CMFRI Special Publication No.121

Handbook on Application of GIS as a **Decision Support Tool** in Marine Fisheries

Indian Council of Agricultural Research
Central Marine Fisheries Research Institute

Handbook on

Application of GIS as a **Decision Support Tool** in Marine Fisheries

Dineshbabu A.P., Sujitha Thomas and Dinesh A.C

Published by
Dr. A. Gopalakrishnan
Director
Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
Ernakulum North. P.O, No.1603 Cochin-682 018, Kerala, India.

www.cmfri.org.in
Email: director @cmfri.org.in
Tel.No.+91 0484-2394867 Fax 0484-2394909

Authors:
Dineshbabu A.P, Sujitha Thomas
Central Marine Fisheries Research Institute
&
Dinesh A.C
Geological Survey of India, Mangalore

Cover:
Illustration of possibilities of using satellite technologies in marine fisheries management and also for assuring safety of the fishermen at sea.

Publication, Production & co ordination
Library and Documentation Centre, CMFRI

Design: Graficreations

Printed at: PrintExPress, Kaloor, Kochi

Dineshbabu A.P, Sujitha Thomas and Dinesh A.C., 2016. Handbook on Application of GIS as a Decision Support Tool in Marine Fisheries, CMFRI special publication No.121. Central Marine Fisheries Research Institute, Kochi., 2016: 104.

CMFRI Special Publication No.121
ISSN No. 0972-2351

Preface

Geographic Information Systems (GIS) has contributed immensely to fisheries research in all parts of the world and GIS has become an integral part of the decision support system for fisheries development. Till last decade, the support of GIS in formulating the management measures in Indian fisheries was limited. But in recent years, the installation of Global Position System (GPS) has led to wide scale adoption of geo-spatial technology in most of the commercial vessels. These adoptions opened up new vistas for collection of fishery data in spatial dimensions adding up more accuracy and sea truth to the data collected and studied. The utility of GIS based fisheries management depends on the success of integration of fishery information with technology. Since these are separate branches of science, the expertise is to be developed in integrating them to provide best results. The present hand book is intended to develop expertise for fishery researchers in designing the data collection system for GIS based analysis. Knowledge of the fishing gears and fishery resources are essential for selecting the routines for spatial analysis and projection in GIS platform. The protocols described in this hand book are a result of various levels of interactions between the fishery researchers and GIS experts for more than five years. These protocols can serve as a handy tool for incorporating spatial data in fisheries distribution studies. The hand book also provides guidelines and precautions for fishery researchers while analysing marine fisheries data on a GIS platform. Further, the book provides the scope of incorporating GIS routines to study the fishery in relation to variability in environmental and ecological characteristics. The prospects of GIS based studies in developing monitoring, control and surveillance (MCS) in fisheries management with vessel monitoring system (VMS) and marine spatial planning for sustainable development of fisheries and mariculture are also discussed in the handbook.

A. Gopalakrishnan
Director, Central Marine Fisheries Research Institute, Kochi

Contents

Introduction

Geographical Information Systems (GIS), otherwise known as Geographic Information Science is being applied in various forms. In the modern era GIS has become an integral part of daily life. GIS was basically developed as a tool for terrestrial use such as infrastructural development, watershed management, agriculture and forest conservation, but later it became a supporting tool in many developmental activities. Looking at its vast application, many software applications were developed to support data analysis and are being updated, with increasing requirement from different fields. In augmenting global fish production, GIS based technology has also contributed immensely. In India, as a technological intervention, most of the larger fishing vessels are equipped with state-of-the-art equipment making them capable of operating in greater depths, increased endurance at sea and better accuracy in locating fish. Presently GPS based data on fishing operations and catch is maintained by most of the large commercial fishing vessels.

Once fishing operations were extended beyond a single day, the importance of the spatial component of the fishery data gained importance. The lack of such data has often led to inaccurate estimates and misleading interpretation on species distribution. During earlier days constraints such as lack of expertise and insufficient financial resources were the major lacuna in incorporating spatial data in fisheries research. At present GPS are affordable and fishing fleets are fitted with high resolution GPS and fishermen have acquired skills to operate this equipment. With such advanced infrastructural facilities, it is time for technological interventions to achieve sustainable fish production. Geographic information system (GIS) is widely used by fishery managers and policy makers as an active aid in decision making. Nevertheless its role in scenario testing and socio economic analysis is yet to be established in marine fisheries. This hand book is an attempt to empower fishery researchers to analyse and present the collected data in an illustrative platform. Such illustrative data can be used as a decision support tool for fisheries management. Globally, spatial planning and use of GIS in various phases of fisheries development have been in practice for over a decade, however, in India, GIS application in fisheries is often restricted to inland water bodies and aquaculture. Unlike in agriculture and closed water bodies, fishery managers and policy makers in marine fisheries sector have little chance in conducting on site observation of commercial fishing operators' grounds.

When marine fisheries was restricted to 30m depth zone, the research and monitoring organizations were able to gather highly reliable information based on the fishery distribution from the landing pattern, and also had infrastructural and financial capabilities to conduct exploratory surveys in these depths to verify the information collected, leading to accurate management advisories. Ever since the operation of fishing fleets extended beyond 30 to 50m depth, the fish landings in the fishing harbors were not representing the fishery distribution because the fishes were caught from far and wide fishing grounds. Monitoring of fisheries from these grounds by regular exploratory surveys by government organizations is impossible due to the huge expense involved. In this scenario, the marine fishery researchers who depend on fish landing data do not have a strong reliable data base regarding the extent of distribution and abundance of each species in the fishing ground, to help them to evolve policies in fisheries management. It is very encouraging that almost all mechanized fishing vessels are fitted with GPS and they are regularly using it. If fishery data collected by fishermen can be given a spatial component, researchers and policy makers will have a comprehensive picture of fishery distribution and abundance of many marine fishery resources, which will result in meaningful fishery management policies which can be made acceptable to the fishermen since they are also partners in this participatory research. More often, the findings by research organisations could not be presented in a convincing manner to the policymakers and end users due to incapability of visual projection. GIS based mapping will provide an opportunity to address these issues such as intensity of fishing pressure, vulnerability of ecosystem and species to decide upon the introduction and reduction of fishing fleets, rationalisation of fishing operation, seasonal and spatial closure of fishery etc.

What are the important spatial technologies applied in fisheries?

Satellite based technologies which are capable of handling spatial data, revolutionized natural resource management over a period of time. For example: the geographic information systems (GIS), the global positioning system (GPS) and remote sensing (RS) are the most popular technologies, and they have become an integral part of day to day activities of human life. Their use in terrestrial infrastructure development is well defined and their utility in aquatic, especially in the marine sector, is being steadily established.

What is Remote Sensing and how does it differ from GIS?

Remote sensing (RS) is the acquisition of information about an object or phenomenon without making physical contact with the object, and thus, in

Fig.1. Illustration of Remote Sensing using satellite.

contrast to on site observation (Wikipedia). Remote sensing technologies are used to gather information about the surface of the earth from a distant platform, usually a satellite or airborne sensor. Most remotely sensed data used for mapping and spatial analysis is collected as reflected electromagnetic radiation, which is processed into a digital image that can be overlaid with other spatial data(Fig.1). Reflected radiation in the infrared part of the electromagnetic spectrum, which is invisible to the human eye, is of particular importance for vegetation studies. For example, chlorophyll strongly absorbs blue (0.48 mm) and red (0.68 mm) wavelength radiation and reflects near-infrared radiation (0.75 - 1.35 mm). The spectral properties of vegetation in different parts of the spectrum can be interpreted to reveal information about the health and status of crops, forests and marine phytoplankton.

Remote sensing was the first satellite based technology that revolutionized marine research, but, later, with its limitless possibilities, GIS has also opened up vast potential for marine fisheries research and management. Remote sensing is used in marine fisheries to get images of study area, which are captured by the satellites. The role of the fisheries scientists is to analyse the various components of the available images with relation to sea truth information, whereas GIS mapping is custom made according to the requirement of the decision support needed, for which inputs of expertise in marine fisheries field is absolutely essential.

What are the components of Geographic Information System?

A "Geographic Information System" (GIS) is a computer-based tool that allows you to create, manipulate, analyze, store and display information based on its location.

Fig. 2. Models of user component of GPS units which are widely operated in fisheries.

While comparing with RS, applications of GIS have immense potential, which enable the storage, management and analysis of large quantities of spatially distributed data. This data is associated with it's respective geographic features. GIS makes it possible to integrate different kinds of geographic information, such as digital maps, aerial photographs, satellite images and global positioning system data (GPS).

What is GPS (Global Positioning System) and how does it help in GIS based resource mapping?

GPS technology has provided an indispensable tool for management of natural resources as well as infrastructural development. GPS is a satellite-and ground-based radio navigation and locational system that enables the user to determine very accurate locations on the surface of the earth. Although GPS is a complex and sophisticated technology, user interfaces have evolved to become very accessible to the non-technical user. Out of the three components in GPS ie, space, control and user, the user component is the one used to collect data from the field and is generally termed as GPS at the field level (Fig.2).

Simple and inexpensive user component of GPS units are available with accuracies of 10 to 20m, and more sophisticated precision GPS can obtain centimeter level accuracies. Locational positions are established by calculating the distance from the field GPS receiver to a selected set of satellites (three or four). The distance to each satellite is established by establishing the length of time it takes a signal to travel from each satellite to the GPS receiver. GPS can be used to acquire a fixed point location, to trace a route, or bound a polygon in the field. GPS data can be an input into a GIS for integration with other data sets. The key is to ensure data is collected in a known and desired spatial reference system or can at least be transformed to another spatial reference system. In marine environment GPS is the basic instrument, which provides the spatial data for GIS analysis. GPS position and information collected by GPS is fed to GIS software.

What is the software component of GIS and how can it be accessed?

In strict terms, any software which works with spatial data and a map can be called GIS software. In a general sense, GIS software integrates, stores, edits, analyzes, shares and displays geographic information. Tools in GIS software allow users to create interactive queries (user-created searches), analyze spatial

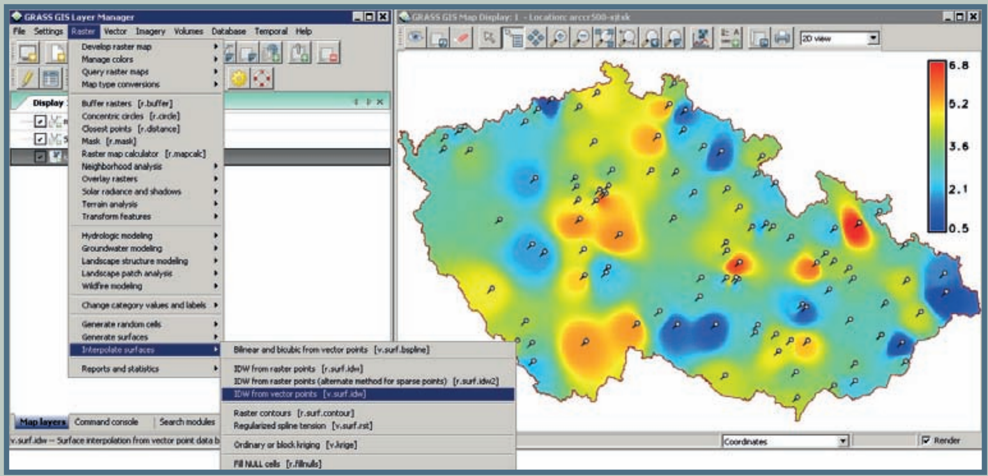

Fig.3. Desktop view of GRASS GIS, a widely used open source GIS software.

information, edit data in maps, and present the results of all these operations. There is a wide range of software available in the market to cater to the needs of the user. Many are proprietary, closed source, and quite expensive. Apart from the priced ones, there are a number of open source software developed which can be freely downloaded from their respective sites. Some of the open-source desktop GIS softwares which are widely in use include GRASS GIS (Fig.3), gvSIG, ILWIS, JUMP GIS/OpenJUMP, MapWindow GIS, QGIS ,SAGA GIS.

How important is Geo-referencing in GIS mapping and how are the physical maps digitized?

Geo referencing and digitizing the maps, based on which further studies are to be completed, is the most important requirement for the GIS study. All geographic data available cannot be used for specific scientific work which need accuracy. In the case of identifying landing centres, finding out the depth of operation etc., the field data support is extremely important. The process of integrating available map with the data collected by physical observations is called geo-referencing (Fig.4). Geo-referencing is an obligatory step in the digitizing process. Digitizing in GIS is the process of "tracing", in a geographically correct way, information from images/maps. The process of geo-referencing relies on the coordination of points on the scanned image (data to be georeferenced) with points on a geographically referenced data (data to which the image will be georeferenced). To obtain a reliable map, it is better to collect as much ground truth data as available. By "linking" points on the image with those same locations in the geographically referenced data, a polynomial transformation is created that converts the location of the entire image to the correct geographic location. In

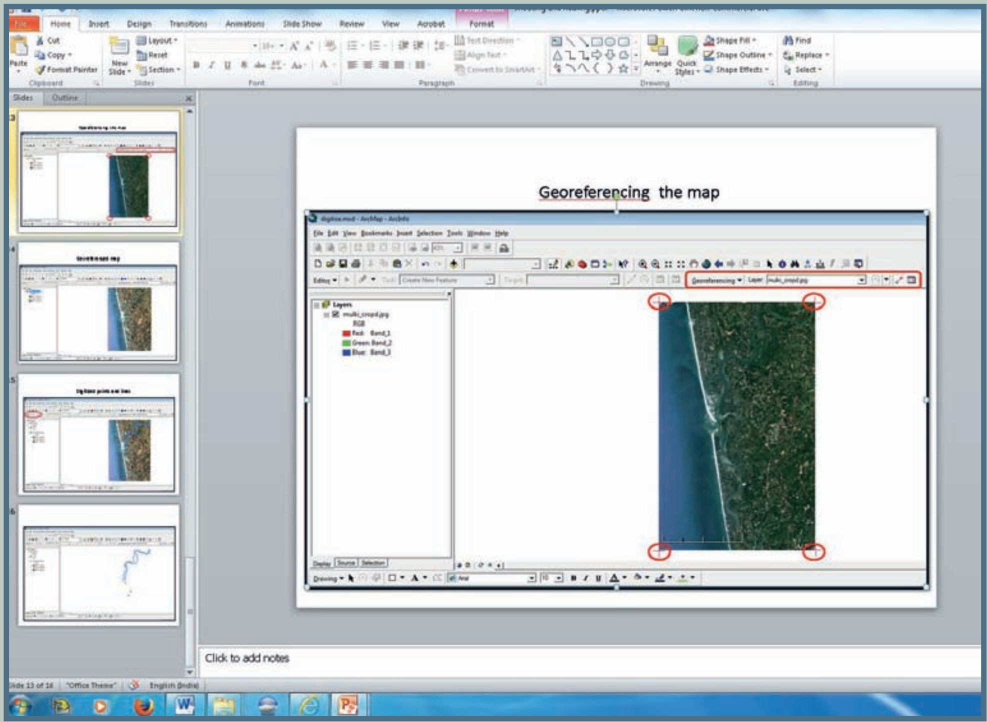

Fig.4 Geo-referencing Shambavi River, Karnataka, using GIS software

the case of coastal and marine research, the selection of control points on the coast is very important. The points should be easy to confirm as representing the same geographic location (political boundary, landmark of harbours, river mouth etc.). The data collected should be spread across the image to be registered. Good overlap between the two datasets is also important.

The geo-referencing toolbar is probably not visible when you first open all GIS software. You can open it by clicking on view, selecting toolbars, then activating the geo-referencing toolbar option.'

What is the importance of geo-referencing marine fish landing in GIS mapping?

For GIS mapping of marine fisheries resources, basic data requirement is the information regarding the latitudinal and longitudinal coordinates of the centre from where fishing vessels operated (Fig.5a-c). The centre from which the fishing operations are carried out will serve as the base point for all resource mapping. Various data on fishing and fishery related information can be incorporated in the inventory. The basic information needed are name of landing centre, district, its location with latitude and longitude (GPS reading), gears operated from the landing centre, seasonality of each gear operation, distance covered for fishing from the centre, seasonal changes in direction of fishing activity, etc.

How are the GPS data collected from boats being converted into resource maps?

In marine fisheries the GPS provides the geolocation of fishing operation, and species related information such as catch rate or catch per haul (for trawlers) can be attributed to those GPS points. For example, in the case of a trawler operating from the south west coast of India, the trawler will have a GPS address for the point of shooting net and after trawling for some time the net will be hauled, and the GPS address of the hauling point will also be noted. The distance between these is the trawling distance covered. The time required to reach from the shooting point to the hauling point will give the trawling speed. By calculating the opening of the trawl mouth as the width and hauling distance as length the

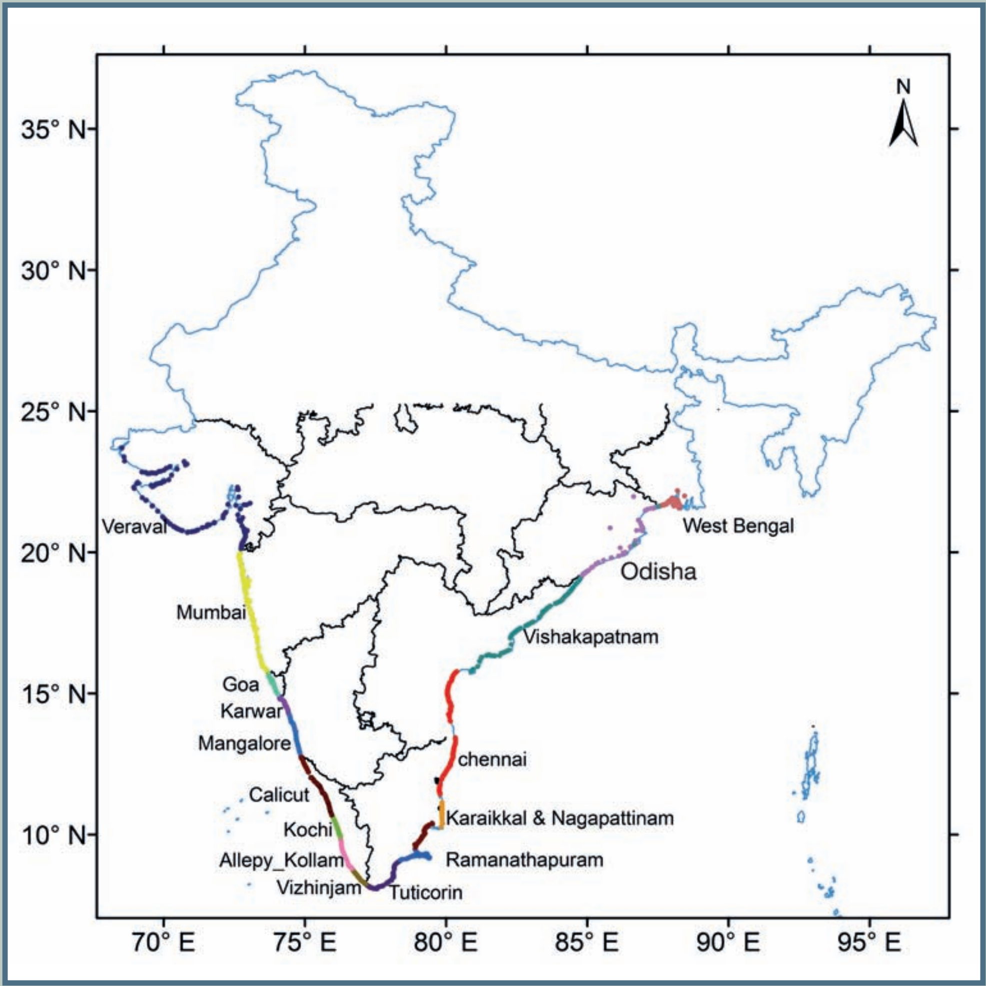

Fig.5a. GIS based All India Inventory of marine fish landing centres of nine maritime States and Union territories.

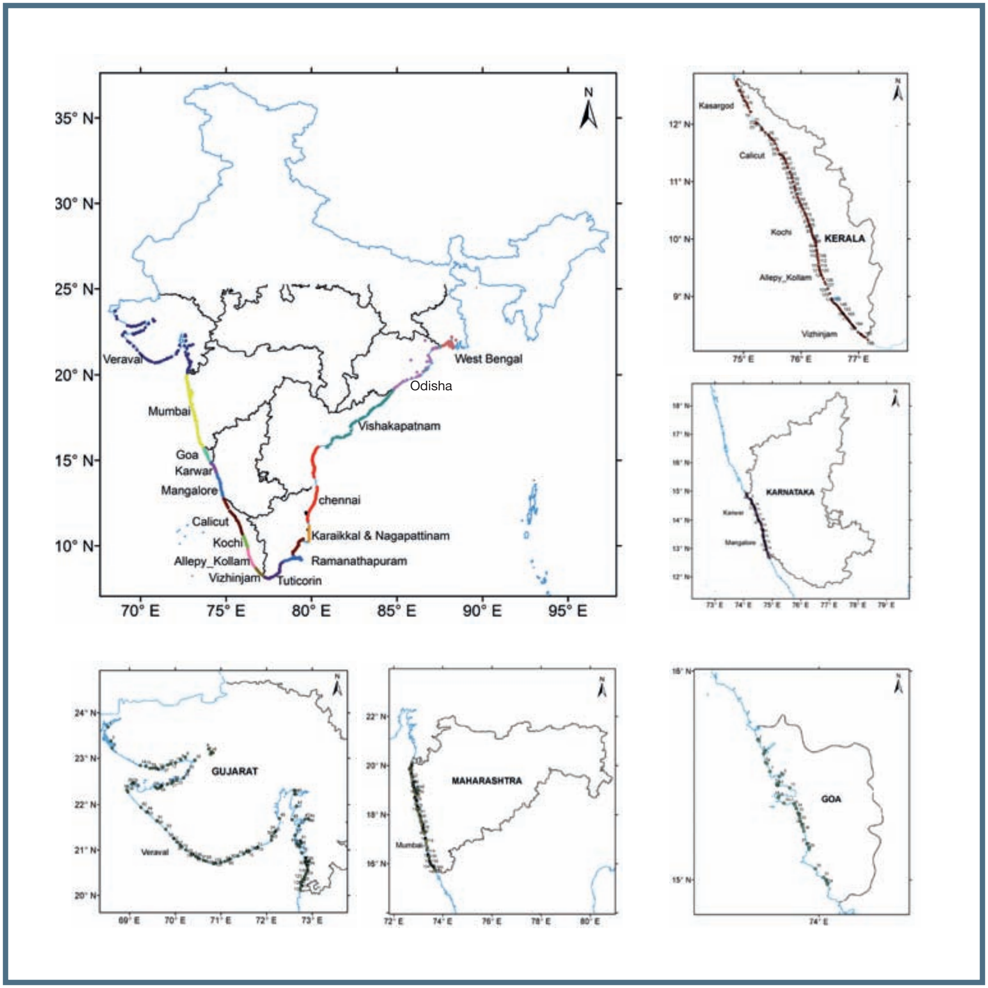

Fig.5b. GIS based Inventory of marine fish landing centres of maritime States and Union territories of west coast of India

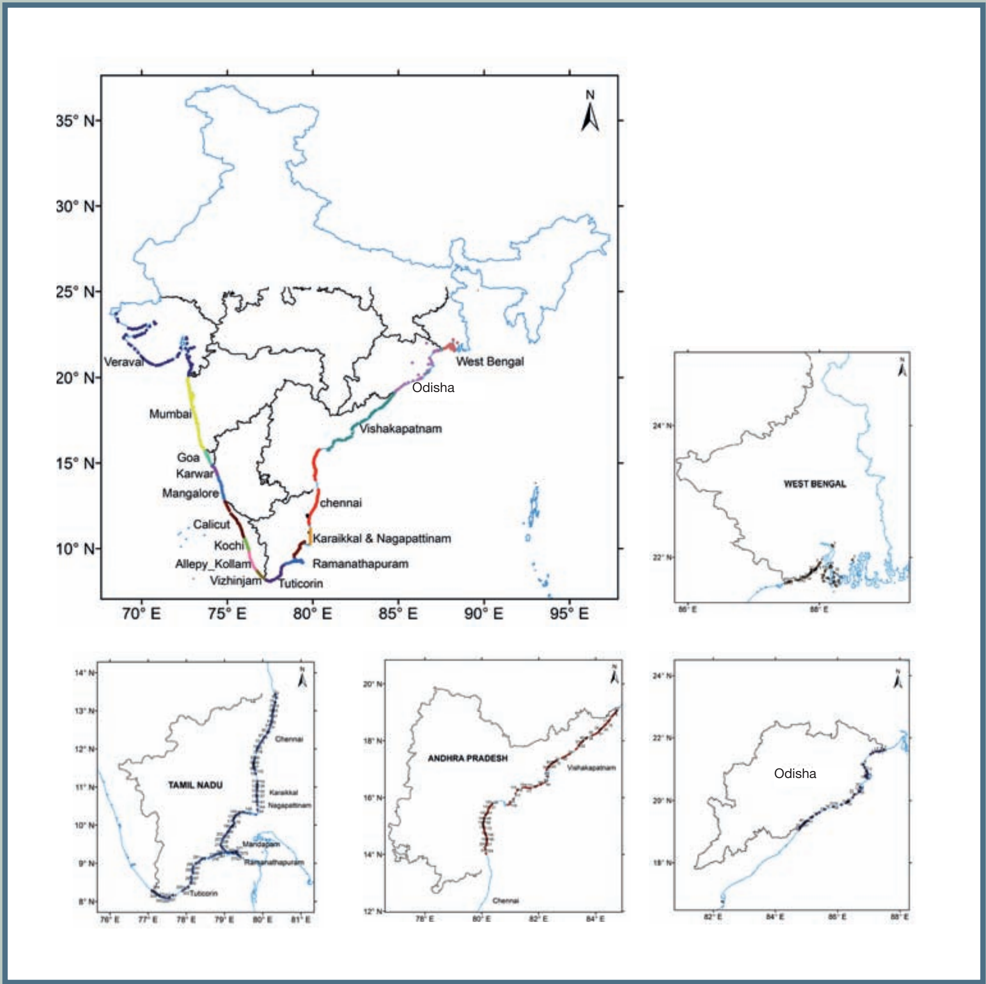

Fig.5c. GIS based Inventory of marine fish landing centres of maritime States and Union territories of east coast of India

area covered for each haul can also be calculated.

GPS points will be entered in the GIS software manually or with the help of data storage and retrieval software. The illustration of mapping of the GPS points collected by trawlers operated off Karnataka is demonstrated below.

In fig 6a, the data points of shooting the nets (red) and hauling the net (black) is entered from data base. From shooting and hauling points the direction of the hauling can also be identified (Fig .6b).

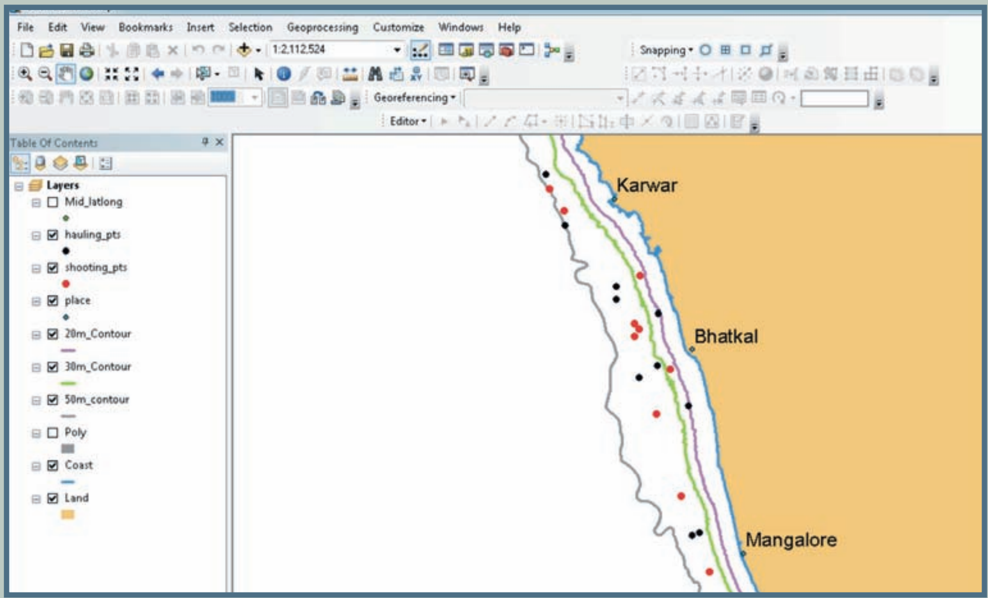

Fig.6a. Representation of shooting and hauling points and direction of hauling using GIS software.

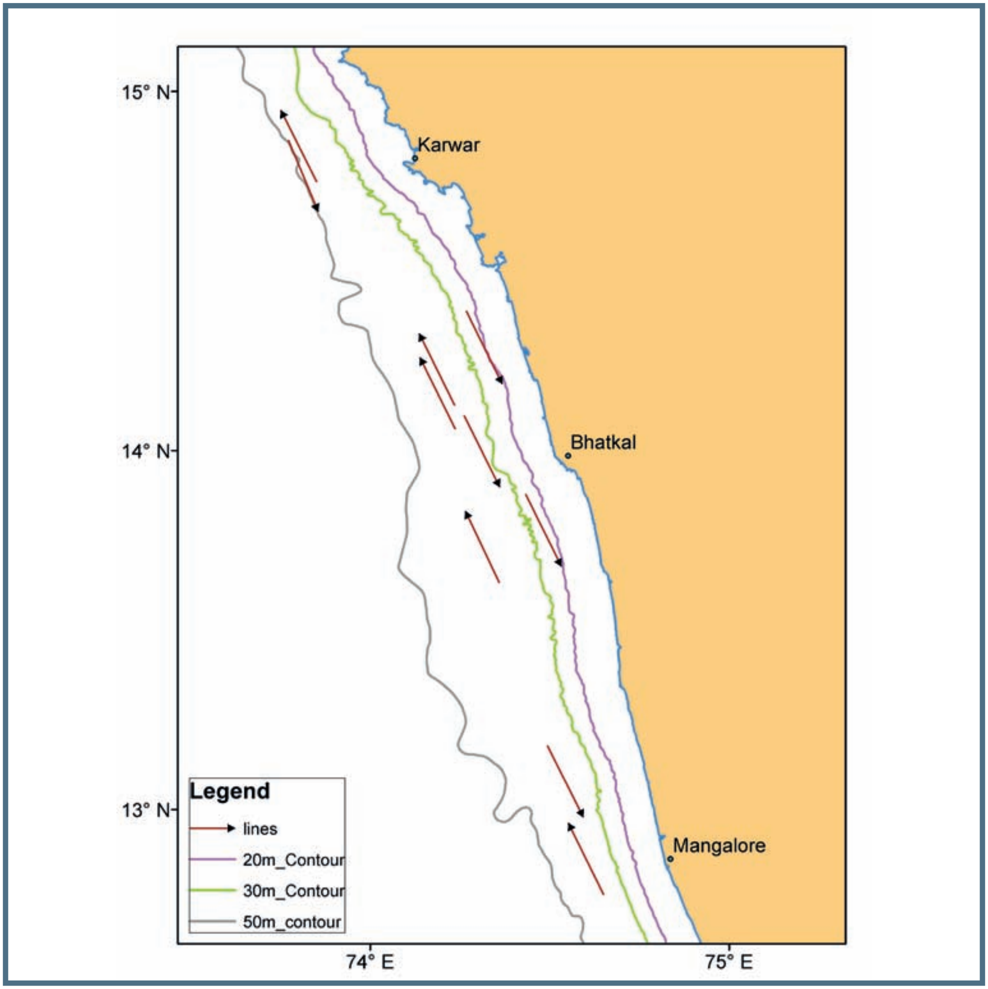

Fig. 6b. Direction of trawling tracks

The data points are connected and separate polygons of the fishing ground are drawn (Fig.7a,b). Specific polygons are drawn according to the species studied. Generally, for demersal fishes, the fishes caught in the trawl have the probability of distribution of 10m on both sides of the trawling track. If there are continuous hauling points available in a fishing ground, the polygon will be connected as a single large fishing ground. If the information is not continuous, separate polygons of fishing are drawn. In many cases, the data deficient points represent areas unsuitable for trawling also, for which sea truth data may not be available and therefore cannot be treated as a continuous fishing ground.

Fig. 8a shows how fishery data is being incorporated in the hauling data. For representing the catch or catch rate of the haul, the midpoint of the hauling track is found out using GIS software. The respective catch or catch rate is attributed to the midpoint and based on the quantity of the catch/catch rate the fishing ground is identified as high and less abundant (Fig 8b).

How are GIS maps different from other cartography?

GIS maps can give qualitative information on the required data, such as groups/species/juveniles/adults. Layers can be individually or collectively separated by queries and the layers can be studied in terms of their importance.

What are the utilities of GIS mapping in fisheries?

By using GIS, we can incorporate much information into a single system and execute common database operations. For example, GIS allows you to perform statistical analysis or spatial queries, to explore 'what-if' scenarios, and to create predictive models. For example, GIS can help answer questions such as:

- What exists at a given location?
- What is the probable reason for the spatial assemblage of biota?
- What are the changes occurring in the biota over a specific point in time?
- What is the application of GIS as a management tool?

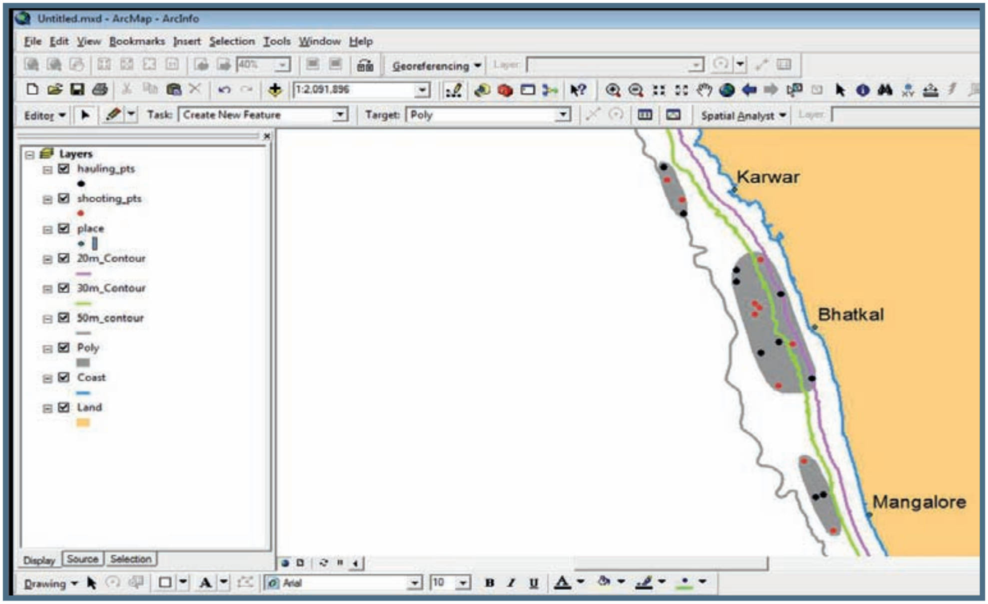

Fig.7a. The data points are connected to make polygons representing the fishing ground

.

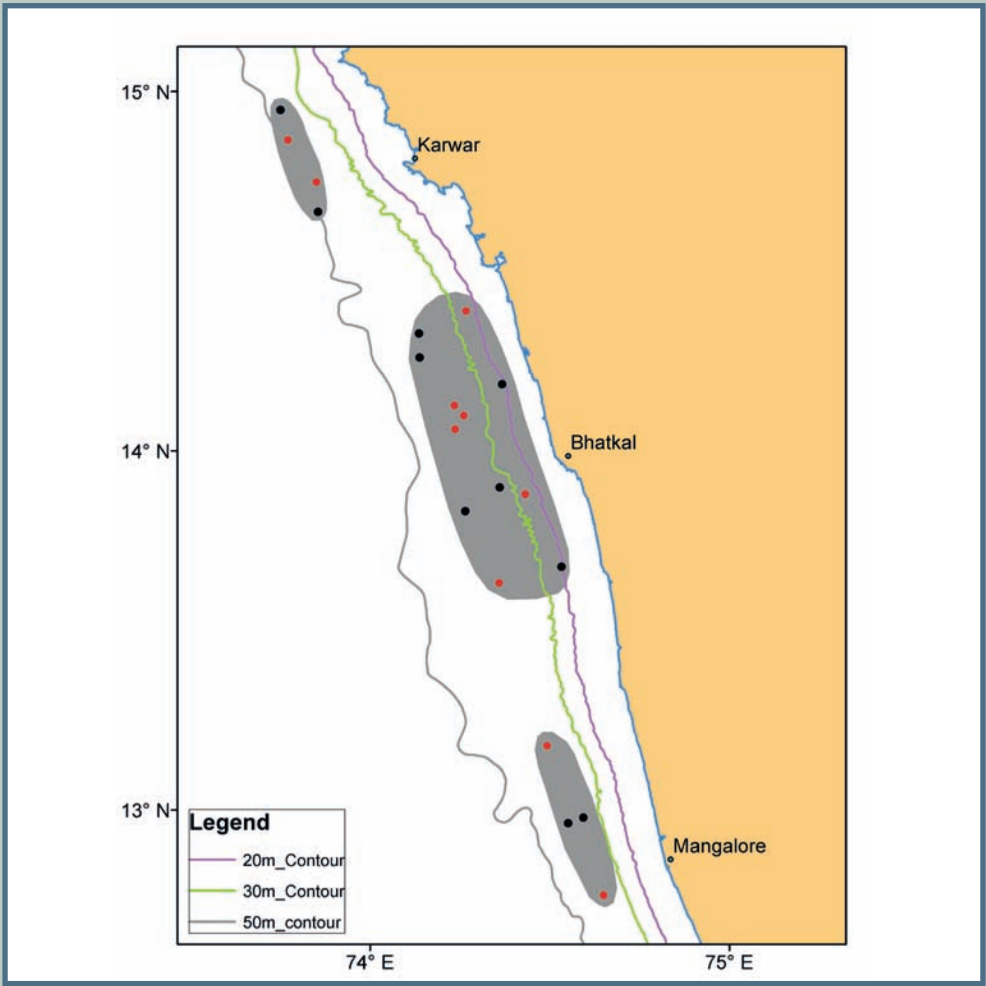

Fig. 7b. Shooting and hauling points with polygon of trawling grounds

What exists at a given location?

In a marine environment, the ecosystem consists of biotic and abiotic components. Their co-existence and interaction determines the productivity of the ecosystem. The distribution of each species varies considerably with depth and area. Even though the marine environment is highly dynamic, there may be some specific factors such as environmental parameters, water currents, bottom features, availability of food etc. which determine the distribution of fish. By collecting the

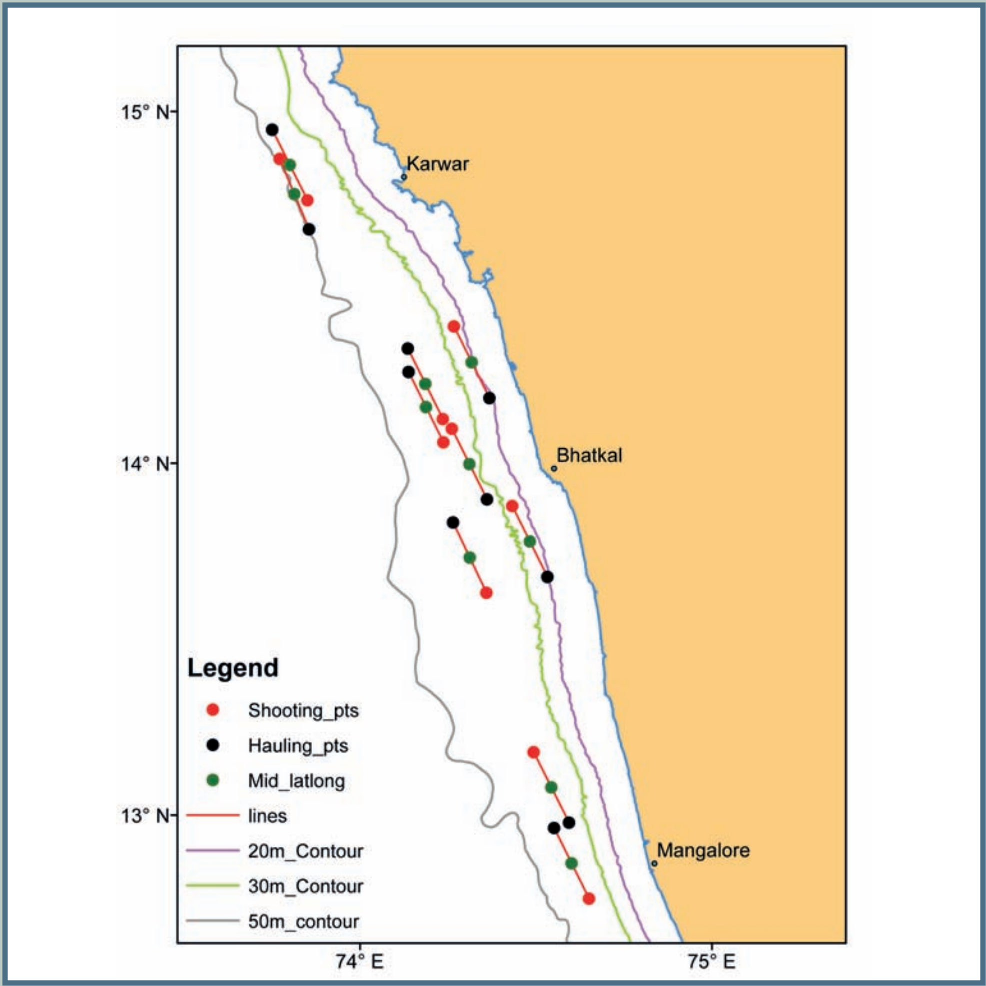

Fig.8a. Trawling tracks with midpoints to assign the catch rate.

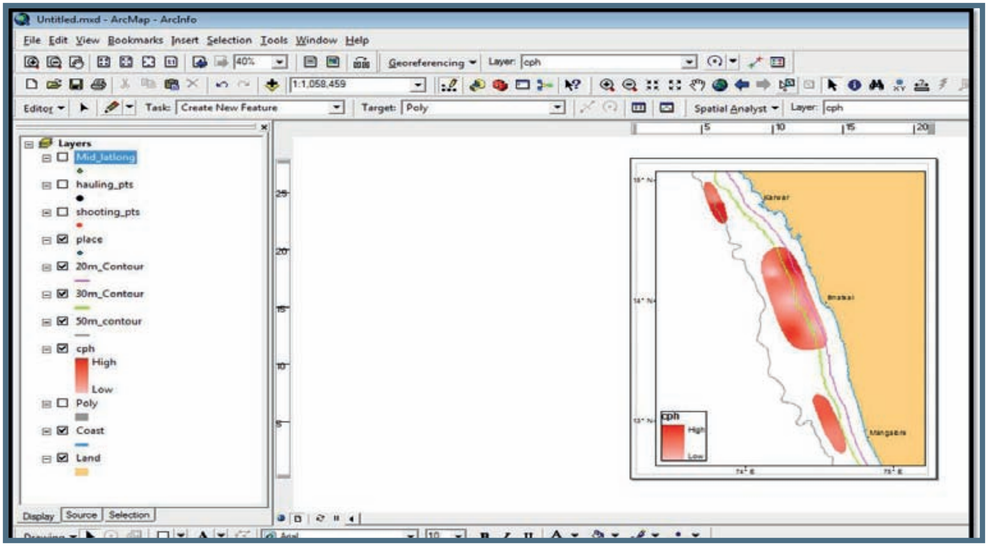

Fig. 8b. Creation of fish abundance maps from collected fishing and fishery data

GPS co-ordinates of the fish caught, the area of distribution of the species can be mapped. If long-term time series data is available, it will help in generating monthly maps, which will provide information on seasonal changes occurring in the species distribution in different fishing grounds. Databases on the different life stages of a species such as juveniles, spawners etc., can also be mapped in the form of different layers which make the maps more informative regarding any species(Fig.9). If time series data is available, it will help in tracing migration in juvenile and mature stages. There is a possibility of *in situ* growth measurements, if the database on length frequency is strong enough from the selected fishing ground.

Resource distribution layer properties

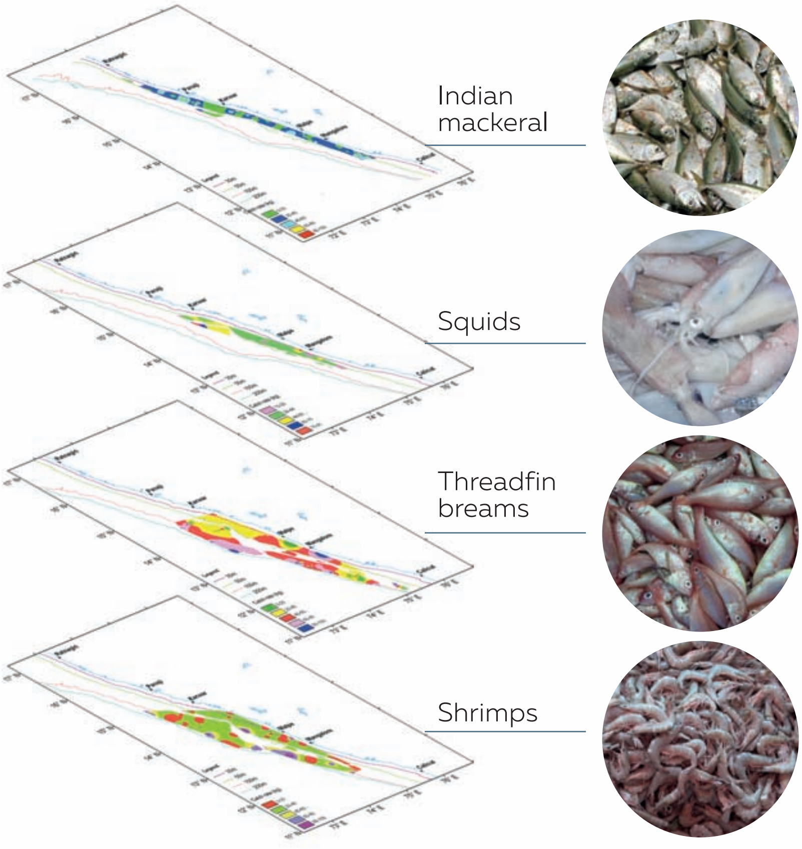

Fig.9 Illustration of layer properties on the GIS software enabling the analysis of different layers of resources from the same fishing ground

There will be trophic related assemblage of fishes and also substrate associated assemblages of fishes. The seasonal analysis of the spatial database can provide trophic dependence of various species in the marine ecosystem. In many cases, information on the species indirectly provide evidence on the type of the substratum also. If the species is known for its association with reefs and if regular data is available on the distribution of the fishes of this habit,

this database will indirectly provide indications of existence of reef in the vicinity of its distribution. The database on distribution created in GIS format can be used for assessing biodiversity, understanding the importance of the fishing ground in terms of conserving biodiversity and sustaining fisheries.

What are the driving forces for the spatial assemblage of biota?

Spatial data on the distribution of fishes will provide the species composition in the ecosystem with its geographic and bathymetric distribution. There are fish groups which are distributed in the surface and the upper column of the water, there are species which are having the dependency on the substratum and there are fishes capable of moving towards the surface and bottom. The distribution of these groups will have a definite reason for their assemblages. Pelagic and column fishes move according to the availability of food and also according to the oceanographic characteristics. Temperature plays a major role in their migration. Time series data studies on oceanographic variables and fish availability will help in understanding the affinity of the distribution of fishes to oceanographic variables such as wind, current, temperature, salinity etc. Data in time and space on species abundance and oceanographic variables will help in predicting availability of fishes on the basis of oceanographic information (Fig. 10). In the case of demersal fishes and crustaceans, bottom features and bottom biota serve as the major reason for their assemblages.

What are the changes occurring in the biota over a specific point in time?

There are various anthropological and natural interventions happening in the marine ecosystem. If the influences are analysed in spatial platform, management

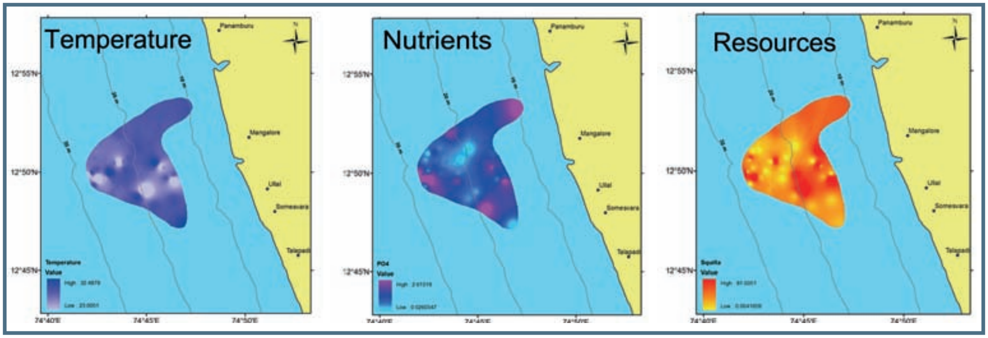

Fig.10 GIS based analysis of experimental trawling data along Mangalore coast with its temperature, nutrient and resource abundance

measures can be derived according to the specific issues and policies can be focused according to the severity of the impact. The most important anthropogenic intervention in marine environment is fishing itself. With technological support, marine fisheries has been developing at a rapid pace with tremendous impact on marine environment. Most of the changes are intended to increase the production and the world benefits immensely with increased fish production. High market demands led to over-capitalization in the marine fisheries sector, which started exerting heavy pressure on marine ecosystem. Fishing pressure in grounds of areas of abundance of juveniles and spawners can be identified and the impact of the fishing pressure on the resources can also be determined. GIS provides an opportunity to understand the changes in the species composition in a particular fishing ground over a period of time. GIS will give answers to the queries on the status of fishery and biodiversity, if the fishing pressure continues at the present level or if it increases. The increase in marine pollution is another anthropogenic pressure on ecosystem which can also be assessed with GIS studies. GIS based studies provide "what if" scenarios on the increase of temperature on the distribution of pelagic fishes, and policies can be formulated according to the changing scenarios.

What is the application of GIS as management tool?

Most of the management options evolved during different periods of fisheries development for sustaining marine fisheries did not yield desirable results because of non-acceptance and non-compliance of management regulations by fishermen. Enforcement of regulations was not successful as the fishermen felt that the policies did not represent ground realities and research findings were not presented in a convincing manner. Ever since the operation of fishing fleets has been extended beyond 30m to 50m, spatial characteristics of fisheries has remained relatively unknown for the researchers and policy makers. For comprehensive policies, incorporation of the knowledge about the spatial distribution of fishes has become essential. In this scenario, spatial data collection and GIS based analysis have become a crucial component in the formulation of acceptable fishery management policies. GIS based studies will help in developing management tools for fishing effort restriction, avoidance of juvenile exploitation, reducing the bycatch, conserving biodiversity and endangered species, identifying critical ecosystems, declaration of fishery refugia and marine protected areas (MPA) etc. The possibility of illustrations and projection of probable impacts through GIS software will provide more transparency on the suggested management measures and may improve adoption levels by the fishermen.

Protocols developed for data collection and analysis of trawl data for resource mapping

Trawl fisheries

Trawlers are the major mechanized fishing fleet which contribute to the fisheries production of India. Analysis of Indian marine fisheries production trend shows that between 2001-10, 80% of the marine fisheries catch was from trawlers. Modern day trawlers are equipped with modern equipment and higher engine capacity to fish more efficiently, leading to increased production. Trawlers target mainly demersal fishes and shellfishes which are location specific and more or less sedentary in nature. Intensity of trawl fishing has a vicious impact on benthic ecology and biodiversity. The biological and economic loss due to discards is one of the important issues that fishery managers have to tackle. Of late, mid-water trawl nets have been targeting the fast moving fish shoals, resulting in unprecedented exploitation of juveniles of commercially important finfishes. Improvements in craft and gear technology to increase fish production are becoming counter- productive. Collecting distribution information of the fishery is comparatively easy from single day trawlers that leave the fishing port early morning and return by afternoon. In the early years, single day operation was the pattern of trawling and the depth of operation was limited to 30 to 50 m with the voyage time of 5 to 8 hours. The entire catch was brought to the shore and a similar scenario continues in single day operating vessels in many landing centres. The multiday trawlers go for voyage fishing for more

than one night extending from 9 to 13 days. Though the trawl is a non-selective gear, there is a targeted fishery in each season. Major targeted resources are shrimps, cephalopods and high valued demersal fishes. High opening bottom trawls, midwater trawls and semipelagic trawls are operated which target demersal, semipelagic and pelagic fishes. In multi-day operating vessels it is observed that the comparative economic viability depending on the demand for the species in the landing centre is the driving force for bringing the fish preserved or without preservation. Recent high demand from fish meal plants encourage trawler operators to bring as much catch as possible to shore, eventually reducing discards from trawlers substantially.

Protocols for multiday trawlers

For data collection from multiday trawlers, identification of the trawlers is the most important phase. The crew selected to collect the fishing and fishery data may be given training in data collection. Boat drivers could be entrusted with recording of fishing details. The logbook prepared in local language will ensure more ease and accuracy for the data collected. The sample from each haul can be collected with a token representing the haul details. The samples should be preserved in ice and if some part of the catch is discarded, a sample of the discarded catch should also be collected with information on the total catch discarded in each haul. The token number should be recorded in field diary also. The following is the information to be collected from multiday trawlers for mapping of fishing ground and resource distribution (Table 1 and 2).

Data entry sheets

State:			Fisheries Harbor:	
Boat ID	Boat Type	Engine Capacity	Average Speed	Fish Hold capacity

Data to be entered in field diary (given onboard)

1. Cruise No
2. Date
3. Depth of shooting
4. Time of shooting
5. Shooting latitude
6. Shooting longitude
7. Hauling depth
8. Hauling time
9. Hauling latitude
10. Hauling longitude
11. Net type
12. Mesh size
13. Total catch (kg)
14. Total discard (kg)
15. Number of hauls/day
16. List of commercial species with its percentage by weight.

Analysis in Laboratory	
1.	Token number
2.	Date
3.	Hauling latitude
4.	Hauling longitude
5.	Depth
6.	Total catch
7.	Total discards
8.	Total sample weight
9.	Number of varieties/species in catch (get a representative sample if discards are there, record the same and get a sample of the same.)
10.	Name of each species (organisms are to be identified as far as possible upto species level)

Following studies are to be done in each species recorded	
1.	Weight of each species in the haul (calculation)
2.	Numbers of each species in the haul (calculation)
3.	Mean size of species(calculation)
4.	Number of hauls/day
5.	CPH of all species (calculation)

Table 1: Sample of the log book data, collected for the study from offshore sampling.

Cruise No	1	2	3	4	5	6	7	8	9	10
Token No.	166	154	157	147	82	3	5	9	7	10
Date	4/9/07	5/9/07	06/9/07	07/9/07	08/9/07	09/9/07	10/9/07	11/9/07	12/9/07	13/9/07
Shooting Depth (m)	115	150	150	85	80	85	62	140	84	110
Shooting time	16	9	6.3	13	6.3	7	6	7	10.3	6
Shooting latitude	13.418	13.835	12.667	12.123	11.175	10.839	11.243	11.514	11.773	12.423
Shooting longitude	73.518	73.438	74.438	74.845	75.152	75.262	75.162	74.753	74.718	74.443
Hauling depth	115	150	150	85	80	85	60	139	85	110
Hauling time	19	11.3	9.3	15	6.3	9.3	9	9.3	13	9.3
Hauling latitude	13.493	13.903	12.623	12.048	11.175	11.432	11.328	11.432	11.858	12.346
Hauling longitude	73.488	73.432	74.223	74.865	75.152	74.743	75.152	74.743	74.703	74.432
Net type*	200-300	200-300	300-400	300-400	200-300	200-300	500-600	200-300	200-300	200-300
Mesh size*	1/2	1/2	1/4	1/4	1/4	1/2	1/2	3	1/2	1/2
Total catch (kg)	1000	600	400	100	200	200	1000	600	200	400
Total discard	900	500	350	40	10	75	900	400	100	300
Number of hauls per day	3	3	3	3	4	3	4	4	2	2

* Codes are given for net type and mesh sizes

Table2. Sample of the biology data, collected from georeferenced points represented by token number

Token No	Date	Hauling latitude	Hauling longitude	Depth	Total catch	Total discard	Total sample weight
166	04-09-07	13.493	73.488	115	1000	900	2.495

Species name	Species count	Species weight (kg)	Length frequency	Weight of species in the haul
Apogon sp	48	0.033	XXXXX	616.47
Solenocera choprai	29	0.025	XXXXX	69.98
Arthron sp	4	0.291	XXXXX	104.97
Saurida sp	3	0.042	XXXXX	8.30
Muraenosox sp	1	0.012	XXXXX	15.15
Platycephalus sp	2	0.046	XXXXX	16.23
Grammoplites scaber	2	0.015	XXXXX	5.41
Sepia elliptica	3	0.045	XXXXX	16.23
Charybdis hoplites	1	0.001	XXXXX	0.36
Nemipterus randalli	3	0.33	XXXXX	11.93
Gymnothorax sp	3	0.140	XXXXX	37.17
Colocronger sp	1	0.050	XXXXX	13.28
Dendrochirus sp	1	0.194	XXXXX	51.51
Uraenoscopus sp	4	0.259	XXXXX	68.77

Software developed for easy retrieval of fishing and fishery information to provide as input to GIS software.

Ever since the fishing depth was extended to deeper waters and fishing operations extended from single to multi-days, the fish landing data needed its spatial component of catch, also to provide information on distribution of marine resources. The most important utility of spatial data collection is that monthly and seasonal queries can be answered on distribution and abundance of individual species or group of commercial species, so that policy makers will have a handy tool in deciding the resource based, juvenile abundance based fishery restrictions in different fishing grounds. The data on fishing and fishery, including species level catch, discard, juvenile and spawner information from each haul will become very huge database which is difficult to manage with regular data recording. To achieve the goal of smooth handling of data, intermediate software was developed in Visual Basic. This software helps fisheries researchers to send simple or complex queries and analyses and to plot the result on a map. The respective geo-database tables in GIS and Visual Basic are populated with voluminous data of catch which comprises geographic coordinates, water depths, net types, and commercial fish, discard species etc. Thematic shape files/ feature classes can be prepared by sending queries into these tables. The cruises of each trawler are displayed as lines on the shape files/feature classes. The query results can also be displayed as fish grounds. Catch-discard data can be viewed by clicking on cruise lines displayed on interactive maps. For the analysis of trawl data, a software in Visual Basic was formulated which is named as FRIM (Fishery Resource Information and Management). FRIM facilitates to analyse this data by sending simple or complex queries. The determination of CPH, monthly averages, comparison of fish composition between fishing grounds, analyses of bycatch species, species to species correlation, repetition of species in space and time etc., can be performed with great ease using FRIM. The output can be easily represented on a map using GIS software. The FRIM-GIS outputs will be of great help for fishery resource mapping, planning, policy making and sustainable exploitation of fishery resources (Fig.11a & 11b).

Application of GIS mapping in fisheries management. Assessment of fishing pressure (trawl footprint)

The fishing operation data can be used to understand the extent of fishing operation from a particular fishing ground and the status of fishing ground in the trawl fishing ground operated by trawlers. This is termed as "trawl foot print studies" in fisheries research. The data collected from multiday trawlers operated off Mangalore is illustrated in Fig. 12 to understand the utility of the data in trawling footprint studies. The illustration has incorporated all 1,035 days of fishing operation taken up during 2007-12. The database gives information on fishing ground on particular day/month/season/year basis with operational maps. It shows that trawling operations from Mangalore operated from seas off Calicut in the south (75°E, 11°N) to off Ratnagiri in the north (73.5°E to 17°N). The depth of operation was between 5-167m. The most intensive trawling operations were observed in fishing grounds at 30m depth off Mangalore to Panaji, followed by fishing ground at 100m depth off Malpe to Karwar. Fishing ground at 30m depth off Ratnagiri was also found to be fished with moderate intensity. The present study reveals that most of the fishing operations are concentrated within the 150m depth zone and extension was mainly parallel to the shore, towards south or north. The information on existing fishing pattern

Operation of intermediate software development for feeding, fishing and fishery information to GIS software with queries

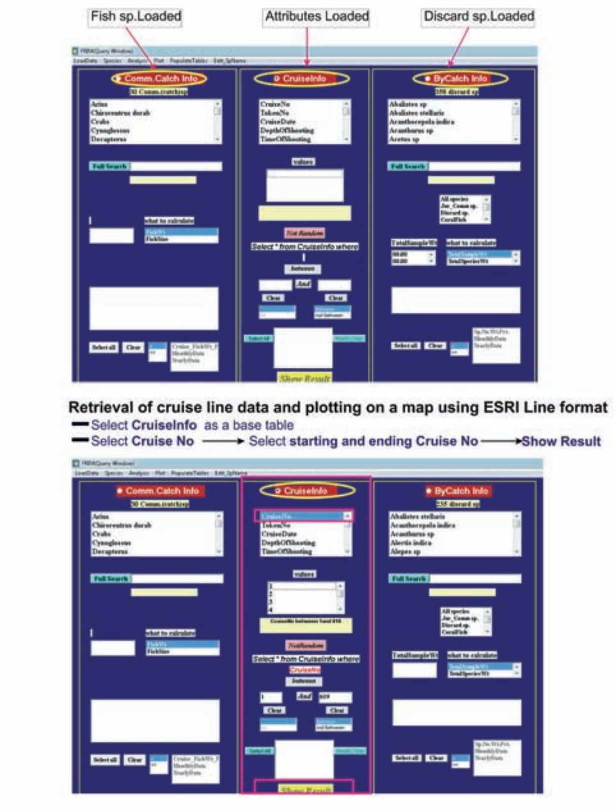

Fig.11a. Desktop view of software developed for data storage and retrieval of multiday trawl data for feeding into GIS software.

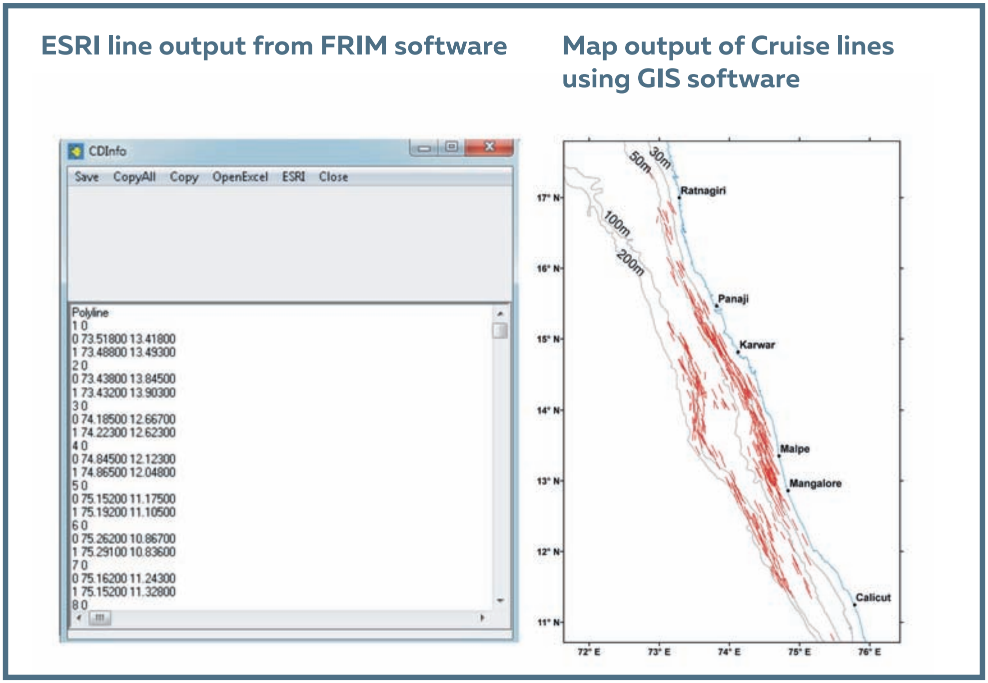

Fig.11b. Desktop view of software developed for data storage and retrieval of multiday trawl data for feeding into GIS software.

in regular fishing grounds by mechanized trawlers will enable a policy framework for the sustainable exploitation of resources from their jurisdiction more efficiently. These maps give a strong basis for participatory decision making on effort reduction in terms of months and seasons with stress on specific resources, very effectively. It is also observed that there are areas without operations in all these years of study and the reason for no trawling was the unsuitability of the bottom topography for

Juvenile and non commercial fishes collected from trawl

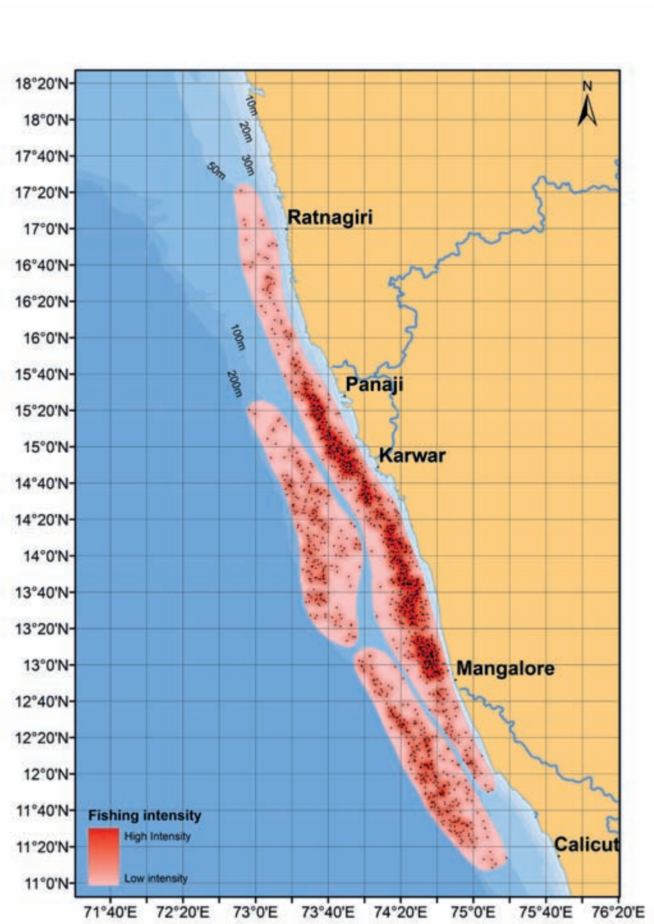

Fig.12 Trawl footprint analysis

trawling. Such areas act as natural protected areas in the marine ecosystem and help in replenishment of commercial resources, by giving protection to juveniles of many commercially important species. The non-trawling areas off Murudeshwar coincide with the unique coral ecosystem and 14 coral species belonging to 11 genera were also identified from this unique ecosystem.

Spatio-temporal distribution and abundance of fishes

A total of 246 species of fin fishes/shell fishes were recorded from trawl landing at Mangalore Fisheries Harbour during 2007-2012. The distribution of each could be mapped to its seasonal distribution and abundance. The fishing grounds from which the species were caught remained unknown during regular landing based fishery estimations. But the present study has provided definite information on the spatio-temporal distribution of most of these fishes. In trawl fishery apart from the landed fishes, discarded bycatch also formed a part of the catch and by including information on discarded bycatch, an exclusive picture of biota of the fishing ground could be understood. In the example given (Fig.13a-c) more than 200 species of finfishes/shell fishes and many unidentified fauna such as jelly fish, gorgonids, echinoderms, coral fishes, juveniles of shark and ray were recorded from the discarded bycatch of trawlers operated off Mangalore Coast during 2008-2009. The spatio-temporal distribution of fishes off Malabar and Konkan coast was illustrated and published in Marine Fisheries Information Service Technical & Extension Service Series, 110 (CMFRI, 2011). These maps can be split into species wise monthly maps too, depending on the requirement. Based on monthly and annual resource mapping, management interventions like effort restrictions and seasonal closure of the fishery in particular fishing grounds could be suggested to reduce the resource damage.

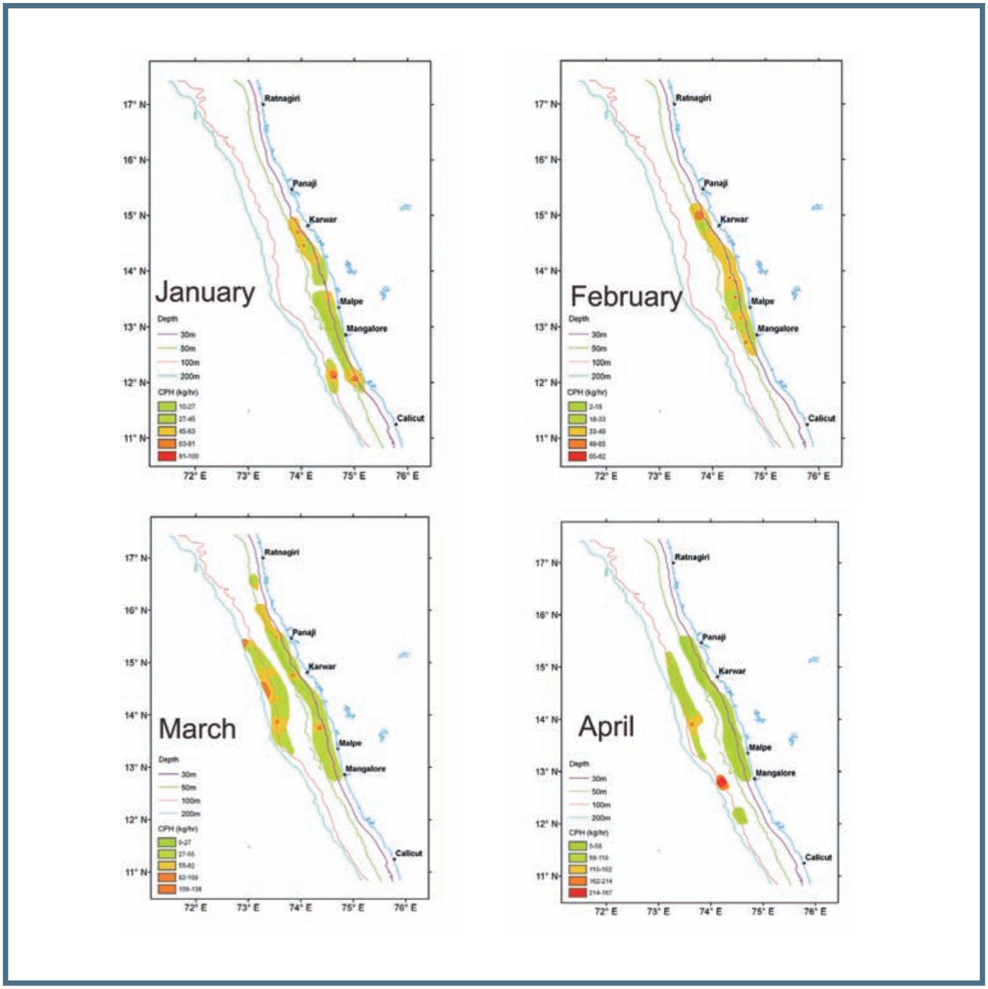

Fig.13a. Mapping of spatio-temporal distribution and abundance of fishery resources in trawl fishing grounds off Karnataka coast in GIS platform (January-April, 2008-2009)

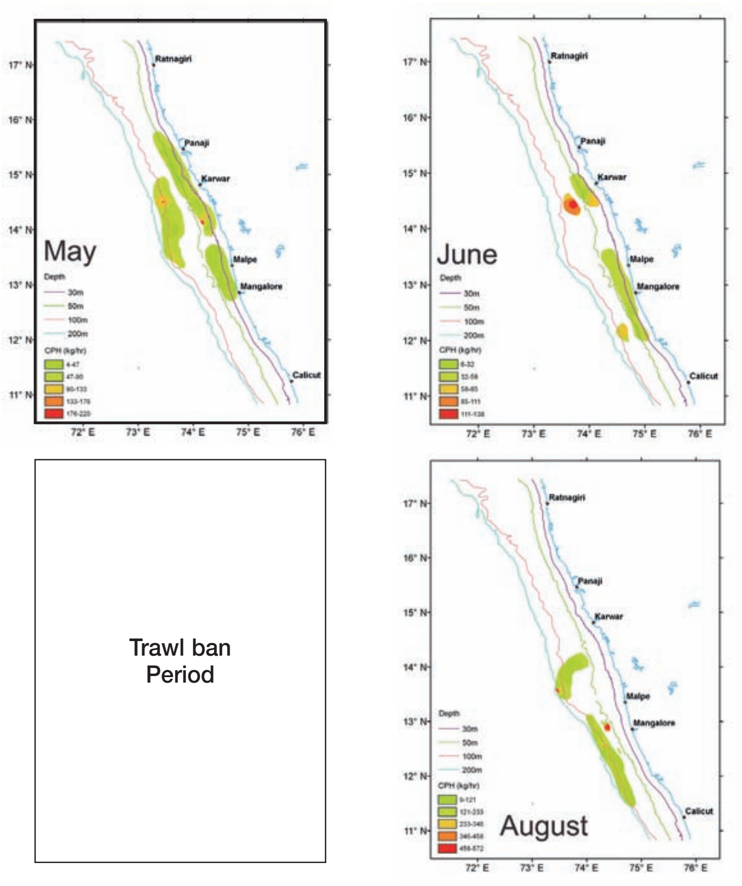

Fig.13b. Mapping of spatio-temporal distribution and abundance of fishery resources in trawl fishing grounds off Karnataka coast in GIS platform (May-August, 2008-2009)

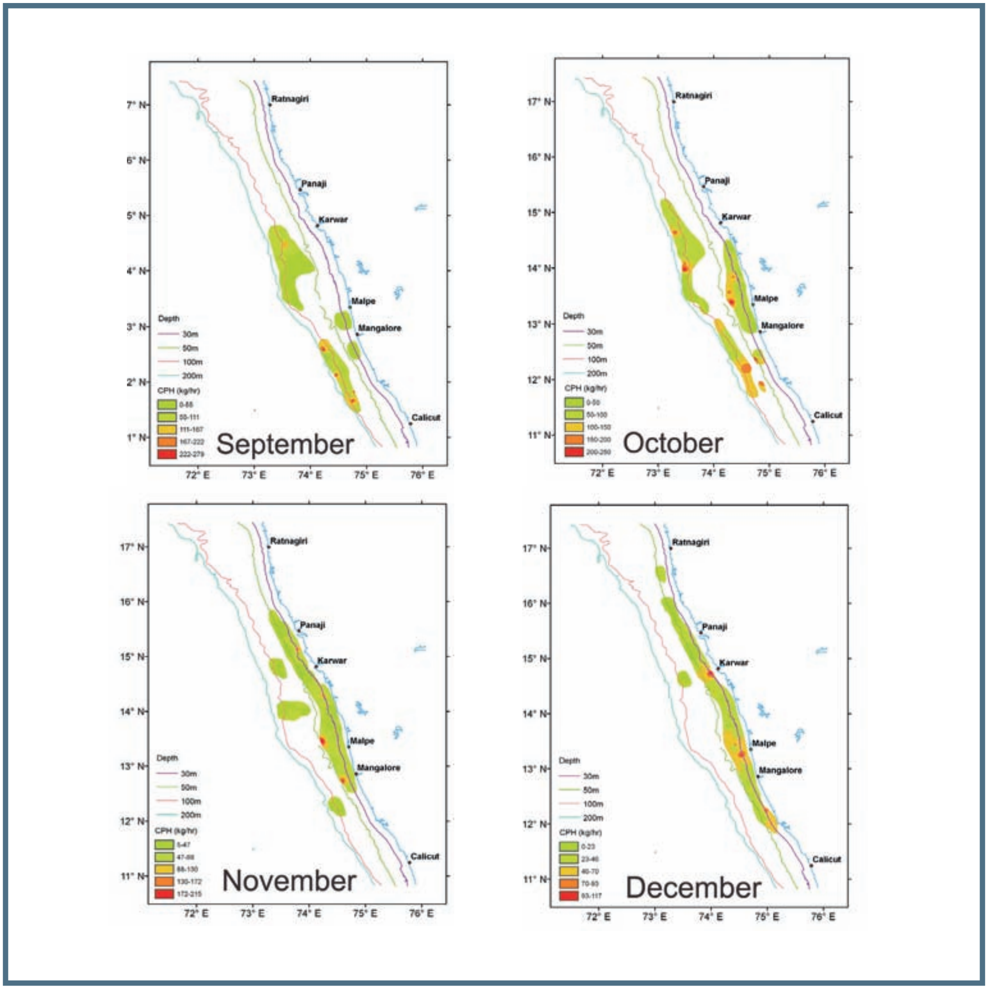

Fig.13c. Mapping of spatio-temporal distribution and abundance of fishery resources in trawl fishing grounds off Karnataka coast in GIS platform (September-December, 2008-2009)

Juvenile and spawner abundance studies

The resource maps of fishes will become more informative if mapped on the basis of their different life stages, such as juveniles, sub adults and spawners. GIS based resource mapping of juvenile and spawner abundance along the Indian coast will provide database for the spatial and temporal closure or restriction in trawl fishery. GIS is found to be a very handy tool for fishery resource mapping. The most important feature of the GIS maps is that, information on each separate group/species/juveniles/adults layers can be individually or collectively separated by queries and the layers can be studied in terms of their importance. 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 utility of the layer character of GIS in bycatch reduction is that, if some juvenile exploitation in a specific species makes considerable impact on the stock position and economics of commercial species, effort restrictions can be imposed in that fishing ground and season with illustrative justifications. Studies on the repeatability of the juvenile abundance in these particular fishing grounds will help in identification of critical fishing ground where seasonal and spatial closure of trawl fishery can be implemented to improve the fishery production in the long run. Resource maps can be used as an excellent tool for the policy makers to grade each fishing ground in terms of commercial value and juvenile abundance, so that the policy making process will be much more transparent. Illustrated maps with seasonal/ fishing ground wise distribution of juveniles and commercial fishes, will help as a useful tool in awareness programs to extend the research findings to the stake holders. For declaration of MPAs and "fish refugia" as well, these studies are important.

The results of the GIS based spatio-temporal mapping of juveniles and spawners of commercial species in the trawl fishing grounds off Mangalore are presented in figures 14a-d and 15a-d.

Ecosystem based studies.

The utility of spatial data collection is that this data will provide information on non-commercial species which have a significant role from an ecosystem perspective. Information on many of these non-commercial species are limited or missing in the landing center based fishery data collection system, since only commercially important species are brought to landing centres. The key species which do not come in the commercial fishery contribute significantly to the food web of the ecosystem as prey for most of the predatory commercial fishes. From an ecosystem perspective these species also have to be rationally exploited. Spatial study of the trawl data brought out distribution of many such species and the most important of them was the small sized crab, *Charybdis hoplites*. Apart from the information of the rare occurrence, the extensive distribution of the species was not understood until the spatial study was initiated. Studies have revealed that this species is distributed widely along trawling grounds off Karnataka coast with varying intensity (Fig.16) and the examination of gut contents of commercial species *Epinephelus* spp and *Nemipterus* spp caught from these grounds show that large quantities of these crabs are consumed by these commercial species. From an ecosystem perspective, such studies will help connect the missing links in the ecosystem and to make ecosystem based fisheries management more effective. Such mapping will also help to identify the keystone species and to identify essential fishery habitats.

Areas and seasons of juvenile abundance of *Nemipterus randalli*

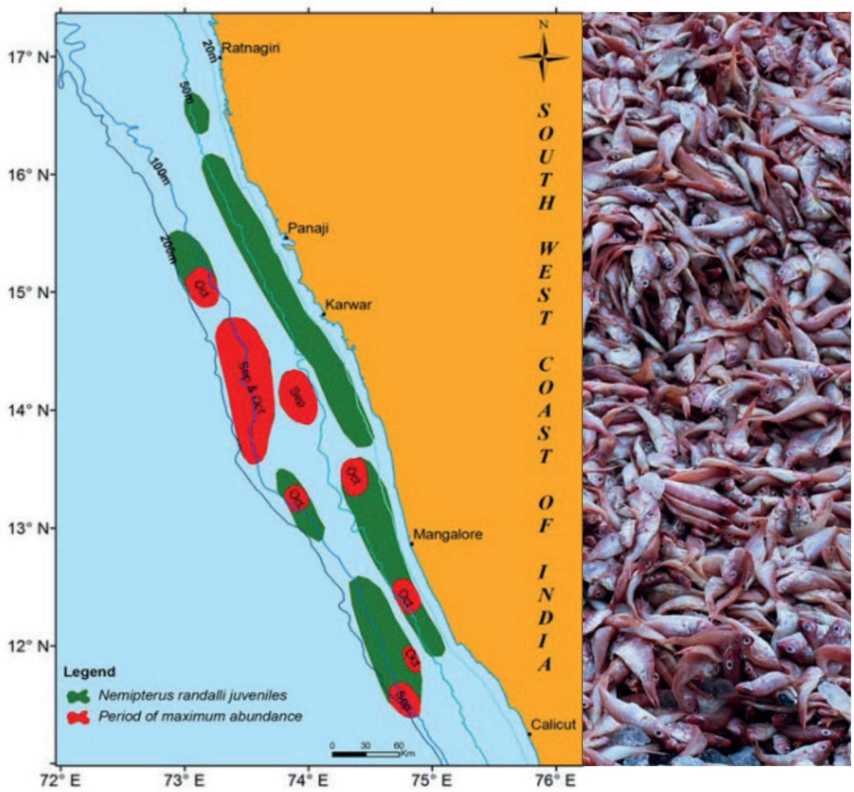

Fig. 14a. Fishing ground and seasons of juvenile abundance of *Nemipterus randalli* identified by GIS based studies.

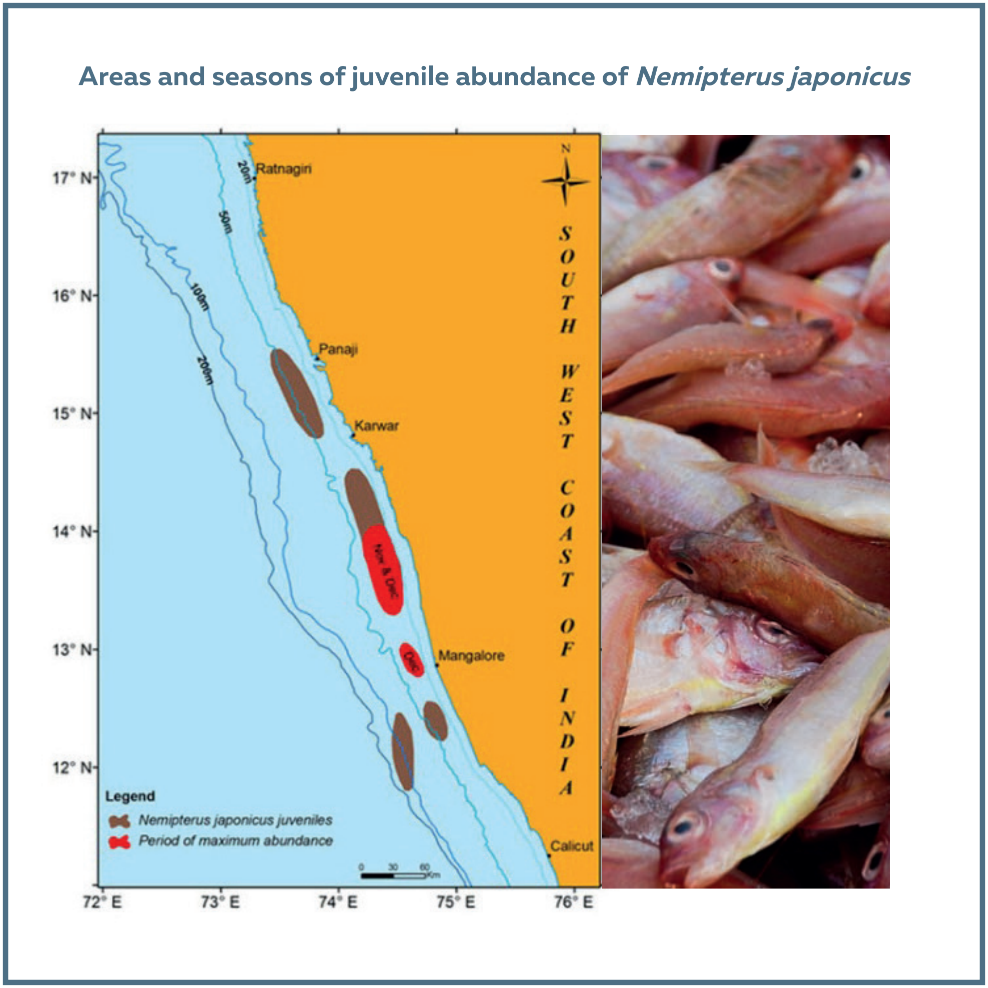

Fig. 14b. Fishing ground and seasons of juvenile abundance of *Nemipterus japonicus* identified by GIS based studies.

Areas and seasons of juvenile abundance of *Lactarius lactarius*

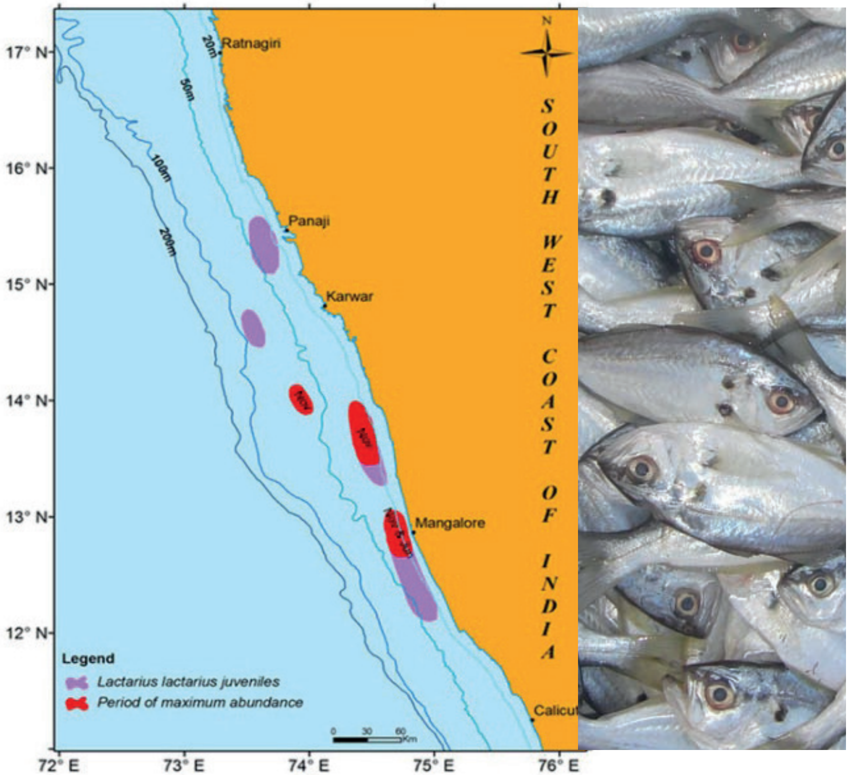

Fig. 14c. Fishing ground and seasons of juvenile abundance of *Lactarius lactarius* identified by GIS based studies.

Areas and seasons of juvenile abundance of *Epinephelus diacanthus*

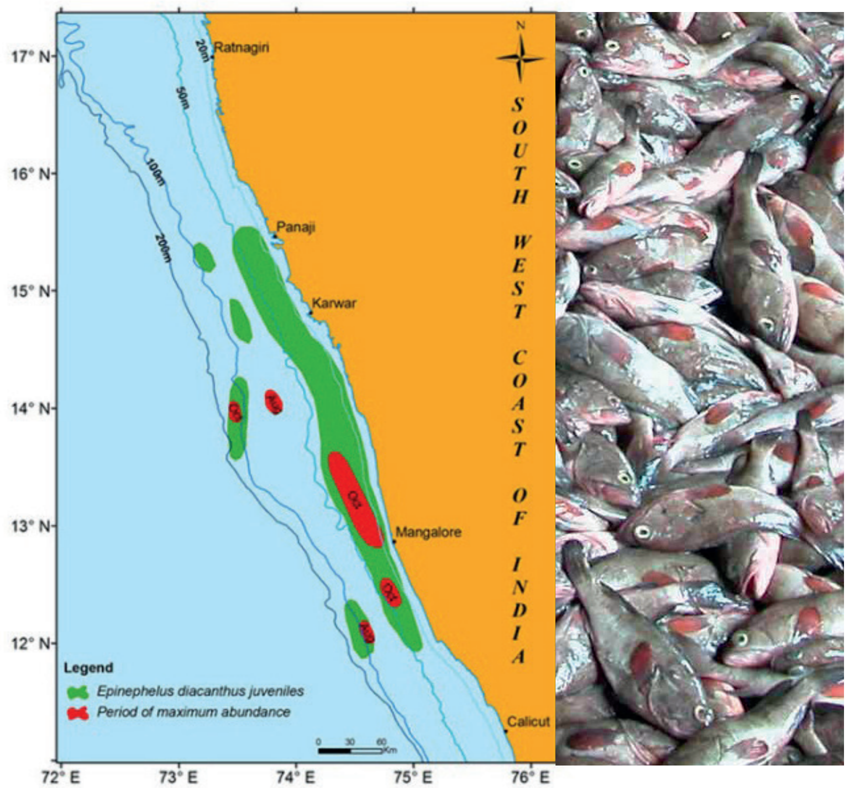

Fig. 14d. Fishing ground and seasons of juvenile abundance of *Epinephelus diacanthus* identified by GIS based studies.

Areas and seasons of spawner abundance of *Nemipterus randalli*

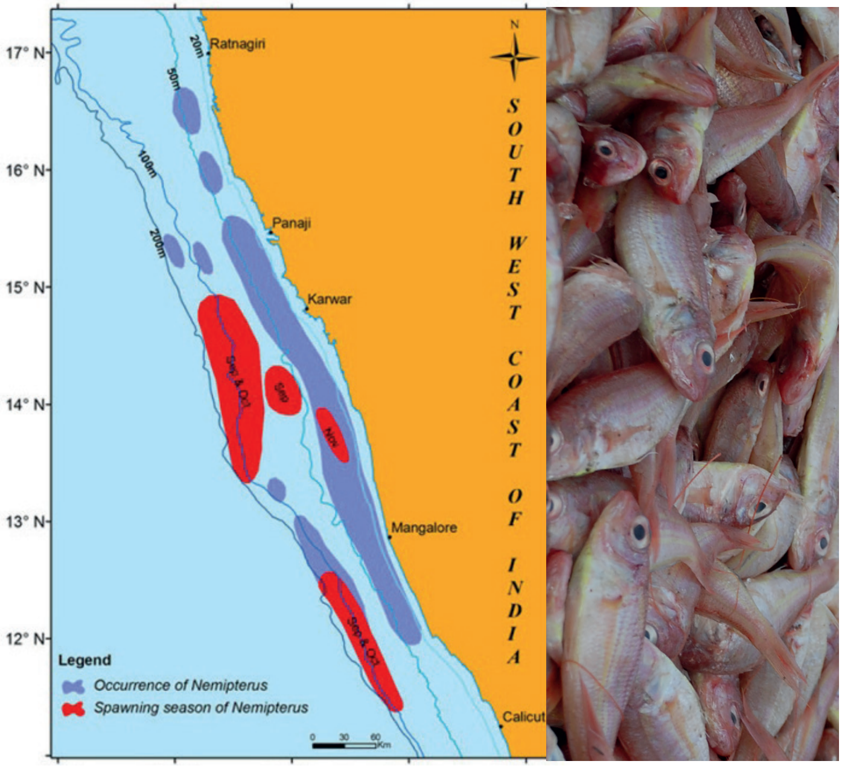

Fig. 15a. Fishing ground and seasons of spawner abundance of *Nemipterus randalli* identified by GIS based studies.

Areas and seasons of spawner abundance of *Metapenaeus monoceros*

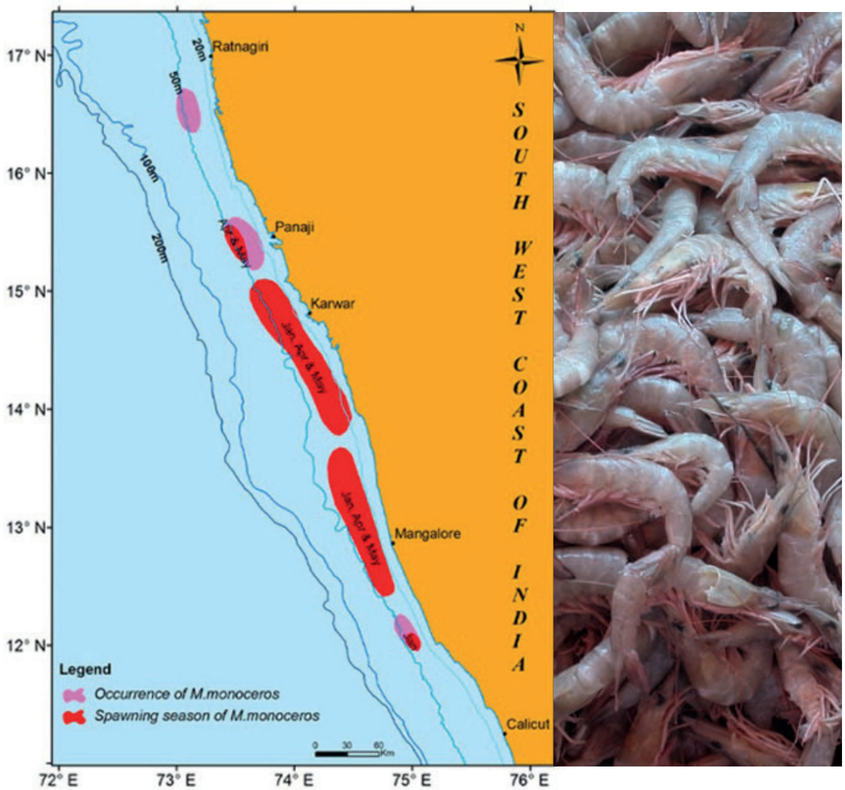

Fig. 15b. Fishing ground and seasons of spawner abundance of *Metapenaeus monoceros* identified by GIS based studies.

Areas and seasons of spawner abundance of *Saurida tumbil*

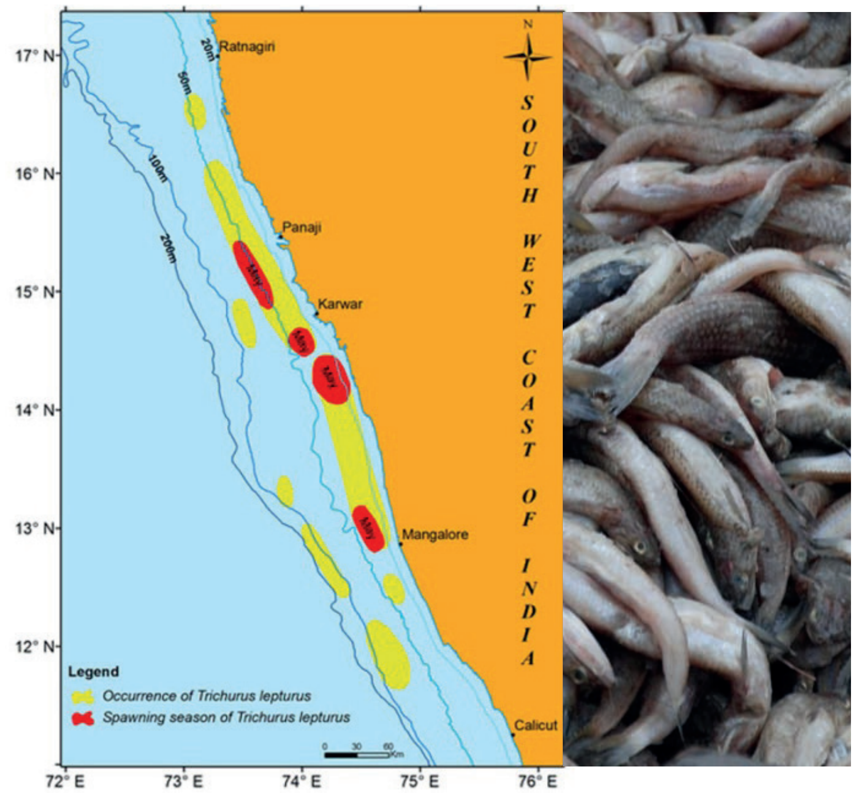

Fig. 15c. Fishing ground and seasons of spawner abundance of *Saurida tumbil* identified by GIS based studies.

Areas and seasons of spawner abundance of *Trichiurus lepturus*

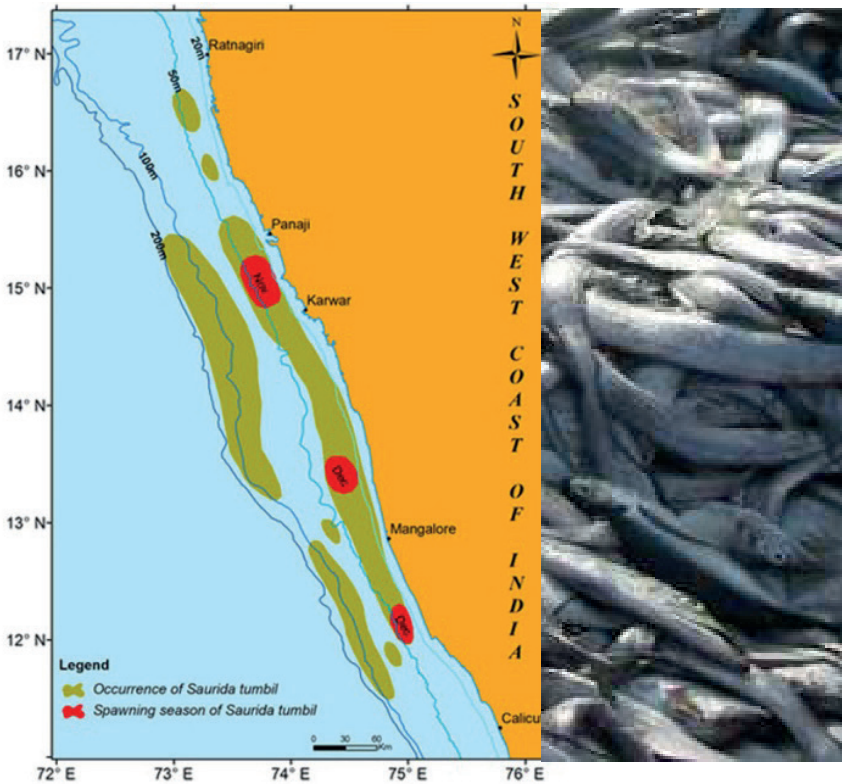

Fig. 15d. Fishing ground and seasons of spawner abundance of *Trichiurus lepturus* identified by GIS based studies.

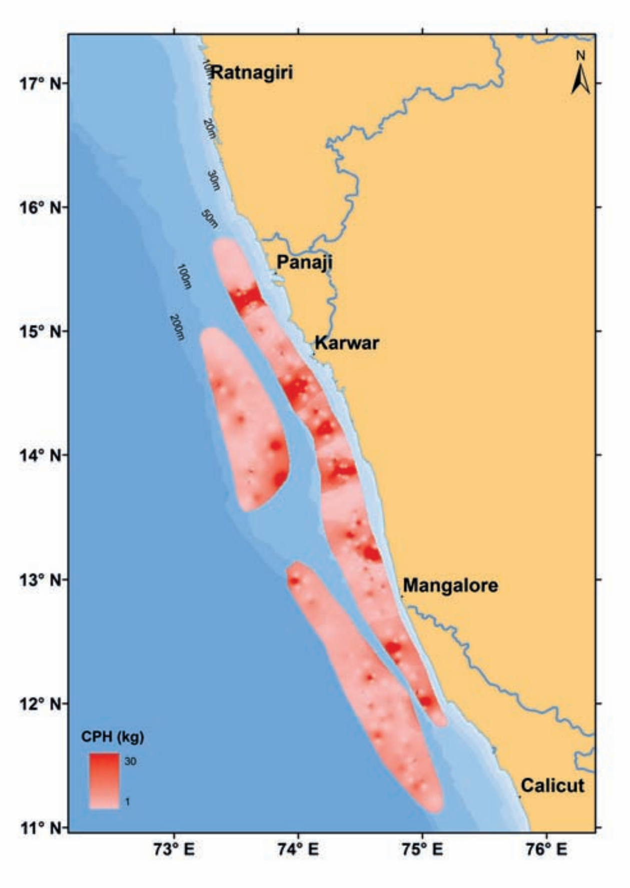

Fig.16. Mapping of *Charybdis hoplites*, which is a non-commercial species and which has very high significance in feeding ecology of the fishing ground off Karnataka by GIS based studies.

Protocols developed for data collection and analysis of gillnet, purse seine and ring seine data for resource mapping.

The protocols developed are based on data collection and analysis of gears mechanized or motorized crafts. The protocol is derived based on the method of fishing and the behavior of fishes caught. Gillnets are more or less stationary gears, with a limited spatial variation, which are being used in nearshore and deeper waters. In gillnetters it is seen that fishermen are following traditional fishing grounds which vary with the season according to the movement of water and movement of fishes. GPS information is used for identifying the fishing ground in each month, and the data on species caught, monthly CPUE, juvenile composition and spawner composition. The information on each species is depicted in graphical/numerical form (Table 3). This mapping will give information on the seasonal fishing grounds, information on distribution and abundance of the species in the identified fishing ground. In the case of purse-seines and ring seines, even though shoaling behavior of the fishes are unpredictable, there are some traditional probable areas of fishing that are being explored by fishermen depending on seawater movement and sea surface temperature. The seines are operated mainly on the visual identification of the shoal. Monthly mapping of the fishing grounds fished will provide information on variation in the fishes caught and variations in juvenile and spawner percentage in each month, which will enable the policy makers to come out with appropriate interventions (Fig.17-20).

Purse-seine operation

Data collection from gill net, purse seine, shore seine and long line

Data collection schedule

Table 3:

State:		Landing Centre:			
S. No	Date (dd/ mm/yy)	Name of the fish landing centre GPS location Gear	Distance travelled from landing centre	Direction in which travelled	Depth of Operation

Species Composition (Average)								
Sl. No	Month	Year	Gear	Species	Catch (kg)	Effort CPUE	CPH	Any other observations

Juvenile composition & spawners (Identify five major resource)

Gear						
Sl. No	Month	Year	Species	Juveniles (%)	Spawners (%)	Any other observations

A sample should be collected from each gear and analysis can be done from the subsample collected

Ring seine operation

Resource mapping using multi-day gillnet data
Station: Mangalore Month: September 2014

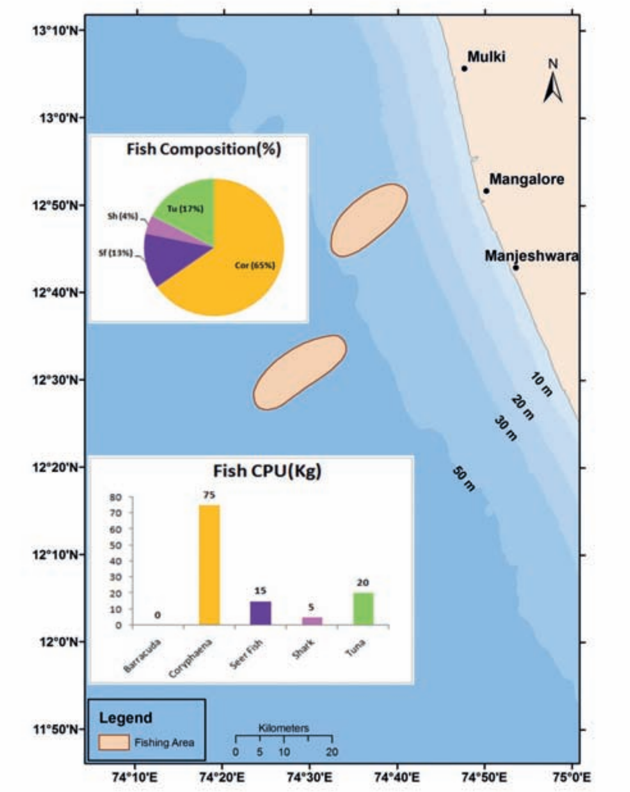

Fig.17. Protocols developed for the resource mapping of species caught by gillnetters off Mangalore coast.

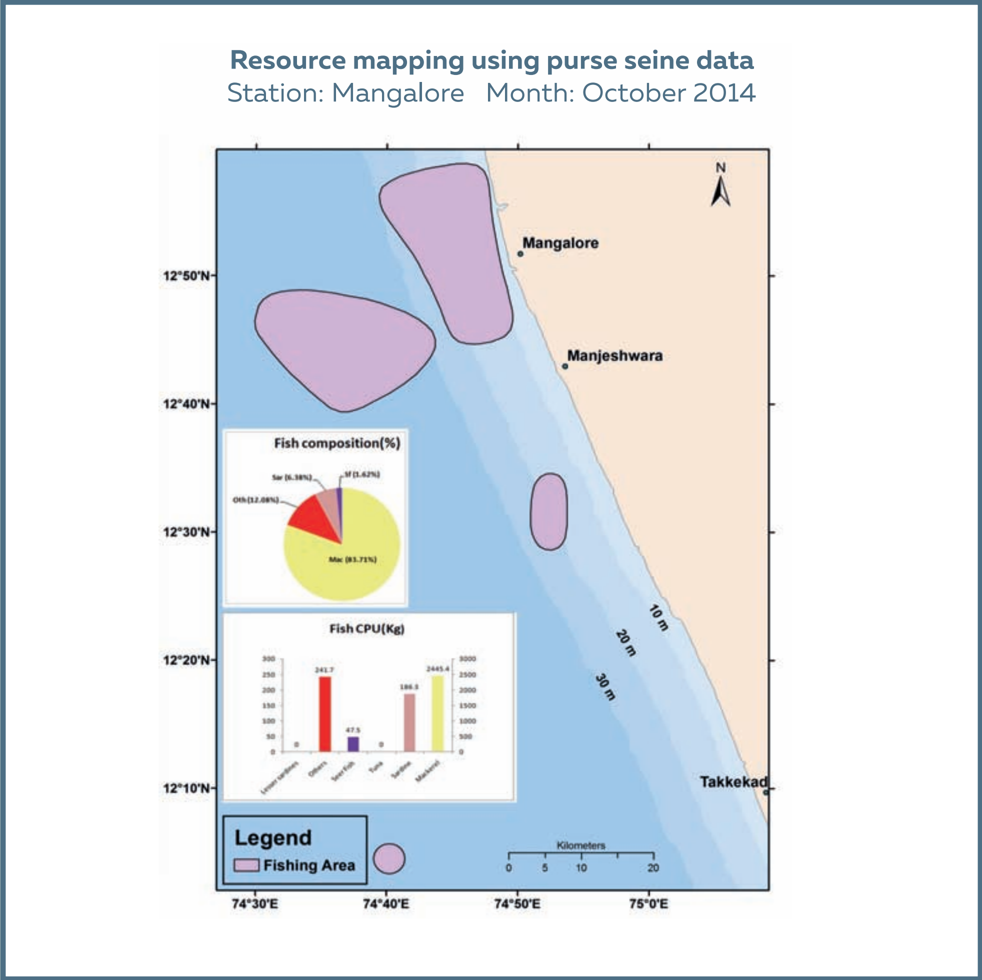

Fig.18. Protocols developed for the resource mapping of species caught by purse seiners off Mangalore coast.

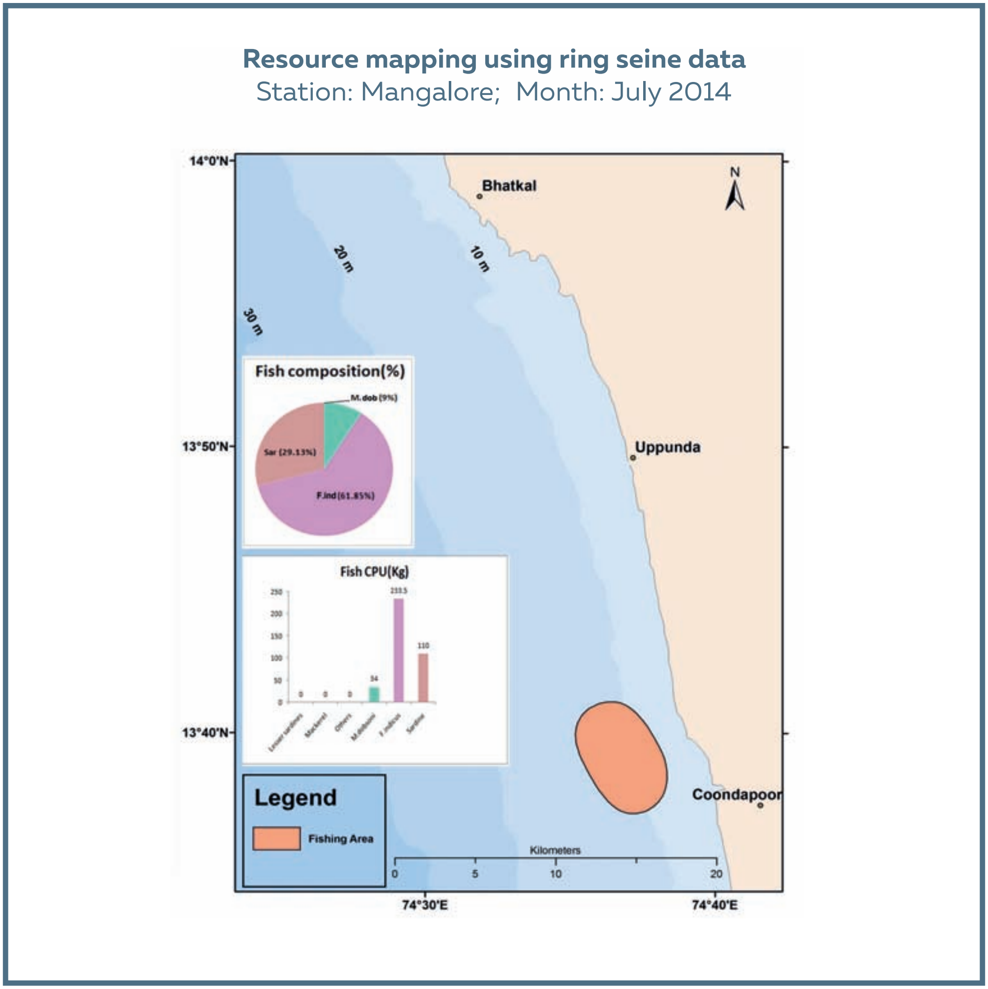

Fig.19. Protocols developed for the resource mapping of species caught by ring seiners off Mangalore coast.

Resource mapping using drift gillnet data
Station: Tuticorin Month: January 2014

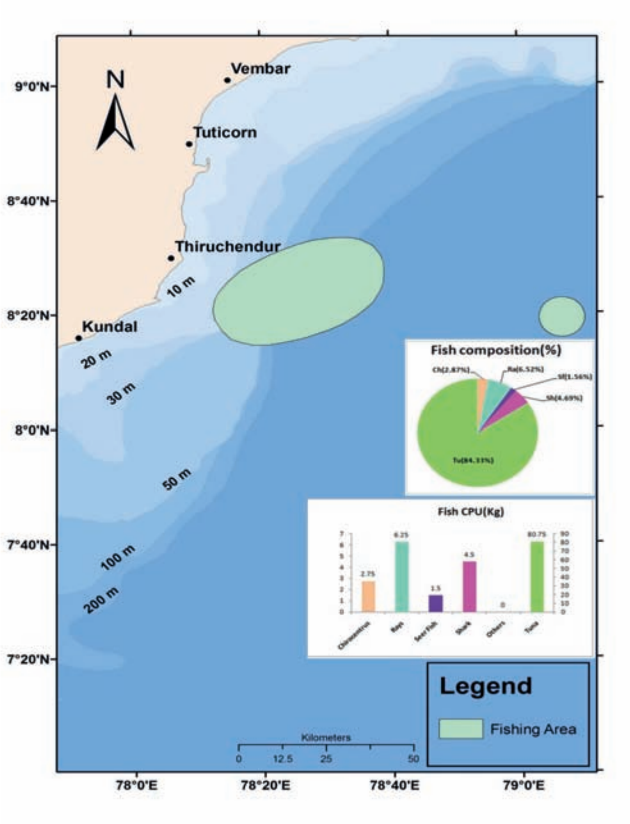

Fig.20. Protocols developed for the resource mapping of species caught by Multiday gillnetters off Tamil Nadu coast

Protocols developed for data collection and analysis of dolnet data for resource mapping.

Dolnet catch and effort data off Mumbai coast, collected with its GPS coordinates were subjected to biological and spatial analysis to derive protocols for the resource mapping from the gear. Areas of operation of dolnetters were identified and mapped in GIS format with the help of GPS coordinates collected along with catch data. Month-wise maps of species composition and juvenile composition of fishery resources were prepared. Temporal/month-wise changes in the composition of catch in terms of their juveniles percentage were prepared to obtain an overall picture of juvenile catch in the dolnet (Fig.21). For illustration of the protocol, dolnet data collected off Mumbai during the year 2014 was used. Data analysis showed that, during the month of April, highest percentage of juveniles were observed in the fishery. Catch and effort data for each month was individually analysed to understand the catch rate, species composition and juvenile composition. An illustration of the analysis of the dolnet fishery for April, the month in which highest percentage of juveniles were observed is presented in Fig.22 to elucidate how GIS based data analysis brings out important information from fixed nets like dolnet and Chinese dipnets etc. During April 2014, fishery was constituted by 100% juveniles in three major species (*Pampus argenteus*, *Trichiurus lepturus* and *Tenualosa toli*). In bombayduck juvenile percentage during the month was around 89%. Similar information can be derived for all the months for which data are available. Analysis with the protocols developed in GIS platform proves that such studies can reveal the seasons of high incidence of juveniles and spawners, which can provide illustrative testimony for taking decisions helping in sustainable fisheries.

Dolnetters of Gujarat

Fishing grounds mapped for dol net operation for 2014

Landing centre: Mumbai, Maharashtra

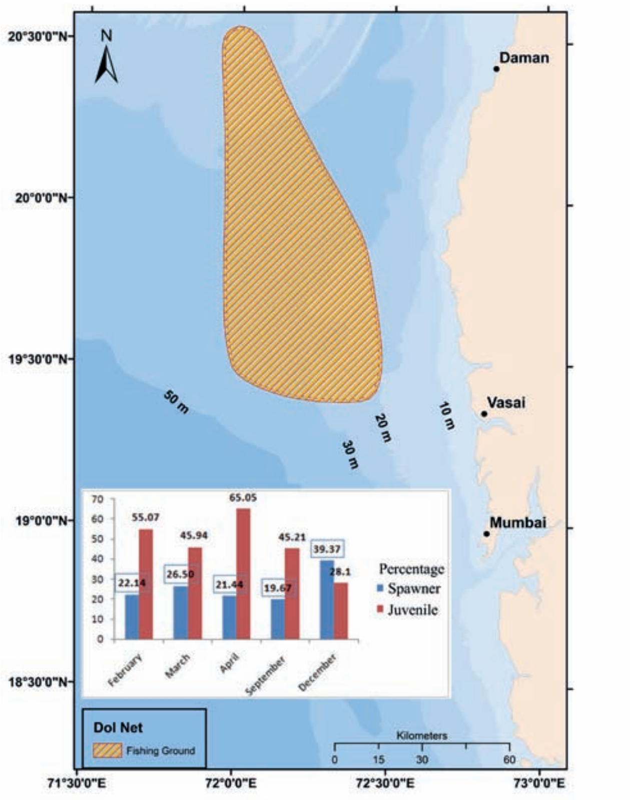

Fig.21. Protocols developed for the resource mapping of species caught by dolnetters off Mumbai coast.

Fishing grounds mapped for dolnet operation for 2014
Landing centre: Mumbai , Maharashtra

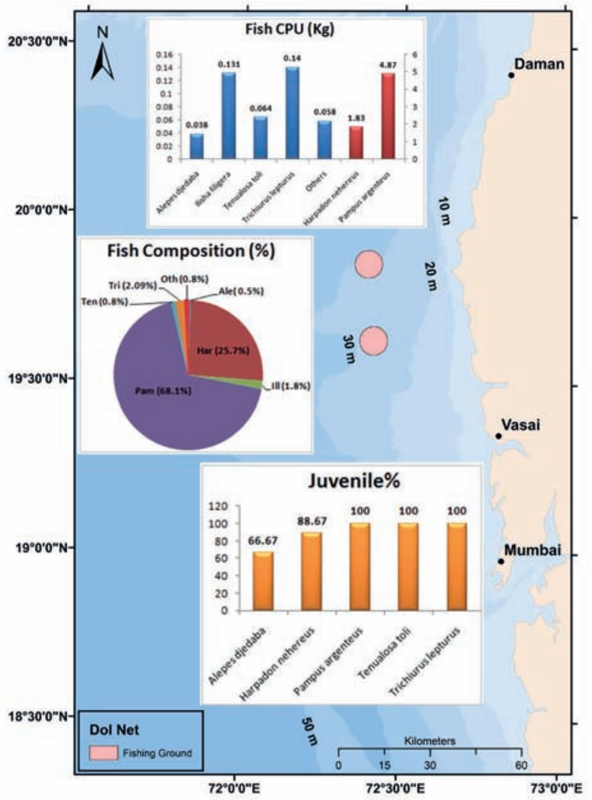

Fig.22. Species composition CPUE and juvenile composition of fishes caught by dolnetters off Mumbai coast.

Protocols developed for data collection and analysis from single day vessels without GPS.

Along the coast of India there are various types of crafts and gears that are in operation and well-defined fishing techniques exist based on the topography, ecology and habitat of the resources available. Though most trawlers, purse-seines and gillnetters use the GPS during operation, there are a number of smaller units that operate single day fishing without GPS. Such units include single day trawls, gillnetters, boat seines, traditional such as catamarans, hook and lines, shore seine etc. Data collected from such operations is also envisaged to put on GIS platform for resource mapping. For bringing this information into GIS platform, a basic GIS inventory of the fishing operation centers is prepared including all fish landing centers along the Indian coast. The information from the inventory forms the basic layer of the resource mapping over which resource data layer will be stacked. The data on the name of landing centre, district, its location with latitude and longitude (GPS reading), gears operated from the landing centre, seasonality of each gear operation, distance covered for fishing from the centre, seasonal changes in the direction of fishing activity, are incorporated in the inventory of the landing centres. A list of dominant species in each gear from each fishing centre is also incorporated in the inventory. The fishery data from the units operated from these centres are mapped with identification of the fishing ground location based on the information on distance and direction of operation from the operating centre (GPS location) (Fig.23). Since fishing is limited to a small geographical area, mapping of a single fishing ground for annual distribution, with the support of tables representing each fishing month with information on CPUE,

Outboard gillnetters

juvenile composition and spawner composition in each month is possible through this protocol (Fig.26). The tables with distribution maps will provide information on the variations in species and variation in juvenile and spawner composition of the fishery. The following data collection schedules are used for the data collection of the information. Traditional fishing such as Thallumadi, Thalluvalai, Hand Trawl, Catamarans are also estimated by this mode of data collection. A sample should be collected from each gear and analysis can be done from the subsample collected.

Data collection schedule

Schedule 1:

State::				Landing Centre			
Sl. No	Date (dd/mm/yy)	Name of the fish landing centre	GPS location	Gear	Distance traveled from landing centre	Direction in which traveled	Depth of Operation

Schedule 2:

Species Composition (Average)								
Sl. No	Month	Year	Gear	Species	Catch (kg)	Effort CPUE	CPH	Any other observations

Schedule 3.

Juvenile composition & spawners (Identify five major resource)						
Gear						
Sl. No	Month	Year	Species	Juveniles (%)	Spawners (%)	Any other observations

Traditional canoe

Trawlers of single day operation

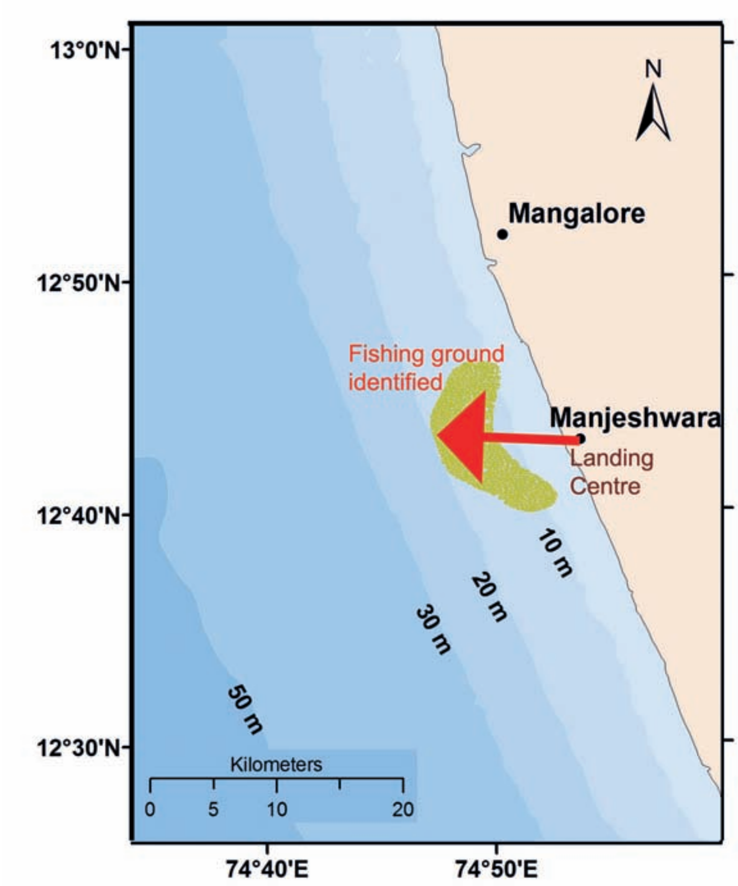

Fig.23. Protocols developed for the resource mapping of species caught by gears operated from crafts without GPS off Mangalore coast.

Shore seine operation

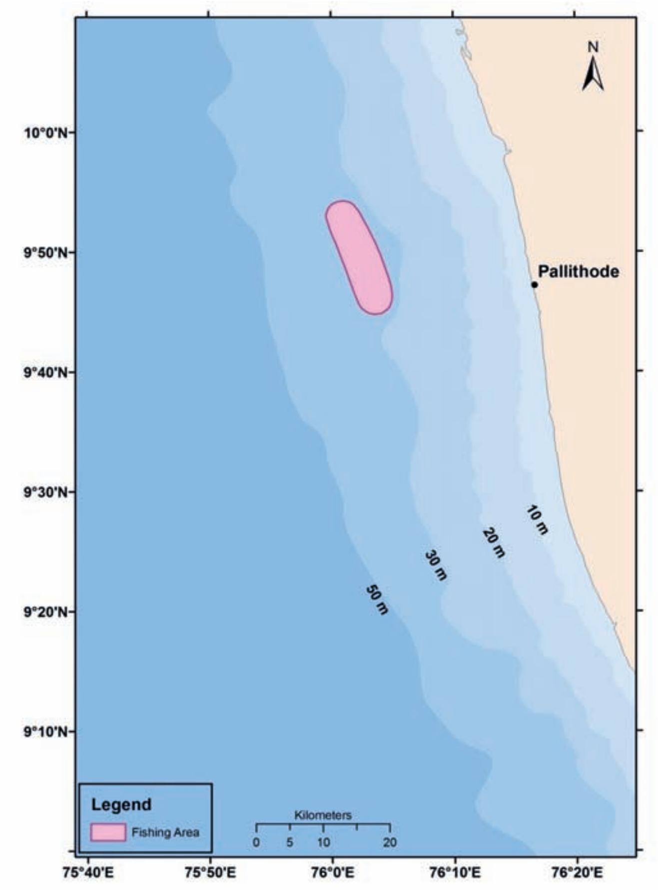

Fig.24. Protocols developed for the resource mapping of species caught by single day gillnetters operated in Pallithode, Kerala

Jan-14

Species	CPU (kg)	Juvenile (%)
R. kanagurta	1.507	0
T. mystax	0.967	0
S.guttatus	0.608	100
Alepes djedaba	0.402	74.0
T. malabarica	0.381	0
M. cephalus	0.302	0
Johnius glaucus	0.253	39.7
Mene maculata	0.145	76.2
Otolithus cuvieri	0.094	100
Kovala koval	0.080	0

Feb-14

Species	CPU (kg)	Juvenile (%)
R.kangurta	1.715	0
T.mystax	0.350	0
Alepes djedaba	0.311	74.0
Alepes kleinii	0.142	0
T.malabarica	0.381	0
Upenaeus vitatus	0.023	0
L.brevicornis	0.022	0

Mar-14

Species	CPU (kg)	Juvenile(%)
Otolithus cuvieri	0.646	1.4
Sillago sihama	0.542	100
S.barracuda	0.524	100
T.mystax	0.523	0
R.kangurta	0.453	0
Carax sp.	0.356	13.3
S.gibbosa	0.278	39.7
Johnius sp.	0.170	8.3
P.sanguinolentus	0.118	100
Alepes djedaba	0.098	85.9

Apr-14

Species	CPU (kg)	Juvenile(%)
P. sanguinolentus	0.818	89.1
T. mystax	0.411	0
A. chacunda	0.365	0
R. kangurta	0.342	0
L.lactaruis	0.288	0
C.lucifera	0.215	88.8
S. insidator	0.196	0
Alepes djedaba	0.096	0
Alepes kleinii	0.037	0
L. bindus	0.017	0

The data being presented with fig. 24 on distribution of species, its abundance (CPU) and juvenile percentage to give spatio-temporal distribution

May-14

Species	CPU (kg)	Juvenile(%)
R. kangurta	2.488	0
T. mystax	0.381	0
Stolephorus tole	0.203	0
Cynoglossus sp.	0.190	0
A. chacunda	0.159	0
O. ruber	0.139	0
S. gibbosa	0.113	0
J. glaucus	0.103	0
J. carutta	0.103	0
M. cordyla	0.096	0

Jun-14

Species	CPU (kg)	Juvenile(%)
M. cepahalus	1.431	0
Arius jello	0.976	0
O. tardore	0.723	0
J. glaucus	0.240	0
Sillago sihama	0.238	0
Caranx tille	0.111	55.8
Epinephelus sp	0.097	100
S. obtusata	0.072	0
S. canaliculatus	0.044	0
Gerrus oyena	0.022	0

Nov-14

Species	CPU (kg)	Juvenile(%)
R. kangurta	0.925	0
T. mystax	0.683	0.3
Kovala koval	0.521	4.6
T. malabaricus	0.262	0
S. insularis	0.217	100
T. setirostris	0.149	0
J. glaucus	0.127	39.3
L.lactarius	0.122	66.4
P. sanguinolentus	0.085	0
Ilisha megaloptera	0,084	0

Dec-14

Species	CPU (kg)	Juvenile(%)
T. mystax	1.680	0
O. tardoore	0.541	0
Ilisha megalopta	0.408	0
T. malabaricus	0.390	0
K. axillaris	0.335	100
L. lactarius	0.148	0
S. gibbosa	0.108	0
S. longiceps	0.092	8.9
R. kangurta	0.045	28.9
J. glaucus	0.040	0

Precautions needed in analysis and mapping of fishery data collected from different gears.

GIS provides a wide range of options for resource mapping and result projections. A wide range of routines available in the software often presents great challenges to fisheries researchers to select the routine which is capable of projecting the fishery data with extreme scientific base. Data from trawlers, gillnetters, seiners and dolnetters is to be treated different as they are fishing with the intention of exploiting the behavior of fishes. Generally, Remote Sensing is the first satellite based technology which overhauled marine fisheries prediction, based on ocean temperature, ocean color and chlorophyll content. In general environmental studies of salinity, temperature etc. In RS, the data collected from different points can be extrapolated for a region and zone by mathematical projections. In the case of fishery data, such mathematical projections should be based on the behavior of fishes and the nature of the fishing ground. The knowledge regarding the fishery has to be incorporated in the buffering for identifying the fishing ground. The possibility given by the software has to be used judiciously with the knowledge of the resources available to make resource mapping as scientific as possible. In trawlers, especially in bottom trawling, the gear is active, sweeping the fishing ground and the species caught are mainly dependent on the bottom features, depth and topography of the sea bottom, where as in gillnetters and seines, bottom features do not make significant impacts. Tidal amplitude and water currents play a major role in the success of dolnet operations. In the case of mapping the trawl net data, Individual hauling data should be drawn and each species distribution should be assessed differently.

The way forward

Correlation with environmental and topographic features

The behavior of fish populations is controlled by the interactions between organisms and their surrounding environmental characteristics. The information layers such as temperature, salinity, bathymetric, wind pattern, currents and primary productivity, can be integrated in to the routine of GIS software, which makes the correlation studies possible with great ease. The data can be analysed independently and also in relation with the oceanographic characteristics. Topographical features such as depth, bottom topography, sediment nature can also be put as additional layers to analyse the relationship of fishery distribution with the bottom characteristics. Nearness to the barmouth and availability of infrastructural facilities in the vicinity also impact on the fishing activity and these features can also be related with fishing pressure distribution, which can also be analysed in GIS platform. Analysis with multiple layers of information will eventually help in the prediction of fishery in terms of environmental factors. Some of the features which help the analysis of distribution of fishes and help in fisheries management are given in Fig. 25.

Application of GIS in developing mariculture.

Indian mariculture which was restricted to bivalve farming in limited parts of the coast, has entered a new phase of development with cage culture of finfishes and shellfishes all along the Indian coast by the beginning of the 21st century. Feasibility of cage culture practices was demonstrated all along the Indian coast by

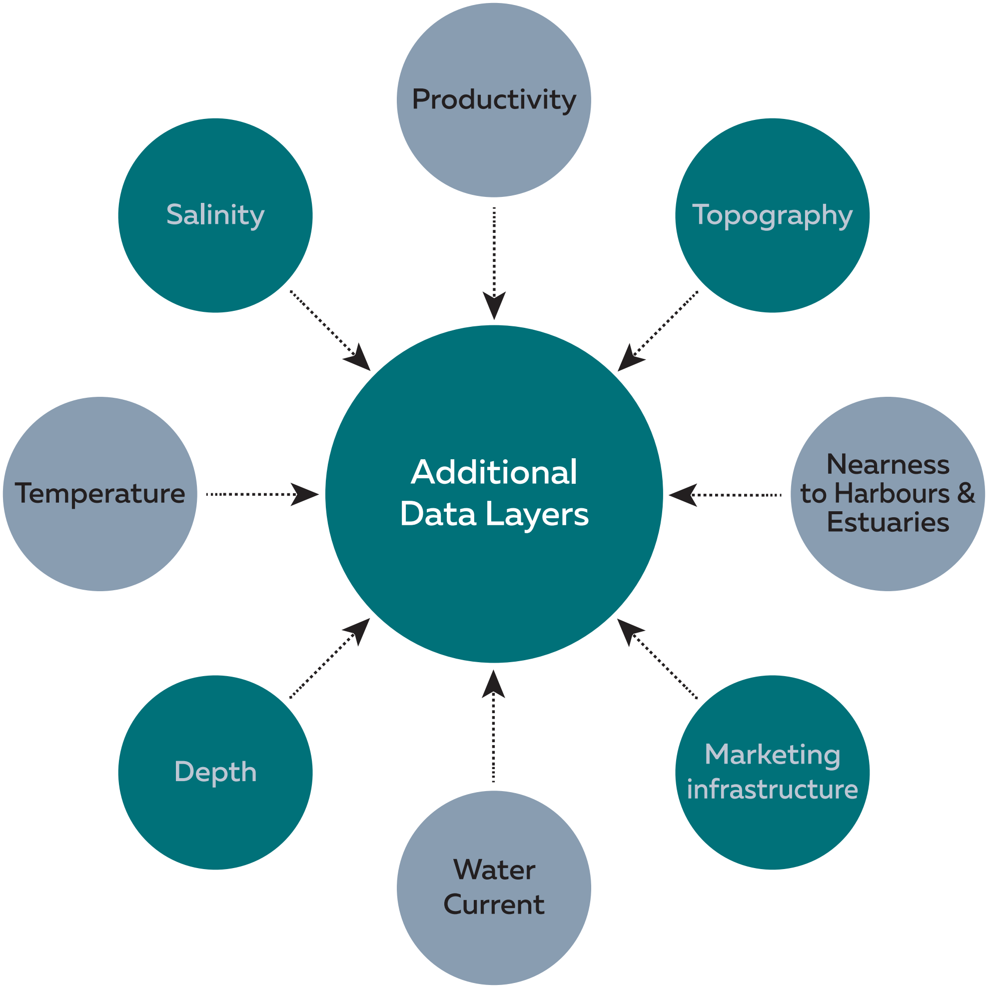

Fig.25. Probable parameters that can be correlated with fishery study, in different layers in GIS platform.

the Central Marine Fisheries Research Institute. These demonstrations attracted developmental agencies and stake holders towards this innovative venture. Getting encouragement from the demonstration of high growth of finfishes in cages, small scale cage culture techniques were also popularised among the fishermen living around saline creeks and estuaries. The growing interest among entrepreneurs and the readiness for financial and technical support by various developmental agencies have opened up a bright future for mariculture development in India. Cage culture of fishes in open sea and estuaries, rack and raft culture of bivalves, pen culture of finfishes and shellfishes are expected to be major activities under mariculture. Spatial planning and zoning, through geospatial technologies is a basic requirement for sustainable mariculture development. This will help in identifying the areas for mariculture where eco-friendly technologies can be proposed without disturbing the interests of the other stake holders of the water body. Mariculture has to be developed in eco-friendly and human friendly criteria. Unplanned development of aquaculture inevitably leads to environmental overload, conflict among user groups and serious economic losses to the industry. GIS technology gives the planner and developer the capacity to evaluate the interaction of a wide range of environmental and social factors which affect the potential of a region for aquaculture development. This complexity of influences is integrated through a ranking and scoring system. Each factor is scored and mapped accordingly. The product of ranks are scores which identify zones where sustainable aquaculture can be developed. The FAO Code of Good Practice for Aquaculture (Annex 8.3) also reflects concepts of sustainability. If these elements and their core values are accepted as the basis for sustainable development, then aquaculture development planning should incorporate them.

Some of the basic principles of good practice for aquaculture are:

- Integration of conservation and development,
- Satisfaction of basic human needs,
- Achievement of equity and social justice,
- Provision for social self-determination and cultural diversity and maintenance of ecological integrity.

Since the open waters are common property in India, any mariculture development activity should be well planned by taking care of the utilization of the common waters. The areas suitable for mariculture activities should be identified by taking care of general utilization of common waters, with minimum disturbance to the ongoing activities. The activities suitable for each geographic area have to be identified and the carrying capacity of all these selected areas should be identified. The site can be identified for bivalve farming, sea farming of finfishes and shellfishes and also estuarine farming. The estimation of carrying capacity will help in suggesting how many rafts, racks, cages can be put in the particular ecosystem/area without disturbing the natural environment. In the case of cage culture, the species to be selected, number of cages to be installed, the stocking density and the extent of distribution of waste from cages without causing pollution, are of major concern in making the production sustainable. Efficient management and strict regulations are required for sustainable development.

Geographic Information Systems (GIS) and remote sensing aided mapping have a role to play in all geographic and spatial aspects of the development and management of marine aquaculture. GIS based spatial planning provides 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 understand the social acceptability and the economic implications of mariculture. A legally viable licensing system and water leasing must be developed and put into practice during the initial development stage itself to avoid any future conflicts among the different stakeholders.

Use of GIS in monitoring, compliance and surveillance in fisheries management

On the basis of the strong data base being created in spatio-temporal platform with the help of GIS, a research program for development of GIS and RS supported VMS (Vessel Monitoring System) is in active consideration in Indian waters. This is proposed to help conservation of the marine fisheries resources and to ensure fishermen safety. Development of VMS is an extension of spatio-temporal assemblage studies of fishery resources and is considered the most practical MCS activity for marine fisheries management. In the present day fishing which is extended to deeper waters, VMS is essential for ensuring safety of fishermen in sea. VMS is proposed as the mechanism and infrastructure for monitoring, control and surveillance activities to strengthen fisheries management. Infrastructural facilities for monitoring, compliance and surveillance have to be made to implement these scientific findings and policies. Since the resource studies are taken up in GPS data base in GIS platform, VMS is an essential development to follow. Along with introduction of VMS, training the fishermen for seamanship and operation of electronic equipment for fishing and security are also essential.

HRD development in application of GIS in Fisheries

For the best use of GIS technology for fisheries management, the shortage is felt in the lack of expertise in fishery researchers in formulation of data collection design suited for GIS software. The hardship is also felt among fisheries researchers in efficient communication of their research issues to geo-informatics experts in an understandable manner. Sufficient exposure to software use will improve the understanding of the potential of the software, which will help in developing appropriate data collection modules suited to the software. It will also enable them to instruct the software operators to use correct modules and appropriate projections. Software plays a supporting role and provides various options for result projection. The accuracy of the projected result depends on the selection of appropriate routine and also on species specific and gear specific interventions given to the software from time to time. The success of incorporation of GIS based information system for fisheries management depends on the integration of fishery information with technology. Since these two are separate sciences, expertise is to be developed in integrating the two, which will provide the best results rather than intruding in the zones of expertise. Expertise should be developed for fishery researchers in designing the data collection system for GIS based analysis, in projection of the research results and in making the researchers effective communicators of the research needs. With the advent of advancement in technology, the equipment required for GIS information collection became affordable, and with many courses being offered in Geo-informatics, professionals in geoinformatics are getting an opportunity to look into new areas of research. These developments provide fishery researchers a great opportunity to include a spatial component in research so that their research results can be presented in more illustrative and informative ways. GIS provides illustrative and convincing research outputs, which will eventually lead to increasing the acceptability of the findings and their inclusion in policy interventions.

National and international endorsement and acceptance of the protocols.

The protocol and concept developed in the application of GIS in marine fisheries of India is recognised by National and International organisations and world renowned authors in fisheries GIS. International Fishery related organizations like Food and Agriculture Organization (FAO) and Asia Pacific Fisheries Commission (APFIC) have appreciated the methodology of spatial data analysis and many authors of international importance have shown interest in being a part of further development in GIS based studies of fisheries of Asia-Pacific Region. Protocols described in this book were used for preparation of following research papers.

1. Preliminary experiments on application of participatory GIS in trawl fisheries of Karnataka and its prospects in marine fisheries resource conservation and management. *Indian J. Fish*., 59(1): 15-22.

2. Spatio-temporal analysis and impact assessment of trawl by-catch of Karnataka to suggest operation based fishery management options. *Indian J. Fish*, 59 (2). pp. 27-38.

3. Gastropod resource distribution and seasonal variation in trawling grounds off Konkan Malabar region, eastern Arabian sea, *Indian J. Geomarine Sci*,43 (3): 384-392

4. Assessment of low value bycatch and its application for management of trawl fisheries. doi: *J. Mar. Biol. Ass. India*., 56 (1). pp. 103-108.

5. Assessment of low value bycatch and its application for management of trawl fisheries. *J. Mar. Biol. Ass. India*., 56 (1). pp. 103-108

6. GIS for Assessing Spatio-temporal Variations in Trawl Bycatch off Mangalore Coast. *Fishery Technology*, 52. pp. 152-156

7. GIS-based spatial data analysis for marine fisheries management as a prerequisite for mariculture development. *Fishing Chimes*, 33 (10 - 11). pp. 91-93.

8. Mapping of fishery resources in trawling grounds along the Malabar-Konkan coast. Marine Fisheries Information Service T&E Ser., Central Marine Fisheries Research Institute, Kochi No. 110, 2011: 1-12.

9. *कोवलम, तमीलनाडु के तटीय क्षेत्रों में उपलब्ध सुरमई मछली के मत्सयन स्थल का जिओस्पेशियल नक्शा. विशेष प्रकाशन सं. 115 जलीय पारितंत्र का टिकाऊपन* (115). pp. 31-33.

These protocols were also used for making the abstracts for presentations in various scientific fora. List of some are enclosed below.

1. Geo-temporal distribution and resource abundance mapping of juvenile and adult threadfin bream, *Nemipterus mesoprion* in trawling grounds

off Karnataka coast. Book of abstracts; International Symposium "Marine Ecosystems, Challenges and Opportunities"; 9-12 February. Cochin:112-113.

2. Concept of participatory GIS (PGIS) in fisheries and its applications in resource conservation and management. Book of abstracts: 9th Indian Fisheries Forum Chennai, December, 2011.

3. Assessment of low value bycatch and its application for management of trawl fisheries. Book of extended abstracts, Ecosystem Approaches to the Management and and conservation of Fisheries and Marine Biodiversity in the Asian Region, 27-30, October, 2013, Cochin, Kerala, 109-111.

4. Use of spatio-temporal data in reducing low value bycatch in trawl fisheries, Abstract of the international Symposium, (Greening Fisheries) on 'Towards green Technologies in Fisheries', 21-23 May, 2013 Cochin : 54-55

5. GIS based resource mapping of fishery resources to reduce CO2 emission by trawlers. Abstract of the international Symposium, (Greening Fisheries) on 'Towards green Technologies in Fisheries', 21-23 May, 2013 Cochin: 73-74. (Received best scientific paper award in the Symposium)

6. Application of GIS in marine biodiversity conservation and fisheries management. In: Proceedings of the Special lecture series on "Marine biodiversity and conservation" College of fisheries Mangalore and Karnataka Science and Technology Academy, Govt. of Karnataka, 17-18, October, 2012: 20-26.

7. Spatial study of catch and effort from fishing vessels to provide policy decision support for fisheries management, Book of abstracts, Marine Ecosystem Challenges and opportunities (MECOS2) JMBAI, December,2-5, Kochi, p 19-20.

8. Geospatial distribution and species diversity in fished taxa along the Indian coast. Book of abstracts, Marine Ecosystem Challenges and opportunities (MECOS2) JMBAI, December, 2-5, Kochi: 185-186.

9. The Role of Innovative Technologies and Impact of Collaboration of Progressive Fishermen in Fisheries Research in Successful Management of Multi-Species Fishery in Tropical Marine Ecosystem: Book of Abstracts – Conferencia, 65TH ANNUAL GCFI, Gulf and Caribbean Fisheries Institute, Santa Marta-2012, COLOMBIA, 5 November 2012 – 9 November 2012: Page 2.

10. Participatory GIS concept as a co-management measure in marine fisheries for evolving and implementing management options, Registration No.25. Abstracts of the Proceedings of Sixth International Symposium on GIS/ Spatial analyses in Fishery and Aquatic Sciences., August 25-29, 2014, Tampa, Florida, USA.Page. 53-54

11. An Introduction to spatial planning for sustaining small scale cage aquaculture and integrated aquaculture. In Sobhana K.S., Shoji Joseph, Sandhya Sukumaran, Kathirvelpandian, A., and Rahul G. Kumar (Eds). Book

of Abstracts, 5th International Symposium on Cage Aquaculture in Asia (CAA5), Asian Fisheries Society, Central Marine Fisheries Research Institute, Kochi and Asian Fisheries Society, Indian Branch, 25-28 Nov 2015, Kochi, India, 28 pp

12. Application of GIS in ensuring marine food security by serving as decision support tool for marine resource conservation. In. Book of Abstract of 4th International UGIT conference on Remote Sensing and GIS applications on Coastal Management. Mangalore, India, 16-17 February, 2016: Page 38.

13. Application of GIS and modelling for analysis of Mackerel distribution along Karnataka coast. In. Book of Abstract of 4th International UGIT conference on Remote Sensing and GIS applications on Coastal Management, Mangalore India, 16-17 February, 2016: Page 03

Further reading

Booth, Anthony J. 2000. Incorporating the Spatial Component of Fisheries Data into Stock Assessment Models. *ICES Journal of Marine Science* 57.

Caddy J. F., and F. Carocci. 1999. The Spatial Allocation of Fishing Intensity by Port-based Inshore Fleets: A GIS Application. *ICES Journal of Marine Science* 56(3): 388-403.

Chopra B.N. 1957. Indian fisheries & Fishing Industry in India – Govt. of India, Ministry of Agriculture.

Craig W., Harris, T., and D. Weiner. eds. 2002. Community Participation and Geographic Information Systems. Taylor and Francis.

Dineshbabu A.P., Thomas Sujitha and E. V. Radhakrishnan 2012. Spatio-temporal analysis and impact assessment of trawl bycatch of Kanataka to suggest operation based fishery management options. *Indian J. Fish.*, 59(2): 27-38.

Dineshbabu A.P. 2013, Trawl fishery of Eastern Arabian Sea, Asia Pacific Fisheries Commission and FAO for the regional guidance for the management of tropical trawl fisheries in the Asian region during 30th September- 4th October 2013, at Phuket, Thailand. http://www.apfic.org/attachments/article/92/APFIC%20(Dinesh,%20India).pdf.

Dineshbabu A.P., Thomas Sujitha, E. V. Radhakrishnan, A. C. Dinesh, 2012, Preliminary experiments on application of participatory GIS in trawlfisheries of Karnataka and its prospects in marine fisheries resourceconservation and management *Indian J. Fish.*, 59(1) : 15-22.

Dineshbabu A P; Thomas, Sujitha and Vivekanandan. E. 2014. Assessment of low value bycatch and its application for management of trawl fisheries. *J. Mar. Biol. Ass. India.*, 56 (1): 103-108.

Graham J., S. Engle, and M. Recchia. 2002. Local Knowledge and Local Stocks: An Atlas of Groundfish Spawning in the Bay of Fundy. Antigonish, Nova Scotia: The Centre for Community-based Management, Extension Department, St. Francis Xavier University.

Hutchings J.A., and M. Ferguson. 2000. Links between fishers' knowledge, fisheries science, and management: Newfoundland's inshore fishery for northern Atlantic cod, Gadus morhua. In Finding Our Sea Legs: Linking Fishery People and Their Knowledge with Science and Management, edited by B. Neis and L. Felt. St. John's Newfoundland: ISER Press.

WJiang H. and Eastman, J.R. 2000. Application of fuzzy measures in multi-criteria evaluation in GIS. *International Journal of Geographical Information Systems* 14(2): 173-184.

Langton, Richard W., Peter J. Auster, and David C. Schneider. 1995. A Spatial and

Temporal Perspective on Research and Management of Groundfish in the Northwest Atlantic. *Reviews in Fisheries Science* 3(3): 201-229.

MacCall, Alec D. 1990. Dynamic Geography of Marine Fish Populations. Seattle, WA: University of Washington Press.

Malczewski, Jacek., 1996. A GIS-based Approaches to Multiple Criteria Group Decision-making. *International Journal of Geographic Information Systems*, 10 (8): 955-971.

Manson, F. J. and D. J. Die. 2001. Incorporating Commercial Fishery Information into the Design of Marine Protected Areas. Ocean and Coastal Management 44: 517-530.

Maurstad, Anita. 2000. Trapped in biology: An Interdisciplinary Attempt to Integrate Fish Harvesters' Knowledge into Norwegian Fisheries Management. In Finding Our Sea Legs: Linking Fishery People and Their Knowledge with Science and Management, edited by Barbara Neis and Lawrence Felt. St. John's Newfoundland: ISER Press.

Meaden, Geoff J. 1999. Applications of GIS to Fisheries Management. In Marine and Coastal Geographical Information Systems, edited by Dawn Wright, and Darius Bartlett. London: Taylor and Francis.

Meaden, Geoff J. 2000. Spatially-Based Fishery Management Systems: Challenges and Prospects. Paper presented at the Marine GIS Technology Conference/Workshop, October 12-13 2000 at FishExpo/Workboat Atlantic, Providence, RI Organizers: Chris Polloni and Richard Taylor.

St. Martin, K. 2004, "GIS in Marine Fisheries Science and Decision Making," in Geographic Information Systems in Fisheries, W. L. Fisher and F. J. Rahel eds. (American Fisheries Society), 2004, pp. 237-258.

St. Martin, Kevin. 2001. Making Space for Community Resource Management in Fisheries. *Annals of the Association of American Geographers* 91(1): 122-142.

Wright, Robert, Stephen Ray, David R. Green, and Michael Wood. 1998. Development of a GIS of the Moray Firth (Scotland, UK) and its Application in Environmental Management (Site Selection for an 'Artificial Reef'). The Science of the Total Environment 223: 65-76.

Acknowledgements

Dr. A. Gopalakrishnan, Director, CMFRI, Kochi

Dr. Prathibha Rohit, Scientist-In-Charge, RC of CMFRI, Mangalore

Dr. G.Maheswarudu, Head, Crustacean Fisheries Division CMFRI, Kochi

Dr. Syda Rao, Former Director, CMFRI, Kochi

Dr. E.V. Radhakrishnan, Former Head Crustacean Fisheries Division, CMFRI, Kochi

Dr. M. Sivadas, Principal Scientist, RC of CMFRI, Chennai.

Dr. S. Lakshmi Pillai, Principal Scientist, CMFRI, Kochi.

Dr. Shobha Joe Kizhakudan, Principal Scientist, RC of CMFRI, Chennai.

Dr. K.M. Rajesh, Senior Scientist, RC of CMFRI, Mangalore

Dr. Shubhadeep Ghosh, Scientist-In-Charge, Visakhapatnam Regional Centre of CMFRI

Shri. Mohammed Koya K, Scientist-In-Charge, Veraval Regional Centre of CMFRI

Smt. Anulekshmi Chellappan, Scientist, RC of CMFRI, Mumbai.

Shri B. Shridhara, Technical Officer, RC of CMFRI, Mangalore

Shri. Y. Muniyappa, Technical Officer, RC of CMFRI, Mangalore

Shri. S Kemparaju, Technical Officer, RC of CMFRI, Mangalore

Shri. G.D. Nataraja, Technical Officer, RC of CMFRI, Mangalore

Ms. Shailaja Salian, Research Scholar, RC of CMFRI, Mangalore

Mrs. Shwethal Anchan, Research Scholar, RC of CMFRI, Mangalore

Mr. Shubankar Biswas, Research Scholar, RC of CMFRI, Mangalore

One machine can do the work of fifty ordinary men.
No machine can do the work of one extraordinary man.

– Elbert Hubbard

Handbook on

Application of GIS as a **Decision Support Tool** in Marine Fisheries

This handbook is the first attempt in India to derive protocols for incorporating spatial data as a decision support tool for fisheries management. These protocols were developed with various levels of interactions between the fishery researchers and GIS experts. The paper prepared based on the protocols described in this handbook received “Best Paper Award” for Innovative use of GIS in “2016 ESRI India Regional User Conference” at Hyderabad, India.

Indian Council of Agricultural Research
Central Marine Fisheries Research Institute
Ernakulum North. P.O, No.1603, Kochi-682 018, Kerala, India.

भाकृअनुप
ICAR

सी एम एफ आर आइ
CMFRI