GIS/RS Applications for an Ecosystem Approach to Fisheries Management

An ecosystem approach to fisheries management and development strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries (FAO, 2003). Recognizing the need for an ecosystem approach stems from the increased understanding of fisheries systems holistically: the interactions within and among fish species; the habitat and wider ecosystem; the fish and fishers; fishing communities; and broader social, economic, and governance systems supporting and influencing.

Effective fishery management cannot separate from the three equal and interconnected aspects of the natural, human and fishery management systems. Conventional approaches to fisheries management only partially consider these dimensions. The Ecosystem Approach to Fisheries Management introduces a series of modifications to conventional fisheries management to improve performance and contribute to sustainable development (USAID, 2008).

The shift to an EAFM from conventional fisheries management requires thoughtful consideration of a number of important issues and challenges. One of them is the availability and analysis of integrated geospatial data in the framework of the process of identification, verification, decision-making, and monitoring evaluation of the implementation of EAFM policy. This paper provides the role of GIS and RS applications as a tool to ensure the successful implementation of EAFM.

Satellite remote sensing (SRS) of the marine environment has become instrumental in ecology for environmental monitoring and impact assessment, and it is a promising tool for conservation issues. In the context of an ecosystem approach to fisheries management (EAFM), global, daily, systematic, high-resolution images obtained from satellites provide a good data source for incorporating habitat considerations into marine fish population dynamics. An overview of the most common SRS datasets available to fishery scientists and state-of-the-art data-processing methods is presented, focusing on recently developed techniques for detecting mesoscale features such as eddies, fronts, filaments, and river plumes of major importance in productivity enhancement and associated fish aggregation (Chassot et al., 2011).

In the context of an EAFM, SRS of the marine environment provides a valuable source of information on the interactions between fish species and their environment. Including environmental effects on fish catchability, abundance, and distribution in the process of abundance index estimation would be a first step to improving scientific advice on the state and management of fish stocks. Identifying spawning and/or feeding grounds based on SRS is also a prerequisite for spatially orientated management measures, such as the implementation of marine protected areas (Druon, 2010; Chassot et al., 2011). In the Pacific, the Hawaii-based swordfish (Xiphias gladius) longline fishery was closed in 2006, because of excessive bycatch of loggerhead sea turtles. Knowledge of turtle habitats gained from tracking and SRS data (see
above) was used to assist fishers in avoiding areas with high turtle bycatch. Launched in 2006, TurtleWatch provided 3-d SST composite maps and weekly ocean currents estimated from SRS altimetry for the fishing ground and the region with the highest probability of loggerhead and longline gear interactions (Howell et al., 2008; Chassot et al., 2011).

Another fisheries-related application of satellite-derived chlorophyll and SST data is that of habitat mapping to elucidate the basic relationships between marine species and their oceanic environment (Sanchez et al., 2008; Kumari et al., 2009; Stuart et al., 2010). In this context, Druon (2010) proposed the use of satellite-derived habitat mapping as a potential tool for the sustainable management of the overfished Atlantic bluefin tuna (*Thunnus thynnus*) in the Mediterranean Sea. Habitat maps can be used either to restrict fishing grounds or to prompt fishers to move towards favourable areas. Satellite data have also been used to predict potential spawning habitat (using SST and chlorophyll) of northern anchovy (*Engraulis mordax*) and Pacific sardine (*Sardinops sagax*) in the California Current (Reiss et al., 2008; Stuart et al., 2010).

Spatial analysis using Geographical Information Systems (GIS) is recognized as an essential tool to integrate ecosystem information from various sources. An experienced GIS user can run many analyzes using off-the-shelf software and readily available data sets – but customized tools can streamline the workflow of these analyzes, and make them feasible for someone with less expertise. One of a successful example on how GIS Application contributes to EAFM is the EcoGIS project by NOAA. The EcoGIS project was launched in September 2004 to investigate how Geographic Information Systems (GIS), marine data, and custom analysis tools can better enable fisheries scientists and managers to adopt Ecosystem Approaches to Fisheries Management (EcoGIS, 2009).

The EcoGIS project has focused on four priority areas:

1. **Fishing Catch and Effort Analysis** - Where, when, and how do fisheries operate within a given area? How have fisheries been impacted as a result of regulatory changes?
2. **Area Characterization** - Within a selected area, what are the physical parameters (e.g. sediment type), biological parameters (e.g. species abundance), and regulatory framework?
3. **Bycatch Analysis** - What are the trends in bycatch among different fisheries and gear types, geographic areas, time periods, depth ranges, and habitat types?
4. **Habitat Interactions** - What types and amount of habitats have been fished using bottom-tending gear?

Of these four functional areas, the project team first focused on developing a working prototype for catch and effort analysis: the Fishery Mapper Tool. These tools will enable simplified and efficient data query, the ability to visualize data over time, and ways to synthesize multidimensional data from diverse sources. These capabilities will provide new information for analyzing issues from an ecosystem perspective, which will ultimately result in better understanding of fisheries and better support for decision-making (EcoGIS, 2009).

Moreover, there are a large number of ways in which GIS might be utilised to assist in fisheries research, and some of these include (Meaden, 2009):

- **Distribution displays** – this is simply cartographic visualisation to show the distribution of any feature or combination of marine or fisheries features.
• Marine Habitat mapping and analysis, e.g. the work of Rubec et al. (1998) in establishing “essential fish habitats” in Florida, plus other work on fisheries oceanography.

• Resource analyses – to quantify and display the disposition of any marine resource or combination of resources.

• Modelling, i.e. these functions include work on illustrating themes, usually in a simplistic or general way, or there may be predictive modelling to show the outcome of potential decisions or actions.

• Monitoring management policies, e.g. optimising the disposition of fishing effort, perhaps via the help of electronic log-book or VMS tracking data.

• Ecosystems relationships, e.g. predator/prey relationships, or relationships between fish distributions and any environmental parameter.

• Stock enhancement, e.g. the timing and selection of sites for artificial stocking, or the optimal siting for mariculture activities.

• Marine Reserve allocation, i.e. both identifying suitable areas for species protection and analysing the results achieved by these areas. This work is complex given the wide number of interested parties (often with conflicting ideals) plus the variety of spatial considerations involved.

• The creation of economic surfaces, i.e. allowing researchers to model the likely income derived from fishery products based on alternative management and resource extraction scenarios.

• Fishing fleet disposition and behaviour, i.e. to best sustain fish yields, vessels need to be optimally deployed throughout a management or ecosystem’s area.

Finally, accurate assessment of EAFM performance requires reliable data at a range of scales. Enhancement and strengthening of data collection systems will assist EAFM implementation. It is the primary role of GIS/RS technology, which becoming a media that able to combine, analyze and present the results of the integrated mapping for all required data. By unites the necessary data into the one mapping system, we can acquire a complete picture about the condition of the ecosystem based on location or by species. It can be concluded that the use of GIS/RS is an essential element in supporting the implementation of worldwide EAFM.

“The application of GIS is limited only by the imagination of those who use it.”

Jack Dangermond, ESRI

Works Cited


Annotated Bibliography


In this study, Chassot et al. present the use of satellite remote sensing for an ecosystem approach to fisheries management. According to them, a comprehensive review of remotely sensed data applications in fisheries over the past three decades for investigating the relationships between oceanographic conditions and marine resources is provided, emphasizing how synoptic and information rich SRS data have become instrumental in ecological analyses at community and ecosystem scales. Finally, SRS data, in conjunction with automated in situ data-acquisition systems, can provide the scientific community with a major source of information for ecosystem modelling, a key tool for implementing an EAFM.


Stuart et al. states that one of the most promising avenues for the use of satellite data for fisheries science in management lies in quantifying objectively the variables that result in large and small year classes of exploited stocks. The influence of fluctuations in the availability of food in the critical period of larval stages can be investigated through the application of ecological indicators describing the variability of the pelagic ecosystem at a given time and place. These indices can increase our understanding of the relationship between ecosystem factors and the recruitment of key species. Despite the many demonstration applications published to date, little use is being made of satellite data to support fisheries science in management. They also discuss some of the obstacles that lie in the way of the operational use of satellite data and suggest actions that could facilitate its broader application.


The EcoGIS project was launched in September 2004 to investigate how Geographic Information Systems (GIS), marine data, and custom analysis tools can better enable fisheries scientists and managers to adopt Ecosystem Approaches to Fisheries Management (EAFM). This report describes the four priority functional areas, the development of the Fishery Mapper tool, and several themes that emerged through the parallel evolution of the EcoGIS project, the concept and implementation of the broader field of Ecosystem Approaches to Management (EAM), data management practices, and other EAM toolsets. One major conclusion from this work is that there is no single “super-tool” to enable Ecosystem Approaches to Management; as such, tools should be developed for specific purposes with attention given to interoperability and
automation. Future work should be coordinated with other GIS development projects in order to provide “value added” and minimize duplication of efforts.


In this study, Meaden states that GIS has become virtually ubiquitous in the world of science and research, if not yet in the world of fisheries or its management. It is also worth noting that almost all uses of GIS in the fisheries area, were related to more-or-less static mapping, e.g. creation of nautical charts, coastal zone management, optimum locations for aquaculture, etc., and it was only in an examination of the potential uses for GIS was mention made of anything more complex. Nowadays, there is almost no facet of the use of GIS for spatial analyses that cannot be attempted. He also provides a number of ways in which GIS might be utilised to assist in fisheries research and management.


Sherman et al. provides the application of satellite remote sensing for assessing fisheries yields productivity. More than $3 billion in support to 110 economically developing nations have been dedicated to operationalizing a five-module approach supporting LME assessment and management practices. An important component of this effort focuses on the effects of climate change on fisheries biomass yields of LMEs, using satellite remote sensing and in situ sampling of key indicators of changing ecological conditions. Warming appears to be reducing primary productivity in the lower latitudes, where stratification of the water column has intensified. Fishery biomass yields in the Subpolar LMEs of the Northeast Atlantic are also increasing as zooplankton levels increase with warming. During the current period of climate warming, it is especially important for space agency programmes in Asia, Europe, and the United States to continue to provide satellite-borne radiometry data to the global networks of LME assessment scientists.


This paper describes the implementation of geographic information systems to systematize, analyze, and display traditional and scientific information to support fisheries management in the Patos Lagoon Estuary, southern Brazil. Artisanal fishing data were documented through a series of interviews conducted during and after fishing trips at harvest spots, and scientific data on environmental variables were obtained from different research institutions. A multi-layer GIS database integrating local fishers and scientific knowledge information was developed with
ArcGIS 8.3 ArcView tools to integrate and translate information into an accessible and interpretable format. The geospatial database interface allowed the selection of specific data characteristics by target species, harvest areas, fishers’ communities, fishing gear, catch-per-unit of effort (CPUE), and monthly landings.


The study supports the importance and the need for an integrated management strategy for the whole watershed to enhance fish yields. Land-use patterns in the catchment areas of Sri Lankan reservoirs, which were quantified using Geographical Information Systems (GIS), were used to develop quantitative models for yield prediction. The validity of these models was evaluated through the application to five reservoirs that were not used in the development of the models, and by comparing with the actual fish yield data of these reservoirs collected by an independent body. The robustness of the predictive models developed was tested by principal component analysis (PCA) on limnological characteristics, land-use patterns of the catchments and fish yields. The predicted fish yields in five Sri Lankan reservoirs, using the empirical models based on the ratios of forest cover and/or shrub cover to reservoir capacity or reservoir area were in close agreement with the observed fish yields.


Geographic information systems (GIS) allow users to explore possible spatial relations that may exist within their data. At the Missouri Department of Conservation (MDC), GIS data is being used to help make management decisions. Thirteen geographic data layers of the Meramec River Basin, Missouri, were used to help demonstrate the usefulness of GIS for making fisheries management decisions. The data were used to help identify potential acquisition areas within the Meramec River Basin.