GIS and Remote Sensing Uses in Marine Protected Areas

Marine Protected Areas (MPAs) are an important conservation tool that can be used to protect and preserve marine resources. The official definition of a Marine Protected Area, according to the International Union for Conservation of Nature (IUCN) is “any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.” (Wood, 2007). MPAs can exist under a variety of names, such as: marine sanctuary, marine reserve, no-take zone, marine park, marine conservation area, etc. Marine Protected Areas are established for multiple reasons, including to protect natural resources, areas of cultural significance, and to provide a socioeconomic benefit to the local community. The ways in which these objectives are accomplished can include regulating fishing to improve fish populations, limiting vessel use to protect reef habitats, limiting use in certain areas to preserve cultural heritage, and creating an opportunity for past pollution to be reversed.

Choosing the location of a new Marine Protected Area requires the planners and management involved to analyze multiple factors. These factors are cost, time, and the environment of the area with respect to ecological, geological, hydrological, socioeconomic, political, and cultural indicators (Wood, 2007). Geographic information systems (GIS) and Remote Sensing are becoming integral tools in the planning and developing process for MPAs. GIS programs have traditionally been desktop based and complicated to use, making them the realm of GIS analysts and experts who understood them. More recently however, with the emergence of more web-based GIS and remote sensing programs, they are becoming more and more user-friendly. This is allowing non-experts, such as the general public, to utilize the programs and participate in the Marine Protected Area planning process (Merrifield, 2013). Applications such as MarineMap are being developed to allow stakeholders in the MPA planning process to participate in the design of the layout of the MPA. MarineMap is a web-based platform that was built using Google Earth and ArcGIS for the California MPA system. The developers wanted to build a low-cost “PGIS”, or a Participatory Geographic Information System. “PGIS seeks to empower non-technical individuals through the facilitation of greater input and access to geographic data and technology particularly as they relate to decision making” (Merrifield, 2013). MarineMap allows participants in the MPA design process to create on their own time an MPA design through the web-platform, and then later share interactively the design with other stakeholders or the management personnel. MarineMap was successfully used with the California MPA system, and has been adapted for the Oregon Territorial Sea Plan (Merrifield, 2013).

MARXAN (a combination of “marine” and SPEXAN, “Spatially Explicit Annealing”) is an algorithm program that can be used with a GIS program such as ArcGIS to design MPA location options in the planning process. MARXAN uses “simulated annealing” that is programmed to design the most optimally efficient MPA with regards to cost. However, a limitation of this software is that it has only been used on a relatively local scale (Wood, 2007).

Geographical Positioning System (GPS) technologies are also a useful GIS tool that can be used in the planning and development of MPAs. By entering coordinates in either latitude and longitude form, or Universal Transverse Mercator (UTM) form, locations relevant to the MPA can be mapped. This is particularly useful when mapping fish habitats, or fishing grounds, when indigenous local knowledge
of the marine environment is incorporated into the GIS system and MPA planning process (Aswani and Lauer, 2006; Friedlander, 2007). GPS can be utilized to incorporate culturally significant locations into GIS software by mapping out the location using data collected from the local population. This can be useful in the MPA planning process to either include these areas in the MPA or avoid them when the MPA is developed, according to the goals of the MPA plan.

Remote sensing technology is useful to the Marine Protected Area planning process because the platforms do not require the stakeholders, managers, or researchers involved in the process to be in the vicinity of the MPA. Benthic maps of coastal marine habitats and environments can be obtained at a large scale using high-resolution aerial photography. Satellite imagery from a satellite such as IKONOS can obtain data at 1- and 4-meter resolution, in both multispectral and panchromatic images (Nagendra, 2013). The data obtained from remote sensing technology can be interpreted to assist in the MPA planning process, or incorporated into GIS software and utilized in the development process (Friedlander, 2007).

The future of GIS and remote sensing with respect to the design and planning of Marine Protected Areas will begin to shift focus towards incorporating social data into the software. Even though efforts are being made to include more social data into GIS and remote sensing programs, the data being collected is still “falling short relative to the human dimensions of the marine environment” (Martin and Hall-Arber, 2008). This lack of information regarding the complex relationships between communities and the marine environment is being referred to as the “missing layer”. The missing layer is the undocumented blank space within the GIS and remote sensing data that fails to represent the social interests and benefits regarding the community with respect to the MPA. It is believed that the missing layer can be “developed via a participatory methodology and will be well received by communities subject to ever-more spatial approaches to management” (Martin and Hall-Arber, 2008). This methodology that has been suggested has been attempted in a few MPAs, but the application has not been widespread yet. For the future, a methodology similar to this will need to be developed and incorporated in the application of GIS and remote sensing to Marine Protected Areas.
Annotated Bibliography

This article described the GIS and remote sensing techniques used to incorporate fishermen’s knowledge of their fishing grounds and stocks in the Solomon Islands of the South Pacific. The researchers identified using local knowledge to build GIS data instead of expert’s knowledge to be a cost-effective measure in the design of marine protected areas. The fishermen’s knowledge was mapped onto aerial photographs of the region, which was later incorporated into a GIS database using GPS and information about the habitats and organisms present. The results were then presented and used to establish sites according to the habitat quality and organisms present. This article is important with regards to the establishment of marine protected areas because it has established the baseline for incorporating social data into GIS and remote sensing systems for future planners of MPAs.

This article analyzes the process of using remote sensing and GIS technologies to evaluate the marine protected areas of Hawaii. First, the MPAs underwent benthic mapping using remote sensing with high resolution aerial photography, IKONOS satellite imagery, and hyperspectral imagery. The data collected was then incorporated into GIS-based benthic habitat maps that exhibited a high degree of thematic and spatial accuracy. Locations were mapped using GPS technology and the biomass of fish populations were sampled and recorded. The biomass of fish were then analyzed and compared in different areas that were protected and unprotected. This information provided a method for the researchers to evaluate efficacy of the marine protected areas. This article illustrates a useful methodology for applying ecosystem-based management through GIS and remote sensing technology, and is suggested to be a easily replicable process for use in a wide variety of MPAs.

This article introduces the concept of a “missing layer” in the GIS and remote sensing technologies in regards to marine protected areas. The missing layer is the lack of social data incorporated into the MPA planning process by planners and managers with regards to input from stakeholders in the community. Examples of this social data could be income information, fishing ground locations, socioeconomic status of the community, or locations of cultural significance within the area. The article describes a method that was developed to define the missing social layer of Northeastern US fishing communities. The method included interviewing fishermen about their fishing locations, then presenting the information collected to their peers in map form to determine the validity. The article then suggests that similar methods be developed for all MPAs being planned to remove the missing layer of social data. Overall, this article had great information about suggestions for future planners of MPAs.

This article describes a relatively newly developed open-source software available to planners, manager, and stakeholders alike. The software is called MarineMap, and was developed for the California MPA system. The software is useful because it is user-friendly and is not designed for use by GIS experts only. MarineMap allows stakeholders to create their ideas for the MPA on a GIS database using Google Earth,
which most persons are already familiar with. The stakeholders can then share their design interactively with planners, managers, and other stakeholders. This allows the stakeholders to become quickly involved in the planning process. This software is already being adapted for use in other MPAs, such as the Oregon Territorial Sea Plan. It is believed that web-based GIS software like MarineMap will become widely implemented in the planning of MPAs in the future. This article was well-written, and very interesting. I will be curious to see where the GIS technology progresses with regards to MPA planning.

This article analyzed the ability of remote sensing technology to monitor change in protected areas. It describes how remote sensing can establish baselines in protected areas that can be used to later evaluate progress in the preservation of the habitat or ecosystem, or assess loss or damage related to natural or human-related events. It covers the remote sensing technologies available such as Landsat satellites with thematic mapper, SPOT with HRG, and Terra with MODIS. It also touches on other technologies such as LiDAR, SAR, and IKONOS. The article then summarized how remote sensing is currently being underutilized in protected area analysis. Overall, this was a well-written article with a thorough overview of the remote sensing technologies with respect to protected areas.

This article describes the history and purpose of marine protected areas, as well as the basic aspects of their development. It then goes on to describe three tools useful to the planning of MPAs, MARXAN site selection tool and multicriteria evaluation (MCE) and fuzzy sets for site prioritization. The study was performed in the Pacific Canadian EEZ (exclusive economic zone). The methodology that was applied was the identification of sites for MPAs that would both conserve biodiversity but also maximize fishing industry profits. The GIS-based framework incorporating MCE and fuzzy sets was determined to be successful with identifying ideal future MPA sites. This article was informative and provided a detailed analysis of different GIS software useful to MPAs.