Healthy Ecosystems Grants 1 Final Report

Project Title: Expanding Ecosystem Service Provisioning from Coastal Restoration to minimize Environmental and Energy
Award Amount: $147,937
Awardee: Louisiana State University
Award Start Date: 09/01/15
Award End Date: 12/01/16
NAS Grant ID: 2000005991

Project Director: John Day
Affiliation: Department of Oceanography & Coastal Sciences, Louisiana State University
Address: 2237 Energy, Coast & Environment Building, Baton Rouge, LA 70803
Email: johnday@lsu.edu
Phone: 225-578-6508

Project Key Personnel:
- David Batker, Earth Economics
- Christopher D'Elia, Louisiana State University
- David Dismukes, Louisiana State University
- Robert Lane, Louisiana State University

I. ORIGINAL PROJECT SUMMARY (from proposal)

The Mississippi Delta (MD) provides environmental and economic benefits through high levels of Ecosystem Goods and Services (EGS) that are valued at $12-47 billion/year with a natural capital asset value of $0.330 to $1.4 trillion (Batker et al. 2014). A quarter of MD wetlands disappeared due to Mississippi River levees and hydrological alteration largely as a result of oil and gas activities and Mississippi River levees. Ongoing delta restoration seeks to reverse wetland loss mainly through river diversions and marsh creation using dredged sediments. The effectiveness and sustainability of restoration will determine ecological and economic sustainability in the MD. Climate change and energy costs are constraints on restoration. Sea-level rise reduces restoration effectiveness by requiring greater elevation and effort wetlands restoration. Diversions and wetland creation are energy intensive activities, sensitive to energy availability and prices.

Study objectives are to conduct an EGS analysis for two large diversions and two wetland creation projects. EGS will be evaluated with and without restoration using methods described in Batker et al. (2014) and newly evolving approaches. The Marsh Elevation Model (MEM, Schile et al. 2014) will be used to predict the sensitivity of restoration success to a range of future projections of sea level rise and energy cost by including subroutines for future climate and energy projections and minimize their impacts. The project will consider the cost implications of timing restoration projects.

The proposed project responds to the FRA by addressing how EGS change over time with, and without restoration activities responding to climate change, sea-level rise, and energy costs. The model will couple the evaluation of EGS with future climate and energy forcings. This work is relevant to the GRP by showing how EGS can expand with restoration under energy and climate constraints. The project results will be presented to a broad international audience through the Land Ocean Interactions in the Coastal Zone program.

The project is innovative. Identification, quantification and monetization (IQM) combines wetland restoration, the response of coastal wetlands to climate change, sea-level rise and energy prices in a physical-economic modeling context. Physical changes (such as greater elevation) are translated via 21 categories of EGS (such as improved hurricane buffering and recreation) and valued with a new tool (the ecosystem service valuation tool, or EVT) into monetary values (i.e., reduced damages due to reduced storm surge, increased fisheries production). Future forcings (i.e., climate and energy costs), the success and sustainability of restoration, and changes in the value of EGS will all be analyzed. Restoration project sequencing will be prioritized.

It is relevant to the goals of the GRP. The project demonstrates complex interactions of environmental forcings (sea-level rise) impacting coastal wetland functions and restoration, system sustainability, and the value of different restoration approaches to EGS provisioning (Goal 3). This shows how sustaining EGS supports healthy and resilient Gulf communities through EGS provisioning, such as improved water quality (health), sustainable fisheries and recreation (economy), and better storm protection (human safety) (Goal 2).

II. PROJECT RESULTS

<u>Accomplishments</u>

This project used a combination of landscape modeling and Ecosystem Goods and Services (EGS) valuation to estimate success for the implementation of several common restoration measures in coastal Louisiana. Specifically, we carried out an EGS analysis for two large river diversions and two wetland creation projects, used a marsh elevation modeling to predict the sensitivity of restoration success to a range of future projections of sea-level rise and energy cost by including subroutines for future climate and energy projections, and considered the cost and EGS implications of the timing of restoration projects with a focus on minimizing the climate and energy impacts.

The Wetland Energy and Climate Restoration Model (WECRM) simulates water level, wetland productivity, sediment deposition and resulting elevation dynamics using subroutines from the Marsh Equilibrium Model (MEM) and the Integrated Wetland Ecosystem Model (IWEM). The MEM is documented in Morris et al. (2002, 2012). The IWEM is documented in Rybczyk & Cahoon (2002) and Rybczyk et al. (1998). Primary productivity and mineral sediment deposition equations were modeled as function of relative elevation using equations from the MEM. The state equations for biomass, organic matter deposition, decomposition and soil compaction were taken from the IWEM. Separate subroutines for salt marsh and swamp were developed for the WECRM and are called WECRM_MARSH and WECRM_SWAMP respectively. WECRM_SWAMP uses biomass state equations for swamp vegetation from Rybzcyk et al. (1998), but adds a subroutine to simulate regeneration of cypress trees as a function of relative elevation in Maurepas Swamp, LA and models primary productivity of trees as a function of relative elevation using a curve fit to data from Megonical et al. (1997). The biomass state equations for WECRM_MARSH were taken from Rybzcyk & Cahoon 2002, primary productivity was modeled as a parabolic function of relative elevation and a half saturation function of suspended sediment concentration using curves fit to data from the coast wide reference monitoring system https://www.lacoast.gov/crms_viewer2/Default.aspx#, this database funded by the Louisiana Coastal Wetlands Planning and Protection Act). The WECRM model code is written in FORTRAN 95 programming language and is available at the following link: https://drive.google.com/open?id=0B_TIZvd_Rsl9R21ua3hkLUJja3c. Sediment input from river diversions was simulated separately from WECRM using a 2D spatially averaged delta progradation model developed by Gary Parker. The model is documented in Parker et al. (1998) and Kim et al. (2009), and can be downloaded on Gary Parker's webpage (http://hydrolab.illinois.edu/people/parkerg/excel_files.htm). No new data or models were generated by this study.

Estimates for EGS were developed from existing literature in coordination with Earth Economics. Earth Economics specializes in ecosystem services valuation, and applies new economics tools and principles to help assess issues of equity, sustainability and the environment. Energy and climate trajectories were developed based on literature review. Unit costs of marsh creation and river diversions were estimated using data from completed coastal restoration projects and estimates put forth by CPRA in the 2012 Master plan. WECRM was used to simulate wetland elevation and productivity dynamics with and without sediment inputs river diversions and marsh creation. This was done for four restoration projects: (1) large sediment diversion into Maurepas Swamp, (2) large sediment diversion into lower Barataria, (3) marsh creation in Lake Hermitage (Barataria), (4) deteriorating marsh nourishment in Little Lake (Barataria). For each restoration project, we estimated costs and EGS values. EGS values were estimated by multiplying unit scale outputs by project area. For each project, a sensitivity analysis was conducted to test the influence of timing on project cost and EGS benefits.

Results indicate that restoration projects completed in the next 5-10 years will not only have greater long-term land gains and benefits compared to projects completed 10 or more years in the future. In addition they will likely come at a lower cost (due to increasing energy prices). Accordingly, we recommend that several large (upstream and intermittently operated, e.g. Day et al. 2016) diversions be planned and completed between now and 2025 to maximize benefits and avoid the impacts of projected increases in oil prices on construction costs.

While marsh creation comes at significant cost and the future affordability of this process is subject to energy price fluctuation, this type of restoration still provides an immediate and relatively long lasting benefit (~20 year). The CPRA should accelerate MC efforts and restore large swaths of the coast as soon as possible. There are several reasons for this: (1) to take advantage of the current period of low and stable energy prices and subsequent restoration costs; (2) to reduce risk of detrimental impacts of future energy price volatility on restoration cost and funding; and (3) to maximize the return on investment, which will decline over time as SLR accelerates even if energy prices do not change.

To reduce energy use, borrow sites for marsh creation and nourishment should be located as close to the fill areas as possible, reducing the need for booster pumps; and wherever possible dredged materials for navigation should be used beneficially. River input can reduce the need for additional dredging in the future by providing a long-term supply of sediment in the outfall basin. Marsh creation and nourishment should be prioritized in areas that fall within the predicted zone of sediment influence of planned river diversions. In the areas where river sediment is plentiful, marshes should be restored to lower elevations, in favor of larger contiguous areas that are less susceptible to erosion and more completely shield coastal communities from storms surge.

Literature Cited:

- Kim, W., Dai, A., Muto, T. and Parker, G., 2009b. Water resources research, 45(6).
- Megonigal, J.P., Conner, W.H., Kroeger, S. and Sharitz, R.R., 1997. Ecology, 78(2), pp.370-384.
- Morris, J.T., Sundareshwar, P.V., Nietch, C.T., Kjerfve, B. and Cahoon, D.R., 2002. Ecology, 83(10), pp.2869-2877.
- Morris, J.T., Edwards, J., Crooks, S. and Reyes, E., 2012. Assessment of carbon sequestration potential in coastal wetlands. In Recarbonization of the Biosphere (pp. 517-531). Springer Netherlands.
- Rybczyk, J.M., Callaway, J.C. and Day Jr, J.W., 1998. Ecological Modelling, 112(1), pp.23-44.
- Rybczyk, J.M. and Cahoon, D.R., 2002. Estuaries, 25(5), pp.985-998.

<u>Initial Outcomes</u>

An original goal of the project had been to differentiate the EGS value of various wetland types (i.e, the value of disaster risk reduction will be different for swamp and marsh habitats). However, based on the primary valuations available in the Gulf coast, for many of the EGS this was not possible (specific reasons noted below). With the exception of fisheries, this assessment has been largely limited to non-market ecosystem goods and services, given the limitations of the EVT. Future work could involve collaboration with state departments to assess the value of marketed services, like alligator, oil and gas, and a more site-specific assessment of fisheries.

The results given in the previous section provide clear guidance for land managers to implement restoration measures in a timely manner in order to avoid the risk of increasing energy prices and sea-level rise. Specific guidance is also given for the different restoration techniques in order to make them more efficient at building new wetlands. The State of Louisiana has plans to spend billions of dollars on coastal restoration, making any potential cost-saving measure valuable.

<u>Unexpected Results</u>

An initial goal of this study had been to connect wetland restoration modelling with ecosystem service valuation (ESV), however it was discovered that this task is more difficult than initially thought. Ecosystem service research has yet to develop methods well suited to connecting ESV with restoration: benefit transfer works, but provides a very course resolution due to the shortage of primary valuation studies, and mapping software that aims to address this purpose (e.g. ARIES or InVEST) are too early in development to be useful.

We initially hypothesized that 1) future trends in climate and energy forcings would increase the cost of restoration, 2) timing of restoration activities would minimize this impact on the cost of restoration, and 3) the sustained value of EGS would be higher for diversions compared to marsh creation. For the most part, these hypotheses were proven true. The value of the results lie in the advice given on how to manage and implement the restoration measures to most effectively build land.

Project Relevance

Researchers and state government officials would be interested in the results of this project.

State government officials directly manage and implement river diversions and marsh creation projects. The results of this project are directly applicable to this. Researchers would be interested in building upon our results and methods.

Education and Training

Number of students, postdoctoral scholars, or educational components involved in the project:

- Undergraduate students: 0
- Graduate students: 2
- Postdoctoral scholars: 2
- Other educational components: 0

III. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Scholarly publications, reports or monographs, workshop summary or conference proceedings

INFORMATION PRODUCTS

Citations for project publications, reports and monographs, and workshop and conference proceedings:

A.R.H. Wiegman, J. W. Day, C. F. D’Elia, E.D. Roy, J.S. Rutherford, G.P Kemp, J.T. Morris, R.R. Lane. (IN PREP.). Modeling the impact of sea-level rise, oil prices, and management strategy on the costs and benefits of sustaining Mississippi Delta marshes with hydraulic dredging. (Target journals: Biophysical Economics and Resource Quality, Journal of Coastal Research, Estuaries and Coasts, Water, Ecological Economics).

BOOK CHAPTERS:

A.R.H. Wiegman, J.S. Rutherford, J.W. Day, (2017). The Costs and Sustainability of Ongoing Efforts to Restore and Protect Louisiana’s Coast. In: Day, J.W. (Ed.), Sustainable Pathways for Mississippi Delta Restoration. Springer, (IN PRESS).

J.S. Rutherford, A.R.H Wiegman, J.W. Day, R.R. Lane. (2017). Energy and climate: global trends and their implications for delta restoration. In: Day, J.W. (Ed.), Sustainable Pathways for Mississippi Delta Restoration. Springer, (IN PRESS).

John W. Day, and Adrian R. H. Wiegman, (2016). Knowledge Gap and Research Question 3: Societal-Scale Adaptations to Net Energy Constraints and the Role of Systems Modeling in the Face of Future Challenges. Implications of Net Energy for the Food-Energy-Water Nexus An NSFfunded workshop at Linfield College, McMinnville, OR 14-16 January 2016. [Co-PIs: Thomas Love and David Murphy, National Science Foundation, award number: 1541988.]

Day, J.W., R.R. Lane, C.F. D'Elia, A.R.H. Wiegman, J.S. Rutherford, G.P. Shaffer, C.G. Brantley, and G.P. Kemp. 2016c. Large infrequently operated river diversions for Mississippi delta restoration. Estuarine, Coastal & Shelf Science doi.org/10.1016/j.ecss.2016.05.001

Day, J.W., J.Agboola, Z. Chen, C. D'Elia, D.L. Forbes, L. Giosan, P.Kemp, C. Kuenzer, R.R. Lane, R. Ramachandran, J. Syvitski, A. Yanez-Arancibia. 2016b. Approaches to defining deltaic sustainability in the 21st century. Estuarine, Coastal & Shelf Science doi.org/10.1016/j.ecss.2016.06.018

Other activities to ensure access to information products:
We are in close contact with CPRA and LDNR officials who plan and operate the major restoration projects in the state, and we keep them informed of our work. They will certainly receive copies of all resulting publications.