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Recent Approaches Using GIS in the Spatial Analysis of Fish Populations

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Abstract

Geographical information systems (GIS) are information systems that can store, analyze, and graphically represent complex and diverse data with spatial attributes. Considering that GIS are rapidly emerging as the analytical tool of choice for investigating spatially referenced fish population dynamics and assisting in their management, it was deemed appropriate to review the state of research within this field and provide examples of current applications. Areas of research that we investigated included databases, visualization and mapping, fisheries oceanography and ecosystems, georeferenced fish population dynamics and assessment, space-based fisheries management, and software. The enhanced analytical functionality offered by GIS, coupled with their optimized visualization capabilities, facilitates the investigation of the complex spatiotemporal dynamics associated with fish, fisheries, and their ecosystems. This paper reviews current GIS research and its application to spatially oriented fisheries management, and illustrates the necessity of carefully evaluating and selecting appropriate GIS approaches for different fishery resource scenarios.

Introduction

There is an increasing awareness by fisheries scientists of the importance of the spatial component within their data. Spatially referenced information is highly dimensional (≥3D) and the data voluminous, often impeding investigation and analysis. This difficulty has been somewhat relieved by increases in computing performance, data storage capacities, and database management systems, and also by new computationally intensive spatial analysis tools. As a consequence, geographical information systems (GIS) are now recognized as the tool of choice in a variety of disciplines when addressing spatially referenced problems (Star and Estes 1990, Maguire et al. 1991). Geographical information systems differ from traditional information systems because they present the opportunity to store, process, analyze, and graphically represent complex and diverse data with spatial attributes within a problem-solving environment (Dueker 1979, Smith et al. 1987, Maguire 1991).

Geographical information systems are frequently used by various disciplines and it is, therefore, not surprising that GIS technology is now being incorporated into the fishery sciences (Giles and Nielsen 1992, Simpson 1992, Li and Saxena 1993, Meaden 1996). For this reason, we review current GIS research and its application to spatially oriented fisheries management, and illustrate the necessity of carefully evaluating and selecting appropriate GIS approaches for different fishery resource scenarios. This paper outlines the background and history of GIS in fisheries management, and describes recent developments in databases, applications, and software. Prospects for the future are discussed, as well.

Background and History

Geographical information systems were developed in the 1960s in terrestrial management fields when sufficient spatially referenced information became available. Geographical information systems are now widely applied in primary and secondary industry, engineering, town planning, and waste management (Marble et al. 1984, Smith et al. 1987, Star and Estes 1990, Maguire et al. 1991). From both fisheries resource research and management perspectives, the application of GIS has been slow, only being adopted in the 1980s. Early applications focused on the management of inland, nearshore, and coastal fisheries (Caddy and Garcia 1986, Simpson 1992, Meaden 1996, Meaden and Do Chi 1996) and aquaculture (Kapetsky et al. 1987, 1988; Meaden and Kapetsky 1991). This was mainly due to the availability of spatial information in these zones obtained mainly from satellite imagery. Although fisheries applications gradually expanded to offshore waters, covering all of the oceans by the 1990s, the number of marine applications is still limited when compared to the terrestrial realm (Table 1).

Caddy and Garcia (1986), Meaden and Kapetsky (1991), Simpson (1992), Meaden and Do Chi (1996), Meaden (1996), and Booth (2000a) outline three issues that have hampered the growth and implementation of fishery GIS. The first is financial, associated with the costs to collect aquatic biological, physicochemical, and sediment data. These costs, together with extra costs related to synthesizing large spatial databases into a useable format, have

Table 1. Stages in the growth of GIS applications to spatial-oriented fishery research and management (adapted from Meaden 2000).

Stage	Characteristics	Dates	Motivation
1	Tentative emergence; very slow growth; mainly used in inland water fisheries management and aquaculture site selection (inland to inshore).	1984-1990	Developments in remote sensing; GIS work at FAO; imitation of other terrestrial GIS activities.
2	Accelerating growth into a wider range of fishery fields (inshore to off-shore).	1991-1997	Increased opportunities through the development of more powerful PCs and certain publications.
3	Consolidation and expansion into more fields. Wider interest base (offshore to distant waters).	1997 →	Data availability and storage; increasing publicity and needs for recognition.

Note: It is too early to determine whether Stage 3 is simply an extension of Stage 2, though there appears to be a leveling off in the publication rate.

hindered the development of aquatic, and in particular marine, GIS. These costs alone (ignoring the costs associated with the training and employment of personnel) are often prohibitive, restricting GIS to developed countries or large commercial concerns. The second reason concerns the dynamics of aquatic systems. Aquatic systems are more complex and dynamic than terrestrial domains and, therefore, require different types of information, both in terms of quality and quantity. The aquatic environment is typically unstable and needs to be recognized as a 3D (spatial) or even a 4D (spatiotemporal) domain. Mapping 4D information (3D + time) is difficult and is often not tackled for this reason. Third, while many commercial software developers have incorporated advanced statistical tools into their packages, there has always been a terrestrial bias, particularly with regard to systems developed for commercial applications. As a result, no effective GIS software is available for handling both fisheries and oceanographic data as it involves resolving problems associated with database storage and graphical representation of heterogeneous vector and raster data sets.

Current Situation

Databases

Meaden (2000) compared the existing problems and inherent complexities of fisheries and oceanography databases to terrestrial systems. Most terrestrially developed GIS are 2D and fewer are 3D (at most 2.5D when surface modeling), thus lack true spatiotemporal (4D) capabilities required for marine applications. As a result, we therefore need to develop 3-4D oriented GIS for fisheries and oceanographic applications. Ocean-based data are usually extremely expensive to collect, thus large agencies are required to collect and share data. Additional funding is required for fisheries/ocean mapping (GIS) and monitoring. There is a clear need to standardize and consolidate data collection structures and database design to adjust for discrepancies in space and/or time. User-friendly and accessible tools are required to convert analog data to digital data, and to process matrix (raster) information. Easier access to oceanographic and satellite information is required together with the establishment of 3-4D database links to GIS.

Application

In order to assess the current situation and progress in GIS, recent applications were carefully reviewed and classified into following four categories: visualization and mapping of parameters related to fisheries resources, fisheries oceanography and their ecosystems, georeferenced fish resource analyses, and space-based fisheries management. Figure 1 illustrates the relationships among these categories.

Visualization and Mapping

Mapping to study habitat and biodiversity is the most basic and common research area to which marine GIS work has been applied. It has been proposed that basic mapping does not constitute a GIS (Booth 2000a), rather it is the generation of secondary data and their analysis that sets it apart from computer mapping or computer-aided design. In a broad sense, univariate mapping is a basic GIS component because advanced GIS analyses are conducted by integrating variables into a multivariate analysis. Geographical information systems have been developed that focus on mapping, atlasing, and exploratory data analysis to obtain a better understanding of the correlations between the distribution and abundance of fish, other species, abiotic and biotic covariates (Skelton et al. 1995, Booth 1998, Fisher and Toepfer 1998, Scott 2000). These analyses are used in further analyses within the system that include generalized additive and linear modeling and coverage overlaying (Booth 1998) and correlation analysis (Waluda and Pierce 1998). Geographical information system overlays of water bodies and road systems are also being used to expedite identification of accessible stream reaches in river basins for biological sampling (Fisher et al. 2000).

Understanding habitat, distribution, and abundance are important issues in fisheries management, especially in the United States, due to the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act requiring amendments of all U.S. federal fisheries management plans to describe, identify, conserve, and enhance essential fish

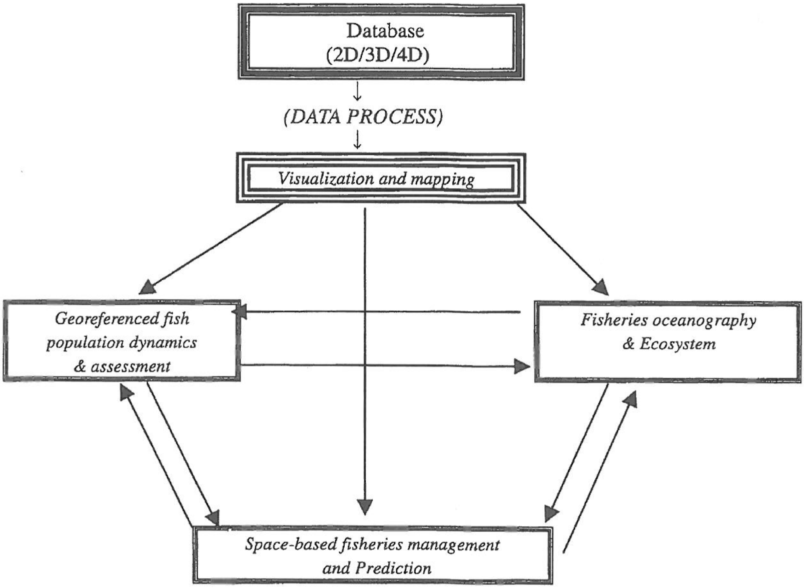

Figure 1. *Relationships among four types of spatial analyses of fish populations using GIS. (Note: These four areas frequently overlap.)*

habitat (EFH). The designation of an EFH will involve the characterization and mapping of habitat and habitat requirements for the critical life stages of each species. In addition, threats (including damage from fishing gear) to EFHs need to be identified, and conservation and enhancement measures promoted. Geographical information system technologies are essential for the successful implementation of this new fisheries management target, particularly in the initial characterization of habitat, the spatial correlation of potential threats with habitat, the evaluation of cumulative impacts, and the monitoring of habitat quality and quantity. Habitat mapping, modeling, and the determination of EFH are now commonly addressed within a GIS framework (Booth 1998, Fisher and Toepfer 1998, Parke 1999, Fisher et al. 2000, Nishida and Miyashita 2000, Ross and Ott 2000).

Fisheries Oceanography and Ecosystems

Fisheries oceanography and ecosystem science refer to that research area relating to spatial relationships among fish, fisheries, oceanography, and ecology. Knowledge obtained through these studies will, therefore, be critical in achieving an ethos of "responsible fishing" and facilitate optimal fisheries management practices (FAO 1995). Since its adoption, the world's fishing nations are gradually promoting sustainable fisheries, protecting their resource bases, and attempting to maintain ecosystem health.

The development of GIS to understand the functional relationships between fisheries and ecosystems is still in the pilot or planning stages. Edwards et al. (2000) addressed ecosystem-based management of fishery resources in the northeastern U.S. shelf ecosystem. The objective of their research was to determine whether the management of marine fisheries resources in the northeastern region of the United States was consistent with ecosystem-based management for an aggregated sustainable yield of commercially valuable species. In their study, a GIS was used to display and analyze spatial data for investigating ecosystem-based management of fisheries resources. Distributions of species, fishing effort, and landing revenues based on 10-minute squares over Georges Bank during a 3-year period were spatially analyzed. Similar maps of fishing effort by gear (fish trawls and scallop dredges) suggest the scope for likely bycatch. An indication of the economic importance of the groundfish areas closed to other fisheries, especially to the Atlantic sea scallop (*Placopecten magellanicus*) fishery, is suggested by revenue coverages. As a result, GIS could well handle the spatial analysis of ecological, technological, and economic relationships and could facilitate reviews of management plans for their consistency with ecosystem requisites. An essential component of this study is a clear understanding of the spatial distribution of interactions among species, fishing effort, and technologies, and markets for fisheries products. Edwards et al. (2000) concluded that GIS will be the only tool for such complex spatial analyses and the research is now progressing with this particular objective.

An interesting GIS area that has scope for development is the linkage of ecosystem-fisheries research with the use of the model ECOPATH (Pauly et al. 1999). ECOPATH can handle numerical evaluations of ecosystem impact of fisheries and can conduct simulations of dynamics among ecosystem elements (trophic interactions in the food web) to provide an overview of the mechanism of marine ecosystem changes depending on fishing effort. If the results of the simulations could be visualized by GIS, more comprehensive spatiotemporal changes of ecosystem members could be portrayed; e.g., changes of biomass, consumption and production rates, diet composition, habitat preferences, and movement rates. With the addition of spatial analytical methods, "ECOSIM/ECOSPACE" has been developed and is being used to investigate a marine ecosystem study off the west coast of Florida (Ault et al. 1999).

Little research has been published concerning migration dynamics using GIS. Saitoh et al. (1999) studied the migration dynamics of the Japanese saury (*Cololabis saira*) by investigating the relationships between oceanic conditions and saury migration patterns through the observation of the movement of pursuing fishing vessels obtained from satellite imagery. The results of overlaying of sea surface temperature (SST) data with fishing boat movement along the Oyashio front clearly indicated the migration dynamics of the Japanese saury.

Kiyofuji et al. (2000) studied the spatial and temporal distribution of squid fishing boats using visible images from the Defense Meteorological Satellite Programs (DMSP) and from the Operational Linescan System (OLS). The relationship between SST obtained from Advanced Very High Resolution Radiometer (AVHRR) developed by the National Oceanic and Atmospheric Administration (NOAA) and fishing boat distribution was also investigated. The preliminary conclusion was that by applying marine GIS, visible images using DMSP/OLS could provide both the position where fishing boats gather and the relationship between fishing boat location and SSTs.

A GIS can easily analyze remote-sensed data. Sampson et al. (2000) provided a numerical assessment of two types of kelp (*Ecklonia maxima* and *Laminaria pallida*) biomass off the West Cape coast of South Africa. High concentrations of kelp occur along this coast in relatively pristine conditions. In recent years, the importance of this resource has been emphasized in relation to its use in alginate extraction and as a commercially highly valuable food source for abalone. Therefore, there is a distinct need to manage this resource, including obtaining estimates of absolute biomass. Sampson et al. (2000) compared past photographic (qualitative) and new quantitative GIS methods. Results showed that the biomass of surface kelp had been overestimated, on average, by 230% using the old methodology. The GIS method based on remote sensing inputs, proved to be a more successful tool in mapping and estimating the biomass of the kelp and it is being modified to model the amount of alginate and abalone that can be produced per year.

A similar system developed by Long et al. (1994b) used aerial photography to identify and delineate seagrass beds, and to estimate seagrass biomass after digitization. Welch et al. (1992) approached coastal zone management using data from image analysis and aerotriangulation to build up a time series of changes in salt marshes. Their GIS, using thematic overlaying and Boolean logic, quantified and visualized changes induced through human impact over a 40-year period. Exciting progress is also being made using 3D GIS to improve our understanding of fish distribution and abundance using hydroacoustics and echo-integration (Wazenböck and Gassner 2000).

Warning et al. (1999) used a GIS to investigate the basic ecological characteristics of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) habitats in shelf-edge and deeper waters off the northeastern United States. Using sighting data and corresponding information on bathymetry, slope, oceanic fronts, and SST, logistic regression analyses was conducted to determine that the distribution of sperm whales was more dependent on depth and slope, while that of beaked whales was more dependent on SST.

Georeferenced Fish Resource Assessment

The need to manage fisheries from a spatial perspective is clear (Hinds 1992). Few attempts, however, have been made to incorporate the spatial variability of stocks' age-structure, maturity, and growth patterns together with catch and effort data into an assessment framework. Commercial catches are georeferenced, with fish being harvested at specific geographic locations as a function of the fishing effort and stock abundance at that location. By neglecting this spatial component, existing assessment models evaluate the status and productivity of the stock based on pooled catch-at-age data, fisheries-independent survey indices, and key population parameters.

Spatially referenced stock assessment has only recently been attempted. Currently, there is a growing interest in the development of marine GIS, both to visualize these spatial data sets and to provide a platform for further stock assessments and forecasting. As a result, a GIS incorporating spatially referenced fisheries data and assessment models would contribute significantly toward integrating this with other data sources and providing quantitative and qualitative management advice, and therefore to consequently improving integrated resources management.

Booth's (1999, 2000b) studies correlated fishing effort with observed age-structured fishing mortality to present a spatial perspective of the status of the resource. Yield-per-recruit modeling was expanded in Maury and Gascuel's (1999) study providing insight into spatial problems inherent to the delineation of marine protected areas and how these might affect fishing operations. These models encapsulate three fundamental aspects to fisheries modeling, all of which are spatiotemporally explicit: the environment, the fish stock, and the fishing fleet.

Corsi et al. (2000) applied an equilibrium biomass production modeling approach to assess the abundance of the Italian demersal resources as a function of spatially distributed fishing effort. Peña et al. (2000) further simplified the stock dynamics model and used a GIS to estimate the nominal yield of jack mackerel (Carangidae) using fishing ground information, and observed yield and sea surface temperature gradients. Using real-time fishing catch and location data, together with near-real-time satellite imagery, a transition probability matrix was used to calculate nominal yields at various thermal gradients. A low-level GIS used by Cruz-Trinidad et al. (1997) conducted a cost-return analysis of the trawl fishery of Brunei Darussalam, south of the Philippines, where optimal fishing patterns were determined using profitability indicators under various economic and operational scenarios. Walden et al. (2000) also developed a simple, yet real-time, GIS for the New England groundfish fisheries. This GIS evaluated various possible fine-scale time-area closures to assess the projected mortality reductions and losses in revenue of three principal demersal fish species: Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and yellowtail flounder (*Pleuronectes ferrugineus*).

Several studies have addressed the estimation of population size from fisheries-independent surveys using GIS. Nishida and Miyashita (2000) estimated age-1 southern bluefin tuna (*Thunnus maccoyi*) recruitment, using information obtained by omni-scan sonar. In their study, a linear relationship was estimated between the strength of the Leeuwin Current into the survey area and the average school size as recorded by the sonar. They noted that young southern bluefin tuna schools were transported to the survey area depending on the expansion (strength) of the Leeuwin Current into the survey area. Therefore, they suggested that recruitment abundance should be estimated by standardization with respect to the expansion (strength) the Leeuwin Current. Similarly, Ali et al. (1999) used scientific echo sounders to investigate fish resource abundance in the South China Sea. They used marine GIS software, Marine Explorer (Itoh 1999), and its built-in kriging procedures were applied to quantify biomass of fish resources.

Space-Based Fisheries Management

Unfortunately, space-based fisheries management is the most poorly represented area in the GIS literature. This is principally due to the "in-house" use of this approach by management agencies and, in many instances, the applications are not suitable for publication in the peer-reviewed literature. It is these systems that have the largest potential as management tools within the public sector, including management and government agencies, as they can incorporate real-time spatially referenced data capture (Hinds 1992). Because the enforcement of fishing effort is a direct way to mitigate fishing impacts on the marine ecosystem as well as fish resources, fisheries managers have been giving some priority to monitoring the locations of fishing vessels. With this in mind, GIS software, which allows for global positioning system (GPS) integration to an onboard computer has been developed and was demonstrated during the Fishery GIS Symposium in 1999 (Simpson and Anderson 1999). Some GPS capability is used by fishermen for relocation to good fishing grounds by analyzing historical data using GIS (Simpson and Anderson 1999).

Data sources include vessel monitoring systems, catch-reporting/logging (Meaden and Kemp 1996, Kemp and Meaden 1998, Long et al. 1994a), and remote-sensed imagery of fishing areas (Kiyofuji et al. 2000, Peña et al. 2000). Foucher et al. (1998) described a prototype GIS that uses simple overlaying tools to quantify areas of conflict between competing fisheries for the octopus (*Octobrachiata*) and groundfish stocks off Senegal. Unfortunately the data used by many of these systems is often entered from handwritten or hard copy catch return reports. This implies a lag from event to the time at which it could be used as information. There is a definite move toward collecting the data in a digital format and transmitting it from vessels still at sea, increasing the adaptability of the GIS (Meaden 1993, Pollitt 1994, Meaden and Kemp 1996).

Caddy and Carocci (1999) described a GIS for aiding fishery managers and coastal area planners in analyzing the likely interactions of ports, inshore stocks, and local nonmigratory inshore stocks. This tool provides a flexible modeling framework for decision making on fishery development and zoning issues and has been applied to the scallop (Pectinidae) fishery in the Bay of Fundy, Canada, and the demersal fishery off the northern Tyrrhenian coastline of Italy.

Research using GIS as a bycatch mitigation tool is in its formative stages. Commercial software programs have been cited as a stumbling block to progress. Hopefully, when this issue is resolved a large number of applications could be expected, as bycatch management is arguably one of the most urgent and serious issues in world fisheries. Published results illustrate that GIS can specify (even pinpoint) the habitat areas of bycatch species on a fine spatiotemporal resolution. Mikol (1999) has investigated vessels targeting Pacific hake (*Merluccius productus*) off the Pacific Northwest U.S. coast, off Washington and Oregon. Ackley (1999) assessed Alaska's groundfish bycatch problem with GIS tools. He investigated time-area closures necessary to minimize bycatch of king crab (*Paralithodes camtschaticus*), Chinook salmon (*Oncorhynchus tshawytscha*), and chum salmon (*Oncorhynchus keta*) in the eastern Bering Sea as part of the groundfish fishery management plan for the North Pacific Fishery Management Council.

Software

Whereas most GIS platforms contain 2D database functionality and high quality graphical output, few progressed beyond 2+D databases, simple geostatistical analysis, and Boolean logic-based overlaying and buffering procedures. These platforms have terrestrial origins and do not have the capacity of handling or analyzing highly spatiotemporally variant data sets. As a result there is no generic commercial software that can efficiently handle fisheries information and its analytical demands. This limits fisheries GIS. Terrestrial GIS have tackled the problems with specialized analysis through customized modules. Fisheries GIS equivalents have been noted in this review.

More than 95% of the papers presented during the First International Symposium on GIS in Fishery Science, held in Seattle in March 1999, used terrestrial 2D or 2.5D GIS software. These software platforms could only handle fisheries and oceanography data to a limited extent, specializing in only a few specific functions such as simple presentation, navigation systems (electrical charts), satellite data processing, contour estimation, database, vertical profiling for oceanographic information, and bathymetry mapping. Although these systems were functional they could not incorporate all of these specific functions into one system. The development of integrated GIS software is required. In addition, such software needs to be used for conducting spatial numerical analyses and modeling with links to stock assessments, simulations, and ecosystem management. Furthermore, such software must be user-friendly and ideally would run without requiring any programming, as fishery scientists in many countries have limited funding to hire GIS specialists and they cannot spend time on programming themselves. Several systems are in the developmental stages (Itoh 1999, Kiefer et al. 1999) and we anticipate their release. Itoh's (1999) menu-driven GIS software (Marine Explorer) is suited to store and manipulate fisheries and oceanography data. Details on Marine Explorer can be found at http://www.esl.co.jp.

Prospects and Summary

Our assessment of the current status on application of GIS in spatial analyses of fish populations is summarized in Fig. 2. As noted, there are few applications in numerical analyses and predictions, which will be the challenging area for the future.

GIS development in any discipline evolves over time, with different emphasis being placed on the results that are produced. Crain and McDonald (1983) noted this development cycle, stating that most GIS started as inventory tools, then progressed to handle a range of analyses before being used extensively to integrate data for management. Fisheries GIS are no exception. Meaden (2000) outlines various fisheries specific challenges to GIS development (Table 2). These hurdles need to be addressed to ensure rapid fisheries GIS development in the future.

There is an urgent need to develop spatially oriented management methodologies due to the limitations of the traditional concept of the pooled single-stock maximum sustainable yield or total allowable catch. Management measures need to be applied in space and time along with considering ecosystem implications, bycatch, multispecies interactions, and the socioeconomic importance of fisheries. In this manner, responsible fishing practices can be pursued while securing protein sources that may be able to mitigate food crises expected in the beginning of the twenty-first century. It is certain that such ecosystem management schemes for responsible fisheries will be complex, prompting the use of GIS as suitable management and assessment tools.

Integrated ecosystem fisheries management is the most important and challenging area in fisheries resources research. The facets are numerous and need careful consideration if GIS technology is to be used. Some prospects are achievable in the immediate future while the rest will occur in the long term. Clearly, some of the challenges are intrinsically interrelated and therefore difficult to separate and it is of little relevance to attempt to compartmentalize challenges between inland, coastal, and marine fisheries. Obviously there is a hierarchy of challenges such that some of them will only affect a minority of activists in this field, and some are likely to be more or less easily overcome. It is the authors' hope that this paper can contribute to promoting fisheries scientists, biologists, managers, fishers, and educators to apply fisheries GIS for optimal utilization and management of our fisheries resources within their wider ecosystems.

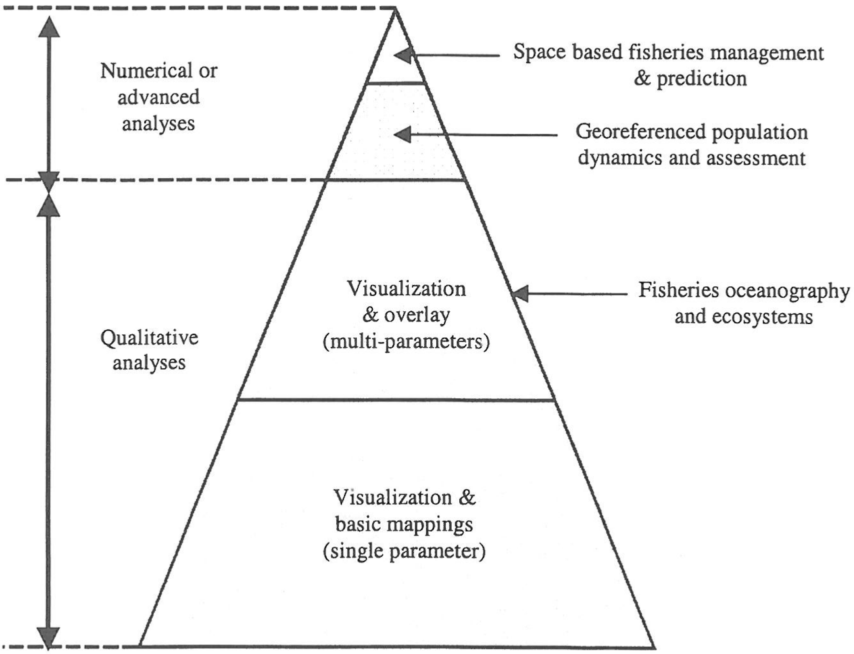

Figure 2. Summary of the current situation of GIS applications in spatial analyses of fish populations. (There are only limited numbers of applications in numerical or advanced spatial analyses, whereas the majority of applications are for qualitative analyses.)

Table 2. Major challenging areas, listed by subject, that can be considered prospects for future GIS application in fisheries resource research (adapted from Meaden 2000).

Data
- Standardization of data collection structures with adjustment for discrepancies in space or time
- Conversion of analog data to digital data
- Consolidation of data gathering and databases
- Automation of data collection
- Establishment of simple database linked to GIS platform
- Consideration of 3D or 4D database for the GIS
- Development of easy method to access oceanography and satellite information
- Development of easy method to process matrix (raster) information

Presentation
- Application of enhanced visualization to fisheries GIS
- Effective and easy way to present 3D and 4D parameters of fisheries and oceanography information such as catch, CPUE, temperature, and salinity

Stock assessment, prediction, and spatial numeral analyses
- Development of linkage between GIS and stock assessment
- Applying GIS methods, models, simulations, and geostatistics in a fluid, dynamic 3D environment
- Development of space-oriented prediction methods for fishing and oceanographic conditions

Fisheries management using GIS
- Space-oriented fisheries management
- Ecosystem-based fisheries management
- Essential fish habitats and marine reserves
- Fishing effort monitoring system using GPS and VMS (vessel monitoring systems)
- Fisheries impact assessment (development of space-based stock assessment)
- Spatial allocation of results of stock assessments such as MSY and TAC
- Monitoring and modeling of quota arrangements

Software
- Development of user-friendly and high performance fisheries GIS software that can handle simple parameters and also satellite information and that can perform simple mappings as well as complex integrated spatial numerical analyses

Human interaction
- Establishment of the international fisheries GIS association for networking to exchange ideas and information
- Collaborative and interactive GIS activities in fisheries resources research by fisheries scientists, oceanographers, fishers, and fisheries managers for effective, meaningful, and realistic achievements
- Fostering a trustful relationship between researchers, fishers, and politicians

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