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
April 16, 2002

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
- Virginia Dale, Environmental Sciences Division, Oak Ridge National Laboratory — Terrestrial indicators

Objectives

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

- 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) Analyze historical trends in environmental changes to identify potential indicators;

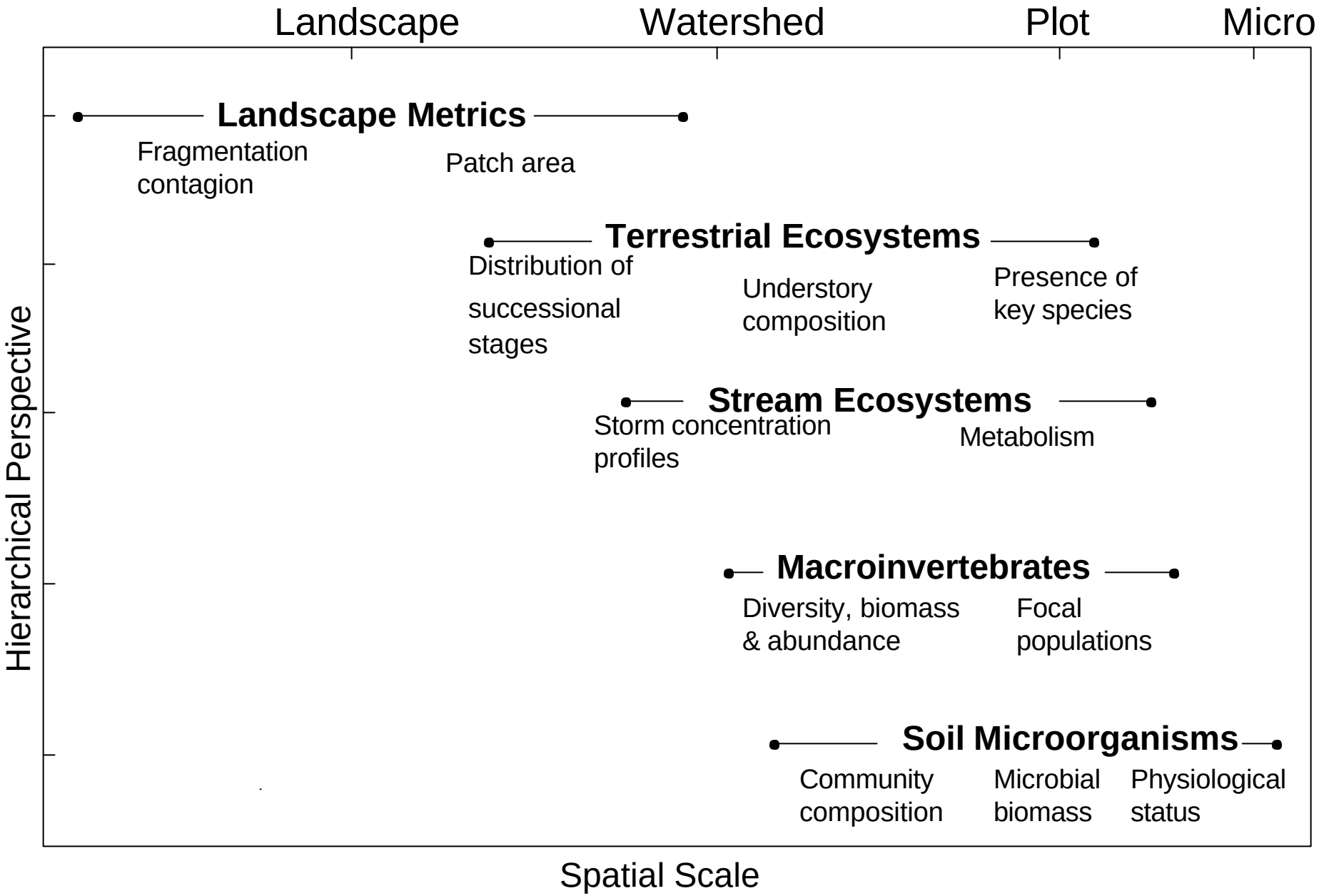
(b) Collect supplemental data relating to proposed indicators (building upon existing data);

(c) Perform experiments to examine how training affects indicators;

(d) Analyze resulting set of indicators for appropriateness, usefulness, and ease of taking the measure;

(e) Develop and implement a technology transfer plan.

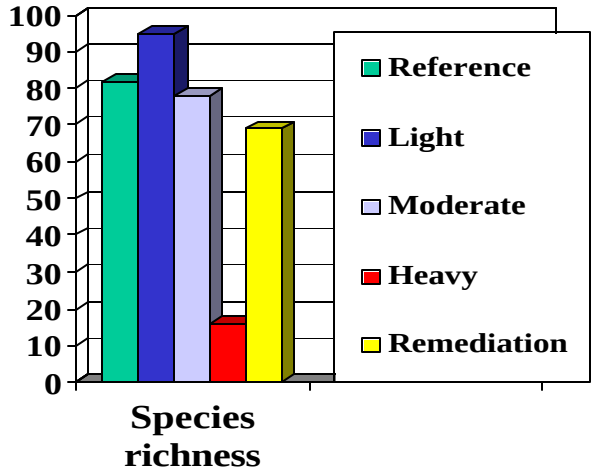
Suite of Ecological Indicators

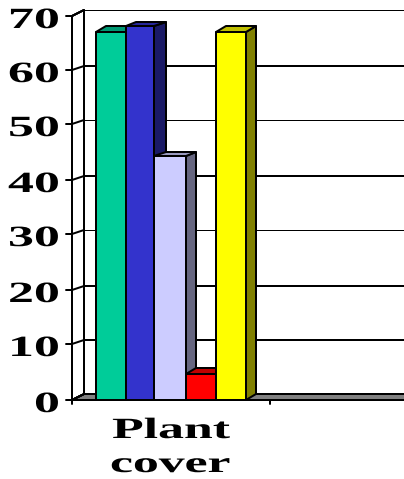


Technical Approach: Terrestrial Studies

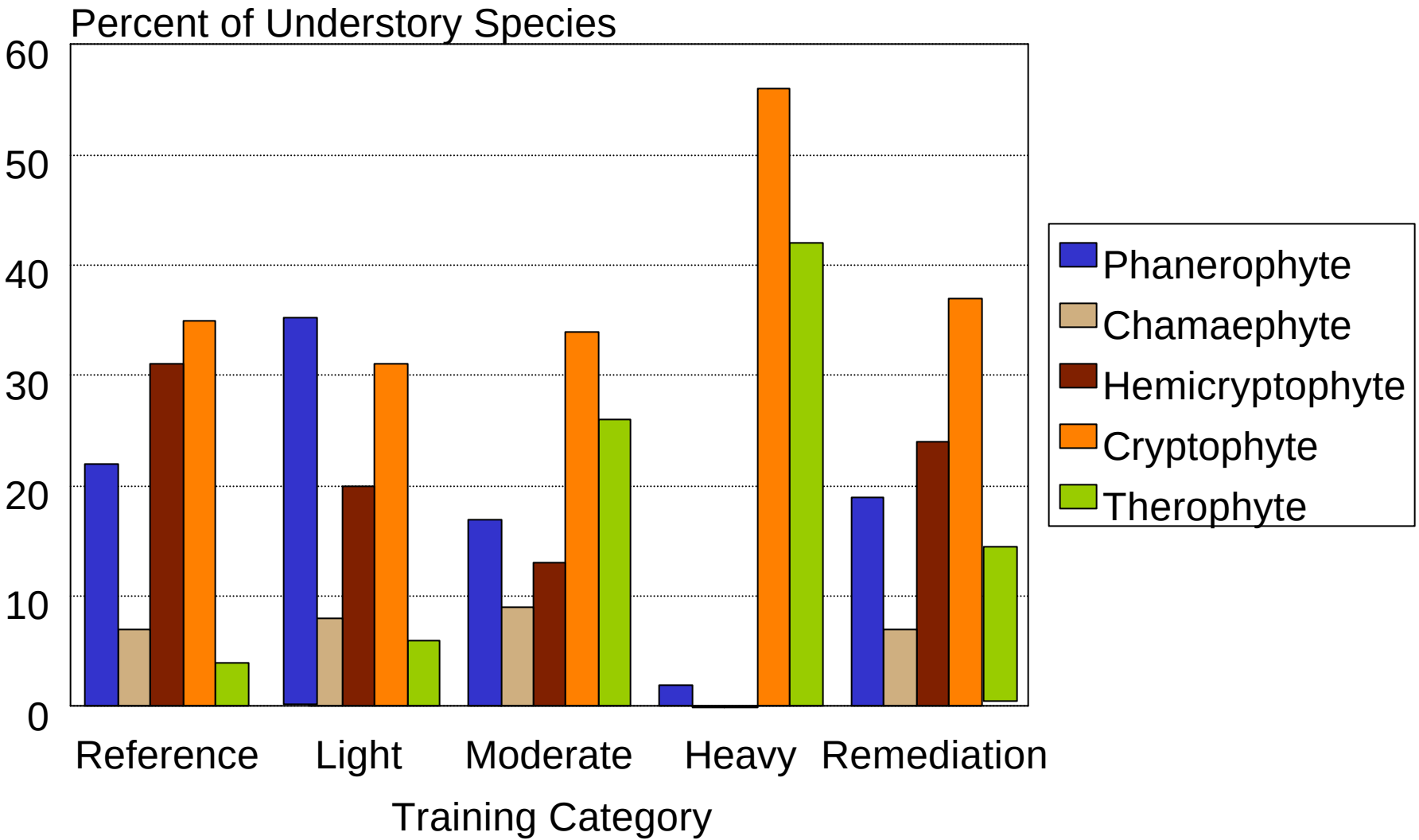
- Candidate indicators
  - Life form composition
  - Plant family composition
  - Key genera
  - Depth of A horizon

- Potential indicators that were not so useful
  - Plant cover
  - Species composition
  - Species richness

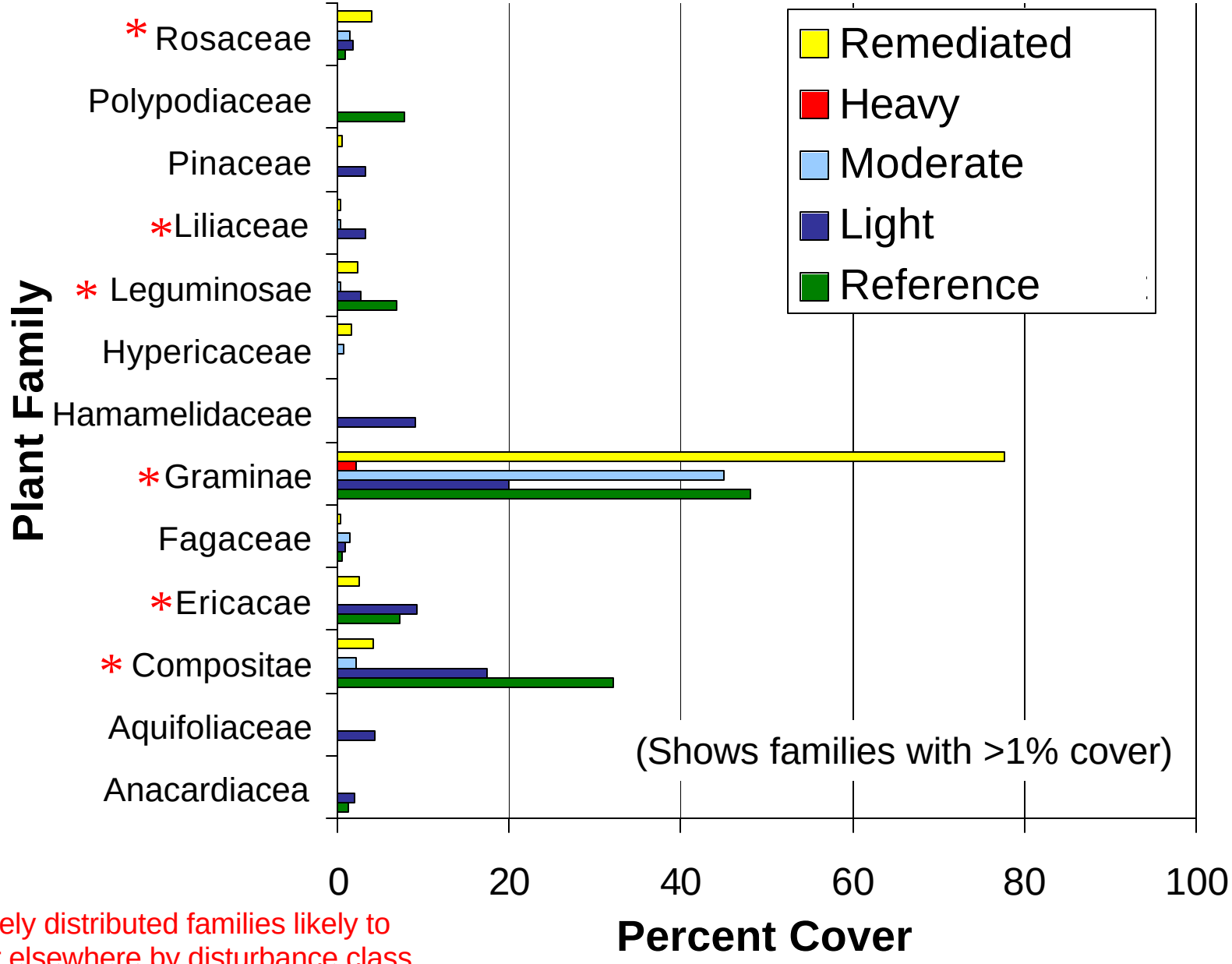




Training Categories Differ According to Life Form Distribution



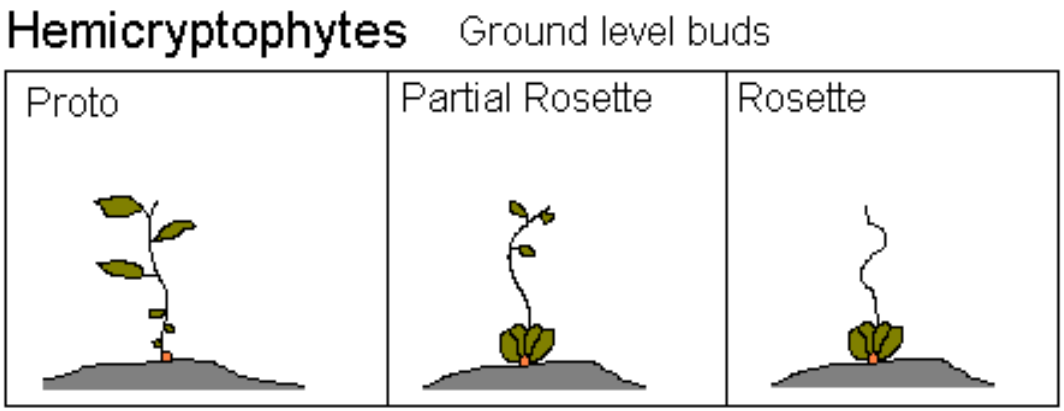
Cover of Plant Families Differs between Training Categories



*Widely distributed families likely to differ elsewhere by disturbance class

Transfer of Information

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



Soil Chemical Biomarker Measurements For Quantitative Disturbance Impacts & End Points for Reversibility

- **Benefits:**
  - **Easy collection of soil cores**
  - **Ship frozen**
  - **Base or commercial laboratory for analysis**
  - **Readily interpretable definition and potential for reversibility**
    (Soil microbiota do not require biological expertise to interpret)

Based on:

Exposure of pine forest surface soils to vehicular traffic - Fort Benning, GA

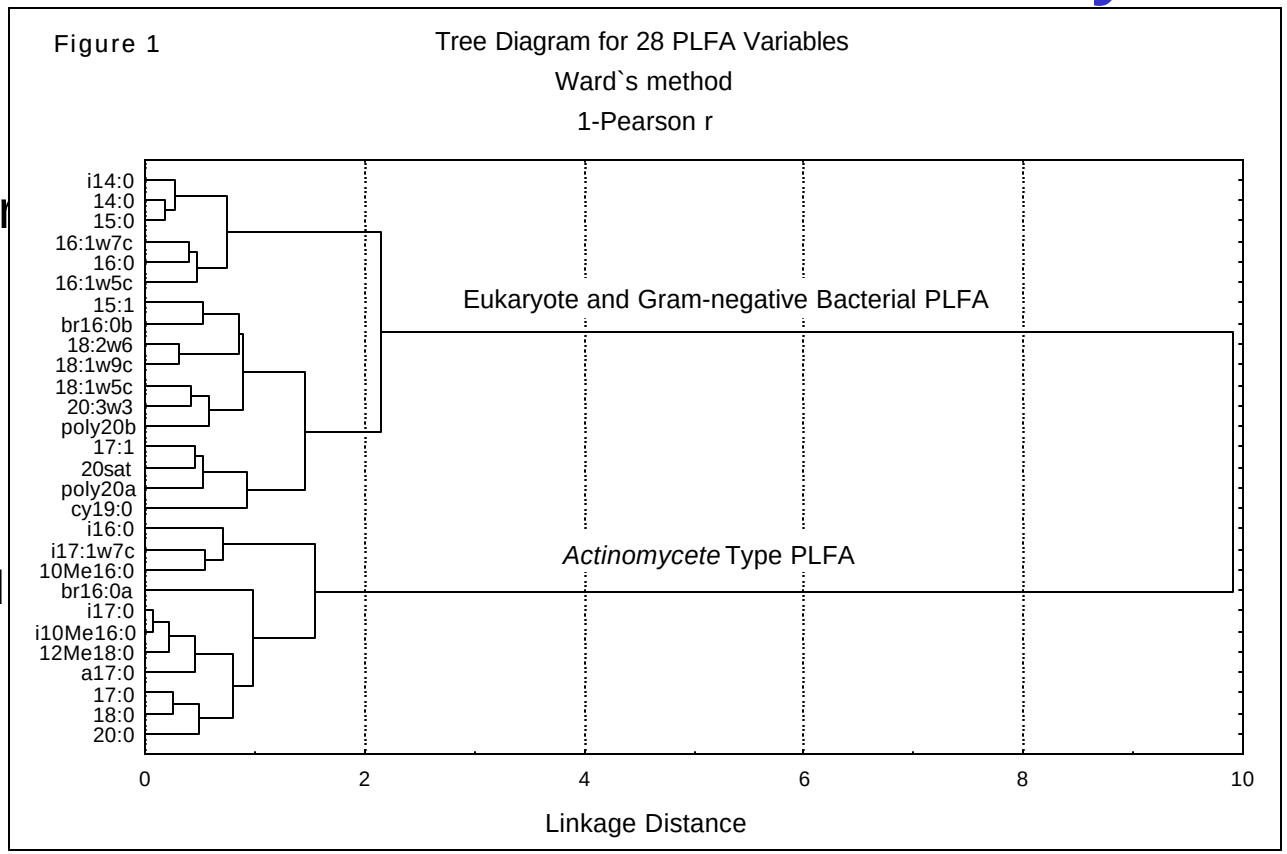
Changes in soil viable microbial biomass and composition determined from lipid biomarker analyses

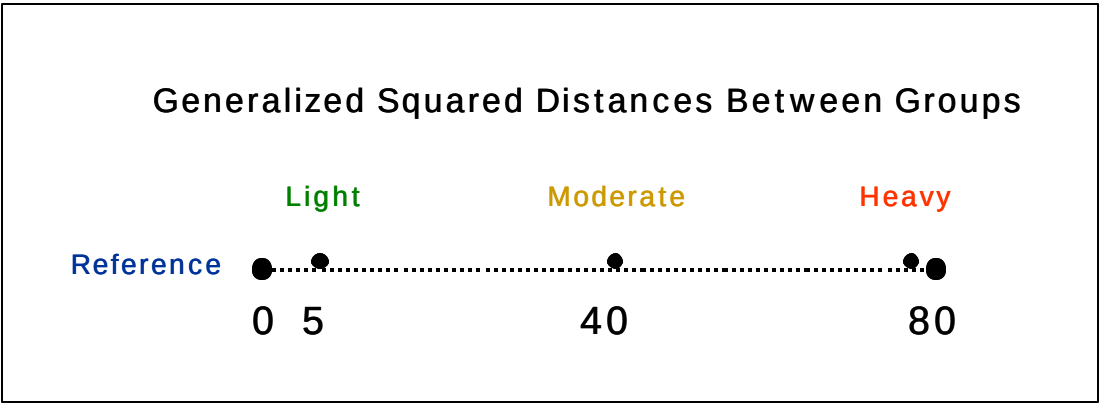
Plant communities & stream ecology responses parallel microbes

Analysis of soil microbial community

Linear discriminant model using 17 phospholipid fatty acid (PLFA) predictor variables

- Reference and light transects were very similar
- Moderate and heavy transects greatly differed



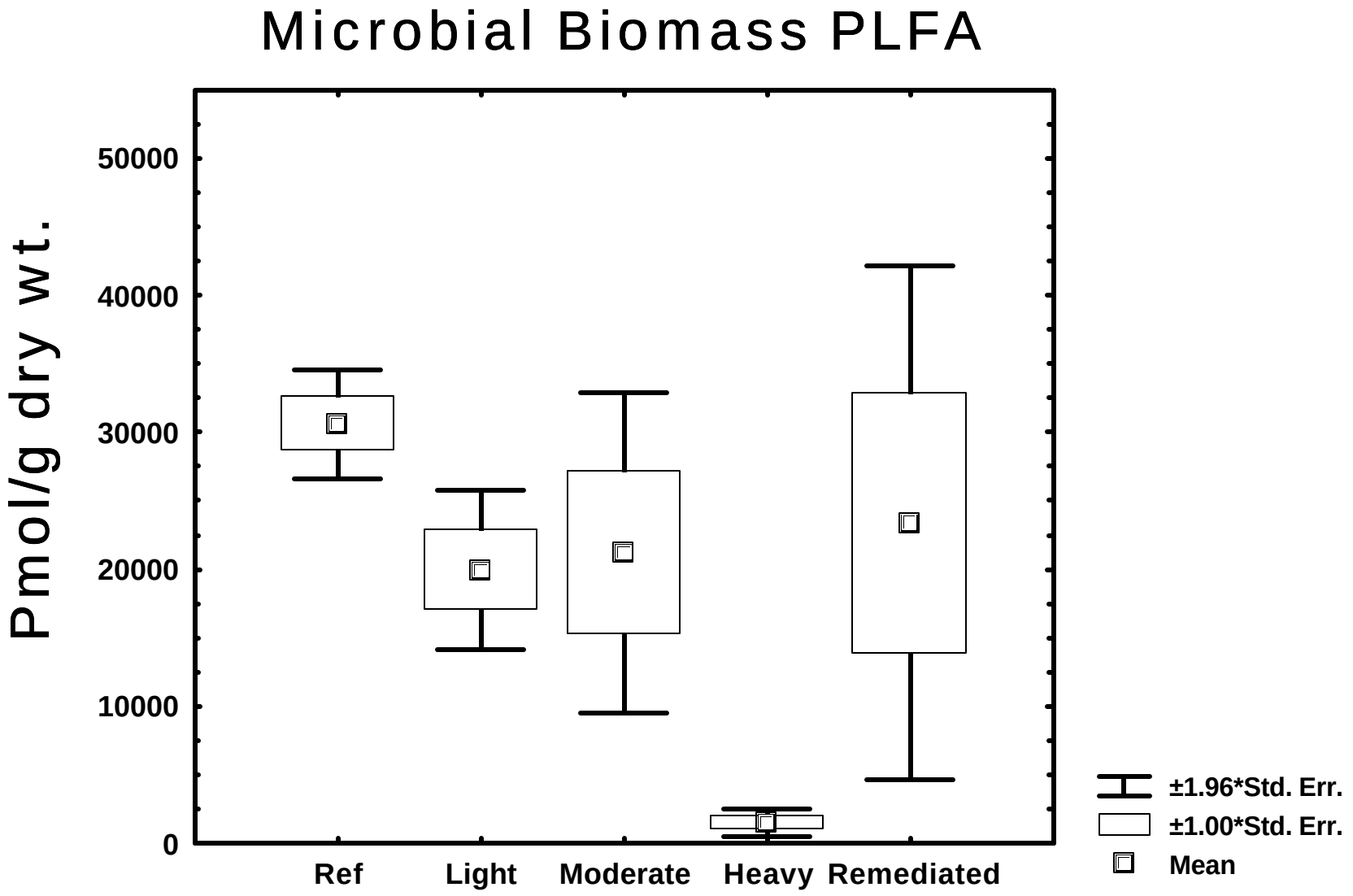


PLFAs included in the Discriminant Model

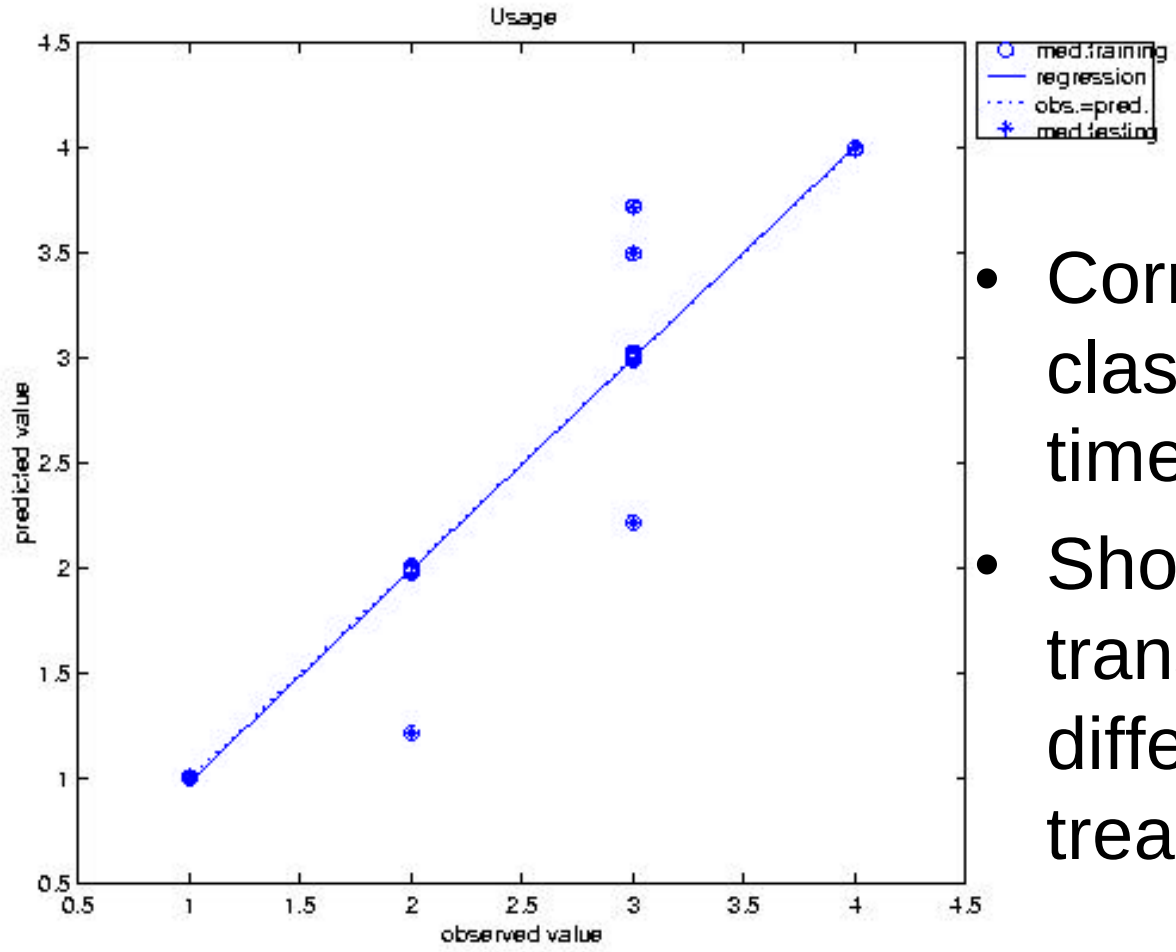
a15:0	i17:0	18:1w9c
i16:0	a17:0	18:0
16:1w7c	Cy17:0	10Me18:0
br16:0a	17:0	Cy19:0
i17:1w7c	i10Me16:0	20sat
10Me16:0	18:2w6	

The heavily disturbed site had significantly less microbial biomass.

Figure 1



Non-linear Artificial Neural Network Analysis



- Correctly predicts classification 66% of the time (25% chance)
- Shows that remediated transects are very different from all other treatments

Technical Approach: Stream Studies

Objective

Develop and evaluate potential indices of disturbance effects on catchment biogeochemistry and stream ecosystems

Approach

Disturbance gradient analysis (disturbance severity quantified at catchment scale as % land denuded)

- Stream sites (2nd-3rd order) over range of disturbance severity
- Measure potential indices across disturbance gradient
- Develop relationships between indices and disturbance severity

Potential Stream Indices of Disturbance

1. **Storm chemistry profiles**

Measurements: NH_4, NO_3, PO_4, Cl, SO_4, electrical conductance, suspended sediments over storm hydrographs

Analyses: concentration vs. discharge relationships, peak concentrations

2. **Diel dissolved oxygen profiles (metabolism indicator)**

Measurements: dissolved oxygen concentrations and deficits at 30-min intervals during baseflow

Analyses: diurnal amplitude, night-time minima

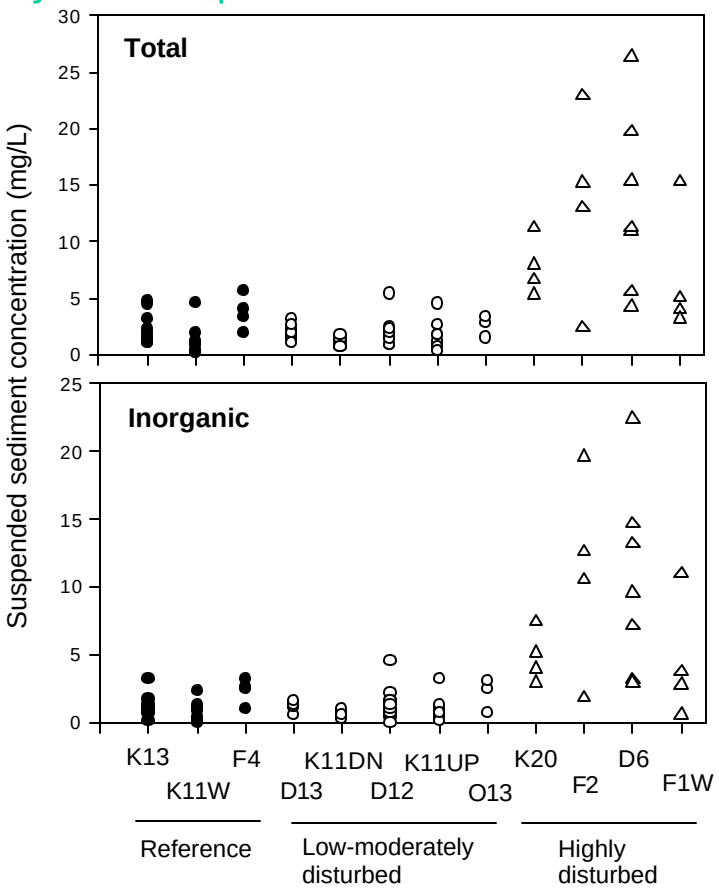
3. **Macroinvertebrate communities and habitats**

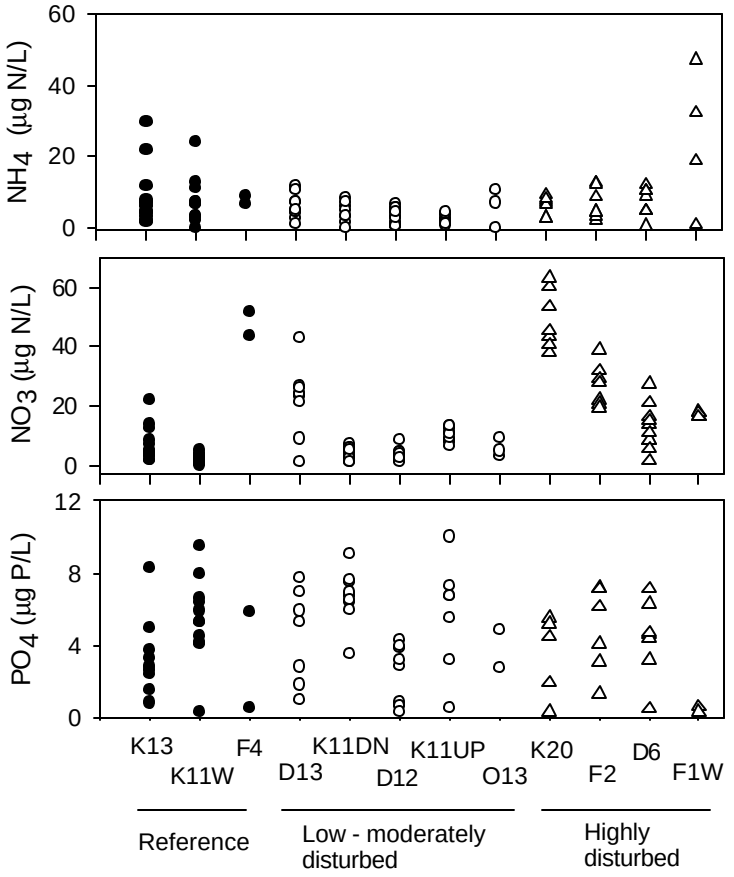
Measurements: numbers, biomass & diversity of benthic macroinvertebrates, bedload sediment movement

Analyses: EPT index, sensitive species abundance, NCBI index, similarity indices, sediment movement over time

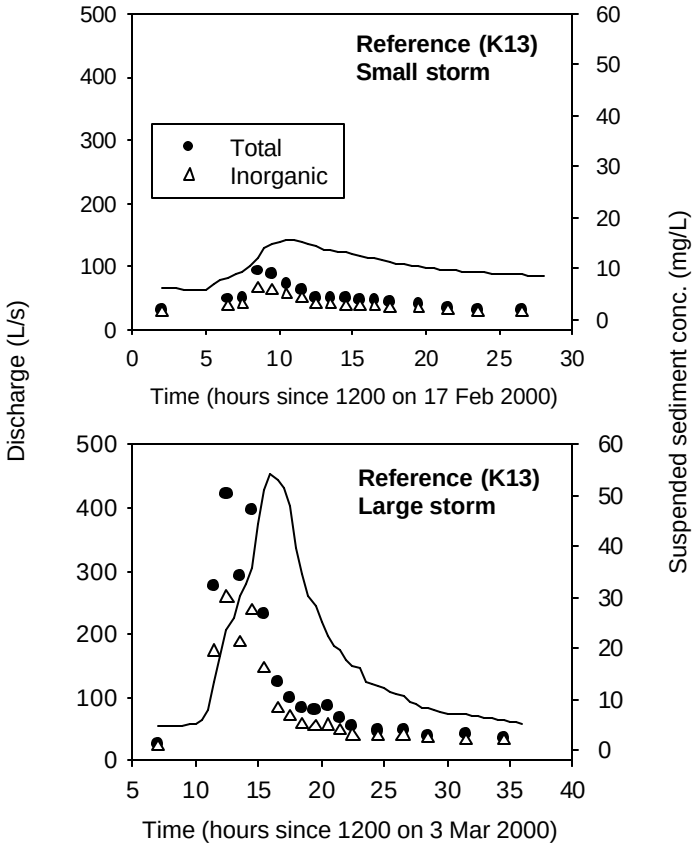
Baseflow suspended sediment concentrations are a good indicator of disturbance (left) but baseflow nutrient concentrations are not (right)

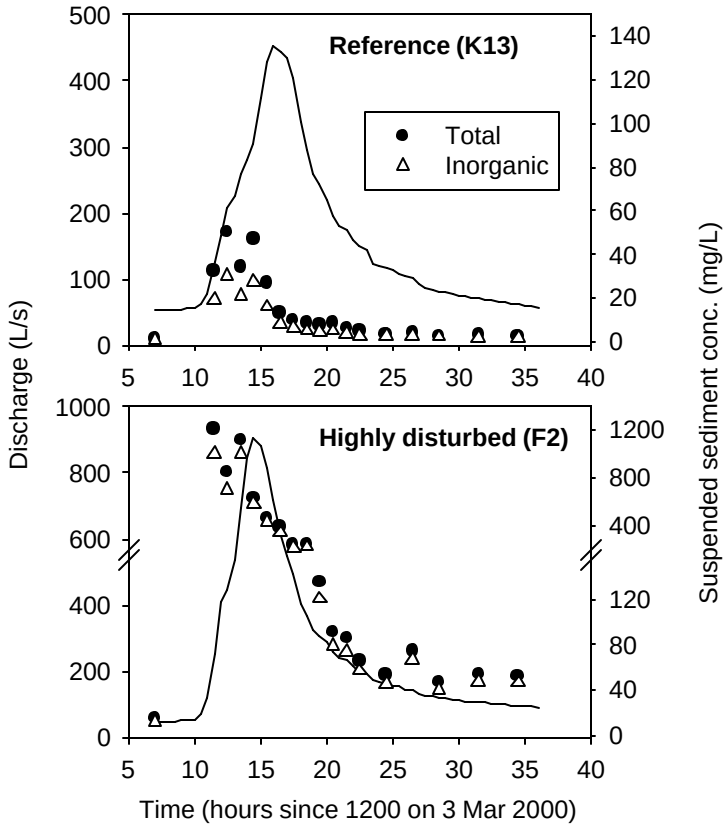
Symbols represent different storms.



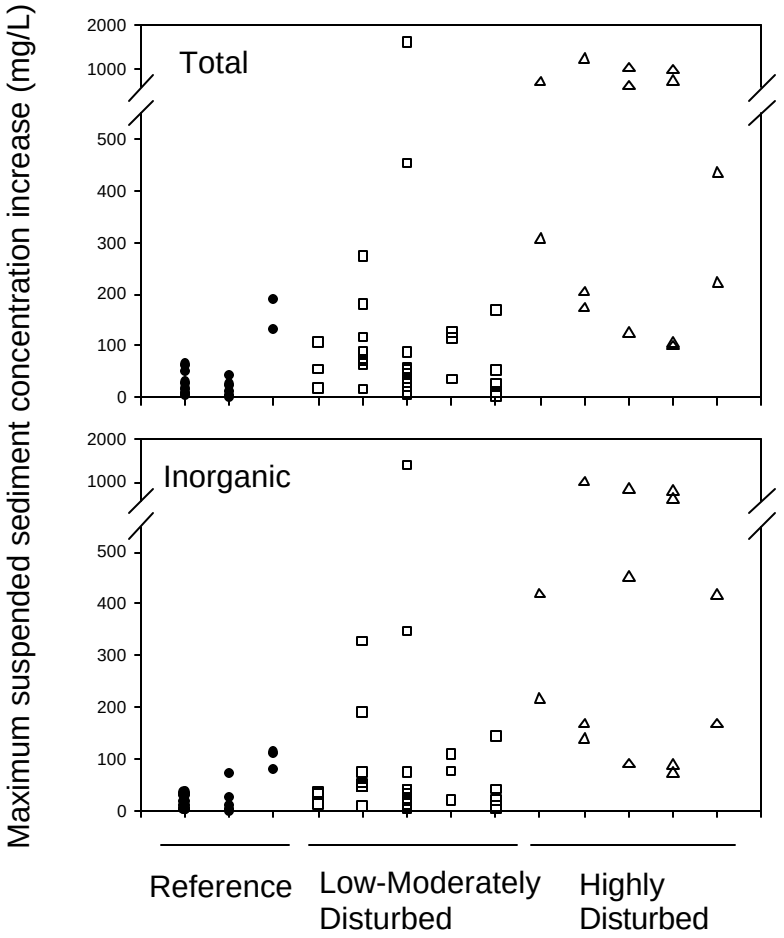


Storm increases in suspended sediment concentration are greater for larger storms (left) and are greater in disturbed streams (right)

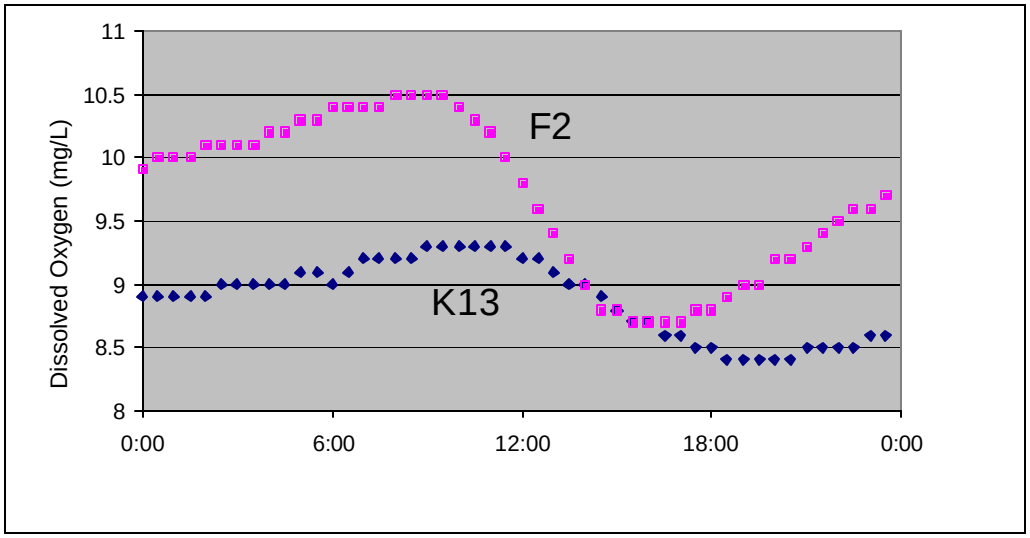




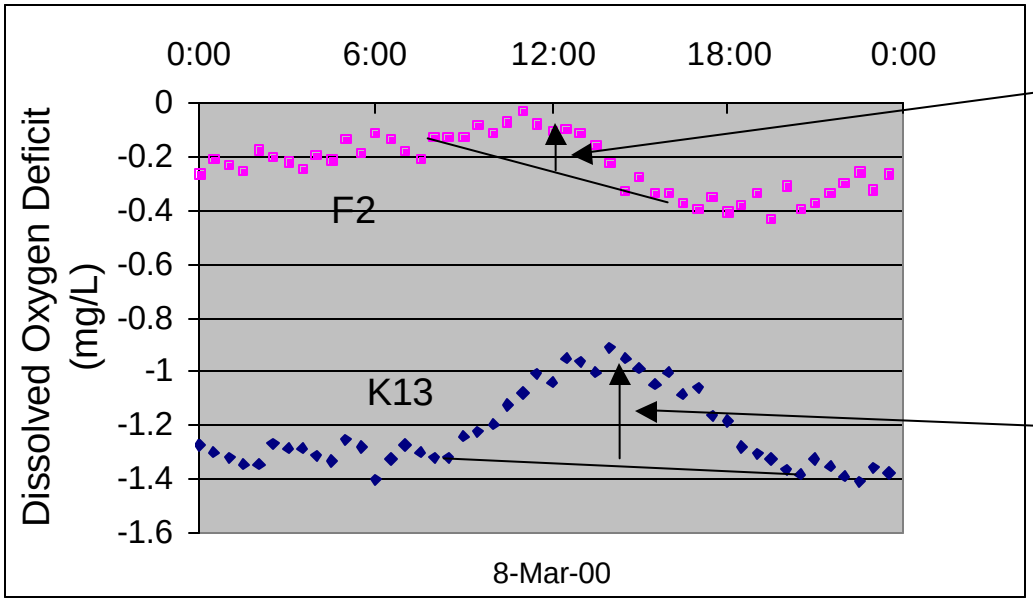
Maximum increase in suspended sediment concentration is a good indicator of disturbance (particularly inorganic sediments, lower panel)



Dissolved Oxygen Profiles (8 Mar 2000)



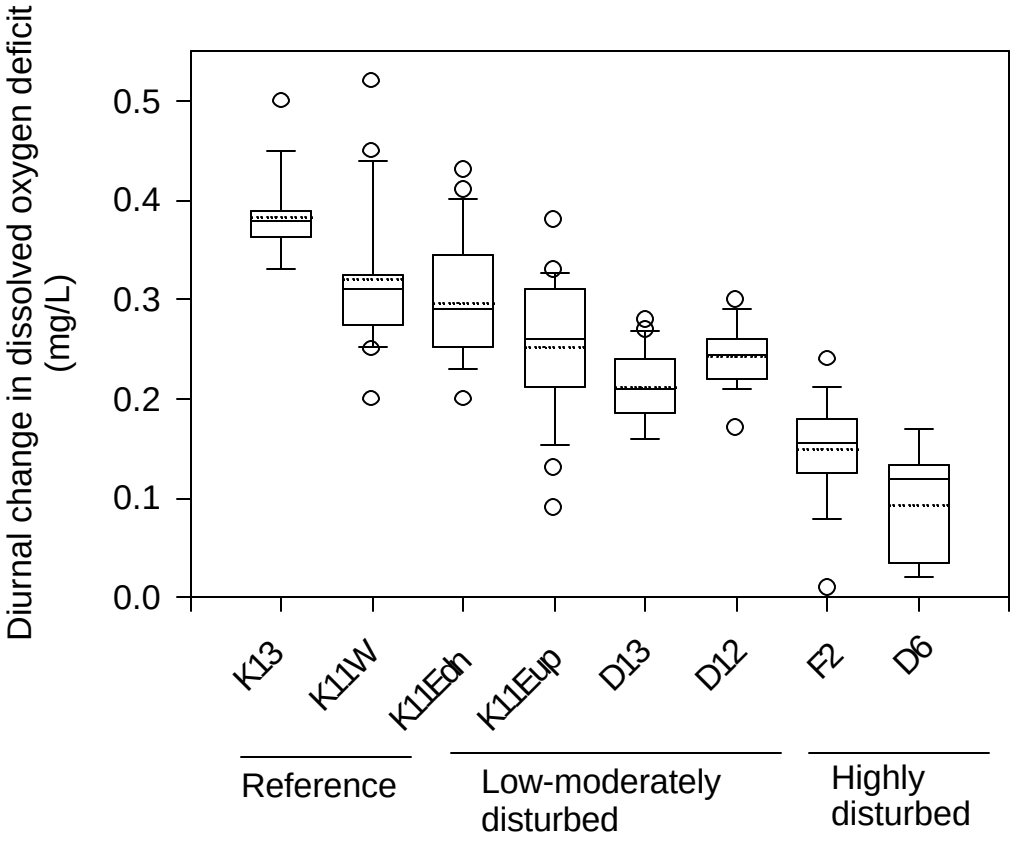
Diurnal dissolved oxygen profiles appear to be a useful disturbance indicator



Low daytime primary productivity in highly disturbed stream (F2)

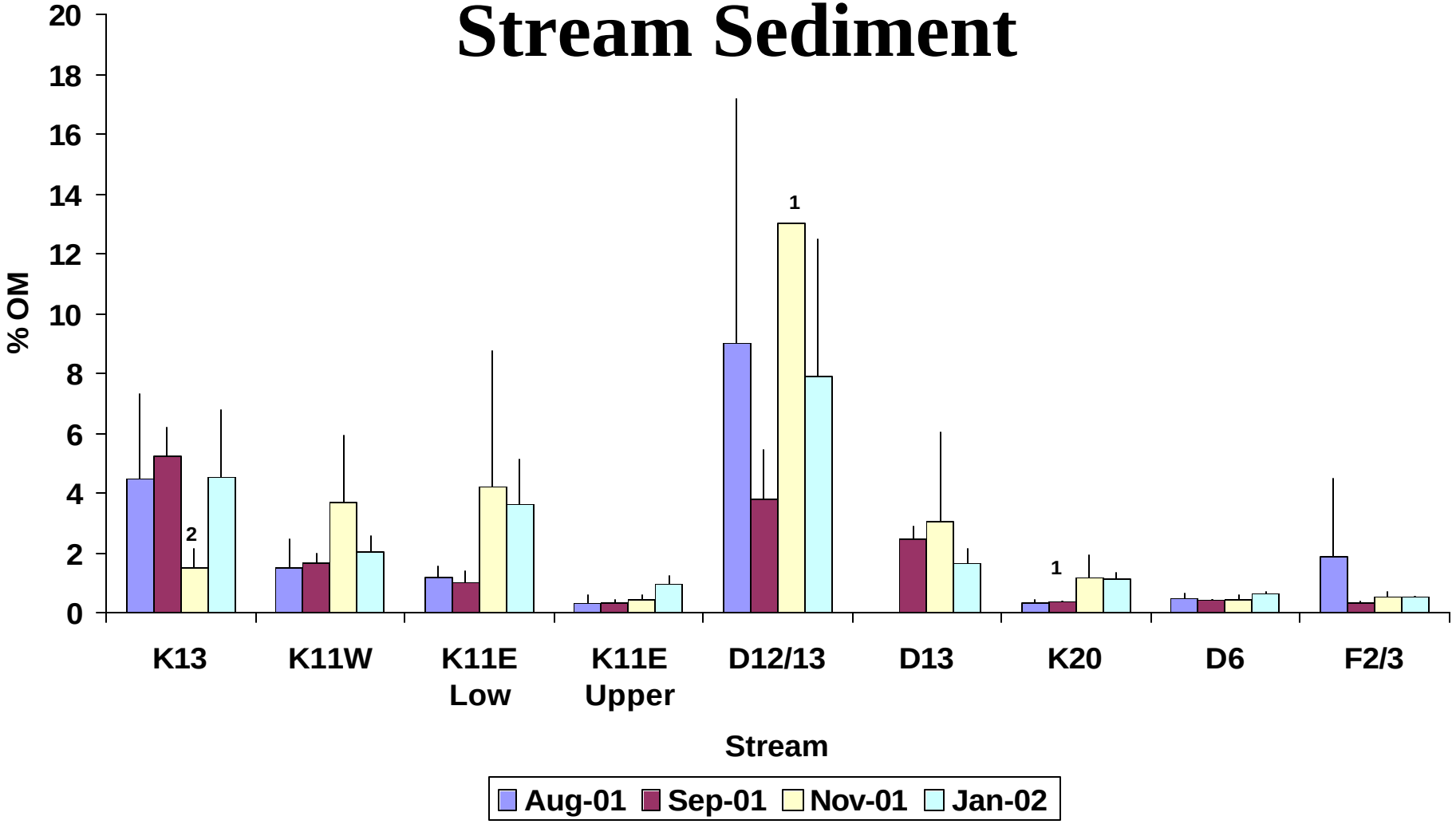
High daytime primary production in reference stream (K13)

Smaller diurnal dissolved oxygen changes with greater levels of disturbance (lower algal productivity)



Median, quartiles, and outliers for dates with mostly clear weather in February and March (period of maximum primary production

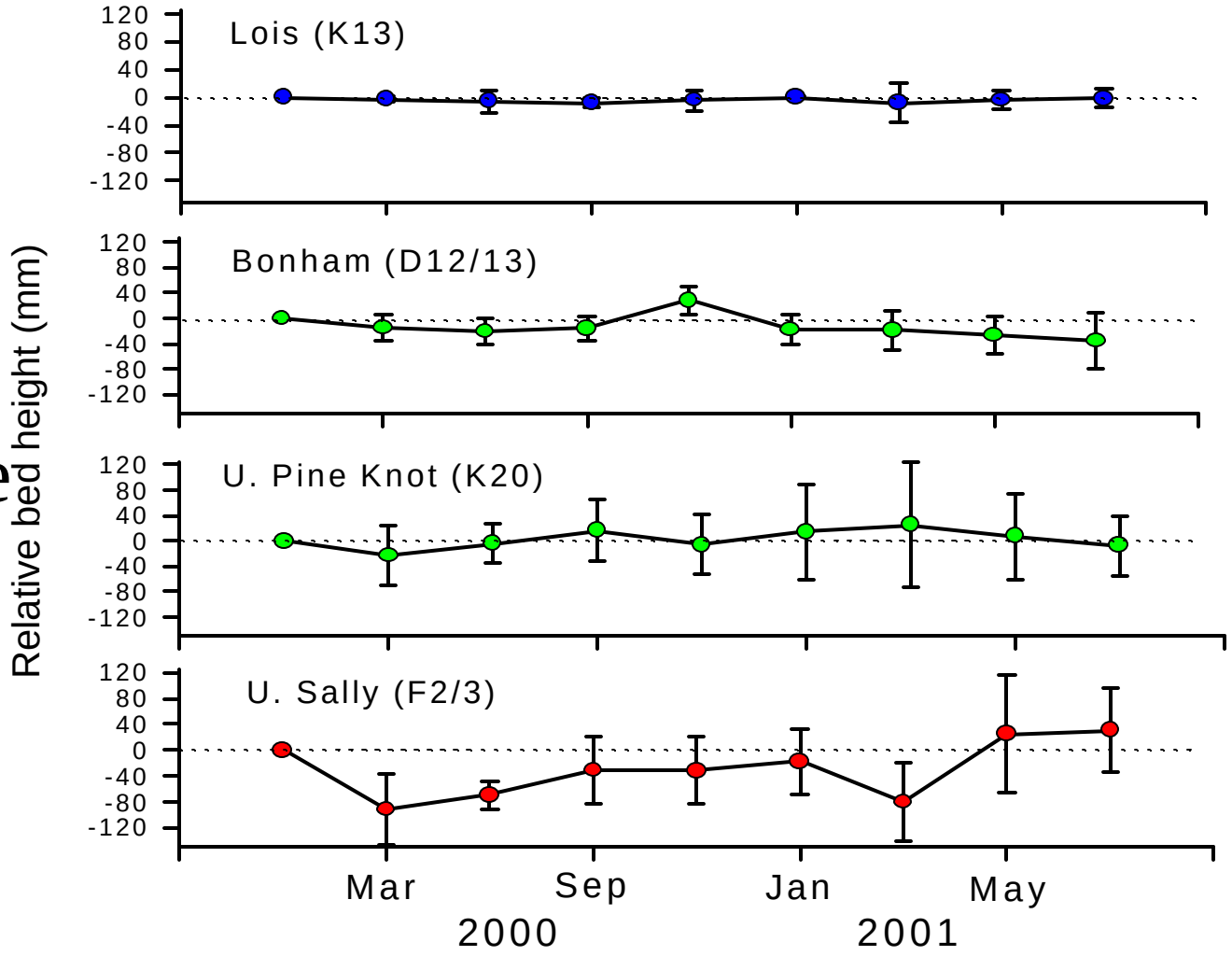
% Organic Matter in Stream Sediment



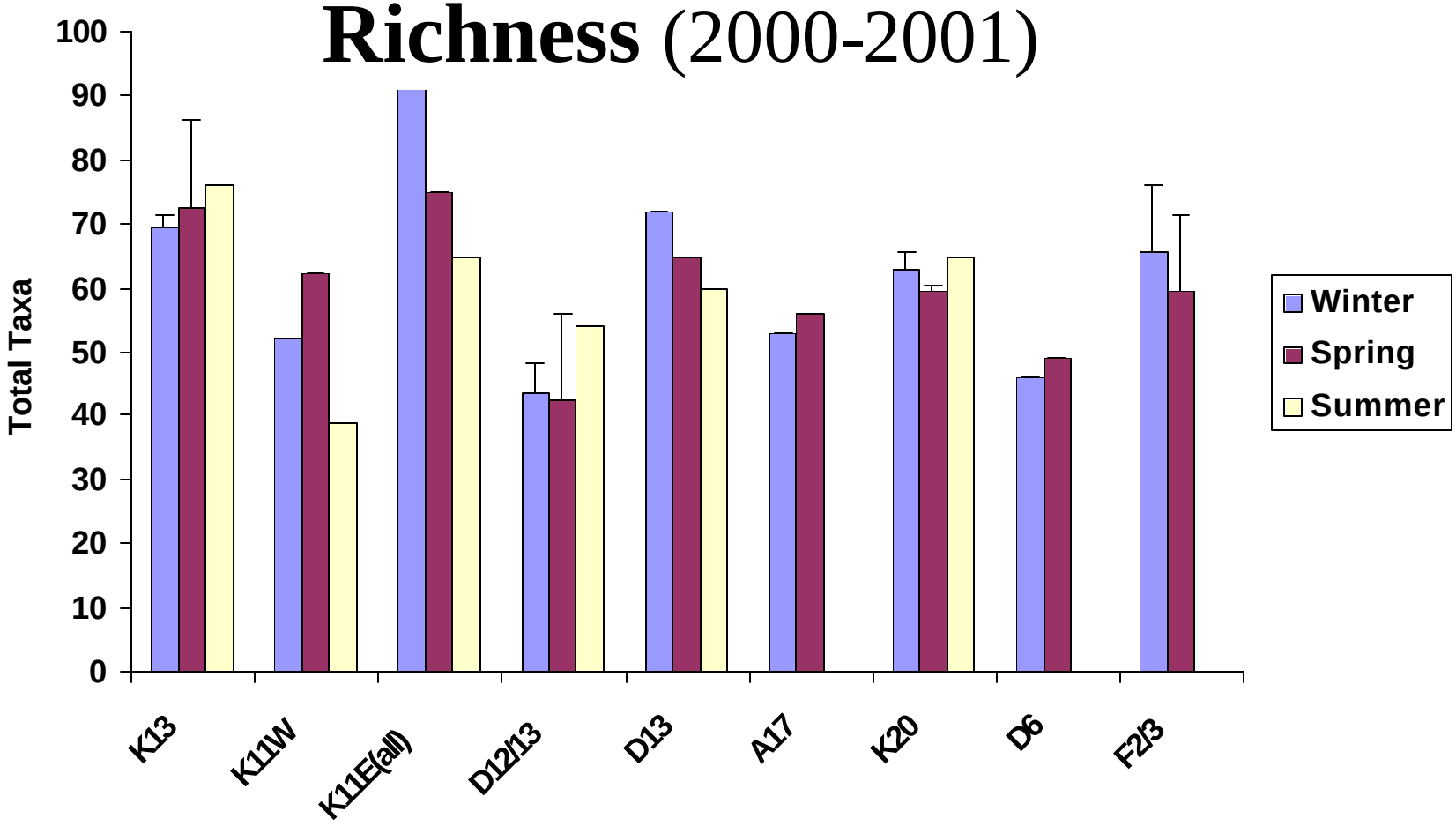
- Increasing Disturbance→

Bedload Sediment Profiles

Increasing Disturbance



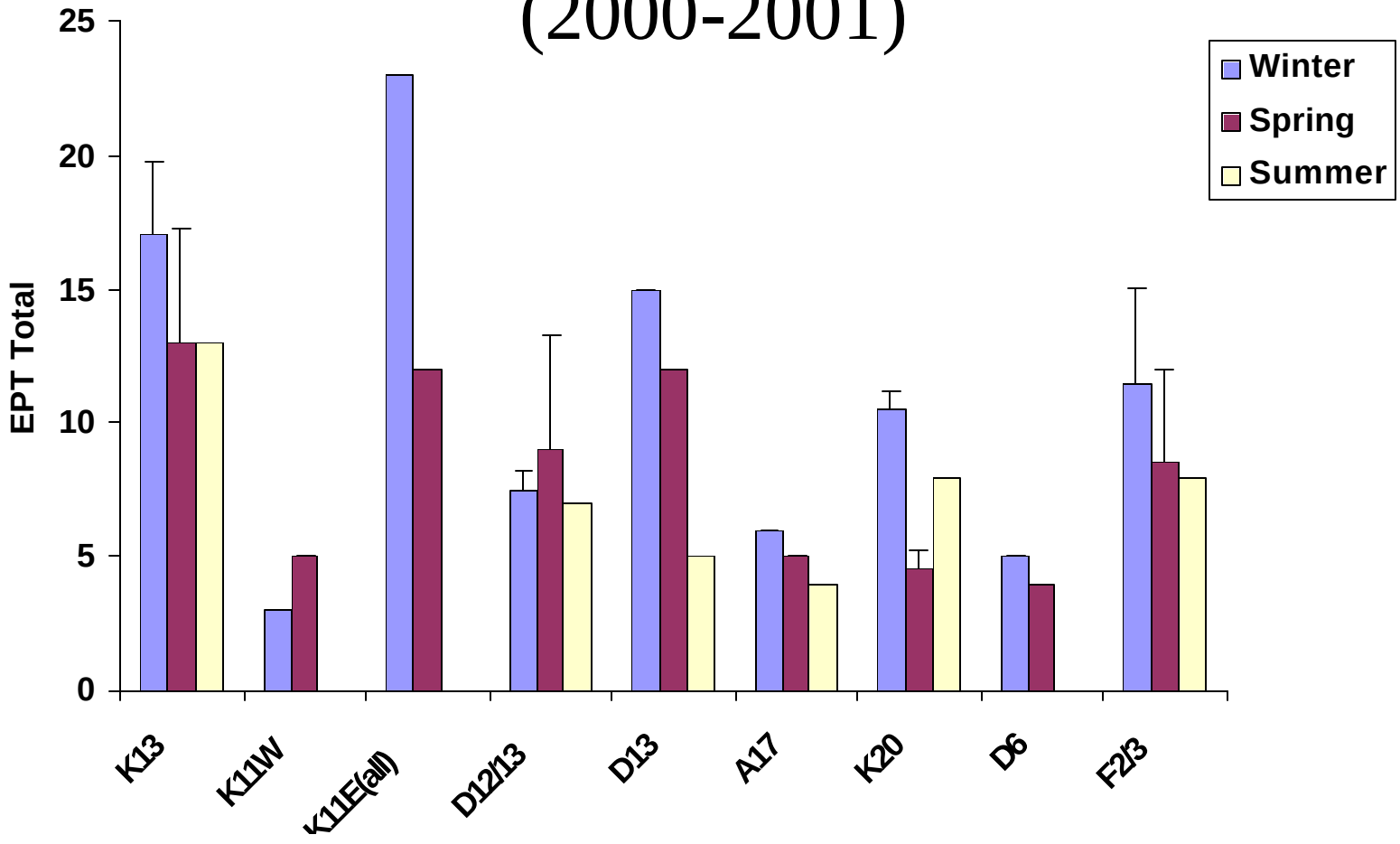
Total Macroinvertebrate Richness (2000-2001)



- Increasing Disturbance→

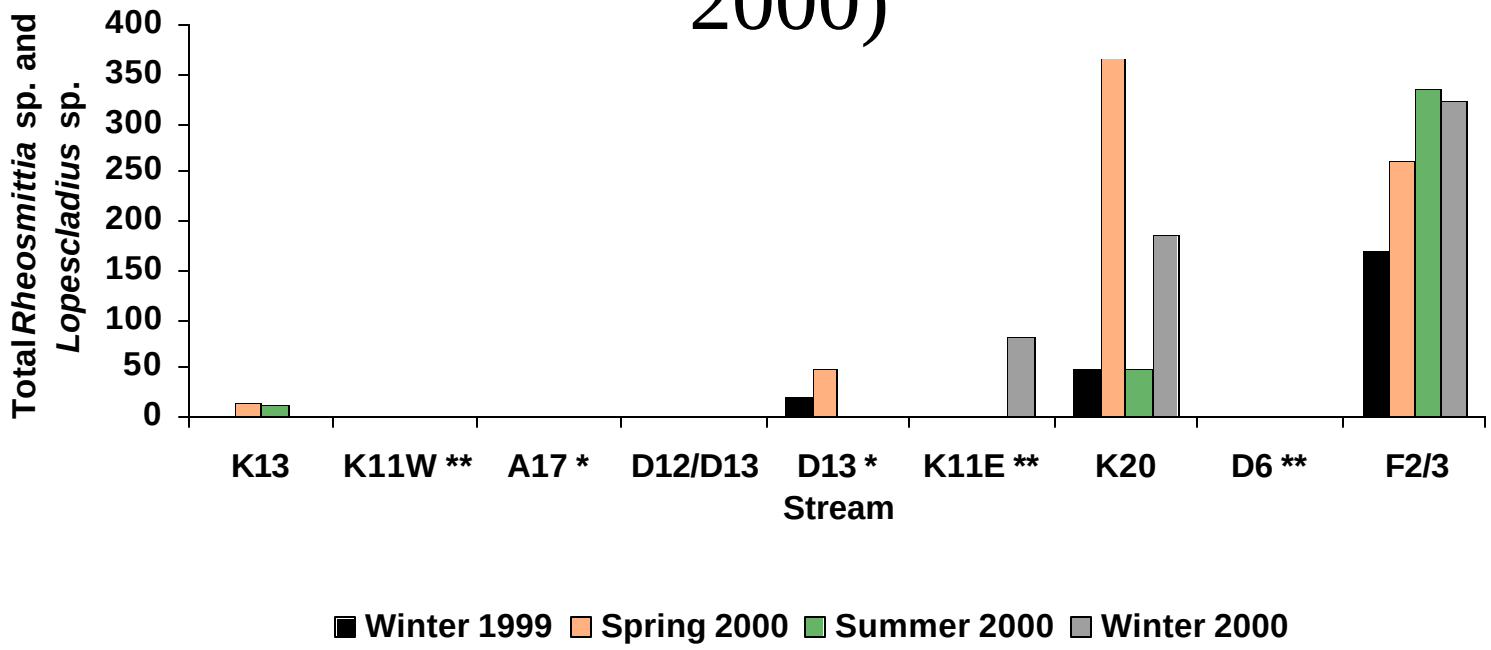
EPT Richness

(2000-2001)



- Increasing Disturbance→

Abundance of Sediment-Tolerant Midges (1999-2000)



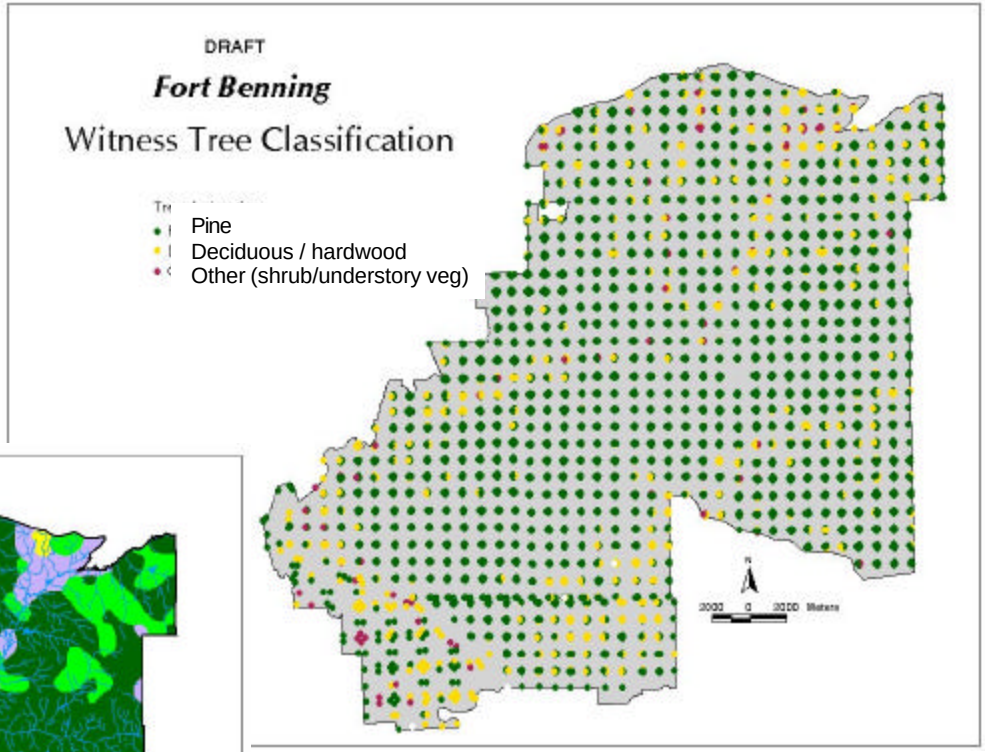
- Increasing Disturbance→

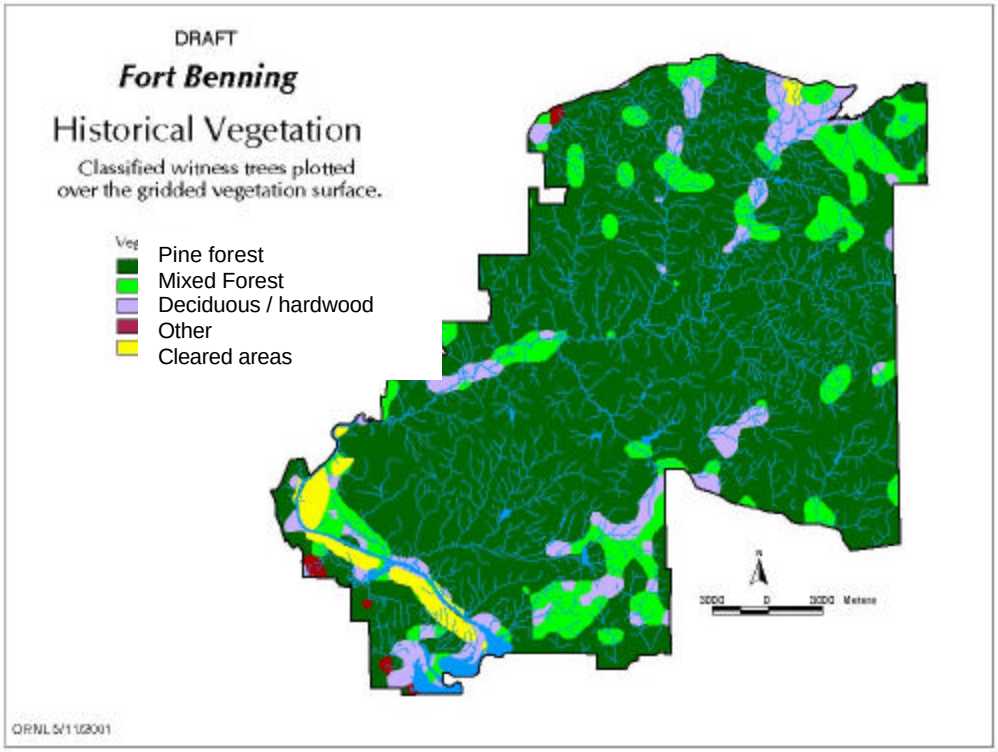
Technical Approach: Landscape Studies

- Explore data availability
- Develop comparable data sets over time
- Analyze changes in pattern and distribution of land cover over time
- Determine which landscape metrics are most useful for indicating change

Fort Benning Historical Vegetation - 1827

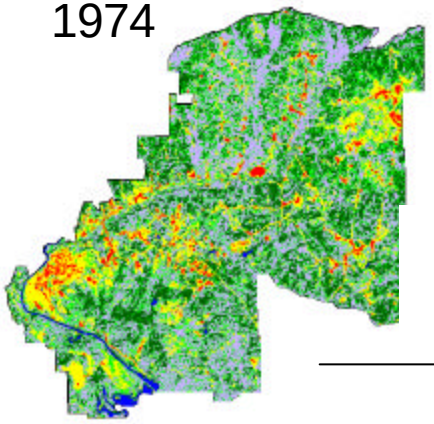
1. Witness tree data
2. Tree classification
3. Interpolation of surface
4. Estimation of cleared areas- large settlements/towns



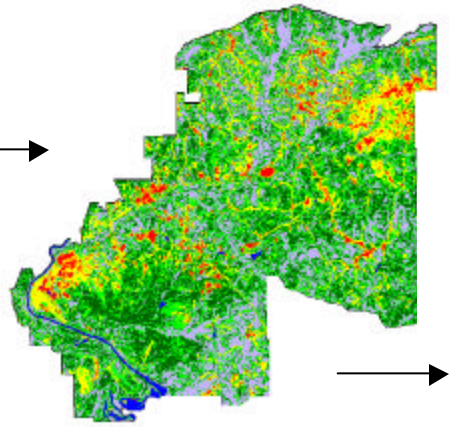


Building the Time Series

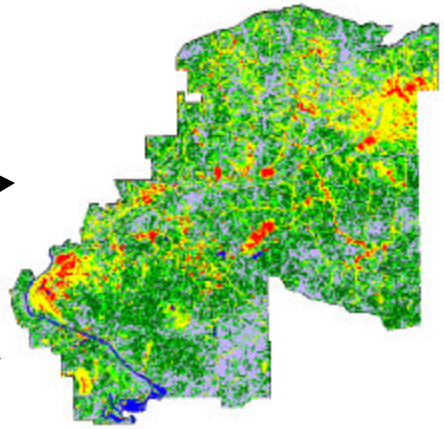
1974



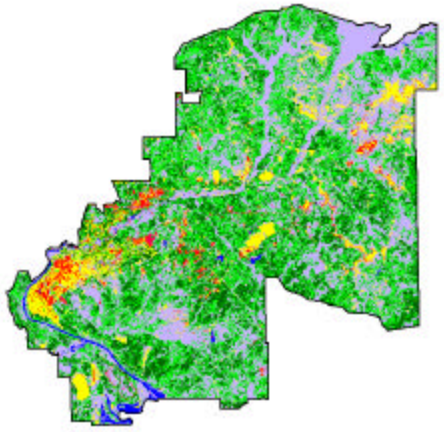
1983/86



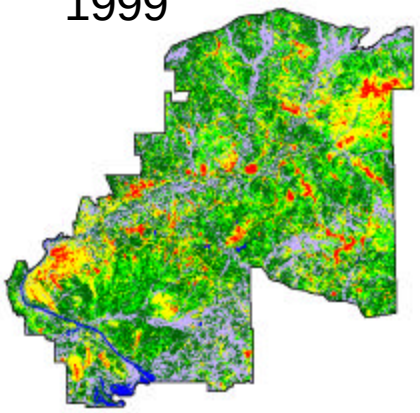
1991



1990-1993



1999



1974,1983/86, 1991-
North American Land Cover Data (NALC)
LandSAT Multispectral Scanner (MSS)

1990-1993-
Multi Resolution Land Cover (MRLC) - USGS

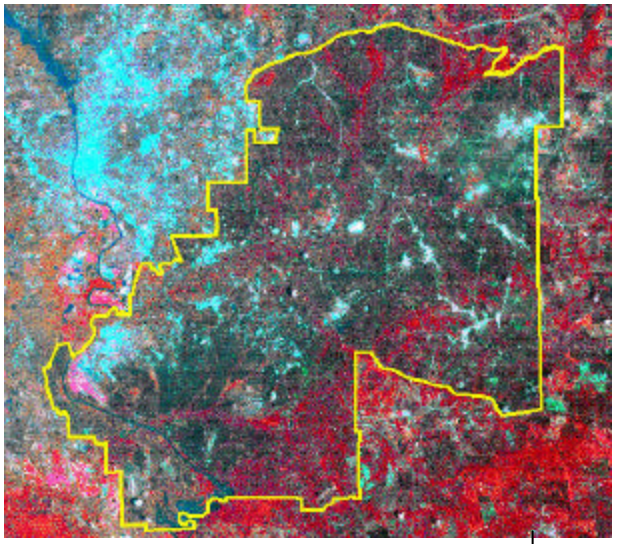
1999-
LandSAT Thematic Mapper

Ft. Benning
Land Cover Classification Key

- Bare ground or developed areas such as buildings. (highly reflective surfaces)
- Non-forest or cleared areas. (ground cover present, includes lawns)
- Deciduous forest (dense)
- Mixed forest (areas of deciduous and pine, widely spaced or sparse forest cover and transitional areas between forest and non-forest)
- Pine forest (dense)
- Water

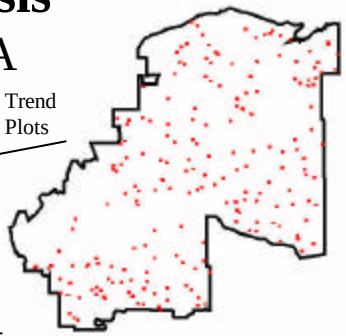
Fort Benning - Land Cover Classification/Analysis

LandSAT Thematic Mapper - July 1999

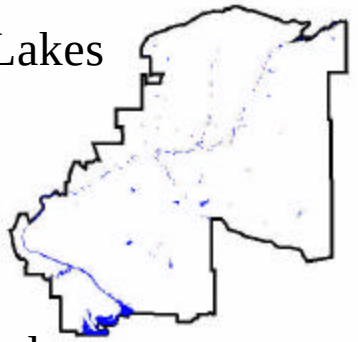


LCTA

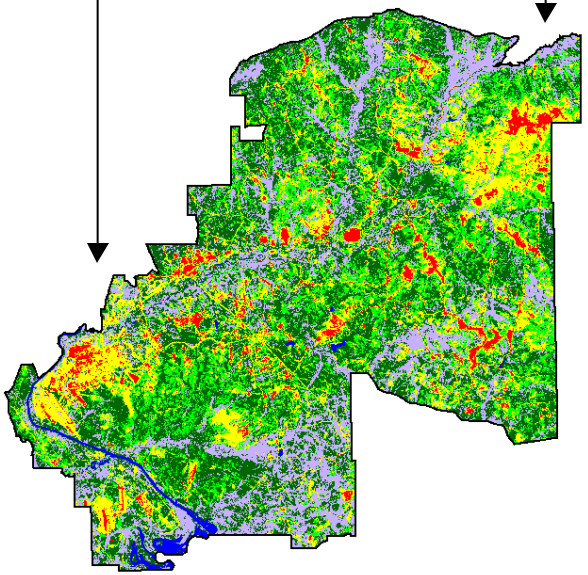
Land Condition Trend Analysis Core Plots



Lakes



Digital-Color Orthophoto 1999



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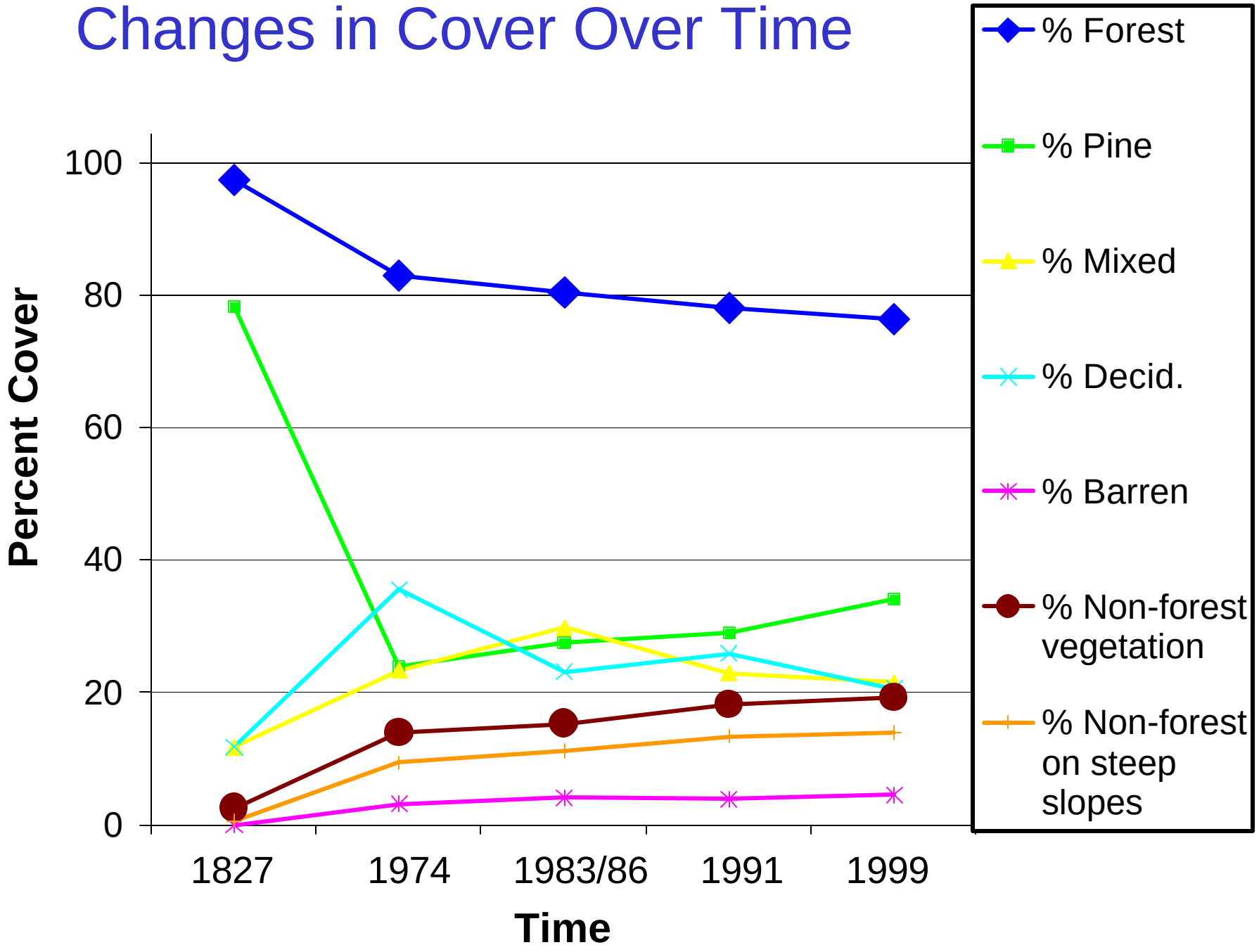
ATtILA

Analytical Tools Interface for Landscape Assessments

-Land Use Proportion Metrics
-Diversity Metrics
-Forest Patch Metrics
-Road Density Metrics
-Riparian Characteristics

Landscape Metrics

Changes in Cover Over Time



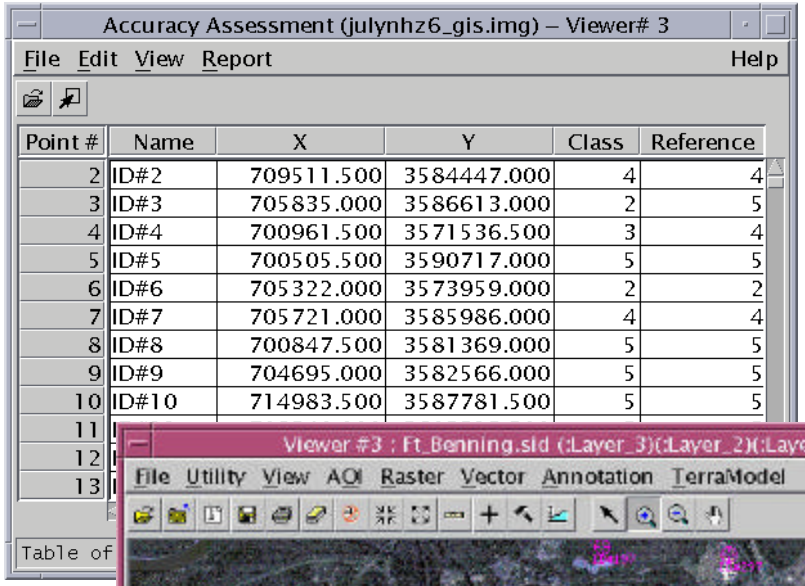
Selected Forest Patch Metrics- ATtiLA

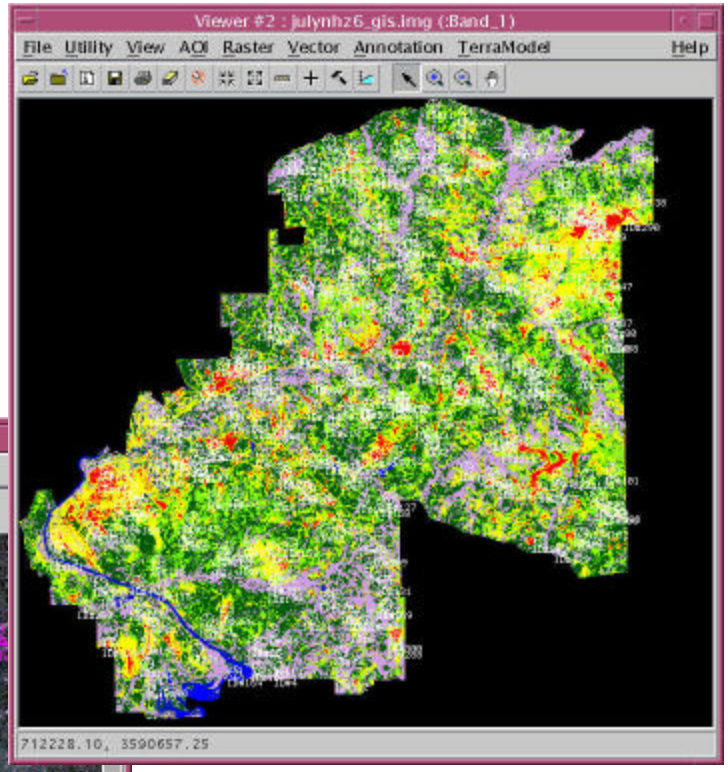
Metric	1827	1974	1983/86	1991	1999
# Forest Patches	3	202	238	248	395
Mean Patch Size	239,833,200	3,000,403	2,467,845	2,291,530	1,408,557
Largest Patch Size	719,348,400	563,396,400	541,213,200	525,078,000	546,213,600
Shannon-Weiner Diversity Index	0.7439	1.4747	1.5274	1.5274	1.6566
Simpson's Diversity Index	0.6312	0.254	0.2381	0.2338	0.22

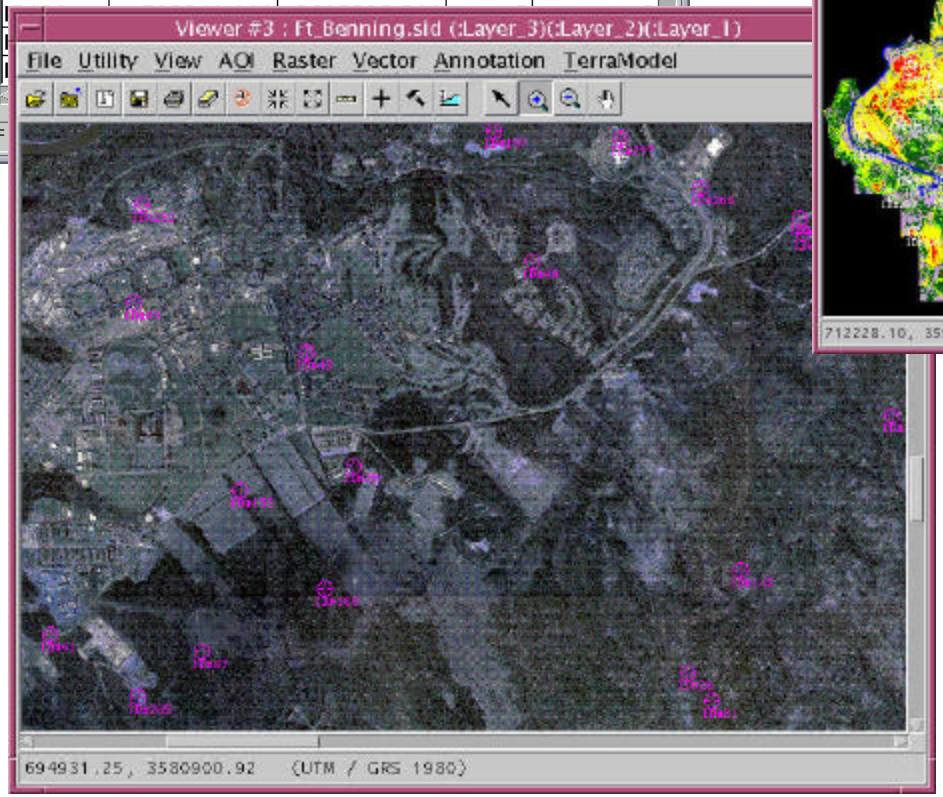
Selected Class Metrics Non-Forest Class (FRAGSTATS)

Metric	1974	1983/86	1991	1999
% Landscape	13.761	15.152	18.065	18.948
# Patches	1638	1713	2175	3751
Mean Patch Size	6.201	6.529	6.129	3.729
Patch Density (#/100ha)	2.219	2.321	2.948	5.082
Total edge (m)	2,520,660	2,830,740	3,179,940	4,080,960

1999 Land Cover Classification : Accuracy Assessment







Purpose: *to quantify the accuracy of the 1999 land cover classification*.

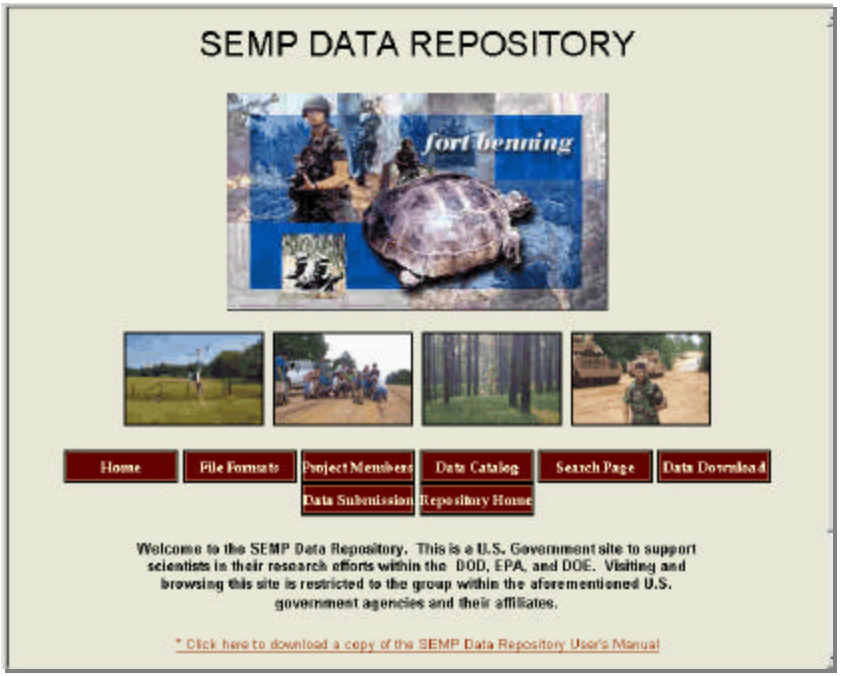
Tools:

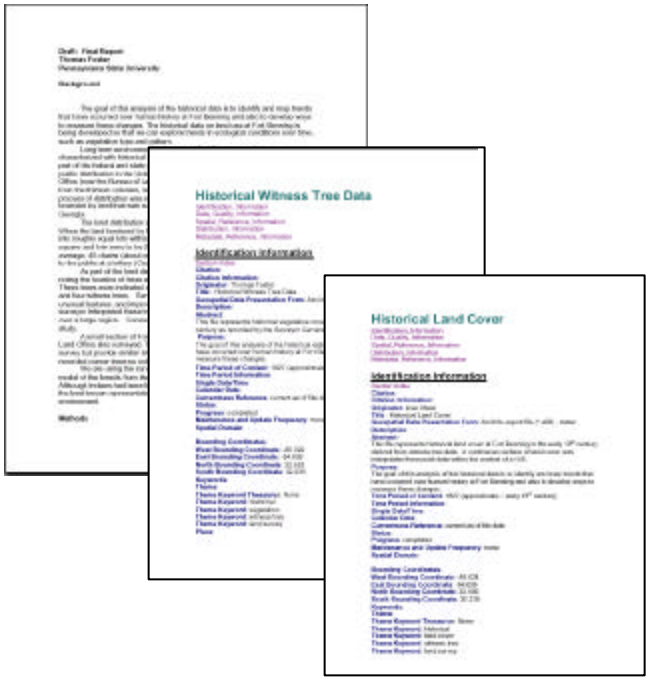
- ERDAS IMAGINE Software
- 1999 Classified Land Cover from ETM+ Image
- 1999 Digital Color Orthophoto 0.5 m resolution

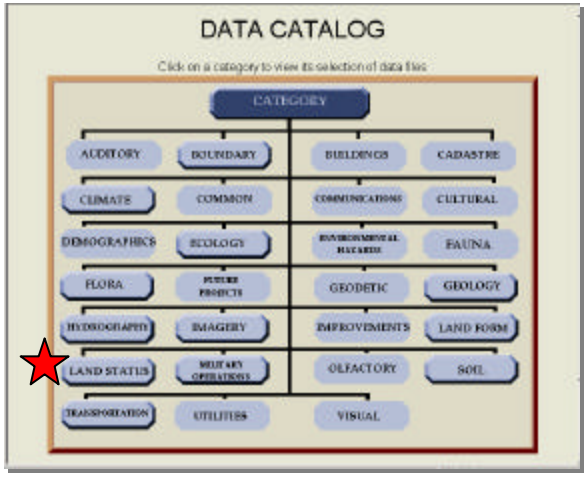
Next Steps

- Complete ongoing analysis
- Implement experiment designed to test indicators
- Re-evaluate candidate indicators
- Work with Benning staff in transfer of technology

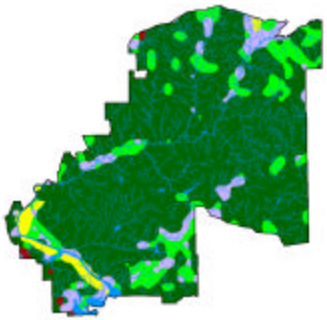
Submitted Historical Data, Metadata and Reports to the SEMP- ECMI Data Repository







Witness Tree - Point Data



Historical Land Cover

Other Data Entered into ECMI

- Understory vegetation
- Microbial Community
- Benthic invertebrates
- Storm chemistry data

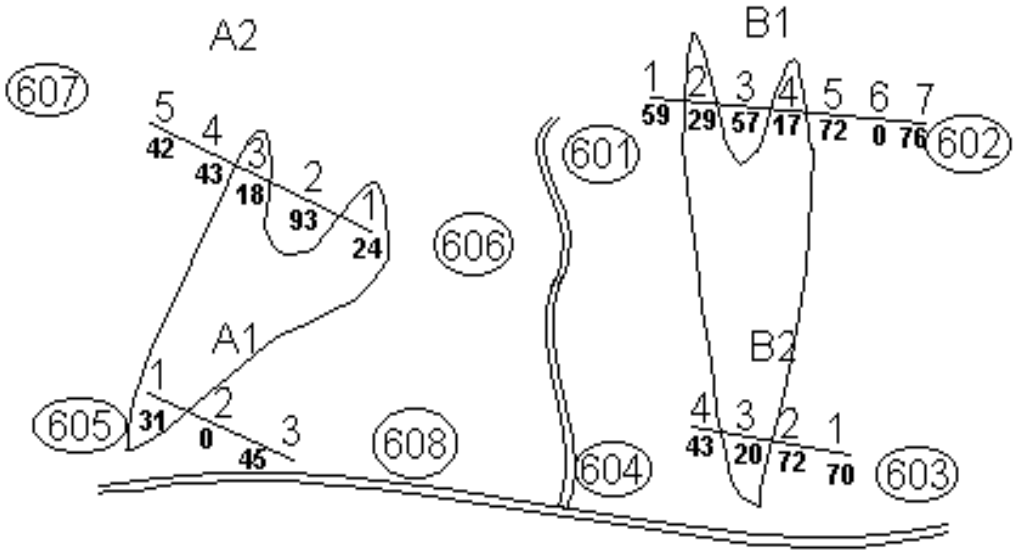
Experiment Being Established in K11

Pre- and post-disturbance monitoring

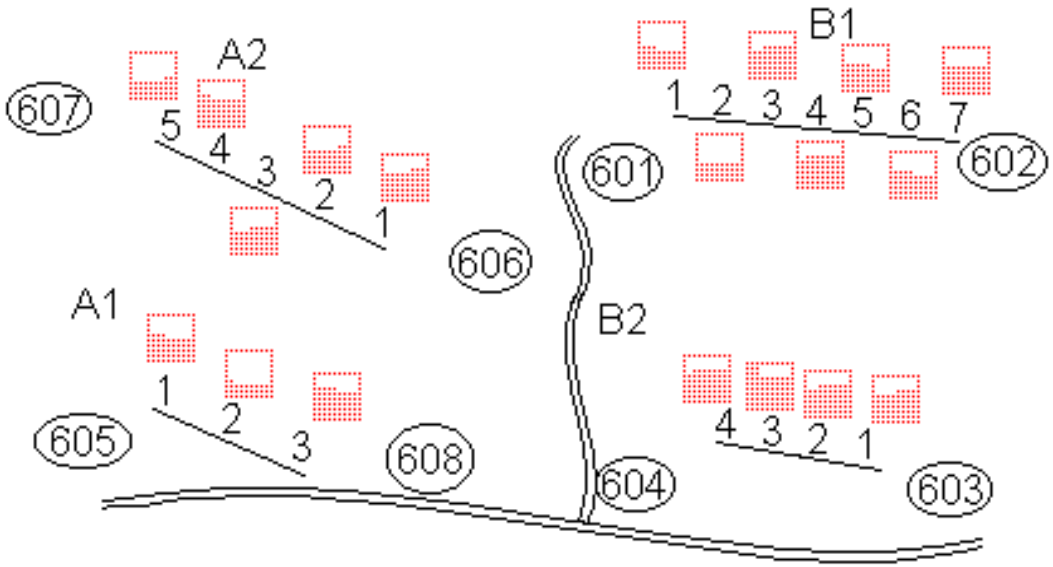
- Canopy characteristics
- Understory vegetation
- Soil microbial community
- Storm water runoff
- Benthic invertebrates
- Soil conditions (Garten and Collins)

General Patterns from K11 Experimental Site

Oldest trees in plots

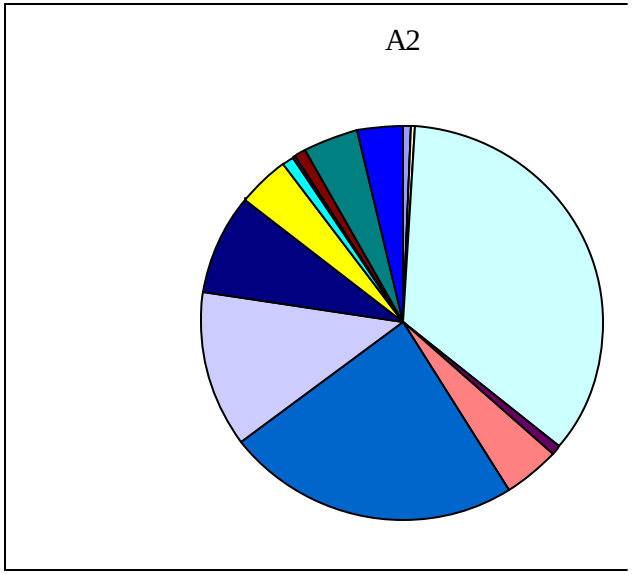


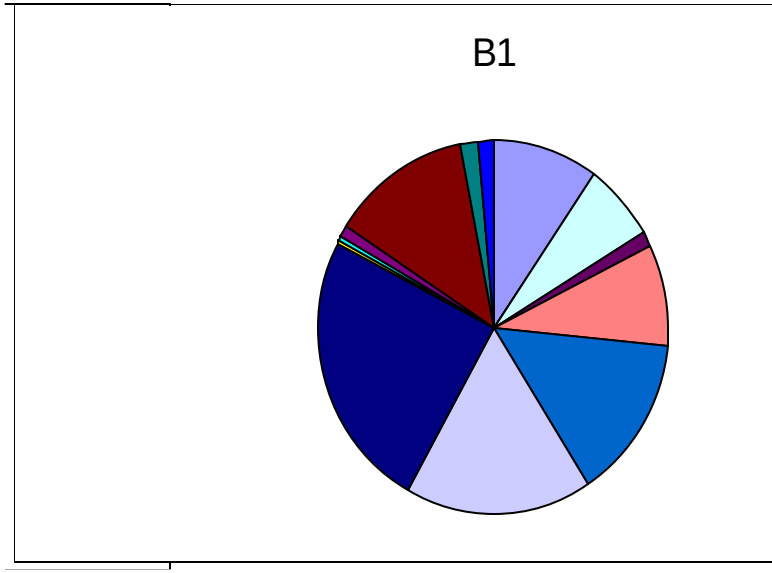
% Canopy cover

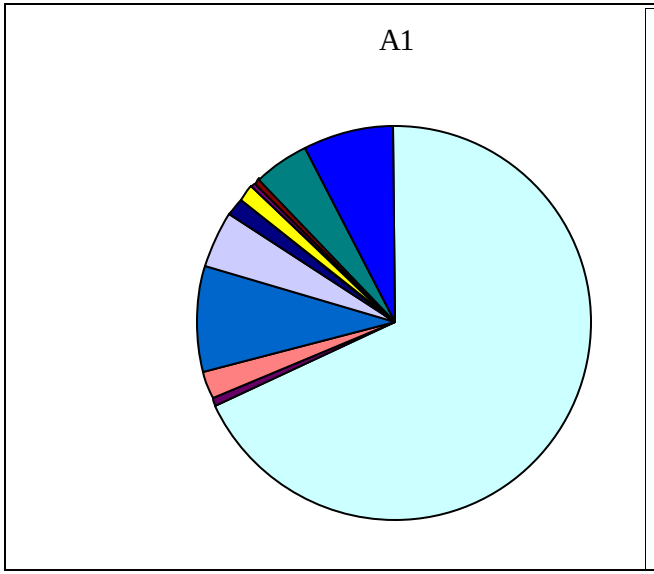


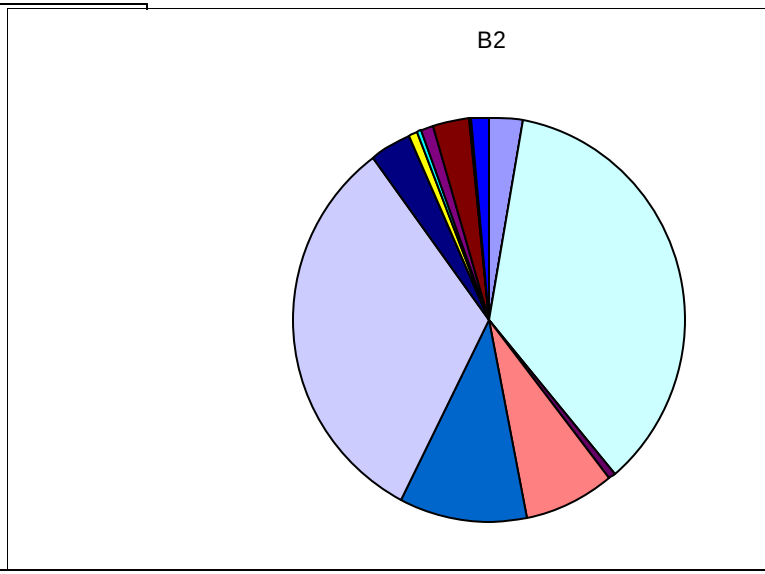
Life Form Distributions of Sample Sites

- Pteridium agulinium
- Optuntia compressa
- Anacardiaceae
- Aquifoliaceae
- Compositae
- Ericaceae
- Fagaceae
- Graminae
- Hamamelidaceae
- Hyperciaceae
- Liliaceae
- Leguminosae
- Pinaceae
- Polypodiaceae
- Rosaceae
- Clethraceae









Products to Date

Publications:

- Beyeler, S.C. 2000. Ecological indicators. Master's thesis. University of Miami in Ohio.
- Dale, V.H. and Beyeler, S.C. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators 1: 3-10.
- Dale, V.H. , Beyeler, S.C., and Jackson, B. In press. Vegetative indicators of anthropogenic disturbance in longleaf pine forests. Ecological Indicators.
- Foster, H.T., II and Abrams, M.D. In review. Physiographic analysis of the pre-European settlement forests in east-central Alabama. Canadian Journal of Forest Research.
- Peacock, A. D., S. J. MacNaughton, J. M. Cantu, V. H. Dale and D. C. White. 2002. Soil microbial biomass and community composition along an anthropogenic disturbance gradient within a longleaf pine habitat. Ecological Indicators 12:1-9.

Posters:

- Dale, V.H. and Beyeler, S.C. Ecological indicators: Tools for ecosystem management. SERDP Annual Meeting, December 1999, Washington, DC
- Dale, V.H. Ecological indicators. Workshop on Ecological Models for Resource Management. October 2000, Oak Ridge TN.
- Dale, V.H. "Ecological indicators for land management. Ecological Society of America Annual Meeting, August 6, 2001, Madison, WI.
- Dale, V.H., Feminella, J., Foster, T., Mulholland, P., Olsen, L. Selecting a suite of ecological indicators for land management. SERDP Symposium, Dec. 2001, Washington, DC
- Maloney, K.O., J.W. Feminella, and P.J. Mulholland. Effects of watershed disturbance on macroinvertebrate communities in small streams at Fort Benning, GA. 2002 North American Benthological Society, Pittsburgh, PA.

Presentations

- Dale, V.H. Views from the Ridge: Considerations for Planning at the Landscape Scale, sponsored by the Pacific Northwest Research Station, USDA Forest Service, Vancouver, Washington, Nov. 2-4, 1999.
- Dale, V. H. Symposium on "Urban landscape ecology" at the 15th Annual US Landscape Ecology Symposium, Fort Lauderdale, Fl., April 15-19, 2000.
- Dale. V.H. EcoSummit 2000: Integrating the Science. Halifax, Nova Scotia, Canada, June 18-22, 2000.
- Dale, V.H. Using indicators for restoration and management. Ohio State University. November 2, 2000.
- Dale, V.H. Lessons for Ecosystem Management. Fall Line Workshop. March 6-7, 2001, Aiken, S.C.
- Dale, V.H. Use of indicators. Workshop on "Climate Change and Species Survival: Implications for Conservation Strategies," February 19-21, 2001, The World Conservation Union (IUCN) in Gland, Switzerland.
- Dale, V.H. "Top Ten Issues in Landscape Ecology" session at the 16th Annual Symposium on Landscape Ecology, Tempe Arizona, April 2001
- Dale, V., L.Olsen, and T. Foster Landscape Patterns as Indicators of Ecological Change at Fort Benning, GA. US International Association for Landscape Ecology 17th annual symposium in Lincoln, Nebraska, April 2002.
- Foster, T. "Evolutionary Ecology of Creek Residential Mobility," Southeastern Archaeological Conference, Macon, Georgia, November 2000.
- Maloney, K.O., J.W. Feminella1, P.J. Mulholland, V. H. Dale and L. M. Olsen. Effects of past and present land use practices on small streams at Fort Benning, Georgia Ecological Society of America, Aug. 2002, Tucson, AZ.
- Olsen, Lisa M. and Virginia Dale. Landscape Patterns as Indicators of Ecological Change at Fort Benning, GA. ESRI User Conference, July 9-13, 2001, San Diego, CA.
- White, D.C., Peacock, A.D., S. J. Macnaughton, J. M. Cantu, V. H. Dale. Ninth International Symposium on Microbial Ecology Interactions in the Microbial World, Amsterdam, The Netherlands. "Changes in soil viable microbial biomass and composition reflect disturbance impacts and may serve as quantitative end points for reversibility"; August 27, 2001.

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

Coordination with Other SERDP Projects

- "Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation" will use hyperspectral data (primarily AVIRIS) to map and model the spread of invasive weeds at Fort Benning in coordination with our site specific data
- "A Regional Simulation to Explore Impacts of Resource Use and Constraints" will build upon our data and other ECMI information to integrate environmental effects of on-base training and testing and off-base development and other decisions
- "Riparian ecosystem management at military installations determination of impacts and evaluation of restoration and enhancement strategies" will co-locate some stream sampling sites and use some of our stream ecological indicators.