CHAPTER 15

# Integration of Spatial Attributes in Fishery Biological Studies: The Paradigm and a Case Study of Large Pelagic Fishery In the NW Coast

**MOHAMMED KOYA K.**
**Pelagic Fisheries Division**
ICAR-Central Marine Fisheries Research Institute

***Need for spatial data in fisheries research and resources management***

Wide spatial distribution and temporal variations in abundance are unique features of fishery resources (Vivekanandan, 2005). The spatial variability of the stock reflects the pattern in fishing effort, thereby the fishing mortality owing to the target stock being aggregated or due to management restrictions, distance to port, vessel size, and the experience and habits of individual fishers (Yong, 2014). Ignoring this spatial variation can lead to serious biases in estimates of fishing mortality and yield (Hart 2001). Indexes related to catch rates or abundances are used often in the stock assessments or are the indexes for monitoring fish stocks despite the fact that the non-random spatial distribution of fish and fishing effort makes the interpretation of commercial catch rate (CPUE) difficult (NRC 1999). Such targeted deployment of fishing effort results in constant or increasing CPUE even though the stock size is decreasing till a point where the stock is at very low levels. A number of fish stock shave collapsed due to such misinterpretation of CPUE, the prominent being the case of northern cod (Hilborn and Walters 1992). These clearly points to the fact that understanding the spatial dynamics of a fishery is an important issue in fisheries management. The management that does not consider the spatial dynamics of a fishery may be less successful in optimising harvest and building an understanding of the interactions between the fishery and other environmental variables (NRC 1999, Hart 2001).

Many of the fisheries management tools generally have spatial component either explicitly through time and area closures, or implicitly through allocation of quota to regions or to fleet sectors with different distributions. Spatial management tools have also been used to protect spawning aggregations, to reduce bycatch, or to meet other single-species objectives. Paradoxically, often, the indexes used for arriving at the management practices as well as for monitoring the management tools are derived from the traditional non-spatial population dynamics models (Pauly et al., 2003). Spatial management measures such marine protected areas (MPA) protect critical habitats from destructive fishing practices, provide insurance against unforeseen ecosystem impacts of fishing, and protected critical life stages of harvested species. Hence, indicators used for evaluation and monitoring of spatial management tools need essentially be spatial

Ecosystem-based fisheries management (EBFM) aims to sustain healthy marine ecosystems and the fisheries they support. It has been developed to move beyond single species management by incorporating ecosystem considerations for the sustainable utilization of marine resources. Ecosystems are spatially heterogeneous and spatial patterns and processes are important to ecosystem structure and function though the distribution of fishing activities depends on distribution of the targeted resource (which in turn depends on oceanographic habitat and interspecific interactions) as well as economic considerations. The species-habitat associations play an important role in ecosystem management, whereas these associations rarely connect with the stock assessment efforts mainly due to lack of spatial information needed to relate habitats to fisheries surveys and fishing effort.

Spatial aspects of fisheries will have very high priority in the alternatives postulated to the present regime of fisheries science and management (Martin, 2004). Use of Geographical Information System (GIS) in decision-making and policy development is growing in many fields and it has a great potential to contribute to the 'spatial turn' in marine fisheries science and management. Two major foundations of the paradigm are acquisition of data (spatially explicit) and scientific analysis. A paradigm shift towards GIS based marine fisheries decision-making warrants radical change in approach of the scientific and management institutions.

Marine Spatial Planning (MSP), a process developed from the bottom up to improve collaboration among all coastal and ocean interests, and to better inform and guide decision-making that affects their economic, environmental, security, and social and cultural interests. Fisheries are not usually fully integrated in the MSP and the often-cited argument for the non or partial integration is that the data on spatial demands of fish and fisheries cannot yet be provided in a spatial and temporal quality adequate for MSP purposes. However, research on integration of fisheries into MSP has gained momentum recently (Janssen *et al*., 2018). The Great Barrier Reef Marine Park zoning, which gives spatial designation for fisheries and other human uses,is a good example for integration of fisheries in the MSP.

***The Practice and the Way forward***

Fishery dependent data is the major source of information used for deriving the management measures globally though fishery independent, survey based assessments are also used by few developed countries. Spatially explicit effort data for fisheries remain comparatively sparse and are often concentrated around the industrial fleet, relying on electronic logbook-ID-type tracking systems such as VMS (Vessel Monitoring System) and AIS (Automatic Identification System). Such information is scanty from the artisanal and small scale fisheries. The artisanal or small scale nature of the fishery and lack of documentation and self-reporting by the fishers is the major hurdle in recording the spatial data of fisheries in developing countries like India.

The only spatial measure used for management of marine space in India is the MPA, designated for conservation of sensitive organisms or habitat. Lack of spatially-explicit information on the fisheries is the major lacunae in using spatial measures in fisheries management. The National Marine Fisheries Policy-2017 calls for several management interventions for sustaining the fishery like species-specific and area-specific management plans comprising of spatial and temporal measures.The Policy has noted the significance of Marine Spatial Planning (MSP) in view of the competing demands for ocean space.The CMFRI have initiated research projects for gathering spatial data on commercial fisherieson participatory mode and so far spatial information on fisheries of Karnataka, Gujarat, Andhra Pradesh etc. have been documented. The advancements in the satellite technologies for communication and tracking can aid monitoring of vessels for fishing areas, pattern and tracks. Integrating this with the vessel based log-books; on-board as well as port-observers together with the use of electronic devices for real-time reporting can pave way for development of spatially explicit information base on the commercial fisheries of India.

***Spatially referred Data Acquisition: Indian context***

In a fishery dependent study, spatially referred catch data can be collected only with the active and voluntary participation of the fishermen. Identifying a respondent fisherman is a tricky job needing good acquaintances of the fishing harbour or landing center and players and the processes therein and rapport building. When in the harbour, the fishermen generally will be busy carrying out the unloading of catches and trading amidst planning for the next voyage and they generally will be reluctant to respond to queries. Hence, timing the meeting with the fishermen is crucial for successful negotiations. Skipper (Tindel) of the vessel is the ideal person for engaging in data recording as he oversees the shooting and hauling processes while managing the vessel from the wheel house. Identify and negotiate with the skipper of the fishing vessels, installed with GPS on board. Most of the multiday vessels and some single day vessels carry GPS on board nowadays.

The data collection schedule should be simpler and prepared in vernacular language for convenience of fishermen. Schedule should essentially have fields for noting the coordinates (latitude and longitude) of shooting / setting and hauling and date /time of shooting/hauling, depth of the area etc. A list of expected species (local names) be provided with fields against each for noting the quantity (nos or Kg) caught. Additional blank fields may be provided for noting the details of fishes if any beyond the list and for other special observations. Fields for noting the general weather, sea condition (visibility, current (strength and direction)) etc if provided can fetch additional information though it will be comparative and qualitative. Individual schedules sufficient for the voyage period clipped to a file may be provided in the beginning of each voyage. The filled in schedules should be collected back on their arrival at port preferably prior to unloading the catch and have a quick glance for the species and quantity recorded. This would facilitate observation of the species composition and quantity landed by the vessel helping in validation of the data reported by the skipper.

***Data Entry, Validation and Analysis***

The data collected may be entered in to a database date wise/operation wise. The database should have provision for entering all the information (qualitative and quantitative) noted by the fisherman. Relative accuracy of the fishing points may be ascertained by plotting the fishing points in any GIS software or Google Earth. Outlier fishing points if any can be identified by this process for elimination or correction. Outliers occurred due to faulty GPS position reading or recording can be rectified in consultation with the fisherman or eliminated. There are several GIS software that can be used for detailed analysis and presentation of the results. Q GIS, Arc GIS, Geomedia etc are few popular GIS software used in marine applications.

***Case Study: Spatial features of Large-mesh gillnet fisheries off Gujarat- Important fishing grounds, sensitive areas and interaction of non-tuna and ETP species with the tunas.***

**The Setting**

Large-mesh gillnet based fishery for the large pelagic is a major fishery along the coasts of Saurashtra in Gujarat next only to the trawl and Dolnet fishery. They carry out multiday fishing generally for 3-7 days in a voyage and use gillnets made of multifilament nylon (poly amide) 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. A participatory study was conducted to understand the spatial features of the gillnet fisheries in collaboration with three fishing boats and spatially explicit fisheries data were collected during 2011-16. The study revealed many features of the gillnet fisheries in Gujarat. The succeeding paragraphs brief describe the approach, methodology and few results of the participatory study.

**Data Acquisition and Analaysis**

Customized log sheets in Gujarati were provided to three selected large-mesh gillnetters at Veraval fishing harbour where a large fleet of large-mesh gillnetters operate. The log sheets had fields for noting date and time of operations, GPS position of shooting and hauling the net, details of catch (approximate weight) including species composition, *etc*. 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.

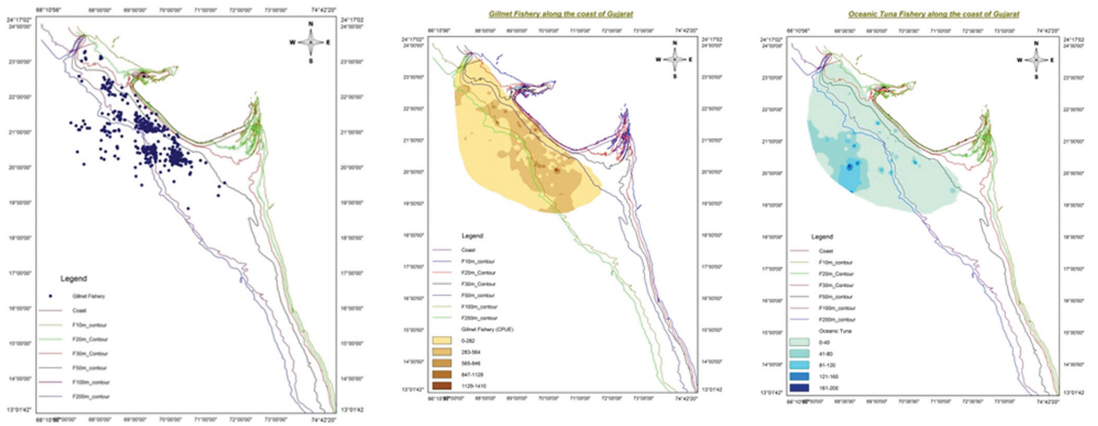
The information provided by fishers were digitized on an MS excel 1997-2003 format compatible to GeoMedia Professional 2014 GIS platform date-wise. Accuracy of the fishing positions were checked by overlaying the points in Google Earth as the position and the track of fishing in the voyage revealed relative accuracy of the data. Catch composition were verified by port observation. The fishermen were consulted at regular intervals using the graphical outputs of preliminary analysis during which the catch information and fishing points were ratified and outliers if any were removed. Species composition and seasonal variations were analysed using MS Excel as well as one way ANOVA. Statistical techniques like Tukey's*post hoc* analysis, Pearson's correlation analysis, hierarchial cluster analysis etc. were used for understanding the variations and relationship among catches. GeoMedia Professional 2014 and its extensions were used to create a georeferenced map for the abundance and distribution of different groups/species etc.

**Results**

The major target resource of the fishery is the tunas, especially the neritic tuna species-the longtail tuna (*Thunnus tonggol*) and Kawakawa (*Euthynnus affinis*). Quantum and species composition of the catch varied with the area of operation and the season. Seer fishes, queen fishes, mahimahi, cobia etc also formed considerable catches in the neritic areas while the resources like oceanic tunas and billfishes constitute catch in the fishing operations near or beyond the continental break. Incidence of oceanic resources in the fishery is relatively higher during the winter months. Unicorn leather jacket (*Alluterus monoceros*), a neritic, reef associated resource formed considerable catches in the peak winter months. Trigger fishes, wolf herrings, moonfishes, remoras etc formed the low value bycatches besides occasional incidences of endangered species like the turtles and dolphins. The spatially referred catch data obtained by the study revealed the intricacies of the variation in catch composition of gillnet fisheries over time and space, bycatch and discards in the gillnet fisheries, spatial and temporal patterns of the fishery and gave an idea on the movement of the target and bycatch species in the fishing grounds.

## Spatial features of the large mesh gillnet fisheries

The study revealed that the operational area of gillnetters of Gujarat is limited to the continental shelf along Gujarat and the adjacent oceanic region between 18°N and 23°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°N and 22°N latitudes at 50-100m depth zone and only 17% was expended in the oceanic areas *i.e*. beyond the continental shelf break at around 200m depth contour. Fishing in the oceanic areas were mainly during late winter (February) and summer months (March-May). The Fig. 2 provides the species composition and the seasonality of the catches.




Gillnet fishing points | Coastal tuna grounds | Oceanit tuna grounds

Fig. 1. Spread of fishing points of the observed gillnetters and major grounds for coastal and oceanic tunas

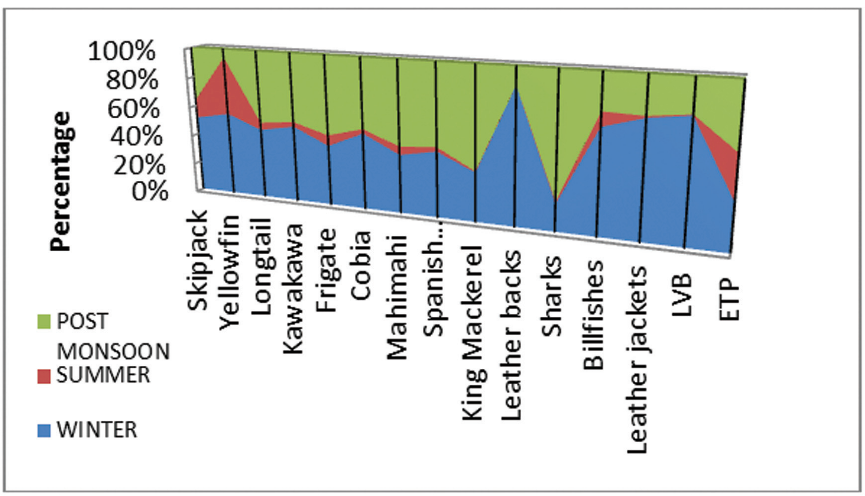



Fig. 2. Species composition in gillnet fisheries and its temporal variations

**Interaction of Tunas with the non-target species**

The catch covered 16 taxa comprising of tunas (64.62%) and non-tuna species (35.26%) (billfishes, seer fishes, cobia, mahimahi, queen fishes and leatherjacket and low value bycatch (LVB) comprising of less valued fishes such as clupeoids (wolf herrings, shads, etc), needlefishes, flying fishes, triggerfishes, remoras, moonfish, eels, etc.) and ETPs (0.12%) comprising of turtles and dolphins. Neritic tuna formed nearly 92% of the total tuna catch. Three distinct clusters; (1) oceanic tuna and neritic tunas, (2) leatherjackets and other non-tuna species; and (3) ETP were visible. The ETP species exhibited a weak (49.18%) similarity with all other resources (Fig.3). Tuna (neritic and oceanic) and non-tuna catch (leatherjacket and other non-tuna species) showed 53.31% of similarity. The similarity percentage between the tuna groups observed was 56.52%, depicting a distinct difference in the neritic and oceanic tuna catches. The leatherjacket and other non-tuna species were having maximum (71.29%) similarity.

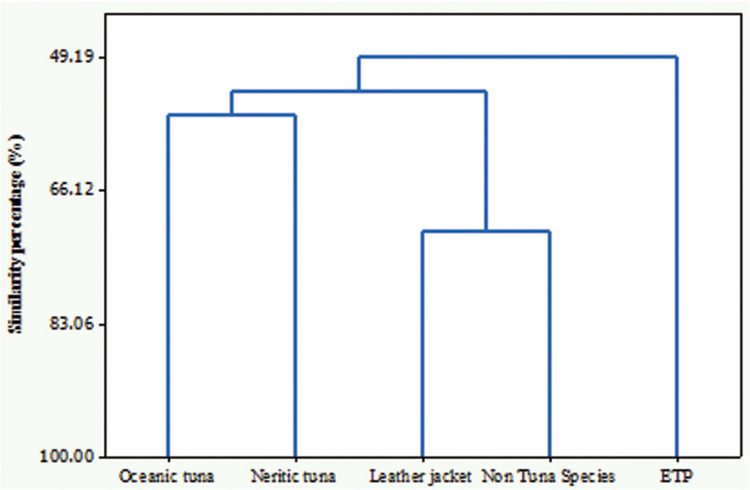



Fig. 3. Results of cluster analysis

Near exclusivity in abundance of unicorn leatherjackets, especially in winter months was observed with the catch of the species forming over 70% of the total in operations were the species dominated the catch (with the remaining being the LVB). Abundance zones of the species indicate clear seasonal pattern with winter being ranked the highest in the Kruskal-Wallis test followed by post monsoon. There was a depth preference by the species with the fish occurring only beyond 30m depth zones and being dominant at the depth zones 51-100m (Fig. 4). There was one major zone of abundance at the depth between 51-100m off south Saurashtra and a minor zone of congregation off Porbander (Fig.5). This uniqueness in abundance patter of the species provoke to study the ecological and oceanographic forcing guiding it and the study is underway to unravel the mystery considering the niche it occupy.

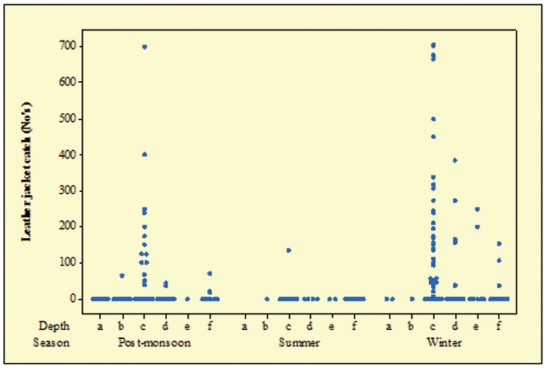



Fig. 4. Dot plot of leatherjacket catches in gillnet across the seasons and depths (a=, 30m, b=31-50m, c=51-100m, d=101-200m, e=201-300m and f=>300m)

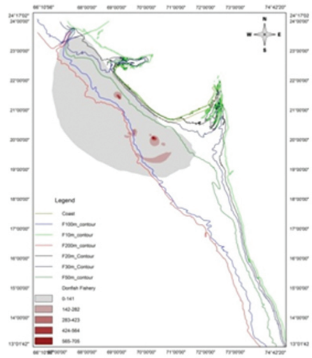


Fig. 5. GIS Map depicting the Fishing grounds of *Alluterus monoceros*

## ETP incidences and sensitive grounds off Gujarat

The ETP species- turtles and dolphins occurred only in 4% and 10% of the fishing operations respectively with a catch rate of 0.05 and 0.11. Dolphin incidence in gillnet was more during summer months while turtle incidence was less during summer months and more in post monsoon months (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.

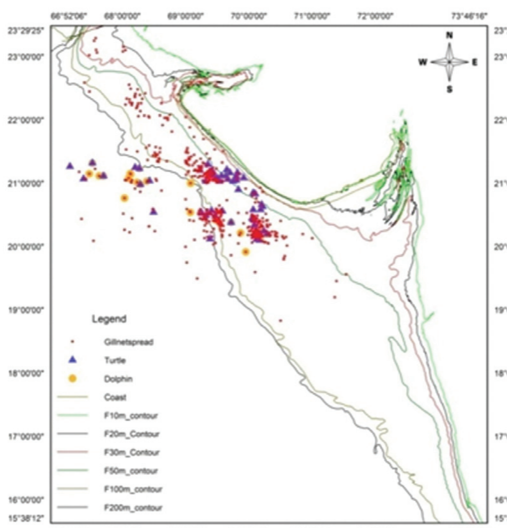



Fig. 6. Spatial points of incidence of ETP species in gillnet fishing off Gujarat

### Hints of potential Spawning Area

Longtail tuna, one of the neritic species has a very unique distribution pattern globally; limiting to the continental shelf areas of large landmasses in the Indo-Pacific. All through the distributional range and fishery, ready to spawn females or males were seldom reported from any gear indicating the movement of the spawning population from the fished areas. A spatial study of the tuna fishery off Gujarat depicted abundance of large size fishes beyond the continental shelf areas during the summer months (Fig 7); the period of gonadal development and spawning, affirmed the offshore movement of the species for spawning akin to the reports from the South Pacific and elsewhere in the northern Arabian Sea through landing based biological studies.

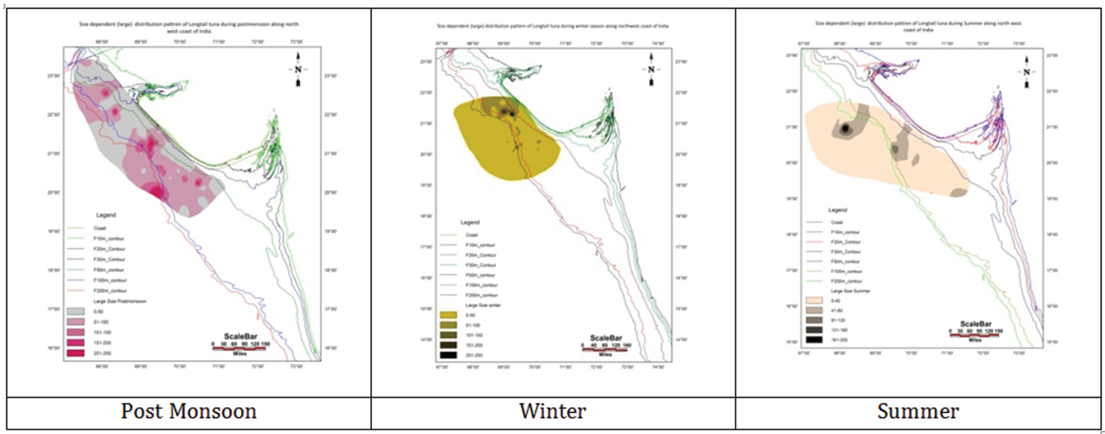



Fig. 7. Seasonal pattern of abundance of adult longtail tuna off Gujarat

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