similar to the report by Shahid (2015) and were cleared from the net and released back to the sea immediately while dolphins enmeshed in the net were very weak or died when hauled up. Though fishermen report that most of the turtles released were live and made their way in to the water, the actual survival rate is uncertain as they are not monitored for long. Gear modifications or use of alternative materials, depth of net setting, limiting the maximum size of the mesh *etc.* are few ways of mitigating the turtle bycatch (FAO, 2009). Gilman *et al*. (2009) and Gillet (2011) also suggested many measures to mitigate turtle and mammal bycatch in gillnet including incentives for fishermen and industry participation in conservation, eco-labelling programmes, industry self-policing *etc*.

Major limitation of the study is the lack of onboard observation for verification of fishermen's report as well as limited coverage of fishing boats. However, the study demonstrates potential role of fishermen in resources management research, paving way for their proactive involvement in resources management and conservation. Awareness need to be generated among the fishermen in not only conservation of ecologically important resources and compliance of prescribed management measures but also in willingly participating in vessel based data generation enabling regular monitoring of the catches and bycatch. The study can be replicated at national scale to develop better understanding of the intricacies of gillnet fisheries for bringing in management interventions to sustain the fishery. Integration of electronic self-reporting by the fishermen coupled with video recording or on-board observers would enable us to have quality information and monitor the fishery at near real-time.

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