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GIS in Fisheries Management

Introduction

Fisheries management in large scale was very difficult to be implemented and observed due to the technology limitation to support the studies. The advent of Geographic Information Systems (GIS), however, has made it possible to assess habitat quality, quantity and distribution of fish (Douglas. John 2009) in large scale area observation such as lake (Douglas. John 2009), bay (Clark. Randall 2004), ocean (Zheng. X. 2002), strait (Garofalo. G 2007) reefs (Bello. P. Javier 2005) and large marine protected area (Stelzenmüller. Vanessa 2008). In this paper, I will briefly present the use of GIS in the field of marine fisheries, inland fisheries and the future use of GIS in fisheries management system. That includes not only the sea-related areas but also land- connected part such as port, fisheries processing facilities and fisheries community, known as Socio-Ecological Marine Connections (Da Silva. P.Patricia 2005).

GIS in marine fisheries

Geographic information systems (GIS) technology is rapidly becoming a management and research tool for fisheries professionals (Fisher and Toepfer 1998). Many researches and studies in marine fisheries field have used GIS to model suitable habitat for certain species, distribution of fish, and fish species diversity (Garofalo. G 2007; (Zheng. X. 2002); (Clark. Randall 2004). Recently, the study involves more complex model (Nilsson. Per 2007). In this study the authors applied GIS to investigate spatial distribution of fishing effort based on trawl fishing data.

Constant demands on the coastal zone from a wide range of human activities suggest that the continued function of natural communities may be threatened in some areas (Le Pape. Olivier 2003). Thus, it is needed to determine the suitable area for certain species, especially commercial species to ensure the health of its stock. Two methods have been observed as common technique determining a suitable habitat in GIS. *First technique* has used physical factor such as bathymetry, sediment structure and river plume influence to identify the perfect habitat for common sole (Le Pape. Olivier 2003). By integrating the distribution of these factors in the study area and overlaying it with trawl data, they delineated the study area into some categorical measure which area good, moderate or not suitable for common sole. *The second*, (Bello. P. Javier 2005) initialized the study by incorporating spatial analysis of potential habitats to estimate abundance, density and biomass of spiny lobster (*P. argus*). The latter study, ground check is conducted by surveying the classified area in term of lobster abundance and its bottom type. The GIS analysis that has been used on the two researches above can be further extended to investigate anthropogenic disturbance that might take place on the study area (Le Pape. Olivier 2003). This information will be very useful for fisheries manager to set up fisheries management area and its buffer area, in order to protect the habitat and the organism that live in that area.

Marine fisheries can be characterized by gear type and target species. Trawl fisheries is often selected as an object of research because it is a well established system. This typical fisheries characteristic allows possibilities of controlling fishing effort by regulation (Rettig 1984). Total area trawled by the fishing gear at any given time is then identified as an intensity of fishing activities in that particular area (Nilsson. Per 2007). The analysis of this research began by producing a grid theme of the trawl area as fishing intensity. The raster data type is then converted back to vector type data where each point represents the sum of fishing intensity. Further analysis can be done by overlaying this fishing intensity map with habitat map to see how large area was affected by trawling activities and we could analyze the bottom type that is preferable for trawl fishery.

GIS in freshwater fisheries

Managing large area, such as lakes and rivers will be easier said than done, unless we have sufficient tool to analyze, and display our data. GIS has a lot of features to conduct spatial study, however researchers often have to utilize additional function to conduct their research in order to have better result. General additive model (Zheng. X. 2002) and generalized linear model (Le Pape. Olivier 2003) are some of the additional functions that used together with GIS software.

The added value of GIS allows researchers to do quantitative measures of fish habitat in large area such as lakes (Douglas. John 2009) and rivers (Webb. A. D. 1999). The use of GIS in freshwater fisheries has assisted the researcher to integrate topographic data, geology, together with other water-quality monitoring data, such as temperature and dissolved oxygen (DO) and ecological field survey information in their analysis(Douglas. John 2009); (Webb. A. D. 1999). Unlike marine fisheries where GIS application is very limited (Fenzhen SU 2005), inland fisheries more likely to have advantages since it has smaller area and has more availability of supporting data. That is because GIS application is widely used in terrestrial area which most the freshwater fisheries associated with.

Assessing the critical area for certain species by quantifying fish habitat (Douglas. John 2009) , managing catch (Webb. A. D. 1999) and aquaculture site survey (Nath. Shree S. 2000) are the common use of GIS in inland fisheries. Fishing regulation and management are based on this data analysis. In an example, having a good data on fish habitat such as the location, area, number of average catches on the area and bundled with geological data and water survey data, a fisheries manager can make a good decision of which area should be closed and when should be opened for fisheries. Besides this, useful output and carrying capacity of ponds, lake or river can be predicted by utilizing this result.

Future use of GIS in marine fisheries management

Geographic information system in marine fisheries characteristically focus on mapping the fishing ground, characteristic of marine environment (Da Silva. P.Patricia 2005) fish distribution (Zheng. X. 2002), and fishing effort (Nilsson. Per 2007). Even though this information is very important input to fisheries management in order to manage the marine resources, they are all only focused on the sea (Da Silva. P.Patricia 2005). New

approach of fishing management should consider the fishing community on land and their connection to marine resources (Da Silva. P.Patricia 2005) when it comes to the decision making process. This is very important, because not only we need to protect our marine resources; we need also to have broader understanding to how a new regulation will affect fishing community and stakeholder in the future.

Recognizing the fact that GIS can be used as quantitative and qualitative measures, the blend of ecological data, geological data, fisheries statistical data, and socio-economic data, as long as they are stored and organized systematically and can be related to a geographic place (Da Silva. P.Patricia 2005); can be a very powerful tool to fisheries manager to do a comprehensive assessment on fisheries. The idea that is proposed to connect these data is then called as “socio-ecological marine connection mapping” (Da Silva. P.Patricia 2005).

Additional References:

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Annotated Bibliography

Bello. P. Javier , R. L. V., Liceaga. C.M.A. , Zetina. M. Carlos , Cervera. C. Kenneth , Arceo. B. Patricia ,and Hernandez. N. Hector (2005). "Incorporating spatial analysis of habitat into spiny lobster (*Panulirus argus*) stock assessment at Alacranes reef, Yucatan, Mexico." Fisheries Research 73 (2005): 37-47.

The authors claimed that this is the first article that has utilized remote sensing and GIS as tool in fish stock assessment for lobster especially in a large scale research. Landsat TM image was used to determine the initial sampling locations based on unsupervised algorithm, as the result is thirteen-spectral class images that will be used to design sampling location. Handheld GPS is then used to confirm the location on the ground. Overlapping lobster survey data with the thematic habitats map has been carried out using GIS software. By integrating all the output from GIS analysis, the authors obtained the estimation of abundance, density and biomass per habitat of lobster for whole research area. The article is well written and explained the detail of remote sensing and GIS procedure they have followed. Overall, this is a good reference to start your research with, especially in case of lobster stock assessment.

Da Silva. P.Patricia , a. F. C. (2005). Human Dimensions of Marine Fisheries: Using GIS to Illustrate Land-Sea Connections in the Northeast U.S. Herring, *Clupea harengus*, Fishery. Marine Fisheries. The USA, Government Printing Office. 4: 19 – 25

First of all, the article has brought a good understanding of interaction between fishers, other fishery participant and fishing ground. The article gave us the fact that most of the GIS applications are based on fishing ground GIS-type application, instead of socio-ecological GIS application. The lack of effort to visualize land-sea connection is due to the difficulty of integrating the physical data that biologists, ecologist and oceanographers have provided with socioeconomic data from social scientist. The authors believed that by integrating these two aspects of data, we are not only protecting our marine resources but also we can understand the impact of protective management measures on fishing communities and stakeholder. The articles provided the current uses of GIS application in marine fisheries study such as; Marine productivity hotspots, aquaculture site selection, fishing effort by state, delineation of fishing grounds and fish movement tracking, etc.

Herring fishery in northeastern of the United States of America has been taken as a model of further research of socio-ecological mapping proposed by authors. The research objective was to identify the links between marine resources and human communities. This research was started by observing new regulation on herring and its impact on current and future access to the fishery and the changes of catches from stakeholders. The geographic distribution on herring fishery, behavior of fishing fleet and its gear type, processing type and key ports are displayed and mapped using ArcView 8.3 GIS system. Even though the map is considered as over implication of herring fishery, it gave us good information on how the changes of measures in fishery have changed the community, in

term of services and other facilities in the port and its effect on lobster fishery in New England.

The weakness of this article is it is too long and so many subtopics that author tried to explain and they may not be aware of the reading endurance of the reader. The good part is it provided us with good information of current GIS application and its output. In this article, the authors described simple model on how the socio-ecological model can be conducted on real fishery such as Herring.

Douglas. John , H. T., Abery. Nigel and Allen. Micheal (2009). "Application of GIS modelling to quantify fish habitats in lakes." Lakes & Reservoirs: Research and Management 14: 171 - 174

Fish habitats in lakes are very critical due to limitation of suitable temperature and dissolved oxygen (DO) to live for certain species. Mapping the suitable area in such a large scale was very complicated before GIS comes into play. Delineation of which area will be or not be suitable for Brown trout was the main concern of this research. Brown trout as a common species in Lake Eildon has been utilized to conduct this research. Defining the temperature limit and DO for brown trout is important, since these parameters will be used on mapping the suitable habitat for trout. GIS analysis was used to map and display the suitable species during winter and summer time. The map was generated using GIS model of temperate, stratified lake based on brown trout water temperature and DO tolerances water the depth of the particular location. The result showed that during the summer time the Eildon Lake has less area to support the brown trout due to "habitat squeeze" caused by increasing temperature on the lake. From these results, the authors can take estimation how large the suitable area during the summer and winter time and what is actual carrying capacity of the lake to support brown trout. This article is the output of an excellent research that has successfully integrated the use of modern technology, such as; GPS transmitter and acoustic technology, to help establishing spatial distribution of brown trout in the Eildon Lake.

Garofalo. G, F. F., Gristina. M , Cusumano. S , and Sinacori. G (2007). "Stability of spatial pattern of fish species diversity in the Strait of Sicily (central Mediterranean)." Hydrobiologia 580 (2007): 117 - 124.

Garofalo. G et al., 2007 has conducted research on demersal fish species in the strait of Sicily, central Mediterranean. The study used scientific bottom trawl survey that has been collected from 1994 - 2003 during the spring season. The number of fish caught on the survey processed and sorted based on the species, and then its abundant will be labeled as number of fish per square kilometer. To characterize the diversity of certain species, Shannon diversity index has been chosen on this research. Inverse distance weighting tool in ArcGis was used to interpolate geo-referenced data into regular grid. The 10 years observation results were plotted to have the average geographical distribution of species diversity. This analysis gives us the description of which area has the highest density and which one has the lowest. Finally, it can be concluded that the areas that have the highest

density support the biomass of demersal resources and should be the highest priority to the fishery management system. This article explicitly mentioned the tool that used for the analysis and explained step by step how the authors conduct the GIS analysis. It is an excellent article, however, the material and method section should have had more proportion of the article in order to give the reader better understanding on what and how the data analysis was conducted.

Le Pape. Olivier, C. F., Mahe'vas. Ste'phanie, Lazure. Pascal, Gue'rault. Daniel , De'saunay. Yves (2003). "Quantitative description of habitat suitability for the juvenile common sole (*Solea solea*, L.) in the Bay of Biscay (France) and the contribution of different habitats to the adult population." Journal of Sea Research 50 (2003): 139– 149.

This Article describes the spatial distribution of Juvenile sole based on autumnal beam trawl surveys conducted in the Bay of Biscay (France). The study emphasized the distribution of juvenile sole in relation to the physical condition of the bay such as bathymetry, sediment structure and river plume influence. Two models have been developed to observe the suitability of the sole habitat. The latter will be integrated with GIS plus model to quantify the density of sole juveniles and display the nursery ground that most suitable for this particular species. In this article, GIS has been used as a calculator tool where GIS calculate an index of juvenile abundance based on the extent of geographic stratum areas. Visualization of this calculation will be the average distribution of the nursery grounds with regard to habitat suitability. Beside this function, the author has used GIS to assess the anthropogenic effect that might disturb the nursery ground that is caused by any coastal development such as harbor extension. It is good article in fisheries science which has combined mathematical model and GIS function as its tool.

Nilsson. Per, Z. F. (2007). "Spatial distribution of fishing effort in relation to seafloor habitats in the Kattegat, a GIS analysis." Aquatic Conservation: Marine And Freshwater Ecosystems 17 (2007): 421 - 440.

The study took place in Kattegat, the fishing ground for Danish and Sweden fisherman. A high resolution fishing effort data based on the frequency of individual tow was used in the study. The research was initialized by producing a grid theme, assuming that the fishing tow has 5 x 5 km square in two dimension perspective around the gear set position. The area swept by fishing activity will be calculated using GIS tools and will be defined as fishing effort in that respective area. Overlaying the fishing effort data with bottom type map gives more information about where the fishing area took place and its intensity over the years of observation. The result showed that 55 % of the trawl activity took place in the deep rocky habitat and 41 % in the muddy area. Integrating the fishing effort data and its respective habitat with the disturbances effect that might be produced from the trawl activity to the environment, fisheries manager will have a good understanding on how to regulate the fishing activity and can wisely set up the management area to preserve the environment and fish stock in the same time. Overall

this article is very comprehensive research that provided us a good example on how GIS has been used to analyze the fishing activity and its relationship to the environment.

Stelzenmüller. Vanessa, M. F., Bernard. Guillaume, Cadiou. Gwenaël, C. h. R. Camilleri. Matthew, Criquet. Géraldine, Dimech. Mark, et al. (2008). "Spatial assessment of fishing effort around European marine reserves: Implications for successful fisheries management". *Marine Pollution Bulletin* 56: 2018 - 2026.

This is the most interesting article among my references. The article studied the significance of MPA in supporting the adjacent water in term of fish stock. The study has used GIS software combined with statistical method, known as generalized additive model. At first, the authors superimposed grid with cell sizes, from 250 m by 250 m to 750 m by 750 m, assumed that it will compromise the length of fishing set and the size of study area, the latter, the author aggregated all the fishing effort as effort density (measured of number of gear deployment per kilometer square). The combination of GAM and GIS made the analysis possible, this type of analysis then popularly know as geostatistic. The result of this study showed that there is an indication that most of fishing fleet will be congested outside the MPA border. Knowing this fact, fishing management will come handy to fishing manager when it comes to the point that new rule is needed to regulate the fisherman.

Zheng. X. , G. J. P., D. G. Reid, and I. T. Jolliffe (2002). "Does the North Atlantic current affect spatial distribution of whiting? Testing environmental hypotheses using statistical and GIS techniques." *ICES Journal of Marine Science* 59 (2002): 239–253.

Physical oceanography factor such as ocean temperature often be observed and related to the distribution of certain commercial fish species. In this journal, the authors have used sea surface temperature (SST), sea bottom temperature (SBT) and depth to investigate the distribution of whiting in regard of their changes over the seasons. Generalized additive models (GAM) have been utilized as quantitative measure while GIS tool has been used to check the result of statistical calculation with its location in the ocean. In this research, GIS contributed very significant help when the statistical result tells negative relationship of SST and whiting distribution. GIS analysis corrected the wrong assumption of statistical value by displaying the area of whiting distribution in broader view of its spatial location. In a nutshell, without utilizing GIS as a spatial analysis the statistical calculation will direct the research in a wrong conclusion of whiting distribution. This is an excellent article about whiting spatial distribution in regards with physical oceanographic factor. However the result showed possible bias that leads the result in dubious circumstance.