A STATEWIDE APPROACH FOR IDENTIFYING POTENTIAL AREAS FOR WETLAND RESTORATION AND MITIGATION BANKING IN GEORGIA: AN ECOSYSTEM FUNCTION APPROACH

Elizabeth A. Kramer and Steven Carpenedo

AUTHORS: University of Georgia, College of Agricultural and Environmental Sciences, Conner Hall, Athens, Georgia 30602, 706-542-3577
REFERENCE: *Proceedings of the 2009 Georgia Water Resources Conference*, held April 27–29, 2009, at the University of Georgia.

Abstract Georgia ranks second among EPA Region 4 states in estimated wetland acreage and has a rich diversity of wetland types. Georgia is currently the nations 10th most populous state and is projected to double in population within the next 25 years. A large fraction of this growth is projected for areas proximal to wetlands, such as coastal counties. Currently in Georgia there is no coordinated statewide program for the identification and prioritization of landscape-level wetland areas used for wetland mitigation banks or other restoration activities. As a result, current restoration efforts benefit the immediate area and satisfy "no-net-loss", but may not contribute greatly to the overall health of the watershed. Developing a prioritization map of potential wetland restoration areas will help natural resource managers focus restoration efforts in areas that will provide the greatest cumulative effect on the health of a watershed and surrounding communities.

The purpose of this project is to provide state, federal and non-governmental natural resource managers with a Georgia-specific GIS database of potential areas for wetland mitigation banks and conservation and restoration projects using a GIS model to prioritize wetland functions and values. The potential wetland restoration areas (PWRA) prioritization model is constructed in two components; component one prioritizes wetland areas based upon ecosystem functions, and component two prioritizes wetland areas based upon threats to these functions. In addition to providing information for the 404 and 401 processes, the output could provide information and coordination for many statewide planning activities.

INTRODUCTION

On April 10, 2008, the Army Corps of Engineers and the Environmental Protection Agency published the new rules for compensatory mitigation for losses to aquatic resources in the Federal Register. The new regulations establish performance standards and criteria for the use of permittee-responsible compensatory mitigation, mitigation banks, and in-lieu programs to improve the quality and success of compensatory mitigation projects for activities authorized by the Department of the Army permits (Federal Register, 2008).

These new rules emphasize the process of selecting a location for compensation sites should be driven by assessments of watershed needs and how specific wetland restoration and protection projects can best address those needs. These rules emphasize the use of science-based assessment procedures to evaluate the extent of potential water resource impacts and the success of compensatory measures. This watershed approach to compensatory mitigation requires the Corps of Engineers to use a number of considerations when evaluating future projects which include: landscape position and how locations will provide the desired current and future aquatic resource functions in a changing landscape; habitat requirements of important species as well as habitat loss trends, sources of impairment, development trends and other regulatory programs that may affect watersheds and habitat, such as stormwater; the interaction of uplands with wetlands and the maintenance of terrestrial resources for maintaining ecologically functioning aquatic resources; and finally the watershed approach should not focus exclusively on a specific function but rather a suite of functions that are typically provided by potentially affected aquatic resources.

Under the direction of Georgia Environmental Protection Division (GAEPD) and a technical steering committee, we developed a GIS watershed-based planning tool to identify where wetland mitigation will have the greatest impact on aquatic resources as assessed by wetland functions and values and identify a prioritization using a human impact assessment on aquatic resources. The product is a set of GIS based maps that identify prioritized potential wetland restoration sites that is usable at multiple spatial scales, statewide to local watersheds and a map that identifies cumulative human impacts based upon past, present and future threats to aquatic resources assessed at a watershed scale. The prioritized potential wetland restoration sites represent a landscape level assessment (White & Fennessy 2005) of the spatial location and configuration where compensatory wetland mitigation sites may provide most of the ecosystem services desired by resource managers.

METHODS

A technical steering committee was organized by the GAEPD with the and charged with the mission to guide the process of developing a watershed based planning tool that will help increase the effectiveness of compensatory wetland mitigation in Georgia. The technical steering committee included participants from state and federal governmental agencies, non-governmental organizations and forest product industry groups that would potentially use this information either for regulatory, planning, or management purposes. The committee's first task was to identify key ecosystem functions and values that the group wanted to be represented in the watershed models. The list consisted of water quality and water quantity protection; flood control and flow regulation; biodiversity conservation; connectivity; ease of restoration; education; recreation; scenic value; and wildlife habitat.

After a thorough literature review, nine submodels were developed to represent the ecosystem functions that produced the final potential wetland restoration site index. These layers are:

- Restorable land cover classes - We chose to classify restorable landcover classes into three separate groups, (ranked 9) as high potential for restoration, (ranked 6) potentially restorable, and (ranked 1) landcover classes considered as non-restorable. All of the restorable and non-restorable landcover classes were derived from a combination of the 1974 and 2005 Georgia Land Use Trends (GLUT) database which identifies 13 general landcover classes (NARSAL 2006). Landcover classes that are considered as high potential for restoration must have been considered as wetlands (i.e. forested wetlands, freshwater emergent marshes, or saltwater / brackish marsh) in the 1974 GLUT database and converted to a non-wetland landcover class in the 2005 GLUT database (Zedler 2006). Regardless of whether an area was classified as high potential for restoration, if it was designated as low or high intensity urban, open water greater than 5 acres (White & Fennessy 2005), forested wetlands, freshwater emergent marsh or saltwater brackish marsh in the 2005 GLUT database it was considered as a non-restorable.
- Hydric soils - Potential wetland restoration sites were categorized based on their intersection with low conductivity / hydric soils identified in the US General Soils Map for Georgia (STATSGO) (USDA 2006). To account for the different soil characteristics in each physiographic region in Georgia, the STATSGO soils database was queried based on generalized EPA Level 3 Ecoregion separately. The GLUT 1974 database (NARSAL 2006) was used to determine which attributes in the STATSGO database encompassed the majority of identified wetlands in each ecoregion. Four major attributes in the STATSGO database were common to all ecoregions in the state and used in various combinations to select low conductivity / hydric soils. STATSGO soils that meet the requirements were given a value of nine and considered as primary potential wetland restoration sites. All other soils were classified as a six, secondary restoration sites, except those that corresponding with non-restorable landcover classes received a value of one.
- Jurisdictional designation - Compensatory wetland mitigation sites by definition should be developed where they would be ensured permanent protection under Section 404 of the Clean Water Act. Each US Army Corps of Engineers District develops a working definition of jurisdiction, as long as it is at least as restrictive as the federal jurisdictional wetland designation. The Savannah District, which is responsible for Georgia, defines jurisdiction as within 100 feet of navigable waters or within the 100 year floodplain, whichever is greater (*D. Crosby, pers. Comm.*). The jurisdictional designation layer is a ranked combination of data sources that identify sites that may potentially be jurisdictional based on the Savannah District definition. Sites that received a rank of nine are either adjacent to navigable waters or within the 100 year floodplain.
- Water quality and quantity index - The water quality and quantity index (WQQI) is used to evaluate where potential wetland restoration sites may have the greatest positive effect on non-point source impairments to water quality. By identifying the positions in the landscape where saturated variable source runoff accumulates and restoring wetlands and riparian buffers in these areas, we can use compensatory wetland mitigation as a tool to improve water quality (Zedler 2006) and potentially flood control and flow regulation (Cedfeldt et al. 2000). The water quality and quantity index is the product of two separate indices, a Potential Runoff Index (PRI) and a Distance to Impairment Index (DII). The Potential Runoff Index was designed to calculate the potential proportion of saturated variable source runoff entering open waterbodies after a two year 24 hour storm event. To accomplish this we incorporated into the PRI; landcover classification, hydrologic soil groups (HSG), hydrologic conditions and antecedent runoff conditions. The distance to impairment index (DII) was developed to rank individual landcover class pixels contribution to nonpoint source pollution based on their hydrologic flow distance to all streams, rivers and lakes. The distance to impairment index is a measure of a potential wetland restoration sites position in the landscape (White & Fennessy 2005), and thus their potential effect on limiting nonpoint source pollution.

- Connectivity to existing conservation lands - The Georgia Conservation Lands Database (GADNR 2005) is used to evaluate where potential wetland restoration sites would increase the connectivity, size and identified ecosystem functions of existing conservation areas. Conservation areas include local, state and federal land holdings, existing US Army Corps of Engineers wetland restrictive covenants, and privately held conservation easements. Connectivity (S_i) to existing conservation areas was calculated using an area weighted connectivity function (Möilanen & Nieminen 2002). This connectivity function is used because it decreases the importance of a potential restoration site as its distance from an existing conservation area increases.
- Terrestrial dispersal corridors between wetlands - The terrestrial dispersal corridors between wetlands layer is used to rank potential wetland restoration sites based their ability to positively influence the metapopulation dynamics of facultative wetland species. In this layer wetlands are determined by the average weighted species richness model (AWSR) developed for the "Comprehensive Wildlife Conservation Strategy for Georgia" (GADNR 2005). The average weighted species richness model identifies and ranks areas of natural vegetation by the number of potential species present, their federal status and their global and state Natural Heritage ranking. The connectivity of wetlands was calculated using a two step process. The first step was the development of a grid of habitat resistance to the dispersal and migration of *Rana clamitans* using general resistance coefficients. Habitat resistance is important in that the landscape structure defines the physiological costs of an amphibian dispersing through a landscape and the behavioral response of the organism to that cost (Mazerolle & Desrochers 2005; Wiens 1997). The second step ranks the connectivity between wetlands based on the nonrandom movement of juvenile and adult amphibians during dispersal and migration by the potential value of a given wetland for species of conservation concern. The gird of habitat resistance is incorporated into connectivity as it defines the path of least resistance, or dispersal corridors, an amphibian may follow when dispersing between source habitats.
- Hydrological connectivity of wetlands - The hydrologic connectivity of wetlands is used to evaluate the position in the landscape where potential wetland restoration sites may have the greatest impact on flood control and flow regulation through increased storage capacity of wetlands. The hydrologic connectivity of wetlands was developed in two steps. The first step was creating a binary gird of all wetlands in the 2005 Georgia Land Use Trends Database (NARSAL 2006). The binary grid was used to determine hydrologic connectivity and the patch and neighborhood based spatial configuration statistics (Gustafson 1998) of wetlands. The second step in determining the hydrologic connectivity of potential wetland restoration sites to existing wetlands was calculating the connectivity of wetlands using a ranked connectivity function (Möilanen & Nieminen 2002). The final layer represents the position in the landscape where potential wetland restoration sites may have the greatest effect on reducing flood volumes and maintaining flows.
- Natural upland habitat surrounding wetlands - The natural upland habitat surrounding wetlands layer is used to determine the where in the landscape potential wetland restoration sites will provide the greatest benefit to wildlife, increases conductivity, and maintains water quality and quantity. Natural vegetation patches were developed by combining the distribution maps from the GAP vertebrate species models which identifies suitable habitats for a species, given their natural history traits (Kramer & Elliott 2005). To isolate natural upland vegetation patches, all natural vegetation that intersected with 1974 GLUT wetland classes were removed. Semlitsch (1998) reports that a 164 meter buffer around a wetland encompassed 95% of the maximum distance surveyed species moved into terrestrial habitat. we chose a radius of 500 meters to encompass more vagile species (Semlitsch 1998; Semlitsch & Bodie 2003) and to represent the local scale that affected presence and absence as found by Price et al. (2004) and others (Guerry & Hunter 2002; Pope et al. 2000; Semlitsch 1998; Semlitsch & Bodie 2003).
- Maintenance of high water quality streams for biodiversity protection - The maintenance of high water quality streams layer is used to evaluate where potential wetland restoration sites may have the greatest positive effect on minimizing non-point source impairments to high priority streams as identified in the State Wildlife Action Plan (GADNR, 2007). The maintenance of high water quality streams uses the exact methodology as previously decribed water quality and quantity index. The only change is in the stream datasets evaluated. Whereas, the water quality and quantity index evaluated all streams 1st order and greater, the maintenance of high water quality streams only uses streams identified as high priority for aquatic biodiversity conservation. The final layer represents locations where potential wetland restoration sites would minimize impairments to streams and rivers and increase the likelihood that populations of aquatic species of conservation concern continue to persist.

Potential Wetland Restoration Site Index (PWRSI)

The PWRSI is an additive model used to highlight areas where restoration of wetlands would have the greatest benefit on the identified ecosystem functions and values. The first two model layers, restorability and hydric soils are used as a mask to refine the sites. The other layers are added together and then reclassified on a scale of one through nine, where sites having a value of nine have the highest potential to provide greatest potential of restoring desired ecosystem functions and values and one having the least.

Development of a Human Development Index (HDI)

The second model is an assessment of some of the current and future threats to aquatic resources, by human activities. This assessment was performed at the 12 digit HUC. This information can be used to help prioritize mitigation bank locations within service areas. This index is also an additive model that uses eight different input layers these layers include:

- Stream Fragmentation - Stream impoundments alter the hydrologic flow of streams and rivers affecting the instream, upstream and downstream functions of wetlands. Stream fragmentation of aquatic systems within each 12 digit HUC was determined by applying a modified fragmentation index developed by Merrill (2001). Merrill's methodology measures and sums the length of free flowing streams and rivers both above and below a stream segment for a pre- and post-impoundment period. We modified Merrill's methodology, to make it applicable to determining the percent of streams that remain free flowing within a 12 digit HUC. The National Hydrography Dataset was used to determine the change in the length of free flowing stream miles from 1974 to 2005. The pre-impoundment stream miles were then compared to the post-impoundment stream miles to calculate a percent of the total stream miles that remained free-flowing in 2005.
- Percent of impaired streams and rivers - The length of streams and rivers that are considered as impaired were calculated using the most current dataset of impaired streams and rivers, which was obtained from the GA EPD. The GA EPD dataset was clipped by 12 digit HUC, and then the length of all stream segments were summed to get a total length of impaired streams and rivers.
- Wetland Activity Index - The wetland activity index was developed to determine the change in wetland density by 12 digit HUC from 1974 -2005 as a result of changes in land use. This layer seeks to look at all forms of land use and the effect it has had on the density of wetlands within 12 digit HUCs in this 30 year period. The Georgia Land Use Trends Database was used to determine the change in the density of wetlands within a 12 digit HUC from 1974 – 2005. The density of wetlands in 1974 was determined by comparing the total area of a 12 digit HUC to the area of existing wetlands within that 12 digit HUC. The 1974 GLUT database was used to determine the 1974 density. The same procedure was run for determining the density of wetlands in 2005, using the 2005 GLUT database instead of the 1974 database. The density of wetlands in 2005 was then subtracted from the density of wetlands in 1974 to determine the change in the density of wetlands from 1974-2005.
- Percent impervious surface - The percent of impervious surface within a 12 digit HUC was calculated using the 2005 Georgia Impervious Surface Cover database developed by the Natural Resources Spatial Analysis Laboratory (NARSAL 2006). This database determines the percent of a 30 m pixel that is considered as impervious surface.
- Projected future development in 2025 - The projected future threats to wetlands from development was developed to highlight the 12 digit HUCs where potential urban development may have the most impact to existing wetland complexes. The SLUETH model forecasts potential growth scenarios based on a variety of input datasets and exclusion layers. The output of a project growth model is the probability that a pixel will be considered as urban in the year 2025. To simplify the results, all pixels that had 50% or greater probability of being urban in 2025 were retained and given a value of one. All other pixels, 49% probability and less, were given a value of zero. The reclassified project growth in 2025 was then compared to the area of urban land cover classes in 2005 by 12 digit HUC to determine the potential change of this 20 year period.
- Change in average wetland contiguity from 1974 to 2005 - The change in contiguity of wetlands by 12 digit HUC is indicative of historic pressures placed upon wetlands and their ability to provide essential ecosystem services. As the contiguity of wetlands decrease, wetlands have less capacity to store and treat quantities of water (Jackson 2006). Thus, having an overall effect on the water quality within a 12 digit HUC. The reduction in the contiguity of wetlands also impacts the flood storage capacity of watershed potentially increasing runoff amounts and developing "flashier" and more flood prone streams and rivers (Dunne & Leopold 1978). The reduction in the contiguity of wetlands also impacts the hydrologic processes in a 12 digit HUC by reducing the recharge zones and potentially resulting in reduced base flows.
- Change in average wetland proximity from 1974 to 2005 - The change in the average proximity of wet-

lands is an indication of wetland complexes within 12 digit HUCs ability to provide essential ecosystem services such as the ability to support biodiversity. As wetlands become increasingly isolated the stability of populations of species that rely upon wetlands becomes increasingly unstable.

- Riparian fragmentation 1974 – 2005 - Continuous and adequate riparian buffers are essential for maintaining desired ecosystem services. The change in the mean length of riparian buffers by 12 digit HUC was calculated using methodology and AMLs developed by Kramer and Bumback (2005).

RESULTS

The potential wetland restoration index identified that of all lands in Georgia providing some ecosystem benefits through wetland restoration, on 2.9% fall into the top three classes (Figure 1). This is equal to 391,188 ha. Currently the state of Georgia is 12.4% forested wetland, by restoring the high valued areas, we would increase the state's forested wetlands to 14.2%. These restored areas would most likely provide greater services such as biodiversity protection and enhancement of water quality and better water quantity management.

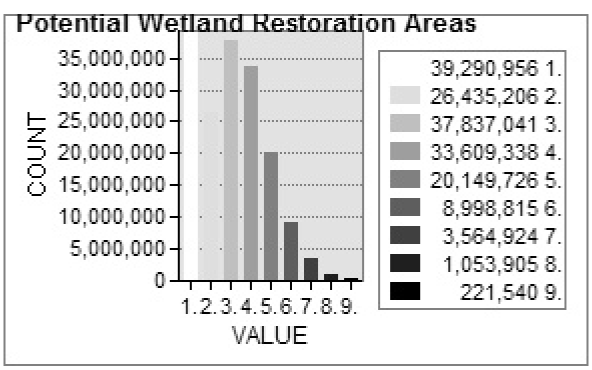

Figure 1. Distribution of Potential Wetland Restoration Areas

Approximately 17% of the state aquatic resources are heavily impacted by human activities (Figure 2), and are found in classes 7, 8, and 9 of the HDI. By contrast, 25% of the state falls into classes 1, 2 and 3, which represent low human impact. This information is helpful for land and resource managers to prioritize management activities to reduce impacts on these aquatic resources.

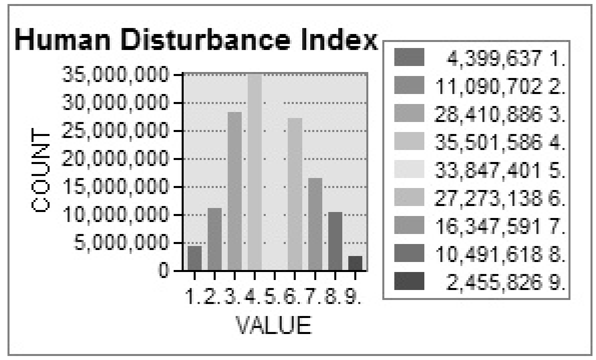

Figure 2. Distribution of pixels for the Human Disturbance Index

CONCLUSIONS

The work presented in this paper is a first attempt at moving towards a scientifically based watershed approach towards wetland mitigation and restoration. In the past, wetland mitigation bank siting has been an arbitrary process which does not guarantee that the bank will enhance, protect and improve aquatic resources in a watershed. This new approach provides an opportunity to select sites that will better protect aquatic resources. Combining the prioritized wetland banking areas with the human development index will allow for future watershed planning with hopes of better protection of aquatic resources and to help minimize the impact of wetland loss through various development activities.

This is a first attempt at performing a statewide assessment. We are now moving into a second phase to refine and develop additional models. These include a statewide assessment of existing wetland condition and the identification of priority mitigation banking areas for tidal and marsh wetlands.

REFERENCES

Cedfeldt, P. T., M. C. Watzin, and B. D. Richardson. 2000. Using GIS to identify functionally significant wetlands in the Northeastern United States. Environmental Management **26**:13-24.

Dunne, T., and L. B. Leopold 1978. Water in Environmental Planning. W. H. Freeman and Company, New York.

Federal Register, April 10, 2008.

Guerry, A. D., and M. L. Hunter. 2002. Amphibian distributions in a landscape of forests and agriculture: An examination of landscape composition and configuration. Conservation Biology **16**:745-754.

Jackson, C. R. 2006. Wetland hydrology. Pages 43 -78 in D. P. Batzer, and R. R. Sharitz, editors. Ecology of freshwater and estuarine wetlands. University of California Press, Berkeley, CA.

Kramer, E., and B. Bumback. 2005. A Statewide Analysis of Riparian Vegetation Change, from 1974 to 1998 in K. J. Hatcher, editor. 2005 Georgia Water Resources Conference, held April 25-27, 2005 at the University of Georgia, The University of Georgia, Athens, Georgia.

Kramer, L., and M. Elliott. 2005. Identification of conservation opportunity areas in Georgia. GAP Analysis Bulletin **13**:14-20.

Mazerolle, M. J., and A. Desrochers. 2005. Landscape resistance to frog movements. Canadian Journal of Zoology-Revue Canadienne De Zoologie **83**:455-464.

Merrill, M. D. 2001. Local and watershed influences on stream fish biotic integrity in the Upper Oconee watershed, Georgia, USA. Institute of Ecology. University of Georgia, Athens.

Möilanen, A., and M. Nieminen. 2002. Simple connectivity measures in spatial ecology. Ecology **83**:1131-1145.

NARSAL. 2006. Georgia Land Use Trends. University of Georgia, Institute of Ecology, Natural Resources Spatial Analysis Laboratory, Athens, GA.

Pope, S. E., L. Fahrig, and N. G. Merriam. 2000. Landscape complementation and metapopulation effects on leopard frog populations. Ecology **81**:2498-2508.

Price, S. J., D. R. Marks, R. W. Howe, J. M. Hanowski, and G. J. Niemi. 2004. The importance of spatial scale for conservation and assessment of anuran populations in coastal wetlands of the western Great Lakes, USA. Landscape Ecology **20**:441-454.

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology **15**:1113-1119.

Semlitsch, R. D. 2002. Critical elements for biologically based recovery plans of aquatic breeding amphibians. Conservation Biology **16**:619-629.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology **17**:1219-1228.

USDA. 2006. US General Soils Map (STATSGO) for Georgia. Soil Survey Staff, National Resources Conservation Service, US Department of Agriculture.

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

Wiens, J. A. 1997. The emerging role of patchiness in conservation biology. Pages 93-107 in S. T. A. Picketts, editor. The ecological basis of conservation: heterogeneity, ecosystems and biodiversity.

Zedler, J. B. 2006. Wetland restoration in D. P. Batzer, and R. R. Sharitz, editors. Ecology of freshwater and estuarine wetlands. University of California Press, Berkeley, CA.