Indicators of Ecological Change

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A SERDP Ecosystem Management Project (SEMP)
being implemented at Fort Benning, GA

SEMP Technical Advisory Committee Meeting
September 2004
Participants

- Jack Feminella and Kelly Maloney, Department of Biological Sciences, Auburn University — Stream macroinvertebrates
- Thomas Foster, Anthropology Department, Pennsylvania State University — Historical land cover
- Patrick Mulholland, Environmental Sciences Division, Oak Ridge National Laboratory — Aquatic ecology
- Lisa Olsen, Environmental Sciences Division, Oak Ridge National Laboratory — Geographic information and landscape analysis
- David White, Aaron Peacock, and Sarah McNaughton, Center for Environmental Technology, University of Tennessee — Soil microbiology
- Sharon Hermann and Dan Wyrick, Department of Biological Sciences, Auburn University — Terrestrial indicators
- Virginia Dale and Dan Druckenbrod, Environmental Sciences Division, Oak Ridge National Laboratory — Terrestrial and landscape indicators, integration
Objectives

1) To identify indicators that signal ecological change in intensely versus lightly used ecological systems.

2) To ensure that these indicators are feasible for the installation staff to measure and interpret and thus can become a part of the ongoing monitoring system at the installation.
Technical Approach

(a) Determine criteria for indicator selection *
(b) Analyze historical trends in environmental changes to identify potential indicators;
(c) Collect supplemental data relating to proposed indicators (building upon existing data);
(d) Perform experiments to examine how training affects indicators;
(e) Analyze resulting set of indicators for appropriateness, usefulness, and ease of taking the measure;
(f) Develop and implement a technology transfer plan.

Hypothesis: There is a suite of ecological indicators

- **Landscape Metrics**
  - Fragmentation contagion
  - Patch area

- **Terrestrial Ecosystems**
  - Distribution of successional stages
  - Understory composition
  - Presence of key species

- **Stream Ecosystems**
  - Storm concentration profiles
  - Metabolism

- **Macroinvertebrates**
  - Diversity, biomass & abundance
  - Focal populations

- **Soil Microorganisms**
  - Community composition
  - Microbial biomass
  - Physiological status

Landscape Approach

What metrics best describe changes in patterns for the entire Fort Benning area?
Landscape Analyses: Major Results

- Vegetation maps developed from different data sources can be compared
- Changes over time occurred in the vegetation at Forest Benning
  - 1827 to 1974
    - Percent cover of forest declined
    - Pine coverage decreased
    - Increase in deciduous, mixed and nonforest cover
  - 1974 to 1999
    - Gradual increase in the nonforest vegetation (esp. on slopes)
    - Decline in cover of forest vegetation
      - Increase in pine cover
      - Decrease in deciduous cover


Fort Benning Historical Vegetation – 1827

1. Witness tree data
2. Tree classification
3. Interpolation of surface
4. Estimation of cleared areas - large settlements/towns

Ft. Benning
Land Cover Classification Key

- Red: Bare ground or developed areas such as buildings, (highly reflective surfaces)
- Yellow: Non-forest or cleared areas, (ground cover present, includes lawns)
- Light Blue: Deciduous forest (dense)
- Green: Mixed forest (areas of deciduous and pine, widely spaced or sparse forest cover and transitional areas between forest and non-forest)
- Dark Green: Pine forest (dense)
- Blue: Water
The most useful metrics for distinguishing changes in land cover classes at Fort Benning:

- Percent cover
- Total edge (with border)
- Number of patches
- Mean patch area
- Patch area range
- CV of patch area
- Perimeter area ratio
- Euclidean nearest neighbor distance
- Clumpiness

[Choice of metric depends on question]

Terrestrial Indicators: Sampled vegetation and soil microbes in five discrete land-use types (based on observations and experience of Fort Benning staff)

- Reference
- Ground infantry
- Marginal to tracked vehicles use
- Recent tracked vehicle use
- Restored to plantation
Terrestrial Indicators

- **Overstory**
  - Maximum tree age
  - Canopy cover

- **Understory**
  - Percent cover by life form
  - Percent cover by plant family

- **Soils**
  - Depth of A horizon
  - Soil microbial attributes (as determined by lipid biomarker analyses)
    - Biomass
    - Composition
Narrowed List of Plant Indicators

All plant species and life forms

All plant families and life forms

Select plant families and life forms

Transfer of Information

Plant Families and Life Forms Seen in the Fort Benning Area: A Field Guide

Hemicryptophytes  Ground level buds

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<th>Partial Rosette</th>
<th>Rosette</th>
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Analysis of soil microbial community structure and biomass under different military uses

Benefits:
- Easy collection of soil cores
- Ship frozen
- Base or commercial laboratory for analysis
- Potential for monitoring changes
- Readily interpretable

Non parametric approach and parametric approach can be used to classify new information.

Interpretation guide and model will be provided to resource managers that will calculate distance relationships for new microbial data.
K11 Experimental Methods:

- Understory surveyed with Braun-Blanquet percent cover scale in June 2003, Sept 2003, and June 2004
- Raunkiaer (1934) Life-forms used as Functional Types
- % cover transformed using arcsine square-root
- Repeated-Measures ANOVA with SPSS 12.0 GLM
Total Cover

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<th>Factor</th>
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<th>P-value*</th>
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<td>Time</td>
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<td>Quadratic</td>
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<tr>
<td>Treatment•Time</td>
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<tr>
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* G-G adjustment to df’s
Phanerophytes

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<tr>
<td>Quadratic</td>
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</tbody>
</table>

* G-G adjustment to df’s
Research Conclusions

• Total cover initially reduced; however, returns to control levels within growing season

• Phanerophytes and Cryptophytes account for majority of understory cover for both control and treatment

• Phanerophytes display reduced cover through time

• Chamaephytes increase cover through time but not impacted by tracked-vehicle disturbance

• Hemicryptophyte, Cryptophyte, and Therophyte cover may be promoted through time by tracked-vehicle disturbance

Management Implications

• Phanerophytes readily serve as an indicator of understory structure and cover that are reduced by tracked-vehicle activity

• Hemicryptophytes, Cryptophytes, and Therophytes may also serve as an indicator that are promoted by tracked-vehicle activity

• These functional types meet most of the criteria ideally associated with indicators (easily measured, sensitive, anticipatory, etc.)

• These indicators nest into the broader suite of indicators across spatial scales being developed at Fort Benning
Technical Approach: Stream Studies

Land-use gradient analysis (land-use intensity quantified at catchment scale as % land denuded)

Disturbance intensity defined as the sum of:
% bare ground on slopes > 3%
% road coverage

Disturbance classes:
Ref. – K11W, D13, K13 (1.8 – 3.7%)
Low – K11E, F4, F3 (4.6 – 8.1%)
High – D12, F1E, K20, F1W, D6 (10.5 – 14.7%)
Part I:
Potential stream indicators of land use at Fort Benning?
Methods

Water Chemistry –
12 streams 2000 – 2002
grab samples
~ 6 times per year
DOC and pH
coarse woody debris & streambed organic matter – 12 streams measured in 2002 and 2003
Flashiness (9 streams)

LN(Flow) L sec\(^{-1}\) vs. Time (h)

- Flow values: 3.5, 4.0, 4.5, 5.0
- Time values: 0, 2, 4, 6, 8, 10, 12, 14
Bed stability

9 streams measured in Jan. and July 2003

Stability estimated as absolute difference in height between 2 periods

Macroinvertebrates – 7 streams sampled seasonally 2000-2002

4 Hester-Dendy sites (3 H-D units per site)
2 D-frame sweep nets
Fish – 8 streams sampled seasonally in 2003

Electroshock

Semotilus thoreauianus

Pteronotropus euryzonous
Stream Chemistry (baseflow)

With increasing disturbance level:

- Inorganic suspended sediment concentrations increase
- pH increases
- Soluble reactive P and DOC decline
- Some evidence that NH₄ and NO₃ concentrations increase
Macroinvertebrates
### Spring
- **Number EPT**: $R^2 = 0.77$, $p = 0.009$
- **Number Chiron. Taxa**: $R^2 = 0.58$, $p = 0.045$
- **Florida index**: $R^2 = 0.95$, $p < 0.001$

### Summer
- **Number EPT**: $R^2 = 0.52$, $p = 0.069$
- **Number Chiron. Taxa**: $R^2 = 0.68$, $p = 0.022$
- **Florida index**: $R^2 = 0.77$, $p = 0.009$

### Winter
- **Number EPT**: $R^2 = 0.86$, $p = 0.003$
- **Number Chiron. Taxa**: $R^2 = 0.71$, $p = 0.017$
- **Florida index**: $R^2 = 0.91$, $p = 0.001$
% catchment as bare ground and unpaved roads

summer

GASCI

R² = 0.92
p < 0.001

FLSCI

R² = 0.96
p < 0.001

winter

GASCI

R² = 0.90
p = 0.001

FLSCI

R² = 0.59
p = 0.045
Spring

$R^2 = 0.76$

$p = 0.007$

Summer

$R^2 = 0.84$

$p = 0.003$

Winter

$R^2 = 0.86$

$p = 0.002$

P. euryzonus

$R^2 = 0.73$

$p = 0.009$

S. thoreauianus

$R^2 = 0.83$

$p = 0.003$

$R^2 = 0.80$

$p = 0.004$
Part II:
Are small streams influenced more by historic than contemporary land use?
Historic land use (pre-1942)
Military land use

**CRACK RIFLEMAN** firing as advance is made. Recalls "Charge of Light Brigade."

**A RIVER IS CROSSED.** The two biggest demonstrations seen by OC’s are the battalion in attack and the river crossing, shown here in part.

**A GENERAL OR ANY MEDIUM TANK** goes through a puddle brought up for a Gungho run years ago. (L C Sarno, Philet.

**FIRING 37 MILLIMETER** service ammunition in anti-tank instruction at Bickford Range.
Contemporary land use

Selective Harvest

Roads

M1 Abrams

Controlled Burn
Methods

Land use: Aerial Photography (1944) 
Landsat Thematic Imagery (1999).

Proportion of land on slopes > 3% for each time period as:

• bare ground and unpaved road cover (BG)
• non-forested (fields)
Proportion of Catchment Disturbed

% of catchment as BG, unpaved roads, and F

Catchment (in order of 1999 disturbance)

1999

1944
Submerged Coarse Woody Debris

Proportion of catchment as bare ground and unpaved roads

1944

$R^2 = 0.31$

n.s.

1999

$R^2 = 0.81$

$p = 0.0002$
Percent Macroinvertebrates as Clingers

Proportion of catchment as bare ground and unpaved roads

1944

$R^2 = 0.92$
$p = 0.001$

1999

$R^2 = 0.65$
$p = 0.029$
Number of EPT Taxa

1944

$R^2 = 0.82$

$p = 0.005$

1999

$R^2 = 0.75$

$p = 0.011$

Proportion of catchment as bare ground and unpaved roads
Georgia Stream Condition Index

1944

GASCI score

Proportion of catchment as bare ground and unpaved roads

1999

$R^2 = 0.58$
$p = 0.046$

$R^2 = 0.94$
$p = 0.0003$
Number Fish Taxa

1944

$R^2 = 0.84$

$p = 0.001$

1999

$R^2 = 0.44$

n.s.

Total fish taxa

Proportion of catchment as bare ground and unpaved roads
Ecosystem Process: Stream Metabolism

- Respiration rates decline with increasing disturbance level
- GPP rates are very low and show little effect of disturbance

Summary

• **DOC** and **pH**
  – weak indicators
  – best explained by contemporary land use

• **Stream physical habitat:**
  – **CWD, BPOM, Flashiness**: good indicators and best explained by contemporary land use
  – **Stability**: weak indicator, explained by historic land use

• **Macroinvertebrates:**
  – **EPT**: good indicator, explained by historic land use
  – **Chironomidae richness** and **GASCI**: strong indicators and no legacy effect

• **Fish:**
  – **Assemblage metrics**: poor indicators, related to historic land use.
  – **Population metrics**: good indicators, both sensitive and tolerant populations related to contemporary land use
Submitted Data to the SEMP Data Repository

• Landscape Data
• Understory Vegetation
• Microbial Community
• Benthic Invertebrates
• Storm Chemistry Data

Historical and Current Land Cover
Integration

Contributions to Other SEMP Projects
- Criteria for selecting a suite of indicators
- Protocol for selecting indicators
- Data from our studies on indicators: terrestrial, stream, and soil microbes
- Historical vegetation map
- Disturbance experiment

Coordination with Other SEMP Projects
- Baseline information provided by ECMI and LCTA
- Co-location of sampling sites and sharing of data with other SEMP projects
  - Storm hydrological chemistry
  - Stream macroinvertebrates
  - Soil samples
- A comprehensive picture of changes in microbial community structure
Products

Publications:

*Journal:* 8 published or in press and 7 in review
*Book chapter:* 1
*Other:* 3

Presentations:

32 Professional meetings – for example:
- Alabama Water Resources Conference
- American Society of Testing and Materials (plenary)
- Ecological Society of America (symposia)
- Ecological Society of Germany, Switzerland and Austria (plenary)
- American Society of Agronomy (symposium)
- DoD Conservation Conference
- Geological Society of America (symposium)
- International Association of Landscape Ecology
- Integrating the Science (Plenary)
- North American Benthological Society
- Southern Forestry and Natural Resource Management GIS Conference
- Society of American Archaeology
- Ecology Interactions in the Microbial World (symposium)
- The World Conservation Union (IUCN) workshop

8 Other meetings
Outreach to other efforts

- Co-Chair NEON workshop on land use and habitat alteration, August 2004
- Co-Chair NEON workshop on climate change, August 2004
- Member, Science Advisory Committee of the US Department of Interior Grand Canyon Monitoring and Research Center, 2000-2004
- Member: National Academy Committee on Ecological Impacts of Road Density, 2000-2004
- Environmental Protection Agency Scientific Advisory Board
  - Ecological Processes and Effects Committee-Chair 2002-2004
  - Chair of review panel of EPA’s report on the Environment, 2004
- Advisory Committee and participant in workshop and symposium on “Land Use in Rural America” 2001-2003 *
- Scientific Review Committee for The Nature Conservancy, 2000-2001
- Sustainable Biosphere Initiative, Chair of Advisory Committee for the Land Use Initiative, 1999-2000

Next Steps

• Complete data analysis
• Submit scientific papers
• Debriefing for Fort Benning resource managers
• Poster at SERDP Symposium
• Lessons learned from the application of experimental disturbances
• Final report
  – clear definition and descriptions of each indicator
  – sampling protocols
  – laboratory protocols
  – data analysis and interpretation guidelines
• Testing of indicators
  – DMPRC proposal (submitted February 2004)
  – Fort Bragg Fall Line proposal (revised version submitted Sept 2004)