Chapter 19

Application of Geographic Information System in Fisheries Management

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19.1 Introduction

Geographic Information System (GIS) is a computer based information system designed to work with spatially referenced data. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis (Clarke, 1986). These abilities distinguish GIS from other information systems and make it valuable for explaining events, predicting outcomes and planning strategies and hence GIS is looked upon as a tool to assist in decision-making and management of attributes that needs to be analyzed spatially (Burrough, 1986).

Fisheries management and planning has many spatial components and issues in fisheries like habitat loss and environmental degradation have spatial dimensions (Geoffery and Thang, 1996). Fishery biologists, aquatic resource managers and decision makers have to address many issues of great complexity associated with fisheries like pollution, coastal zone degradation, overexploitation of resources, habitat destruction, resource allocation and conflicts that have their roots in spatial differentiation (Caddy and Garcia, 1986; Meaden and Chi, 1996). GIS technology can be of great help to clarify the issues and to find solutions by treating many spatial components simultaneously (Graaf et al., 2003).

19.2 Data acquisition for fisheries GIS

The actual methods employed for data collection, the degree of details collected and the volume of data collected could depend on a number of factors like the time available, the capital outlay planned, the skills and number of personnel involved, the availability and usefulness of any existing data, the size of the area being studied, the equipment available and the purpose for which it is required (Masser and Blakemore, 1990) Primary and secondary data collection sources, techniques and equipment for a marine fisheries resources GIS are summarized in Table 19.1.

Table 19.1: Sources of primary and secondary data for GIS on marine fisheries

	Primary Data	Secondary data
Data format	Fish, water, fishing vessels, ports, coast	Tables, photographs, maps and charts, books, acoustic images, digital databases
Data sources	The real world	Library, remote sensing centers, Govt. offices, mapping agencies, hydrographic offices, research institutes, digitizing agencies
Data acquisition methods	Fishery surveys, questionnaires, sketches, photographs, remote sensed data	Networking, digitizing, scanning, online searching, databases
Equipment	Measuring equipment, cameras, data loggers, sensors, acoustic equipment, positioning systems, research vessels	Scanner, digitizer, computers and peripherals, image analyzing equipment

Adapted from Geoffery and Thang (1996)

Data acquired by primary data collection techniques could be in many forms such as photographic, numeric, digitally encoded, labeled pictorial and written descriptions, colour coded and graphical. The basic form of data collection is the manual method which may include direct mapping or survey sketching and interviews using questionnaires. Data can also be collected using Global Positioning Systems (GPS). Specially designed multi-media devices and data loggers are used for automatic or semi-automatic collection of data. Data from fisheries oceanographic cruises, remote sensing, hydro-acoustic data and videography are important sources of data for GIS for marine fisheries (Talukdar and Tyce, 1990). Echosounders gather data for underwater mapping and detect the presence of fish and biomass (Miller,1991; Mills and Perry, 1992; Somers, 1992; Miller, 1994).

19.3 Application of GIS in marine fisheries

The subject area of fisheries is extensive and complex and GIS offers the potential to perform a wide range of management related functions.

Caddy and Garcia (1986) identified the following areas as appropriate for GIS applications:

- Mapping of local environments and production systems
- Designing statistical data collection surveys
- Planning scientific resources surveys
- Preparing inventories of resources
- Elaboration of management plans
- Mapping fishing effort distribution and fishing grounds
- Mapping in support of international agreements
- Remote sensing and subsequent mapping

Major areas of application of GIS in fisheries include (i) marine water conditions and habitats, (ii) natural marine resources, (iii) fisheries management – resource allocation and regulation, (iv) fishing effort and catches, (v) marketing of fishery products, (vi) mariculture and (vii) coastal zone management.

19.4 Marine habitat mapping

Water quality parameters which are of importance in fisheries include temperature, salinity, dissolved oxygen, water colour, chlorophyll content, turbidity, density, currents, etc. In order to identify habitat types and their spatial disposition, it is necessary to collect data on various ecosystems such as coral reefs, sea grass beds, estuarine areas, coastal seas, oceanic areas, upwelling areas, mangroves, etc. and also on sea bottom types and bathymetric features (Sala et al., 2002).

Probable data sources on marine water conditions and habitats for a fisheries GIS are (i) resource surveys, (ii) marine acoustic surveys, (iii) oceanographic databases, (iv) hydrographic charts, (v) tide tables, (vi) topographic maps, (vii) thematic maps and (viii) remotely sensed data from satellite borne sensors such as Advanced Very High Resolution Radiometer (AVHRR), Coastal Zone Colour Scanner (CZCS), Sea-viewing Wide-Field-of-View Sensor (SeaWiFS), High Resolution Multi-frequency Microwave Radiometer (HMMR), Ocean Colour Monitor (OCM) and Synthetic Aperture Radar (SAR) (Roberts and Ricketts, 1990).

Mapping has been widely used in marine resources management. It provides resource managers a spatial overview of the resources and environment while describing the physical and biological attributes. Remote sensing and acoustic techniques are used to build datasets on oceanic areas of interest, which could be used for mapping of bottom topography and fisheries related environmental parameters. Castillo et al. (1996) used GIS techniques to analyze the spatial distribution of three pelagic fisheries (anchovy, sardine and jack mackerel) off the coast of Northern Chile in relation to surface temperature and salinity profiles and concluded that the distribution of these species was associated with strong thermal and haline fronts. Multiple linear regression analysis of a regional fish and habitat database was used to determine the possibility of using GIS derived landscape-scale habitat variables to explain the spatial variability in the density of sport fishes in the rivers of Michigan's Lower Peninsula (Creque et al., 2005). Using a GIS, Franklin (2003) did a Benthic Habitat Mapping in the Tortugas region, Florida which allowed for the synthesis of several different types of data, including bathymetric surveys, side-scan sonar, *in situ* visual analysis and aerial photogrammetry.

19.5 Marine resources

Resources surveys are usually done to gather quantitative data which may be of help in estimating biomass and establishing not only yield potential, but also changes in stock numbers or indications of the biological productivity of the water (Isaev and Seliverstov,1991). GIS would be able to provide additional graphical output on this type of information and also allow for more refined analysis such as time series correlations, inter-species correlative analysis, contiguity analysis and cluster analysis (Iversen et al., 1993). Werner et al., (1993) attempted to simulate, by the use of passive particles, the fate of the early life stages of cod and haddock which spawn on the Georges Bank in the Northwest Atlantic. In this study, time series GIS implemented by the use of temporally interpolated data have shown various indicators of the degree of relationship between the passive particles and the current speed and direction. Thomson et al., (1992) developed a conceptual model to show the effect of the North Pacific currents on migration routes of sockeye salmon (*Oncorhynchus nerka*) and their likely landfall location by the use of GIS.

19.6 Fisheries management

Spatial aspects concerning fisheries management and regulation are discussed by Morgan (1991), Symes (1991), Waters (1991), Hinds (1992),

and Alexander (1993). Ecosystem based management is now seen as a desirable approach for sustainability of fisheries (Morgan, 1991). An ecosystem approach to management may set aside Marine Protected Areas (MPAs) in which access and exploitation are controlled and GIS would be a useful as a tool for regulation of MPAs (King, 1995).

The primary data for development of a GIS for management of fisheries resources, could be obtained from legal documentation and bulletins produced by the concerned departments and secondary data could be sourced from the regional fisheries bodies and maritime atlases (Arnason, 1991). Fishing area could be partitioned for purposes of management, in terms of catch regulations such as mesh size, size of fishing gear, fishing rights, total allowable catches and area closures (Caviedes and Fik, 1993). Monitoring of fishing fleet using satellite based tracking systems is now seen by many governments as the most practical way of regulating the operations of fishing vessels, especially those targeting migratory and straddling stocks. GIS may find wide applications in such approaches to fisheries management.

19.7 GIS and fishing effort and landings

Monitoring of catch and effort is one of the core tasks in the fisheries management (Symes, 1992). Evaluation of fishing effort encompasses a variety of techniques and considerations (Hilborn and Walters, 1992). It is useful if the catch data per vessel is disaggregated as much as possible in terms of species, location and time of capture, method of capture, age and size of the individual catch components, etc., for purpose of developing a GIS for fisheries management. The acquisition of catch and effort data in fisheries is often difficult because of the dubious accuracy, incompleteness and mixed formats in which data are available (Hilborn and Walters, 1992). Meaden and Kemp (1996) attempted a GIS using catch and effort data of trawl operations with GPS position data, which enables aggregation of the catch data to unit areas of management. Miyabe and Bayliff (1990) produced a GIS map for bigeye tuna in the eastern tropical Pacific. Spatial distribution of catch and effort in a fishery for snow crab (*Chionoecetes opilio*) was done with the help of GIS by Swain and Wade (2003).

19.8 GIS in marketing of fishery products

Markets for fish and fishery products are highly volatile both from a temporal and spatial perspective. Market information obtained from various ports and marketing authorities can be stored in a database system, from where it can be extracted for mapping for GIS purposes. GIS can be very

useful in its capacity to instantly map both spatial and temporal changes during various stages of marketing of fishery products. It can also be of use in seeking to establish market for under-utilized species. GIS has the potential to facilitate the disposal of fish from vessels to on-shore processing plants. Analysis of spatial differences in species or product preferences for any specific market area can be done using GIS.

19.9 GIS and aquaculture

The importance of aquaculture in fish production is increasing and the activity will be competing with traditional fisheries for space in aquatic environments (Meaden and Kapetsky, 1991). Use of appropriate geographic information systems and remote sensing technologies have been advocated as a management tool, for developing aquaculture and resolving conflicts Kapetsky et al., 1987; Kapetsky and Travaglia, 1995). Silvert (1994) outlined a computer based simulation model to facilitate aquaculture site selection. Various studies using GIS for aquaculture location have also been attempted by Mooneyhan (1985), Kapetsky et al. (1988), Kapetsky (1989), Ali et al. (1991), Kapetsky et al. (1991) and Kapetsky (1994).

19.10 GIS and the coastal zone

Critical coastal zone systems important to fisheries include mangrove forests, coral reefs submerged sea grass meadows and kelp beds, lagoons, estuaries, intertidal marshland and mud flats and beaches. Human activity along the coastal zone often leads to its degradation. There are spatial and temporal variations in the extent and degree of any of these activities. The ability of GIS to integrate physical, ecological, socioeconomic information makes it an ideal assessment tool to support management decisions in the coastal zone (Gilman et al., 2001). GIS has been used in shoreline monitoring and management (Rongxing et al., 1998), spacio-temporal analysis of beach morphology (Mitasova et al., 2003) and community hazard planning and vulnerability analysis (McLaughlin et al., 2002; Wood and Good, 2004).

19.11 GIS and long term global climatic changes

Global warming and climatic changes have significant impacts on aquatic ecosystems. Warming of aquatic environment may cause species displacement either directly or indirectly through changes in ocean circulation and the location of upwelling (Hsieh and Boer, 1992). Keleher and Rahel (1996) used GIS to study the salmonid distributions in the rocky mountain region in Wyoming and potential habitat loss due to global warming. Wu et al. (2002) used a GIS based methodology to assess the vulnerability of Cape

May County, New Jersey to flood hazards associated with coastal storms and sea-level rise. Vafeidis et al. (2008) developed a global coastal database called the Dynamic Interactive Vulnerability Assessment (DIVA) Coastal Database that were referenced to information on physical, ecological, and socioeconomic parameters, including data on factors such as waves, water quality, sediment fluxes, elevation, population distribution for impact and vulnerability analysis.

19.12 Conclusion

Recent developments in areas such as mapping, capture methods, data structure, algorithms, storage, visualization and graphical display, 4-D GIS, error handling procedures, GIS warehousing, data mining tools and multimedia GIS could enhance the capabilities of GIS as a tool for decision support for fisheries management and in explaining events, predicting outcomes and planning strategies for sustainable fisheries development.

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