GIS-based spatial data analysis for marine fisheries management as a prerequisite for mariculture development.

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Focal Points at a Glance: *The authors tell us in this contribution that in mariculture development in open waters, marine spatial planning is a major pre-requisite in allocation of marine zone for cage installation and projection of Environment Impact Assessment (EIA), monitoring and management of mariculture farms in addition to its uses in marine fisheries management which includes integrating the resources in the environmentand also regulating of the fleets.*

Fishery Science and fishery technology contributed immensely in augmenting fish production globally. Fisheries management so far has mainly focused to develop sustainable fish resources involving individual species located within a homogenous and region-wide area. However, these do not consider the multi-dimensionality of the ocean system and therefore fail to account for factors such as resource depletion, spatio-temporal variations in stock recruitment, etc. Geographical Information Systems (GIS) combined with other analytical tools and models permits improved spatial management. It allows input of digital geo referenced data to produce maps; textual, graphical and tabular outputs which in turn are important management aid is for planners, managers and researchers both in the capture fisheries as well as in mariculture. All fisheries management models used in population dynamics omit the use of spatial dimensions and hence do not give the true picture of the existing stock. The slow emergence in the use of GIS in marine fisheries is mainly due to the unique and inherent characteristics such as mobility and three dimensionality of the ocean environment and fisheries resources. However, the use and need for GIS applications to marine fisheries to come out with suitable management options integrating the resources/ environment and fleets/regulation relationships is now well recognised and accepted all over the world. In mariculture development in open waters, marine spatial planning is the major prerequisite in allocation of marine zone for cage installation and projection of Environment Impact assessment (EIA),monitoring and management of mariculture farms.

What is GIS and GIS mapping

GIS stands for Geographic Information Systems. Technically, GIS is a branch of computer science that deals with assembling data about a physical location. GIS allows us to view, understand, question, interpret, and visualise data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. The basic input for GIS is derived from Global Positioning System (GPS), which a location system based on a constellation of about 24 satellites is orbiting the earth at altitudes of approximately 11000 miles. With some consideration for error, GPS can provide any point on earth with a unique address (its precise location). GPS tells us "where", whereas GIS tells us "what". Geographical maps are one of the most important tools researchers, cartographers, students and others can use to examine the entire Earth or a specific part of it. Geographical maps are pictures of the Earth's surface. They can be general reference and show landforms, political boundaries, water, locations of cities. GIS maps are combination of several spatial datasets (points, lines, or polygons), create a new output vector dataset which are visually similar to stacking several maps of the same region. GIS maps are thematic maps, which make non-geographical information interactive in a geographic context. It uses geographic data interactively to provide answers and information, using maps as a dashboard for the work. A combination of overlay combines the geographic features and attributes tables of both inputs into a single new output.

Layer characteristics of GIS map of marine fisheries resource distribution

Fishes are distributed unevenly in the sea based on the topography, physiological adaptations and biological needs. GIS is a very useful tool in depicting the spatio-temporal distribution of fishes in a given region. GIS arranges the data collected periodically in different layers which can be retrieved as per the projections required and each layer can be analysed individually. The basic and most important requirement for preparing GIS map in marine fisheries is the creation of a database. The details of all the species available in the region have to categorised under phyla, family, order, group, genera *etc.* and brought in database. Database is generally stored in MS access format and for spatio-temporal distribution mapping and smooth handling of data, the GIS and Visual Basic ver 6 are used. Visual Basic is populated with data of commercial catch and other details, which comprises geographic coordinates, water depths, net types, and commercial fish species *etc.* Thematic shape files/feature classes are prepared by sending queries into these tables. The cruises of each trawler are displayed as lines on the shape files/feature classes. The respective geo-database tables are mapped in ArcGIS or any GIS aided software. Queries made on extent of

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fishing ground, temporal changes in fishing ground, spatial distribution of fishes, spatial distribution of species in different seasons, spatial assemblage of adult and juveniles of particular species can be illustrated in ArcGIS as maps. The interface software between the database and GIS software is critical and is done with the constant interaction of fishery scientists and software analysts.

The illustration of group-wise layers in the resource maps is given in the Fig. 1. The possibilities of the GIS maps (layers of information) are immense. Mapping is only a basic information in GIS application and the most important aspect of GIS-based study is the data analysis.

Application of GIS maps in marine fisheries management and conservation of marine resources

The GIS based studies will give a clear picture of the spatio-temporal distribution of fishes in the selected study area and help in identification of critical fishing grounds in terms of fishery and marine biodiversity. The analysis of information collected in layers will help in identifying spawning period, spawning area, juvenile segregation, juvenile migration, *in situ* growth of different species, resident taxa of particular fishing ground, multi-group assemblages and the basis for the multi-group assemblages and their dependencies, trophic structure of fishing grounds with "Ecospace" and "Ecotran" concepts, identify sites for installing FADs and marine cages; and justification for declaration of Critical ecosystems and MPAs *etc.*

Identifying resident taxa and fish assemblages

Fishes are not distributed evenly in the given area. Some species are migratory and some are resident. Data on various aspects collected at regular intervals from a selected geographical area will give information on the resident taxa. These data which are collected as individual identities have to be merged to get a clear picture of the resources abundance dynamics of the population, etc. This merging and relating can be done using the GIS and the final result will be very useful and powerful tool for the policy makers to come out with workable options for management of the fishery. Time bound studies in particular fishing ground can reveal the biological characteristics of resident taxa like, *in situ* growth, *in situ* mortality, and measure the effect of fishing pressure,spawning area, spawning period of individual species,larval, juvenile and spawner migrations and feeding migrations of individual species.Analysis of GIS maps will give detailed information regarding fish assemblages and inter-dependency of the species in particular geographical area, which will further provide valuable information on ecological interdependence. The information on environmental characters of the geographic area and physical characters of the substratum also can be incorporated in the study to understand the basis of its fish assemblages, their migrations within the given area, preference of the species in terms of temperature, pressure, food and substratum. Further, ecosystem based fisheries management and concepts of ecospace also can be carried using GIS , making it easier for stock assessment studies and to come up with fisheries management options in terms of fish assemblages in a particular fishing ground.

Study of distribution of different life stages of species, like juveniles and spawners in space in time.

From fishery sustainability point of view, information on spatial distribution of juveniles and spawners is very important.Once the seasonal abundance of juveniles and spawners is identified from the geographic area, exploratory surveys pertaining to the area can be planned and, based on this, the critical nature of the zone can be ascertained. This will enable the fishery researchers/managers to derive suitable fishery management action plans like restriction of fishing at a particular fishing ground during the particular season.

Illustration of the utility of GIS-based studies in identification of critical ecosystems and suggestions on Marine protected areas and artificial reef installation is given in Fig.2. This is based on the result of GIS based fishery distribution studies carried out along Karnataka coast with the data collected from commercial trawlers. In this study, areas of high juvenile catch in trawls were studied on a spatio-temporal basis. The study showed that in terms of quantity of juveniles being caught, September, 2008 contributed the highest from beyond 50 m depths. With this kind of background information, fishery researchers can give more thrust on data collection and scientific analysis of the catch from this particular fishing ground. If similar trend of juvenile fishery continues during consecutive years, then, fishing ban only during these months can be considered as management option to protect the juveniles from this critical fishing ground. Application of GIS can provide illustrative proof, which in turn will enable the policy makers, to convince stakeholders regarding the scientific basis of such policy interventions. Similarly, trawl catches in March, 2008 were found to contain juveniles of a maximum number of species and this can be considered as a critical area for biodiversity losses. With GIS based studies, such fishing grounds also can be brought under strict scientific scrutiny and decisions to restrict fishing in such fishing grounds can be taken. It will also enable the policy makers to suggest introduction of artificial reefs and FADs. Fishery scientists have contributed extensively towards sustaining marine fisheries and securing the health of marine ecosystem. But, due to the limitation of the existing visual projections, it was difficult to present most of the scientific findings in a convincing manner to the policymakers and end users.The data base, when created on GIS platform with illustrations in the form of maps, will work as a tool for the policy makers to find mutually agreeable solution to tackle problems in conserving and managing the fishery with the active participation all stakeholders.

Role of GIS in marine spatial planning

Project implementation in open sea, for capture fishing or mariculture, requires good planning, taking into account the topography, prevailing environmental conditions, current patterns, stake holders involved with the complex system, etc., of the marine zone. GIS is the best way to get a holistic picture of the different criteria to be taken into account for planning. Many developed countries use marine spatial planning in undertaking various activities and developments in marine sector. Planning with spatial allocation for the Industrial activities, transportation, mining, tourism, natural resource management and fisheries, strikes a balance in country's development without

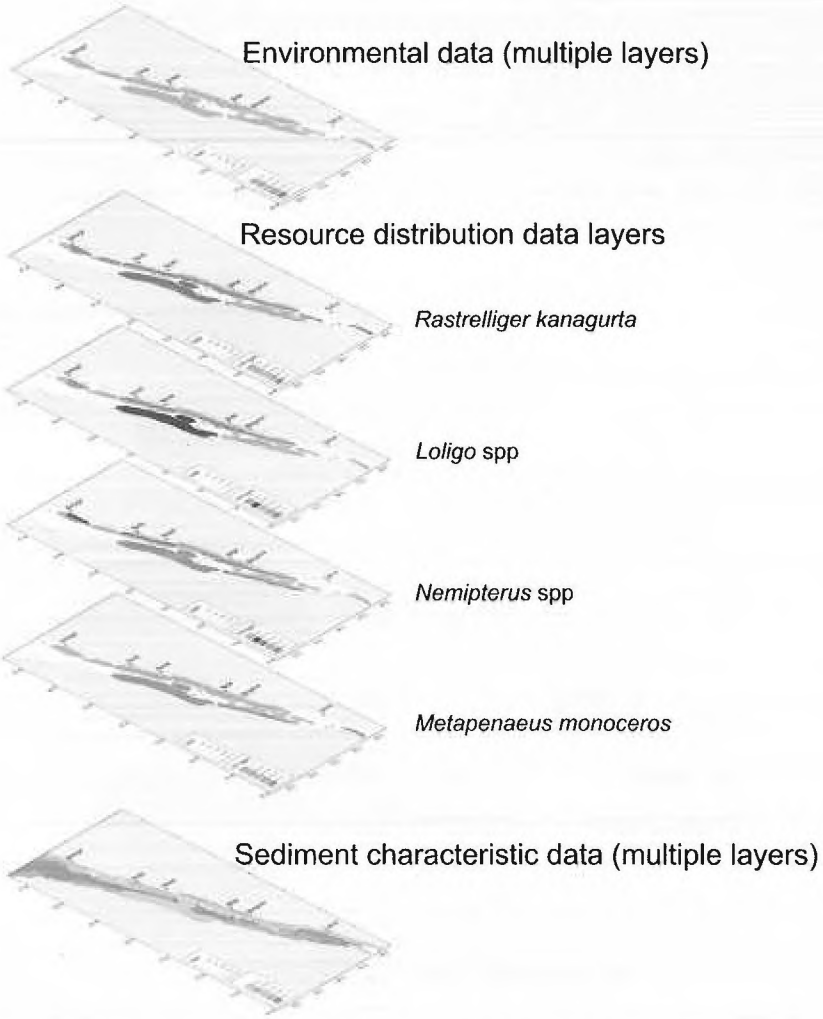

Fig.1. Illustration of different layers of group of fishes and illustration of different layers of size groups of fishes in GIS map which can be retrieved individually for analysis.

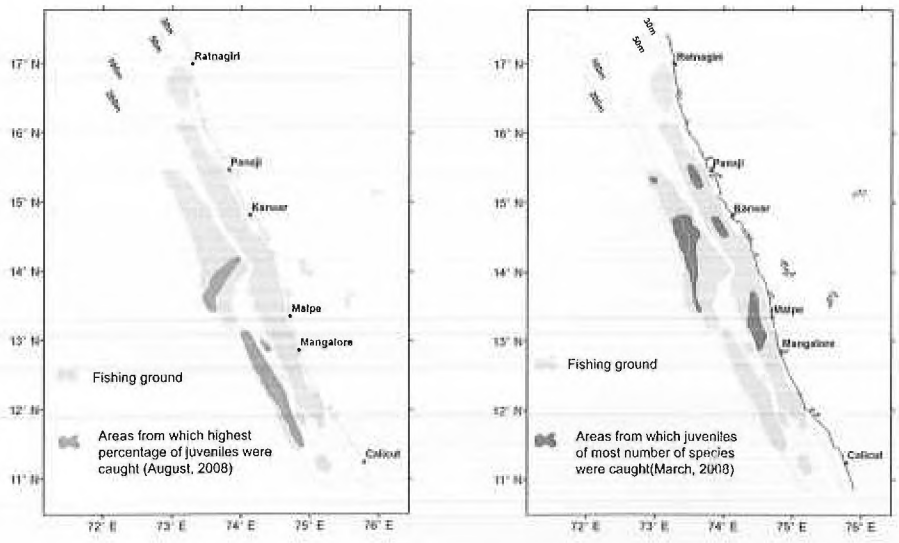

Fig.2. An example of serving GIS maps as decision making tool in fishery management and biodiversity conservation.

hampering the activity of other sectors. Spatial planning in marine fisheries development is still in its early years of development but the benefits of this advanced scientific application has been recognised and GIS is being used as powerful spatial planning tool.

Importance of GIS in mariculture development

It is a widely accepted fact that spatial analysis and spatial applications in aquaculture that relate to ecosystems is the most realistic solution in impact assessment studies for projecting the probable impacts of cage installation and cage culture. The spatial planning integrates the physical parameters (like current, waves, bottom structure, temperature), chemical parameters (like salinity, DO, BOD, COD, nutrients, the distribution of the waste, decomposition of waste) and biological parameters (productivity, species suitability and stocking density *etc*). GIS based spatial planning gives us the projection scenarios of various physical and biological parameters and will help the scientists to come out with suggestions on species suitability for cages, carrying capacity of the water body, stocking density of the cages and the best feeding strategies and feeding schedules incorporating all chemical, biological and physical features. GIS projections are capable of resolving conflicts for space and resources between stakeholders and also to help to understand the social acceptability and the economic implications of mariculture.

Spatial planning and modelling with GIS, especially in marine systems in India, is still in a nascent stage., The technology and the technologists to use the software as well as the marine researchers working on different aspects of fisheries are aware of the advantages of using multi-dimensional platforms. An earnest effort has to be made by the different groups to come together and develop expertise in the use of GIS in managing the fishery and mariculture of our country. The expertise available in India in spatial planning, in terms of Geo-informatics professionals, pro-active fishery scientists and institutional support from various organisations can bring about very progressive changes in marine spatial planning in India and GIS -based spatial planning can be used as a basic tool in monitoring and managing mariculture in India.