Monitoring for Ecosystem Restoration

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Water Operations Technical Support (WOTS)
Monitoring and Adaptive Management
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Overview

Presentation outline:

- Problem definition and challenges
- Definition of monitoring
- Purposes of monitoring
- Current guidance from HQ
- Principles of monitoring
- Categories and elements of monitoring
- Methods of monitoring
- References

Problem Definition and Challenges

- Kondolf and Micheli 1995, NRRSS publications, *Journal of Applied Ecology* 2005 forum on river restoration standards, Zedler 2007: monitoring is critical for multiple needs, ignored, and poorly executed
- OMB and WRDA 2007: benefits of ecosystem restoration activities must be documented; monitoring needs to be addressed
- USACE works in many ecosystem and project domains and at multiple scales

Monitoring Categories

- Large scale environmental monitoring for program or project prioritization, selection, and design—baseline, status and trend
- Programmatic review and design
- Project implementation compliance
- **"…assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed…"** for both restoration and mitigation activities
- Validation of conceptual models

General Project Monitoring Objectives

- Determine and prioritize needs
- **To support adaptive management**
- **Assessing and justifying expenditures**
- **To minimize costs and maximize benefits**
- **To determine “ecological success”, document, and communicate it**
- **To advance state of practice**

WRDA 2007

Guidance documents for Sections 2036 (a) and 2039 issued on 31 August, 2009.

- USACE CECW-PB. Implementation Guidance for Section 2039—Monitoring Ecosystem Restoration. Memorandum.
- USACE CECW-PC. Implementation Guidance for Section 2036(a)-Mitigation for Fish and Wildlife and Wetlands Losses. Memorandum.

Project Monitoring--Definition

"…includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits."

USACE CECW-PB, 8/31/09

Section 2039-Monitoring Ecosystem Restoration

- Applies to CAP, specifically authorized projects, and other programmatic authorities
- Development of a monitoring plan will be initiated during plan formulation, focusing on key indicators of project performance.
- Description in the decision document must include rationale for monitoring, specific metrics, the relationship of those metrics to support performance standards addressing desired objectives or decision formulation, uses of the information, and delineation of roles and responsibilities in information management.

Section 2039-Monitoring Ecosystem Restoration

- The plan must specify nature, spatial characteristics, duration, and periodicity of monitoring, disposition of monitoring and analysis, costs, and responsibilities.
- Scope and duration should include the minimum monitoring actions necessary to evaluate success. Need not be complex.
- Monitoring plan will be reviewed during ATR and IEPR as necessary.
- Monitoring plan commences upon completion of construction.
- Monitoring will be continued until “restoration success” is documented by District Engineer in consultation with federal and state resource agencies and determined by Division Commander.

Section 2039-Monitoring Ecosystem Restoration

- Success determined by an evaluation of predicted outcomes vs. actual results.
- Financial and implementation responsibilities for monitoring will be included in the PPA.
- Cost-shared (under Construction) component not to exceed 10 years. Cost shared monitoring costs must be included as part of the project cost and cannot increase the Federal cost beyond the authorized dollar limit. Monitoring can end sooner if success is determined.
- Monitoring beyond 10 years is a 100% non-Federal responsibility.

Section 2039-Monitoring Ecosystem Restoration: Adaptive Management

- An adaptive management plan is required for all ecosystem restoration projects.
- It must be appropriately scoped to project scale.
- The rationale and cost of AM and anticipated adjustments will be reviewed as part of the decision document.
- Identified physical modifications will be cost-shared and must be agreed upon by the sponsor.
- Changes to the AM plan approved in the decision document must be coordinated with HQUSACE.
- Significant changes needed to achieve ecological success that can't be addressed through operational changes or the AM plan may be examined under other authorities.
- Costly AM plans may lead to re-evalution of the project.

Section 2036(a)-Mitigation for Fish and Wildlife and Wetlands Losses

Mitigation plans must include:

- A description of actions to achieve mitigation objectives
- The type, amount and characteristics of habitat being restored.
- Ecological success criteria
- A monitoring plan
- An adaptive management plan
- A description of land interests to be acquired

Salient Points about Guidance

- The Policy has been established
- The profile, use, and importance of monitoring are increasing with project partners potentially playing a bigger role
- “Ecological success” is a central criterion and needs precise definition in individual project contexts
- Monitoring is NOT research and NOT about the process; it’s for efficient, effective application

Restoration process—monitoring roles (in bold)

1. **Define problem**
2. **Develop restoration objectives**
3. **Develop a conceptual model**
4. **Develop restoration hypotheses using model**
5. **Choose target parameters for specific goals**
6. **Evaluate and test hypotheses if possible**
7. Develop design
8. Develop feasibility, cost, and benefit analyses
9. Develop final design
10. **Perform monitoring and adaptive management**

Principles of Project Monitoring

The monitoring must be able to support:

- The ability to make timely, cost-effective, mid-course corrections or improvements(AM)
- The ability to demonstrate to others that the project is meeting or exceeding performance goals
- The “learning organization” and the states of practice and applied science

Characteristics of an Optimal Monitoring Program

- Clear monitoring program goals and objectives
- Appropriate scaling (temporal and spatial) and resource allocation for data collections, management, intrepretations, and analyses
- QA/QC procedures, possible peer review
- Programmatic and procedural flexibility when indicated
- Reasonable costs
- High implementation efficiency
- Reportability to diverse audiences

Objectives: Structural, Functional, Service-related

- Environmental improvement may be gauged through changes in both ecosystem structure and function.
- Defining “structure” and “function” (from Heal et al. 2005)
  - Ecosystem structure refers to both the composition of the ecosystem (i.e., its various parts) and the physical and biological organization defining how those parts are organized.
  - Ecosystem function describes a process that takes place in an ecosystem as a result of the interactions of the plants, animals, and other elements in the ecosystem with each other or their environment.
    - Ecosystem goods and services are those functions that provide clear value to society

Common Categories of Objectives

Category	Description	Sample Objectives
Hydrogeomorphology	Physical setting of an aquatic ecosystem and includes physical processes such as hydrologic cycling, local and regional climate, geologic history and process, and watershed land use change as well as the interaction of these processes to create the sediment regime, channel hydraulics, and local geomorphology.	Benefits: Maintain peak flows sufficient to induce overbank flooding. Services: Promote watershed retention of fine sediment to avoid costly filtration.
Biogeochemistry	Refers to the "chemical integrity" of a system and addresses the concentration of nutrients, contaminants, and other constituents in an ecosystem as well as their fate and transport.	Benefits: Enhance riparian denitrification. Services: Reduce drinking water treatment costs.
Biological Systems	"Biological integrity" results from the reproduction, survival, and colonization by living components of ecosystems.	Benefits: Increase fish-based index of biotic integrity. Services: Increase shellfishery yield.
Socio-economics	Instrumental value to humans through local, regional, and national economic benefits, local development and infrastructure, active use (e.g., recreation), and passive use (e.g., aesthetics).	Benefits: Increase habitat for recreationally hunted waterfowl. Services: Reduce disease by regulating vectors (e.g., mosquitoes).
Cultural-Personal Values	Intrinsic values associated with an ecosystem and their direct and indirect influences on ecosystem processes. (e.g., cultural interaction, politico-legal processes, personal/institutional motivations)	Benefits: Provide fair treatment of historically disenfranchised communities. Services: Provide an aesthetically pleasing project.

Techniques for Objective Setting

- **Structured objective setting** (Gregory and Keeney 2002):
  - Step 1: Write down the concerns you want to address.
  - Step 2: Convert the general concerns into specific, succinct objectives.
  - Step 3: Organize objectives.
  - Step 4: Clarify what is meant by each objective.
- **Application of existing assessments**: Agency, NGO, and state assessments are important sources of existing conditions for ecosystems and taxa and often highlight problem areas for restoration.
- **Use of conceptual models**: Conceptual model development can provide a forum to discuss system function, goals, and objectives.
- **Referenced-based approaches**: Reference ecosystems may also help project teams identify desirable characteristics of a system and natural ranges of variability, and then incorporate those into objectives.

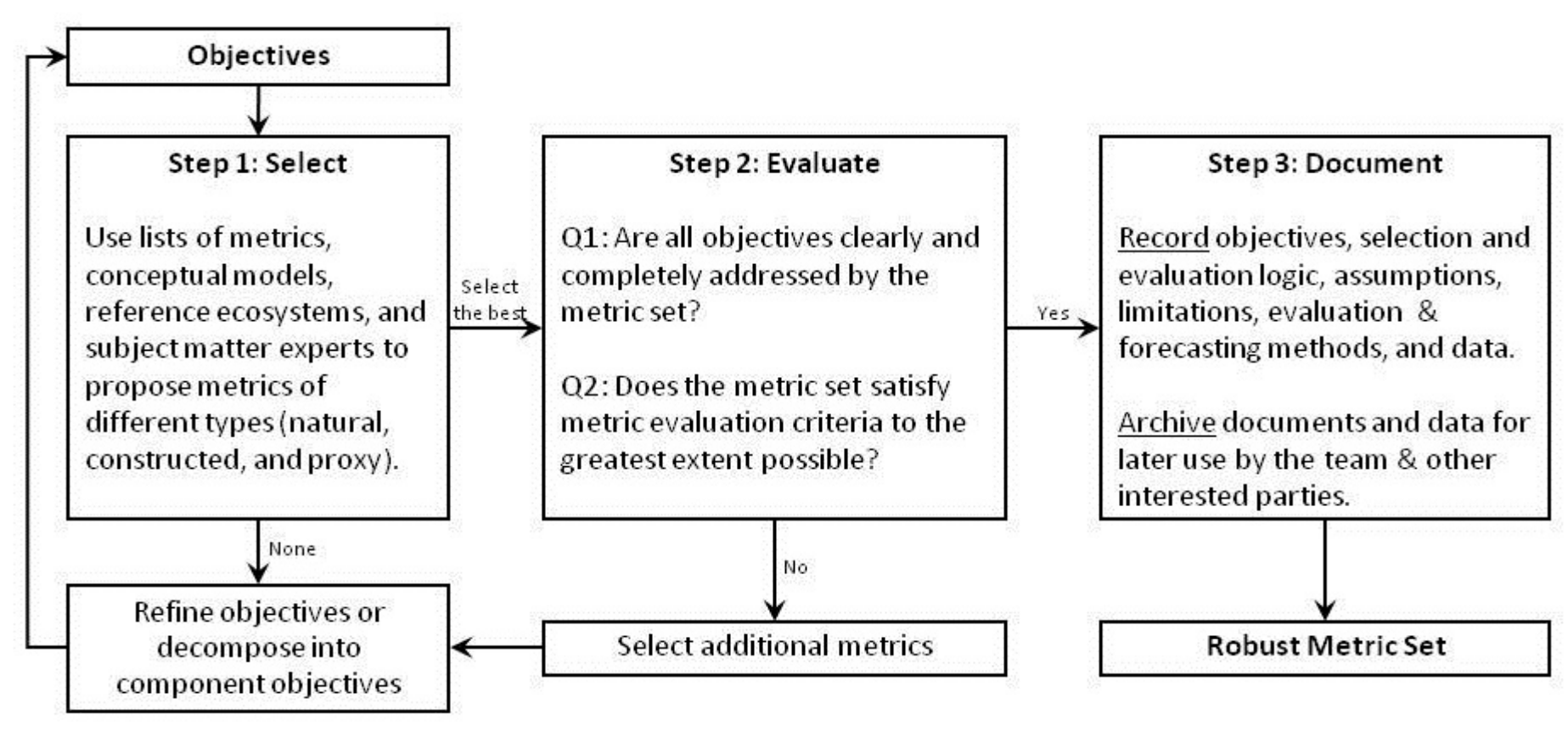
Evaluating Objectives

- Objectives should be iteratively developed and critically evaluated by the project development team, cost-share sponsor, partner agencies, stakeholders, and other interested parties (e.g., HQUSACE).
- A few key points of consideration include:
  - Useful objective sets are complete, clear, non-redundant, specific, flexible, understandable, measurable, attainable, congruent, and acceptable.
  - Objectives should be separate from metrics and alternatives.
  - Key thresholds for achievement should be explicitly noted in objectives.
  - Address dependency among objectives.
  - Objectives reside in a hierarchy of local, regional, agency, and national scale decision-making.

What is a “metric”?

- Ecosystem restoration projects often have multiple objectives.
- **Metrics are measurable properties that quantify the degree to which objectives have been achieved (Reichert et al. 2007).**
- Multiple metrics relating to ecosystem structure, function, goods, and/or services may be required to assess the overall benefits associated with a restoration project.

Metric Development



What does a good metric set look like? (McKay, 2009)

EPA (2000) – EMAP

1: Conceptual relevance
- 1.1: Relevance to the assessment
- 1.2: Relevance to ecological function

2: Feasibility of implementation
- 2.1: Data collection methods
- 2.2: Logistics
- 2.3: Information management
- 2.4: Quality assurance
- 2.5: Monetary costs

3: Response variability
- 3.1: Estimation of measurement error
- 3.2: Temporal variability (within-season)
- 3.3: Temporal variability (across-year)
- 3.4: Spatial variability
- 3.5: Discriminatory ability

4: Interpretation and utility
- 4.1: Data quality objectives
- 4.2: Assessment thresholds
- 4.3: Linkage to management action

NRC (2000) – National Ecological Indicators

General Importance	Conceptual Basis
Reliability	Statistical Properties
Data Requirements	Necessary Skills
Robustness	International Compatibility

Temporal and Spatial Scales of Applicability

Costs, Benefits, and Cost-Effectiveness

Keeney and Gregory (2005) – Decision Metrics

Comprehensive	Direct
Operational	Understandable
Unambiguous	

Desirable Metric Properties

Relevant

Unambiguous

Comprehensive

Direct

Operational

Understandable

Evaluation Criteria

Criterion	Description
Relevant	Relevant metrics account for specified objectives and priorities of decision-makers (e.g., resource significance, project authority) at appropriate spatial and temporal scales and resolution. To maintain scientific validity, a relevant metric is repeatable and verifiable.
Unambiguous	Unambiguous metrics clearly measure consequences of alternatives and are not obscured by direction, magnitude, scale, thresholds, or uncertainty.
Direct	Direct metrics address objectives as clearly as possible. This underscores the importance of measuring what can be controlled by a given action since restoration success can be reliant upon many variables beyond the control of the restoration team.
Operational	Operational metrics are logistically and analytically achievable with available resources and capability. If a metric cannot be assessed, forecasted, or monitored within budget, time, or labor constraints, then it cannot feasibly inform decisions.
Understandable	Understandable metrics clearly communicate decisions to those interested in the analysis.
Comprehensive	Comprehensive metric sets address the suite of objectives and cover the potential range of consequences. In terms of implementation, comprehensiveness is often captured through multiple metrics and well-designed monitoring and forecasting programs.

Techniques for Metric Comparison

Technique	Examples
Narrative Description	• Listing evidence: Multiple metrics are presented in parallel. • Best professional judgment: Metrics are integrated using judgment and experience, logic, or causal criteria. • Scoring and indexing: Individual lines of evidence are scored or weighted by the analyst and combined quantitatively (e.g., USACE budget ranking criteria).
Arithmetic Combination	• Simple arithmetic: summation or averaging • Nested combination: Nesting arithmetic combinations to capture a known process (e.g., habitat suitability indices combine multiple variables). • Conversion to consistent units: dollars, energy, habitat units, etc. • Transformation to consistent scales. Normalized to an equivalent scale (e.g., 0 to 1), dividing project benefits of a relative benefit (e.g., FWOP), use of reference conditions
Multicriteria Decision Analysis	This technique uses weighted combination of metrics to capture their relative importance in a decision. Although not explicitly weighted, even the simplest arithmetic combination methods are implicitly weighted; that is, all parameters are assumed to have equal weight and import. Although weights are subjective and derived from expert opinion in MCDA, judgments are collected using visible and traceable methods.
Interdependent Combination	Analysis of dependencies can range in complexity from simple linear dependency of fish passage projects to intricate Bayesian belief networks.

Evaluating Metric Comparisons

- Practicality: What resources (time, cost, expertise) are available for use in the analysis?
- Transparency: What is the public profile of the decision? Are analyses commensurate with the importance of the decision? What are expected external impacts of the decision?
- Value: What is the role of value in the decision? Are some objectives and metrics more important than others from scientific or social perspectives?
- Analytical Requirements: Are there multiple metrics? Is there a need for quantitative combination? Can scoring or indexing meet the project needs? Do the metrics have equivalent units? Can metrics be combined linearly (e.g., arithmetic mean, summation)? Are there non-linear effects associated with combination (e.g., geometric mean, thresholds)? Do metrics need to be transformed to a consistent scale for comparison?
- Uncertainty: How much uncertainty is there in assessments or forecasts of the metrics? Could this uncertainty alter the decision made? To what degree should methods be able to track uncertainties?
- Dependency: Are objectives interdependent? Are these dependencies quantifiable?

Developing a monitoring program

1. Define the problem, goals, and objectives
2. Conduct baseline or comparative (e.g. reference) studies
3. Develop, review, or refine the conceptual model
4. Categorize and coordinate data needs
5. Choose monitoring parameters (controlling factors, structure, or functions? direct or indirect? abiotic and biotic? supplemental?), methods, and performance criteria
6. Specify sampling design (spatial limits, periodicity, frequency, sample numbers), processing, roles, duration
7. Determine analytic needs
8. Develop data management, storage, and flow paths
9. Identify action triggers for AM
10. Estimate cost and component costs
11. Modify M&AM as necessary

Technical Challenges

- Varying techniques for form or process-based restoration techniques
- System context—many projects are narrow in scope and goals
- Design and utilization of hierarchical or multi-scaled approaches
- Parsing of the restoration signal from exogenous influences, the "natural range of variation, and direct from indirect effects of restoration actions
- Non-linear phenomena, e.g. critical thresholds
- The temporal or spatial roles of the target ecosystem's disturbance regime, stochasticity, and hysteresis (a specific response to restoration may not reflect the response to impact in rate or trajectory)
- Scalability of findings
- Numerical and statistical issues
- QA/QC

Factors in Choosing Monitoring Intensity

- Size of project
- Public profile of project
- Consequences for project success or failure
- Complexity of project and ecosystem
- Roles of disturbance regime
- Range of natural variation
- Diversity of project set and settings

Varying Ecosystems=Varying Drivers, Structural Characteristics, Functional Processes

- Freshwater wetlands
- Streams and rivers
- Lakes and reservoirs
- Subtidal estuaries
- Estuarine and coastal wetlands
- Open coastline and near coastal waters

Monitoring Design Categories

- Before-After (BA)
- Before-After-Control-Impact (BACI)
- Intensive Post-Treatment (one or few sites)
- Extensive Post-Treatment (many sites)
- Staircase (many sites implemented regularly over many years)

Statistical Tools

- Power analysis to help determine duration, number of sampling sites, and number of samples are needed to detect a change in a parameter of interest
- Testing tools (e.g., parametric, regression, non-parametric, bootstrap, multivariate, etc.)—select before monitoring design is completed
- In many smaller or simpler cases, descriptive statistics are adequate (see earlier slide on monitoring intensity)

Commonly used protocols and measures

- Biomonitoring (diatoms, algae, macroinvertebrates), including RBP
- HGM
- HEP
- Geomorphic measures
- Trophic state index
- Fish IBI
- Top carnivore (fish) index
- Water column bacteria
- Specific conductivity
- Eutrophication
- Acidification
- Salinity trends
- Thermal alteration
- Contaminant presence or nutrient loading

Case Study-CERP

http://www.evergladesplan.org/pm/recover/recover_docs/map/MAP_5.0_Implement.pdf

Criteria for selection:

- Criterion 1 - Does the monitoring component address a critical issue in the regional conceptual ecological models?
- Criterion 2 - Does the monitoring component have the ability to discriminate between CERP and non-CERP effects?
- Criterion 3 - Is this the most cost-effective manner in which to execute the monitoring component?
- Criterion 4 - Does this monitoring component complement, leverage, or utilize relevant ongoing monitoring programs or initiatives?
- Criterion 5 - Is the monitoring component a keystone element in assessing restoration expectations?

Case Study-CERP

http://www.evergladesplan.org/pm/recover/recover_docs/map/MAP_5.0_Implement.pdf

Criteria for selection:

- Criterion 6 - Is the monitoring component an intermediate link toward understanding why other important components have changed?
- Criterion 7 - Is there an adequate long-term record for the monitoring component?
- Criterion 8 - Does the monitoring provide supporting information for interim goal/interim target indicators?
- Criterion 9 - Does monitoring this component provide information that will be important to stakeholders in determining if the goals and objectives of the CERP are being achieved?
- Criterion 10 - Are data provided by this monitoring component necessary within: (1) 0-2 years,
- (2) 2-4 years, (3) 4-6 years, (4) more than 6 years?

Case Study-CERP

- >75 spatial, abiotic, and biotic elements
- Careful scaling
- Extensive WQ, hydrometeorological, and hydraulic measures
- Robust QA/QC program (http://www.evergladesplan.org/pm/qaot.aspx)

Central Peer-reviewed Sources

- Bernhardt et al. 2005. Synthesizing U.S. River Restoration Efforts. *Science* 308:636-637.
- Kondolf and Micheli. 1995. Evaluating stream restoration projects. *Environmental Management* 19: 1-15.
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- Ralph, S.C. and G.C. Poole. Putting monitoring first: designing accountable ecosystem restoration and management plans. In Montgomery et al., eds. 2002. *Restoration of Puget Sound Rivers.* Seattle: UW Press.
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Central Federal Publications

- National Research Council, 1992. Restoration of Aquatic Ecosystems.
- Thom and Wellman. 1996. Planning Aquatic Ecosystem Restoration Monitoring Programs. IWR Report 96-R-23.
- Yozzo et al. 1996. Planning and Evaluating Restoration of Aquatic Habitats from an Ecological Perspective. IWR Report 96-EL-4.
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- USFS RMRS series

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Questions and Feedback

Presentation recording:
http://el.erdc.usace.army.mil/wots/wots.html

Next Presentation: 10 October 2013: Geomorphic, Hydrologic and Hydraulic Surveys, Sarah Miller, ERDC-EL

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