Measuring BRIs Using Ecological & Social Context

Lisa Wainger, PhD
University of Maryland Center for Environmental Science
Solomons, MD
wainger@umces.edu
Outline

1. Review BRI definition
2. How end uses of BRIs inform their development
3. Creating & measuring BRIs
4. Examples and methods for overcoming data gaps
5. Aggregation and other analytic considerations
6. Sources of additional information
7. Group exercise – Developing BRIs
What are Benefit Relevant Indicators (BRIs)

- Measurable indicators that capture the connection between ecosystems and people
- The point of hand off between ecologists and economists – that combine ecological and social information
- A complement or stepping stone to valuation or an alternative

Diagram:
- Action
- Ecosystem function: Ecological indicators
- Ecosystem service: Benefits relevant indicators (eco+soc data)
- Social benefit: Benefits Assessment (value/preference)
BRIs identify conditions under which an ecological change is likely to be valued

**Ecosystem Service Opportunities**

Biophysical changes
- $\Delta$ wave height
- $\Delta$ water quality
- $\Delta$ habitat
- ...

**Human Well-Being Outcomes**

Health & Safety
- Home protection
- Food production
- Water supply
- ...

Fulfillment
- Recreation
- Satisfaction of environmental stewardship
- ...

BRIs
How are BRIs Used?

1. Quantitative Communication
   • Summarize impacts in quantitative units
   • *Tons CO2e sequestered* & *Number of homes protected*

2. Cost Effectiveness Analysis
   • Uses a single metric or index to compare performance
   • *2 lives saved / $1 spent*

3. Multi Criteria Decision Analysis
   • Preference-weighted and normalized benefits
   • *20 points of recreation benefits* (relative units)
Cost-Effectiveness Analysis
BRI Goal: Generate performance metric for comparing alternatives

![Graph showing risk-adjusted benefits and costs for different fire scenarios. The graph compares less cost-effective fires to best-buy fires, indicating that best-buy fires tend to have higher benefits at lower costs.]
BRI goal: Enhance cost-effectiveness of decisions

Simulated program cost (million $)

Practice-based

Performance-based

71 million AEI points

$806 million

Spatial BRI weighting + behavioral responses to policy

Weinberg and Claassen, March 2006 USDA ERS Economic Brief
BRI goal: Provide inclusive view of benefits

Economic Benefit Index

- Existence
- Bequest

urban
- Property protection
- Recreation

rural

Non-Monetized Benefits
Monetized Benefits
Creating BRIs that match end uses

1. Complement
2. Stepping stone
3. Alternative
Example of a complement to valuation

Identify equity concerns

- Complement
  - Ecological Indicator
    - $ \Delta$ Storm surge height
  - BRI
    - $\Delta$ People disrupted
  - $\$ Value
    - Property Damage (homes * value)

Stepping Stone

Alternative
Example of a **stepping stone** to valuation

*Match to benefit transfer variable*

**Complement**

**Stepping Stone**

**Alternative**

- **Ecological Indicator**
  - $\Delta$ Fish community

- **BRI – Opt 1**
  - $\Delta$ fishing days

- **BRI – Opt 2**
  - $\Delta$ Game fish + Angler income

- **$\text{Value}$**
  - WTP for recreational fishing
Example of a **replacement** for valuation

*Express relative importance of something that will not be monetized*

- Complement
- Stepping Stone
- Alternative

**Ecological Indicator**
- \( \Delta \text{Habitat} \)

**BRI (Rarity)**
- <10% of historic extent remains
- Site is 30% of restorable area

- $ Value

---

12
What elements make a good BRI?

• Metrics come as close as possible to something that people would be willing to pay for
• Represents magnitude of use or intensity of concern
• Reveals meaningful tradeoffs
1. **Quality** is sufficient for users
   - Charismatic birds are present

2. **Complements** - Capital and labor available
   - Piers and boardwalks provide access

3. **Demand** - Users or beneficiaries present / possible
   - Potential birders living in driving distance

4. **Reliability** of the future stream of services
   - Surrounding landscape is protected from development

5. **Scarcity** and substitutability
   - Few alternative birding sites or other sites are congested
Examples + data realities

Use of site quality

Action
Δ Manure management

Ecological Indicator
Δ Index of biotic integrity

BRI
Δ Aquatic system health or resilience

$ Value
WTP for Δ health or resilience (nonuse value)
Examples + data realities

Use of site quality

Action
Δ Manure management

Ecological Indicator
Δ Index of biotic integrity

BRI
Δ Aquatic system health or resilience

$ Value
WTP for Δ health or resilience (nonuse value)
Examples + data realities

Use of site quality

- Action
  - Δ Manure management

- Ecological Indicator
  - Δ Index of biotic integrity

- BRI
  - Δ Nutrient runoff weighted by effect on aquatic invertebrates

US EPA Chesapeake Bay Program
Benefit Relevant Indicator

Complementary Inputs

Co-location of labor and capital

Pollinator Habitat

Not relevant

Relevant if within range

Food Provision

BRI: Area of pollinator-dependent crops within flying distance of pollinator habitat
Benefit Relevant Indicator
Demand

Mazzotta, Wainger et al. 2015 *Ecological Economics*

BRI: Increased game fish density in areas of high freshwater fishing demand
Benefit Relevant Indicator
Scarcity (use value)

Action
△ Restore streams

Ecological Indicator
△ Groundwater recharge

BRI_1
△ Recharge where irrigation used

BRI_2
△ Recharge where irrigate + gw levels declining

Groundwater Level Trend

Columbia Water Center
Benefit Relevant Indicator
Scarcity (Non-Use)

Hudy et al. 2008

Brook Trout Status

Non-use Value for Species of Concern

BRI: \( \Delta \) stream miles suitable for reproduction of trout species of conservation concern

\[ \Delta \text{ Riparian buffers} \rightarrow \Delta \text{ Sediment runoff + water temp} \rightarrow \Delta \text{ Habitat quality for reproduction} \]
The current vs future information gap
**Future benefits inferred from existing conditions**

**Western Governors’ Crucial Habitat Assessment Tool**

Example from scarcity indicators

**Establishing Conservation Priorities**

Acres in highest priority categories (1-2) within or adjacent to project

**Crucial Habitat Rank**

- 1: Most crucial
- 2: Least crucial

**Project site**
Underpinnings of BRIs

- **Scarcity, Substitutability, Irreplaceability**
  Underlies metric choices
  In general, the scarcer a service is, the more an increase in its quantity is likely to be valued, all else equal

- **Manage data gaps**
  Express importance to people to the extent supported by data and understanding
Aggregating Indicators

Do they capture relative importance of changes?

![Economic Benefit Index](chart)

- Shoreline protection
- Aesthetics
- Commercial fishing
- Recreational fishing
- Recreational boating
Aggregating indicators

*Outside of MCDA*

- Use expert judgment and/or statistical properties of data to compare and/or combine variables
- Fill gaps when empirical relationships between variables and outcomes are unknown
- Must be used cautiously to avoid creating bias or unintended consequences
Common aggregation approaches

• Normalization
• Standardization
• Simple weighting
  (user or expert judgement rates intensity of concern)
• Multivariate statistical approaches
  (e.g., evaluate “distance” to a user-specified ideal)
Multivariate distance metrics

Initial State

Future State

Anti-Ideal State

Ideal State

Change in environmental status

Management Effectiveness
Pros and cons of multi-metric aggregation

Pros
- Simplifies results
- Reveals synergies and tradeoffs
- Some methods reduce double counting and/or biases (but not eliminate)

Cons
- Methods embed many unexplored assumptions
  - Often ignore thresholds or other non-linearities in benefits
- Some methods double-count benefits
  = opportunity to game stakeholder processes
- Simple mathematical choices can unintentionally bias results
  - E.g., A single high or low outlier values can make moderate changes appear unimportant when normalizing
<table>
<thead>
<tr>
<th>Category</th>
<th>Method</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Best/Worst Quintile</td>
<td>Count the number of variables in the best/worst quintile.</td>
<td>Jones et al., 1997</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>Add the normalized values of all variables.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PCA Distance</td>
<td>Transform variables to adjust for correlations, then calculate Euclidean distance from a reference.</td>
<td>Johnson, 1988; Mahalanobis, 1936</td>
</tr>
<tr>
<td>Distance-based</td>
<td>State Space</td>
<td>Adjusts for correlations by calculating the Mahalanobis distance from a reference.</td>
<td>Dubois, 1979; Gatto and Renaldi, 1987; Tran and Duckstein, 2002</td>
</tr>
<tr>
<td></td>
<td>Criticality</td>
<td>Calculates fuzzy distance to a hypothetical &quot;natural&quot; state.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Analytical Hierarchy Process (AHP)</td>
<td>Multi-criteria tool that uses decision-maker preferences in the calculations.</td>
<td>Saaty, 1980</td>
</tr>
<tr>
<td>Grouping</td>
<td>Cluster Analysis</td>
<td>Uses a robust partitioning method to group watersheds.</td>
<td>Wickham et al., 1999</td>
</tr>
<tr>
<td></td>
<td>Self-organizing Maps (SOM)</td>
<td>Uses neural networks to group watersheds.</td>
<td>Kohonen, 2001; Tran et al., 2003</td>
</tr>
<tr>
<td>Overlay</td>
<td>Stressor-Resource Overlay</td>
<td>Composite coloring, counts high-stress variable values and high-resource variable values.</td>
<td>Landis and Wiegars, 1997; Jackson et al., 2004</td>
</tr>
<tr>
<td></td>
<td>Overlap</td>
<td>Comparison of two regional maps to highlight differences.</td>
<td></td>
</tr>
<tr>
<td>Matrix</td>
<td>Stressor-Resource Matrix</td>
<td>Computes scores based on correlation values to rate stressors and resources.</td>
<td>Gentile, et al., 1999; Harris et al., 1994; Parkhurst et al., 1997</td>
</tr>
<tr>
<td></td>
<td>Univariate Regression</td>
<td>Computes scores based on regressions of stressors on individual resources.</td>
<td></td>
</tr>
</tbody>
</table>
Other Analytic Details

Spatial extent considerations (servicesheds)

• Does service value decline with distance?
• What is the appropriate range of beneficiaries?
  • Species ranges (e.g., pollinators)
  • Networks & social conditions (e.g., downstream, likely driving distance)
  • Proximity-independent (e.g., climate risk mitigation)
Other Analytic Details

Temporal Analysis Issues

• Benefits are often measured as a stream of services through time
• Benefits may depend on future (unmeasured) conditions
• Not obvious how to discount future BRIs
BRIs fulfill two important needs for ecosystem services assessments

1. Enable lay audiences to clearly connect ecological outcomes to their own well-being
2. Improve analysis of tradeoffs by representing benefits that are not possible or feasible to monetize
Resources

Descriptions of Methods


• Wainger et al. (in press). A proposed ecosystem services analysis framework for the US Army Corps of Engineers. ERDC/EL TR-xx-xxx. Vicksburg, MS: U.S. Army Engineer Research and Development Center

Some example implementations of BRIs


Technical resources


• Scarcity data sources and metric aggregation: Wainger, L., K. Gazenski, E. Murray. (in review). Using scarcity and reliability data to value ecosystem services: assessment of currently available resources and metric aggregation methods. USACE ERDC Technical Report; some info at waingerlab.cbl.umces.edu/ecoscarcity (and Gazenski et al. poster at ACES 2016)
Developing Benefit Relevant Indicators

EXERCISE
BRI Exercise Steps

1. Select a conceptual model

2. Develop BRIs that incorporate at least one of these elements
   - Quality is sufficient
   - Complements - Capital and labor co-located / available
   - Demand - Users or beneficiaries present / possible
   - Reliability of the future stream of services
   - Scarcity and substitutability

3. Produce flow chart summarizing BRIs and connections
Factors to consider
- Qualities relevant to beneficiaries
- Complements - Capital and labor
- Demand - Users or beneficiaries
- Reliability
- Scarcity and substitutability

**BRIs (people implicit)**
Weight extent of biophysical change by a quality that is relevant to beneficiaries
Examples:
- Area with stable groundwater levels (water supply)
- Number of rare species with enhanced population viability (non-use value of aquatic ecosystem)

**BRIs (people explicit)**
Weight a biophysical change by the number of affected people or the intensity of concern
Examples:
- Number of private well users with stable groundwater supply