The Use of GIS/ RS in the Planning and Creation of Marine Protected Areas

Marine Protected Areas, otherwise known as MPAs, are resource management sites that have been implemented across the coastlines and oceans of the world in order to protect and conserve natural marine ecosystems, threatened species, and maritime cultural heritage. MPAs have been developed internationally and largely unsystematically over the course of the last sixty years, and as such, they are known by several different names, including ‘marine reserve’ and ‘marine park’. Additionally, each MPA has its own unique set of regulations and management schemata, depending on which country it belongs to and what specific purpose it serves.

Designating and managing a space such as a marine protected area often involves a substantial amount of scientific research, stakeholder disputes, and difficult management decisions. One set of tools that make all of this easier, though, is the combination of geographic information systems (GIS) and remote sensing. There are many practical applications for GIS and remote sensing within the management framework of MPAs, and these tools allow MPA managers to perform a variety of tasks, including sea-floor and habitat mapping and near-by land use analyses, as well as running land use analyses and siting algorithms.

Without a doubt, the time when GIS and remote sensing are most valuable to marine protected areas is during the phase in which an MPA is being sited and zoned. During this time, MPA planners and managers must consider a number of factors affecting suitability, including biodiversity, the presence of threatened or endangered species, the presence of commercially exploitable species, water quality, adjacent land use, and human use of present natural resources (Aswani & Lauer 2006, Portman 2007). Habitat mapping and spatial analyses performed with the help of GIS and remote sensing allow for all of these factors to be accurately represented, weighted, and considered. Traditionally, habitat mapping for a marine protected area involves incorporating data that has been collected from random in situ visual feild-dive surveys into a GIS database (Aswani & Lauer 2006). This allows for scientists and managers to assess biodiversity and the absence or presence of species in a particular locale. Additionally, planners can incorporate bathymetric data from soundings and side-scan sonar into the GIS database to provide scientists with the sea-floor’s topology and its hydrogeologic composition (Franklin, et.al. 2003). Such data can be used to create polygons for establishing boundaries, as well as points that indicate specific locations of unique features. Later, GIS can be used to further layer, classify, and analyze this data before producing a final hard copy map.

Unsurprisingly, data used for habitat mapping can also come from remote sensing. Aerial photography can be used to identify and classify shallow habitats and benthic substrates without the need for in situ surveying (Franklin, et.al. 2003). In one particular MPA case study, maps created from corrected aerial photographs were shown to local villagers, who in turn used their indigenous knowledge of the surrounding ecosystem to help scientists find and identify benthic features and animal populations. Field dives were performed to validate the indigenous data, however the exercise proved to be a useful example in demonstrating the standalone capabilities of orthophotos in MPA siting (Aswani & Lauer 2006).

Recently, scientists and managers have also begun using satellite-based remote sensing to aide in mapping habitats for siting MPAs. Due to the relatively low spectral resolution in satellite sensors and the effects of Rayleigh scattering, most satellites cannot distinguish between fine features within certain habitats. However, the IKONOS 2 and Landsat 7 TM satellites, which feature high spatial resolution
sensors, have proven to be well-suited for discriminating between more coarse features within habitats. Images derived from IKONOS and Landsat 7 can easily be used to delineate boundary polygons for an MPA (Mumby & Edwards 2002). The Landsat satellites have an additional use within the realm of MPA siting: coastal land-use analyses. Many countries with coastal resources such as beaches and mangrove swamps have included these areas within their MPAs. Images obtained over the course of several years from Landsat can be used to identify natural and anthropogenic changes in these resources, and allow scientists and managers to observe which areas are in critical need of preservation (Hossain, Tripathi, & Gallardo 2009).

Another use of GIS in the process of planning MPAs, while not commonly thought of as a traditional GIS application, is siting algorithms. Integrating siting algorithms into GIS “helps [to] identify marine reserve systems that comprehensively represent habitat types in a sensible spatial arrangement” (Leslie et. al. 2003). In other words, GIS-based siting algorithms make it easier for a scientist or manager to site an MPA in an unbiased, cost-effective manner. Siting algorithms focus on minimizing the space taken up by a reserve network. Popular types of GIS-based siting algorithms include the “greedy” algorithm, which focuses on species richness; the “rarity” algorithm, which focuses on the presence of rare species; and the simulated annealing algorithm. Iterative algorithms like the greedy and rarity algorithms “order each planning unit according to set of criteria, and then choose the highest ranking site”; these algorithms run quickly and efficiently, but they only produce a single outcome. In comparison, the simulated annealing algorithm “starts with a completely random reserve system, and trial solutions are iteratively explored through sequential random changes to the set of planning units in the system. At each step, the new set of units is compared with the previous set, and the best one is accepted” (Leslie et. al. 2003). A simulated annealing algorithm, while less popular than iterative algorithms in reserve siting, is considered more efficient and produces multiple site possibilities for a manager to choose from. (Leslie et. al. 2003).

GIS is also used to zone MPAs once their overall site has been decided upon. Zoning, a concept that is typically applied to terrestrial town planning, “defines spatial objectives and accompanying restrictions in a format understandable to those who have a stake in protected area management and are on-going users of area resources” (Portman 2007). Simply put, zoning tells MPA users who is allowed to enter the area, and what they are allowed to do there. Multi-criteria analysis models run within a GIS give managers multiple options for zoning, and are considered extremely flexible because they allow managers to modify plans as new data becomes available. In using a multi-criteria analysis model in a GIS, a MPA manager will assign values to a set of high-level criteria which are then subset with related lower-level criteria. These ranked criteria are then used to create GIS grids, which are analyzed for concordance and classified. The resulting output is a spatial model of the zoned MPA. A manager can run and re-run these analyses any number of times with different variables to obtain different outputs that are all feasible zoning options (Portman 2007).

In the end, a scientist or manager faced with the task of establishing a marine protected area has many GIS and remote-sensing based applications to choose from. These applications work to ease a manager’s burden by facilitating mapping and spatial data analyses like no other hardware or software can. As technology becomes more and more advanced, scientists, managers, and officials in charge of MPA siting and creation will continue to embrace GIS and remote sensing as efficient, user-friendly means of reaching their goals. In reality, MPAs and GIS and remote sensing are both relatively new advances in the sciences and both have a long way to develop. Hopefully, one day remote sensing technologies will be able to advance to the extent that MPA managers and scientists will be able to use them to their full potential and accurately map benthic habitats. When this becomes possible, the amount of time spent on MPA siting should reduce drastically, and should help to bring even more MPAs into existence.
Annotated Works Cited


This paper focused on a unique social and environmental study in which aerial photography was used in conjunction with indigenous knowledge and dive surveys to map the benthic habitat of a proposed MPA. In the study, villagers in the fishing communities of the Solomon Islands were shown maps derived from ortho-corrected aerial photography, and were asked to identify reefs, benthic habitats, and special characteristics of the local marine environment by drawing polygons on the map. These data were later georeferenced and integrated with GIS. While stakeholder participation is common in siting an MPA, actually using indigenous knowledge about local ecology to map the benthic habitat is practically unheard of. Refreshingly, the study found that the data garnered from the indigenous population was fairly accurate, and that georeferencing local knowledge is an inexpensive and useful means of producing baseline site maps for the MPA siting process. This article was very well written, easy to comprehend, and clearly defined how GIS can be used within an MPA. While the authors were very explicit in detailing their GIS/RS -related methodology, I do not feel that this paper was as much about GIS as it was about the social aspects of planning an MPA. With this in mind, I believe that this case study should serve as an excellent example to scientists and managers trying to establish MPAs in and around fishing villages, regardless of whether they use GIS / RS technologies or not.


The paper Benthic habitat mapping in the Tortugas region was my most important source for understanding the role GIS and remote sensing play in sea-floor mapping. The authors took care to describe step-by-step the process they undertook in mapping a region of the sea floor off the Florida Keys. This study utilized a wide range of data types, including aerial photogrammetry and in situ visual surveys. The data was inputted to a GIS and later used to classify habitat types. The composite digital map that resulted from this paper is exceptionally clear and easy to interpret. Overall, this paper is a wonderful case study in sea-floor mapping and I highly recommend it to anyone interested in the subject.


Land use dynamics in a marine protected area system... focuses on how images gathered from Landsat satellites between 1990 and 2005 were used to assess coastal land use changes within Thai MPAs. Both well written and comprehensive, this paper examines how GIS and remote sensing can play an active role in MPA management as well as siting. Though MPA siting was never specifically mentioned as a use for GIS-based land use studies, the authors make it clear that such studies have a wide range of applications. This journal article also proved to be extremely useful in detailing the process of using GIS for land-use studies. The study utilized a number of GIS/RS applications and processes, and due to the very explicit nature of the paper, the study can be easily replicated. I highly recommend this paper for anyone interested in how GIS can be used as a monitoring tool.


As a forewarning, I should note that scholars who are not mathematically inclined may want to avoid reading this particular paper. While the authors have done a fairly good job explaining mathematical terms and simplifying examples, the body of this paper can be difficult to read and I found the sheer amount of numbers scattered throughout to be positively off-putting. I do realize, of course, that GIS is a very quantitative field of science, and that any paper dealing with mathematical algorithms will read more or less like a dense calculus textbook. These grievances aside, I can now discuss the actual content of the paper.

The purpose of the paper was to discuss siting algorithms and explore their potential for use in marine protected areas. In order to test for suitability, the authors created a GIS model based on the Florida Keys National Marine Sanctuary and ran an algorithm known as a simulated annealing algorithm to produce multiple siting possibilities for an MPA system. Overall, GIS is mentioned very little in this paper, and had I not stumbled upon this paper via a GIS related publication, I would not have recognized siting algorithms as a GIS application at all.


The general purpose of this paper was to determine if the IKONOS 2 satellite, launched in 1999, was more suitable for mapping coral reefs than other remote sensing devices. In particular, it was tested against the Landsat 7 satellite and the CASI digital aerial photography sensor. While the IKONOS 2 satellite did prove to be more accurate than Landsat and CASI in discriminating between fine details within a habitat, it was found to be overall unsuitable for this task and fared much better at discriminating between habitats themselves. The IKONOS satellite was also found to be unsuitable for mapping large tracts of the sea floor because the cost of using it becomes prohibitively expensive. Instead, data from the Landsat 7 satellite, which is available to the public at no cost, is a much more feasible solution. In general, this paper was not particularly difficult to read and comprehend, and I believe that it has the potential to be a very useful resource for any individual looking to map the sea-floor using satellite-based remote sensing.


Author Michelle Portman’s paper on zoning MPAs turned out to be a very interesting and unique case study. In it, she proposed a method for zoning a planned MPA whose boundaries fall in both Israeli and Jordanian waters. Because this particular MPA is subject to two very different sets of regulations and affects stakeholders in two different countries, it was particularly challenging for Portman to zone. To aid her in this task, Portman chose to use a multi-criteria analysis model; a flexible model that uses ranked criteria derived from environmental data and stakeholder preferences to output multiple possible zoning schemes. Portman’s modeling resulted in three potential zoning schemes. Along the way, she was careful to explain her entire process and how it relates to GIS. This paper was easy to read, and focused a great deal on stakeholder interactions and preferences. I believe that this paper is a must-read for any MPA manager dealing with conflicting stakeholder interests or difficult boundary issues.