Ocean Zoning and GIS

The intense competition for ocean space among human users has increased dramatically over the last century as the variety of marine resource usage has increased with population growth, technological advances, and human preferences. The oceans are no longer solely the realm of fishermen. In general, the oceans are a publicly owned resource and are managed by governments. In recent years, the necessity for new methods of ocean management have become clear as costly disputes have arose over conflicting usage of ocean waters. Conflicting usages are often site-specific and as such the focus has shifted towards spatial management of the oceans. Many federal and state governments are now looking towards ocean zoning as a means toward effective management. Ocean zoning involves dividing and area into “zones” and within those “zones” regulating uses to achieve a specified purpose. GIS has been an essential tool in the two main components of ocean zoning; one being creating maps depicting zones, and the second being the determination of the optimum utilization of the zones.

Oceans are vast and featureless making spatial management a real challenge. GIS has been instrumental in allowing people to visualize features of the ocean which are hidden beneath the surface. In addition GIS allows for the creation of virtual management boundaries in the marine environments. Traditionally, ocean regulation has been focused on sector based management with over 20 federal agencies implementing over 140 different ocean related statues (Crowder et al, 2006), not to mention the many state and local agencies and their statues. The fragmented governance of the oceans has become a greater problem as new activities such as placement of aquaculture or wind farms increase the likelihood of usage conflicts and the question of who governs these areas. Ocean zoning can help alleviate some of these problems by adding a spatial element that defines areas within which activities may occur while maintaining existing regulations for fishing, shipping, and other marine related activities. Ocean zoning is a way to simplify or coordinate management of the existing regulatory system.

Ocean zoning is inherently dependent upon the use of GIS technologies. The maps depicting zones are made using GIS and the digital maps produced aid in the distribution of information in an easily understandable way. In addition, the optimal locating of specific usages are all dependent upon the mapping and analysis of new or existing data. Some of the most prominent usages that are being analyzed for ocean zoning are protection of marine habitats, commercial fisheries, renewable energy development, aquaculture, shipping, and mineral exploration.

An important first step in ocean zoning is mapping biophysical conditions and existing human uses in the oceans (Crowder & Norse, 2008). Overlaying these datasets in GIS makes it easy to visualize conflicting ocean usage. For instance, mapping shipping lanes immediately excludes these “zones” of the oceans from aquaculture development as the two activities are incompatible. On the other hand, two usages such as windfarms and recreational fishing could be compatible and the zoning could permit both of these activities.

GIS has been used to analyze existing data in a spatial context, especially for commercially exploited fish species. Often times the life history characteristics of exploited fish species are fairly well know. By analyzing these life history characteristics along with measured physical characteristics in a spatial context additional information can be gleamed. Valavanis and others (2004) show how mapping of remotely sensed data of productivity and temperature and an existing database of fisheries catches can be combined in GIS to determine essential fish habitat in different times of the year. Protecting essential fish habitat is required for sustainable fisheries and is often one of the top considerations in
ocean zoning. Olsen (2009) suggests that through the usage of GIS and GPS technologies fishermen are no longer “fishing” for some species such as sea scallops, but are “farming” them in designated zones, harvesting from specific areas (like a terrestrially zoned agricultural areas) and leaving other areas to serve as nurseries.

Humans are traditionally farming marine species in aquaculture operations as well. As the concern over the environmental impacts and lack of space for inshore aquaculture operations has increased, the development of offshore farms has also risen. The ideal location of these farms has to take into account many variables including conflicting usages, environmental concerns, and farming logistics. Longdill and others (2008) used Multi Criteria Evaluation techniques to assess and map the suitability of areas off of the Coast of New Zealand for aquaculture by interpolating spatial data to raster format and using a additive and a weighted geometric mean model to obtain a suitability index. These methods can be used for the siting of many types of marine usages by changing the criteria put into the model. For instance, one of the criteria for aquaculture siting was remotely sensed Chl a concentrations (a proxy for food concentrations). This criteria is important for aquaculture operations siting but not necessarily so for wind farm development, different criteria such as wind speed and depth would likely be analyzed for. These are both examples of how the oceans could be zoned for specific purposes by analysis of data within GIS.

Fisheries and aquaculture management are particular areas that GIS has been particularly useful but managing fisheries independently of the rest of the ecosystem is not sufficient as multiple stressors have cumulative and interactive effects. Spatial mismatches of existing governance and ecosystems are common, where jurisdictional boundaries are too small for effective management of large ecosystems (Crowder et al., 2006). Ocean zoning has often been cited as an ideal management tool in ecosystem-based management which is an integrated approach to management that considers the entire ecosystem, including humans (Halpern et al., 2008; Crowder & Norse, 2008). Humans are often becoming the subjects of ecological studies, mapping their distributions and spatial and temporal patterns and how these distributions affect the ecosystem (eg. Dalton et al., in press)

Ocean zoning has begun to be implemented at both the national scale and state level. Massachusetts’ Ocean Management Plan and Rhode Island Ocean Special Area Management Plan are both in the draft phase but are the first such efforts in the United States. As a nation the US is lagging behind Canada, Australia, and a handful of European nations which have all begun to investigate the utility of Ocean Zoning as a management practice at the national level (Douvere & Ehler, 2009). GIS has been an essential component in the development of all of these plans and would not have been possible without the technology. Ocean zoning and ecosystem-based management are the future of management in our oceans.
Annotated Bibliography


This paper is concerned with marine spatial planning and how it can be used for marine ecosystem-based management. Ecosystem-based management is a hot topic in science at the moment and here it is defined as “an integrated approach to management that considers the entire ecosystem, including humans”. The authors state that ecosystems are “places” so therefore ecosystem management is “place-based”. However, they argue against sectoral management and in favor of spatial planning where ecological aspects such as population connectivity and food webs are factored in alongside jurisdictional and socio-economic factors. They point towards GIS, remote sensing, telemetry, modeling and other scientific techniques to describe the dynamics of marine ecosystems which can then be overlayed on socio-economic and jurisdictional boundaries to determine the most effective management strategies.


This article describes how the development and utilization of GIS has revolutionized the way that some fisheries are managed. The article specifically focuses on the Sea Scallop fishery off the Northeast United States but points to the utility of GIS mapping for the management of other species. The main premise of the article is that detailed mapping of sea scallops and their ecology have allowed for the switch from “fishing” for sea scallops to “farming” sea scallops by harvesting from specific designated areas on maps. GIS technology has made information previously only accessible to fisheries managers understandable to the general public and fishermen. This accessibility and ease of use has also lead to “counter-maps” that refute management practices. The author continually makes references to how marine management is beginning to resemble land based management and how ocean-zoning is very similar to zoning on land. She suggests that GIS has been instrumental in this new way of managing the oceans because it has allowed for the visualization of marine ecosystems that were once hidden beneath the ocean surface.

Peter T. Harris, Tanya Whiteway, High seas marine protected areas: Benthic environmental conservation priorities from a GIS analysis of global ocean biophysical data, Ocean & Coastal Management, Volume 52, Issue 1, January 2009, Pages 22-38,

This paper takes ocean zoning to a scale that has not really been looked at previously. The authors divide the entire ocean floor into 11 different “seascapes”. Six benthic data layers (depth, slope, sediment thickness, primary production, bottom temperature, and bottom dissolved oxygen) were
converted to 11km X 11km pixels by interpolation the existing data and then overlayed to create the seascape classes. The seasapes contained 53,713 different polygons representing the 11 different classes distributed throughout the globe. They looked at the distribution of the different seasapes using the AccInfo “Focal Variety” tool and found that areas around trenches, volcanic ridges, and island arcs contained the most amount of seasapes, indicating that they were the most heterogeneous and diverse areas and possible candidates for protected areas. The authors also looked at ecological parameters like perimeter to area ratio of the polygons and how these attributes might affect management. Many of the seasapes were mainly found outside of the Exclusive Economic Zone (EEZ) which means they would require international conservation measures to ensure that they are protected. I think that the methodologies used would be useful in the zoning of near-coastal waters if done at a larger scale (smaller pixel size).


This paper deals with using GIS-based models to determine offshore areas suitable for the development of Aquaculture Management Areas off the coast of New Zealand. They are specifically looking at zoning for aquaculture but the methods they use could be appropriate for different uses such as offshore energy production. They used the Multi-Criteria Evaluation (MCE) technique to examine a number of criteria that are relevant to the siting of aquaculture farms. These criteria can either enhance or detract from the suitability of the site or they can be constraints from other uses. The criteria were transformed to comparable units by Parameter Specific Suitability Functions given each criteria a score between 0 and 1. They looked at a number of unique criteria, one of the most important being the productivity of the area (i.e. food supply) which was remotely sensed using CHL-a data derived from SeaWiFS satellite. This paper was very well written and gave a detailed description of how GIS models can be used to effectively zone the oceans, in this case zone for aquaculture.

Vasilis D. Valavanis, Stratis Georgakarakos, Argyris Kapantagakis, Andreas Palialexis, Isidora Katara, A GIS environmental modelling approach to essential fish habitat designation, Ecological Modelling, Volume 178, Issues 3-4, 1 November 2004, Pages 417-427

I included this paper because it dealt with using GIS modeling to designate essential fish habitat, not simply mapping fish catch. GIS applications have the ability to aid in the determination of essential fish habitat which is defined by US Congress as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity”. This paper describes how GIS and remote sensing have been used to determine EFH of short-finned squid. Satellite imagery of sea surface temperature (SST) and chlorophyll concentrations were used in addition to salinity measurements, bathymetry and fisheries production and fishing activity were used in the determination of EFH. Kriging was used to calculate bathymetry from a point dataset from a collection of ship soundings. The model consisted of four stages, the third stage outputs an EFH grid in terms of SST, Chl-a, and SSS then the fourth stage combines the grid maps into one polygon coverage that has all of the attributes of the preferred living conditions of the squid. This was an interesting paper as it took known life-history characteristics and were able to “transform” these known characteristics into easily interpretable spatiotemporal distribution maps.
Tracey Dalton, Robert Thompson, Di Jin, Mapping human dimensions in marine spatial planning and management: An example from Narragansett Bay, Rhode Island, Marine Policy, in press, Volume 34, Issue 2, March 2010, Pages 309-319

This paper takes methods utilized to determine spatial and temporal heterogeneity of the natural environment and applies them to an analysis of the heterogeneity of human use patterns in Upper Narragansett Bay. The authors conducted shipboard transects on 50 days throughout the summers of 2006 and 2007 and categorized vessels into 7 categories from row boats to industrial vessels (e.g. tankers). GIS was used to compare their observations to existing water use types delineated by the RI Coastal Resources Management Council. They also made grid maps, dividing the Upper Bay into 1248 different cells and mapping the presence or absence of each type of vessel in each cell over the 50 days. They also used the software program Fragstats to analyze a number of different landscape patterns. They also discussed the importance of knowing the variability in human usage of the marine environment in marine spatial planning and zoning.

Additional References

