Lead Article

# Passive georeferencing: A promising approach for finding probable fishing grounds

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## Abstract

Fishery management can benefit greatly from the use of geographic information system tools for habitat mapping, georeferencing fish catch and fishing effort data, and linking catch to oceanographic and biochemical parameters. As exploratory fishery resource surveys are time-consuming and expensive, landing centre-based surveys are frequently used in India to estimate the marine fishery resources. But it is challenging to map the habitat of the resources in such surveys as the resources seen at the landing centre are not geo-tagged. Passive georeferencing refers to the process of determining the geographical location of an object or entity using external information without actively transmitting any signals and is useful in situations where active transmission may not be desirable or feasible, and it allows for effective tracking and positioning without relying on active participation from the object being located. In this paper, the application of passive georeferencing approach for finding probable fishing grounds has been discussed along with its pros and cons and concluded with the way forward.

***Keywords***: *Marine fishery, resource assessment, fishing grounds, passive georeferencing*

## Introduction

India has a rich and diverse marine fisheries sector due to its extensive coastline of about 8118 kilometres and a vast Exclusive Economic Zone (EEZ) of approximately 2 million square kilometres (https://dof.gov.in/marine-fisheries). The marine fisheries sector in India plays a crucial role in providing livelihoods, food security, and economic growth for millions of people. The Indian marine waters are home to a wide variety of fish species, including both pelagic and demersal species. The Arabian Sea on the west coast and the Bay of Bengal on the east coast are the major fishing grounds. India is one of the world's largest producers of fish, both marine and inland. The marine fish production in India is substantial, contributing to both domestic consumption and export markets.

Marine fishery management is of paramount importance for various ecological, economic, social, and sustainable reasons. Proper management ensures the responsible use and conservation of marine resources, enabling long-term benefits for both current and future generations. Effective fishery management helps maintain the health and integrity of marine ecosystems. By preventing overfishing and destructive fishing practices, ecosystems can maintain their ecological balance, support biodiversity, and provide essential services like nutrient cycling and habitat provision. Proper management ensures that fish stocks are harvested at levels that allow them to reproduce and replenish, thereby supporting food security and livelihoods.

Effective management relies on accurate and up-to-date data about fish stocks, ecosystem dynamics, and fishing practices.

Fishery management encourages scientific research and data collection, leading to better-informed decisions. Sustainable fishery management contributes to the conservation of marine biodiversity by protecting habitats and reducing the impact of fishing on non-target species. To this end, an assessment of the availability of marine resources will be helpful in deriving management plans by ensuring the sustainable harvest of the resources. Geographic Information System (GIS) tools are very useful in fishery management for mapping of habitats, georeferencing information on catch and effort and linking catch with the oceanographic and biochemical factors. GIS is a powerful technology used to capture, store, manipulate, analyse, and present geographic or spatial data. It combines various types of data, such as maps, satellite imagery, aerial photography, and attribute data (information about specific locations or features) to create interactive maps and visualisations. GIS allows users to present their findings and analyses in various formats, from printed maps to interactive web applications. This makes it easier to communicate information and insights to a wider audience. It allows users to understand and make informed decisions about spatial relationships and patterns, by providing tools for analysing and manipulating data to uncover spatial designs, associations, and trends. GIS applications are diverse and span various fields, including environmental management, natural resource exploration, disaster management, agriculture, and more. It aids in monitoring and managing natural resources, tracking changes in ecosystems, assessing environmental impacts, and planning conservation efforts. GIS has transformed the field of environmental management by providing insights into complex ecosystems. Researchers can make informed decisions about biodiversity preservation, ecosystem restoration, and sustainable resource management by visualising data on species distribution, land cover, and pollution levels.

## Application of GIS in Fisheries

While terrestrial applications of GIS began in the late 1960s, its use in the marine environment didn't expand until the 1980s. The importance of computer-based mapping and spatial analysis in fisheries was stressed by Caddy and Garcia in 1986. During 2000, Meaden proposed a conceptual model for GIS in fisheries, explaining why its adoption in the sector was initially complex. Although mapping proved successful in capture fisheries, it has also gained importance in aquaculture (Mooneyhan, 1985). Initially, GIS for location analysis relied on remote sensing imagery. Subsequently, aquaculture locations, characterised by relatively stable nearshore environments, facilitated the development of GIS-based methods through simple survey mechanisms. Simpson (1992) recognised the potential of remote sensing to provide marine data relevant to GIS applications, including monitoring fishing effort, tracking pollutants, mapping bathymetry and seabed habitats, and measurements of water column properties, in the early stages of GIS adoption in fisheries. Early improvements witnessed in this using coastal GIS datasets included creating models of fish-habitat suitability, especially in inshore zones with features like mangroves, estuaries, seagrass beds, and littoral environments that could be easily mapped. GIS tools have found extensive applications in marine fisheries management and research, enabling scientists, policymakers, and stakeholders to make informed decisions for sustainable and efficient fisheries practices. The integration of spatial data and advanced analytical tools in GIS has revolutionised how marine resources are monitored, managed, and conserved. Despite advancements throughout the latter part of the last century, GIS applications in fishery-related work remained fragmented, incomplete, and predominantly small-scale (Jayasankar *et. al*., 2013). Owing to the potential it offers to the fisheries sector here we discuss a few thematic areas where GIS tools can be effectively utilised:

**Fisheries Resource Mapping:** GIS can be used to create detailed maps of marine habitats, including seafloor topography, coral reefs and other critical habitats. These maps provide a spatial context for understanding fish distribution, migration routes, and spawning areas, helping fisheries managers identify regions where conservation efforts should be concentrated.

**Fisheries Management Zones:** It aids in defining and demarcating different fisheries management zones based on factors such as species distribution, depth, and fishing regulations. By dividing fishing areas into zones with specific regulations and restrictions, authorities can enforce sustainable practices and prevent overfishing.

**Vessel Monitoring Systems (VMS):** Many fishing vessels are equipped with GPS devices that track their movements in real time. GIS helps integrate VMS data with other spatial datasets, enabling authorities to monitor vessel activities, track fishing patterns, and enforce fishing quotas and restricted areas.

**Bycatch Reduction:** GIS helps in identifying areas with high bycatch rates, where non-target species are accidentally caught. By analysing spatial data, fisheries managers can devise strategies to reduce bycatch, such as adjusting fishing gear, modifying fishing techniques, or designating bycatch mitigation areas.

**Marine Protected Areas (MPAs):** GIS tools help in managing marine protected areas, which serve as sanctuaries for fish and other marine organisms. By overlaying habitat maps, migration routes, and fishing zones, authorities can strategically locate and size MPAs to ensure effective conservation and sustainable fisheries.

**Ecosystem-Based Management:** GIS facilitates a holistic approach to fisheries management by incorporating environmental data like ocean temperature, currents, and nutrient levels. This helps in understanding the interconnections between species, habitats, and environmental factors, leading to more informed and integrated management strategies.

**Illegal, Unreported, and Unregulated (IUU) Fishing Detection:** GIS plays a role in combating IUU fishing by analysing vessel movement patterns, identifying unusual behaviours, and detecting potential IUU fishing activities. This enhances surveillance and enforcement efforts to curb illegal fishing practices.

**Impact Assessment:** Before initiating new development projects in marine areas, such as offshore wind farms or oil rigs, GIS can be used to assess their potential impact on fisheries. By overlaying project plans with fishery habitat and migration data, planners can mitigate negative effects on fish populations and habitats.

**Data Visualisation and Communication:** GIS provides a platform for presenting complex fisheries data in visually intuitive formats, such as interactive maps and dashboards. This aids in effective communication among stakeholders, policymakers, and the public, fostering collaboration and understanding.

In this paper, the application of passive georeferencing approach for finding probable fishing grounds has been discussed along with its pros and cons.

## Passive Georeferencing: A GIS Tool for Finding Probable Fishing Grounds

Passive georeferencing in marine fisheries refers to the practice of inferring the geographic coordinates of fishing grounds, fishing activities, or other marine phenomena using existing data sources and environmental indicators. This approach is particularly valuable when direct data collection methods like active georeferencing (e.g., GPS) are not feasible or when researchers aim to make informed predictions about potential fishing locations. Identifying potential fishing grounds using passive georeferencing involves using existing data sources and environmental indicators to infer areas where fish are likely to be abundant. Given the substantial diversity of marine fishery resources in tropical countries, adopting a scientific sampling scheme for data collection is the most pragmatic approach. As exploratory fishery resource surveys are time-consuming and expensive, landing centre-based surveys are commonly practised to make an assessment of resources. In such surveys, the lack of geo-tagging of the resources observed at the landing centre makes it difficult for the mapping of the habitat (Jayasankar *et. al*., 2020). India stands out among a handful of nations for utilising a sampling theory-based approach to gather data on marine fish catches and fishing efforts. To facilitate this, data on marine fishing villages, landing centres, fishing vessels, and equipment were compiled to construct a sampling framework. This framework is routinely updated to accommodate sector changes through comprehensive surveys conducted across India.

To obtain species-specific catch details, fishing efforts, particulars about fishing vessels and gears, and other relevant information, a systematic scientific sampling scheme named stratified multistage random sampling design (SMRSD) being employed (Sukhatme *et al*., 1958). This methodology is leveraged to calculate monthly landings and fishing efforts within distinct, non-overlapping fishing zones that span the entire coastline of India, encompassing 1269 landing centres distributed across 65 coastal districts in 9 coastal states and 2 Union Territories (CMFRI-FSI-DoF, 2020). The SMRSD approach ensures comprehensive data collection from all these landing centres. Under the current data collection system, proficient technicians (harbor-based observers) equipped with species identification expertise adhere to schedules devised through SMRSD.

In the past, due to the limitations in the level of mechanisation of fishing vessels, Indian fishermen had a restricted range, and the reported catch at a designated landing centre was typically linked to the nearby coastal area. However, the scenario changed significantly as powerful engines became prevalent, transforming fishing into a more professional pursuit, with mechanised boats embarking on extended journeys lasting for weeks. This extensive fishing activity had an immediate consequence: there was a lack of accurate information about the specific locations where the catches were obtained. This spatially specific data is crucial for comprehending and simulating the dynamics of fish resources.

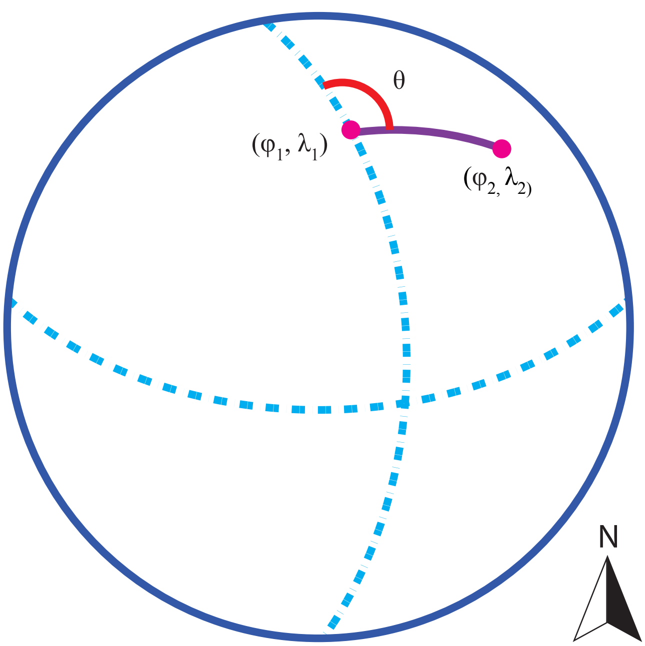
While the GPS devices could aid in precisely pinpointing fishing grounds, the challenge lies in retroactively assigning geographical coordinates to historical data that lacked latitude and longitude details.

Usually, the landings records have information about bearing and the distance covered by the craft surveyed and using the following Haversine formula for finding the destination coordinates given distance and bearing from start point coordinates, probable latitude and longitude of the fishing grounds can be obtained:

$$\varphi_2 = \operatorname{asin}( \sin \varphi_1 \cdot \cos \delta + \cos \varphi_1 \cdot \sin \delta \cdot \cos \theta )$$

$$\lambda_2 = \lambda_1 + \operatorname{atan2} (\sin \theta \cdot \sin \delta \cdot \cos \varphi_1, \cos \delta - \sin \varphi_1 \cdot \sin \varphi_2)$$

where $\varphi$ is latitude, $\lambda$ is longitude, $\theta$ is the bearing (clockwise




from north), $\delta$ is the angular distance d/R; d being the distance to destination, R the earth's radius (mean radius = 6,371km), 'asin' is arcsine (i.e. the inverse sine) of a given number and 'atan2' is the arctangent (or inverse tangent) of the specified x- and y-coordinates.

## Algorithm for finding the probable fishing ground

Steps in implementing the passive georeferencing for finding the probable fishing ground are as follows:

**Step1:** Obtain the Coordinates (latitude and longitude in degrees decimals) of the fish landing centre ($\varphi_1$, $\lambda_1$)

**Step 2:** Extract the distance travelled (in kilometres) and direction (in degrees from North) in which the distance covered from the landing centre-based surveys

(mostly, the bearing is recorded in the form of eight directions: viz., north, northeast, east, southeast, south, southwest, west and northwest in the landing centre-based surveys)

**Step 3:** Choose a random number from (337.5–360 & 0–22.5), 22.5–67.5, 67.5–112.5, 112.5 -157.5, 157.5–202.5, 202.5–247.7, 247.5–292.5 and 292.5–337.5 according as the direction travelled are north (0°), northeast (45°), east (90°), southeast (135°), south (180°), southwest (225°), west (270°) and northwest (315°), respectively as the new bearing.

(The range of deviation for a given direction is set at ±22.5 degrees to account for any variations in the actual bearing. The goal is to choose a random bearing that is still relatively close to the given direction without straying too far off track. Deviating beyond 22.5 degrees would make the chosen direction closer to a different nearby direction. By adding and subtracting this range from the given direction, a random bearing within reasonable proximity is determined.)

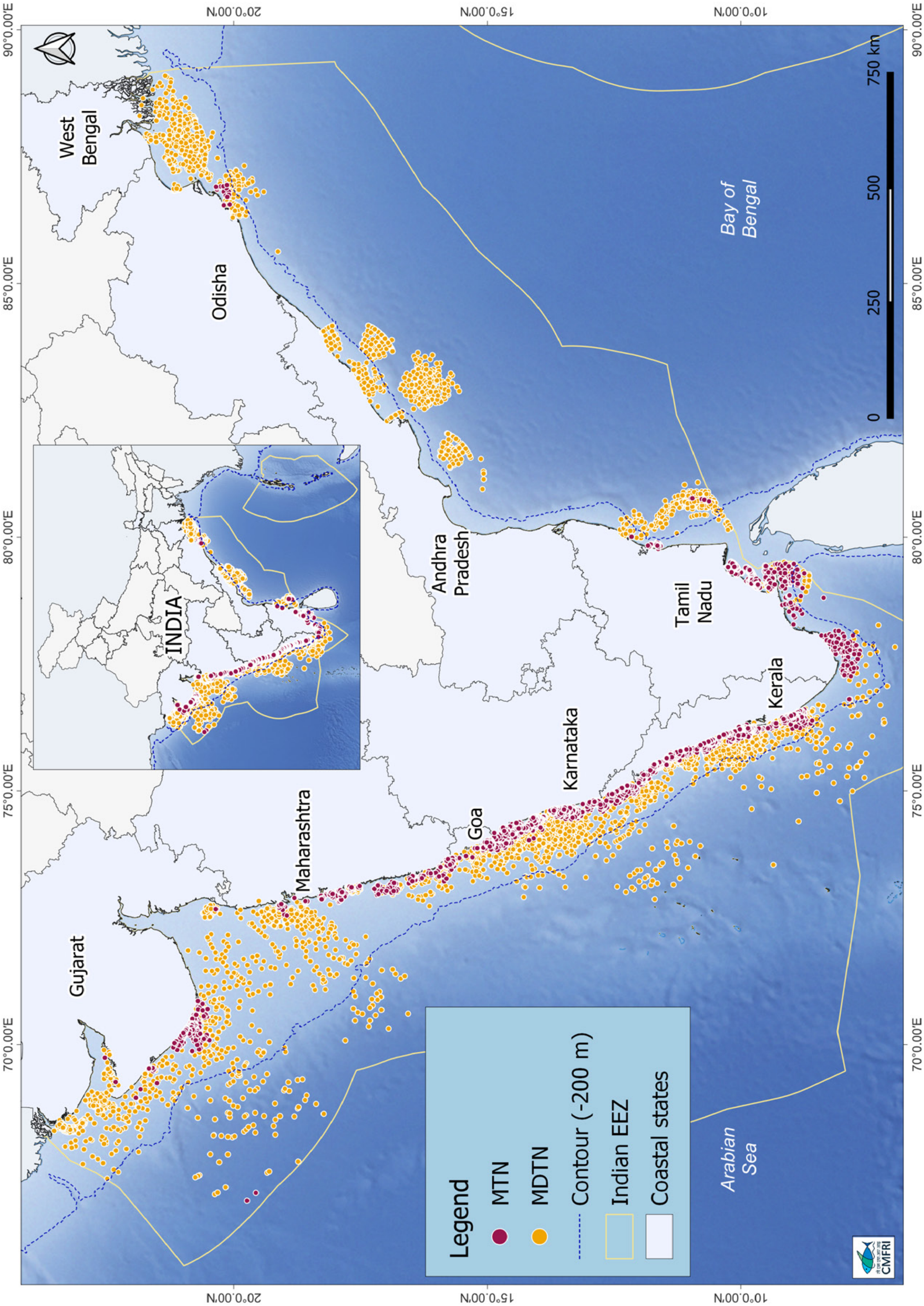
**Step 4:** Use the Haversine formula discussed earlier to work out the destination coordinates ($\varphi_2$, $\lambda_2$) using the start point coordinates, distance and the new bearing.

(The degree decimal values are converted in radians by multiplying by π/180 whereas radians are converted back to degree decimals by multiplying the values by the 180/π)

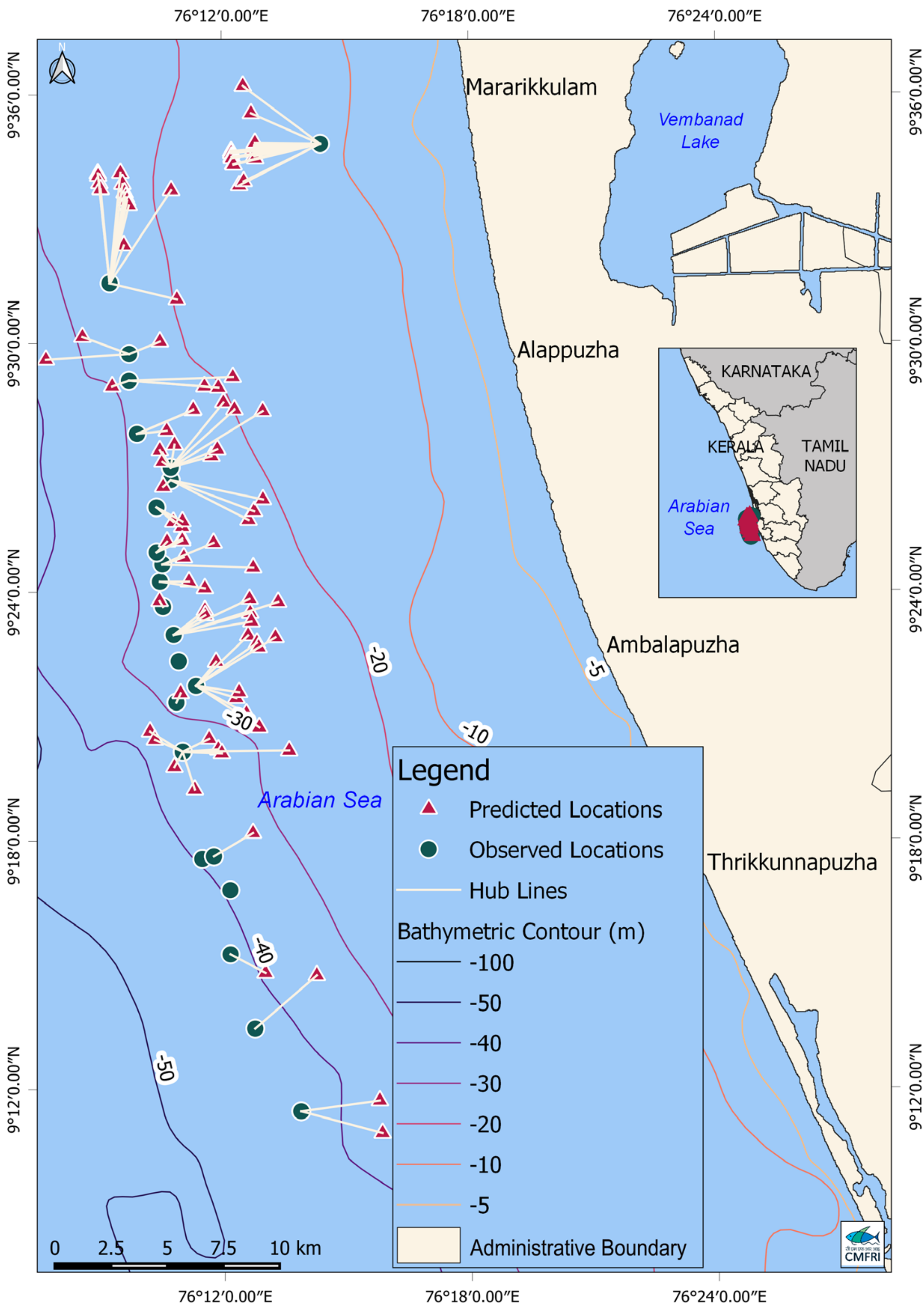
## Finding Probable Fishing Grounds: An Illustration

Trawlnet fishing is a major contributor to India's seafood production and exports. It plays a crucial role in providing livelihoods for coastal communities and meeting the protein needs of the population. Trawlnet fishing in India targets a wide range of species, including shrimps, cephalopods and other various demersal fish species. Shrimp trawling, in particular, is a significant sub-sector of trawlnet fishing due to the high demand for shrimp in international markets.

Like in many parts of the world, trawlnet fishing in India faces challenges related to bycatch—unintended species caught




Probable trawl fishing grounds in Indian EEZ during the year 2018




Observed grounds of Indian oil sardine and passive georeferenced points off Kerala coast along with the target species. This can include juvenile fish, non-target fish species, and even endangered species. The landing centre-based survey data collected using SMRSD on bearing and distance from landing centre of trawlers operated in the Indian Exclusive Economic Zone (EEZ) during the year 2018 has been taken as a case study to depict the probable trawl fishing grounds (spatial coordinates). This has been done separately for single-day trawl net (MTN) and multi-day trawl net (MDTN).

It is very evident from the above figure that the predicted coordinates of the MTN operations are mostly near shore. Besides, the predicted coordinates indicated significantly lesser MTN operations on the east coast compared to MDTN, with very meagre in the northeast region. It can also be noted here that few predicted coordinates on MTN operations are much farther from the coast and nearing the boundary of EEZ, which probably requires more analysis. It also pointed the need of a thorough sea truthing either by VMS or by GPS records of some randomly selected boats to validate the algorithm and to ensure the accuracy of the predicted points. A validation for all the projected points would be time consuming and very expensive and hence, a study on the accuracy of projection can be made based on few randomly selected points.

In this line, an attempt was made by Varghese *et al.* (2022) using a few data points on the actual fishing grounds of Indian oil sardines on the southwest coast collected under the ICSSR-IMPRESS Project (Gills *et al.*, 2022) during 2020. The projected coordinates were found out using the algorithm explained in previous section. The observed and projected coordinates in the region were plotted and it is very evident that there are discripancies between the observed and projected coordinates and found that the difference was nearly 5 Km on an average. The difference between the observed and projected coordinates could be because of the inaccuracies associated with the information pertaining to the distance travelled and the bearing or with regard to the limited number of points used for the validation. Relying solely on the Haversine function, it is possible to calculate the bearing and distance to reach a specific target point. However, when it comes to fishing, this task becomes considerably more complex. It is also to be mentioned here that while projecting the probabale fishing gounds, consideration of the species available depth could be a candidate to improve the prediction accuracy. Another attempt in this direction was done by Vase *et al.* (2022) to account for the probable error in the information provided by the crew on the distance travelled by conducting a survey in the northeastern Arabian Sea and found an error limit of ±20% from the actual distance and hence, another random number chosen from distance travelled ±20% could be taken as the new direction to work out the destination coordinates. The above discussions lead to the scope for the improvement of the existing algorithm so that such kind of inaccuracies can be corrected and prediction can be done with reasonable reliability.

## Conclusion

The Indian marine fisheries sector plays a vital role in providing nutritional security, livelihoods, and economic growth to millions of people. As the sector navigates challenges related to sustainability and environmental concerns, there is an increasing emphasis on adopting responsible and science-based approaches to ensure the long-term viability of India's marine fisheries resources. Marine fishery management is crucial for maintaining the health of marine ecosystems, supporting livelihoods, ensuring food security, and promoting economic stability. It involves a combination of science-based approaches, regulations, and stakeholder cooperation to strike a balance between resource utilisation and conservation for the benefit of present and future generations. GIS has revolutionised the way we make decisions by providing a spatial perspective on data, allowing us to see patterns, trends, and relationships that were previously hidden. As technology continues to advance, the potential for GIS to address complex challenges and drive innovation across various sectors remains boundless. The integration of spatial data and advanced analytical tools enhances our ability to understand and address the complex dynamics of marine ecosystems and their interactions with human activities.

Passive georeferencing can be a cost-effective alternative to active methods like vessel-based GPS tracking or underwater mapping. It relies on existing data sources and can make use of remote sensing technologies. By integrating various environmental data, such as sea surface temperature, chlorophyll concentration, and ocean currents, researchers can create a holistic picture of potential fishing grounds. This multidimensional approach enhances the accuracy of predictions. Passive georeferencing allows for relatively quick analysis and decision-making, especially when time-sensitive factors like seasonal fish migrations are involved. Passive georeferencing has its limitations, as the accuracy of the inferred location depends on the quality of available reference data, the precision of the methods used, and potential errors in the data sources. However, it can be a useful approach when active data collection methods like GPS are unavailable or impractical.

## The Way Forward

Whenever a task of this nature and magnitude is taken up, the pitfalls are just part of the discourse. When an attempt is made to backcast information, unlike forecasting, the level of accuracy must be a tad higher. Though spatial backcasting is not new, a necessity of this kind is really a big challenge.

Going strictly by the Haversine function, the bearing and distance can always lead to the point of the target. However, in the case of fishing, this is much more complicated. With mathematical functions yielding consistent and constant results, there is always the possibility of the fishing ground being pinned down to a small point. Towards this, as part of the Evolutionary Algorithm (EA), randomisation of the presumed grounds was the next logical stop. However, how much random and whether they need to be fuzzy, whereby radial randomness is induced, or vectorised randomness is to be targeted etc. were in the realms of further focus and thus, the second-level tools and techniques of passive georeferencing evolved. But outside the purview of the methodological arena, there were challenges lurking in the form of inadmissible projections of landing centres. In specific instances, randomising the bearing may result in a direction that would lead towards the coastline. To address this, some correction factor needs to be made to limit the randomisation range on one side to enhance the realism of the randomisation process. This correction factor could range from a small parameter governing the proportion of randomness to a full-fledged factor that apportions the uncertainty dynamically. Studies in this direction too have been pursued.

At this juncture, it would be worthwhile to revisit the whole need and utility value of this method and, thus, the tool. It's important to note that while passive georeferencing can provide valuable information about potential fishing grounds, it's just one tool among many that fishers and fisheries managers use. With fisheries being locality/ground specific alongside being gear and resource-specific, the grounds targeted, although there could be many, may not be infinite and certainly not perfectly random. There is a component of repeatability in the behaviour of fishermen targeting a specific set of resources as much as the habitat similarity of the fishes in that region. Thus, any refinement in the attempt of passive georeferencing must be biologically vibrant too while being stochastically alert. It is here the indigenous wisdom of fishermen and their involuntary switch to better "neighbourhood" options come into play. Combining passive georeferencing with active methods and local knowledge can result in more accurate and comprehensive predictions of potential fishing grounds.

Passive georeferencing predictions might lack direct confirmation of fish presence, potentially leading to false positives or overlooking important fishing areas. This is the hallmark of this tool, as it is perceived as a seemingly independent assessment of fishing grounds, thus indirectly an indicator of pockets of fish presence. Different fish species have varying habitat preferences and respond differently to environmental cues. The knowledge on the availability depth of marine species, referring to the specific range of depths at which a particular species is found in the ocean, holds crucial significance and this can be integrated through machine learning algorithms to improve the prediction accuracy in passive georeferencing. For example, when one can be sure of the depth of straddling of a set of resources, especially epipelagic and mesopelagic ones, the algorithm to trace back their pocket boroughs could always have an element of multivariate discrimination. Tools that help estimate the probability of classification and grouping through misclassification error minimisation can very well be a candidate for being considered. Support Vector Machines, roughly put, a non-linear all pervasive discrimination tool, can come in handy here. Such discriminatory power propped up by computational power can really make wonders in unravelling patterns of fish aggregation hitherto playing coy to traditional modelling wisdom. Thus, tools of data science can always hone up the effort to improve the accuracy and reduce the prediction variability of passive georeferencing.

Many neural network algorithms, especially those that have classification, grouping and finalisation of causal factors, could prove to be quite useful in these challenging scenarios. Presence-absence or even ordinally trained models with suitable activation functions like those used in recurrent neural networks (RNN) like Long Short Term Memory (LSTM) machines can be quite useful. The recurrence of factors and derived factors would reinforce the tree of decision-making more placidly with sufficient robustness. Hence such machines are always a vista to explore when it comes to reverse estimating the fishing grounds.

Environmental indicators are integral to passive georeferencing of marine fish species as they provide the environmental context that influences species distribution, movement, and behaviour. Incorporating these indicators enhances the reliability and applicability of passive georeferencing methods in understanding and predicting the spatial dynamics of marine species. As in the case of any spatio-temporal series analysis, extraneous variables certainly add rigour to the efforts of maximising the model entropy. Despite being a tradeoff between precision and parsimony, more informed models are always robust in facing unprecedented scenarios. Thus, a branch of derived information on the environment that usually is supportive of detrimental to the growth and reproduction of targeted resources can always be a game changer in such modelling exercises. With deep-niched resources, these factors get more complex as their direct influence gets less pronounced, and thus it makes all the more imperative to treat any information pertaining to environments as a three-dimensional one, the third tag of depth joining the latitude-longitude markings.

Sea truthing holds significant importance in the context of passive georeferencing. Sea truthing involves collecting ground-truth data from actual observations at sea, and it plays a critical role in validating and improving the accuracy of passive georeferencing techniques. It enhances the accuracy, reliability, and applicability of georeferenced data by validating methods, refining algorithms, and accounting for real-world variability. As it is said in survey literature, for a local level sampling 20% would be ideal so that in a period of five years or so a cumulative sampling of size matching the population could be achieved, the sea truthing mechanism if put in place in a structured manner would always be a boon to improving such prediction paradigms. Though 20% is quite expensive going by the sheer volume of boat trips, having a sample of at least 2- 5% will augur well in tuning the model machines well. As is in vogue, with 75% plus of the surveyed information needs to be put for training the models, the higher their number, the better would be their performance. Sea truthing has another dimension, too. If done on a voluntary basis, the fishermen would find the same as an extension of their traditional wisdom and thereby, such exercised would be chronicling that part of their profession, too. Any tool to passively locate the fishing grounds must be constantly focussing on improving itself on the basis of such real-time information. A participatory approach, too, is worthy of mooting between the modelers and the fishermen, which will end up mutually beneficial. In a way, these may reinforce other methods of resource density tracking and prediction like Potential Fishing Zone (PFZ) advisories too.

Advances in remote sensing technology and data availability will enhance the accuracy and timeliness of passive georeferencing predictions. Utilising machine learning algorithms can help analyse complex environmental datasets and identify patterns that are not readily apparent to human analysts. Such deployment of multi-sensor data coupled with fine-tuned machine algorithms can give wings to efficient conversion of computer intelligence and, thereby bringing unexpected yet crucial patterns of factorial interplay to the fore. This can prove to be worthy of its salt as it mixes traditional modes of modelling concepts with evolutionary as well as expectation maximisation algorithms. The result of such an amalgamation of the algorithmic renaissance with faster to obtain information could always be an optimistic proposition in these kinds of challenging assignments. Continued efforts to validate passive georeferencing predictions through ground-truthing and collaboration with fishers will enhance the reliability of results. Even the reliability metrics can be professionally attuned to the fisheries. Rather than just being dependent of root mean squared error (RMSE) or certain information criteria, the model selection based on a more studied prediction involving the fishery dynamics, even the economics of it would make the reliability more organic and comprehensive.

Once the predicted coordinates are validated at species level on a spatially gridded scale, the potential distribution of fish species in marine environments based on the analysis of environmental variables and species occurrence records can be studied through species distribution models (SDMs). It would further help in estimating marine resource biomass on a gridded scale and thereby enable more informed and sustainable management of marine fisheries resources. Modeling fish biomass is a uniquely challenging proposition due to its myriad dissimilarities and equally numbered associations. Starting from trophic level-based modelling to individual-based models, these kinds of models always lacked proper anchoring on the niche under study. Though primary production coupled models have always been there, their success rate had been diminishing with the increase in diversity of the ecosystem. Thus, if through independent or nearly independent means, the niches could be arrived at, modelling gets all the more simpler, be it on a mass scale or individual level.

With climate change scenarios under CMIP6, which are based on a totally different basis of shared socioeconomic pathways (SSPs) available, the incorporation of niche locating algorithms can propel the possibility of studying their dynamics in the longer run. With a sufficiently longer set of seasoned niche predictions coupled with biomass dynamics available, the coming decade may see the possibility of strong projections of shift of resource pockets founded on a very strong spatio-biological platform. This would be a springboard for a plethora of predictions and policy precursors. The envelopes rooted in bio-climate blocks are a strong step forward in this pursuit. Even though bioclimatic envelope models provide valuable insights into potential species distributions, they are strongly based on correlations between species occurrence and environmental variables. Therefore, needless to add, the model accuracy depends on the quality and quantity of input data, as well as the complexity of the species' interactions with its environment. These aspects, when properly addressed, would always fit into the larger scheme of things, which may see a humble beginning with exercises like passive georeferencing.

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