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Application of Geographic Information Systems (GIS) in Mapping Fish Species Distribution and Taxonomic Data

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Abstract
By handling several geographical components simultaneously, GIS is a technology that may be used to clarify problems and find solutions. For the past 15 years, aquaculture research has evaluated the suitability of coastal areas for farming operations using GIS. Aquaculture management issues including habitat availability, the many uses of estuarine waters, and research on how water quality affects the production of finfish and shellfish may all be studied using GIS. Additionally, GIS has been utilized to address frequent issues between aquaculture operations and marine duck habitats. FAO developed the website GIS Fish, which offers access to global information on remote sensing, mapping, and geographic information systems (GIS) as they pertain to aquaculture and inland fisheries. The US Fish and Wildlife Service, the US Geological Survey, and other federal and state organizations utilize GIS to help in conservation efforts. GIS is used in many aquatic scientific fields, including as oceanography, marine biology, stream ecology, aquatic botany, limnology, and hydrology. Applications include using satellite imagery to identify, monitor, and lessen habitat damage. The state of inaccessible locations can also be depicted through imagery. Scientists can monitor movements and devise a plan to identify areas of concern. GIS may be used to monitor population shifts, endangered species, and invasive species. Much research on wetlands has been conducted with an emphasis on their management and conservation features, with encouraging outcomes.

Keywords: Geographic information systems (GIS), Mapping Fish Distribution (MFD), Taxonomic Data (TD)

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Introduction

A system based on the computer whose characteristic is that it observes and interprets the information referenced on behalf of geographic information. It utilized data concerning a specific location. A geographic information system is based on hardware and computer software arranged to store, manage, evaluate, edit, infer, and then represent the data on behalf of geographic information. This usually occurs in the range of spatial-type databases. A tool completely based on the computer to map and analyze the things that are found and all those happenings on the earth can be covered under the term geographic information system (Cheriyan et al., 2023). Geographic information systems arrange the tasks of common databases, such as issues, and analyze them statistically with the unique mindset and observation of geographic-related advantages provided by the maps. Let's consider the example of a Geographical information system to understand this concept. The features of maps, graphs, statistics, and cartography represent the features concerning geographical information like location, natural sources, streets, buildings, and demographics. One of the clearest aspects of a Geographical information system visualization is all those things that happen while visiting a trip on Google Maps(Miller, 2012). The functional subsystems of a geographic information system are a subsystem that is related to a subsystem, a subsystem that is about the storage of data and its retrieval, a subsystem that is based on the representation and observation of data, and a subsystem that is related to the output of data and representation of it. Here, a discussion will happen about the components of a geographic information system, like people, methods, data, software, and

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hardware(Board et al., 1998). All these five components built the base of this system that enables the users to observe, visualize, and bring improvement in a wide spectrum of issues related to the real world. The main purpose of the Geographic information system is to improve the ability to make decisions and planning. It also becomes the source of the distribution of data and handling of the information. It also involves eliminating all that information found in duplication(Robertson, 2009). The information that is collected from various means is also included. The applications of Geographic information systems are based on investigating scientific information, managing races, and planning for development. Various retail businesses use the geographic information system, which can prove helpful in determining the location of new stores. Marketing companies utilize a geographic information system to decide who the marketing stores and restaurants are and the location of that marketing(Arunkumar et al., 2015). Let's discuss the key benefits of a Geographical information system. It involves the decision-making of better quality, bringing improvement in cost savings, opportunities that are all about marketing, mapping, management of resources in a natural way, prevention from disastrous events, and management of useful information. The division of fishes is typically done in the form of three groups sure: class Agnatha, in which jawless fishes are involved; class Chondrichthyes, in which fishes of cartilaginous type are involved; and the superclass Osteichthyes, in which bony fishes are involved (Mironga, 2004). The two groups mentioned last come in the infraphylum Gnathostomata, a category in which vertebrates with jawed features are included. The distribution of fish seen in the present time happens due to the geographic history, the earth's upgrade, and the ability of fishes to undergo changes of evolution type and inhabit the available places. Fish must be placed in groups on behalf of their habitat and geographical area. The largest group of vertebrates is based on fish. Four classes of fish are placed together on behalf of their distant relationship with each other. Four groups of fishes are based on jawless fishes, consisting of two classes: Cartilaginous and Bony fishes (Scott, 2001). The feature of jawless fishes is that they have a round mouth. The decrease in the number of fish species is very dangerous throughout the world and is dangerous to such an extent that it has become very difficult to calculate. The main reason for this difficulty is the deficiency of trustworthy information on the level of Geographic information. The habits of freshwater fishes have been destroyed disproportionally, which will become the reason for the reduction in the fish population in freshwater. Limitations can also be seen in the areas of biogeographic type. The challenge of conservation into freshwater is very difficult because the taxa of the aquatic type are very tough to map(McAllister et al., 1994). This problem was declared for the fish of California's freshwater after the development of software and such databases, which are of underlay type. The system was built to capture, map, store, and report the dynamics of targeted species of spatial and temporal type by applying spatial units that are spatial, just the primary objects that need to be indexed. Due to human activities, changes are happening in the global environment. These changes are widespread and rapid. This idea is correct for the freshwater ecosystems. These systems are affected by human activities. Pollution, diversion of water and infrastructure, flood protection, habitat changes, invasive species, and many stressors are the factors that badly affect freshwater ecosystems(Santos et al., 2014). Much informal research has been done on the biogeography of African fish in freshwater. Boulenger (1905) provided the first thorough biogeographic study of fish species in Africa. His suggestions have now been expanded upon. Checklists and the release of fresh distribution pattern records were the main topics of the early literature, whereas syntheses concentrated on establishing a connection between species distribution patterns and the climatic and geological histories that caused them. The presently recognized paradigm of eleven ichthyofaunal areas was first presented by Roberts (1975). The Maghreb, Nilo-Sudan, Upper Guinea, Lower Guinea, Zaire, Quanza, and Zambezi provinces were divided from Africa, as were the East Coast, the Cape, and Madagascar. These provinces were built based on large-scale patterns found in Myers (1937) and Boulenger (1905). In evolutionary or analytical terms, they were not rigid biogeographical zones. Nevertheless, they served as the basis for regional types as they were useful in determining the fauna's variety (Adekayode, 2006). As technology advances, more research is being done on the use of GIS in reservoir fisheries management. GIS applications in fisheries have been implemented to assess the effectiveness of GIS in habitat analysis and complicated reservoir management, with an emphasis on the marine environment and lentic systems. Consequently, it is necessary to advance GIS applications in reservoir situations. Reservoir applications involve significant advancements in data collecting and visualization of three-dimensional data, collaboration across agencies and governments, understanding of reservoir properties, and improved methods of measuring water quality data. Gathering spatial data is essential for reservoir fisheries GIS applications. It is essential to determine the depth layers and classify the habitats to estimate potential fish distribution and fishing regions, including appropriate habitats for fish species and fishing activities. Water level variations have also significantly impacted fish distribution and fisheries in reservoirs. Fish population dynamics, including recruitment and spawning, are impacted by variations in water level. Planning and managing fisheries involve serious problems and several geographical components. The defining of fishing grounds, transportation networks, markets, habitat loss, and environmental degradation may all be categorized as spatial concerns. Spatial components are the migrations and movements of resources. Fisheries scientists, managers of aquatic resources, and decision-makers must thus tackle the issues with great difficulty, particularly in developing nations. By the way, with the use of several geographical components, GIS is a technology that may assist in understanding issues and lead to solutions. However, many individuals are either ignorant of or terrified of the technology and its possibilities for managing fisheries. For the past 15 years, aquaculture research has evaluated the suitability of coastal areas for farming operations using GIS. Aquaculture management issues including habitat availability, the many uses of estuarine waters, and research on how water quality affects the production of finfish and shellfish may all be studied using GIS. Additionally, GIS has been utilized to address frequent issues between aquaculture operations and marine duck habitats. FAO developed the website GIS Fish, which offers access to global information on remote sensing, mapping, and geographic information systems (GIS) as they pertain to aquaculture and inland fisheries. The US Fish and Wildlife Service, the US Geological Survey, and other federal and state organizations utilize GIS to help in conservation efforts. GIS is used in many aquatic scientific fields, including as oceanography, marine biology, stream ecology, aquatic botany, limnology, and hydrology. Applications include using satellite imagery to identify, monitor, and lessen habitat damage.

Research Objective

The main objective of this objective is to understand the application of Geographic Information Systems (GIS) in Mapping Fish Species Distribution and Taxonomic Data.

Literature Review

Researchers reveal that studies on the Meenachil River were made using GIS.GIS helps identify the geographical zones for this river. Researchers used the Kriging Interpolation Model to study the impact of monsoon season on the diversity of fish species in 2016(Cheriyan et al., 2023).studies explain that the interaction of fish species with fishery systems is evaluated using scientific research surveys. The data related to fisheries management is obtained from fisheries-based researchers, who reveal the behavioral patterns of different fish species. Fisher data obtained from fisheries surveys reveal information about the noninvasive species of fish found in the north Aegean Sea (Evangelopoulos et al., 2024).studies predict that ecosystem conservation is related to protecting ecosystem biotic components. The patterns of fish species living in the longitudinal section of the river are obtained through biogeography (Itsukushima, 2024).Studies claim that the degradation of aquatic ecosystems is due to various reasons. Climate factors influence the habitat degradation of fish species. The use of robust quantitative methods is preferable to assess the number of fish species found in the fresh water and to check their abundance (Jan, 2024).studies reveal that introducing fish species into a new aquatic ecosystem creates a biodiversity shift. The introduction of rainbow trout in the Himalayan ecosystem resulted in the overlap of brown trout with the native snow species. this overlapping of fish species in the same habitat results in the degradation of habitat(Jan et al., 2023). Studies suggest that some valuable fish species are extinct because of certain anthropogenic factors. These factors result in the decline of native fish species. A species distribution model is used to evaluate the distribution of catfish species in freshwater. after evaluation, these models provide reliable solutions to save fish habitat from anthropogenic factors (Kagayama & Oshima, 2023).studies conclude that in South African states, the FBIS promotes the strategy adopted by fish conservation and management teams to conserve fish species in aquatic ecosystems. FBIS is developed to provide information regarding the threatened species in the aquatic environment to conserve them(Kajee et al., 2023).studies explain that to evaluate the presence of native and nonnative fish species in the Volga-kama River the use of datasets is made in scientific research. This dataset provides details about the diversity found in nonnative and native species (Karabanov et al., 2023).scholars' studies predict that the distribution of aquatic species in marine ecosystems is determined through GIS. All the data regarding the dispersion of fish pollution in the ecosystem, as well as about their habitat, is predicted by a GIS technology-based system. The migration patterns of fish species also provide insight into their taxonomic background (Konaté & Etchian, 2023). Studies have claimed that the diverse changes in the aquatic ecosystem have resulted due to certain climatic changes because of the shift in climate conditions only a few fish species have survived and a large number of fish species has been designed. also, only a few endemic fish species are found in CAE(Korkmaz et al., 2023).studies show that diverse changes in climate have impacted the *tridacna maxima* Species found in the aquatic ecosystem. Understanding this species' spatial distribution pattern makes it easier to conserve this species. The species distribution model is effective for creating conservation strategies to save endangered species from drastic climatic shifts(Liu et al., 2024). Also, the diversity of freshwater species is greatly impacted by climatic shifts. fish species move from one ecosystem to another to protect themselves from sudden changes in the acquired environment. The adaption of endemic species to special ecosystems is due to their ability to showcase fewer trait fluctuations(Masoumi et al., 2024). The use of SDMs is preferable for determining the distribution of species using oceanographic data. The impact of changes in climatic conditions on fish species occurrence and abundance is predicted by SDMs. SDMs are renowned for their efficacy in providing strategies for future species conservation (Matthews, 2023).Scholars' studies conclude that information about the location and distribution of coral reef species is essential to prioritize activities for their conservation. Different models are used to determine the spatial distribution of coral reef species in the Indian Ocean (McClanahan et al., 2024).The data obtained from GIS predict that some IAS species have been introduced into freshwater to study the impact of the introduction of nonnative species in a habitat (Mohd Dali et al., 2023).studies suggest that the species distribution model is used to determine the presence of queen snapper in aquatic ecosystems. the movement of finfish in water is determined through SDMs(Overly & Lecours, 2024).taxonomical studies are made using GIS. The exact location of species underwater is predicted using GIS. The visualization of species in the aquatic environment is explained through their distribution patterns. Mapping the whole aquatic ecosystem using GIS helps determine the taxonomic history of species (Padua, 2024).Studies show that fisheries-based programs have been developed to make the conservation of fish species effective. The AHP concept is utilized to study reef-based seafood. The selection of the marketplace for seafood is studied using GIS (Peralta-Milan et al., 2024).The digitalization process has eased the taxonomic classification of species. Imaging technology is a digitalized technology used to detect the exact presence of fish species in the big sea. Digital technology provides details about the morphological features of fish. each fish species is unique and has different morphological features from other species. information regarding each unique aquatic species provides insight into the species' taxonomic history, making its conservation process easy (Rivot, 2023).Studies suggest that coral reefs are the most diversified species on earth. Certain factors degrade coral reef habitats. These factors include human activities and climatic factors. RECIFS is a technology-based system that provides data about the pollution of coral reefs. large geo-taxonomic data regarding coral reefs are used to make conservation strategies for future coral reef protection (Selmoni et al., 2023).Studies explain that Colombian fishery sectors use SDM to create effective guidelines for protecting the species found in the Colombian Sea. understanding the distribution patterns of species in Colombia's sea makes it easier to develop effective management strategies for fisheries. also, the decision-making process for formulating community guidelines is controlled by SMD (Selvaraj et al., 2023).

Geographical Information Systems (GIS)

A Geographic Information System (GIS) is a computer program that analyses and displays data with a geographic reference. It makes use of data associated with a certain location. A GIS analysis may show, for example, that a rare plant that is found in three different places is all situated on north-facing slopes higher than 1,000 feet and receives more than 10 inches of precipitation per year. GIS maps may then display all of the locations in the area with similar conditions, assisting researchers in locating more of the rare plants. Based on the geographic position of farms using a certain fertilizer, GIS analysis of farm sites, stream locations, elevations, and rainfall may identify which streams are most likely to carry that fertilizer downstream. The increase in the world's population, technological advancements, and the growing demand for seafood have all contributed to the overfishing of marine fisheries in recent decades. Marine fisheries are working towards achieving the degree of sustainability that will ensure their long-term existence, while also tackling problems such as overfishing, overcapitalization, stock depletion, bycatch and discards, IUU fishing, climate change, fishing disputes, pollution. Fisheries managers must collect and integrate a large quantity of data from several sources to make management choices since they have to cope with an increasing number of difficult problems due to natural and man-made disturbances. This necessity led to developing geographic information system (GIS) applications for managing maritime fisheries. Geographic information systems (GIS) may be used to combine many forms of geographic data, such as digital maps, satellite photographs, aerial photography, and GPS data. It used to be challenging to map the distribution of resources from big data sets. New mapping techniques for massive data interpretation have been developed due to the shortcomings of conventional cartography techniques for mapping and documenting resource distribution over a large geographic area with abundant resources. Cartography was later improved for mechanization and use through computer graphics, computer-aided design, and computing advancements. Many organizations invested significant funds in further computer mapping research in the 1970s, including GRID and GEOMAP, as well as Harvard University's SYMAP project. Because of the enormous potential of this technology, the first private, commercial software companies released GIS in the 1980s. According to studies, GIS is a collection of computer technology, software, data, and people used to collect, store, update, alter, analyze, and display information connected to space. It is possible to gather and enter data into the system for any problem, location, or time frame. The degree of fishing pressure, the sensitivity of ecosystems and species when determining whether to introduce or reduce fishing fleets, the rationalization of fishing operations, the seasonal and spatial closure of fisheries, and other challenges may all be addressed by GIS-based mapping. Maps make up the majority of GIS output, while tabular, statistical, or graphical representations are also possible. Through graphical representations, GIS helps managers make decisions by allowing them to investigate novel concepts and resolve geographical issues involving complex environmental linkages. (GIS) is now a crucial component of limnology and aquatic science. Water is dynamic by definition. Water-related features are, therefore, constantly evolving. Technology breakthroughs have enabled scientists to improve every facet of scientific research, from computer mapping of environments to satellite surveillance of species, to keep up with these changes.

Figure 1: Geographical Information Systems (GIS)

Geographic Information System (GIS) Mapping in Fisheries

A scholar completed most of the early work on GIS, and the first use of the technology was in the Gulf of Nicoya on Costa Rica's Pacific coast in the mid-1980s. They found that managing small bodies of water for fisheries and aquaculture in northeastern Zimbabwe may be done inexpensively using remote sensing and geographic information systems. It is discussed that the value of resource mapping, especially in developing nations' new exclusive economic zones, and the usefulness of fisheries thematic mapping in the context of fisheries generally. Additionally, they acknowledged that resource mapping is a crucial first step in developing fisheries resource management plans, coastal planning, research vessel surveys, statistical and information-gathering systems, and environmental impact assessments. In the 1990s, GIS applications about fisheries and aquaculture grew in scope, encompassing atlases, habitat mapping, marine ecosystem productivity mapping, fisheries management, and human impacts on fishery ecosystems. It states that almost half of the GIS work focused on marine fishing difficulties to balance aquaculture and inland fisheries. Scholar used the proportional mapping method to map the number of fish caught in each area of African nations; larger circles denoted more significant catch. It is examined that the spatiotemporal distribution patterns of cuttlefish abundance and the connections between their abundance and environmental factors on the Atlantic coast and nearby waters using statistical methods and geographic information systems. They observed that during mild winters, the center of high abundance in offshore deepwater shifted from south to north. Using trawl surveys, mature females and juveniles of Octopus vulgaris were examined and mapped using spatial indicators and geo statistics to describe the main aspects of the recruitment and spawning phases off the coast of southern Morocco between 1998 and 2003 (Faraj & Bez, 2007). It was easy to discern the spatial patterns of the recruiting and spawning phases: juveniles were patchier, less regionally spread, more anisotropically distributed, and more dispersed along the coast. Additionally, they discovered that the Dakhla stock's geographical distribution differed from that of the other stocks of the same species in different settings.

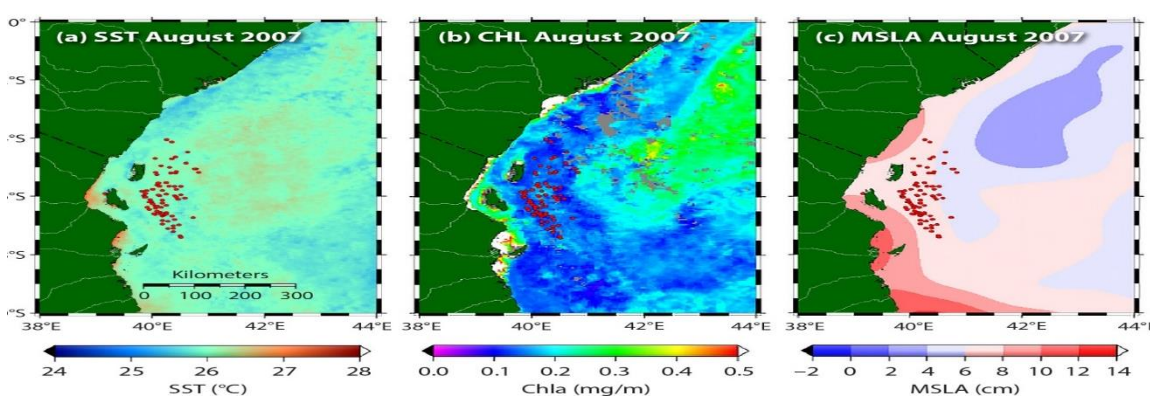

Figure 2: Geographic Information System (GIS) Mapping in Fisheries

GIS and Fish

Due to the challenge of acquiring spatial data on habitats or creatures in underwater environments, GIS was not previously a viable source of analysis. The development of hydroacoustic telemetry, side-scan sonar, and radio telemetry has allowed researchers to follow fish species and build databases that may be used to generate a geographical representation in a GIS application. Using radio and hydroacoustic telemetry, biologists may find fish and obtain relevant data for those locations, such as substrate samples, temperature, and conductivity. Biologists can map the bottom of a river using side-scan sonar to get an idea of potential habitats that are exploited. The distribution of fish and their habitats may be shown by superimposing these two data sets. The pallid sturgeon has been studied using this approach.

Large volumes of data are gathered over time and may be utilized to monitor migratory patterns, spawning sites, and preferred habitats. Previously, this data would be manually mapped and superimposed. This data may now be stacked, arranged, and analyzed in a previously impossible way by entering it into a GIS application. A GIS program's layering feature enables a scientist to examine many species simultaneously to identify potential watersheds that these species share or to single out one species for more research. In collaboration with other organizations, the US Geological Survey (USGS) was able to map the pallid sturgeon habitat regions and migratory patterns with the aid of GIS. To monitor sturgeon movements and expedite data gathering, the Columbia Environmental Research Centre uses a customized version of ArcPad and ArcGIS, both ESRI (Environmental et al. Institute) programs. A relational database was created to handle tabular data for every single sturgeon, including initial catch and reproductive physiology. It is possible to make movement maps for certain sturgeon. These maps make it easier to follow each sturgeon's path throughout time and place. This made it possible for these researchers to plan and prioritize the work of field staff in order to monitor, map, and recapture sturgeon.

Figure 3: GIS and Fish

GIS and Macrophytes

They give fish, animals, and other species food, shelter, and habitat. Invasive species that coexist in our ecosystem are just as interesting as naturally existing ones. Agencies and their respective resource managers are modelling these significant macrophyte species using GIS. Resource managers may use GIS to evaluate the distributions of this significant feature of aquatic habitats on a regional and temporal scale. Among the numerous potential applications of GIS is the capacity to monitor changes in vegetation across time and place to forecast such changes. Resource management requires accurate maps of the distribution of aquatic plants in an aquatic ecosystem. The potential presence of aquatic vegetation can be predicted. For example, by creating a statistical model that determines the likelihood of submerged aquatic vegetation, the USGS has developed a model for the

American wild celery (Vallisneria americana). To make their model predictions available online, they connected to the *Submersed Aquatic Vegetation Model ArcGIS Server website from the Environmental Systems Research Institute (ESRI). By establishing human avoidance zones, these projections for the distribution of submerged aquatic plants may impact foraging birds. Birds can be allowed to feed unhindered if the locations of these spots are known. Managers can be informed when it is anticipated that the aquatic vegetation in these significant wildlife habitats will be scarce in a given year. Resource managers now have serious conservation concerns about invasive species. Managers can map plant locations and abundances using GIS. The threat posed by these invasive plants may then be assessed using these maps, which will also assist managers in choosing control tactics. Surveying these species and then downloading the results into a GIS program is possible. In addition, native species might be incorporated to ascertain how these ecosystems react to one another. By comparing biological parameters, GIS models might forecast future breakouts using known data on existing invasive species. GIS is being used to assess risk variables by the Connecticut Agricultural Experiment Station Invasive Aquatic Species Program (CAES IAPP). Managers can geo reference the locations and quantity of plants using GIS. This makes it possible for managers to analyze and control invading groups by displaying them next to native species.

Implications

1. Stream fish and decapod spatial occurrence data from a national database and current surveys were merged with geospatial land use, geomorphologic, climatic, and spatial data in a geographical information system (GIS) to model fish and decapod occurrence in the Wellington Region, New Zealand. 2. In a single operation, we developed a single model that predicted the whole fish and decapod assemblage. Using a shared set of predictor factors, we employed a multi-response artificial neural network (ANN) to predict each species' arrival at a site. 3. The predictions made by the ANN using this landscape size data proved to be very accurate based on assessment metrics that were not affected by species abundance or probability thresholds. The projections were significantly impacted by the latitudinal and elevational position of the site reach, the size of the catchment, the average air temperature, the kind of plant, the proportions of land use in the catchment, and the geology of the catchment. 4. A habitat-suitability map for each of the 14 species across the regional river network was then produced using a GIS and the geospatial data available for the whole network. Monitoring and forecasting temporal changes in fish communities brought on by human activity and climate change, locating areas that require protection, biodiversity hotspots, and areas that are appropriate for the reintroduction of rare or endangered species are just a few of the many possible applications for this prediction map.

Applications of Geographic Information Systems (GIS)

Future research should use GIS for reservoir fishery management to evaluate the effects of humans on fish population dynamics and reservoir dynamics. Relationships between fish species and their surroundings should also be examined, as should intraspecific or interspecific interactions like prey/predator competition. For a deeper comprehension of the interactions in reservoir dynamics, Estimating the size, relative abundance, presence or absence of fish species, and suitable habitats for fish populations are also crucial. Thus, the location of preferred and essential fish habitats, the impact of terrestrial land uses on aquatic fish habitat and water quality, the area of different habitats at different water levels, biodiversity assessment, the identification of sport/commercial fishing zones with respect to aquatic fauna and flora, and animal movement monitoring all require the use of GIS. In conclusion, there is almost no limit to the possibility of using GIS in reservoir fisheries management applications. GIS plays a major role in both the sustainability of fish species and the sustainable use of water resources in reservoirs. Modelling fish distribution, abundance, and habitat, projecting future capacity, and assessing the functional life of reservoirs are all made possible by GIS. Increasing the opportunity for fisheries scientists to learn, gain experience, and use relevant GIS data and technology might enhance this potential. Numerous spatial dynamics, including fish population migration and movement, habitat categorization, and fishing area classification, are part of fisheries management. Other significant topics, such as habitat loss and environmental degradation, also have spatial aspects. Decision-makers, scientists, and managers of fisheries and aquatic resources must thus address the complexity issue. By taking into account a variety of geographical factors, GIS helps to clarify the problems and makes solutions feasible in this situation. Thus, GIS has enormous promise for managing fisheries in reservoirs.

Conclusion

GIS solutions may save billions of dollars a year by using appropriate route planning to deliver products and services. The daily management of numerous natural and man-made resources, such as transportation, power, water, and sewer networks, is frequently aided by GIS. GIS applications in the study of marine and coastal ecosystems are a new area of study. GIS-based marine geographical interpretation has emerged as a key instrument for marine conservation, planning, and policymaking. For the administration and use of marine environments, including maritime transportation, fishing, recreation, waste disposal, and conservation, GIS is essential to the collaboration of organizations in several international agreements. GIS is the most promising technology for resource availability analysis, despite the fact that several others are being developed.

GIS aids in assessing the environmental health of river and lake basins, determining the potential for food fisheries, and allocating resources between aquaculture development and fishery management. It also aids in determining the magnitude, location, and cause of harmful environmental effects. We can create workable plans for tracking, controlling, and minimizing environmental harm due to GIS. The federal government should implement a cooperative initiative with the state governments through their remote sensing centres and universities to use GIS tools in the fishing industry. Such a project should be approved and funded by the Planning Commission's National Remote Sensing Agency and Space Application Centre. While there have been relatively few studies conducted in the inland sector, a number of GIS-based research have been conducted in the maritime sector. In order to maximize output potential, more attention should be paid to the use of GIS in the inland fishing industry.

References

Adekayode, F. (2006). Application of geographic information systems (GIS) in mapping soils of Owena forest reserve, Southwest Nigeria. *Nigerian Journal of Soil Science, 16*, 35-42.

Arunkumar, A. A., Manimekalan, A., Manikandan, V., & Velmurugan, P. (2015). Fish species richness and habitat quality mapping with geographical information system across Cauvery River in Tamil Nadu, India. *Journal of Aridland Agriculture● Vol, 1*, 1.

Board, W. R. C., Shiels, M. A., Carline, R. F., & Stauffer Jr, J. R. (1998). Application of Geographical Information System Technology to Fish Conservation in Pennsylvania Phase I.

Cheriyan, L. P., Appukuttan, A., & Oommen, M. (2023). Geographic Information System-based Analysis of Fish Diversity Trends of River Meenachil, Southern Western Ghats, Kerala. *Current World Environment*, *18*(1), 311-330.

Evangelopoulos, A., Karampetsis, D., Christidis, A., Gubili, C., Sapounidis, A., Adamidou, A., Kamidis, N., & Koutrakis, E. (2024). Non-native fish species in the North Aegean Sea: a review of their distributions integrating unpublished fisheries data. *Frontiers in Marine Science*, *11*, 1398037.

Itsukushima, R. (2024). Longitudinal distribution of fish fauna and characteristics of indicator species in the East Seto Inland Ecological Region within the Japanese Archipelago. *Limnologica*, *107*, 126187.

Jan, A. (2024). Predicting Species Distribution in Freshwaters Facing Climate Change and Biological Invasions Using Ecological Niche Models.

Jan, A., Arismendi, I., Giannico, G., & Flitcroft, R. (2023). Habitat overlap among native and introduced cold-water fishes in the Himalayas. *Scientific reports*, *13*(1), 15033.

Kagayama, S., & Oshima, T. (2023). Current status evaluation of an endangered freshwater bagrid catfish using species distribution modeling in Chiba Prefecture, Japan. *Japanese Journal of Environmental Entomology and Zoology*, *34*(2), 47-56.

Kajee, M., Henry, D. A., Dallas, H. F., Griffiths, C. L., Pegg, J., Van der Colff, D., Impson, D., Chakona, A., Raimondo, D. C., & Job, N. M. (2023). How the Freshwater Biodiversity Information System (FBIS) is supporting national freshwater fish conservation decisions in South Africa. *Frontiers in Environmental Science*, *11*, 1122223.

Karabanov, D. P., Pavlov, D. D., Dgebuadze, Y. Y., Bazarov, M. I., Borovikova, E. A., Gerasimov, Y. V., Kodukhova, Y. V., Mikheev, P. B., Nikitin, E. V., & Opaleva, T. L. (2023). A Dataset of Non-Indigenous and Native Fish of the Volga and Kama Rivers (European Russia). *Data*, *8*(10), 154.

Konaté, S., & Etchian, O. (2023). Spatial Analysis of Fish Distribution Patterns: Integrating GIS and Taxonomic Data for Insights. *FishTaxa-Journal of Fish Taxonomy*, *27*.

Korkmaz, M., Mangıt, F., Dumlupınar, İ., Çolak, M. A., Akpınar, M. B., Koru, M., Pacheco, J. P., Ramírez-García, A., Yılmaz, G., & Amorim, C. A. (2023). Effects of Climate Change on the Habitat Suitability and Distribution of Endemic Freshwater Fish Species in Semi-Arid Central Anatolian Ecoregion in Türkiye. *Water*, *15*(8), 1619.

Liu, S., Li, T., Cong, B., Yang, L., Zhang, Z., & Zhao, L. (2024). Unveiling the suitable habitats and future conservation strategies of Tridacna maxima in the Indo-Pacific core area based on species distribution model. *Ecology and Evolution*, *14*(9), e70187.

Masoumi, A. H., Esmaeili, H. R., Khosravi, R., Gholamhosseini, A., Korkmaz, M., & Jeppesen, E. (2024). Species on the move: Impacts of climate change on the spatial range of endemic fishes of the eco-sensitive semi-arid area of the Arabian Peninsula. *Science of the Total Environment*, *947*, 174095.

Matthews, K. (2023). Improving Species Distribution Models of Continental Shelf Fishes off California.

McAllister, D. E., Schueler, F. W., Roberts, C. M., & Hawkins, J. P. (1994). Mapping and GIS analysis of the global distribution of coral reef fishes on an equal-area grid. In *Mapping the diversity of nature* (pp. 155-175). Springer.

McClanahan, T., Friedlander, A. M., Chabanet, P., Bruggemann, J., Wickel, J., & Azali, M. (2024). Modeling the spatial distribution of numbers of coral reef fish species and community types in the Western Indian Ocean faunal province. *Marine Ecology Progress Series*, *730*, 59-78.

Miller, J. (2012). *Geographic information system techniques for the mapping of access routes, habitat suitability and variations in the distributions of common carp (Cyprinus carpio) throughout Malheur National Wildlife Refuge*

Mironga, J. M. (2004). Biodiversity mapping in Kenya: the use of geographic information systems (GIS). *Biodiversity*, *5*(3), 16-25.

Mohd Dali, M. Z., Umar, R., Ismail, N., Juahir, H., Mohd Nasir, M. S. A., Khaleel, A. G., Madiran, N. A., Abdul Kari, Z., Wei, L. S., & Tahiluddin, A. B. (2023). Detection and management of freshwater invasive alien species through environmental DNA analysis and Geographic Information Systems: a review. *Sustainability*, *15*(12), 9497.

Overly, K. E., & Lecours, V. (2024). Mapping queen snapper (Etelis oculatus) suitable habitat in Puerto Rico using ensemble species distribution modeling. *Plos one*, *19*(2), e0298755.

Padua, S. (2024). Mapping for taxonomic studies.

Peralta-Milan, S., Baba, O., & Salmo III, S. (2024). Application of the Analytic Hierarchy Process and Geographic Information System in Selecting Sites for a Seafood Market Study. *The Philippine Agricultural Scientist*, *107*(1), 1.

Rivot, W. B. (2023). Fish taxonomy in the digital age challenges and opportunities. *FishTaxa-Journal of Fish Taxonomy*, *30*.

Robertson, D. R. (2009). Shorefishes of the Tropical Eastern Pacific online information system. Proceedings of the Smithsonian Marine Science Symposium,

Santos, N. R., Katz, J. V., Moyle, P. B., & Viers, J. H. (2014). A programmable information system for management and analysis of aquatic species range data in California. *Environmental Modelling & Software*, *53*, 13-26.

Scott, L. E. P. (2001). *The development of a geographic information systems based atlas of southern African freshwater fish, and its application to biogeographic analysis* Rhodes University].

Selmoni, O., Lecellier, G., Berteaux-Lecellier, V., & Joost, S. (2023). The Reef Environment Centralized InFormation System (RECIFS): An integrated geo-environmental database for coral reef research and conservation. *Global Ecology and Biogeography*, *32*(5), 622-632.

Selvaraj, J. J., Cifuentes-Ossa, M. A., Penna-Narvaez, J., Miranda-Parra, M. A., & Herrera-Rozo, F. A. (2023). Species Distribution Models as Tools for Community Empowerment and Informed Decision Making in Colombia’s Chocó Pacific Coast Fisheries. *Fishes*, *8*(7), 349.