Ecological Economics 100 (2014) 74–84

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Methodological and Ideological Options

Trajectory economics: Assessing the flow of ecosystem services from coastal restoration

Rex H. Caffey [a,*], Hua Wang [b], Daniel R. Petrolia [c]

[a] Center for Natural Resource Economics & Policy, Louisiana State University, Department of Agricultural Economics, 179 Woodin Hall, Baton Rouge, LA 70803, USA
[b] Center for Natural Resource Economics & Policy, Louisiana State University, Department of Agricultural Economics, 211 Woodin Hall, Baton Rouge, LA 70803, USA
[c] Department of Agricultural Economics, Mississippi State University, 301-A Lloyd-Ricks-Watson Bldg., Box 5187, Mississippi State, MS 39762, USA

ARTICLE INFO

Article history:
Received 16 August 2013
Received in revised form 14 January 2014
Accepted 17 January 2014
Available online 18 February 2014

Keywords:
Ecosystem services
Coastal restoration
Reclamation
Economics
Wetland
Diversions

ABSTRACT

Monetized estimates of ecosystem services are increasingly cited as partial justification for a wide range of environmental restoration initiatives, yet parallel applications of these values in performance assessment have been limited. Incorporated into traditional economic models, such values can offer potential insight on programmatic efficiency and help to inform policy tradeoffs within and between competing methods. For this analysis, acreage trajectories and cost functions are developed for dredge- and diversion-based land reclamation methods in coastal Louisiana, USA. Benefit–cost models are constructed from which ecosystem service values are initially derived via break-even analysis and then specified to inform comparative case studies. Results indicate that the minimum service value required to offset project expenditures is typically higher for “natural” diversion-based restoration relative to “rapid” dredge-based methods under historic project conditions. Accounting for climatological and socioeconomic risks widens this gap, with benefit–cost ratios for dredge-based reclamation exceeding that of diversions in 16 benefit–cost simulations conducted over a 50-year project horizon. Taken together, these results highlight the influence of time and risk in the assessment of competing project alternatives, and suggest the need to reframe restoration efficiency in terms of the aggregate flow of ecosystem services, versus the per unit costs of terminal stocks.

1. Introduction

A perennial concern in the policy application of ecosystem services is the extent to which quantitative methods can be used to adequately capture the value of provisioning, regulating, supporting, and cultural functions provided by natural systems (Arha et al., 2007; Barbier et al., 2011; Pendleton, 2008; Ruckelshaus et al., in press). Such concern is especially prominent in the field of economics, where methodological debate over non-market valuation has existed for decades (Arrow et al., 1993; Carson, 2012; Diamond and Hausman, 1994; Haab et al., 2013; Hanemann, 1994; Hausman, 2012; Kling et al., 2012; Portney, 1994; Randall, 1994). Not surprisingly, ecosystem restoration programs charged with efficient stewardship of public funding have eschewed financial expressions of project benefits, relying instead on biophysical measures for performance evaluation. For example, large-scale restoration programs in coastal Louisiana and the Florida Everglades have historically gauged restoration performance via habitat suitability indices (Bartoldus, 1999). Such metrics allow for a standardized expression of project benefits and the mandated cost-efficacy assessments required by authorizing legislation (Public Law 101–646, 1990; Public Law 104–303, 1996).

Despite this operational history, monetized estimates of ecosystem services are increasingly cited within the scientific and programmatic literature of these programs and in support of a wide range of federal initiatives focused on conservation and restoration of wetlands (Barbier, 2013; Cullinane-Thomas et al., 2012; NOAA, 2009; USDA, 2007). In support of coastal restoration programming, for example, economic estimates are most often estimated for habitat provision, nutrient assimilation, and storm surge attenuation (Batker et al., 2010; Costanza et al., 2008; Petrolia and Kim, 2011; Petrolia et al., forthcoming). This expanded accounting is at least partially driven by the need to justify billions of dollars in federal requests for ecosystem restoration during an era of heightened public scrutiny and fiscal restraint (Mather Economics, 2010; Pendleton, 2008). The use of these estimates, however, is not limited to program justification. Incorporated into traditional economic

* Corresponding author at: Louisiana State University, Department of Agricultural Economics, 179, Woodin Hall, Baton Rouge, LA 70803, USA. Tel.: +1 225 578 2393; fax: +1 225 578 2716.
E-mail addresses: rcaffey@agcenter.lsu.edu (R.H. Caffey), hwang23@lsu.edu (H. Wang), petrolia@agecon.msstate.edu (D.R. Petrolia).

http://dx.doi.org/10.1016/j.ecolecon.2014.01.011
0921-8009

models, monetized ecosystem services offer insight on programmatic efficiency and help to inform policy trade-offs within and between project types. Such guidance is of particular importance in rapidly deteriorating ecosystems where competing restoration methods vie for limited funding.

1.1. Rapid vs. Natural: Coastal Land Reclamation in Louisiana

Coastal restoration in Louisiana is conducted through a wide variety of vegetative, hydrologic and structural methods,[1] but two major project types have come to dominate planning efforts in the past decade. A majority of program spending in recent years has been allocated for "marsh creation" projects, in which coastal land is reclaimed rapidly through the mechanical extraction and delivery of dredged sediments (Aust, 2006; LCPRA, 2012; Merino et al., 2011). Concurrent with this trend has been a growing call from the restoration science community in favor of large-scale river diversion projects designed to mimic the alluvial land building process (Allison and Meselhe, 2010; DeLaune et al., 2003; LCPRA, 2012; Nittrouer et al., 2012; Simenstad et al., 2006). To some extent, emergence of these two primary, sediment-oriented forms of restoration is indicative of a growing concern that time is a major limiting factor in addressing coastal wetland land loss in the lower Mississippi River delta plain. In the past century alone, the region has lost more than 1880 mile^2 of coastal land, primarily due to hydrologic modifications and flood control measures that have greatly impeded the deltaic processes that once sustained the Louisiana coast (Barras et al., 2003; Dunbar et al., 1992).

In the wake of recent natural and manmade disasters, the State of Louisiana has integrated the formally independent agencies responsible for coastal infrastructure protection and coastal habitat restoration. Consistent with this integration and in recognition of the scale of the crisis, restoration policy has expanded from the environmental suitability metrics (e.g. dollars per habitat unit) that once dominated project prioritization (Bartoldus, 1999). In recent years, strategic planning has emphasized land-building as a primary goal of coastal restoration, and dollars per acre as a metric of programmatic efficacy (LCPRA, 2012).

Though planning in the region has acknowledged the need for both dredge- and diversion-based reclamation, the former method is often disparaged in the restoration science community. The general assertion is that coastal marsh created with a dredge is less functional, and that ecological restoration should aim to restore processes, not structures (Reed, 2009; Simenstad et al., 2006). Moreover, the front-loaded benefits of marsh creation are often discounted by an accounting regime focused on end-of-stage performance. As a result, comparative efficiency assessments often describe dredge-based reclamation as the most expensive form of coastal restoration (LCPRA, 2012; Schleifstein, 2012, 2013). Conversely, the relatively slow pace of diversions has been criticized by some stakeholders in favor of more immediate results. This criticism is compounded by private sector concerns over project-driven changes in channel hydrology and basin salinity. Opposition from navigation and fishing interests has been a limiting factor to diversion implementation and operation, resulting in construction delays and restrictions to the timing and volume of water outflows (Allison and Meselhe, 2010; Caffey and Schexnayder, 2003; Das et al., 2012; Gramling et al., 2006).

While these two approaches are not mutually exclusive, their relative contributions are central to a growing economic and ideological debate between advocates of each method, and one typically defined by a narrow interpretation of costs and benefits. Given the scale of coastal land loss in Louisiana and the reality of limited funding, a more objective economic assessment is required to assess efficiency of these methods in the provision of ecosystem services.

[1] For a comprehensive review of restoration projects by type and location, see: LCWCRTF (2012).

2. Study Approach

Previous research on restoration economics has focused primarily on biophysical metrics and terminal unit costs as the basis for efficiency comparisons (Aust, 2006; Merino et al., 2011; Turner and Boyer, 1997). In this analysis, project acreage is the standardized unit through which ecosystem services are examined through an actuarial comparison of dredge- and diversion-based restoration. The process is two-fold. Monetized values for ecosystem services are initially derived via project-specific, break-even sensitivity analysis. This process avoids the guess work associated with extrapolation by determining the minimum dollar value of benefits required to offset project costs under a range of temporal and spatial assumptions. The second step involves specifying aggregated service estimates (storm surge attenuation, habitat, and water quality) to inform scale-, location-, and risk-specific performance comparisons. Taken together, the process constitutes an alternative framework for evaluating economic trade-offs and is consistent with the State's Coastal Master Plan, which identifies land-building as a primary programmatic goal (LCPRA, 2012).

Specific objectives of the research include: 1) estimating representative acreage trajectory and cost functions for dredge-based and diversion-based reclamation projects; 2) examining the relative sensitivity imparted by model parameters under various assumptions related to time, location, and distance; and, 3) developing risk-constrained case studies to illustrate policy tradeoffs between and within restoration methods.

3. Data and Methods

Benefit and costs functions for dredge-based "marsh creation" (MC) projects and diversion-based (DIV_1) restoration were developed through a review of authorized projects submitted to the Coastal Impact Assistance Program (CIAP), the Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA), and the Louisiana Coastal Area (LCA) Comprehensive Ecosystem Study. While these programs differ in the methods used to evaluate and select projects for funding (annual versus multi-year), they typically allocate project spending under three standard categories: 1) engineering and design; 2) project/structure construction, and 3) operation and maintenance. Given the small number of observations available for the fitted diversion model (DIV_1), a second model of diversion benefits (DIV_2) was utilized to capture a wider suite of nutrient and sediment contributions at specific flow rates, and is detailed in Section 4.3.

Benefit and cost functions were incorporated into a net present valuation framework and sensitivity analyses were conducted to examine the relative importance of specific project attributes under various risk scenarios. Parameter means were used to develop baseline benefit–cost (BC) projections and simulations were conducted by allowing a single, user-specified parameter to vary across its known range and solving for the break-even ecosystem service value ($/acre/year) necessary to achieve a benefit–cost ratio equal to one. Risks were characterized through an expected valuation framework incorporating data on hurricane landfall probability and through a proxy measure representing socioeconomic constraints. Case study simulations were conducted for lower and upper estuary locations to illustrate project and site-specific opportunities and constraints (Wang, 2012).

3.1. Acreage Trajectories

Generic characterizations of restoration trajectories for each method were developed from a survey of technical review documents produced by CIAP, CWPPRA and LCA for the years 1992–2010. Acreage projections derived from *future-with-project* minus *future-without-project* calculations were available for 38 individual projects (23 MC, 15 DIV) with target scales ranging from 234 to 5706 acres. Sufficient data on inter-period acreage projections, however, were available for only six of the