Integrated or ecosystem-based management is the paradigm that most states favor for management of natural marine resources and one of the initiatives heralded within this framework is the concept of large marine ecosystems (LMEs). LMEs and LME-based management are ways for countries to address sustainability concerns within their respective marine ecosystems and to manage resources in a transboundary nature. Since successful implementation of LME-based management involves a thorough knowledge of ecosystem interactions, it seems clear that Geographic Information System (GIS), and its ability to integrate different layers of data seamlessly, would be a natural tool to use in LME-based management. The focus of this paper is how GIS can be used to address pertinent information, in order to operationalize LME-based management.

LMEs are, “relatively large regions on order of 200,000 km² or larger, characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations,” (Sherman, 1995). LMEs are defined areas of the ocean, falling within the jurisdictional boundaries of countries they border. Currently there are 64 identified LMEs worldwide located along every coastline in the world (Sherman & Duda, 2002). As a defined area of ocean space, LME boundaries must be mapped. The method currently employed for this task is GIS. GIS provides the basic framework for LME classification and is now being utilized as a tool to address specific management concerns inherent with LME-based management.

To successful implement LME-based management, Sherman notes that one must assess the sustainability of the ecosystem through five modules: productivity of the ecosystem, fish and fisheries, pollution and ecosystem health, socioeconomic conditions and governance (1995). The first three modules represent a focus on the natural ecosystem and it is here where GIS is currently being utilized, though not on a LME scale.

The marine environment is fluid and three dimensional, and as such, organisms living within it are generally harder to study than their terrestrial counterparts. Studying the interactions between organisms living within an area of the sea, as well as the environmental influences on the particular area, are at the heart of the LME concept and critical for LME-based management. GIS goes a long way in helping to understand these interactions.

The productivity of the ecosystem module described by Sherman (1995) focuses on zooplankton biodiversity, plankton biomass and primary production. Thematic Mapper, Multi Spectral Scanner and AVHRR allow researchers to obtain information on chlorophyll concentration, which is necessary to assess primary production (Barale & Folving, 1996). AVHRR, which assesses water temperature, coupled with remote sensing measuring ocean color and sea surface evaluation allow researchers to determine relationships leading to phytoplankton biomass and productivity (Barale & Folving, 1996). Ocean color can also provide information on global climate as well as forecasting local plankton blooming (Barale & Folving, 1996). Layering of relevant data can assist managers in pinpointing areas of a LME that may be more affected by environmental perturbations or anthropogenic influence.
Knowledge of the second module referred to by Sherman, fish and fisheries is equally important for LME-based management. Establishing baseline knowledge of essential fish habitat is critical in fisheries management. Tools associated with GIS such as sidescan sonar, aerial and digital ortho photos, and remote sensing techniques help researchers identify different habitat types. Once habitat type is known, researchers can use GIS to create maps that pinpoint habitat type and create separate maps for each habitat (McRea et al., 1999). If a specific habitat is not previously known different data sets mapped within GIS, such as bathymetry, sediment structure, salinity, water temperature, can be helpful in defining habitat for certain species (Le Pape et al., 2003). GIS can assist in examining the interactions between certain predators, such as seals, and prey by simulating distribution of predators based on data including habitat types, water depths, and seal haul out sites (Bjørge et al., 2002). Aerial and digital ortho photography can also be used to illustrate temporal changes in habitat (Robbins, 1996), which provides historical context for fisheries in relation to habitat alteration. Sherman notes that critical fisheries information including: growth, fecundity, age and stomach content analysis (1995). This data, though not obtained by GIS, can be input into GIS, and through a process of overlaying the information with bathymetry maps, maps of the coastline and sampling sites, distribution patterns of fish weight, growth, and age can be recognized and mapped (Fortunati et al., 2002). Fisheries science is complex and there are many different layers of data necessary to accurately manage a fish stock, habitat, predator prey relationship, biodiversity of region, and reproduction traits of the species. While many of these data are not captured in GIS, they can be synthesized and relationships between them analyzed using GIS.

The third module described by Sherman, pollution and ecosystem health can also be addressed through GIS techniques. Anthropogenic activities exert enormous amounts of pressure on the marine environment. In many LMEs, these pressures represent the majority of stress on ecosystem health (Shalovenkov, 2000)(Sherman & Duda, 2002). Pinpointing specific sources of pollution, as well as linked watersheds are currently being conducted using GIS and this information is invaluable for LME-based management. AVHRR has been used to show water turbidity, indicating the extent of pollution runoff from rivers in the Black Sea (Shalovenkov, 2000). Satellite imagery and aerial photography have been used to provide information on land use and coastal development, two factors, which heavily contribute to pollution, erosion and sedimentation (Stanbury & Starr, 1999). LANDSAT imagery can also be used to identify important watersheds and stream courses (Stanbury & Starr, 1999). Once incorporated into GIS, maps can be produced, which will allow managers to develop appropriate management plans to address these activities and their influence on overall ecosystem health.

The usefulness of GIS has been well demonstrated for the first three modules described by Sherman for ecosystem sustainability. Though there have been no studies conducted using GIS for an entire LME, the layers of data created on fisheries, productivity and ecosystem health can all be synthesized in GIS and assist managers attempting to implement LME-based management. GIS can be applied to the study of natural systems in marine resource management on any scale. What has been lacking to date is work with GIS to address the socioeconomic and governance modules of LME-based management. Once these types of data are input into GIS, facilitating the implementation of LME-based management will become much easier.

GIS and LME-based management go hand in hand. GIS provides the most seamless, complete, integration of various layers of data, which is critical to understanding ecosystems and ultimately managing them. The only inhibiting factor foreseeable in the future to utilizing GIS in LME-based management is lack of data.
caused by insufficient infrastructure in a country. If means become available and infrastructure improves in many countries, there is no reason to think that GIS cannot or will not be the pivotal instrument in successful implementation of LME-based management for marine natural resources.

References:


Annotated Bib

Jesse Stuart

Mechling

Annotated Bibliography:

Barale and Folving’s paper provides in depth detail about the information that remote sensing can provide in regards to the marine environment. Due to the large scale of the study area, the researchers found remote sensing techniques and satellite imagery more useful in providing information on physical and biological processes of coastal areas. AVHRR along with Thematic Mapper and Multi Spectral Scanners were used to provide information on ocean color, optical properties of sea surface, sea temperature, runoff areas and anthropogenic loads. GIS is mentioned as the tool to model and map data collected from the remote sensing and satellites. Though the article is relatively old, the authors demonstrate that these types of technology will increase in the future and will provide a wealth of information for large-scale and long term monitoring.


In this paper, Bjørge et al. use GIS to map areas of harbour seal foraging distribution compared with different types of fishing along the Norwegian coast to assist in coastal management and citing of future fish farms. Many different layers of GIS data were incorporated into the study; allowing the researchers to create maps that simulated the distribution of seals and their consequent interactions with local fisheries. Though the authors do not go into too much detail describing the technical work with GIS, the study is thorough and demonstrates how GIS can be used for ecological data i.e. distribution of seals due to habitat and socioeconomic data i.e. citing of fish farms and fisheries capture data.


Garibaldi and Caddy discuss in their paper the use of GIS in mapping the distribution of selected species throughout the Mediterranean and Black Seas. The research was undertaken to provide information on “Natural Management Areas,” within the two seas and what GIS approach was the most appropriate. The authors discovered that by using a grid of points they were able to best determine spatial distribution of species, yet they conclude that there are limitations to using GIS in the marine environment. This paper illustrates how GIS can be used to provide information for fisheries management, but also discusses some potential drawbacks to GIS in the marine environment.


Juda’s paper gives a brief overview of the large marine ecosystem (LME) concept, discussing the five modules, which are utilized to assess LME sustainability: productivity of the ecosystem, fish and fisheries, pollution and ecosystem health, socioeconomic conditions and governance. This paper is one of the first to focus on the governance module and provides necessary steps in order to achieve ecosystem sustainability through the governance module. Juda discusses the importance of using the technology
of GIS and remote sensing as tools to assist policy makers convey policies and provide understanding to issues of interactions and interrelationships.


The paper by Le Pape *et al.* looks intensively at common sole distribution within the Bay of Biscay using GIS to identify and describe sites for its early life stages. GIS allowed the researchers to use different layers of data: bathymetry, sediment structure, salinity class and geographic sector to determine habitat suitability. These data were then combined with a generalized linear model of sole distribution to determine how different habitats contributed to total stock. The paper is quite technical and is a bit confusing when describing the work GIS preformed. What becomes clear, however, is that GIS was essential in providing information, which will ultimately lead to designation of essential fish habitats.


In the paper by McRea *et al.*, the authors discuss the use of GIS techniques along with sidescan sonar in mapping habitat area along the coast of Alaska. The images derived from the sidescan sonar were used to assess habitat place and type and then input into a GIS system. Once the data were input into the GIS, the researchers could then separate the data into different layers, such as rocky outcrops and bathymetry or volcanic rocks and bathymetry, and knowing which fish species prefer certain habitats, create maps that depicted critical habitat for those species, in this are being rockfish. Due to the large area of the study, approximately 25 minutes of latitude, the researchers made three separate maps, which GIS then seamlessly put together. The paper offers another good example of how GIS can be used in fisheries management, by pinpointing areas of essential habitat, and also how different sections of a relatively large study area can be seamlessly connected.


This paper describes Robbins’ use of GIS in determining the temporal change in seagrass cover in Tampa Bay. Through the use of aerial photography and GIS, Robbins was able to create maps that compared seagrass cover for the years 1988, 1990 and 1992. A key issue that the author illustrates in the article is whether the change in seagrass, which increase over those four years, could be explained by the confines of mapping area. Robbins makes note that when using GIS and aerial photos at a scale of 1:24000, it is critical that one considers the resolution, scale and minimum cell size while interpreting the data. The paper is good in pointing out potential GIS deficiencies, as well as its use in temporal studies of habitats.

In this paper, Shalovenkov discusses effects of anthropogenous pollution on the Black Sea. While the paper does not focus on GIS, GIS and AVHRR were the primary tools from which the data from the Black Sea was analyzed. The writing of the paper is somewhat awkward, which could be due to the author being from the Ukraine, but the paper illustrates the usefulness of GIS when studying marine ecosystems. The GIS data provides information on bathymetry, drainage basins bordering the Black sea, distribution of certain species and spatial distribution on benthos biomass. All this information leads the author to study the effects of pollution and conclude that anthropogenous loads in the Black Sea are widespread and acute.


This is one of the definitive papers describing the concept of large marine ecosystems. The five modules currently referred to for marine ecosystem sustainability are laid out in this paper: productivity, fish and fisheries, pollution and ecosystem health, socioeconomic and governance. Sherman gives more attention to the first three modules, which focus on the natural systems of the ecosystem. The paper makes no mention of GIS but discusses ways of collected data for the three modules including: continuous plankton recorder for productivity, trawl data for fisheries and monitoring of contaminants in the water column for ecosystem health. It is clear from the paper that there needs to be a system to bring all the information together, particularly for a large area, and that GIS would fit this need. Though Sherman does not discuss the best way to bring this information together, the paper lays the foundation for the concept of LMEs.


Stanbury and Starr’s paper provides a good basic introduction to the use of GIS in marine resource management. In a clear and precise manner the authors describe GIS and its applications to the marine environment. Using data collected in the Monterey Bay National Marine Sanctuary they illustrate how GIS may be used for a number of marine concerns including: monitoring coastal land use and change, identifying watersheds at risk of sedimentation, mapping point source discharge and providing maps and information of sensitive areas. They discuss the importance of metadata in GIS and conclude that GIS is well suited to marine resource management.

**Other References:**


