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GIS for Fisheries Management in Reservoirs

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GIS for Fisheries Management in Reservoirs

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Introduction

Inland fish production has emerged as a major contributor to the total fish production with a contribution of over 60%. The total fish production from both marine and inland sources was 8.67 million tons during 2011-12 (Table 1), whereas the projected fish production by 2020 is 10.79 million tons (http://www.planningcommission.nic.in). Fish caters to the nutritional security of the nation in general, and of the rural poor of the coastal area, in particular. The realization of the target of fish production would be possible only by increasing the inland fish production.

Malampuzha reservoir, Kerala

Table 1. Fish production in India 2011-12 (in million tons)

Marine	3.37
Inland	5.30
Total	**8.67**

Source: Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Govt. of India.

Reservoirs are a prominent feature of the hydrology of river systems; which are used to impound and store water for public water supply, flood control, irrigation, recreation, hydropower, wildlife habitat and fisheries. Reservoir area contributes 29.07 lakh hectares of water body in India (Table 2) and is a potential resource for inland fisheries. Unlike other water bodies, most of the reservoirs are abound with freshwater round the year and are comparatively free from pollution. So there exists a clear opportunity for fisheries development in reservoirs.

Table 2. Inland water resources in India

Sl. No.	Water Resources	Spread
1.	Rivers and canals (in km)	195210.00
2.	Reservoirs (in lakh hectares)	29.07
3.	Tanks and ponds (in lakh hectares)	24.14
4.	Beels, oxblow and derelicts water (in lakh hectares)	7.98
5.	Brackish water (in lakh hectares)	12.40

Source: Handbook of Fisheries Statistics, 2011

There are some issues that are unique to the reservoirs which need to be addressed from the reservoir management point of view. Natural process like erosion in the catchment area and its deposition in various parts of reservoir gradually reduce the capacity of the reservoir. Dead as well as live storages are affected by this phenomenon. Silt due to sedimentation from the upland and surrounding areas poses threat to the aquatic environment in general and for fisheries in particular. One of the major factors that retards benthic invertebrates fauna in the reservoir eco-system is the rapid deposition of silt and other suspended particles (FAO, 1995). Information about the quantity of the silt and the consequent reduction in the capacity of the reservoir is necessary for planning and operational purposes and the same can be estimated through scientific capacity surveys. It is also essential to know the geo-morphological characteristics of reservoir area for sustainable management of fisheries in the reservoir.

Currently, the average productivity of reservoirs in India is 20.13 kg/ha/yr with small sized reservoirs having greater productivity at 49.90 kg/ha/yr (Table 3).

Table 3. Fish productivity of reservoirs

Type of reservoir	Productivity (Kg ha^{-1} $year^{-1}$)
Small	49.90
Medium	12.30
Large	11.43
Pooled	20.13

Source: Reservoir Fisheries of India, FAO Corporate Document Repositories, 1995

Highly productive reservoirs in India are Chulliyar of Kerala, Aliyar of Tamil Nadu, Gulariya of Uttar Pradesh, Meenkara of Kerala and Bundh Beratyha of Rajasthan (Table 4).

Table 4. Fish productivity in selected reservoirs of India

Reservoir	Productivity (Kg ha^{-1} $year^{-1}$)
Chulliyar (Kerala)	316
Aliyar (Tamil Nadu)	194
Gulariya (Uttar Pradesh))	150
Meenkara (Kerala)	107
Bundh Beratyha (Rajasthan)	95

Source: Reservoir Fisheries of India, FAO Corporate Document Repositories, 1995

However, the contribution of reservoirs to fish production is hardly one percent. Fish productivity of reservoir could be increased substantially to exploit these potential water resources, covering three million hectares, through suitable fishery management practices. The present low level fish production in Indian reservoirs is attributed to inadequate management practices including improper stocking in the reservoir system. Scientific norms are seldom followed for the selection of species for stocking and State Fisheries Department farms are not able to produce sufficient seed. The policies hitherto adopted in Indian reservoirs emphasize mainly stocking fingerlings of a species or a combination of species unmindful on the density levels or ratios warranted for the biogenic capacity of the reservoir. Species used and the rate of stocking are determined by availability of fish seed only (FAO, 1997). Insufficient understanding of reservoir eco-system prevents us from carrying out effective management practices. In most of the medium and large reservoirs, the fish production is extractive in nature with minimum human intervention in the eco-system management leading to the declining productivity (FAO, 1995).

A sound understanding of the eco-system, including the bathymetric characteristics of the reservoir enables the fishers to select appropriate fishing craft and gear for fishing operation and make use of the reservoir eco-system for suitable species-specific cage culture and other fish culture activities for sustainable management of reservoir fishery. The capacity survey of the reservoir to estimate the extent of sedimentation in the water body could add yet another dimension to the monitoring of eco-system management. Sedimentation is the deposition of earthly materials carried out by the inflow in to the reservoir. It is the phenomenon by which capacity of the reservoir is reduced on account of the passage of time. The sediment deposit adversely affects the storage capacity. For effective planning and storage of water optimally it is necessary to find the actual rate of sedimentation and revise the capacity of the reservoir. Sedimentation surveys in India started way back in 1870. However a systematic survey was conducted only in 1958 when the Central Board of Irrigation and Power undertook a co-ordinated scheme of reservoir sedimentation. Under the VIIIth Five Year Plan, the Central Water Commission (CWC) conducted a survey of the 144 reservoirs of the country using conventional techniques (CWC, 2001). In their recommendation, CWC asserted that the capacity survey needs to be done on regular basis once in five years for major reservoirs. Exhaustive hydrographic survey in the reservoir using echo-sounder and GPS to collect spatial data of latitude, longitude and elevation of the bathymetric area of the reservoir and subsequent warehousing of the data in a GIS platform will be an important tool to address some of the above issues regarding the capacity and bathymetry of the reservoirs.

Geographic Information Systems (GIS) is a frontier technology that enables the warehousing of spatial and attributes data and the spatial analysis of the datasets to generate the spatial information. Complex real life physical features can be modeled after this sort of digital spatial database, which constitute simplified thematic layers in a GIS platform. Once the geographic linking of the spatial data is done, many types of analysis could be performed on the basis of individual or multiple layers of datasets to generate location specific information. A GIS developed on reservoir could be used to estimate the volume of the reservoir which in turn could be used to quantify the capacity of the reservoir. GIS technology is also used to estimate quantitatively the silt that has taken place in the reservoir and changes in water spread area over the years. The morphometric map of the reservoir bed could also be generated in a GIS platform to visualize the side-wise and underneath characteristics of the benthic area of the eco-system, which will adequately throw light on the bathymetric characteristics of the reservoir area. This in turn helps us to characterize the bathymetry for the selectivity of suitable fishing gear that could be used for optimum and sustainable fishing in the reservoir area. Taking note of the bathymetric characteristics, appropriate fish culture programmes including possible cage culture programmes for sustainable fish production could also be taken up. The information pertaining to the reservoir, generated through this GIS study could be used by farmers and policy makers to carry out sustainable fisheries management programmes. This sort of GIS developed being a spatial database system, could be used for development of Reservoir Fisheries Information System which in turn can be used for the development of Decision Support System to facilitate policy decisions with regard to reservoir fishery in our country. The study could be used to carry out further spatial modeling studies of the reservoir, thereby improving the reservoir fishery.

The 3D visualization of reservoir includes assessment of volume of the reservoir, estimation of the silt deposited and mapping of bathymetry derived from the spatial 3D dataset of latitude, longitude and elevation of the geographic points of the reservoir area, collected through hydrographic survey or using remote sensing techniques. It would be possible to have a sound perception on the bathymetric characteristics, extent of sedimentation and storage capacity of the reservoir using GIS tools. A 3-D Spatial database encompassing all environmental parameters and water quality parameter of the reservoir in a GIS platform would be modeled as a Reservoir Information System which could be made use for monitoring the reservoir system for sustainable fishery management.

Bathymetric data (the 3-D bathymetric values of latitude, longitude and elevation of reservoir bed area) is collected from an optimum number of bottom bed points of the reservoir to represent the whole bottom area, using the portable echo sounder

Conceptual model for development of GIS based Fisheries Management Information System

Hydrographic survey to collect 3-D data of latitude, longitude and elevation of the bathymetric area of the reservoir

Development of Triangulated Irregular Network (TIN) of the reservoir using the 3-D data

Development of Digital Elevation Model (DEM) of the reservoir

Generation of Contour map of the bathymetry of the reservoir

Estimation of the water spread area and storage of the reservoir

Estimation of the silt due to sedimentation in the reservoir over the years using the spatial model

Generation of 3-D map and three dimensional visualization of the reservoir

Incorporation of fisheries data for selectivity of gears for capture fishery and identification of hot-spots for fish culture

Suggesting strategies and providing advisories for sustainable management of fishery in the reservoir

During the season of maximum water level, hydrographic survey could be carried out in the reservoir along the virtual transects of optimum interval along the reservoir so as to cover the whole water surface. Using echo-sounder and GPS, that are connected on-line, the continuous bathymetric data of latitude (La), longitude (Lo) and depth of water column (D) of the reservoir area along these linear paths will be collected. Elevation data set (El) is derived from Depth data set (D) using the formula.

$$El = Wl - D$$

Where, Wl is the water level of the reservoir from the Mean Sea Level on the day of observation.

The dataset of latitude, longitude and elevation (La, Lo, El) is the three dimensional (3-D) dataset of the bathymetry of the reservoir.

and GPS. These points can be used to generate the Digital Elevation Model (DEM), Triangular Irregular Network model (TIN) of the reservoir using appropriate Geo-Spatial analysis tools. The 3-D data set of latitude, longitude and elevation (La, Lo, El) could also be used to generate contour lines of different width. The optimum contour width of the contour lines can be determined using either iterative methods or using functional relation between contour interval and volume of reservoir.

The determination of the contour interval can be validated using 3-D visualization of the bathymetry using the contour map generated out of the contour lines and the categorization of the bathymetric features through ground truth survey. Water spread area and volume of the reservoir can also be calculated using the appropriate geo-spatial analysis tools.

Contour map, TIN and DEM are used to develop 3-D view of the reservoir. Categorization of the bathymetric area could be carried out using ground truth survey in the reservoir area and using other remote sensing data like LISS III imagery of the area during minimum water level. These information could be utilized for the 3-D visualization of the bathymetric area of the reservoir thereby giving location-specific advisories to stakeholders for selectivity of gears for sustainable capture fishery and selection of fish species for suitable cage culture and other fish culture activities for sustainable culture fishery for better management of reservoir fisheries. Estimation of silt due to sedimentation can be calculated from the volume of the reservoir, which can be easily calculated from the 3-D GIS.

Conclusion

One of the main drawbacks in development of fisheries in reservoirs has been the gap in information regarding the bathymetric characteristics of the reservoir eco-system. The paucity of information on the geo-morphology of the eco-system hinders us from taking effective decisions regarding the most suitable capture fishery methods to be used in the reservoirs. The only management measure taken thus far is to stock the reservoir and give licenses to fishermen in the area, mostly tribal fishermen, to harvest the fish. Very little thought has been given while organizing the fishing effort in reservoir as an input of fishery (FAO, 1995). Fish harvesting systems are primitive and have been by and large restricted to gill nets, long lines, hook and lines and traps. As for the crafts, in some reservoirs in India, small traditional canoes and small FRP boats are being used for fishing, whereas there is no fishing craft in use in many reservoirs. For instance, in Malampuzha in Kerala inflated rubber tyre tubes are used by fishermen to stay afloat while fishing. CIFT has introduced and popularised coracles in reservoirs which are now being used in Karnataka, Andhra Pradesh and NEH states (CIFT, 2013).

A 3-D GIS model on reservoir eco-system can clearly visualize the geo-morphological characteristics of the benthic area of the reservoir. It could help us to identify suitable fishing gear to facilitate sustainable capture fishery. It could also be effectively used to propagate culture fishery, including cage culture by identifying species-specific hot-spots in the reservoir eco-system. A GIS model based on reservoir eco-system could be used as a spatial database with a further scope to include more data pertinent to the environmental and water quality parameters of the reservoir. A full-fledged spatial database of the reservoir in a GIS platform could be used to develop Reservoir Fisheries Resources Information System. This Information System could be a decision support input to stakeholders and policy makers to improve the reservoir fishery for optimizing inland fish production in a sustainable manner. Further inclusion of physico-chemical data sets pertinent to productive traits of reservoir eco-systems could help evolve it into a reservoir management model for fisheries and other livelihood and commercial activities.

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