The Vermont Monitoring Cooperative: Integrated Forest Studies for the 21st Century

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ABSTRACT

Understanding and managing our forests today requires an ecosystem approach, coordinated long-term monitoring and research, and integration of data across multiple disciplines. This report discusses how the Vermont Monitoring Cooperative uses these approaches in its intensive program of forest ecosystem research and monitoring.

The Vermont Monitoring Cooperative (VMC), started in 1990, is a unique partnership among the University of Vermont, the Vermont Agency of Natural Resources, and the US Forest Service. Establishment of the VMC was motivated by the need for scientists, resource managers, and policy makers to have access to timely and relevant data on conditions and trends in our forests, atmosphere, surface waters, and wildlife, as well as on overall ecosystem health. The objectives of the VMC are to: (1) coordinate and integrate monitoring and research activities and data, (2) provide basic environmental and ecological monitoring data to resource managers and research scientists, and (3) identify trends in the physical, chemical and biological components and processes of Vermont's forested ecosystems.

The VMC's main study site is located on Mount Mansfield in northern Vermont (44°30' N, 72°51' W), encompassing over 2,200 ha of state and university owned forested land between 400 and 1,200 m elevation in three watersheds including northern hardwoods, montane spruce-fir, and alpine ecosystems. Over 30 environmental and ecological research and monitoring projects are underway involving 18 cooperating agencies. A second site at the Lye Brook Wilderness Area in the Green Mountain National Forest was established in 1993; current activities there are focused on monitoring air quality, surface waters, amphibian populations and forest health.

The VMC monitoring program addresses physical and chemical attributes of atmospheric and forested environments, and ecosystem monitoring tracks forest health and composition, forest insect, amphibian and bird diversity, and surface water biota. The VMC research program emphasizes functional relationships among ecosystem components, particularly with respect to environmental change and forest management. Finally, a critical component of the VMC is data integration, the active coordination of data into meaningful associations and user-friendly relational databases using the Voyager Data Exploration software system.

INTRODUCTION

It is becoming increasingly clear that significant and complex changes are taking place in our environment. Some of these (e.g., changes in acid deposition, photochemical oxidants, climate, stratospheric ozone depletion, and land use) have the potential to affect ecosystem vitality, productivity, diversity, and integrity. Certain stresses (such as acid rain) may be reduced somewhat in the relatively near future, but others (such as climate change and stratospheric ozone depletion) are certain to worsen over the next century. For a variety of reasons it is important to track these changes, but our baseline data and monitoring programs are often inadequate.

In addition, we have very limited information about the health and baseline conditions of forested ecosystems in Vermont and other places, and our ability to identify and address changes in ecosystem condition and function is minimal. We lack the ability to perceive subtle changes in ecosystem condition over time, to identify causal relationships, to recommend or undertake effective protective or remedial actions, or to manage ecosystems for sustainable use of their resources.

Thus, there is a pressing need to better understand environmental changes and their interaction with the forested ecosystems we are so dependent on. In the past, our approach to these problems has generally been short-term, reactive and single-disciplinary, yielding limited knowledge about ecosystem function. Today, as environmental problems become more subtle and interactive, and we recognize the need for ecosystem-scale management, our research and management practices must become more long-term, integrated, multi-disciplinary, and founded on good ecosystem science. To do this, we need (i) long-term, systems-oriented, ecological monitoring, (ii) coordinated environmental monitoring, and (iii) integration of these activities with research on ecosystem function and responses.

The Vermont Monitoring Cooperative (VMC) was formed to address these concerns in Vermont. Growing out of a series of discussions between scientists and resource managers in 1989, a conceptual plan for a long-term ecological/environmental monitoring program developed (Scherbatskoy and Poirot, 1989; Scherbatskoy, 1990a). In FY 1990 the U.S. Congress appropriated $250,000 for the establishment of this program in Vermont. The VMC was conceived as a science-management partnership, involving the active participation and cooperation of many groups in a coordinated manner to:

(1) coordinate and integrate monitoring and research activities and data in Vermont;

(2) provide basic environmental and ecological monitoring data to resource managers and research scientists; and

(3) identify trends in the physical, chemical and biological components and processes of Vermont's forested ecosystems.

STRUCTURE AND APPROACH

The VMC is a unique organization in that it was created (a) *de novo*, (b) as a partnership between resource managers and scientists, and (c) to coordinate and integrate monitoring and research at intensive study sites. An administrative structure was developed which supports the effective interaction of the science and management communities in Vermont to address the program's goals, as shown in Fig 1.

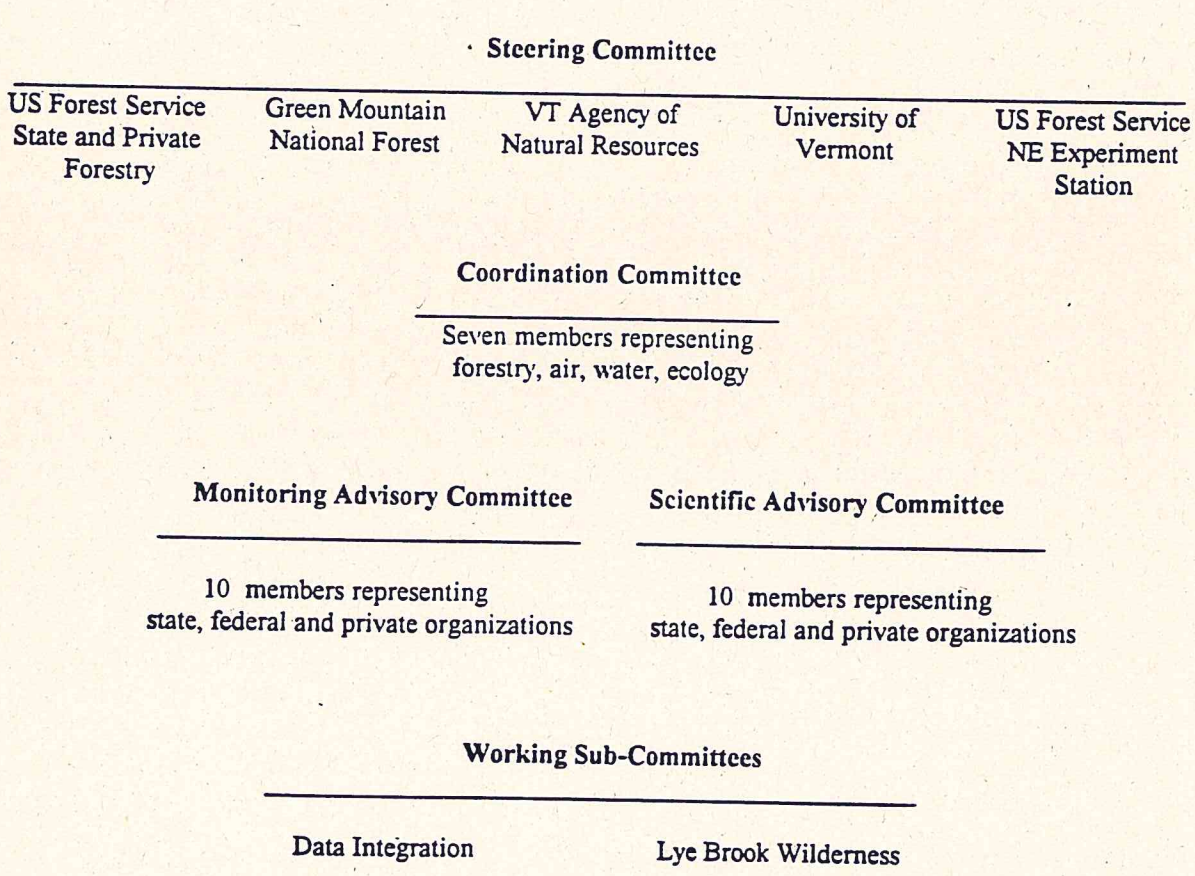

Figure 1. Organizational structure of the VMC.

Early in the development of the VMC, a focused planning process was undertaken to obtain input from resource managers, scientists, policy-makers and the public on program goals and design, and on monitoring and research priorities (Scherbatskoy, 1990a). An assessment of all known monitoring programs in northern Vermont (the region of the first planned intensive study site) was undertaken to determine which data and programs provided a foundation for future monitoring and research (Scherbatskoy, 1990b). Of 20 existing monitoring activities at the site that were of sufficient quality to continue, 14 are active now.

The first year of new monitoring and research under the VMC was 1991, with a total of 21 monitoring projects being conducted by eight major organizations. In 1993, there were 32 monitoring projects underway at the Mt. Mansfield site; in addition, there were 12 long-term research projects underway there. These activities are identified in detail in Annual Work Plans (e.g., Wilmot and Scherbatskoy, 1993), and results are summarized in Annual Reports (e.g., Wilmot and Scherbatskoy, 1992). Participants and cooperators in the VMC include academic institutions, private organizations, industry, and federal agencies (Table 1).

In 1993, the VMC expanded to include a second intensive study site in southern Vermont, at the Lye Brook Wilderness area (a Class I Wilderness Area under the US Clean Air Act) in the Green Mountain National Forest. A number of activities were initiated there in 1993, including ecological land mapping, amphibian monitoring, lichen surveys, surface water chemistry and biota monitoring, and atmospheric deposition monitoring. A working sub-committee was established (Fig. 1) to coordinate these activities and to assist in integrating them into the overall VMC program.

Financial support for the VMC comes from a combination of federal funds obtained for operation of the core program and individual grants obtained by participants. The anticipated budget for FY 1994 is approximately $290,000 from federal sources for core operations and $245,000 from other state, federal and private funds for related participant-funded activities.

The VMC has attracted the attention of state and federal scientists, managers and policy-makers both as a significant program of integrated, long-term ecosystem monitoring and research, and as a model for effective coordination of resources to address contemporary forest ecosystem management problems. In 1993, the VMC Mt. Mansfield study site was identified by the US Forest Service as a satellite in its Intensive Site Ecosystem Monitoring (ISEM) program.

To ensure a coordinated and integrated monitoring and research program, the VMC requires all participants to apply annually for project and location approval. This takes the form of a brief application form which asks for the project's objectives, relevance to VMC goals, proposed location and duration, possible incompatibilities with other projects, and which requires the applicant to provide an annual progress report and to share data at some point in time. The

application is evaluated by the Coordination Committee (Fig. 1). Data on project location is recorded in a GIS base map to be used to help prevent land use conflicts.

Table 1. VMC participants and cooperators.

Middlebury College
Biology Department
Geography Department
National Atmospheric Deposition Program
National Oceanic and Atmospheric Administration
Northeast States for Coordinated Air Use Management
University of Vermont:
College of Agriculture and Life Sciences
Department of Botany
Entomology Research Laboratory
School of Natural Resources
U.S. Environmental Protection Agency
U.S. Forest Service:
Green Mountain National Forest
Northeastern Forest Experiment Station
State and Private Forestry
Vermont Agency of Natural Resources:
Air Pollution Control Division
Department Fish and Wildlife
Department of Forests, Parks and Recreation
Water Quality Division
Vermont Institute of Natural Science

Monitoring program

The atmospheric component of the VMC monitoring program addresses the meteorology of forests and the ambient atmosphere, and atmospheric chemical deposition. These activities are outlined in Table 2. Several meteorological stations are currently deployed at different elevations and, for one study, at multiple heights within the forest canopy. The major goal of these measurements is to characterize both ambient meteorology and within-forest conditions. A related research project uses a forest canopy access tower to characterize meteorology, chemical concentrations, and other canopy variables at multiple heights within a hardwood forest canopy.

Monitoring activities for chemical deposition address wet and dry deposition of major nutrients, aerosol concentrations of nutrients and trace metals, and gaseous pollutants. A number of these activities are part of larger national monitoring networks (e.g., NADP). Special attention has recently been given to monitoring atmospheric mercury in precipitation, aerosol and vapor phases. In addition, a UV-B monitoring program was recently initiated using a broad-band (290-315 nm) instrument (Yankee Environmental Systems).

Table 2. VMC atmospheric monitoring

1. Meteorology:	a. Air quality monitoring site (ambient, 400 m) b. Canopy tower (in-forest, 400 m, multiple levels in canopy) c. Mid-elevation forest (in-forest, 600 m) d. High elevation forest (in and above forest, 1000 m) e. Mt. Mansfield summit (ambient, 1200 m)
2. Precipitation chemistry:	a. NADP/NTN (wet-only, major nutrients, weekly) b. AIRMoN (wet-only, major nutrients, daily) c. Mercury (daily) d. VAPMP (bulk, pH only, daily)
3. Aerosols:	a. Fine particle mass and chemistry (2.5 μm, 24 hr, 3 x week) b. Coarse particle mass (10 μm) c. Particulate mercury d. Particulate NO_3, SO_4, NH_4 (filter-pack, weekly) e. IMPROVE (visibility)
4. Gasses:	a. Ozone (ambient, continuous) b. Ozone gradients in the canopy (in-forest, continuous) c. Vapor-phase mercury d. HNO_3 and SO_2 (filter-pack, weekly)
5. Radiation:	a. PAR and total b. UV-B (broad-band)

Ecosystem monitoring activities are outlined in Table 3, and address forest condition, fauna biodiversity, and surface water characteristics. As with the atmospheric monitoring, a number of these studies are parts of larger national or international programs. An important aspect of these studies is that, in addition to providing baseline data, they support research on functional

relationships within the ecosystem. For example, data on birds, insects, and forest canopy condition provide opportunities for analysis of trophic relationships, which in turn, can be related to data on forest conditions at plot and watershed scales.

Research program

One of the motivations for establishing the VMC was the belief that integrated research and monitoring on multiple aspects of forested ecosystems are needed to better understand and manage these complex systems. Another motivation was the need for resource managers and scientists to have access to timely, site-specific data on environmental and ecological conditions and trends in our forests, atmosphere, surface waters, and wildlife. These two goals are central to two key aspects of the VMC program, integrated research and data integration, as discussed below.

Table 3. VMC forest ecosystem monitoring.

1. Forest health:	a. National Forest Health Monitoring Program
	b. North American Maple Decline Project
	c. VT Hardwood Health Survey
	d. Forest canopy condition
	e. Sugar maple regeneration
	f. Tree elevational limits
	g. Lichen biodiversity
	h. Ozone-sensitive vegetation
2. Fauna biodiversity:	a. Amphibian populations
	b. Forest bird surveys
	c. Forest insect pests
	d. Insect biodiversity
3. Surface waters:	a. Aquatic macro-invertebrates in streams
	b. Aluminum chemistry in streams and ponds
	c. Stream-flow and water quality

The goal of the VMC research program is to take a systems approach to analysis of structural and functional aspects of forested ecosystem response to environmental change and human use. This involves: **(1) ecosystem monitoring** of the physical and chemical environment, forest condition, and forest inhabitants, **(2) ecosystem research** to identify

relationships among chemical cycling, trophic relationships, impacts of stressors, and (3) **systems analysis** of these data to provide assessments of ecosystem-level function using data integration techniques (Voyager, modeling), sensitivity analyses of ecosystem driving, response and indicator variables, and development of an integrative model of ecosystem function. Major VMC research projects currently underway are summarized in Table 4.

Table 4. Major VMC research areas and projects.

Elemental Cycling
Mechanisms of canopy ion exchange at the branch and leaf level.
Foliar N resorption during senescence in sugar maple.
Responses of elemental cycling in forests to environmental change.
Hydro-geochemistry of a hardwood watershed.
Behavior of atmospheric mercury in deposition and snow-melt.
Ecosystem Function
Responses of ecosystem processes and functions to management and experimental manipulation.
Environmental gradients in a hardwood forest canopy.
Biogeography and winter hardiness of balsam fir.
Biodiversity of non-pest forest insect populations.
Mapping genetic and morphological characteristics of forest trees.
Data Integration
Development of techniques and theory for multi-disciplinary data management and integration to support ecosystem management.
Relationships among insects, sugar maple condition, and meteorology in Vermont.

Some of the important strengths of the VMC research program include: (1) partnerships between scientists and managers, including academic, state, and federal involvement in multiple disciplines, providing a program that addresses current issues with scientific integrity, (2) an interdisciplinary program examining multiple aspects of ecosystem structure and function, an approach needed to support ecosystem management, (3) work in multiple-use forests, where priorities include recreation, timber and wildlife management, aesthetics, and research, typical of much of Vermont, (4) basic research on system function, ecosystem processes, and applied research on effects of environmental change and interactions with

forest management activities, (5) education and outreach including student research experience and dissemination of timely and appropriate information to the public.

Another unique and important aspect of the VMC program is a commitment to bringing the monitoring and research data together in a user-friendly, informative data management system. Toward this goal, the VMC has chosen the Voyager Data Exploration System (Lantern Corp., Clayton, MO) as an important tool for managing and integrating diverse data sets with large spatial and temporal domains. Voyager is a relational database system running under Windows in a PC environment, allowing a user to "browse" large complex data sets by navigating with a mouse through space, time, and variable views of the data. A free limited version of the program is available (the Voyager Viewer) which can be used to view Voyager data files and serves as an effective tool for sharing data. An example of a Voyager view of NADP precipitation chemistry data is shown in Fig. 2. Several data integration efforts underway within the VMC are summarized below.

1. Data integration project: A pilot demonstration project using Voyager to integrate multiple data sets into a user-friendly data communication and analysis system, including air quality, forest health, meteorology, insect populations, and surface waters. Printed and electronic reports on this project will be available early in 1994.

2. Meteorology: Multiple meteorological data sets (ambient, in-forest, mountain-top, etc.) are being combined in Voyager with forest health, aerosol and precipitation chemistry data to facilitate evaluations of relationships among these variables.

3. Regional ozone computer network: A pilot project in cooperation with NESCAUM is compiling daily maximum ozone concentrations for northeastern states and provinces and reporting them monthly over a regional computer bulletin-board in Voyager format.

4. Sugar maple health assessment: Five years of data on meteorology, maple health and Thrips (an important pest of maple) populations are being combined in Voyager to address questions about interactions among these factors.

SUMMARY

An overview of the Vermont Monitoring Cooperative (VMC) was provided. This new program combines the efforts of resource managers and scientists to address questions about responses of forested ecosystems in Vermont to environmental change and management. The premise of the VMC is that long-term, integrated monitoring and research that is coordinated among scientists and managers is needed to properly evaluate these questions. VMC monitoring emphasizes the chemical and physical environment and characteristics of the forested ecosystem. The VMC research program builds on this rich monitoring base and

emphasizes elemental cycling and relationships between ecosystem structure and function. Finally, a major VMC effort addresses the integration and management of extensive and diverse data to provide useful information to a number of user groups on inter-relationships and trends in ecosystem components.

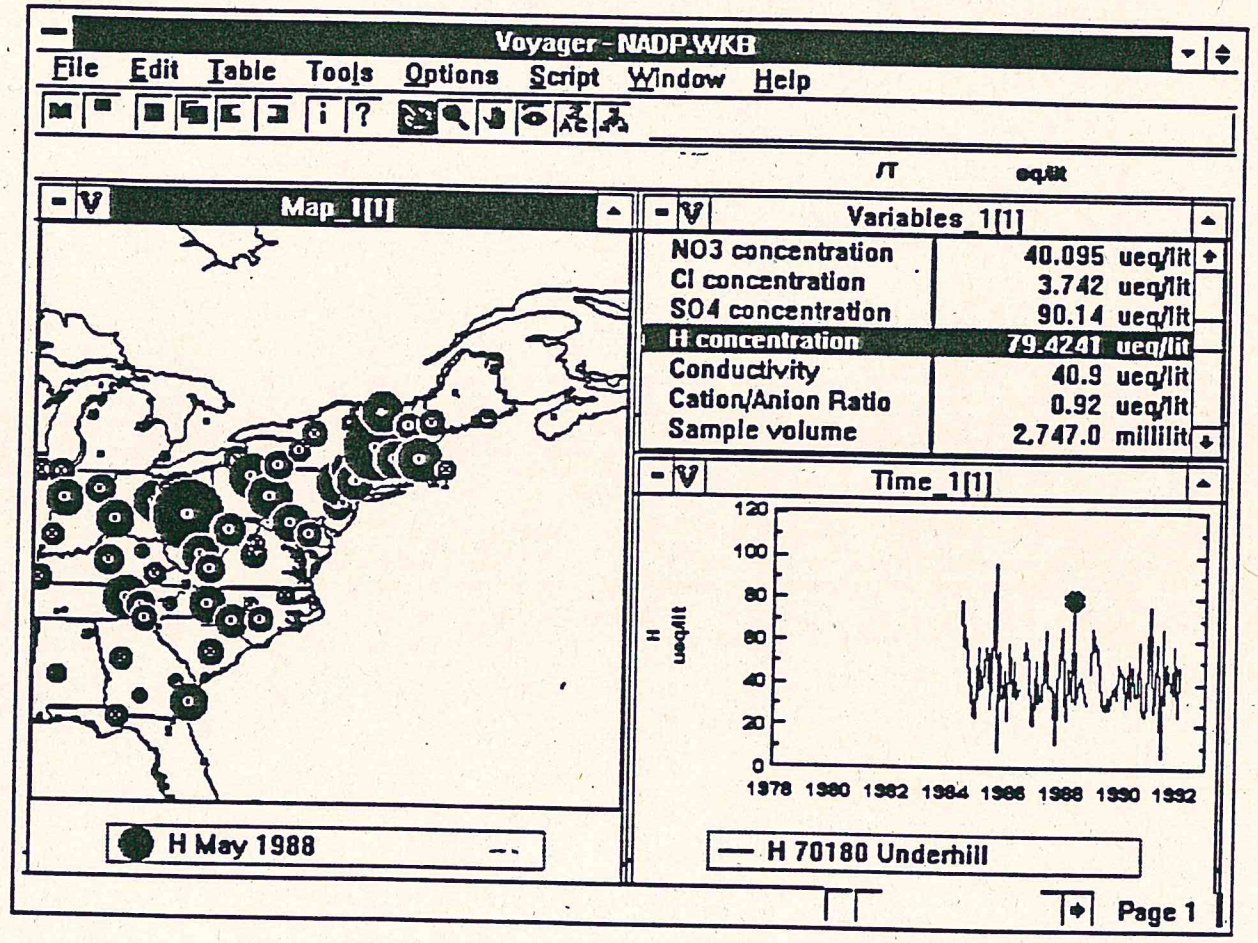

Figure 2. Typical Voyager view of NADP data showing spatial, temporal and variable views of data.

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