Wetland ecosystems are valuable habitats that face significant threats from a variety of sources. In the United States and around the world, wetland habitats are affected by climate change, sea level rise, introduced species, and a range of human-induced changes. Historically, wetlands have been drained and filled to create land for the construction of coastal cities. Dams and dikes were created to control tides and storm surge in order to reduce flooding, and ditches were cut to reduce the number of pools available for breeding mosquitoes. Marshes are also impacted by road, bridge, marina, and residential construction. Changes in marsh hydrology lead to changes in salinity regime, nutrient processing, movement of sediment, habitat for juvenile organisms, and other ecological functions (Warren et al. 2002). Some salt marshes convert to freshwater systems as runoff from upland accumulates behind dikes (Warren et al. 2002). In 1982, Lewis estimated that 90 percent of coastal salt marshes from Virginia to Maine had been impacted by human activity.

In order to combat the loss of marsh acreage and ecological function, wetland restoration projects have been undertaken in many parts of the US. In some cases the replacement of lost marsh area and/or function is required by law (Roise et al. 2004). The restoration process could be broken down into three main parts: the initial planning, the physical work that must be done to alter the site, and the process of assessment and monitoring following restoration (Wilcox and Whillans 1999). As technology has developed, GIS has become an important tool for many ecologists. GIS is particularly useful in the planning and assessment stages of restoration projects. Although many managers and researchers are exploring the many applications of GIS, there are still ways in which this tool is not being used to its fullest potential.

A logical place to start in discussing the role of GIS in wetland restoration is with the planning stages. When considering a site for restoration, one must consider the causes of degradation at the site as well as the ultimate goals of the restoration. It is also important to know the specific characteristics of a potential site in order to predict the success of restoration. Wetland characteristics include natural and invasive plant species, the size of the restoration site, tidal amplitude, slope and elevation of the site, and the potential for shoreline erosion (Woodhouse and Knutson 1997). GIS can play a role in addressing many of these foundational questions.

The restoration of Metzger Marsh in western Lake Erie is one example of a project planned using GIS. Kowalski and Wilcox (1999) used digitized aerial photos to understand historical changes in land use, vegetation cover, and the Lake Erie shoreline. Over time, periods of increased water level caused marsh vegetation to drown and increased the rate of erosion of the barrier beach that shielded the marsh from storm waves. These insights led the authors to propose the creation of a structure to replace the barrier beach, as well as a water control device to draw down the water level of the marsh, allowing the re-growth of marsh vegetation (Kowalski and Wilcox 1999).

Many restoration projects are undertaken because construction projects require the destruction or alteration of existing marshes. In this case, the law often dictates that new marshes be created to replace the lost marsh area and/or function. In North Carolina, the NC Coastal Region Evaluation of Wetland Significance (NC-CREWS) is a GIS-based metric used to rate wetlands based on water quality, hydrology, wildlife habitat, and risk of development (Roise, Gainey and Shear 2004). NC-CREWS uses
data such as proximity to permanent water, width of habitat corridors, etc. to set High, Med, and Low values for the various ecological functions. Roise, Gainey, and Shear (2004) used NC-CREWS to show how transportation planners could design road corridors that minimize both wetland impact and construction costs. In this way, the need for costly (and possibly ineffective) restoration efforts could be balanced with the costs of road construction. Once the layout of a new road system has been determined, NC-CREWS can also provide the foundation for locating potential restoration marshes (Roise, Shear, and Bianco 2004).

Rozas et al (2005) used aerial photos georeferenced to Digital Ortho Quarter Quadrangle (DOQQ) maps to estimate the amount of marsh edge that would result from various wetland designs in Galveston Bay, Texas. The authors predicted that increasing the amount of salt marsh edge would increase the amount of protective habitat available to commercially valuable shrimp and crabs. Their analysis predicted that the most cost-effective and commercially beneficial design would be a matrix of medium-sized marsh islands surrounded by shallow water (Rozas et al 2005).

The same techniques that are important in the planning stages can also be useful in the analysis of the success of restoration efforts. For instance, aerial photography can reveal how quickly new marsh is eroded by waves and tides. Orthophotos can also show which plant species come to dominate an area and how the extent of open water changes over time. An interesting follow-up to the work by Rozas et al (2005) in Galveston Bay would be a field and GIS study to determine changes in the shrimp and crab populations following creation of the marsh islands. GIS could be used to determine post-restoration crustacean densities in various parts of the marsh, as well as changes in the numbers of birds, fish, and mammals using the new marsh.

One of the most common applications of GIS in marsh restoration is the preliminary cost-benefit analysis (Rozas et al 2005; Roise, Gainey, and Shear 2004; Roise, Shear, and Bianco 2004). This is an important stage of the process because marsh restoration is a long process that is not always successful. One review of the literature found that of 87 published studies of marsh restoration, 20 percent achieved their stated goals, 20 percent did not, and the rest fell somewhere in between (Keddy 1999; Lockwood and Pimm 1999). Roise, Gainey, and Shear (2004) cite “unrealistically low cost estimates” and “overly optimistic expectations for marginal sites” as two contributing factors to low restoration success rates. Project costs could potentially be reduced if much of the preliminary planning was done by computer rather than by field crews.

Bedford (1999) suggests that scientists do not yet do enough to consider the ecological context in which restoration sites exist. She suggests that scientists should consider the potential impacts to the entire watershed as they plan the restoration of a single marsh. GIS is a tool that is uniquely suited to this type of analysis. Understanding the connections between plants, animals, soils, hydrology, and human land use over an entire watershed would be an enormous task to approach with statistics. But maps of these features and the data imbedded in those maps in a GIS framework could significantly reduce the complexity of the task.

DEMs (digital elevation models), HUCs (hierarchical unit code watershed delineations), DOQQs (digital ortho quarter quadrangle maps), orthophotography, and satellite imagery are among the many GIS databases and tools that can be of use to marsh restoration ecologists. But although GPS has become ubiquitous in ecological fieldwork, GIS has not yet been used to its fullest potential. GIS can increase efficiency and potentially reduce costs during planning, as well as help to provide a strong scientific foundation to a debate that is strongly influenced by politics and economics. In the realm of policy and public relations, GIS can provide clear and informative
presentations of complex data. Although researchers and coastal managers have found many applications for GIS, it is clear that they have only begun to explore the potential of this versatile tool.

Literature Cited:


Annotated Bibliography:


In 1979, construction began on the Kis-Balaton Water Protection System (KBWPS). This was an attempt to re-flood the Kis-Balaton Wetlands in Hungary, which had been drained beginning in the 1830s and continuing through the first half of the 20th century. The goals of this project were to create historical vegetation maps using GIS and old maps, to quantify historical changes in land cover types and extents, and to construct a DEM of the area and use this to determine depth of standing water over time, then correlate water depth to the vegetation maps. The vegetation maps were created from three military surveys of Austria-Hungary, as well as aerial photographs and ground surveys. DEM was made from a digital contour map combined with a GPS survey. This project required a huge amount of labor! The historical maps were georeferenced using landmarks like road intersections and churches.


In this paper, the authors use GIS during the planning stages of a freshwater marsh restoration project in western Lake Erie. One strength of this paper was the authors' use of a variety of tools, including aerial photographs and conversations with local residents, to understand historical changes in land use, vegetation cover, and the Lake Erie shoreline. They used GIS to understand the protective function of the historical barrier beach and to design a replacement structure across the mouth of the restored marsh. Unfortunately, this paper presents only the theory and preliminary restoration work at this location. It would be helpful to see a follow-up paper that explores whether or not their approach will be successful.


This article presents a GIS-based tool for decision-making concerning restoration projects. The goal of the tool is to identify potential marsh restoration sites that are most likely to successfully achieve goals valued by scientists and the public. This is an interesting method, as it incorporates surveys of wetland ecologists as well as the general public. Samples of the surveys are included in the article. Tools like this one greatly simplify the decision-making process, particularly in the early stages. Although this may result in less scientifically rigorous decision-making, it may mean that significant work is ultimately accomplished, if it speeds up the process and provides clearer results to policy-makers and taxpayers.

According to the Clean Water Act of 1972, transportation construction projects that impact wetlands must compensate for the loss of wetland acreage or function by restoring wetlands elsewhere in the impacted watershed. This paper shows how planners can use GIS to locate and select optimal wetland restoration sites. Potential restoration sites were rated using the North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS), which uses GIS to rate wetlands based on water quality, hydrology, wildlife habitat, and risk of development. Roise et al developed a mathematical model that uses the functional rating and the acreage of the wetlands parcels to determine optimal restored marsh areas for the various functional units. While the authors acknowledge the inadequacies inherent in a discrete rating system like NC-CREWS, they demonstrate the need for such quantitative models.


This is another paper related to wetland restoration as part of road construction projects in North Carolina. This paper shows how GIS can be used at the design stage of construction projects to prevent wetland impact while minimizing construction costs. A mathematical model was used to draw optimal road corridors that minimized construction costs as well as impact in each of the NC-CREWS functional categories. This is a significant paper because it and the companion paper listed above demonstrate the practicality of GIS applications in wetland management. The authors acknowledge the shortcomings of mathematical models in predicting ecological processes, but they show how important it is for corporations and governments to have quantitative tools with which to make scientifically informed decisions.


Rozas et al used GIS to compare the cost of a series of restoration projects in Galveston Bay, Texas to the impact on populations of commercially valuable shrimp and crab species. They used GIS software and digital orthophotos to calculate the area of marsh edge, habitat that is particularly important for these crustaceans. They also calculated the length of newly constructed marsh habitat as an estimate of the cost of the restoration efforts. The cost-benefit analysis performed in this paper could be an important tool for coastal managers in the planning stages of a restoration project. However, the assumptions made by the authors potentially greatly over-estimated the fishery value and underestimated the costs of their restoration efforts. This paper focused on only three species with similar habitat requirements. A truly useful cost-benefit analysis for restoration would need to be much more complex than this paper and incorporate a broader spectrum of plant and animal species. It would be interesting to see a follow-up to this paper in which the authors’ estimates are compared to actual impacts on the crustacean population a few years after restoration.