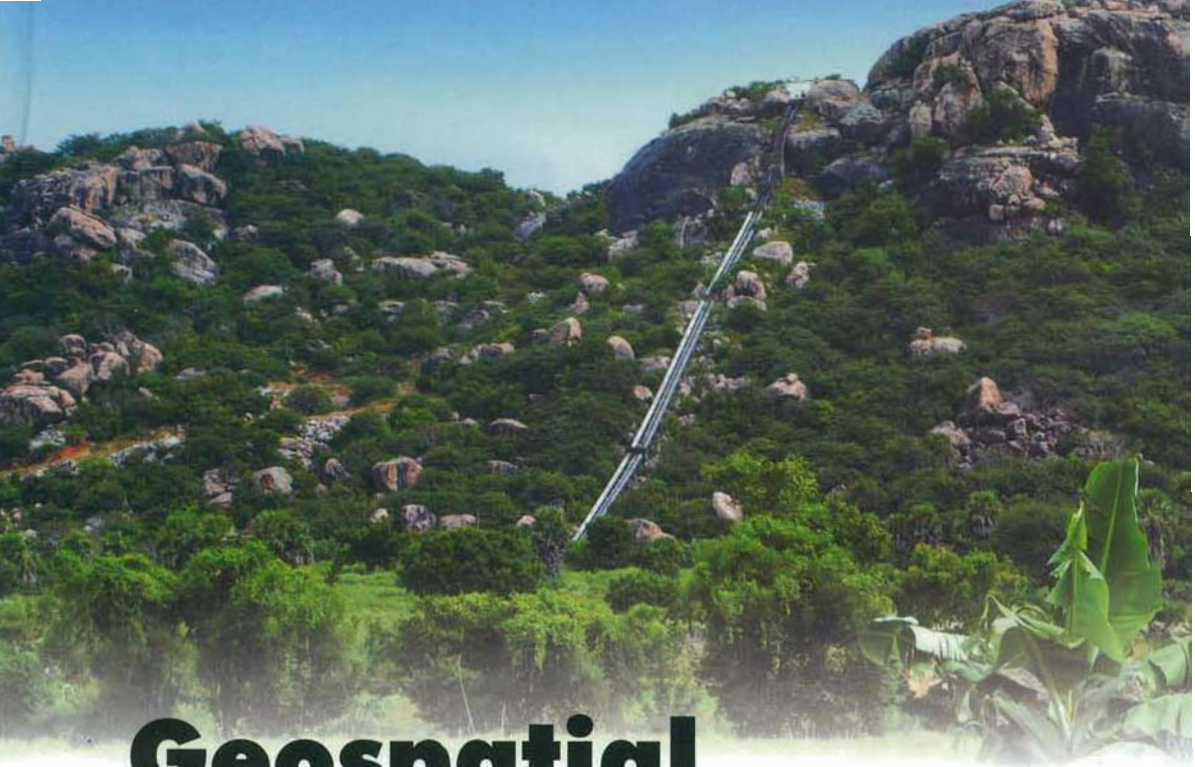

Geospatial Technologies for Natural Resources Management

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Chapter - 31

Marine Geographic Information Systems and Their Application in Fisheries Management

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Abstract

GIS in marine fisheries has taken off much later than its application in land. But the strides made in this field since 1990's has been quite significant, as many serious mapping studies and modeling initiatives have been recorded. With the third dimension added to the 2D spatial data, the marine GIS have all the ingredients of making it a fertile domain for research for decades to come. Most of the studies and products pertaining to GIS in fishery management had been revolving around mapping of habitats, geo-referencing of catch and effort data and modeling linking oceanographic and biogeochemical factors with living resources. Satellite remotely sensed information like ocean colour can act as a surrogate to fish biomass. Further remotely sensed SST, wind and other parameters can be effectively modeled to predict fish abundance, their habitat and related aspects. This manuscript pours into the various products and outputs based on GIS in marine fisheries around the world and the Indian initiatives.

Keywords: *GIS, Marine Resources, Oceanography, Primary Productivity and Climate change*

1.0 Introduction

Geographic Information Systems (GIS) have been one of the most prolific scientific enhancements in recent past, which by virtue of out of box expansion of traditional database concept have opened up an entirely new vista of knowledge and opportunities. It's probably one such unique application where information collation and analysis happen hand in hand resulting in palpable mining of data in perspective. A formal introduction to GIS would define it as a collection of computer hardware, software, data and personnel designed to collect, store, update, manipulate, analyze and display geographically referenced information. By virtue of its conceptualizations, there are no single GIS; systems can be assembled in an infinite number of ways. This is one such field, which probably always seeks the frontiers of innovations in the fields of ICT and modeling.

2.0 GIS in Marine Fisheries

Albeit terrestrial applications of GIS had commenced by the late 1960s, its application got extended to marine environment only in the 1980s. Meaden (2000) outlined a GIS Fisheries Task Conceptual Model that described why GIS was a complex task for early adoption in the sector. Caddy and Garcia (1986) highlighted the importance of computer based mapping and spatial analysis to fisheries. While the mapping proved to be a successful tool in capture fisheries arena, it concomitantly was felt as a valuable tool for aquaculture also (FAO, 1985; Mooneyhan, 1985). In its infancy the application of GIS for location analysis was performed mostly using remote sensed imagery. The aquaculture locations deal with near shore environment which do not vary much and hence simpler survey mechanisms fitted the bill when it came to development of GIS-base. During the early phase of GIS adoption by fisheries, Simpson (1992) noted that remote sensing had potential to generate much marine data of relevance to GIS applications, such as data for monitoring fishing effort, tracking pollutants, mapping bathymetry and sea-bed habitats, and providing measurements of physical and biological properties in the water column. The earliest improvisation made using such coastal GIS datasets was construction of spatially explicit models of fish-habitat suitability, particularly in inshore zones where, for instance mangroves, estuaries, sea grass beds, bottom sediments and littoral environments could be mapped with relative ease. The mid 1990's heralded a lag phase in the use of GIS in fishery related research and the first International Symposium on GIS in Fisheries Science was held in 1999 and the themes covered in that

conference were, Fisheries oceanography/ habitats, Fishery resource analysis, Remote sensing and acoustics, Ecosystems/ forecasting, Estuary and coastal management, General review (The First International Symposium on GIS in Fisheries Science, 1999). But throughout the fag end of last century the type of application of GIS for fishery related work was very fragments, non-comprehensive and much of small -scale work. As pet Fisher (2007), the following are the main thematic areas that presently utilize GIS with respect to fisheries:

a. Habitat mapping : This is a process where sea-bed types are classified in terms of sediments, morphology, depth and benthos using data from various acoustic sonar devices and biological sampling. Over the last decade the importance of habitat mapping has increased markedly and in many ways habitat maps are now expected to form the basis of management for marine ecosystems (Grinson et al., 2011).

b. Species distribution and abundance : With unmatched dynamism and interwoven complex existence, marine species pose challenges in mapping their distribution to statisticians and ecological modelers.

c. Fisheries oceanographic modeling: The linkages between fish occurrence and oceanographic variables are modeled. This involves aggregating data from a wide variety of sources like satellite remote sensing and fisheries surveys. Only a GIS has the functional capability of carrying out the necessary complex modeling.

d. Fishers' activities: With the advent of Vessel Monitoring System (VMS) to track bigger fishing crafts on-line, the log books and their information got augmented to generate accurate assessments of locations of fishing activities. Small and subsistence scale fisheries have less proficient data reporting mechanism.Hence, geo-referenced information structured over space and time could easily help in seeking the relationships between fishing effort and marine ecosystems.

e. Fisheries management: The core aim of fisheries management is to unstintingly monitor and strive to sustain the stocks, and availability.Application of GIS rooted inferences allow better decisions to be made on factors such as closed areas, stock abundance, stock enhancement, marine reserve locations, fishing effort distribution, behavior and fishing mortality rates.

f. More recent updates and overviews of recent GIS applications in fisheries management and research one may consult Fisher and Rahel (2004), Nishida et al (2004) and Meaden (2009).

3.0 Application Products and Software based on Marine GIS

With the coming of age of GIS in fisheries management, especially that of marine fisheries, many a new software and application have come up around the world for effective utilization of geo tagged data. The marine GIS, by virtue of its additional dimension in the form of depth (bathymetric contours) has given an altogether different tone and tenor to such products vis-à-vis land based GIS tools. Let us review a couple of such tools:

3.1 EcoGIS- GIS Tools for Ecosystem-based Fisheries Management

EcoGIS which is a collaborative project between National Oceanic and Atmospheric Administration (NOAA) Fisheries, NOAA Ocean Service and four fishery councils for the Atlantic and Gulf of Mexico, has developed a set of GIS tools to better enable both fisheries scientists and managers to adopt ecosystem approaches to fisheries management. These models developed as extensions of popular ESRI GIS software, ArcGIS9.x, generate spatial and temporal analyses using map layers, commercial fishery observations and vessel trip reports. Ecosystems approaches are adaptive, geographically specified, take account of ecosystem knowledge and uncertainties consider multiple external influences and strive to balance diverse societal objectives (NOAA 1999, Garcia et al 2003). With the conventional single species or compartmentalized resource based management plan showing serious lacunae, ecosystem approaches to management are gaining favor among fisheries managers and scientists (Murawski 2005). Spatial analysis using GIS is recognized as an essential tool in moving towards this kind of approach (Busch et al. 2003). Based on the outcome of a workshop conducted in 2004 (NOAA 2004) EcoGIS team zeroed in on four priority areas viz. (a) Fishing effort analysis, (b) Area characterization, (c) By-catch analysis and (d) Habitat interactions. The framework was to aim at an end product, which would enable simplified and more efficient data query, the ability to visualize data over time and to synthesize multidimensional data from diverse sources and to provide new information for analyzing specific issues from an ecosystem perspective.

The main facets of the tools involve ArcGIS extension (DLL), which would create time-and-area summarized maps of fishing effort and catch from logbook, observer or fishery-independent survey data sets. The

extension allows users to query the selected source data by species and gear, specify a time frame and time step, set up bins for spatial summary (regular grid or predefined polygons) and choose variable to summaries catch, discards and effort.

With the additional options of this tool allowing the user to render catch and fishing effort through time the base for the way in which the data is to be summarized is finalized. Another option in the toolbar allows the user to explore the relationship between the fishery data and environment base layers. This tool coupled with extensions which use simple map overlay techniques to provide report for a user defined area and a facility to map exclusively the by-catches reported from the area under focus which ends up with the depiction of quantity and types of habitat fished by bottom operated fishing gear which is realized as an intersection between the vessel track and the prior developed habitat map.Such combinations of prior information and dynamic updates gel too well to ring in efficient angles to view the ecosystem (Fig.1).

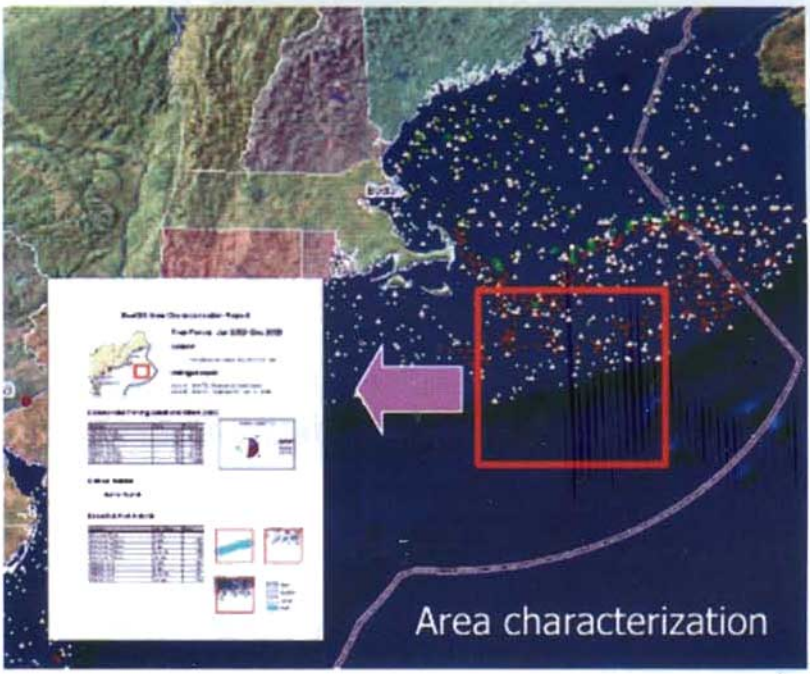

Fig.1 : Area characterization using the filters

3.2 Fishery Analyst

This product of Mappamondo GIS is aimed to effectively query fishery data, visualize temporal and spatial patterns of fisheries

dynamics and analyze the filtered information. The main functions are quantitative estimation and figuring out of catch and effort and their variation in space and time, analysis of fishing vessel and gear utilization, data quality control and deriving information on the location of important economic and threatened species. This application, originally fabricated as an extension to ESRI software, ArcGIS Desktop has been upgraded as an online version using web adaptation. This adaptation has enhanced the accessibility, data sharing, integration, centralization and resource optimization. The coding is platform independent and with the base in Google, this product is an easy to use GIS solution (Fig. 2).

Fig. 2 : Fishery analyst online interface

4.0 Case studies of GIS Applications to Fishery-based Topics

Some notable international studies are illustrated below:

a. In search of the optimum time to release juvenile chum salmon into the coastal waters of northern Japan: With salmonid stocks rapidly declining worldwide and with salmon being an ideal species for large-scale hatchery rearing, the release of salmon directly into the coastal environment appears to be a sensible and economic strategy. In fact, this practice has long been followed in Japan. Miyakoshi et al. (2007) show how, for nearly a century, the quantitative release of chum salmon into the coastal waters around the northern Hokkaido region of Japan is closely mirrored by the return of chum

salmon, especially since the 1970s when releases greatly increased. This is one of the most successful marine stock-enhancement programmes in the world. Nevertheless, the success rates could be greatly enhanced if an appropriate match could be made between a number of variables such as size of hatchlings, sea temperatures, food availability and stocking densities. Miyakoshi et al. used remote sensing data to establish sea-surface temperatures and this was related to the date of hatchling release and the release location for the period 1997 to 2001.

b. Identification of the essential fish habitat for small pelagic species in Spanish Mediterranean waters: Small pelagic fish such as sardines and anchovies provide an important fishery along Spain's Mediterranean coast. Spatial abundance data obtained from annual acoustic surveys were combined with environmental data in a GIS environment to generate a model that showed the likely optimum relationships between abundance and location for both anchovies and sardines. The model outcomes were then used to help define essential fish habitats (EFH) for these species. The statistical methods used to derive the EFH are described by Bellido et al. (2008). The environmental variables used were bathymetry, sea-surface chlorophyll-a and sea-surface temperatures. Bellido et al. noted substantial interannual variability in the distribution and quality of the EFH, particularly for anchovy, and they commented on the importance of assessing EFH for the management of the local marine resources.

c. Development of a GIS for the marine resources of Rodrigues Island: Rodrigues Island, a small island in the Indian Ocean, is located about 600 km east of Mauritius, and like many similar islands in the tropics, it is under pressure from natural resource exploitation and increasing tourism. Until recently, there was a complete lack of structured information on marine resources and this hampered any attempts at management. Since 2000, a GIS (using MapInfo software) has been incrementally developed by the University of Wales with funding from various aid projects (Chapman and Turner, 2004). Biotope mapping based on satellite imagery and ground truthing was carried out for the entire lagoon area surrounding the island, which at 240 km2 is the largest lagoon in the Indian Ocean. As a result of the mapping effort, 42 separate biotopes within four main habitat groups were

described, i.e. coral, consolidated limestone, lagoon mud, and sand and rubble. Figure 3.4 shows a satellite image of the island and the distribution of main habitat types in the lagoon. The GIS is linked to a relational database to store and display site-based data, including biotope descriptions, photographs, species lists, illustrations and environmental data. A rich variety of GIS outputs was derived and the analysis of some of this output has helped to improve the designation of marine protected areas and other conservation measures. This GIS comes complete with a detailed user's guide plus a companion document that describes the GIS in detail, including the processes involved in developing the system and the research projects behind the data.

5.0 Studies Carried out in India

a. Indian marine fisheries data collection is a quite systematic statistically sound activity spearheaded by Central Marine Fisheries Research Institute (CMFRI) since 1950's. The six decades of data collected on marine fish landings and efforts was initially focused on the thousand and odd landing centres on an uninterrupted temporal sequence. Earlier due to the limitations in the mechanization of crafts, the reach of Indian fishermen was quite limited and the landings reported at a landing centre were attributable to the coastal zone adjacent to the centre. But with the advent of powerful engines the fishing turned out to be quite a professional activity with mechanized crafts venturing out for weeks together. The immediate result of such extensive fishing venture is the lack of precise information regarding the fishing grounds where exactly the fish were hauled. Such spatially tagged information is quite essential for studying and modeling the fish resource dynamics. Although modern gadgetry involving state of art GPS etc. could help in pin pointing the grounds, it is quite a task to geo-reference past data which had no latitude - longitude tagging. However with the advent of GIS software, it is possible to passively geo-reference the grounds (Fig. 3). Usually the landings records have information about the bearing and distance covered by the craft surveyed and using the Haversinefunction to measure distances on curved surfaces, the probable latitude and longitude of the fishing grounds could be zeroed in. (Jayasankar et al. 2011).

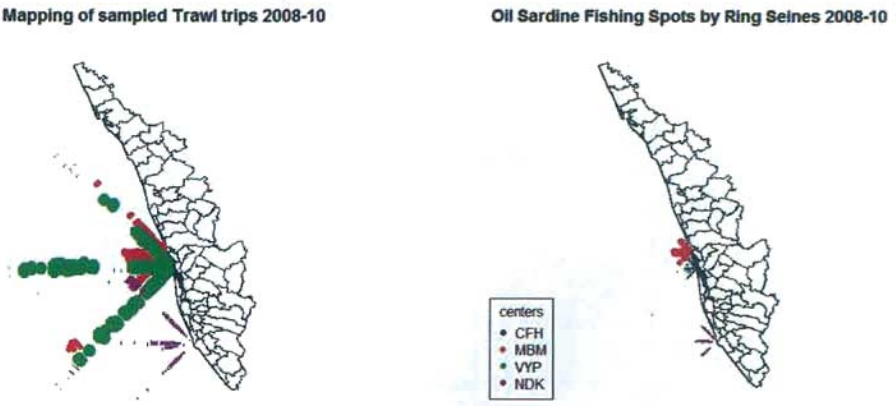

Fig. 3 : Passively georeferenced grounds of trawls and ring seines off Kerala

b. PFZ forecasts, based on Indian Remote Sensing Satellite P4 Ocean Colour Monitor (IRSP4-OCM) derived chlorophyll data and National Oceanographic Aerospace Administration-Advanced Very High Resolution Radiometer (NOAA AVHRR) derived SST are generated thrice a week by Indian National Centre for Ocean Information Services (INCOIS). These forecasts are disseminated with an objective to exploit the fishery resources in an efficient manner and to help the fisher-folk in identifying fish stocks and in designing successful harvesting strategies (Grinson et al., 2012).

c. Thematic mapping of tuna and tuna like resources off the North western coast of the country is carried out by CMFRI using *in situ* fishing realizations over all the major seasons of the year (Fig. 4). The maps give an insight into the availability, dynamics and location of grounds of such highly mobile resource. Buoyed by conducive results got from such studies a dedicated satellite monitored tagging experiment has also been initiated (CMFRI annual report 2011-12).

d. The climate change and the vulnerability of the marine resources to the warming up of tropical waters is a matter of research concern. The change in the average seas surface temperature which is one of the prime factors affecting the pelagic marine resources of the country has been a unique case of interest (Fig. 5). The kriging and spatial interpolation options available in GIS software was used to study the progress of the temperature spikes since 1961 (Vivekanandan, 2011)

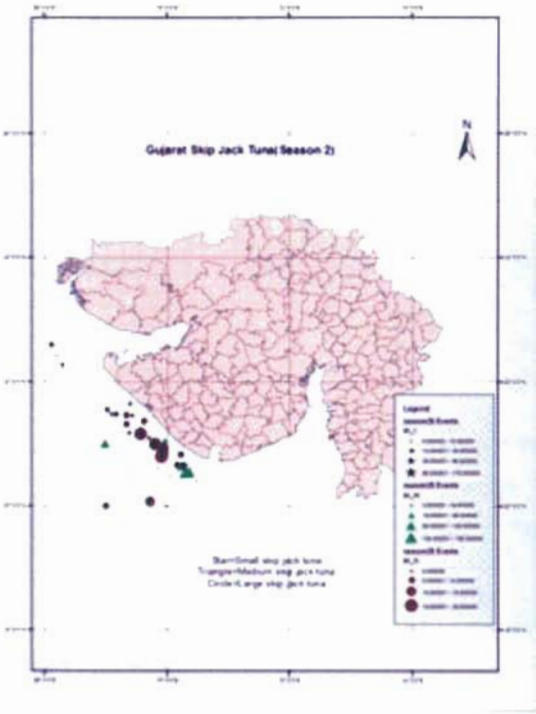

Fig.4 : Tuna fishing grounds off Gujarat coast

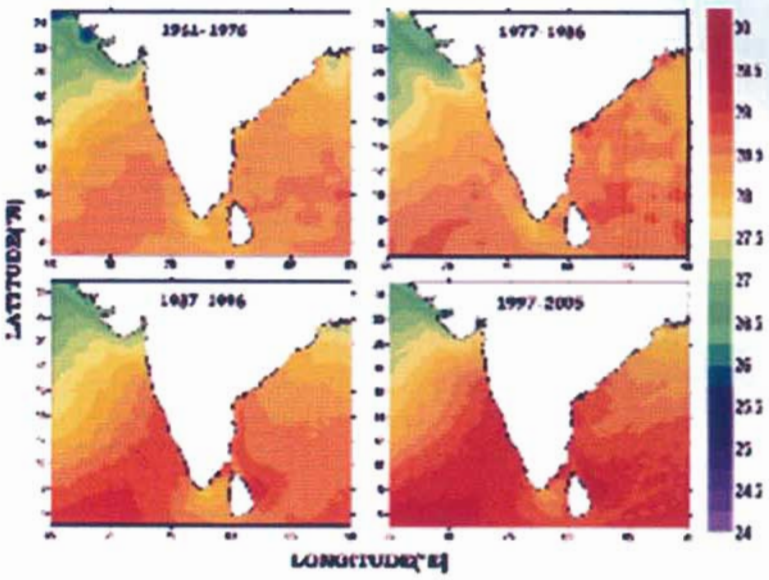

Fig.5 : The marauding progress of heatingof oceanic water since 1961

With more and more focus piling upon sustainable management of fishery resources, it is imperative of any state to precisely map the various grounds of its marine resources. A full-fledged GIS peppered with geographic, oceanographic and bio-geochemical layers juxtaposed with the resource abundance and dispersal would go a long way to shoulder up the efforts to monitor and manage these resources as the marine fishery potential is quite huge but not inexhaustible.

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