Identifying high-payoff areas for restoration investments: Assessing spatial heterogeneity of ecosystem service benefits & costs of repair

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Speaker Introduction by Professor Bill Dennison
Identifying high-payoff areas for restoration investments: Assessing spatial heterogeneity of ecosystem service benefits & costs of repair

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Talk Outline

A. Conversational Economics
   1. What environmental economics can / cannot do
   2. Dollar valuation vs. relative benefits of restoration

B. Restoration decisions based on investment rules
   1. Finding investments with high potential for returns
   2. Understanding Restorability / Managing risk
   3. Examples from Intermountain West & Chesapeake Bay

C. Optimizing multi-scale economic returns from restoration
Questions Addressed with Environmental Economics

Predicting Stressors
- What trends in human behavior suggest future conflicts with natural resource management?

Evaluating Policy Options
- Which policy options will effect the biggest changes in environmental stressors?
- What is an efficient way to achieve an environmental goal?

Evaluating Preferences & Values
- What do people value about natural resources?
- How much do people value a positive change in those resources?
- How risk averse are people to a negative change in a resource?
Questions environmental economic tools are not designed to address

Total system value
• What is this ecosystem worth?

Unproven harms avoided
• What is the value of avoiding a change that has unknown consequences?
Evaluating policy options: What’s under the light post?

Economic Impacts

- What is a change in a resource costing us? (i.e., to maintain a service)
  - What are the direct expenditures?
  - What are the indirect costs or lost revenues?

Costs ≠ Social benefits
Why aren’t costs avoided equivalent to benefits?

• Spending does not completely reflect the values people hold (e.g., people value things that are free)
• Actual spending may not represent an efficient allocation of societal resources (tradeoffs not considered)
• Benefits accrue when social welfare is improved or maximized (i.e., when benefits exceed costs)

In practice, costs avoided are frequently used as a proxy for social benefits
Prioritization Decisions for Restoration

Where should scarce resources be invested to maximize benefits derived from ecosystems?

• How do we maximize the returns from Program X?
• What benefits did we get from Program X?
Two Types of Value Measures

1. Absolute ($$) measures
   – Usually preferred, but not always possible
   – Often developed as “average” values ($ per acre) so not useful for prioritizing sites

2. Relative (non-$) measures
   – Most useful to support sustainable resource management decisions to:
     • Avoid, minimize, and mitigate environmental impacts
     • Prioritize sites for environmental restoration
## Measuring Ecosystem Value

<table>
<thead>
<tr>
<th>Direct Use Services</th>
<th>Indirect Use Services</th>
<th>Existence Services</th>
<th>Life Support Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Timber</td>
<td>• Flood control</td>
<td>• Bequest value</td>
<td>• Global climate regulation</td>
</tr>
<tr>
<td>• Non-timber forest products</td>
<td>• Drinking water improvement</td>
<td>• Spiritual enrichment</td>
<td>• Nutrient Cycling</td>
</tr>
<tr>
<td>• Fishing / Hunting</td>
<td>• Protecting Health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Bird Watching</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Decreasing Measurability in Terms of $$$
System to Translate Wetland Features into Public Values

Opaluch et al. 2003
## Professional Survey

<table>
<thead>
<tr>
<th>Habitat For:</th>
<th>Potential for site to provide functions listed below:</th>
<th>Insufficient Information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Significant Potential</td>
<td>Limited Potential</td>
</tr>
<tr>
<td>Wading Bird</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Waterfowl</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Shorebird</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Marsh Dependent Songbird</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other Songbirds</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Overall Bird Habitat</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Marsh Resident Fish</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Marsh Non-resident Fish</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Overall Fish Habitat</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Opaluch et al. 2003
### Example Results of Professional Survey

#### Habitat Score for Silver Creek

*Scale 0 - 5*

<table>
<thead>
<tr>
<th>Species Group</th>
<th>Before</th>
<th>After</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>3.70</td>
<td>3.82</td>
<td>0.12</td>
</tr>
<tr>
<td>Fish</td>
<td>2.74</td>
<td>2.90</td>
<td>0.16</td>
</tr>
<tr>
<td>Shellfish</td>
<td>2.84</td>
<td>3.03</td>
<td>0.19</td>
</tr>
<tr>
<td>Mosquito Control</td>
<td>2.74</td>
<td>2.90</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*Opaluch et al. 2003*
Public Survey

1. On this page, compare restoration plans 1 and 2 and vote below for the plan you prefer:

Check one box:

<table>
<thead>
<tr>
<th>I choose NEITHER PLAN ($0 per year)</th>
<th>I choose RESTORATION PLAN 1 ($20 per year)</th>
<th>I choose RESTORATION PLAN 2 ($20 per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological Improvement to RI Bird Populations*</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ecological Improvement to RI Fish Populations*</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ecological Improvement to RI Shellfish Populations*</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Potential to Control Mosquito Nuisance*</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

Access for Recreation

<table>
<thead>
<tr>
<th>Size of Salt Marsh</th>
<th>Restoration Plan #1</th>
<th>Restoration Plan #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of the Plan to YOUR HOUSEHOLD</td>
<td>Viewing platforms &amp; no trails 3 Acres</td>
<td>$20 per year in higher state taxes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 Acres $20 per year in higher state taxes</td>
</tr>
</tbody>
</table>

*As judged by wetland experts, compared to all other potential salt marsh restoration projects in Rhode Island.

Opaluch et al. 2003
## Example Results of Public Survey

### Value Index for Silver Creek

<table>
<thead>
<tr>
<th>Category</th>
<th>Change in value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>4.5</td>
</tr>
<tr>
<td>Fish</td>
<td>0.2</td>
</tr>
<tr>
<td>Shellfish</td>
<td>0.3</td>
</tr>
<tr>
<td>Mosquito Control</td>
<td>0.2</td>
</tr>
<tr>
<td>Public Access</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total Change</strong></td>
<td><strong>5.2</strong></td>
</tr>
</tbody>
</table>

Opaluch et al. 2003
Issues in Developing Dollar Valuation of Ecosystem Changes

1. Burden is on ecologists and economists to produce exact relationships between ecosystem changes and economic outcomes
2. Most natural systems have a limited number of services that can be monetized
3. The change in a local system can be minor in terms of economic outcomes and the dollar valuation will reflect this
4. By the time you can demonstrate direct benefits of restoration, costs are high
Current State of Monetizing Changes in Natural Resources

• Data are rarely available for rigorous site-based economic models to value changes in natural resources
• Original studies are costly to implement and results tend to be controversial
• Benefit transfer of existing monetary studies is most common (e.g., to evaluate proposed regulations)
Uses of Relative Value Measures

- Demonstrate benefits are maximized for a given level of spending
- Provide alternative evidence of benefits when the monetary values are low or controversial
- Quantify wide range of benefits per dollar spent
- Create implicit dollar values (Is it worth at least $X?)
  - Cost per Life Saved
  - Habitat Units Saved per $ Spent
Comparing Restoration Options

Cost

Benefits

No
Low Benefits
High Costs

High Benefits
High Costs

Yes
Low Benefits
Low Costs

High Benefits
Low Costs
Prioritization as value investing: Lessons from Wall Street

1. Preserve & maintain capital
2. Invest in undervalued assets with high earning potential
3. Manage risks not just returns
4. Invest for long-term not short-term gains
Benefits per unit effort as a function of site and landscape quality

Benefits

Restoration Effort

Site Quality

Landscape Quality

A

B

C

D

High

Med

Low
## Measuring capital and earnings potential

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Quality</strong></td>
<td>How well does this site provide biophysical <em>functions</em> necessary to the service?</td>
</tr>
<tr>
<td><strong>Service Opportunity</strong></td>
<td>What features of this site make this <em>service</em> available and valuable at this location?</td>
</tr>
<tr>
<td><strong>Service Scarcity</strong></td>
<td>How rare is this service in the user area?</td>
</tr>
<tr>
<td><strong>Service Loss Risk</strong></td>
<td>Is this service likely to be lost or impaired from uncontrollable forces?</td>
</tr>
</tbody>
</table>
2001-2003 Fires Treated & Untreated in Idaho

Source Data: USFS, BLM
Cheatgrass- & Medusahead-Dominated Site
Native-Dominated Site
Enhanced Fire Risk Due to Cheatgrass

Source Data: J. Menakis USGS and ICBEMP
Find undervalued assets with high earning potential

1. Benefits of Successful Restoration
2. Probability of Successful Restoration
3. Costs of Treatment

\[
\text{Cost - Effectiveness} = \frac{\Delta \text{Benefits} \times \text{Probability of Success}}{\text{Costs of Treatment}}
\]
Recreation Demand by Location

Preference for sites is based on:

- **Site quality for intended activities** (e.g., probability of hunting success)
- **Ancillary qualities** (e.g., wildlife viewing opportunities, quality of wilderness experience)
- **Complementary goods** (e.g., proximity to developed campsites)
- **Cost of use**

High returns generally occur where:

- High quality sites
- Lack of substitutes of comparable high quality
- Low cost of access
- Low risk of service disruptions
Antelope Rifle Hunting
User Day Density

Source Data: Idaho Dept. of Fish and Game
Potential Trip Density
Hunting Site Quality X Trip Density
Substitutable hunting areas (future)
Service Value

Supply & Demand Analysis

GIS data

- Land cover
- Trails
- Roads
- Population
- Public Access Lands

Service Value Index

- Probability of animal encounter
- Number of people able to drive to site in 3 hours
- Number of sites within 40 miles offering same qualities

Hunting Value Index
Areas with a view of James Island
3-D Visualization of restoration project

Aesthetic Analysis Components
- Scale Contrast
- Compatibility
- Spatial Dominance
Economic Benefit Indicators for Mid-bay Island Sites

- Barren Island
- James Island
- Hoopers Island
- Smith Island
- Ragged Island
- Little Deal Island
- Holland Island
- South Marsh Island

Economic Benefit Index

Categories:
- Shoreline protection
- Aesthetics
- Commercial fishing
- Recreational fishing
- Recreational boating
Specify the relative importance of each of the following management priorities:

- Protecting biodiversity
- Providing recreational opportunities
- Protecting quantity or quality of regional water supplies
- Supporting commercial resource extraction
- Supporting agricultural crop productivity

Relative Priority:
- Biodiversity
- Recreation
- Water Quality
- Resources
- Agriculture

Sensitivity Analysis: Management Goals

Bar chart showing:
- Site 1: 50%
- Site 2: 10%
- Site 3: 80%
Conclusions on Assessing Benefits

1. Economic values are location-based & depend on quality, scarcity and replaceability of services
2. Not every ecosystem service lends itself to dollar valuation
3. Demonstrate restoration benefits by understanding the damage function
4. Benefits may appear low unless risk of future degradation is considered
5. Risk of uncontrollable service loss affects measured benefits
6. Risk of treatment failure affects expected benefits
Restorability Model

Probability of Success

Cheatgrass regrowth

New cheatgrass infestation

Native / Non-native regrowth

Site Variables

Landscape Variables

Stochastic Variables
Restorability – Site Factors

![Map showing restorability levels across different regions with color coding for high and low restorability areas. The map includes a scale for miles.]
Spatial Pattern Variables to Assess Restorability
Managing Investment Risk

- Evaluate uncertainty of benefits by estimating restorability
- Manage performance risk by:
  1. choosing appropriate scale and intensity of response
  2. choosing portfolio of restoration sites based on their uncorrelated responses to stress
- Strategy to manage risk will not select only high risk - high vulnerability sites
## Example Cost-Effectiveness Analysis

### Restoration Site

<table>
<thead>
<tr>
<th></th>
<th>Site A</th>
<th>Site B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Total Cost (1000s $)</strong></td>
<td>$250</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Performance Risk</strong></td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Increase in Benefit Index</strong></td>
<td>14,000</td>
<td>30,000</td>
</tr>
<tr>
<td><strong>Risk-Adjusted Benefits</strong></td>
<td>7,000</td>
<td>18,000</td>
</tr>
<tr>
<td><strong>Benefit Index / Cost Ratio</strong></td>
<td>28</td>
<td>18</td>
</tr>
</tbody>
</table>
Dredged Material Placement Options

- Agricultural Placement
- Artificial Island Creation
- Island Restoration
- Building Products
- Landfills / Brownfield Capping
- Confined Aquatic Disposal
- Mine Placement
- Open Water Placement
- Shoreline Restoration
- Wetland Restoration
Cost vs. Habitat Benefits for Suites of Dredged Material Placement Alternatives

~590 suites
Habitat Benefit Index (based on BEWG scores)
Legal & Political Risk

1. No law to prohibit, none or minor public/regulatory issues
2. No law to prohibit, moderate public/regulatory issues
3. No law to prohibit, significant public/regulatory issues
4. Law prohibits, minor public/regulatory issues
5. Law prohibits, significant public/regulatory issues
Remaining Suites after Screening for Legal/Political Risk

Cost $ Millions
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0

Habitat Benefit Index
~50 suites (based on BEWG scores)
Simulation-optimization model with uncertainty

**Targets to maximize / minimize**
(mean, standard deviation, etc. of environmental goal)

**Control variables & uncertainty**
(variables expressed as distributions)

**Constraints**
(budget, resource stocks)

**Optimization**

**Targets**
1. Recreational benefits * R
2. Ranching productivity * R
3. Habitat benefits * R

**Control variables & uncertainty**
1. # acres treated
2. Treatment intensity

**Constraints**
1. Total budget
Lessons Learned – Cheatgrass Case Study

• Lack of documented decision model creates suspicion among all interest groups
• Managers want sufficient detail in decision analysis to be able to represent diverse situations
• Multi-criteria decision analysis roughly captures current methods of prioritization
• Lack of explicit consideration of costs, prioritizes high-benefit sites, but not highest cost-effectiveness
Decision Support Continuum

- Cost Oblivious Decision Making
- Cost Effectiveness Analysis
- Cost Benefit Analysis
- CBA + Risk Analysis

Increased Information for Decision Making
Prioritizing Restoration / Investments

1. Which services are expected to improve with restoration?
   (Did we match the scale of restoration to stressors?)
2. What is the value of the change in services?
   – What damages / costs are avoided by restoring now at this location?
   – What are the quantitative effects on ecosystem services
3. What will it cost to restore & maintain ecosystem services?
4. What is the probability that services can be successfully restored?
Research Support

- Environmental Economic Analysis of Dredged Material Placement Options in the Chesapeake Bay (Maryland Port Administration)
- Prioritizing Invasive Species Management: Cheatgrass case study [Program of Research on the Economics of Invasive Species Management (PREISM), Economic Research Service, USDA, under Cooperative Agreement #43-3AEM-3-80092]
- Indicators for Regional Vulnerability Assessment (US EPA)
- Risk-Based Decision Support System for Managing Coastal Systems Exposed to Multiple Stressors (NOAA/SERC)
- Prioritizing Wetland Restoration - Web Tool (NSF/URI)
Acknowledgements

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- Tom Roberts (BLM)
- Brandon Brown (BLM)
Question Time

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Question Time
(cont’d)

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