The Use of GIS to Facilitate Habitat Restoration

Michelle Denault

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Habitat restoration is a relatively new field within the scientific community. It uses a broad matrix of science and tools in order to accomplish an integrated approach to ecosystem management. Restoration ecology is defined by the Society for Ecological Restoration as “the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems”. In practice, this field can cover direct restoration, mitigation, or conservation. Because it is such a new science, it can often appear that practitioners are flailing in the dark or that each project seeks to reinvent the process. As such, there can be a lot of negativity surrounding such an imperative field in a modern era where habitat of all kinds is being destroyed in the name of progress (Hobbs et al., 2006). While there are some who might argue that the availability of restoration gets in the way of protection by demonstrating that degraded areas can be fixed, it is my belief that this field offers hope for those areas that have already been sacrificed to development and growth.

One of the most important tools for restoration is geospatial information systems (GIS). The first step of a restoration project involves categorizing key sites. Often, site suitability maps are created to either prioritize or identify restoration sites (Gkareveli et al., 2004; Tash and Litvaitis, 2007; White and Fennessy, 2005; Ximenes and Scott, 2007). These maps can be created through the use of GIS layers which contain the attributes necessary to sustain the desired habitat. Each layer contributes a value towards the suitability index and together, these layers categorize sites on a sliding scale of suitability. The information that these layers contain varies with the restoration project at hand. The data can vary greatly from digital elevation models (DEMs) to land use land cover data to soil properties to historical locations of habitat. Environmental factors can be as important as topology within these analyses. However, these models are only as good as the data that is put into them. Error can be found in a number of sources including data limits, data inaccuracies, a lack of detailed field data, and a lack of necessary habitat parameters knowledge (Holl et al., 2003). Another weakness in these models is that they are rarely updated with the successes or failures of actual restoration projects, so it can be difficult to adjust the models to become more accurate in the long term. However, despite these weaknesses, they are the best tool available for site identification and they can be very useful when the data used to create them is strong.

Another application of GIS involves the mapping of injured habitat. Once the sites are identified, they can be precisely located, measured, and mapped using a field gps. The data from the gps is easily transferred to a GIS and then analyzed to determine the degree of damage and the cost/time that will be required to restore the habitat. Not only can the habitat be viewed on a site by site index but the GIS also allows for landscape analysis. In addition, restoration can occur on a variety of scales as each site is recognized. Specifically, this kind of identification is currently being used for litigation on boat groundings in the Florida Keys. The legal action provides much needed funding to reverse the impacts that boats have on seagrass beds in these shallow waters (Kirsch et al., 2005). Although this is only one example, it shows how GIS can work with policy to facilitate restoration by identifying habitat problems and needs.

It seems that while site suitability modeling is the most commonly used GIS application in restoration ecology, it still has a long way to go. As habitat restoration becomes more common, it is my hope that both successes and failures will be regularly reported. This information can be used to make more accurate site suitability maps for all kinds of restoration projects. There can be a certain frustration when a restoration is unsuccessful, but we can learn as much from failure as we can from success. With such information, these models can become more precise and more able to predict outcomes. Unfortunately, they will never be completely accurate as environmental conditions can vary from year to year. In addition, such global factors such as climate change can add parameters that will change restoration outcomes in ways we can only guess. The best thing we can do is to learn from our mistakes and keep moving forward.

That being said, it is very exciting to see more watershed and larger site priority mapping. For too long, restoration has focused on case by case projects without regard to where the most good can be accomplished (Holl et al., 2003). By looking at the greater landscape, we can make the most out of the available resources. My hope is that future restoration will begin to look at more than just a single habitat or species. With more complex analysis, it will become possible to determine a myriad of different restoration projects that can work hand-in-hand in order to best complete a complex habitat matrix whose diversity can support itself under potential stresses. Of course, for this to be possible, it is not only necessary to better use the technology available, but to increase the multi-disciplinary nature of habitat restoration. Although this may be possible, it is unlikely to occur swiftly.

I am most excited by those technologies which make field mapping more possible and applicable to habitat restoration. I hope to see more gps receivers in the hands of ecosystem managers as gps becomes more accurate and affordable, giving them the ability to recognize and map the beginnings of habitat degradation. If such sites are documented early enough, then it may be possible to implement small restoration projects to deal with the problem when it is more manageable; stemming degradation and rehabilitating habitat before it is a large problem and thus costly. Many necessary projects are unable to proceed due to lack of funding, so it is important to optimize funds and resources as much as possible. Using GIS for early degradation detection may be an important step to decreasing response time to needed action. As the technology becomes more accessible and affordable, we can only find more new and exciting applications in the field. This will only do great things for our environment as we recognize the possibilities inherent in GIS applications for habitat restoration.

Additional Citations:

Hobbs, R.J., D.A. Falk, M. Palmer, and J. Zedler. 2006. The Foundations of Restoration Ecology: The Science and Practice of Ecological Restoration. Island Press.

Annotated Bibliography:

Gkaraveli, A., J.E.G. Good, and J.H. Williams. 2004. Determining priority areas for native woodland expansion in Snowdonia National Park, Wales. Biological Conservation 115: 395-402.

The United Kingdom has a long history of dense population and land use. As such, there are very few original forests of that island nation left today. This article explores the use of GIS in prioritizing areas for native woodland creation within Snowdonia National Park. The basic suitability map gives high priority to areas that had historically been native woodlands, semi-natural woodlands, and sites close to existing native woodlands. This was placed in conjunction with the environmental factors necessary to produce successful native woodland including an elevation model. What I found most interesting about this article was the fact that local farmer preference was taken into consideration as well as the habitat value of existing vegetation. This is an excellent prioritization because it takes into account straight suitability, defragmentation of the landscape, the needs of local farmers, and alternative habitat use which takes habitat restoration from all angles. It is a practical model which may actual see use.

Holl, K.D., E.E. Crone, and C.B. Schultz. 2003. Landscape Restoration: Moving from Generalities to Methodologies. BioScience 53(5): 491-502.

This article reviews the various approaches that are commonly applied in restoration ecology and focuses on how restoration could become more effective. While this field attracts funding and volunteers for implementation, it is rarely implemented scientifically. There is a certain frustration that every project must reinvent the wheel by experimentally determining the best way to undergo restoration. This article suggests the use of documentation, monitoring, statistical analysis, and predictive modeling to avoid such waste of funding. It suggests the use of GIS to predict the most effective use of time and resources for habitat restoration by prioritizing sites for the greatest likelihood of successful restoration. However, these models are limited due to a lack of detailed field data, a lack of explicit model limitations, and a lack of knowledge of what parameters will cause a restoration project to succeed. While I found this to be a good overview of the limits of restoration, I feel that it falls prey to the common feeling of hopelessness that many restoration articles put forward. While there is much information that must be gathered for success, restoration is a necessary part of the modern landscape and such negativity is not productive.

Hyatt, T.L., T.Z. Waldo, and T.J. Beechie. 2004. A Watershed Scale Assessment of Riparian Forests, with Implications for Restoration. Restoration Ecology 12(2): 175-183.

This study seeks to use GIS analysis to identify restoration and protection potential for salmon and trout habitat in the Pacific Northwest. Salmonid habitat is associated with large woody debris which creates pool habitat in small streams. This study included aerial photograph delineation of riparian areas as well as percent shade, diameter class, stem density, and forest type of each stand. The riparian information was added to stream information which included gradient, confinement, length, and stream information to determine which had the greatest fish habitat potential. I liked the fact that the model was field verified to create an error matrix which is often missing from such restoration modeling exercises. Although this study was meant to identify priority areas that might otherwise be missed, I think that a watershed assessment should be one of the first steps in a restoration project in order to identify the best areas before a large investment of time and money. In such a circumstance, the use of GIS can be invaluable.

Kirsch, K.D., K.A. Barry, M.S. Fonseca, P.E. Whitfield, S.R. Meehan, W.J. Kenworthy, and B.E. Julius. 2005. The Mini-312 Program – An Expedited Damage Assessment and Restoration Process for Seagrasses in the Florida Keys National Marine Sanctuary. Journal of Coastal Research 40: 109-119.

This article describes the process of mapping vessel groundings which cause seagrass destruction in the Florida Keys National Marine Sanctuary. As seagrasses are already suffering from habitat degradation and climate change, this can be a significant impact, especially with the large number of groundings that occur every year. Through the use of a surveyor-grade gps receiver, it is possible to quickly and efficiently transfer data to a GIS in order to map these areas. This, in turn, facilitates litigation with the parties responsible which results in compensatory restoration projects at these grounding sites. I found this article to be delightfully descriptive from grounding identification to mapping, estimation of recovery time, litigation, compensation, and restoration. By making this process swift and economical, it is possible for even the smallest seagrass loss to be pursued and restored. I feel that even the smallest restoration can be immensely important in the long term, especially when the degradation could spread if unchecked. Not only was this article well written, but it was compelling.

Tash, J.P., and J.A. Litvaitis. 2007. Characteristics of occupied habitats and identification of sites for restoration and translocation of New England cottontail populations. Biological Conservation 137: 584-598.

This article explores the possibility of habitat restoration and relocation for New England cottontails since their habitat and population has shown a marked decrease recently. Using previous studies of New England cottontail populations, this study sought to determine the environmental and habitat ranges most advantageous to the rabbits in order to prioritize new population sites. The GIS model ranked sites based on quality, size, and proximity to current populations. Preferred habitats tend to be disturbance based, but it is possible to manage for that kind of habitat if all other parameters are within the preference range shown by the model. I found it interesting that it was necessary to divide the model into three regions of New England as it generally seems that these areas are not significantly different. However, it is possible this differentiation is based on cottontail population differences rather than environmental parameters. I thought it was an interesting choice this model only focused on public and non-profit conservation land rather than opening up the possibility of private conservation. I found this mode of thought rather limiting although practical. However, I do believe the study took into consideration a lot of factors in order to try and make the best use out of any possible restoration project.

White, D., and S. Fennessy. 2005. Modeling the suitability of wetland restoration potential at the watershed scale. Ecological Engineering 24: 359-377.

This article investigates the tendency for wetland restoration to occur without consideration for its placement within a watershed. The authors believe that by looking at potential restoration sites on a watershed scale, it is possible to maximize the output of restoration projects and help improve downstream water quality and wetlands as well as increasing flood control. The sites are identified through a restoration suitability index which uses GIS to take into account soil properties, land use, land cover, topography, and water quality. Interestingly, the study created three different models which had different weighting schemes for the available variables. Although the models had similar amounts of high potential restoration area, each cell had a value which varied depending on the model. To my mind, this indicates the necessity of further fieldwork to determine which model actual portrays the best restoration potential for wetlands. Even though I applaud a study which seeks to employ watershed level restoration, there are too many questions left unanswered for this model to be useful in a practical manner.

Ximenes, A.dC., and P.C. Scott. 2007. Selecting suitable sites for red mangrove restoration using GIS and geoprocessing. Anais XII Simposio Brasilerio de Sensoriamento Remoto, Florianopolis, Brasil 4331-4338.

Mangroves are adapted to living in difficult margin environments. This study investigated previous literature to determine which site characteristics are most important for mangrove success. Three parameters, particle size, soil organic matter, and interstitial water salinity were chosen for a site suitability model. These parameters were easily measured throughout the lagoon chosen for this model at 18 sampling stations. GIS mapped and categorized these parameters within the intertidal zone to create the suitability map. The map showed that areas currently inhabited by mangroves fell within the high suitability range, indicating the accuracy of the information and model used. Although restoration did not occur due to lack of funding, I liked the fact that this model was not entirely theoretical. The authors went into the field to gather their initial information and went back to determine that the model accurately categorized known areas. Should the funding ever be made available, this is a restoration project waiting to occur. It is also a model that should it be shown to be successful on a local scale could be broadened to a more generalized scale for mangrove restoration elsewhere.