GIS and its applications in Marine Fisheries Conservation and Management in Karnataka, India

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Abstract: Geographical Information System (GIS) has become a major component of modern life and the contribution of this system in daily life has been increasing by the new invention of technology and methods. GIS and its application was very limited in marine fisheries till last decade, but now scenario has been completely changed with development of successful protocols for application of GIS in marine fisheries in India. GIS has made strong footprint with advanced technology in identifying the geographical location of fishing areas, making digital database with better presentation methods like maps, graphs, diagrams, layer illustration etc., analyzing the species database with oceanographic environments to protect marine biodiversity and conserve the marine ecosystem. GIS and its technologies have added a new leeway in marine fisheries by applying its tools for extracting scientific output from the collected data. Application of GIS in marine fisheries is being implemented as a project for the first time in India along Karnataka coast. Trawlers are the major contributors of the marine fisheries in India and present study was based on the database created on the trawl fisheries of Karnataka coast. The GPS based geo coordinates of the fishery showed that the fishing is being carried out in the fishing grounds between 72^0E to 76^0E longitude & 10^0N to 18^0N latitude and bathymetric depth of the fishing grounds are minimum 10m to maximum 150m. The fishing areas are mainly extended in parallel manner towards across the state boundaries and 267 species has been exploited by trawlers, which were operated along the coast during 2010-2015. For free handling of geo coded data and resource distribution mapping, ArcGIS Desktop 10.0 and its components were used. The spatio-temporal information about species has been modified in thematic features and shape files with attribute table by Interpolations methods of Spatial Analyst Tools in the ArcGIS desktop software. By these studies the data layers for the 267 species were created, and the oceanic environmental parameters and benthic features of the sea floor according to the depth range were brought into analysis. The study showed that GIS based studies help in evolving management tools for fishing effort restriction, prevention of juvenile exploitation, reducing trawl bycatch, conserving biodiversity, identifying critical ecosystem, explanation of fishery "refugia" and Marine protected areas (MPA) etc. The possibility of illustrations and projection of probable impacts through GIS software provided more transparency on the suggested management measures, which would improve adoption level by the fishermen. This paper mainly presents how GIS and it applications put immense impact on marine fisheries with the help of ArcGIS and its various components.

Key words: GIS applications, Fishery conservation and management, Karnataka state, Spatial Analyst Tool.

Introduction:

Technologies aid in enhancing fish production globally. The availability and distribution pattern of marine fishery resources in India follow a typical pattern in tropical waters. The fishery resource is constituted by a large variety of species coexisting in the same fishing ground. Several measures for rational exploration of the fishery resources have been codified and contemplated in the past and their implementation has been found in several researches. If the fishing is continued in the present level, the existence of the wild stocks from the exploited fishing grounds will be threatened and a collapse of stocks is likely. Pragmatic measures of management and conservation with help of technological support are to be taken up immediately to avoid such stock depletion.

In the history of marine fisheries, the most efficient technological interventions are trawls, which have been presumed widely throughout the world and have contributed greatly to increase marine fish production. However, due to extensive operations, bottom trawling has caused physical and biological disturbances into the sea bottom and the marine ecosystem (Jennings and Kaiser, 1998). Trawlers are the major and motorized fishing gears which contribute to the fisheries production especially along west coast of India. According to Central Marine Fisheries Research Institute, India that 80% of the marine fisheries catch is from trawlers present era and during last eras trawlers are further equipped with modern and scientific gadgets and more engine capacity for increasing contribution in marine fishery in open sea. In India modern time fishing vessels are equipped with new technologies which are capable of operating in greater depth, more endurance in sea, accurate fish finding, GPS based data collection and recording of spatio-temporal distribution of marine fishes (Dineshbabu et al, 2013). Issues in overexploitation can be solved by the awareness creation regarding the utility of these gadgets for biodiversity conservation and fishery management. Ignoring the spatial component often leads to inaccurate estimation and often misleads to interpretation on the distribution and biology of species like growth, feeding, reproductive pattern etc.

GIS (Geographical Information System) is a dynamic tool which coordinates the spatial component with the present temporal studies. Use of GIS in marine fisheries and decision making in fisheries has been more limited and its impact has yet to be felt to any degree. The use of GIS in fishery by managers and policy makers as effective aid in decision or several scheme making and socio economic studies has to be formed in marine fisheries. In fisheries major application of GIS at present are in identification of suitable sites for aquaculture, management of marine fisheries, conservation of biodiversity, managing the coastal regulation zone etc. Study of planning marine resource and mapping of aquatic species, fish disease modeling and management, study of temporal/spatial changes in fish production and composition, environmental impact estimation, distribution of various marine species in relation to physical habitat aspects, study socio economic impact of spatial changes in demand and supply of marine resources and products are the advanced applications, which will be of immense help in marine fisheries sector. In India, the utility of GIS in marine fisheries and its immense possibilities in solving long lasting issues in marine fisheries has been a topic of research during the last decade and Central Marine Fisheries Research Institute demonstrated the utility of GIS in marine fishery resource mapping. GIS applications are recognized as a useful tool for biodiversity studies (Dineshbabu et al, 2012), resource mapping, Thomas et al,

2014) and for conservation of juveniles by suggesting marine protected areas (MPA) and "fishery refugia" (Dineshbabu et al, 2014). GIS based policy interventions are projected as a decision making tool for trawl bycatch reduction (Dineshbabu et al, 2012, 2015) for the sustainability of the fishery along Indian coast.

In order to effectively and sufficiently access and publish such spatial data of marine fishery, there has been the need to develop Spatial Data Infrastructures, which aid in interpreting barriers between users and producers of this spatial information (Andrew Binns, 2005). This papers present how GIS and it applications put immense impact on marine biodiversity conservation management with the help of its various components. Also helps to analyze the relation between oceanographic environment and distribution of marine fisheries resources of an area for further studies.

Materials and Methods:

Fisheries Data for the study was collected from ICAR-Central Marine Fisheries Research Institute, Mangalore during 2010-2015. The database completely described the trend of trawl fishery of Karnataka in various ways. The information of on board catch, bycatch and discard were collected from a trawler, which had modern scientific gadgets and fully operated from Karnataka Coast during 2010-2015 on daily basis for 1051 days. The trip duration of a wooden trawler (16.2m) was 9 to 10 days of multiday trawling with a one day breaking of loading and ice-filling between the trips in this time period. According to the availability of resources the trawler used to carry three different types of nets with about 10 various codend pieces to reform the codend of the trawl nets. Due to environmental changes of tropical areas trawling is banned for two months (June-July). The data collection and analyses was done by following methodology, which is developed by ICAR-Central Marine Fisheries Research Institute (Dinesbabu et al., 2012). After recording all these information, the data has been transformed into digital mode by storing in MS Access file.

serialno	cruiseno	cruisedate	depthofshooting	timeofshooting	shootinglat	shootinglong	depthofhauling	timeofhauling	haulinglat	haulinglong	totaldiscard	totalcatch
1	650	8/8/2010	86	4:30:00 PM	12.30004	74.50307	86	7:30:00 PM	12.25619	74.50049	0.777	24.223
2	651	8/9/2010	126	6:00:00 AM	12.22183	74.4315	126	9:00:00 AM	12.09683	74.48983	50	90
3	652	8/10/2010	126	1:00:00 PM	12.3455	74.37984	126	4:00:00 PM	12.22083	74.4375	100	150
4	653	8/11/2010	122	4:30:00 PM	12.39883	74.35952	122	7:30:00 PM	12.27383	74.41333	75	185
5	654	8/12/2010	124	9:30:00 AM	12.382	74.3705	124	12:30:00 PM	12.48167	74.3205	50	100
6	655	8/13/2010	117	1:00:00 PM	12.43283	74.3805	117	4:00:00 PM	12.33167	74.43034	100	200
7	656	8/14/2010	128	6:00:00 AM	12.18167	74.4395	128	9:00:00 AM	12.05683	74.49767	75	135
8	657	8/15/2010	99	9:30:00 AM	12.3975	74.44122	90	12:30:00 PM	12.2725	74.49117	75	230
9	658	8/19/2010	130	3:30:00 PM	12.3601	74.3662	130	7:30:00 PM	12.19333	74.44967	150	230
10	659	8/20/2010	144	6:00:00 AM	12.23333	74.40417	144	9:00:00 AM	12.12517	74.405	100	350
11	660	8/21/2010	122	9:30:00 AM	12.13317	74.48566	122	12:30:00 PM	12.2575	74.428	50	115
12	661	8/22/2010	116	1:00:00 PM	12.4515	74.3665	116	4:00:00 PM	12.31833	74.415	100	225
13	662	8/23/2010	124	1:00:00 PM	12.12167	74.48682	124	4:00:00 PM	11.99667	74.545	200	250
14	663	8/24/2010	124	6:00:00 AM	11.92167	74.54684	124	9:00:00 AM	12.04817	74.48534	100	125
15	664	8/25/2010	140	4:00:00 PM	12.09	74.03167	140	7:30:00 PM	13.0275	73.96167	100	175
16	665	8/26/2010	116	9:30:00 AM	12.92879	74.07947	116	12:30:00 PM	12.80677	74.15408	50	85
17	666	8/28/2010	138	6:00:00 AM	12.5125	74.26855	138	9:00:00 AM	12.63767	74.21001	150	175
18	667	8/29/2010	117	9:30:00 AM	12.76467	74.17767	117	12:30:00 PM	12.88917	74.12334	600	625
19	668	8/30/2010	87	1:00:00 PM	14.05928	73.64963	87	4:00:00 PM	14.17944	73.61599	50	150
20	669	8/31/2010	82	4:30:00 PM	13.31833	73.8875	82	7:30:00 PM	13.19333	73.94217	50	225
21	670	9/1/2010	88	6:00:00 AM	13.29	73.806	88	9:00:00 AM	13.415	73.75183	50	230
22	671	9/2/2010	118	9:30:00 AM	12.97667	74.0345	118	12:30:00 PM	12.85167	74.093	10	210
23	672	9/3/2010	118	1:00:00 PM	11.88783	74.58434	118	4:00:00 PM	11.76183	74.6385	25	75
24	673	9/4/2010	123	4:30:00 PM	11.69057	74.655	123	7:30:00 PM	11.56583	74.71133	150	185

Table 1: Database in access format

For free handling of data and resource distribution mapping, mainly ArcGIS desktop version 10.0 and its components have been used. The spatio-temporal information about species has been modified in thematic features and shape files with attribute table in the ArcGIS software. The spatial

information thus collected was used as an input for the GIS study (Graham et al. 2002). Now, ArcGIS is used as advanced and powerful engine to produce, analyze, store and visualize the geo-coded information in layer basis. In this study, to generate the base maps some procedure has been followed in ArcMap 10.0 licensed version, viz. For digitizing coastlines and state boundaries of India and other bathymetric contour lines according to sea depth level, the gridded, scanned and geo-referenced toposheets and hydrographic charts have been taken from Geographical Survey of India with respective sheet numbers for Indian region. After that, mid value of the shooting and hauling position of multiday trawling along Karnataka coast has been calculated and added from the MS-Access to ArcGIS platform and based on those points, fishing ground has been digitized and spatial distribution map of marine species has been created in daily, monthly, annually and seasonal basis for better way to represent, handle and carry the database of marine species.

ArcGIS and its several components are one of the best user free hand GIS software to build and develop spatial data infrastructure in marine fisheries area. A spatial database is a system that helps to exchange and share data between people about any chosen study area. Many countries around the world are making and developing spatial data infrastructure as a way for better managing and sharing their spatial data sets (Rajabifard and Williamson, 2004). Spatial analyst tool is used from ArcTool box to interpolate raster from the fisheries database according to selected significant parameters.

Results and Discussion:

Making map of Marine trawl fishery in GIS

The trawl fishery of Karnataka has been focused during the last decades. The multiday trawl fishing operation from Karnataka coast during 2010-2015 is shown in the Figure 1. The map shows the complete 1051 days fishing operation and the database is strong enough to provide core information of fishing ground on daily, monthly, annually and also seasonal basis with created maps by ArcGIS. It is observed from the map that the all fishing grounds are located between 72^0E to 76^0E Longitude & 10^0N to 18^0N Latitude and bathymetric depth of the fishing grounds are minimum 10m and maximum 150m. These maps are very useful for making participatory decision on per hour effort reduction in terms of months and seasons.

Some no trawling areas are observed in the trawling grounds due to the rocky nature of bottom topography, which is also known as sea mount in geographical terms. Seamounts are exclusive environments which support rich level biodiversity. "No fishing areas" and "Marine harbors" can be analyzed on the basis of spatio-temporal data of marine fish distribution (Manson and Die, 2001). Satellite data illustrate that Indian Ocean has various small to moderate sized seamounts, mainly accomplice with its ridge systems (Craig and Sandwell, 1998; Iyer et al., 2012). In the Indian Economic Exclusive Zone, seamounts are situated along the west coast mostly (Kitchingman and Lai,
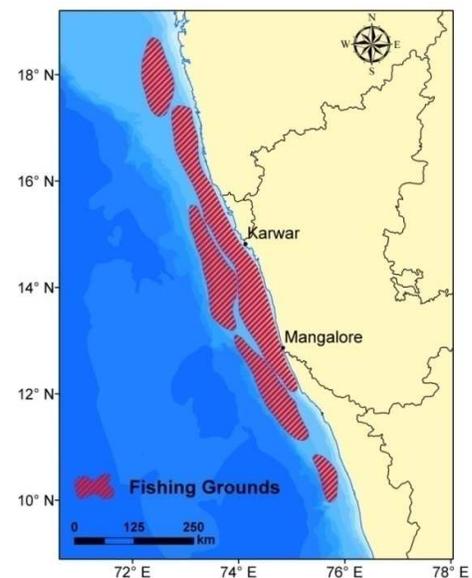

Figure 1: Marine Trawl Fishery (2010-2015)

2004; Iyer et al., 2012), but information available about their ecology, bathymetry and biodiversity are insufficient (Qasim and Wafar, 1979).During intensive fishing time those areas plays as natural protective areas for juveniles, which may be help them from commercial trawl fishery.

Illustration of Spatial information of Marine fisheries

Storing information in layer basis with individual or collective manner is essential process of illustration of spatial information of marine species. This layer basis information can be used for marine fisheries studies with variation of age like juvenile or adults. In the present study layer illustration has incorporated all the days of fishing operations, which were taken up during last five years (2010-2015). These layers have been produced in ArcGIS to identify the catch per hour of species in trawling operation in monthly, seasonally and yearly basis. Figure 2 is showing the yearly basis scenario of catch per hour (weight) of fishing operation with specific unit.

Figure 2: Illustration of information about Catch per weight of marine species
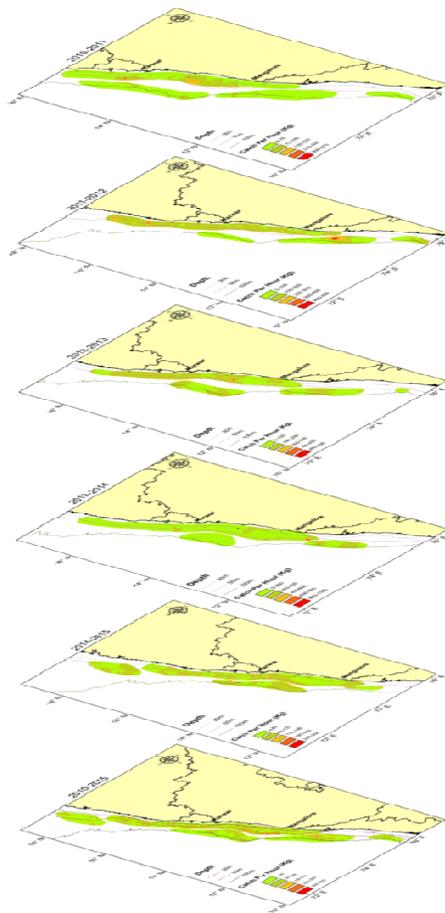
With this illustration process some suggestions can be given for reducing marine resource damage and restrictions be given on effort trawling in particular fishing grounds. Most important part is that all quires related on distribution and abundance of individual or group of species could be used as a

tool by policy and decision makers for predicting the resource based, juvenile wealth based fishery restriction in various fishing grounds (Dineshbabu et al., 2012).

Generating Fishing Ground and its Extension

To generate the fishing ground from MS –Access, the data has been created with the calculated middle latitude and longitude value of shooting point and middle latitude and longitude value of hauling point with a specific buffer area of that particular position. The generated fishing grounds have been given specific color and style combinations to different years for better understanding and the final output was created in layout view of ArcGIS desktop platform. While analyzing, it can be clearly observed that the fishing ground has been extended beyond the Karnataka state boundary during the fishing operation for 2010-2015. Present study narrates that most of the fishing ground are located within the 150m depth and it is mainly extended in parallel manner towards other states. Existing fishing pattern in these grounds are appropriate for making policy of marine biodiversity conservation. The fishing operation during 2010-2015 from Mangalore fishing harbor has been extending day by day, which is observed clearly from figure 3.
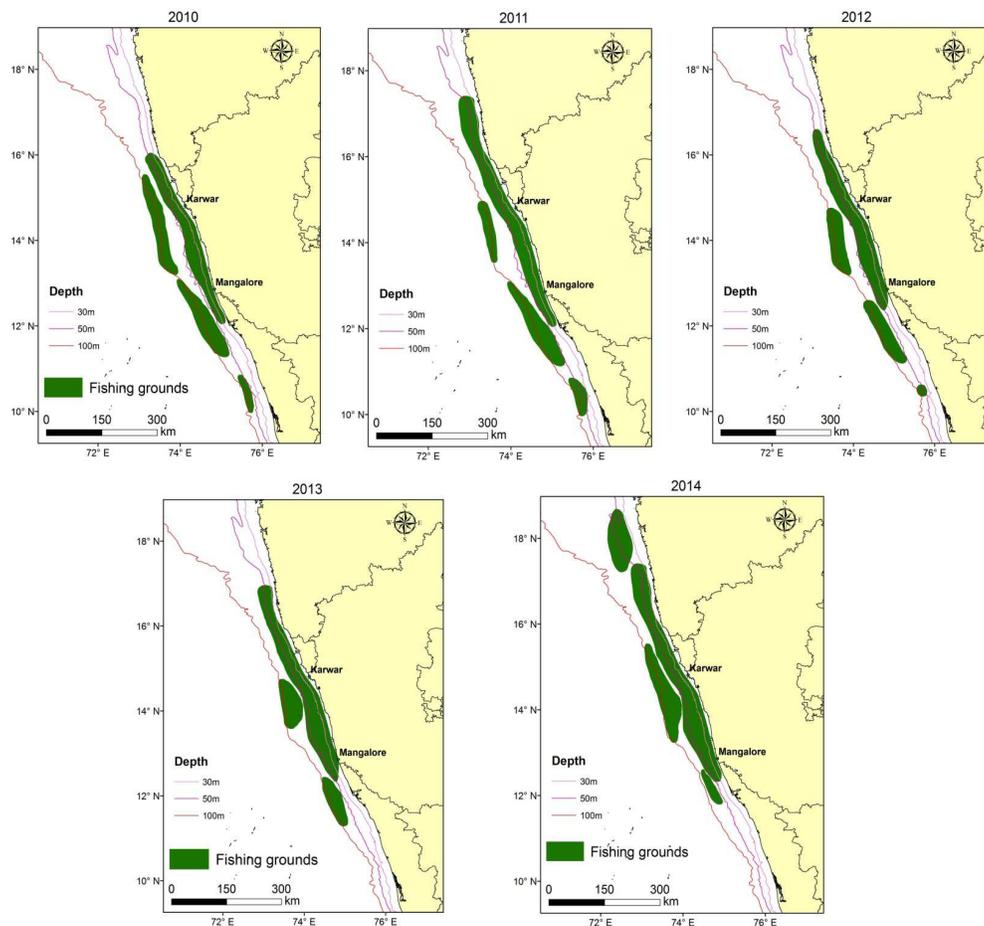

Figure 3: Extension of Trawl Fishing Ground

The information of traditional fishing grounds with existing fishing pattern will help to make policy for the sustainable exploitation of marine fishery resources and these maps form a strong basis for making decision to reduce effort in terms of months, seasons and annual for harvesting any specific resources. Maps of trawling grounds in different month, season and annual give an opportunity to assess the fishing grounds to limit the extent of fishing pressure (Dineshbabu et al., 2012).

Conclusion:

Oceans cover almost two thirds of the surface of the World, monitoring weather patterns and preserving a huge variety of plant and marine life (UN, 2003). There are several rights and responsibilities and countless of activities to protect marine environment, often governed by separate countries and agencies. In order to maintain these rights and activities in marine area effectively, clear spatial certainty of marine boundaries is needed (Collier et al., 2003). This goal can be achieved through the use of spatial data infrastructure and decision making tools such as ArcGIS.

The marine resources database can also be analyzed in a development platform like ArcGIS. Statistical analyses play an important role in marine biodiversity conservation and also their stock assessment. For better analyze now R is the best statistical platform which is having several packages to generate linear and non-linear models and other required models. The analyzed models can be linked with ArcGIS with the help of Marine Geospatial Ecology Tool (MGET), which is completely developed and maintained by Duke University and the method has been implemented in this study. MGET is the best key to build relationship between GIS and Statistics in Research field. The exclusive methods have been applied on experimental basis in Central Marine Fisheries Research Institute of India for analyzing and making a relation between oceanographic and marine fisheries environment.

Acknowledgement:

References:

1. Andrew Binns, Lisa Strain, Abbas Rajabifard, Ian Willamson, 2005. Supporting Decision Making and Management in the Marine Environment. Marine GIS, Vol.9, Issue 8.

2. Collier, P.A., Todd, P.J. and Hirst, B. 2003. First steps towards an Australian Marine Cadastre, 1st National Spatial Sciences Conference 2003: Spatial Knowledge without Boundaries, Canberra, 22-28.

3. 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.

4. Dineshbabu, A.P., Sujitha Thomas, E.V. Radhakrishnan. 2012. 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.

5. Dineshbabu, A P and 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). pp. 103-108.

6. Dineshbabu, A P and Thomas, Sujitha and Dinesh, A C (2015) GIS for Assessing Spatio-temporal Variations in Trawl Bycatch off Mangalore Coast. Fishery Technology, 52. pp. 152-156.

7. Graham, J., Engle, S. and Recchia, M. 2002. Local knowledge and local stocks: an atlas of groundfish spawning in the Bay of Fundy. The Centre for Community-based Management, Extension Department, St. Francis Xavier University Antigonish, Nova Scotia, 63 pp.

8. Jennings, S. and Kaiser, M. J. 1998. The effects of fishing on marine ecosystems. Adv. Mar. Biol., 34: 201-352.

9. Kitchingman, A. and Lai, S. 2004. Inferences on potential seamount locations from mid-resolution bathymetric data. In: Morato, T. and Pauly, D. (Eds.), Seamounts: biodiversity and fisheries. University of British Co-lumbia Fish. Centre Res. Rep., 12: 7-12.

10. Manson, F.J. and Die, D.J., 2001. Incorporating commercial fishery information into the design of marine protected areas. Ocean Coast. Manage. 44:517-530.

11. Qasim, S. Z. and Wafar, M. V. M. 1979. Occurrence of living corals at several places along the west coast of India. Mahasagar, 12(1): 53-58.

12. Rajabifard, A., and Williamson, I.P. 2004.Regional SDI Development – A Fundamental Framework, Journal of Geospatial Today. Vol. 2, Issue 5, India.

13. Thomas, Sujitha, Dineshbabu, A.P.; Sasikumar, Geetha. 2014. Gastropod resource distribution and seasonal variation in trawling grounds off Konkan Malabar region , eastern Arabian sea, Indian Journal of Geomarine Sciences,43 (3): 384-392.

14. UN (2003), Oceans and the Law of the Sea, Oceans and the Law of the Sea Homepage, http://www.un.org/Depts/los/index.htm, Accessed 21th July 2016.

15. Wessel, P. 2001. Global distribution of seamounts inferred from gridded Geosat/ERS-1 altimetry. J. Geophys. Res., 106 (B9): 19431-19441.