

Reporting the Forest Ecological Integrity of Northeastern National Parks

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- Natural Resource Challenge
- Inventory and Monitoring Program
- Vital Signs Monitoring



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- Northeast Temperate Network
- Vital Signs Monitoring Plan
- Protocols:
 - Forest Health
 - Lakes and Streams
 - Forest/Grassland Birds
 - Wetlands
 - Rocky Intertidal
 - Coastal Birds



Forest Monitoring Goals

Monitor trends in structure, function, and composition of forested ecosystems, including soils, and key stressors

Interpret and report condition (ecological integrity) of forested systems



“Ecological Integrity” measures structure, function, and composition compared to desired conditions based on management goals and the range of natural variation



Forest Monitoring Objectives

Defined for structural, functional, and composition metrics at multiple scales (landscape, stand, tree)

For example:

Functional metric:

Soil chemistry (acid stress)

Objective:

Determine trend in Ca:Al **ratio**

Trigger Point:

Molar ratio below one
indicates significant acid stress





Sampling Design



Population: All upland forests and woodlands within park boundaries

Sample Size: 326 permanent plots (10 to 152 per park)

Site Selection: By park, GRTS (spatially balanced and randomized)

Temporal Schedule: 4 rotating panels (4 years for complete cycle)

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Plot Sampling

Measures:

- Stand structure
- Snag abundance
- CWD
- Canopy closure
- Tree condition
- Tree growth
- Tree mortality
- Tree regeneration
- Understory diversity
- **Biotic homogenization**
- Soil chemistry
- Landscape context

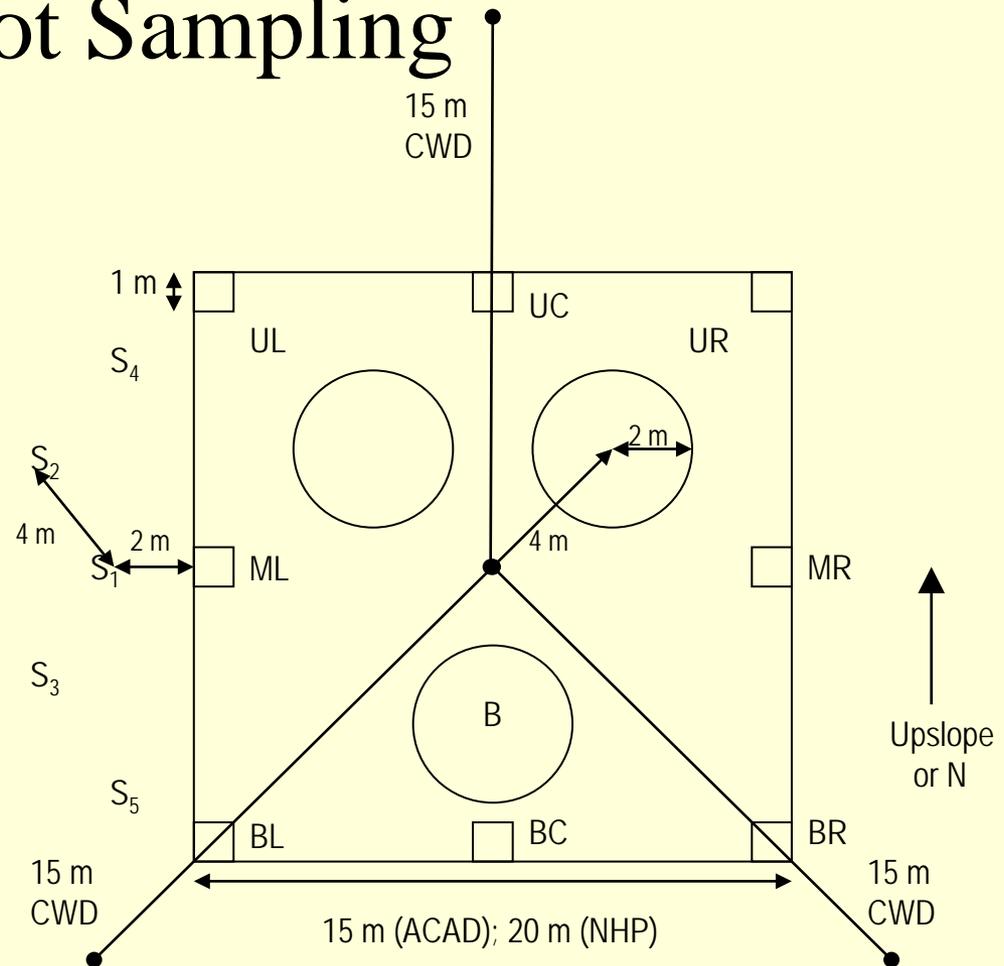


Figure 1: NETN plot layout showing square tree plot with 3 nested 2-m radius regeneration microplots, 8 1-m² veg quadrats, and 3 15-m CWD transects. S_x is location of soil sample.



Data Analysis

Status: Snapshot of metrics during each 4-year interval for each park

Trend: Linear trends of metrics using GLM or hierarchical models (investigating other methods, including non-linear models)

Ecological Integrity: Summary reports for managers that present metrics and interpret their meaning for ecosystem structure, function, and composition

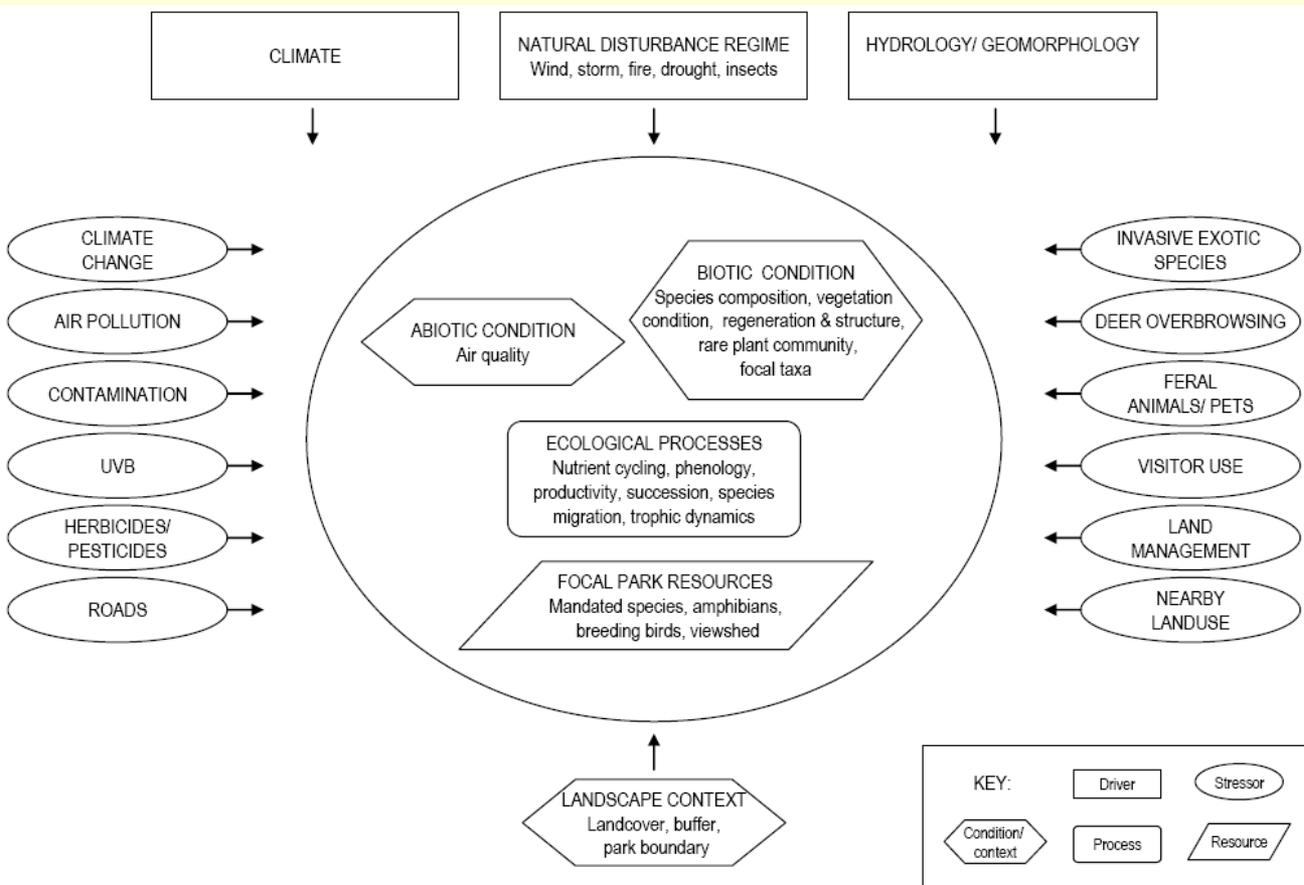
$$y_{ij} = b_0 + b_1 (t_j - t_0) + \eta_i + \varepsilon_{ij}$$

$$y_{(i+n),j} = b_0 + b_1 (t_{(i+n),j} - t_{ij}) + b_2 (x_{(i+n),j} - x_{ij}) + b_3 (t_{(i+n),j} - t_{ij})(x_{(i+n),j} - x_{ij}) + \eta_{ij} + \varepsilon_{ij}$$

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Steps to EI Reporting



Conceptual Model:
Conceptual understanding of system that identifies important characteristics, processes, and stresses

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Steps to EI Reporting

Metric Selection:
Choose key structural, functional, and compositional attributes that are informative, have low response variability, and are cheap to collect

Table 1. NETN Forest Protocol monitoring objectives			
	Metric	Monitoring objectives	Vital Sign(s)
Stand metrics	Stand structural class	Determine status and trends in the distribution of structural classes across park, and compare to that expected under natural disturbance regimes.	Forest vegetation
	Snag abundance	Estimate status and trends in snag abundance and size class distribution.	Forest vegetation
	Coarse woody debris (CWD)	Determine status and trends in coarse woody debris volume.	Forest vegetation
	Canopy closure	Determine status and trends in canopy closure in mature stands. Examine correlation between canopy closure and climatic stress, storms, pest and pathogen outbreaks and other disturbances. To be developed.	Forest vegetation
	Photopoint	Provide visual reference of plots for long-term comparison.	Forest vegetation
Tree metrics	Tree condition	Qualitatively assess condition of trees by species.	Forest vegetation, Exotic animals - early detection
	Tree growth and mortality rates	Determine growth and mortality rates of canopy tree species. Examine correlation between these rates and air pollution, pest or pathogen outbreaks, climatic stress or other known stressors.	Forest vegetation, Acidic deposition & stress, Ozone
	Tree regeneration	Determine status and trends in quantity and composition of tree seedling establishment in forest understory.	Forest vegetation, White-tailed deer herbivory
Understory metrics	Understory diversity	Determine status and trends in exotic plant species cover. Determine change in cover or extent of species indicative of deer browse pressure and other stress.	Forest vegetation, White-tailed deer herbivory, Acidic deposition & stress, Ozone
Soil metrics	Forest floor condition	Qualitatively assess forest floor condition and estimate trends in spatial extent of earthworms and trampling impacts.	Forest vegetation, Visitor usage, Exotic animals - early detection
	Soil chemistry	Determine status and trends in soil Ca:Al and C:N ratios to assess the extent of base cation depletion, increased aluminum availability and/or nitrogen saturation impacting NETN forest soils.	Forest vegetation, Acidic deposition & stress
Landscape Metrics	Landscape context	Determine status and trends in forest patch size, and proportion of surrounding area in natural cover and in anthropogenic landuse.	Forest Vegetation, Landcover, Landuse



Steps to EI Reporting

Define Levels: Base levels on existing literature, pilot testing, or first years of monitoring and management goals

Levels should separate acceptable from undesired conditions

Assign confidence to levels to assist interpretation

Levels can vary by habitat, location, or management realities

Table 1: Metrics and ratings for interpreting the ecological integrity of NETN forest and woodland ecosystems.

Metric	Ecosystem	Rating		
		Good	Caution	Significant Concern
Tree regeneration	Forest	Seedling ratio ≥ 0	Seedling ratio < 0	Stocking index outside acceptable range ¹
Tree growth and mortality rates	Forest	Growth $\geq 60\%$ mean and Mort $\leq 1.6\%$	Growth $< 60\%$ mean or Mort $> 1.6\%$	

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Steps to EI Reporting

Generate Report: Convey status and trend of key parameters in a meaningful way

Saint-Gaudens Forest Monitoring Results



Tags identify trees in the plot that have been measured and identified.



A stake is numbered & used to designate the center point of a forest plot.

PLOT	C/N	C/N Rating	Ca/Al	Ca/Al Rating	CWD Volume	Stand Structure
SAGA 1	21.14	CAUTION	0.63	CAUTION	2.12%	Old Growth
SAGA 2	23.08	CAUTION	19.17	GOOD	1.7%	Mature
SAGA 3	22.01	CAUTION	5.59	GOOD	1.64%	Mature
SAGA 4	28.80	GOOD	0.45	CAUTION	1.25%	Mature
SAGA 5	17.27	CAUTION	96.50	GOOD	0.00%	Old Growth
SAGA 6	20.32	CAUTION	3.66	CAUTION	0.00%	Old Growth
SAGA 7	24.42	CAUTION	1.11	CAUTION	0.82%	Mature
SAGA 8	25.54	GOOD	1.09	CAUTION	3.55%	Old Growth
SAGA 9	21.47	CAUTION	2.09	CAUTION	3.06%	Pole
SAGA 10	25.52	GOOD	0.36	CAUTION	0.00%	Mature

Tree Regeneration for the park is rated as good with a regeneration ratio of 2.08.

Soil Chemistry-Nitrogen Saturation
The impacts of atmospheric nitrogen deposition are measured through changes in carbon to nitrogen (C:N) ratios in the soil. Nitrogen is a limiting nutrient necessary for plant growth that has historically been retained within northeastern forested ecosystems.

Soil Chemistry-Acid Stress
An indicator of acidification stress to forest vegetation is measured in soil water or soil and is the ratio of calcium to aluminum (Ca:Al). Acidic deposition acidifies soil, leaching important base cations (Ca²⁺, Mg²⁺, K⁺) from the soil and increasing availability of aluminum; this deprives vegetation of necessary nutrients, and increases availability of a toxin (Al³⁺).

Coarse Woody Debris and Snags
Dead wood, in the form of standing dead trees (snags) and fallen coarse woody debris (CWD) are important structural features of forest stands that provide habitat for wildlife and fungi. This metric assesses the density of snags and volume of CWD in relationship to live tree density and volume. Snags and CWD provide important habitat for arthropods, reptiles, amphibians, birds, small mammals, and fungi. Snags are particularly important for cavity-nesting birds, and the density and size of snags is indicative of habitat availability for those species. Coarse woody debris is particularly important for amphibians, reptiles, and small mammals. Unlike snags, coarse woody debris continues to be used by wildlife as it

breaks into smaller pieces over time, thus CWD volume rather than density can be a useful indicator of habitat availability.

Stand Structure
This park-level metric assesses the structural stage distribution of forest stands across a park or region in relation to the expected distribution under natural disturbance regimes.

Tree Regeneration
The quantity and composition of advance regeneration of tree seedlings in the forest understory is assessed in a 2-m radius microplot. Future canopy structure and composition is determined by the quantity and species composition of advance regeneration.

Soil Chemistry-Nitrogen Saturation
The impacts of atmospheric nitrogen deposition are measured through changes in carbon to nitrogen (C:N) ratios in the soil. Nitrogen is a limiting nutrient necessary for plant growth that has historically been retained within northeastern forested ecosystems.

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Examples with 2006 Data

Composition: Invasive Exotic Plant Indicator Species

Detection of 20 priority exotic species, based on eight 1-m² quadrats and a 15 minute timed search of the plot (SE)

Good: < 0.5 species per plot

Caution: ≥ 0.5 and < 3.5 species per plot

Significant Concern: ≥ 3.5 species per plot

ACAD	MABI	MIMA	SAGA	SARA
0.0 (0.3)	0.6 (0.2)	X (SE)	X (SE)	3.0 (0.2)

Sample Size

38 (ACAD)

12 (MABI)

10 (MIMA)

10 (SAGA)

16 (SARA)

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Examples with 2006 Data

Structure: Snag Abundance

Abundance of snags by park or habitat (SE)

Good: $\geq 10\%$ standing **trees** and $\geq 10\%$ med-lg trees are snags

Caution: $< 10\%$ standing **trees** or large snags under-represented

Significant Concern: < 5 med-lg snags per hectare

	ACAD	MABI	MIMA	SAGA	SARA
% standing	16 %	7 %	X	X	22 %
med-lg (≥ 30 cm dbh)	10%, 8 / ha	1%, 2 / ha			5 %, 5 / ha

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Examples with 2006 Data

Function: Soil Chemistry (Acid Stress)

Minimum molar Ca:Al ratio of O and A horizons, measured at one site per plot **as** composite of 3 samples (**SE**)

Good: Ratio ≥ 4

Caution: Ratio ≥ 1 and < 4

Significant Concern: Ratio < 1

ACAD	MABI	MIMA	SAGA	SARA
3.7 (0.6)	110 (37)	X (SE)	X (SE)	200 (48)

Sample Size

38 (ACAD)
12 (MABI)
10 (MIMA)
10 (SAGA)
16 (SARA)

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Examples with 2006 Data

Landscape: Forest Patch Size

Size (ha.) of contiguous forest patch surrounding each plot (SE)

Good: ≥ 50 ha

Caution: < 50 ha

Significant Concern: Not defined

ACAD	MABI	MIMA	SAGA	SARA
1660 (157)	X (SD)	X (SD)	X (SD)	21 (9.2)

Sample Size

38 (ACAD)

12 (MABI)

10 (MIMA)

10 (SAGA)

16 (SARA)

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Acadia NP 2006 Scorecard

Figure 1: 2006 Forest integrity scorecard for Acadia National Park

Metric	Rating
Tree regeneration	TBD ¹
Tree growth and mortality rates	TBD ¹
Tree condition	●
Snag abundance	●
CWD volume	●
Biotic homogenization	TBD ¹
Indicator species - invasive exotic plants	●
Indicator species - deer browse	TBD ¹
Soil chemistry - acid stress	●
Soil chemistry - nitrogen saturation	●
Forest patch size (ha)	●
Anthropogenic landuse	●
Stand structural class	●

¹To be determined once sufficient data is collected.

“At-a-glance” summary
of each metric

Scorecard report
includes details and
interpretation

Results could be post-
stratified by habitat



Current Status

Summer 2007 Field Work: SUNY-ESF forest crew establishing second panel of plots (N = 77)

External Review of EI Methods: Ecological Integrity reporting documents ready for external review (volunteers?)

EI Manuscript: Currently drafting manuscript for *Frontiers*

NPS Collaboration: Working with eastern NPS programs (from the Great Lakes to the Southeast) to coordinate monitoring and reporting methods

Other Collaboration: Working with other state and federal agencies in the Northeast on regional monitoring efforts



Conclusions

Science Based: Our Ecological Integrity report is scientifically sound, flexible, and transparent

Interpretive: Simple summary format is helpful for non-technical audiences

Not a Replacement: Still need rigorous trend and other analyses of raw metrics