Habitat Evaluation Scoring Method to Estimate Ecosystem Service Improvements from Restoration

Timothy Barber, Jennifer Lyndall, and Wendy Mahaney
The Challenge – Valuation of Ecosystem Services from Restoration

Natural resource damage assessments attempt to make the public whole through restoration or replacement of the injured natural resource, or for acquisition of an equivalent resource [CERCLA §107(f)(1)].

How can you value the flow of ecosystem services in a scientifically sound manner?
The Natural Resource Damage Assessment Process

- Evaluate injury to natural resource services
- Determine whether injury has occurred
- Quantify the extent and severity of injury
- Injury estimates are used to scale restoration actions
Valuation of Injury/Restoration Credit

- Best professional judgment
- Literature reviews
- Case precedents
- *Functional assessment methods*
Habitat Equivalency Analysis (HEA)

• Service to service valuation method
• Uses resource-specific units
• Represents “services” provided but for the injury
• Two Components
  – Injury (debit) calculation
  – Restoration (credit) calculation
Habitat Equivalency Analysis

- Parameters
  - Present Year
  - Project Start Year
  - Relative Benefits/Service Improvement
  - Maturation Curve
  - Project Lifespan
  - Discount Rate
Habitat Equivalency Analysis

• Maturity Curve
  – Time to full maturity/recovery of project
  – Shape of recovery trajectory
    • Linear
    • Sigmoidal

• Lifespan
  – Life expectancy of project
  – Can incorporate multiple factors
    • Erosion rates
    • Sea level rise
    • Storm damage
Habitat Equivalency Analysis

• Relative Benefit/Service Improvement
  – Improvement in ecosystem function relative to baseline conditions
    • Historical or pre-incident conditions
    • Adjacent natural marsh condition (reference site)
    • Condition after injury (pre-restoration condition)
  – No standard method of determining service improvement
  – Often arbitrarily determined
Assessing Ecosystem Function

“Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem” – King & Mazzotta 2000

- Biomass production
- Decomposition
- Water retention, storage, processing
- Nutrient cycling
- Soil formation and retention
- Provision of habitat
Functional Assessments

• Used to evaluate ecosystem functions and/or services
• Range from quick, semi-quantitative to detailed, quantitative models
• Examples: WVA, HSI, HGM
  – Mostly for wetland habitats
  – A few for other habitat types
    • Barrier islands, forests, lakes & streams
  – Habitat-specific and often regional
• Input parameters vary by approach
# Functional Assessments

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Components</th>
<th>Habitat Types</th>
<th>Geographic Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>FQI / FQAI</td>
<td>Vegetation by ecological conservatism</td>
<td>Wetland, forest, prairie, savannah (separately by community types)</td>
<td>Regional - US</td>
</tr>
<tr>
<td>HEP / HSI</td>
<td>Quality and quantity of habitat for wildlife, fish, invertebrates</td>
<td>Most terrestrial, wetland &amp; aquatic habitats</td>
<td>Regional - US</td>
</tr>
<tr>
<td>HGM</td>
<td>Assessment of wetland functions (hydrology, biogeochemistry, habitat)</td>
<td>Wetlands (separately for each subclass)</td>
<td>Regional - US</td>
</tr>
<tr>
<td>IBI</td>
<td>Biological condition (fish, plants, invertebrates)</td>
<td>Lakes, streams, wetlands</td>
<td>Regional - US</td>
</tr>
<tr>
<td>RAP</td>
<td>8 Wetland function (hydrology, detritus, vegetation, fauna)</td>
<td>Wetlands (separately by subclass)</td>
<td>Regional – NE and Midwest US</td>
</tr>
<tr>
<td>WET</td>
<td>11 wetland functions (hydrology, recreation, biogeochemistry, habitat)</td>
<td>Wetlands (can compare different types)</td>
<td>US</td>
</tr>
<tr>
<td>WVA</td>
<td>Quantity and quality of habitat</td>
<td>Wetlands, Barrier Island/Headland, Coastal Chenier/Ridge</td>
<td>Coastal Louisiana</td>
</tr>
</tbody>
</table>
New Hybrid Functional Assessment

• Compare baseline site to post-restoration expected improvements
  – Score pre- and post- restoration conditions
  – Score references sites to establish baseline

• Flexible list of parameters
  – Representing biological, physical, chemical, and human use functions
  – Generalizable across habitats & regions
  – Optional weighting factors for parameters
Hybrid Model Parameters

- **Biological Functions**
  - Vegetation quality
  - Wildlife Utilization
  - Biodiversity
  - Habitat Quality

- **Chemical Functions**
  - Water Quality
  - Carbon Export
  - Nutrient cycling

- **Physical Functions**
  - Adjacent upland support
  - Substrate quality
  - Hydrologic Modification
  - Hydrologic Connectivity
  - Erosion Control
  - Shoreline Protection

- **Human Use Potential**
Hybrid Assessment Model

• Scores individual ecosystem functions on scale of 0-4
  – 0 represents little to no functional capacity
  – 4 represents the highest level of function

• Weighting factors can be used to adjust which functional parameters are most important or applicable to a restoration project
## Hybrid Scoring Sheet

<table>
<thead>
<tr>
<th>Metric</th>
<th>Weighting Factor</th>
<th>Pre-Restoration Score</th>
<th>Post-Restoration Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0    1  2  3  4</td>
<td>TOTAL</td>
<td>0    1  2  3  4 TOTAL</td>
</tr>
<tr>
<td><strong>BIOLOGICAL FUNCTION</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Vegetation Quality</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>% Ground Cover</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>% Canopy Cover</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>% Invasive Species</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>% Open Water</td>
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<tr>
<td>Wildlife Utilization</td>
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<td></td>
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<tr>
<td>Fish and invertebrates</td>
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<tr>
<td>Mammals</td>
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<tr>
<td>Birds</td>
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<tr>
<td>Turtles</td>
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<tr>
<td>Habitat Quality</td>
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<tr>
<td>Refugia/Shelter</td>
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<tr>
<td>Nursery Habitat</td>
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<td></td>
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<tr>
<td>Foraging Habitat</td>
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<tr>
<td><strong>PHYSICAL FUNCTION</strong></td>
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<tr>
<td>Adjacent Upland Support</td>
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<td>Substrate Quality</td>
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<td></td>
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<tr>
<td>Hydrologic Modification</td>
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<td>Hydrologic Connectivity</td>
<td></td>
<td></td>
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<tr>
<td>Erosion Control/Sediment Retention</td>
<td></td>
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<tr>
<td>Shoreline Protection</td>
<td></td>
<td></td>
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<tr>
<td><strong>CHEMICAL FUNCTION</strong></td>
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<td></td>
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<tr>
<td>Water Quality</td>
<td></td>
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<tr>
<td>Productivity</td>
<td></td>
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<tr>
<td>Nutrient Cycling</td>
<td></td>
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<tr>
<td><strong>HUMAN USE FUNCTION</strong></td>
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<td></td>
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<tr>
<td>Human Use Potential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE TOTAL</td>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
</tbody>
</table>
### Hybrid Scoring Sheet Criteria

<table>
<thead>
<tr>
<th>Vegetation Quality</th>
<th>0%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Ground Cover</td>
<td>0%</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>% Canopy Cover</td>
<td>0%</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>% Invasive</td>
<td>76-100%</td>
<td>41-75%</td>
<td>21-40%</td>
<td>11-20%</td>
<td>0-10%</td>
</tr>
<tr>
<td>% Open Water</td>
<td>76-100%</td>
<td>41-75%</td>
<td>21-40%</td>
<td>11-20%</td>
<td>0-10%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wildlife Utilization / Diversity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish &amp; invertebrates</td>
<td>Low / no diversity</td>
<td>Moderate-low diversity</td>
<td>Moderate diversity</td>
<td>Moderate-high diversity</td>
<td>High diversity</td>
</tr>
<tr>
<td>Mammals</td>
<td>Low / no diversity</td>
<td>Moderate-low diversity</td>
<td>Moderate diversity</td>
<td>Moderate-high diversity</td>
<td>High diversity</td>
</tr>
<tr>
<td>Birds</td>
<td>Low / no diversity</td>
<td>Moderate-low diversity</td>
<td>Moderate diversity</td>
<td>Moderate-high diversity</td>
<td>High diversity</td>
</tr>
<tr>
<td>Turtles</td>
<td>Low / no diversity</td>
<td>Moderate-low diversity</td>
<td>Moderate diversity</td>
<td>Moderate-high diversity</td>
<td>High diversity</td>
</tr>
</tbody>
</table>

### Habitat Quality For Typical Species in this Habitat Type

<table>
<thead>
<tr>
<th>Refugia/Shelter</th>
<th>Little / no function</th>
<th>Heavily impaired</th>
<th>Moderately impaired</th>
<th>Slightly impaired</th>
<th>Not impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery Habitat</td>
<td>Little function</td>
<td>Heavily impaired</td>
<td>Moderately impaired</td>
<td>Slightly impaired</td>
<td>Not impaired</td>
</tr>
<tr>
<td>Foraging Habitat</td>
<td>Little function</td>
<td>Heavily impaired</td>
<td>Moderately impaired</td>
<td>Slightly impaired</td>
<td>Not impaired</td>
</tr>
</tbody>
</table>
# Hybrid Scoring Sheet Criteria

<table>
<thead>
<tr>
<th>SCORE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL FUNCTION</strong></td>
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<td><strong>PHYSICAL FUNCTION</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Adjacent Upland Support</strong></td>
<td>Subwatershed is &gt; 90% developed</td>
<td>Subwatershed is 70-90% developed</td>
<td>Subwatershed is 40-70% developed</td>
<td>Subwatershed is 20-40% developed</td>
<td>Subwatershed is &lt; 20% developed</td>
</tr>
<tr>
<td><strong>Substrate Quality</strong></td>
<td>Severely altered; function heavily impaired</td>
<td>Highly impacted; function impaired</td>
<td>Moderately impacted; function moderately impaired</td>
<td>Slightly impacted; function slightly impaired</td>
<td>High quality; no functional impairment</td>
</tr>
<tr>
<td><strong>Hydrologic Modification</strong></td>
<td>Severe; heavily controlled</td>
<td>High; function impaired</td>
<td>Moderate; some impairment</td>
<td>Slight; some impairment</td>
<td>None; mostly natural function</td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td>Hydrologic connections severed</td>
<td>Hydrologic connections severely impaired</td>
<td>Hydrologic connections moderately impaired</td>
<td>Hydrologic connections slightly impaired</td>
<td>Hydrologic connections primarily intact</td>
</tr>
<tr>
<td><strong>Erosion Control / Sediment Retention</strong></td>
<td>High erosion, no retention</td>
<td>Moderate-high erosion, little retention</td>
<td>Moderate levels of erosion and retention</td>
<td>Moderate-low erosion, moderate-high retention</td>
<td>Low erosion, high retention</td>
</tr>
<tr>
<td><strong>Shoreline Protection</strong></td>
<td>No protection</td>
<td>Little protection</td>
<td>Moderate protection</td>
<td>Moderate-high protection</td>
<td>High protection</td>
</tr>
<tr>
<td><strong>CHEMICAL FUNCTION</strong></td>
<td><strong>CHEMICAL FUNCTION</strong></td>
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<td><strong>CHEMICAL FUNCTION</strong></td>
<td><strong>CHEMICAL FUNCTION</strong></td>
</tr>
<tr>
<td><strong>Water Quality</strong></td>
<td>Very poor</td>
<td>Severely impaired</td>
<td>Moderately impaired</td>
<td>Slightly impaired</td>
<td>Little impairment</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>No productivity</td>
<td>Low productivity</td>
<td>Low to moderate productivity</td>
<td>Moderate productivity</td>
<td>Typical of habitat type</td>
</tr>
<tr>
<td><strong>Nutrient Cycling</strong></td>
<td>Slow cycling and little nutrient removal</td>
<td>Moderate-slow cycling and removal</td>
<td>Moderate cycling and removal</td>
<td>Moderate-fast cycling and removal</td>
<td>Rapid cycling and high nutrient removal</td>
</tr>
<tr>
<td><strong>HUMAN USE FUNCTION</strong></td>
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</tr>
<tr>
<td><strong>Human Use Potential</strong></td>
<td>Low</td>
<td>Moderate-Low</td>
<td>Moderate</td>
<td>Moderate-High</td>
<td>High</td>
</tr>
</tbody>
</table>
Open Water and Marsh Edge

Source: Environmental Working Group 2007
Vegetative Cover

High vegetative cover

Low vegetative cover

Photo Credit: Mary Sorensen
Landscape Setting: Upland Support

Urban setting – Low upland support

Rural setting – High upland support

Image source: Google
Hydrologic Modification

Severe hydrologic modification

Low hydrologic modification

Image source: Google
Invasive Species

Native Species

Invasive Species

Photo credit: chicagobotanic.org

Photo credit: dnr.wi.gov

Photo credit: chicagobotanic.org
Example Sites

Garbage dump

Reference Marsh

Marsh Dieback

Photo Credit: Mary Sorensen
Hybrid Scoring Example

• **Pre-Restoration Condition**
  – Current condition of the restoration site

• **Post-Restoration Condition**
  – Expected conditions after restoration is completed
  – At full maturity

• **Baseline Condition**
  – Identical habitat type
  – Close proximity to restoration site
  – Not affected by the “disturbance event”
  – Functions as a reference standard for comparison
## Hybrid Scoring Example

**Project Site:** Example One  
**Date:** 2012  
**Habitat Type:** Salt Marsh  
**Name:** TB

<table>
<thead>
<tr>
<th>Metric</th>
<th>Weighting Factor</th>
<th>Pre-Restoration Score</th>
<th>Post-Restoration Score</th>
<th>Baseline Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 1 2 3 4 TOTAL</td>
<td>0 1 2 3 4 TOTAL</td>
<td>0 1 2 3 4 TOTAL</td>
</tr>
</tbody>
</table>

### Biological Function

#### Vegetation Quality
- % Ground Cover: X 3 X 4  
- % Canopy Cover: X 0 X 2 X 3  
- % Invasive Species: X 0 X 4  
- % Open Water: X 1 X 3 X 3

#### Wildlife Utilization
- Fish and invertebrates: X 1 X 3 X 4  
- Mammals: X 1 X 3 X 4  
- Birds: X 2 X 3 X 4  
- Turtles: X 1 X 3 X 4

#### Habitat Quality
- Refugia/Shelter: X 1 X 3 X 4  
- Nursery Habitat: X 1 X 3 X 4  
- Foraging Habitat: X 2 X 3 X 4

### Physical Function

#### Adjacent Upland Support
- X 1 X 1 X 1

#### Substrate Quality
- X 1 X 2 X 3

#### Hydrologic Modification
- X 1 X 2 X 3

#### Hydrologic Connectivity
- X 1 X 3 X 3

#### Erosion Control/Sediment Retention
- X 0 X 3 X 3

#### Shoreline Protection
- X 0 X 3 X 3

### Chemical Function

#### Water Quality
- X 1 X 3 X 3

#### Productivity
- X 1 X 3 X 3

#### Nutrient Cycling
- X 2 X 3 X 3

### Human Use Function

#### Human Use Potential
- X 3 X 4 X 4

### SITE TOTAL

- Pre: 24  
- Post: 61  
- Baseline: 71
• **Pre- vs. Post-Comparison**
  – Improvement of 254%
  – Some conditions improved greatly (water quality, shoreline protection)
  – Other conditions did not improve (upland support)

• **Baseline Comparison**
  – 27% improvement from pre-restoration conditions to post-restoration conditions, relative to baseline
  – Now serves 86% of the function of the reference marsh
Restoration Credit Analysis

• Compared to reference site
  – Relative benefits = 27%
  – Start date = 2013
  – 5 years to full maturity
  – Linear maturity curve
  – 30 year lifespan
  – 3% discount rate
  – 5 DSAYs per acre
Advantages of Using Functional Assessments in HEA

• Provides common framework to estimate service improvements
• Clearly communicates expectations of the restoration project to the public
• Improves linkage between design, valuation, and short- and long-term performance measures
Potential Disadvantages of Using Functional Assessments in HEA

• HEA is a simple tool, allowing maximum flexibility – incorporating functional assessments into process adds complexity
• Very difficult to predict performance of a restored biological system
• Functional assessment metrics do not necessarily translate into ecosystem services
Take Home Messages

• Although very challenging, current regulations require the valuation of services provided from restored habitats
• Incorporating functional assessments into the HEA model provides a more transparent method to predict restoration benefits
• Without a clear basis for the valuation, there is no defensible way to document success or failure of a specific action