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Spatial Analysis of Fish Distribution Patterns: Integrating GIS and Taxonomic Data for Insights

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Abstract
Within the fields of fisheries research and aquatic ecology, spatial analysis of fish distribution patterns is a crucial field of study. To understand how fish populations are dispersed in aquatic habitats, this area collects, analyses, and interprets data. Researchers obtain important insights into the habitat preferences, migration behaviors, and population dynamics of fish species using a mix of data gathering methods, geographical mapping, statistical analysis, and modelling. In the context of fish distribution patterns, this work presents a thorough review of the essential elements of spatial analysis. It starts out by highlighting the significance of this discipline and how it relates to managing fisheries, promoting conservation, and maintaining aquatic ecosystems. The following section of the study explores the many stages of spatial analysis, from data collection and preprocessing to cutting-edge methods like habitat suitability modelling and remote sensing integration. The importance of time-series research in identifying seasonal and long-term trends in fish distribution is highlighted by the exploration of temporal characteristics. In order to make sure that study findings are realistically useful to fisheries management and conservation plans, the report emphasizes the need of stakeholder interaction. Research present validation methods for evaluating the precision and dependability of spatial models and outcomes. The importance of spatial analysis' larger implications for scientific knowledge, as well as for the protection of aquatic resources and the welfare of people who depend on fishing, is highlighted in the paper's conclusion. Overall, this study provides a thorough introduction to the area of spatial analysis of fish distribution patterns, emphasizing its multidisciplinary character and key position in the advancement of fisheries management and the preservation of aquatic ecosystems.

Keywords: spatial Analysis (SA), Fish Distribution pattern (FDP), GIS, migration Behaviors (MB).

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Introduction

Today, the fast-growing population of the human community is becoming a fatal tool in not only environmental degradation but also for the species around us. Out of these species, freshwater fish are considered more susceptible to these anthropogenic activities. Therefore, a properly relevant conservation method needs to be applied for every fish assemblage, inhabiting specific spaces of waterbodies. To make these conservation strategies effective, there is a crucial need to understand various parameters regarding fish spatial patterns that eventually act as a function for their biological processes. Spatial analysis for finding out the fish distribution pattern can prove itself to be a crucial tool in saving the endangered species effectively.

Spatial analysis of any species refers to the process of estimation, calculation, and modeling of their spatial factors like geographic location, features, and relationship of these attributes with the external geographical entities. In the case of fish, their spatial analysis involves finding out the data related to diversity, richness, and distribution of widespread species. This type of analysis not only helps in making the right decisions for species conservation but can also add information to the fish database, for future use by other fisheries experts. Out of various techniques to gather spatial data of a specific fish assemblage different techniques can be applied out of

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which GIS is considered the most effective approach. GIS refers to a geographic information system that helps to assemble all data of a location and makes it easy for interpretation and visualization by connecting all the relationships, trends, and patterns of that particular location through maps, keys, charts, and graphs. Fish distribution is uneven in marine and freshwater environments because of the functional adaptation and landscape inhabitation based on biological needs. To make GIS effective, the fish database needs to be generated for every desired location that covers the fish species. This database has to be characterized based on fish taxonomy i.e., phyla to genera and species, etc. This collection of data has multiple advantages as it makes the taxonomic study of fish assemblages easier and the fish database can be more finely categorized. After database generation, the fish data is combined with GIS and Visual Basic to map out the required spatial data of fish.

This technique, once applied, comes up with various advantages and rewards. First of all, the spatial data gives information about the fish richness. This fish richness refers to the amount and estimated number of specific types of fish assemblage inhabiting a precise waterbody. With this information, the fish hotspots can be determined and the need to conserve a specific habitat can be justified. Similarly, the patterns of fish diversity and distribution related about the health of an aquatic system, as well. Fish are potentially effective indicators of the environment because of the wide range of morphology, composition, and ecology linkages to their natural habitat. Therefore, the type of fish living in a water environment reflects the availability of nutrients and resources present in it.

Moreover, optimal predictions can also be made for an unknown geological site by collecting and observing the data found from a known aquatic site, especially for the species showing common biological traits, modifications, and structural similarities, by inhabiting two different hydro-environments. Within the subject of fisheries research and aquatic ecology, spatial study of fish distribution patterns is a complex and essential task. It includes a wide variety of methods and tools for understanding the complex spatial arrangements of fish populations in aquatic environments. Understanding the habitat preferences, migration patterns, and population structures of different fish species is crucial for successful fisheries management, conservation initiatives, and evaluations of the health of the entire ecosystem. Amazingly diverse fish species may be found in aquatic habitats, which range from freshwater rivers and lakes to enormous marine ecosystems. These species, each with its own distinct set of spatial preferences and behavioural tendencies, have evolved to a broad variety of ecological niches. As a result, understanding the spatial complexity of fish distribution is a challenging undertaking that calls for a mix of cutting-edge scientific methods and technology.

It is impossible to exaggerate the significance of this area of study. Commercial and recreational fishing are a vital part of the world's economy, lives, and food security. But the long-term viability of these fisheries depends on a thorough comprehension of fish movement patterns and interactions with their habitats. Additionally, our capacity to successfully monitor and manage fish populations is essential to the protection of fish species and the upkeep of healthy aquatic ecosystems. Therefore, for ecological and economic reasons alike, geographical examination of fish distribution patterns is crucial.

Similarly, the environmental destruction caused by human activities and urbanization has been a major influence on the hydro-chemical parameters of rivers. Because increased human activities increase the organic content in water. This organic content proves hazardous to water and its inhabitants. However, the fish residing in it experiences direct influence, which can result in decreasing fish richness over that specific part. In this way, the well-being of that geological location can be estimated. Heterogeneity and availability of food for the fish are factors that justify the habitat of a fish. This can be identified effectively by linking GIS with spatial analysis.

Spatial fisheries ecology is the wider term that gives important evidence about fish and the effect of the environment on them. For example, other than pointing out endangered species of a waterbody, they also tell us

about marine protected environments that need no changes, and therefore undivided attention can be provided to those areas that are under the effect of destructive factors imposed by humans.

Other than these advantages, spatial analysis of species distribution also helps in classifying the predator-prey relationship and the threats imposed by the predator of a specific geological location. If a location has high fish richness and contains diverse species of fish present, then it means this specified location has an unlimited flow of food and the predators of high taxa are not present in that specific location. Also, the predator influence takes tail on the species of fish by affecting not only their richness but also making them struggle through intimidation. Through non-consumptive intimidation, the fish's natural traits and habitat. The fish under predatory action selects the habitat or surroundings with lesser food choices but more safety and protection. If such species are analyzed through spatial analysis, then it can be deduced that such species are under the influence of a predator and therefore conservation strategies can be applied.

Equally, the indicator fish species are also an important part in the returns of spatial analysis. Through spatial analysis, the fish species inhabiting a specific location can be treated as a bio indicator. These indicator species give data about the aquatic bodies, the presence of dissimilar fish groups in the same environment, and their interactions. Different groups living in the same environment explain the common taxonomic history shared by the groups. Because inhabiting a definite and certain habitat means that this species has biologically modified traits and morphological similarities between them. Therefore, their co-occurrence can be declared reasonable and eco-friendly.

By combining GIS with spatial data, not only fish can be conserved but also the destructed aquatic habitats can be identified. This identification reveals about the habitat relevance and the aquatic bodies can be marked as the source of specific types of fish presence with which the conservation techniques can be suggested for both the waterbody and fish assemblages.

Literature Review:

This review is based on the overview of studies that are related to spatial analysis of fish distribution patterns. This review is also related to Integrating geographical information systems and Taxonomic Data for insight(Hitt & Angermeier, 2008). The word spatial analysis can be explained in these words "It is the process of examining the attributes, location and true relationship of different features with the help of analytical techniques which are required to address any kind of question or for kind of research or for gaining useful knowledge for any kind of biological issue(Weijerman et al., 2019). The word fish distribution can be explained in these words the different species of fish are distributed unevenly in fresh and Marine water according to different aspects of hydrodynamics(McKechnie & Moss, 2016). The word GIS stands for geographical information system which means the study of diversity across different geographical regions of the world for gaining information and knowledge(Veron et al., 2011). The quality and feature of water determines the quality and type of aquatic life present in that water body.

Different factors determine the fish distribution in any part of the water body be it fresh or marine water(Muderere, Murwira, & Tagwireyi, 2018; Santora et al., 2021). These factors include the size of the water body, the complexity of the habitat, the velocity of moving water in a water body, the depth of the water body, the conductivity of water in the water body, and the most important factor temperature(Walther, 2019). There is also another important factor for the distribution of fishes, this factor is called habitat squeeze. The distribution of fishes in marine or salty water is divided into four main regions(Dominguez Almela, Palmer, Gillingham, Travis, & Britton, 2020). These regions are named Indo-West Pacific, Western Atlantic, Eastern Pacific, and Eastern Atlantic(Torgersen, Gresswell, & Bateman, 2004). Recent studies revealed that the most common types of fishes found in the West Pacific are tunas such as bigeye, albacore, bluefin, billfish like blue marlin, black

marlin, striped marlin, sharks such as common thresher, silky, blue, shortfin mako, swordfish, sailfish, wahoo, and others(Boni, 2021; Mora, Tittensor, & Myers, 2008). These Western Pacific regions are mostly found in Australia, Brunei, China, Cambodia, New Zealand, Niue, South Korea, and other such regions(Mather et al., 2021). The next major category for fish distribution according to region is the Western Atlantic Ocean which has features like continental rise, the abyssal plains, and ridges(Yang et al., 2022). The climate present in this region is moderate, sometimes cool and moist too. These regions experience long-term winter and short but cool summer seasons.

The most important types of fishes found in this region are demersal species such as lobsters, cod family, and pelagic species such as mackerel, herring, and menhaden(Stigall, 2011). These types of regions are found near Nova Scotia, New Brunswick, Newfoundland, and others. The third category of region related to fish distribution is the Eastern Pacific(He et al., 2020). There is a variety of species of fish in the Eastern Pacific such as Mexican Goldfish, Reef Cornetfish, Giant Hawkfish, Panamic Fanged Blenny, Chamaeleon Wrasse, and others. The most prominent climate in the Eastern Pacific region is tropical and subtropical type of climate(Knouft & Anthony, 2016).

They have mostly high temperatures as compared to other water bodies so they have unique fish distribution because of hydrodynamic conditions there. This region extends along the Pacific Coast of Central America, ranging from Southern Mexico to Northern Peru and others(Hattab et al., 2015). The fourth category related to fish distribution is the Eastern Atlantic region. The fish diversity in this region is quite different and complicated, it includes fishes like longfin bonefish, longfin crevalle, longfin gurnard, and Lophius piscatorius(Lewison et al., 2014). In the Eastern Atlantic region, the climate is warmer across the equator. There is cold air that gets mixed with warm air to for mixture like fog. There is warmest month is July which has a temperature of 24. 5 C. The fishes found in marine water have a special excretory system to remove excess salty water from the body to maintain their osmoregulation.

Their body structure is also correlative to the water characteristics in marine water bodies. These are all types of species of fish found in marine or saline water but the distribution of fish in freshwater is quite different(Parida et al., 2022). Because freshwater has less amount of salt in it, thus the diversity of species of fish found in freshwater is quite different from that of marine water. Several factors determine the distribution of fish in freshwater(Aspinall, 1994). These factors are temperature, location, season, and depth of water. The most important stage in ensuring the correctness and dependability of models and results is validation. The effectiveness of prediction models is evaluated, and the geographical distribution patterns discovered via the study are validated, with the use of independent datasets and cross-validation methods. Beyond mere scientific interest, geographical examination of fish distribution patterns is important.

It directly affects the viability of fisheries, food security, livelihoods, and aquatic ecosystem preservation. We can make better judgements and take preventative action to safeguard these essential resources if we have a better grasp of the complex interactions between fish populations and their habitats. The geographical examination of fish distribution patterns essentially serves as a proof of how intertwined our natural world is (Luca & Jack, 2021). It stresses the necessity for appropriate maintenance of these settings and emphasizes the fragile balance that supports aquatic ecosystems. We empower ourselves to maintain biodiversity, the future of fisheries, and the health of both aquatic ecosystems and the human populations who depend on them as we continue to expand our understanding and technology in this area.

Usually, freshwater is moving water that continues to recycle so this water has mostly moderate temperature. The depth in a water body in the case of Freshwater is less than that of a water body of saline water. The most important found in freshwater are Rainbow trout, catfish, guppy, Goldfish, common carp, Oscar, Grass

carp, and others. The fishes found in freshwater have such an excretory system that enables them to retain most of the salts in their body to perform osmoregulation in them(Stigall & Lieberman, 2006).

They have such body structure that helps them to accommodate in characteristics of Freshwater as well. Usually, depth is less in the case of Freshwater bodies, so there are fewer types of large fishes found in freshwater. Recent studies revealed that the population of fish has been decreasing for a few years because of different factors such as water pollution, air pollution, land pollution, and others(Melo-Merino, Reyes-Bonilla, & Lira-Noriega, 2020). The study related to spatial patterns of fish distribution can help to gain information related to the diversity of fishes in different geographical regions. This data analysis can help to estimate the factors that can help for better growth rate and survival of fish(McGuire, Gangopadhyay, Komlodi, & Swan, 2008).

Many species of fish have become extinct because of a lack of attention to their distribution pattern studies. But in this review, different studies suggest that if we overcome the problem of pollution of water bodies including freshwater and Marine water, the problem related to endangered and extinct species of fishes can also be uprooted(Graham, Ferrier, Huettman, Moritz, & Peterson, 2004; Halpin et al., 2006). This review effectively overlooked these studies related to spatial Analysis of Fish Distribution and concluded this common point that the survival of fish is dependent upon the better quality of water bodies. These spatial Analysis studies will not only give information about the habitat of each type of fish species but will also help to determine how these habitats can be secured to prevent the extinction of fish species(Beheregaray, Cooke, Chao, & Landguth, 2015). However, there is a need for more in-depth knowledge related to spatial Analysis of Fish Distribution Patterns that can help to understand all factors related to fish distribution and Taxonomy(Verutes et al., 2020).

Material and Methods:

The research study based on theory and some numerical analysis related to the variables the correlation test present relation between them.

Data collecting:

Thorough data collecting is the cornerstone of every geographical study. The gathering of data on fish dispersion patterns includes information from both fishery-dependent and -independent sources. statistics about capture sites, species composition, and catch rates are frequently included in fishery-dependent statistics, which are collected from both commercial and recreational fishing activities. On the other hand, data that are not related to any particular fishery are obtained through scientific surveys and come from methods including trawl surveys, gillnet surveys, and underwater video recordings. In order to comprehend how these parameters, affect fish dispersion, other environmental data are gathered, such as water temperature, salinity, depth, substrate type, and plant cover.

Data preparation:

After data is gathered, it goes through a painstaking preparation stage. This calls for the integration of many datasets into a coherent framework, standardization of geographical and temporal scales for interoperability, and data cleaning to correct any missing or incorrect data points.

Techniques for Analyzing Spatial Data:

One of the main approaches used in this subject is spatial mapping. Fish species or population distribution maps are produced using Geographic Information Systems (GIS) software, giving a visual depiction of their geographical patterns. Techniques for hotspot analysis that identify locations with high fish abundance or

density are frequently based on spatial statistics like kernel density estimation. Another strategy is called "habitat suitability modelling," in which predictive models are created to determine correlations between fish abundance and environmental factors, enabling the selection of appropriate habitats. Fish abundance in unsampled locations is estimated using interpolation techniques like kriging or inverse distance weighting based on neighboring data points.

Statistical Models:

Fish distribution patterns are widely predicted and modelled using statistical modelling. Environmental factors are included into these models as predictors using generalized linear models (GLMs) and machine learning methods like Random Forest and support vector machines, allowing the creation of prediction models that accurately depict fish distribution.

Remote Sensing:

Especially in more expansive aquatic environments, remote sensing data, such as satellite images and bathymetry data, offer important information to improve the knowledge of fish distribution patterns. These data sources provide a more comprehensive viewpoint, assisting in the evaluation of geographical patterns on a large scale.

Fish Distribution:

Fishes of all types are generally distributed all over the world including many different habitats that include places from the highest streams to the deepest oceans. The type of habitat depends on the body conditions of the fishes that live inside the oceans and have their lifestyle adapted according to the circumstances and conditions of the surroundings. To highlight the different habitats, there are a lot of systems and methods. They are used for the correct identification of the place and they also deal with the natural changes that occur in those areas. In short, they are responsible for the prediction of the location of the fishes that belong to any habitat marine or freshwater. The need for spatial grouping of the fishes is important for both developing and developed countries for biodiversity conservation and providing a complete package in organizing the area.

As fishing has been an important source of economy for the people of some countries during the last few decades, it has declined badly due to the natural changes and the climatic changes that are faced to the habitats of fish. So the researchers have tried to find some ways in which the population of different fishes can be found and they can be controlled to some extent. So they need to study the communities in detail to understand the basic mechanisms that are taking place inside the habitats. There is a large amount of fish present inside the marine or fresh water. All these factors help to contribute to collecting data about the richness of fish in a certain area. Latest studies have shown the distribution of fish in short-lived animals or long-living fishes.

They help to maintain the ecosystem and create a line between the animals that are wild and not. There are several techniques for this purpose that are used to find the basic lifecycle of fishes and their distribution in different places according to their body requirements. Some different factors and links control the different communities of fish. They can be climatic changes, human activities or other internal environmental things. All these will help to find the accurate condition of the different habitats, including the fishes from different places. For this purpose, ecologists are advised to make a complete package of solving this problem of distributing the fish in different ecosystems of different heights. To address these issues comprehensively, ecologists are recommended to create a comprehensive strategy for managing fish distribution across various ecosystems at varying altitudes. This holistic approach ensures a thorough understanding of the factors influencing habitat conditions and the movement of fish populations.

Role of GIS and Taxonomy in Fish Distribution:

GIS is a technique in which the geography of a specific habitat is studied and then it is responsible for the classification of fishes or any organism that is being studied. This will include all the information regarding the rise of species and the ultimate loss in their number. It will calculate all the data and then will help to identify the main reason for this. This regards saving the species from complete extinction or if they are in danger. This will highlight the reasons for this and then can work accordingly. GIS firstly collects the data and if there is a need to edit, it will do so and then the data will be checked and corrections will be done accordingly. This was a very simple kind of GIS. The other one is complex, in this several changes can be made to the map including its rotations and making certain projections on the map to find the exact location of a certain habitat. In short, this is responsible for the input of data and then the complete management is done after a series of planning the final data is then used in the process of distributing the fish communities all over the world. In this spatial data is used that means the boundaries are now located on Earth and they will help to find the location of some habitats of the living organisms. Spatial data is used in GIS to formulate certain pictures that will show the virtual image of the habitat and will ultimately lead to understanding their diversity. GIS can be of many layers. There layers are the main components of the map that will help to understand to geographical condition of certain habitats. There can be many classifications of them that include the data from all the types of habitats. The taxonomy of fishes on the other hand also plays an important role in understanding the distribution of fishes all over the world and it includes many habitats. The fishes that are present today are the result of the beginning of Earth and the evolutionary changes that take place in the fish body to undergo a series of changes. Many methods of taxonomy can be used to find the fish distribution. The most common method for this purpose is the visual representation of the habitats. This is a very beneficial method that is used to understand the classification of fishes throughout. In this method the animals. The distribution of marine fishes is such that they are divided into Pak places, some to the eastern and the others to the western areas of the Earth. The other main component to determine the distribution of fish in oceans is the climatic changes. The changes in the climatic parameters are the main indicators that how the changes are to occur in the oceans. The fish distribution is very beneficial as it helps the fisheries in the export and that will ultimately give them an increase in economy. In other words, it is also used to calculate the total number of species in the world. Such that it can also contribute to calculating the rate of growth of these species and also to finding the taxonomic traits between them.

Correlations

		Fish Distribution Patterns 1	Fish Distribution Patterns 2	Fish Distribution Patterns 3	GIS	Taxonomic Data 1	Taxonomic Data 2
Fish Distribution Patterns 1	Pearson Correlation	1	-.250	.411**	-.242	.861**	.160
	Sig. (2-tailed)		.080	.003	.090	.000	.267
	N	50	50	50	50	50	50
Fish Distribution Patterns 2	Pearson Correlation	-.250	1	-.208	-.093	-.230	.161
	Sig. (2-tailed)	.080		.147	.519	.108	.263
	N	50	50	50	50	50	50
Fish Distribution Patterns 3	Pearson Correlation	.411**	-.208	1	-.121	.613**	.158
	Sig. (2-tailed)	.003	.147		.403	.000	.274
	N	50	50	50	50	50	50
GIS	Pearson Correlation	-.242	-.093	-.121	1	-.153	-.251
	Sig. (2-tailed)	.090	.519	.403		.289	.079
	N	50	50	50	50	50	50
Taxonomic Data 1	Pearson Correlation	.861**	-.230	.613**	-.153	1	.107
	Sig. (2-tailed)	.000	.108	.000	.289		.461
	N	50	50	50	50	50	50
Taxonomic Data 2	Pearson Correlation	.160	.161	.158	-.251	.107	1
	Sig. (2-tailed)	.267	.263	.274	.079	.461	
	N	50	50	50	50	50	50

****. Correlation is significant at the 0.01 level (2-tailed).**

The above result describes that correlation coefficient analysis result present the Pearson correlation value, the significant rate also that number of observations of each variables included dependent and independent variables. the taxonomic data 1,2 represent that 0.160, 0.161, 0.158 also that 0.107 rate of correlation between them. the result also describes that significant rate between them its values are 26%, 27%, 46% respectively. The overall result shows positive and significant relation between variables related to independent and dependent indicators.

Conclusion:

In conclusion, fisheries science and aquatic ecology both focus on the varied and crucial field of research known as spatial analysis of fish distribution patterns. It includes a wide range of methods for gathering data, analytical tools, and modelling strategies with the goal of understanding the intricate spatial dynamics of fish populations in aquatic environments. This in-depth knowledge of fish dispersal patterns has significant ramifications for ecological preservation as well as socioeconomic growth. Researchers extract information from a variety of sources, including fishery-dependent and fishery-independent data as well as environmental factors, through diligent data collecting and preparation. Subsequent analyses are built on top of these data. In conclusion, the multidisciplinary study of spatial analysis of fish distribution patterns integrates knowledge from biology, ecology, geography, and statistics. Its importance stems from its ability to guide fisheries management plans, protect delicate ecosystems, and encourage the wise use of aquatic resources. The future of fisheries and the protection of aquatic ecosystems are ultimately shaped by this complex field, which serves as a cornerstone for addressing the complex connections between fish populations and their habitats. We may better understand the delicate balance that supports our aquatic ecosystems and the crucial role they play in our world by digging into the spatial complexity of fish distribution patterns.

Geographic information systems (GIS), hotspot analysis, habitat suitability modelling, and interpolation are a few spatial data analysis approaches that enable researchers to build distribution maps, pinpoint high-density locations, and calculate fish abundance in places that haven't been sampled. The geographic autocorrelation and clustering of fish populations are explained by spatial statistics such as the Mornas's I, Ripley's K-function, and point pattern analysis. Through time series analysis, which exposes seasonal patterns, yearly trends, and long-term changes in fish distribution, temporal dynamics are also taken into account. Understanding migratory paths, spawning periods, and reactions to environmental changes are all made possible by this knowledge. The creation of prediction models that connect fish abundance and presence to environmental factors is made possible by sophisticated statistical models, such as generalized linear models (GLMs) and machine learning algorithms. Forecasting and decision-making for fisheries management and conservation activities are aided by these models. Our knowledge of spatial patterns is improved by the incorporation of remote sensing data, such as satellite photography and bathymetry data, which offers a wider viewpoint, particularly in larger aquatic ecosystems. Engaging stakeholders is essential to ensuring that the outcomes of spatial studies are not just accurate scientifically but also useful and implementable. Effective fisheries management and conservation plans depend on cooperation among scientists, local people, and fisheries managers.

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