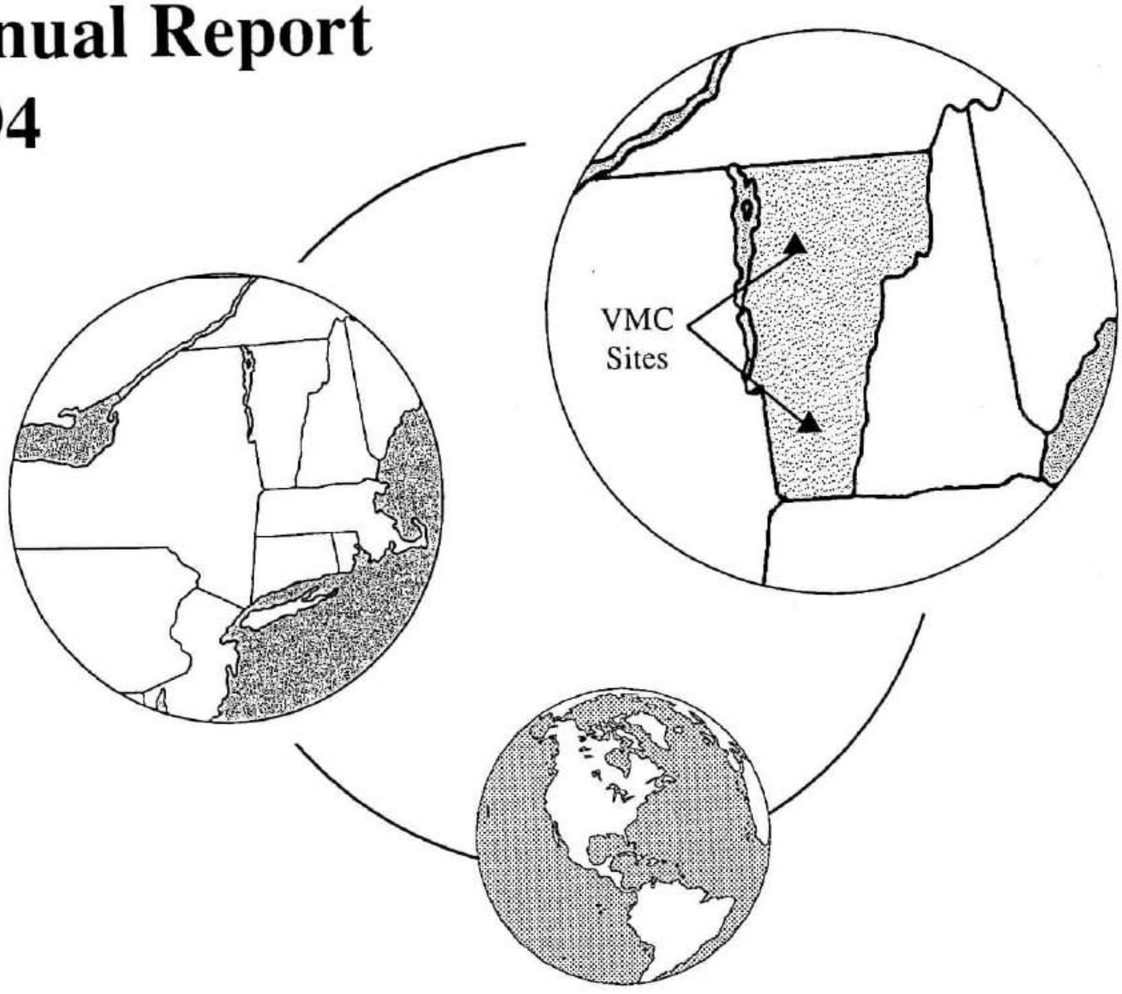
Vermont Monitoring Cooperative

Vermont's Intensive Forest Ecosystem Monitoring and Research Program

Annual Report 1994



A Local Effort to Understand Global Problems

Administered by:

Vermont Department of Forests, Parks and Recreation - University of Vermont - Green Mountain National Forest

Reference citation

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Vermont Monitoring Cooperative

Annual Report for 1994

Sandra Wilmot and Timothy Scherbatskoy
(Editors)

The VMC is Vermont's Intensive Forest Ecosystem Monitoring and Research Program, administered by the Department of Forests, Parks & Recreation, the University of Vermont, and the Green Mountain National Forest.

Additional financial support has been received from the USDA Forest Service, Northeastern Area State and Private Forestry and Northeast Forest Experiment Station.

VMC Annual Report Number 4

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Introduction

Introduction

The purpose of the VMC annual report is to provide a document to all VMC cooperators and interested persons describing preliminary results from studies conducted at the two VMC sites at Mount Mansfield and the Lye Brook Area for the year. Participants in the program are invited to submit their findings for the year in a form that is easily understood by others involved in or interested in the program. It is hoped that this process will facilitate exchange of information and ideas and stimulate cooperativeness in expanding our understanding of forest ecosystems.

This document begins with an overview of program highlights for 1994, then proceeds to specific study results. Results are organized by the type of information collected (atmospheric, flora, fauna, etc.), and within each type are articles for both Mount Mansfield and the Lye Brook Area sites.

During the year, we began to compile and provide documentation on data sets from Mount Mansfield and the Lye Brook Area sites. To reach the goals of the VMC, information in the form of reports and data, needs to be available in a timely fashion to all those groups who can make use of them. The first step begun this year was to design a data documentation system that would be useful cataloging, searching and retrieving the data . A contractor was hired to accomplish this first task. With the framework designed, we then began the next step of data acquisition, and development of a VMC data storage and retrieval system.

Our data storage and retrieval system will center around Internet access. To initiate this system, a UVM student was hired to help create a VMC homepage on the World Wide Web, and to begin the process of describing VMC studies, and providing a framework for future access of VMC reports and data. The World Wide Web address is: **http://mole.uvm.edu/vmc**.

At the Summit Station on Mount Mansfield, a Mount Mansfield Visitor Center was opened with a major effort by the Green Mountain Club, in cooperation with the University of Vermont. One of the displays featured at the center highlights the VMC and it's many ecosystem monitoring and research projects. There will be opportunities in the future to expand on this display, or update it as new information is uncovered.

Other VMC outreach activities included a series of radio programs conducted by the UVM Extension System, highlighting the VMC program and some of the participating studies. Four different radio segments highlighted the VMC program, amphibian monitoring, forest monitoring and ecosystem research projects, with VMC participants interviewed by UVM's Julie Becker, and aired in 3 minute spots on local radio stations. The VMC brochure, which is widely distributed to the public, was updated to include both the Mansfield and Lye Brook Area sites, presenting the program goals, composition, projects, sites, and future directions in a new format.

A new air quality and meteorology monitoring station was installed adjacent to the Lye Brook Wilderness Area as part of the Environmental Protection Agency's Clean Air Status and Trends Network (CASTNet). This will provide our southern Vermont site with measurements of wet and dry acid deposition, ozone and year-round meteorology. Wet and dry acid deposition is measured as weekly samples. Ozone is measured continuously during the ozone season, May thru September. Meteorology measurements include all major variables, and the data can be accessed by telephone, making data available in a timely fashion. This completes a two year process in involving EPA, GMNF, VMC and others to identify and establish this site.

The annual meeting this year featured a mini-symposium on environmental indicators. Representatives from the Agency of Natural Resources and the University of Vermont. Applications for indicators presented included as tools for resource management, ecosystem management and scientific research, in environmental regulation enforcement and in assessing environmental quality. This offered an opportunity for VMC participants to explore how study results might be applied to environmental quality assessment.

Data Integration

Data Management and Integration

The overall targets for VMC data management are: to provide to various user groups appropriately formatted, high quality and readily accessible environmental data and metadata from across Vermont, with special emphasis on the Mount Mansfield and Lye Brook Wilderness study areas; to improve the use of the data sets inside and outside the VMC community through the preparation of summaries and integrated reports; and to develop a Vermont Environmental Decision Support Network which will better match VMC data and expertise with the information needs of educators, resource managers and policy makers.

Current activity in the VMC data management and integration to accomplish these targets includes:

Organizing current data sets and improving data accessibility:

- Develop a Wide Area Information Server (WAIS) that provides an on-line searchable database containing VMC project information and data documentation.

- Utilize a PC-based database application to create a VMC Data Library Card Catalog with project information and data documentation.

- Collect existing data (1990-1995) (Fig. 6), bring up-to-date Category 1 (Internet Accessible) data sets, and develop procedures for the annual update and distribution of the VMC Data Library.

- Improve the design of the existing VMC Data Library, by developing a distributed network of Internet Information Service providers that utilizes the computer resources of participating agencies (Vermont Department of Forest, Parks & Recreation, the Green Mountain National Forest and the University of Vermont) and our cooperators (CAPITA, Middlebury College, USFS Experiment Station, Vermont's Agency of Natural Resources etc.).

- Build anonymous File Transfer Protocol (FTP) archive and World Wide Web (WWW) information service on the Internet.

- Continue to develop Voyager Data Exploration Software as a readily accessible tool for data integration. This will include improving existing maps and adding maps of VMC study areas, updating existing data and compiling additional data sets into Voyager format.

- Compile existing Geographic Information System (GIS) coverages from Mount Mansfield and Lye brook study areas into a spatial database. When necessary create additional coverages to facilitate data collection and integration.

Integrating data sets:

- Develop a long-term plan for data integration.

- Create a master VMC data set that links all the data sets with a common time domain.

- Explore the development of VMC's PC-based Internet-accessible Videoconferencing Network. This network will assist in data integration and synthesis through video, audio and application sharing (data transmission) using the National Information Infrastructure.

- Publish a 1995 VMC Data Integration Report, demonstrating different approaches to data integration, with a focus on using data to help address ecosystem management questions (see below).

The goal of the report is to use VMC monitoring and research data to begin to answer ecological questions pertinent to forest ecosystem management.

For the purposes of this report, Ecosystem Management is defined as:using ecological information to help determine how to produce desired resource conditions, values, products and services in ways that also sustain diversity and productivity of forested ecosystems.

Some of the different spatial scales that might be used to integrate data for this report or in other studies include: stand level, water body, watershed(s), townships surrounding VMC sites, Vermont, Lake Champlain Basin, Connecticut River Basin, Northern Forest Lands, northeastern region, Ecological Land Type.

The following ecological questions will form the framework of this report. Most questions are relevant to ecosystem management in that they help determine what is "normal" for a specific scale, and eventually will aid in determining ecological impacts from management. Existing data from VMC projects will be used to develop answers and insights to each question.

* What is the **natural variability** of ecosystem components?

* What is the **biodiversity** of forested ecosystems?

* What is the current **condition of our forested ecosystems**?

* What are the current **environmental conditions**?

Atmospheric

Deposition and within-forest processing of atmospheric mercury
- 1994 -

Tim Scherbatskoy
University of Vermont School of Natural Resources

Cooperators:

University of Vermont: Joanne Cummings, Carl Waite, Rinda Gordon
Proctor Maple Research Center: Melvin Tyree, Sumner Williams
University of Michigan: Jerry Keeler, Anne Rea
NOAA Air Resources Laboratory: Richard Artz
VT ANR DEC Air Pollution Control Program: Rich Poirot

Abstract:

Deposition and ecosystem processing of atmospheric mercury (Hg) in the Lake Champlain basin has been studied in cooperation with the University of Michigan Air Quality Laboratory since December, 1992 at the VMC Air Quality Monitoring site in Underhill Center, VT (400 m elevation). Daily wet-only precipitation, weekly 24 hr vapor and particulate samples, snowmelt and stream water have been analyzed for total Hg by cold vapor atomic fluorescence spectrometry (CVAFS). Between December 1992 and December 1994, total mercury in precipitation ranged from 1.5 to 44 ng/L; the highest concentrations generally occurred during the summer months. Vapor phase Hg ranged from 1.2 to 4.2 ng/m^3, without much seasonal variation. Particulate phase Hg ranged from 1 to 43 pg/m^3, with the highest concentrations occurring in the winter months. Wet deposition of total Hg in precipitation totaled 9.27 μg/m^2 for 1993 and 7.66 μg/m^2 for 1994. Combined wet and dry deposition of Hg, using estimated vapor phase dry deposition, was 15.0 μg/m^2 for 1993 and 12.5 μg/m^2 for 1994, with the greatest deposition rates in the summer months. In addition, total Hg concentrations in stream-water were monitored in Nettie Brook, a small stream draining an 11 ha mixed hardwood watershed in the Stevensville Brook area. Hg concentrations were 1 to 3 ng/L during base flow conditions, and reached 79 ng/L at peak flow during spring snowmelt. Synoptic sampling of rivers in the same drainage basin also showed significant increases in total Hg during snowmelt periods. Measurements of Hg chemistry of snow-pack and snow-melt were also conducted in 1994, and are summarized here. Finally, an intensive study of Hg in forest canopy throughfall was conducted during the summer of 1994, showing that Hg is significantly enriched in throughfall and that autumn litterfall provides a very large flux of Hg to the forest floor.

INTRODUCTION

There is widespread concern that atmospheric sources of mercury (Hg) may be responsible for increasing Hg burdens in Lake Champlain (McIntosh 1994, Vasu and McCullough 1994). This has been shown to be the case for many remote lakes in the Great Lakes region (Fitzgerald *et al.* 1991), but there are no comparable data for the Lake Champlain basin. Little information exists on levels or behavior of Hg in forested ecosystems, but these may provide important pathways for the transport and transformation of Hg from the atmosphere to aquatic systems. The Lake Champlain basin is characterized by a large (18:1) ratio of watershed to lake surface area, so capture and processing of atmospheric pollutants by forest systems is particularly important to understand in this region (Table 1). Approximately 89% of the basin is in forest and agriculture categories, with the lake itself representing only 5% of the total basin area. This is in sharp contrast to the Great Lakes, which represent a large proportion of their watersheds.

The research program discussed here was established to address concerns about Hg and other toxic metals in the aquatic, terrestrial and atmospheric systems of the Lake Champlain basin. The broad goals of this program include: (1) characterizing Hg concentration and deposition in precipitation, particulate and vapor phases, (2) studying Hg transport and processing within forested watersheds (including snowmelt, stream chemistry and transport, and forest throughfall), and (3) supporting larger Lake Champlain issues (meso-scale modeling of pollutant deposition, trace metal toxicology, and patterns of accumulation of toxics in biota and sediments). From 1992 to 1994, work concentrated on monitoring Hg concentrations in precipitation, vapor and particulate phases, and on obtaining baseline data for Hg and trace metals in stream water and snow-melt. Subsequent work is aimed at developing a better understanding of Hg cycling, mass balance, transport mechanisms and trophic relationships in the ecosystems of the Lake Champlain basin.

RESULTS

Two publications resulted from these studies in 1994. One deals with atmospheric Hg deposition and watershed transport processes (Scherbatskoy *et al.* 1995), and the other focuses on forest canopy throughfall and litterfall (Rea *et al.* 1995). Detailed explanations of objectives, methods and results are presented in these papers, and will not be repeated here. Instead, what follows is a brief synopsis and several tables and figures to briefly summarize key findings from this work through 1994.

Atmospheric Deposition

Monthly average concentrations of total Hg in precipitation, vapor and particulate phases are summarized for 1993 and 1994 in Figure 1. Seasonal patterns are summarized in Tables 2 and 3. These data are comparable in magnitude and trend to values for rural northern Michigan (Burke *et al.* 1995, Hoyer *et al.* 1995, Keeler *et al.* 1995). Monthly wet and dry Hg deposition are shown for 1993 and part of 1994 in Figure 2; dry deposition was estimated from vapor phase Hg concentration as described in Scherbatskoy *et al.* (1995). The total Hg deposition for 1993 was calculated to be 14.97 $\mu g/m^2$, consisting of 9.27 $\mu g/m^2$ wet and 5.70 $\mu g/m^2$ estimated dry deposition.

Surface Water Chemistry

Since October 1993, stream major ion chemistry, flow and environmental parameters have been monitored at Nettle Brook, draining an 11 ha catchment located within a mixed hardwood forest where detailed characterizations of the stream and forested watershed are being conducted. Mercury monitoring in this stream began in March 1994. Total Hg concentrations in streamwater during early spring 1994 are shown for this site in Figure 3. Maximum Hg concentration of 79 ng/L was measured during peak streamflow (76 L/s on 16 April). Hg concentration in the filtered water fraction (0.2 μm) were generally in the range of 2 to 3 ng/L even when flow and total Hg concentrations increased sharply. During the year, Hg export from the Nettle Brook watershed totaled 31 mg/ha (3.1 $\mu g/m^2$), approximately one-fifth of the total wet plus estimated dry deposition for this period (Figure 4). This suggests that a large portion of atmospherically deposited Hg may be retained in the watershed. Synoptic stream samples were also collected in 1994 on three dates at four sites in the Lamoille River drainage basin (Figure 5); these data are summarized in Figure 6 and show that the higher Hg concentrations associated with early spring snowmelt also occur in the larger rivers.

Snow chemistry
The Hg chemistry of the accumulated snow-pack for winter 1994 is summarized in Table 4. Snowmelt, collected daily in early spring 1994 from a large Teflon-coated snow lysimeter, had a range of Hg concentration from 2 to 9.2 ng/L.

Throughfall
Throughfall, green foliage, litterfall, precipitation and ambient air were analyzed for total Hg in a mixed hardwood stand at the forest canopy research tower at the Proctor Maple Research Center in Underhill Center during a six week period in August and September, 1994. During this period, the volume-weighted mean Hg concentration in throughfall (12 ± 8.5 ng/L) was greater than in precipitation (6.5 ± 2.8 ng/L); these data are summarized in Figure 7. Hg deposition in throughfall and precipitation during this period were 1.2 $\mu g/m^2$ and 1.9 $\mu g/m^2$, respectively. Throughfall, therefore, represents a significant addition to total Hg deposition in forested areas. The mean concentration of Hg in litterfall (53.2 ± 11.4 ng/g) was greater than in green foliage (34.2 ± 7.2 ng/g), and annual Hg deposition in litter was estimated to be 13 $\mu g/m^2$ (Rea *et al.* 1995).

REGIONAL CONTEXT

These studies were designed to provide basic monitoring data for atmospheric Hg deposition and to build toward understanding the processes controlling Hg deposition, transport, transformation and accumulation in the watersheds and streams of the Lake Champlain basin. The Hg monitoring site in Underhill Center is the eastern-most site in a 10-site Hg monitoring network operated by the University of Michigan Air Quality Laboratory, and is considered representative of the forested watersheds of the Lake Champlain basin. There is at present no other comparable monitoring program in New England that provides continuous monitoring of Hg in all three phases: precipitation, vapor and particulate. Future work will continue atmospheric and stream Hg monitoring, and will intensify efforts to identify mechanisms governing Hg transport and mass balance in forested watersheds, and basic trophic relationships in surface waters. These are the necessary components of an ecologically integrated analysis of Hg behavior in a complex ecosystem such as the Lake Champlain basin, and it is this kind of approach that will be required as we develop ecosystem management strategies to address the problems of persistent pollutants in the environment.

ACKNOWLEDGEMENTS

Primary financial support for this work was from the NOAA Air Resources Lab (contract # USDC-40EANR-3000923 and others) under the Lake Champlain Special Designation Act of 1990, with additional support from the US EPA OAQPS Great Waters Program and the Vermont Air Pollution Control Division. We also wish to acknowledge the assistance and support of the University of Vermont Proctor Maple Research Center, where much of this work was conducted, and the very able assistance of Joanne Cummings and Carl Waite. This study was undertaken in cooperation with the Vermont Monitoring Cooperative.

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Table 1: Area and percent for total basin area of major land use classes in the Lake Champlain basin, based on aerial photography in 1973 (Budd and Meals 1994).

Classification:	Forest & Wetland	Agriculture	Urban	Surface Waters	Lake Champlain	Total Non-Lake	Total Basin
Area (ha):	1,322,506	567,262	55,840	75,111	113,000	2,020,719	2,133,719
Percent:	62%	27%	3%	4%	5%	-	-

Table 2. Seasonal distribution of volume-weighted mean Hg concentration in precipitation, with weighted standard deviation in parentheses, number of events, precipitation amount and total Hg deposition, in 1993 and 1994 at the VMC field monitoring station in Underhill Center, VT. Seasons are defined as 22 Dec. to 20 Mar. (winter), 21 Mar. to 20 Jun. (spring), 21 June. to 22 Sept. (summer), and 23 Sept. to 21 Dec. (fall).

Season	Mean (ng/L)	Events (n)	Precipitation (cm)	Deposition ($\mu g/m^2$)
Winter 1993	4.4 (3.4)	26	17.7	0.87
Spring 1993	10.0 (5.9)	29	26.6	2.59
Summer 1993	11.1 (4.8)	35	38.8	4.32
Fall 1993	5.3 (3.2)	33	30.2	1.62
Winter 1994	4.5 (3.4)	26	18.7	0.84
Spring 1994	8.6 (4.8)	30	34.3	2.91
Summer 1994	7.8 (5.0)	32	39.6	3.18

Table 3. Seasonal distribution of particulate and vapor phase Hg concentration, with standard deviation in parentheses, and number of samples, in 1993 at the VMC field monitoring station in Underhill Center, VT. Seasons are defined as in Table 2.

Season	Particulate (pg/m^3)	Samples (n)	Vapor (ng/m^3)	Samples (n)
Winter 1993	16 (11)	24	2.21(0.34)	21
Spring 1993	10 (5)	26	2.16 (0.41)	26
Summer 1993	9 (4)	26	1.79 (0.75)	20
Fall 1993	10 (8)	24	1.62 (0.14)	22
Winter 1994	17 (8)	11	1.75 (0.14)	7
Spring 1994	9 (4)	13	1.74 (0.16)	12
Summer 1994	7 (3)	9	1.68 (0.42)	9

Table 4. Mercury chemistry of snowfall and snowpack during winter 1993-94, at the VMC field monitoring station in Underhill Center, VT.

SNOWFALL, 11/28/93 - 3/28/94

	mean	min	max	total
amount (mm)	7.6	1	29	222
Hg concentration (ng/L)	5.3*	1.2	14.5	---
Hg deposition ($\mu g/m^2$)	0.04	0.004	0.22	1.18

* Volume Weighted Mean

SNOWMELT, 3/24/94 - 4/14/94

	mean	min	max
Total Hg (ng/L)	4.8	2.0	9.2
Filtered Hg (ng/L)	2.4	0.8	5.7

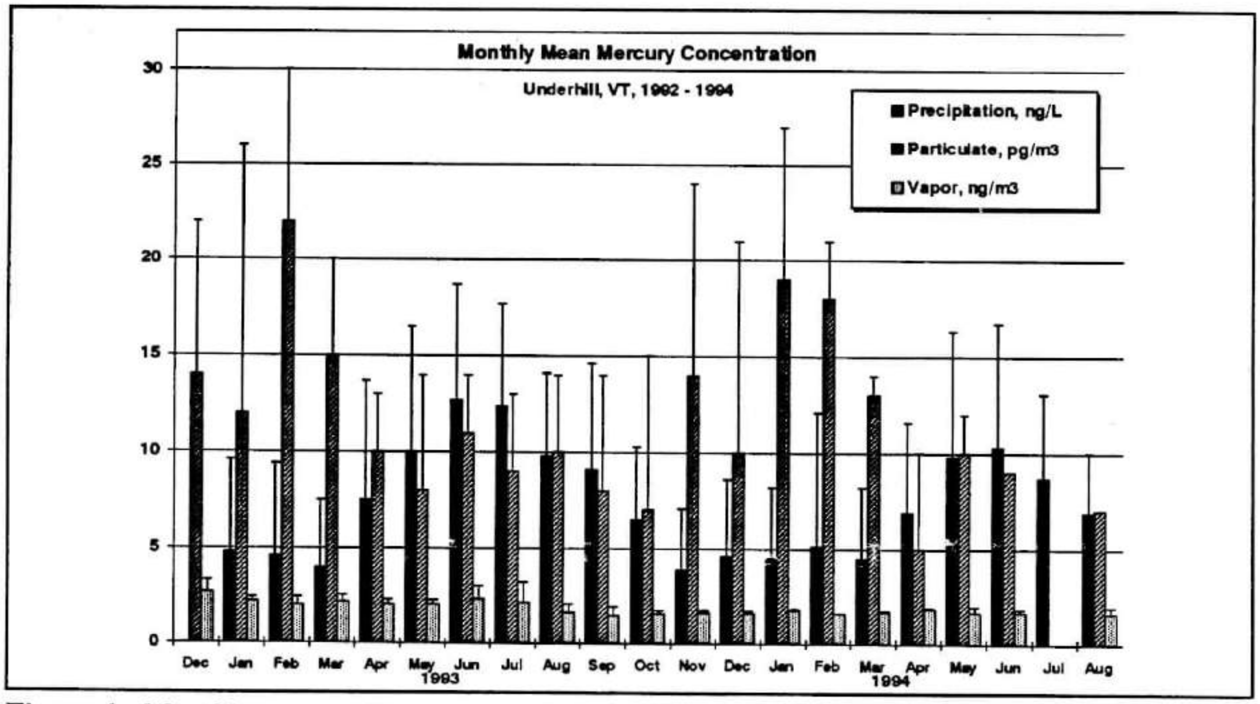


Figure 1. Monthly average Hg concentrations (± SD) in precipitation (volume weighted), particulate and vapor phases for December 1992 through August 1994 at Underhill Center, Vermont.

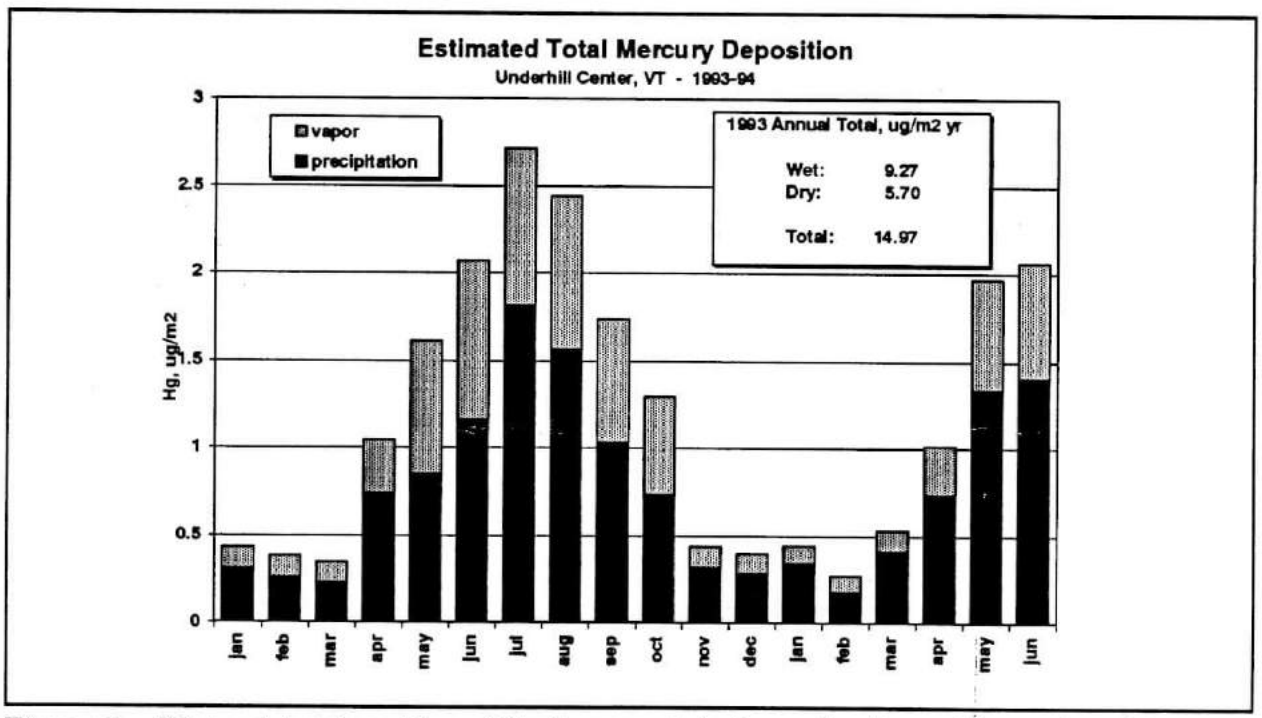


Figure 2. Wet and dry deposition of Hg from precipitation and estimated vapor deposition at Underhill Center, Vermont, in 1993 and 1994.

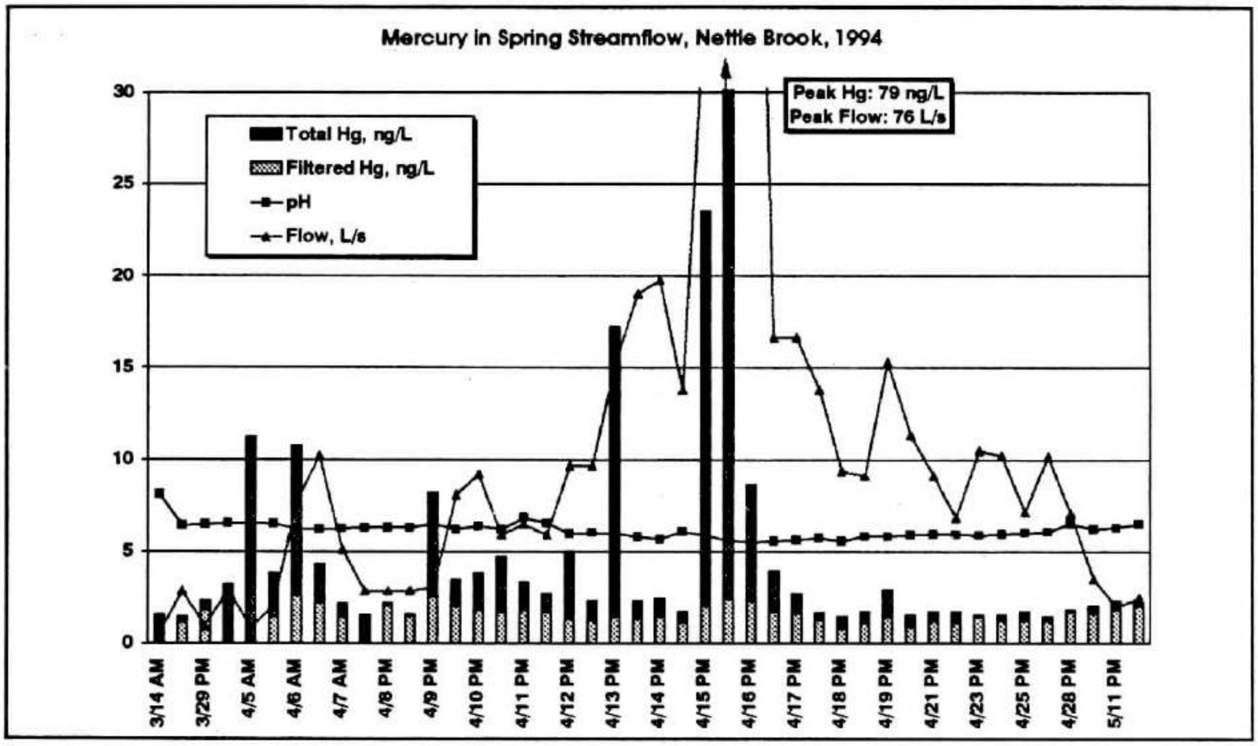


Figure 3. Streamflow, pH, filtered and total Hg during spring runoff at Nettle Brook in northern Vermont in March and April, 1994.

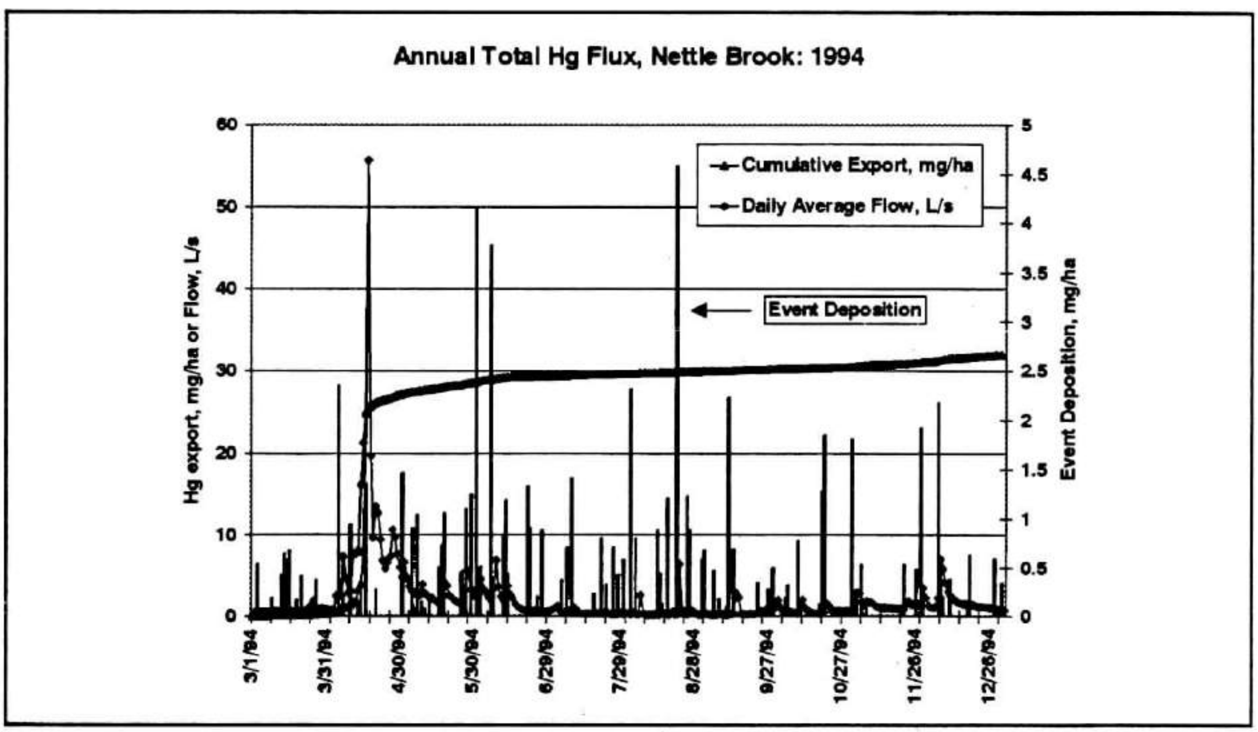


Figure 4. Cumulative Hg export (mg/ha) from Nettle Brook from March through December 1994, daily average flow (L/s), and event deposition.

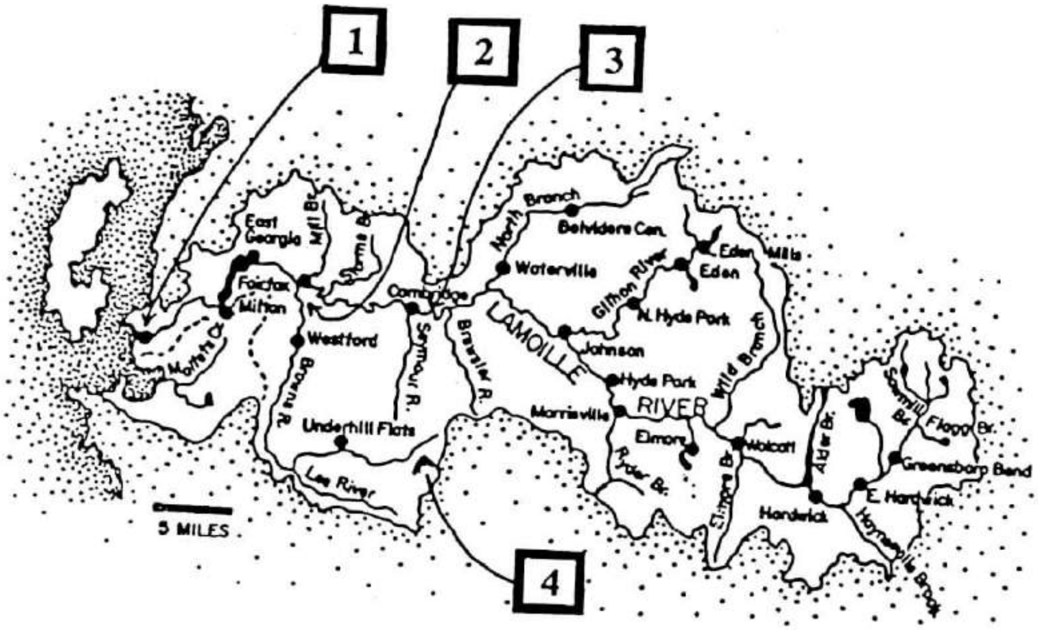


Figure 5. Map of Lamoille River drainage basin in Vermont east of Lake Champlain, showing locations of sampling stations at West Milton (1), Brown's River (2), Jeffersonville (3) and Nettle Brook (4).

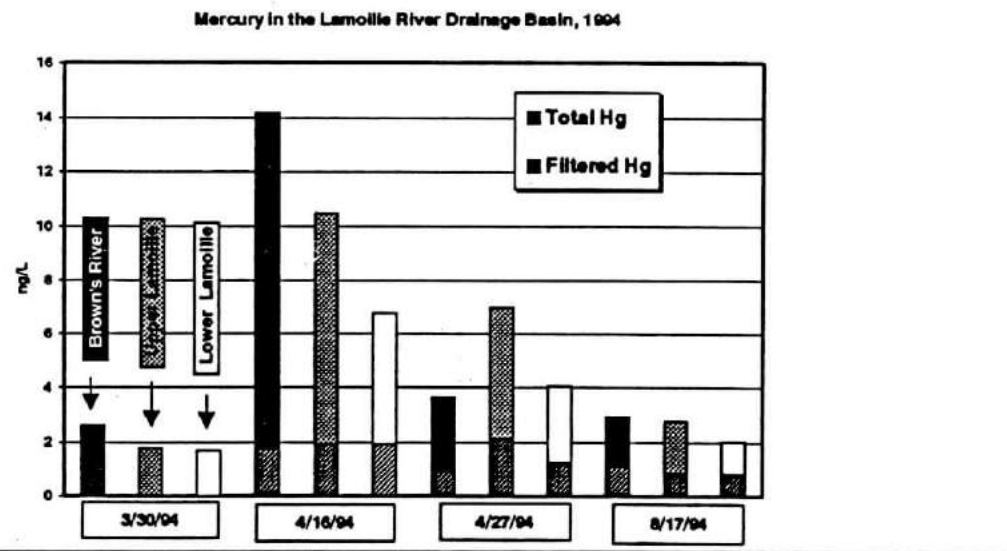


Figure 6. Total Hg in river water at three sites in the Lamoille River drainage basin in northern Vermont in 1994, showing filtered and total Hg fractions (only total Hg data for 30 March).

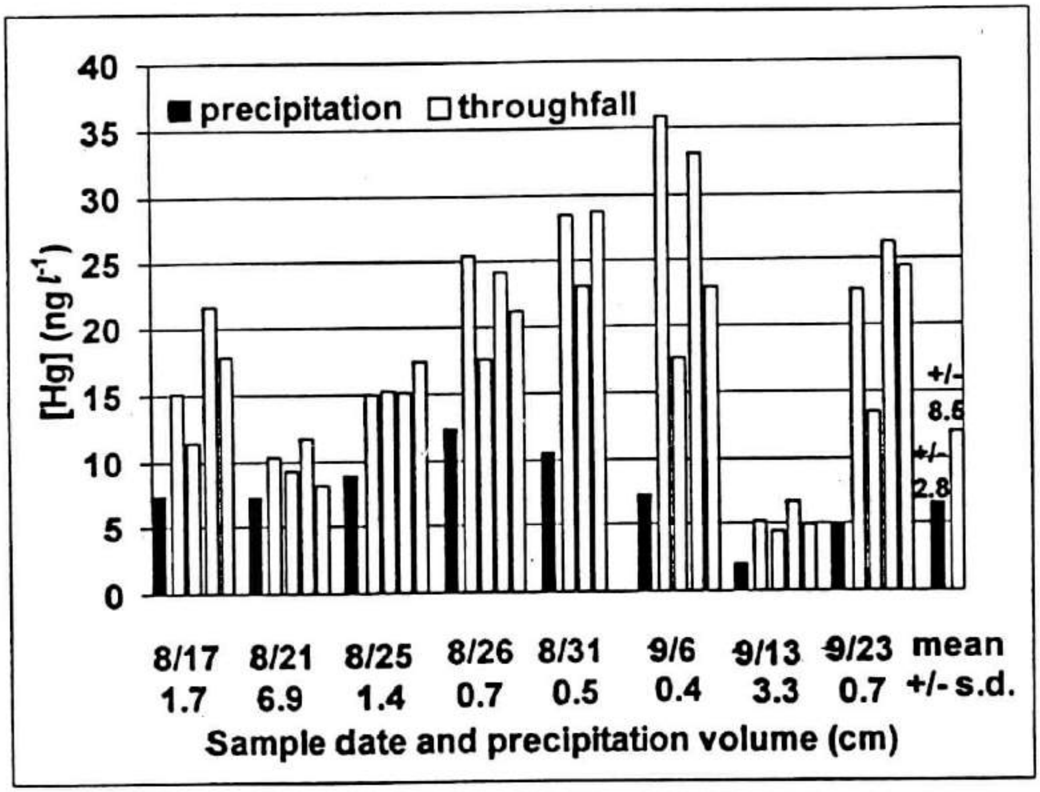


Figure 7. Total Hg concentration (ng/L) in precipitation and throughfall (also showing precipitation volume) for each event for which throughfall was collected during August and September 1994. The last two bars indicate overall mean ± standard deviation.

METEOROLOGICAL AND DEPOSITION CHEMISTRY MONITORING
- 1994 -

Joanne Cummings and Tim Scherbatskoy
School of Natural Resources, University of Vermont

COOPERATORS:
UVM Proctor Maple Research Center (PMRC), VT Dept. of Environmental Conservation (DEC), WCAX-TV staff at Mt. Mansfield transmitter station, National Atmospheric Deposition Program (NADP), US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Lake Champlain Research Consortium (LCRC), National Weather Service (NWS), the Electric Power Research Institute (EPRI).

ABSTRACT:
Continuous monitoring of meteorology and wet and dry deposition chemistry has been conducted at the VMC Mt. Mansfield site. Several projects are underway, including collection of basic meteorological data, precipitation chemistry monitoring, and dry deposition monitoring programs. Continuous hourly meteorology data from PMRC (400 m elevation) are available from 1988 to present, and daily temperature and precipitation data from the summit of Mt. Mansfield (1205 m) are available from 1954 to present. In addition, meteorology is monitored within the forest at the canopy research tower and the Nettle Brook gauging station; these are discussed elsewhere in the Annual Report. The National Atmospheric Deposition Program, operating at PMRC since 1984, provides weekly analysis of major ions in precipitation, while the Atmospheric Integrated Research Monitoring Network (AIRMoN), also at the PMRC, established in January 1993, provides similar data on a daily basis. In addition, atmospheric mercury monitoring in precipitation, gaseous and aerosol phases was established in at the PMRC in 1993, and the Vermont Acid Precipitation Monitoring Program provides daily precipitation pH since 1980 (Mount Mansfield summit) and 1983 (PMRC); these projects are also discussed elsewhere in the Annual Report. The Dry Deposition Inferential Measurement system, started mid year in 1992, provides weekly data on dry deposition of nitrogen (HNO_3 vapor) and sulfur (SO_2) compounds.

OBJECTIVES:
Continuous monitoring of meteorological variables and the chemistry of precipitation and dry deposition at several locations at the VMC Mansfield site.

METHODS:
Several monitoring stations and programs were operated at sites in Underhill in 1994:

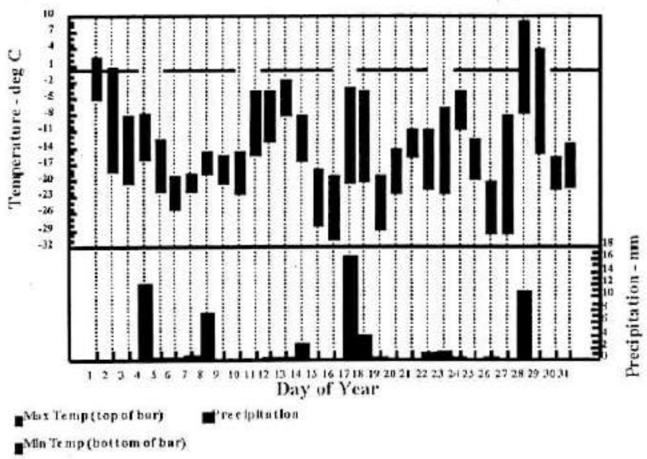
1. Basic Meteorology - Temperature, dew point, wind speed and direction, standard deviation of wind direction, and precipitation amount is monitored at the VMC Mansfield air quality monitoring station at the Proctor Maple Research Center (400 m). This station has remote (modem) access and has been in continuous operation since June 1988. Data are updated continuously and are stored electronically and as hard copy. Data are available from the VMC as spreadsheets (Lotus, Excel), and in Voyager format. Station supervision is by Tim Scherbatskoy and operated by Joanne Cummings and Carl Waite.

Consolidation of the historic and current basic meteorology data from the VMC Mansfield site has been completed, and consists of annual daily and hourly data for all variables. Monthly data summaries are produced routinely. These data are available in ASCII text files, and Excel spreadsheets from the VMC Data Manager. Figure 1 on the following pages graphically displays monthly maximum and minimum temperatures and precipitation amounts for the Air Quality site at the PMRC during 1994.

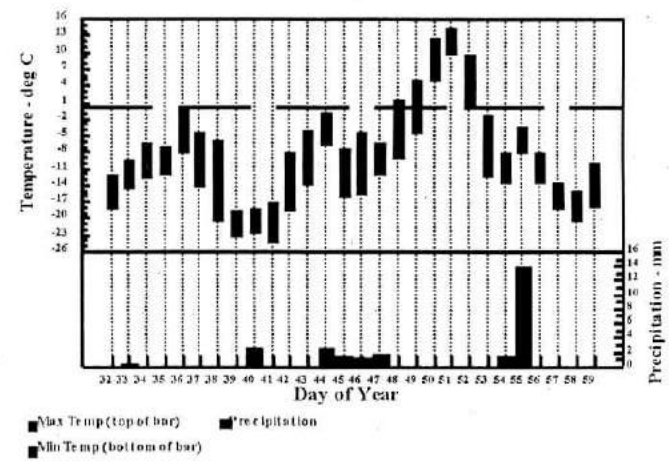
The National Weather Service (NWS) under NOAA supervises a second weather station at the WCAX-TV transmitter station near the nose of Mt. Mansfield (1205 m), one of 45 NWS cooperative weather stations currently operating in Vermont. This station has monitored temperature (daily minimum, maximum and temperature at time of observation) and precipitation amount (daily rainfall, snowfall and snow depth on the ground) since 1954. Data are collected and stored by the National Climatic Data Center. The National Weather Service data is now being used to develop statewide meteorological and depostion maps. The VMC does not directly support this station, but has access to the data for this station and all others in Vermont through the NWS. Data are now available from the VMC in Voyager format for the period 1954-1994, as part of the Vermont Coop Network meteorological database. Data for this project may be obtained from the VMC Data Manager.

Figure 1. Monthly Temperatures and Precipitation Amounts for PMRC in 1994

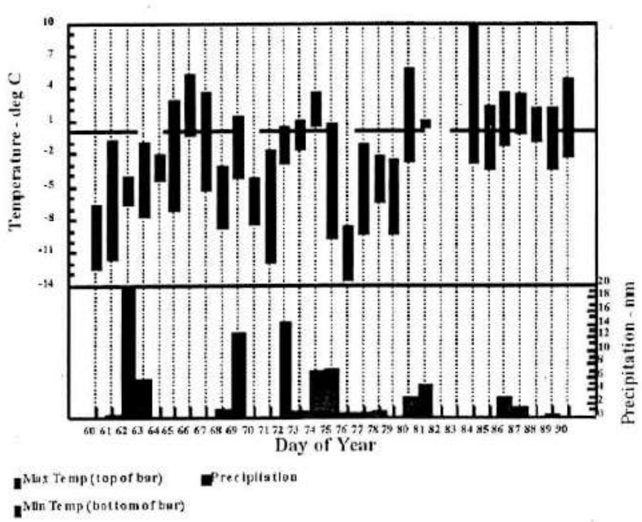
Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - January 1994



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - February 1994



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - March 1994



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - April 1994

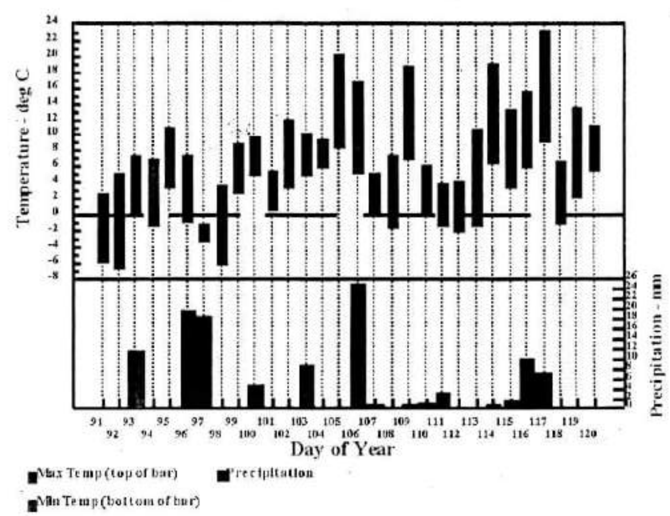
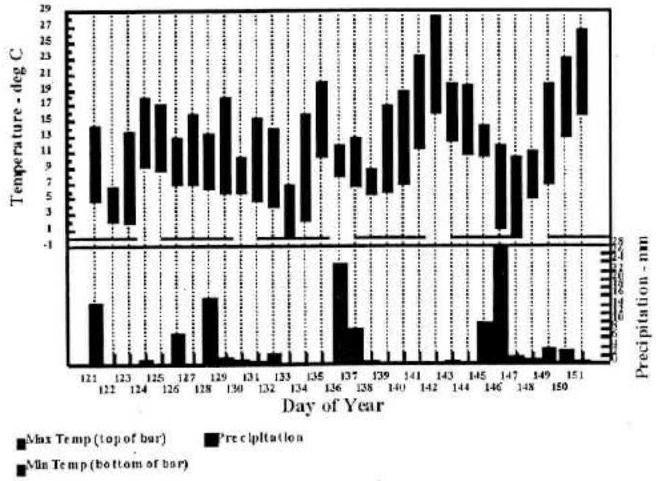
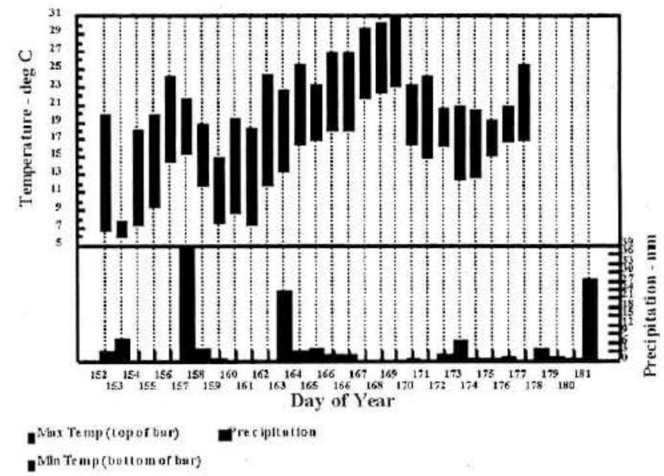


Figure 1 (cont'd) Monthly Temperatures and Precipitation at the PMRC 1994

Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - May 1994

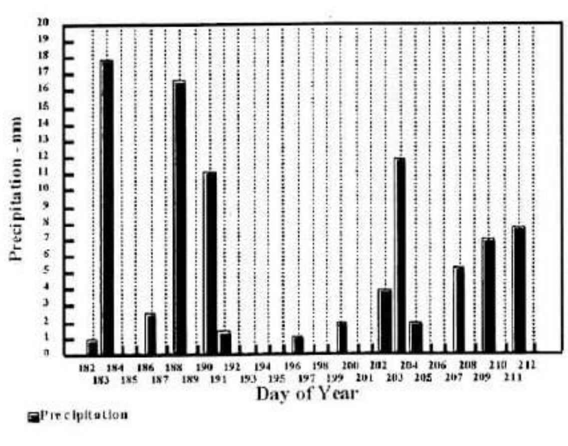


Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - June 1994



Precipitation at PMRC - July 1994

temperature data missing for month



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - August 1994

temperature data missing from 8-1 to 8-17-94

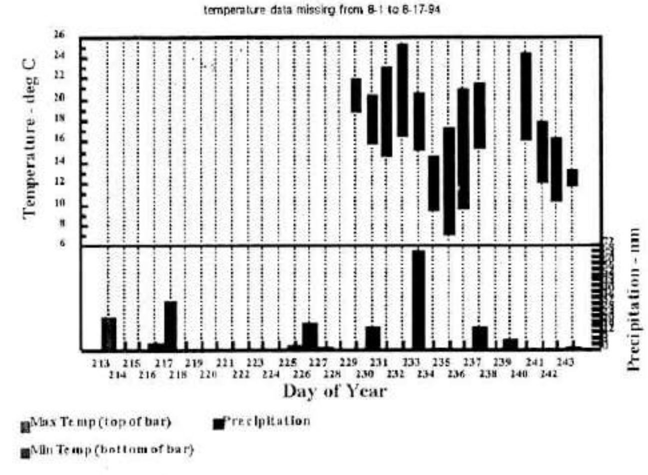
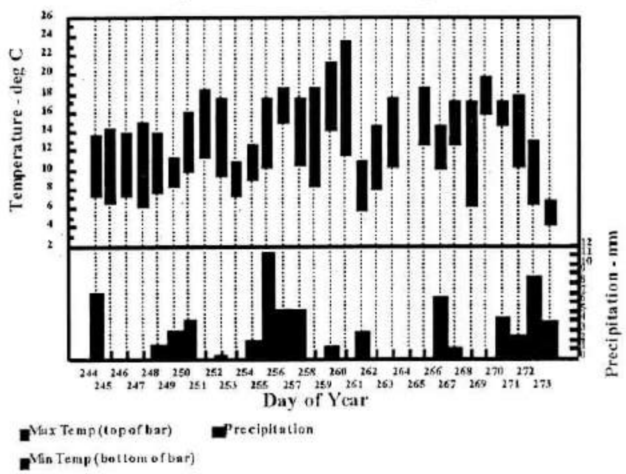
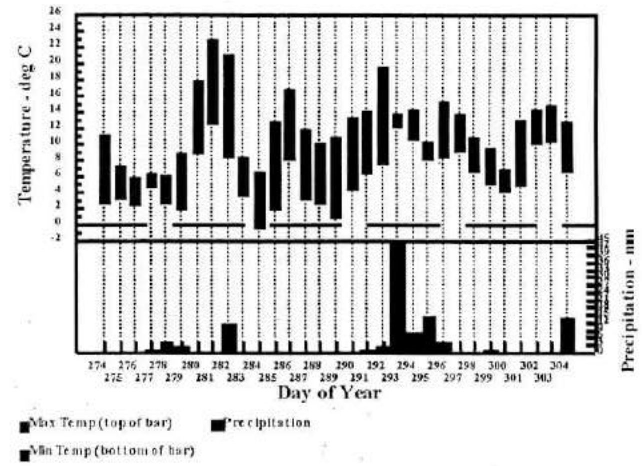


Figure 1. (cont'd) Monthly Temperatures and Precipitation at the PMRC in 1994

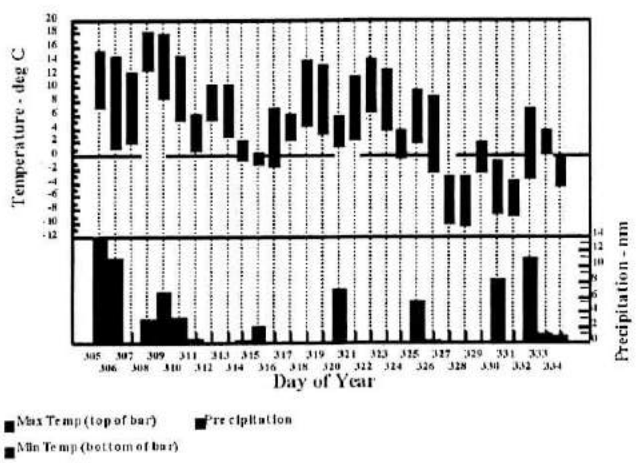
Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - September 1994



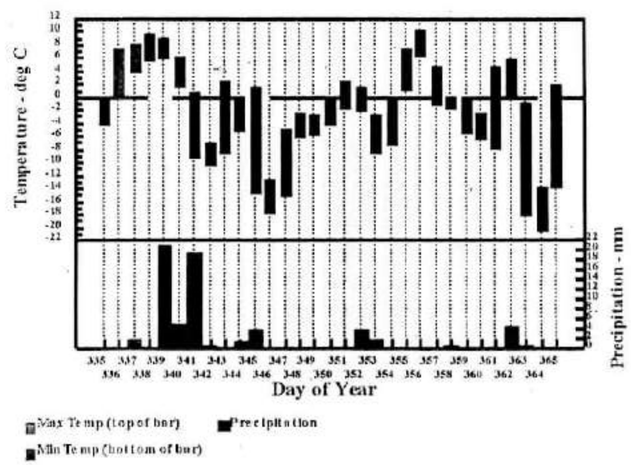
Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - October 1994



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - November 1994



Mean Daily Maximum/Minimum Temperatures
& Precipitation at PMRC - December 1994



2. Precipitation Chemistry - The NADP/NTN (National Atmospheric Deposition Program/National Trends Network) maintains a site at the air quality monitoring station at PMRC (400m) for the weekly collection of precipitation for chemical analysis. Precipitation amount, pH and conductivity are measured locally, and the sample is then shipped to the NADP Central Analytical Laboratory in Illinois for analysis of pH, conductivity, Ca, K, Mg, Na, NH_4, NO_3, Cl, SO_4 and PO_4. The sample collection, field lab processing and shipment proctocols were modified in 1994 after discovery and verification of contamination to samples from an "0" ring which sealed the lid to the sample bucket for shipping. The contamination was not sufficient to negate the data from previous years, but significant enough to require initiation of new procedures.

This station has been operational since 1984, and is part of a national network of over 200 stations including one other in Bennington, Vermont. Data are available from the VMC in Voyager format or in other forms from the NADP Central Analytical Laboratory. The site supervisor is Tim Scherbatskoy, and the site operator is Joanne Cummings with cooperation from Sumner Williams at PMRC. Table 1 on the following pages shows the 1994 annual summary for NADP precipitation chemistry.

AIRMoN (Atmospheric Integrated Research Monitoring Network) is an event based precipitation monitoring program established at the end of 1992 to provide high-resolution data on precipitation chemistry to support regional modeling efforts. There are 7 sites in the network, located in the northeastern US. Except for being an event based sampling program, it follows the protocol and measures the variables of the NADP/NTN program; the sampler is located at the Air Quality site at PMRC (400 m). Station operation is by Joanne Cummings with supervision by Tim Scherbatskoy. The AIRMoN station was installed in December, 1992. Data for the 1994 sample period are not shown here, but can be accessed from NADP.

Table 1. National Atmospheric Deposition/National Trends Network

Data from the NADP station are available for each 2-month period, and as a semi-annual summary from the site supervisor; data is also available for the entire network as an annual and seasonal data summary from NADP; the last annual data summary is for 1994, and is presented in Table 1.

National Atmospheric Deposition Program/National Trends Network

1994 ANNUAL & SEASONAL DATA SUMMARY
(Printed 10/26/95)

SITE IDENTIFICATION

Site	Underhill
State	VT
County	Chittenden
Operation	SAES-University of Vermont/USGS
Funding	USGS
Site No.	470180
CAL Code	VT99
Latitude	44:31:42
Longitude	72:52:08
Elevation	399 m

SAMPLE VALIDITY FOR ANNUAL PERIOD

Sampling Intervals		52
Valid Samples		47
with precipitation		46
with full chemistry#	(45)	
without chemistry	(1)	
without precipitation		1
Invalid Samples		5
with precipitation		5
missing precipitation data		0

SUMMARY PERIOD INFORMATION	Annual	Winter*	Spring	Summer	Fall
First summary day (yrmoda)	940104	931130	940301	940531	940830
Last summary day (yrmoda)	950103	940301	940531	940830	941129
Summary period (days)	364	91	91	91	91
Sampling intervals	52	12	13	13	13
Measured precipitation (cm)	113.6	17.6	31.7	41.9	23.4
Valid samples with full chemistry#	45	10	10	12	11
Valid samples with full chemistry & valid field pH	40	10	10	10	10

NADP/NTN COMPLETENESS CRITERIA	Annual	Winter*	Spring	Summer	Fall
1. Summary period with valid samples (%)	92.3	76.9	76.9	92.3	100.0
2. Summary period with precipitation coverage (%)	100.0	100.0	100.0	100.0	100.0
3. Measured precipitation with valid samples (%)	91.8	83.5	85.7	88.7	100.0
4. Collector efficiency (%)	90.6	66.0	89.8	96.8	97.2
Measured precip. with full chem. & valid field pH (%)	85.9	83.5	85.7	80.6	96.6

STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES

	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH (lab)	pH (fld)
PRECIPITATION-WEIGHTED MEAN CONCENTRATIONS						mg/L						
Annual	0.09	0.013	0.015	0.031	0.30	1.52	0.07	2.04	4.44e-2	4.89e-2	4.35	4.31
Winter*	0.04	0.007	0.006	0.044	0.09	1.98	0.09	0.64	3.88e-2	4.15e-2	4.41	4.38
Spring	0.15	0.020	0.022	0.027	0.32	1.59	0.06	1.58	3.19e-2	3.79e-2	4.50	4.42
Summer	0.08	0.013	0.016	0.035	0.41	1.47	0.07	3.24	6.28e-2	6.73e-2	4.20	4.17
Fall	0.08	0.011	0.011	0.030	0.27	1.35	0.07	1.64	3.63e-2	4.02e-2	4.44	4.40
DEPOSITION						kg/ha						
Annual	1.02	0.148	0.170	0.352	3.44	17.22	0.76	23.12	5.04e-1	5.55e-1	--	--
Winter*	0.07	0.012	0.011	0.077	0.15	3.47	0.16	1.13	6.82e-2	7.29e-2	--	--
Spring	0.48	0.063	0.070	0.086	1.02	5.04	0.20	5.02	1.01e-1	1.20e-1	--	--
Summer	0.32	0.054	0.067	0.147	1.70	6.17	0.29	13.55	2.63e-1	2.82e-1	--	--
Fall	0.19	0.026	0.026	0.070	0.64	3.15	0.16	3.85	8.51e-2	9.41e-2	--	--
WEEKLY SAMPLE CONCENTRATIONS						mg/L						
Minimum value	0.01	0.003	0.003	0.011	0.02	0.20	0.03	0.18	6.76e-3	7.76e-3	3.81	3.78
Percentile 10	0.02	0.003	0.003	0.014	0.05	0.45	0.04	0.36	1.45e-2	1.60e-2	3.99	3.93
Percentile 25	0.04	0.004	0.004	0.019	0.07	0.78	0.05	0.63	2.11e-2	2.79e-2	4.19	4.13
Percentile 50	0.06	0.009	0.011	0.030	0.28	1.49	0.07	1.43	3.55e-2	4.17e-2	4.45	4.38
Percentile 75	0.11	0.025	0.019	0.046	0.38	2.22	0.09	2.76	6.47e-2	7.42e-2	4.68	4.55
Percentile 90	0.38	0.045	0.045	0.101	0.69	3.54	0.20	3.91	1.03e-1	1.18e-1	4.84	4.80
Maximum value	0.48	0.069	0.064	0.272	1.02	9.16	0.55	5.30	1.55e-1	1.66e-1	5.17	5.11
Arithmetic mean	0.11	0.016	0.016	0.045	0.28	1.89	0.09	1.88	4.67e-2	5.31e-2	4.33	4.27
Arith. std. dev.	0.13	0.017	0.016	0.046	0.23	1.72	0.09	1.43	3.40e-2	3.66e-2	--	--
Below detection	3	6	7	0	3	0	2	0	0	0	0	0

OTHER PARAMETERS	Measured Precipitation** cm	Conductivity uS/cm	Equivalence Ratios SO4/NO3	Equivalence Ratios (SO4+NO3)/H(lab)	Equivalence Ratios Cation/Anion
Minimum value	0.03	3.7	0.09	0.88	0.72
Percentile 10	0.46	6.6	0.36	1.05	0.94
Percentile 25	1.10	13.7	0.75	1.25	0.97
Percentile 50	2.13	19.2	1.49	1.40	1.00
Percentile 75	3.06	33.8	2.23	1.61	1.03
Percentile 90	4.41	53.8	3.00	2.66	1.19
Maximum value	8.48	75.6	4.20	4.34	1.36

OTHER ANNUAL & SEASONAL DEPOSITION VALUES

	Total N from NO3 & NH4 (kg/ha)	Equivalence Ratios SO4/NO3	Equivalence Ratios (SO4+NO3)/H(lab)	Equivalence Ratios Cation/Anion
Annual	6.56	1.73	1.51	1.00
Winter*	0.90	0.42	1.17	1.01
Spring	1.93	1.29	1.84	1.00
Summer	2.71	2.84	1.45	0.99
Fall	1.21	1.58	1.54	1.00

Valid samples for which all laboratory chemical measurements were made (the only samples described by the percentile distributions in the STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES).

* Data do not meet NADP/NTN Completeness Criteria for this period.

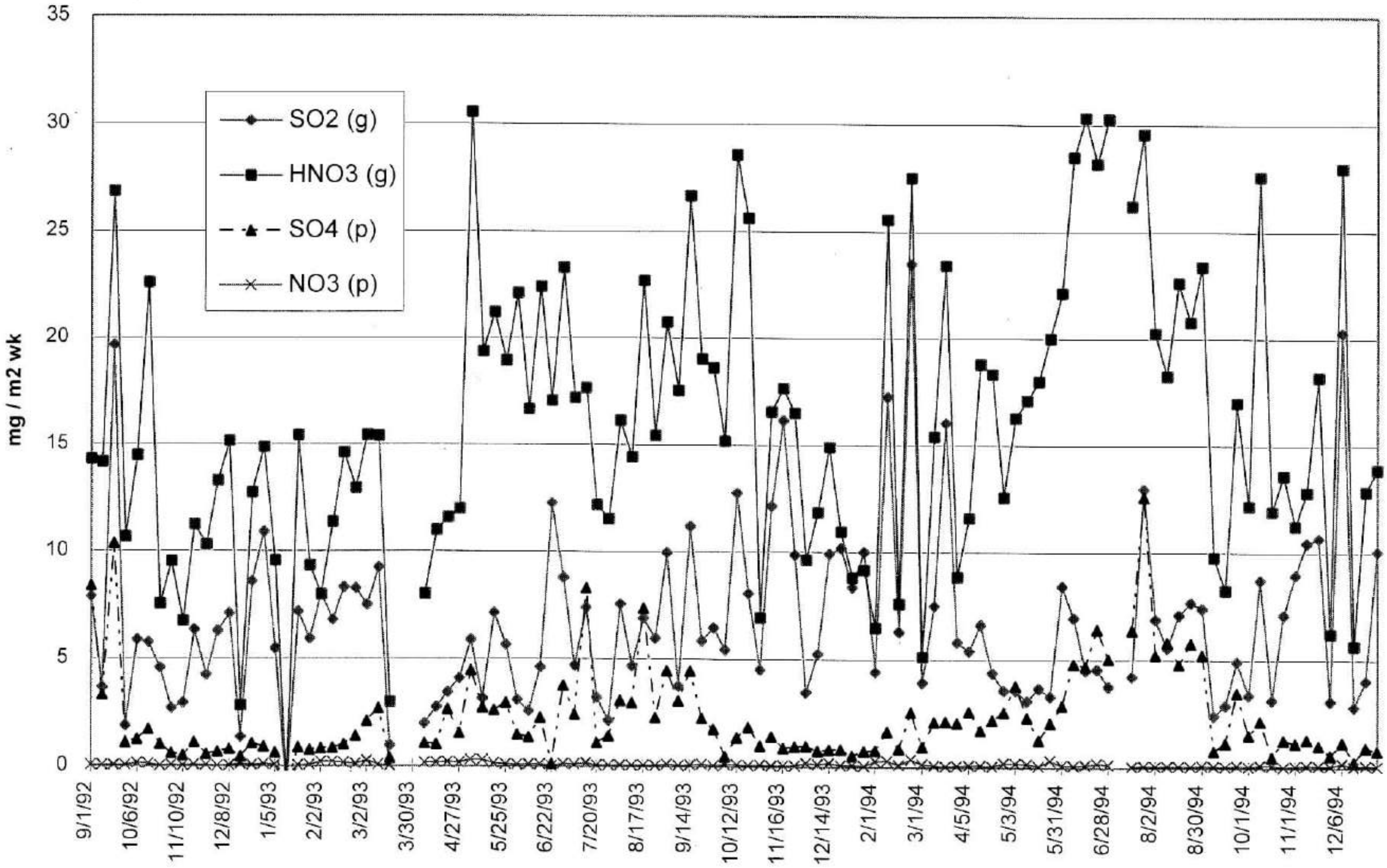
** Measured precipitation for sample periods during which precipitation occurred **and** for which complete valid laboratory chemistry data are available.

3. Dry Deposition - The Dry Deposition Inferential Measurement program was started in August 1992 at the forest canopy research tower at the PMRC. This monitoring program uses filterpack technology to collect continuous weekly samples of dry deposition of sulfur (SO_2) and nitrogen (HNO_3 vapor), and also continuous meteorology including temperature, relative humidity, wind speed and direction, surface wetness and precipitation amount. The goal of this program is to measure atmospheric concentrations of these species and model their deposition rates. This station is one of 10 stations in the NOAA network in the eastern US; the data collected are comparable to other dry deposition monitoring programs in the US operated by the EPA. This equipment is located above the forest canopy at 22 m on the forest research tower. Station operation is by Joanne Cummings with supervision by Tim Scherbatskoy. Filterpack and data analysis are conducted by NOAA, with data returned to the VMC quarterly. Figure 2 shows dry deposition data for 1993-94 at the PMRC forest tower research site.

SIGNIFICANT FINDINGS:

No major analyses of trends and relationships in these projects have been completed at this time. The principle goal of these projects is to provide a high-quality, long-term database on meteorological and chemical deposition for use by VMC cooperators and others. Data are maintained as up-to-date as possible, and are generally available from the VMC in various forms. Periodic reports are made available by the major sponsor of each program (e.g., NADP annual statistical summaries).

Figure 2. Dry Deposition at PMRC Forest Tower 1993-1994



FUNDING:

1. Basic meteorology - The PMRC weather station is maintained with funds from the VMC base budget, the University of Vermont, and the VT Dept. of Environmental Conservation (DEC). During its first two years this station was funded and operated by EPRI as part of the Operational Evaluation Network.

National Weather Service data collection and station operations are supported by the NOAA National Weather Service and WCAX-TV. VMC activity and funding was used for initial acquisition of the data and data processing. Access to future updates of the data is anticipated to be provided at no charge by the Vermont State Climatologist.

2. Precipitation Chemistry - The NADP/NTN program is funded by several federal agencies; operation of the VMC station is supported by the US Geological Survey. Chemical analysis and data management are supported by the USGS. The AIRMoN program is supported by NOAA.

3. Dry Deposition - The overall program as well as the VMC station at the forest research tower is supported by the National Oceanic and Atmospheric Administration (NOAA).

FUTURE PLANS:

All of these stations will continue to operate in 1995. Updates for the Mt. Mansfield weather station (as well as all other National Weather Service Vermont stations) will be obtained in May. The VMC will be installing a remote weather station at 2800 ft in the Underhill State Park area on Mount Mansfield.

Meteorological and Deposition Chemistry Monitoring at the Lye Brook Wilderness CASTNET Site
- 1994 -

Cooperators: Green Mountain National Forest, EPA AREAL Laboratory

Abstract:
Continuous monitoring of meteorology and wet and dry deposition chemistry has been conducted at the VMC Lye Brook Wilderness site. The U.S. EPA, in cooperation with the Green Mountain National Forest and the VMC, has established a CASTNET (Clean Air Status and Trends Network) site at the Lye Brook Wilderness research area (729 m), in southwestern Vermont. The monitoring activities began January 1, 1994. This project provides continuous, site specific air quality data on meteorology, dry depostition of SO2, HNO3, particulate sulfate, nitrate and ammonium, wet deposition of major ions, and hourly average ozone concentrations. The site was established to research the effects of air pollution on the Air Quality Related Values (AQRV'S) of this Class I Wilderness Area. Data from this project are available from the VMC Data Manager.

Methods:
Meteorological and deposition chemistry has been monitored at the Lye Brook site in 1994:

1. Basic Meteorology - The EPA CASTNET site at the Lye Brook Wilderness Area includes a continuous meteorological monitoring station for ambient temperature at 2 and 10 m, relative humidity, surface wetness, precipitation, wind speed and direction and solar radiation. The site is managed by Environmental Science and Technology, Inc. in Durham, NC, under contract from Ralph Baumgardner at the EPA-CASTNET AREAL Laboratory, NC. Data from this site has been obtained by the VMC. Figure one on the following page illustrates monthly temperature and precipitation data for this site.

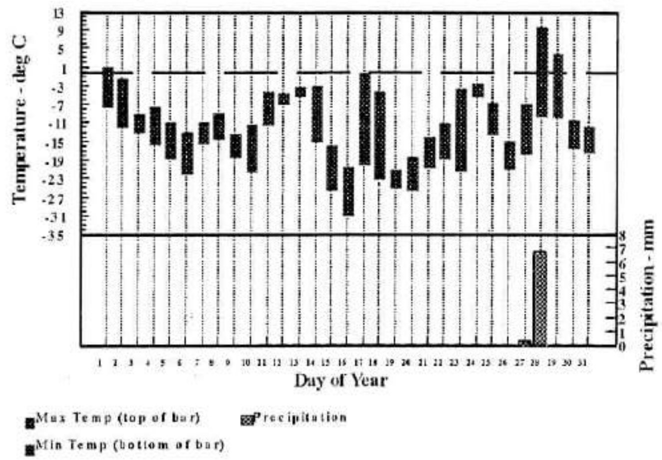
2. Precipitation Chemistry - Precipitation amount is measured and collected on a weekly basis at the Lye Brook Wilderness Area CASTNET site. Samples are analyzed for major ions, acidity, pH and conductivity. The results of the analysis are comparable with other regional and national sites including 200 sites in the NADP network. Data are collected by Environmental Science and Technology, Inc of Durham, NC. This data has not been summarized and made available to the VMC as of yet.

3. Dry Deposition - Dry deposition monitoring at the Lye Brook Wilderness Area is conducted as part of the CASTNET project. Weekly sampling for SO2, HNO3 vapor, particulate sulfate, nitrate and ammonium is collected and analyzed. The results of this research are comparable with other regional and national sites, including the National Dry Deposition Network and ten sites in the NOAA DDIM program. Data is collected by Environmental Science and Technology, Inc., under contract from Ralph Baumgardner, EPA-CASTNET, AREAL Laboratory in NC. The data for this project has been obtained by the VMC but is not presented here.

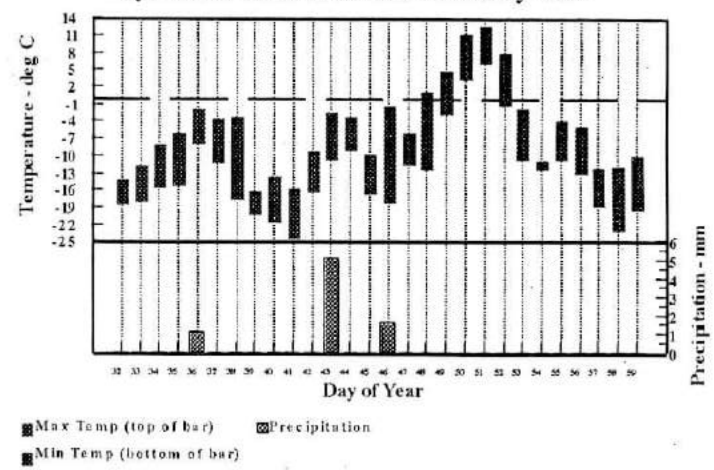
Significant Findings:
No analysis of trends has been completed at this time.

Figure 1. Monthly Temperatures and Precipitation at the Lye Brook Wilderness CASTNET Site - 1994

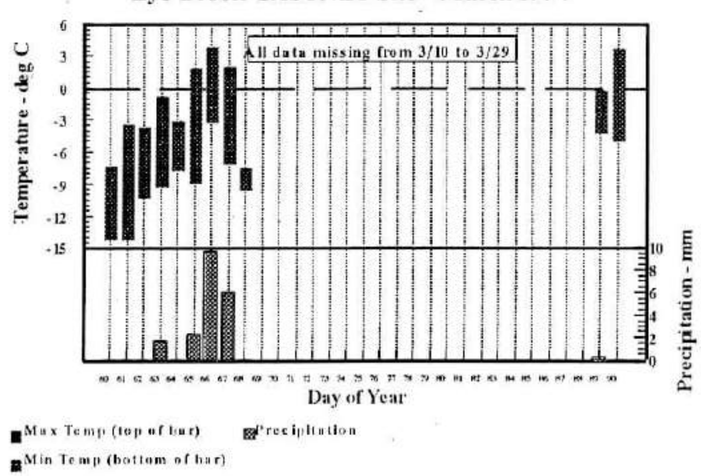
Monthly Temperature and Precipitation
Lye Brook CASTNET Site - January 1994



Monthly Temperature and Precipitation
Lye Brook CASTNET Site - February 1994



Monthly Temperature and Precipitation
Lye Brook CASTNET Site - March 1994



Monthly Temperature and Precipitation
Lye Brook CASTNET Site - April 1994

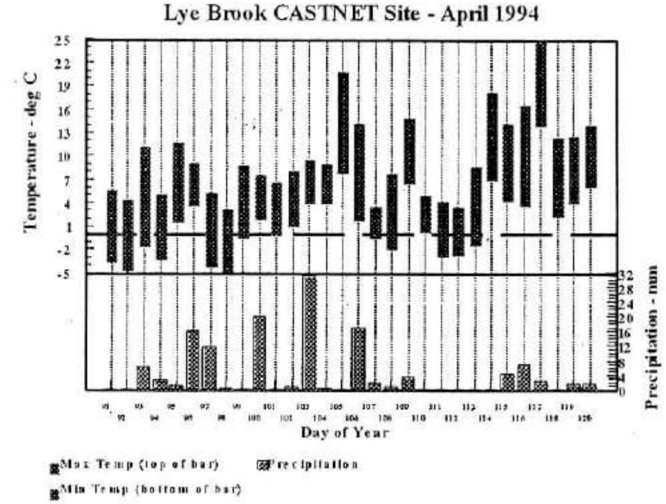
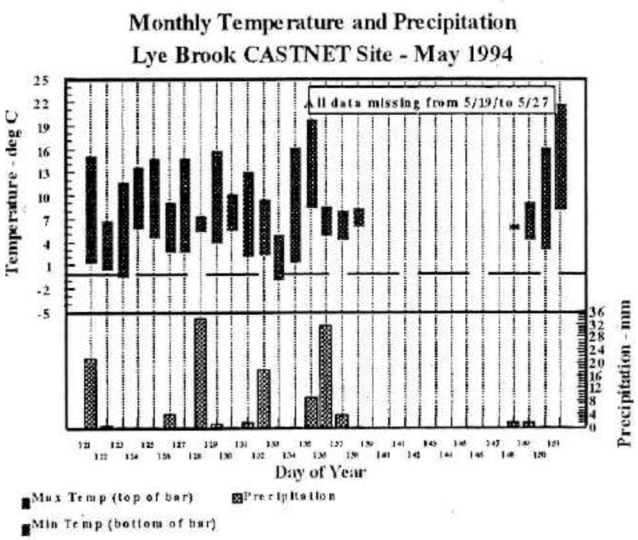
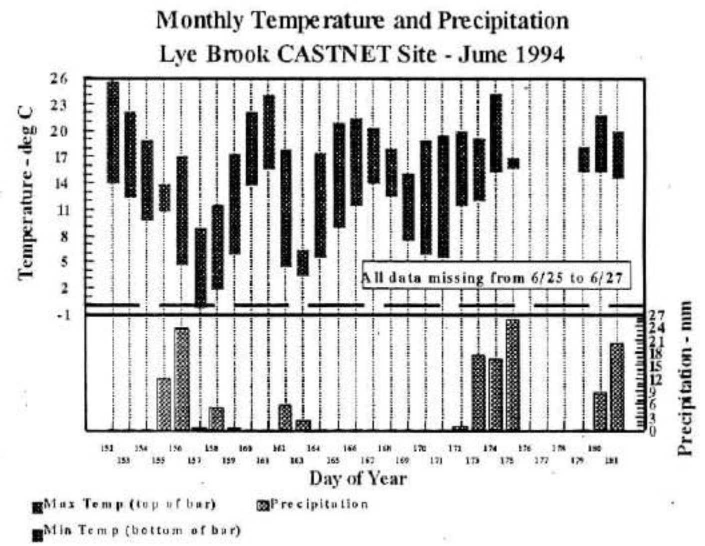
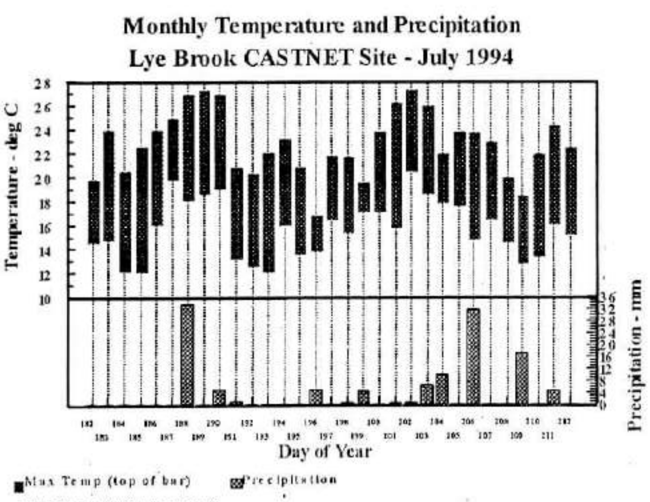


Figure 1 (cont'd) Monthly Temperatures and Precipitation at the Lye Brook Wilderness CASTNET Site - 1994







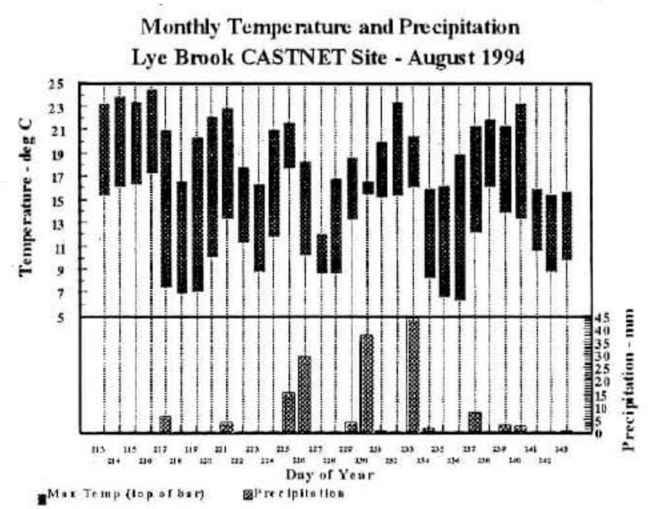
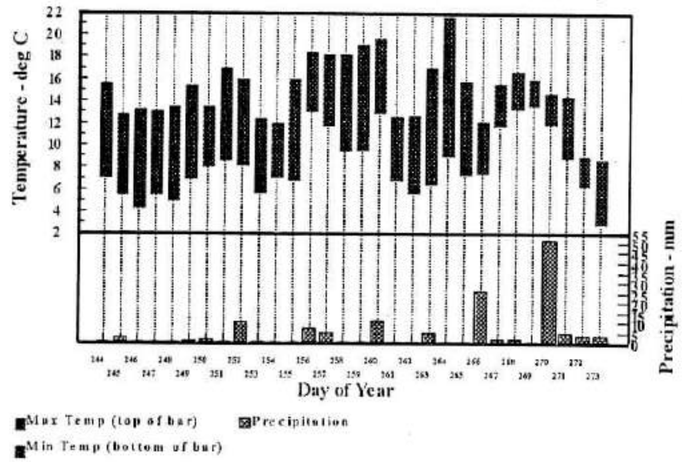
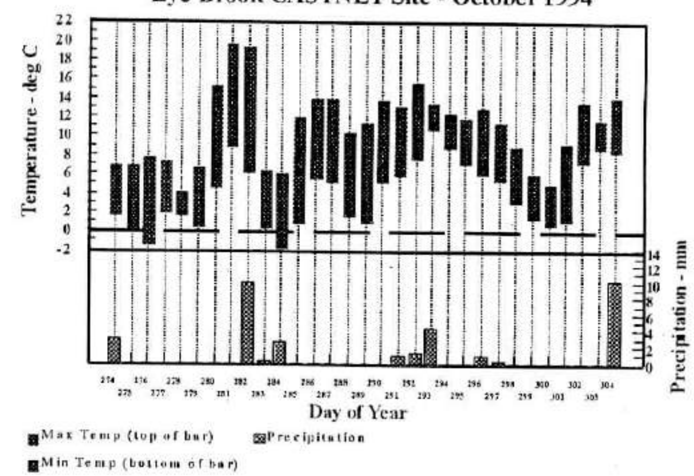


Figure 1 (cont'd) Monthly Temperatures and Precipitation at the Lye Brook Wilderness CASTNET Site - 1994

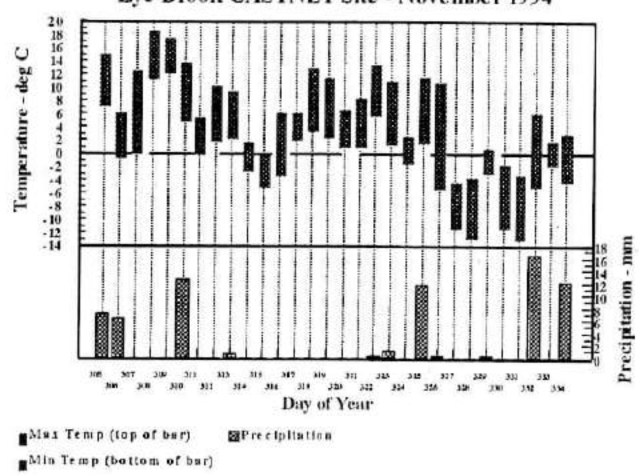
Monthly Temperature and Precipitation
Lye Brook CASTNET Site - September 1994



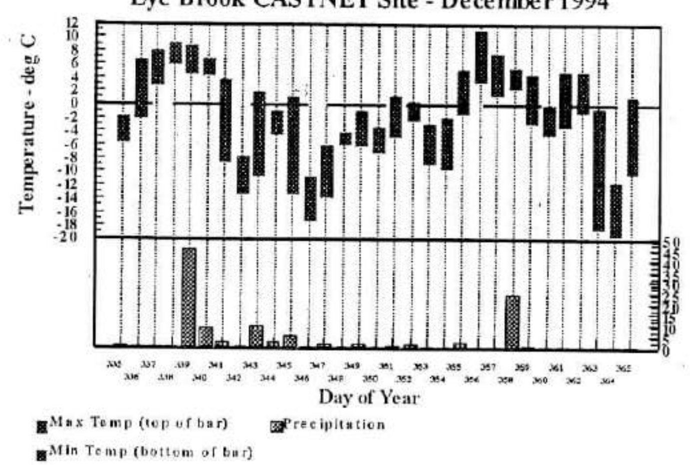
Monthly Temperature and Precipitation
Lye Brook CASTNET Site - October 1994



Monthly Temperature and Precipitation
Lye Brook CASTNET Site - November 1994



Monthly Temperature and Precipitation
Lye Brook CASTNET Site - December 1994



MONITORING OZONE AT MOUNT EQUINOX AND LYE BROOK WILDERNESS, GREEN MOUNTAIN NATIONAL FOREST, SOUTHERN VERMONT - 1994 REPORT

William J. Manning and Christopher J. Bergweiler

Department of Plant Pathology, University of Massachusetts, Amherst, MA 01003-2420

ABSTRACT

From 30 May to 1 September 1994, ambient ozone was continuously monitored with an active sampler (Thermo Electron Model 49 UV-photometric ozone monitor) at the Mt. Equinox Site (549 m) for the sixth consecutive year. Ozone concentrations between late May and early September reached or exceeded 80 parts per billion (ppb) (Green Line Screening Value) for a total of 3 hours (37 hours in 1993), and 50 ppb (probable threshold for sensitive plants) for a total of 493 hours (446 hours in 1993). Ozone concentrations for a single day were highest in June with peak concentrations reaching 86.0 ppb on 13 June , and again on 4 August, when ambient ozone reached a mean hourly concentration of 81.3 ppb. In addition to the ozone monitor at the Mt. Equinox site, ozone was monitored in the Lye Brook Wilderness Area at Prospect Rock (634 m), and at an EPA Environmental Monitoring Site (729 m) at nearby Kelly Stand. Both of these locations, as well as the Mt. Equinox site, were monitored for a six-week period between 5 July and 16 August 1994 using passive filter-type ozone samplers (Ogawa & Co.) for one-week exposure periods. Compared to results from 1993, agreement of mean 7-day ozone concentrations between passive samplers and the active ozone monitor was very good.

INTRODUCTION

In 1964 the U.S. Congress established the National Wilderness Preservation system, setting aside wilderness areas in the United States. As a result of the 1977 amendments to the Clean Air Act, the largest wilderness areas, established prior to 1977, were designated as Class I areas. The intent of these amendments was to prevent significant deterioration of air quality in these areas (1). Federal land managers of Class I areas are thus required to assess air quality and the effects of air pollution on a wilderness area. Their findings are used to make decisions about new pollution-emitting facilities near Class I areas.

Tropospheric ozone has become the most pervasive phytotoxic air pollutant in wilderness areas in the northeastern United States (2,3). Most of the surface level ozone occurring in New England enters the region from metropolitan New York and southward via long-range transport (4,5). Ozone concentrations are normally higher in rural and forested areas, and at higher elevations, particularly in connection with episodes of high temperatures (5,6,7,8).

A number of native plant species respond to ambient ozone by producing typical symptoms of foliar injury, usually a pigmented stipple, with or without chlorosis (9,10,11,12,13,14). This makes it possible to use certain ozone-sensitive plants as bioindicators of ambient ozone (3,12,14,15,16).

In June of 1989, we began to monitor ambient ozone in an open field on a slope of Mt. Equinox, near the Lye Brook Wilderness Area in the Green Mountain National Forest in southern Vermont. Open-top chambers were also used to screen plants for ozone sensitivity and to assess the effects of ozone on selected trees, woody shrubs, and herbaceous plants. Reports of these results for the years 1989-1993 are on file and should be consulted for further detail. Vegetation survey reports from 1988-1993 by J. O'Brien (USFS Durham, NH) are also available.

Our objectives in 1994 were similar to previous years and included (i) continued monitoring of ambient ozone at Mt. Equinox with an ozone monitor and (ii) evaluation of a new passive ozone sampler in relation to the active ozone monitor.

METHODS

Ozone monitor

As in previous years, ambient ozone was continuously monitored with a Thermo Electron 49 ozone monitor, located in an air-conditioned building maintained at 20-28 °C (EPA range 20-30 °C) in an open field (549 m) on a slope of Mt. Equinox. The site lies approximately 11 km west of the Lye Brook Wilderness Area across the valley of the Batten Kill River in southwestern Vermont. The University of Massachusetts laboratory standard ozone monitor (Dasibi 1008 UV-photometric ozone analyzer), calibrated by the Massachusetts Department of Environmental Protection, was used for calibration of the transfer standard ozone monitor, also a Dasibi 1008 monitor, and the on-site monitor. The transfer standard ozone monitor was in turn used for all subsequent audits of the on-site monitor. Full audits were conducted when the on-site monitor was installed and weekly thereafter for a period of four weeks. Partial audits were then performed twice monthly for the remainder of the summer until 1 September, when a full exiting audit was done and the site shut down for the monitoring season.

Passive samplers

Passive ozone samplers are a relatively new monitoring technology. They represent a simple, inexpensive method of cumulative ozone monitoring suitable for remote Wilderness Areas.

During the six-week period between July 5-August 16, 1994, a total of thirty plastic, cylindrical Ogawa passive ozone samplers were exposed to ambient ozone using five samplers at each weekly interval. All samplers were housed in waterproof plastic rain shelters to prevent moisture from contaminating their filters and hung three meters above ground, the same height at which the active monitor samples ambient ozone. Each week, one sampler was co-located with the active ozone monitor at the Mt. Equinox Site, one sampler was placed at an exposed rock outcrop at Prospect Rock (634 m) in the Lye Brook Wilderness Area, and one sampler was located at an EPA environmental monitoring site (729 m) centered in a circular hilltop clearing approximately four hectares in size, near Kelly Stand in the Town of Sunderland, Vermont, approximately 12.5 km southeast of the Mt. Equinox site. The filters were collected weekly and placed in airtight vials, the period of exposure in ambient conditions recorded, and replaced by new filters.

The passive samplers in this study utilized two nitrite-coated filters inside a small plastic cylinder. When exposed to ambient ozone, nitrite is oxidized to nitrate. Exposed filters were removed from the sampler housing and the filter nitrate was extracted and analyzed by ion chromatography to determine cumulative nitrate concentration for a known exposure period (P. Koutrakis, Harvard School of Public Health, personal communication). Cumulative ozone concentration for the same period can then be determined.

RESULTS

Ozone monitor

All average hourly ozone concentrations for the period 30 May to 1 September are included in the Appendix of this report. Summary data for ambient ozone concentrations that reached or exceeded 50 parts per billion (ppb) (probable threshold for sensitive plants) and 80 ppb (Green Line Screening Value) are provided in Table 1.

Table 1: Summary of ambient ozone monitoring at Mt. Equinox, Vermont, 1994 Hours at high ozone concentrations and percent of monthly total

Months	Days	Hours	≥80 ppb*	%	≥50 ppb**	%
May	1.6	39	0	0	32	82.0
June	30	720	2	0.3	224	31.1
July	31	741***	0	0	145	19.6
August	31	744	1	0.1	92	12.4
Sept.	0.7	16	0	0	0	0

* Green Line Screening Value
** probable threshold for sensitive plants
*** periodic power outages: 3 hours lost in July

Ozone concentrations reached or exceeded 80 ppb for a total of 3 hours in 1994. Peak mean hourly concentrations were 86.0 ppb on 13 June, 80.9 on 26 June, and 81.3 on 4 August. The most sustained periods of elevated ozone concentrations occurred in June. Ozone concentrations reached or exceeded 50 ppb for a total of 494 hours, with June accounting for 224 of the total. The months of June and July combined accounted for 75 percent of the total hours exceeding 50 ppb. Mean hourly ambient ozone concentrations for 1994 are compared with those from 1989-1993 in summary fashion in Table 2. Unusually hot, dry weather in 1993 makes comparisons difficult for that season (see Figure 1 in Appendix).

Table 2: Summary of ambient ozone monitoring at Mt. Equinox Site, Vermont, 1989-1994

1989 Total no. of hours and % of total					1990 Total no. of hours and % of total			
Month	≥80 ppb*	%	≥50 ppb**	%	≥80 ppb	%	≥50 ppb	%
June	5	1.5	38	11.3	13	2.2	194	33.7
July	9	1.2	143	19.2	17	2.3	170	22.8
August	0	0	83	11.2	7	0.9	82	11.0

1991 Total no. of hours and % of total					1992 Total no. of hours and % of total			
Month	≥80 ppb*	%	≥50 ppb**	%	≥80 ppb	%	≥50 ppb	%
June	57	1.0	184	31.8	41	5.7	257	35.9
July	32	4.3	228	30.6	1	0	262	15.4
August	29	3.8	202	27.2	2	1.8	165	25.2

1993 Total no. of hours and % of total					1994 Total no. of hours and % of total			
Month	≥80 ppb*	%	≥50 ppb**	%	≥80 ppb	%	≥50 ppb	%
June	20	2.8	141	19.6	2	0.3	224	31.1
July	6	0.8	100	13.6	0	0	145	19.6
August	11	1.5	187	25.2	1	0.1	92	12.4

* Green Line Screening Value
** probable threshold for sensitive plants

Ozone concentrations were generally low in 1989 and 1990, increasing greatly in 1991, and perhaps due to climatic conditions, cumulative elevated concentrations ≥80 ppb have decreased annually from 1992 to 1994. Total hours at concentrations of 80 ppb and above were less in 1994 than in any of the previous five years of ozone monitoring in southern Vermont (Figure 2 in Appendix). However, total hours between 50 and 80 ppb were the third highest in 1994, following 1992 and 1991, respectively.

Passive samplers

Agreement between 7-day mean ozone concentrations determined from the active ozone monitor and results from the passive samplers was generally very good. Active monitor to passive sampler ratios ranged only between 0.8 and 1.4 while the mean ratio for the six-week period was 1.1 (Table 3). This represents a significant improvement over the 1993 results testing passive samplers at five sites where ratios ranged from 1.7 to 8.2 over a ten-week period, with the mean ratio equaling 4.0 (see 1993 ozone monitoring report).

Table 3: Mean 7-day ozone concentrations as determined by passive ozone samplers (Ogawa Assoc.) and an active monitor (Teco 49 ozone monitor)

	Mean weekly ozone concentrations (ppb)*						
Date	O_3 monitor	sampler #1	sampler #2**	sampler #3***	Monitor/sampler ratios		
7/5-7/12	42.2	34.1	30.6	33.0	1.2	1.4	1.3
7/12-7/19	44.2	32.1	30.8	33.2	1.4	1.4	1.3
7/19-7/26	32.5	39.9	36.3	38.9	0.8	0.9	0.8
7/26-8/2	29.1	26.7	27.6	34.7	1.1	1.1	0.8
8/2-8/9	36.8	33.0	34.5	36.3	1.1	1.1	1.0
8/9-8/16	32.5	28.2	27.8	30.4	1.2	1.2	1.1

* Ozone concentrations for the Teco 49 monitor are the average total exposure divided by the sampling period (1 week=168 hours) Teco 49 monitor and the first passive sampler co-located at Mt. Equinox,VT (549 m)

** Sampler located at Prospect Rock, Lye Brook Wilderness (634 m), approximately 11 kilometers to the east of the active monitor site at Mt. Equinox

*** Sampler located at EPA environmental monitoring site, Kelly Stand Road (729 m), approximately 12.5 kilometers to the southeast of the active monitor site at Mt. Equinox

Table 4 gives the passive sampler difference from the active monitor on a percent basis. Passive samplers varied from the active monitor in 1994 between +23 and -30 percent.

Table 4: Percent difference comparison of active monitor-passive sampler mean 7-day ozone concentrations, Green Mountain National Forest and Mt. Equinox, Vermont

Sampling period	sampler 1	sampler 2	sampler 3
7/5-7/12	-19.2	-27.5	-21.8
7/12-7/19	-27.4	-30.3	-24.9
7/19-7/26	+22.8	+12.8	+19.7
7/26-8/2	-8.6	-5.5	+18.7
8/2-8/9	-10.1	-6.0	-1.1
8/9-8/16	-13.2	-14.5	-6.3

Differences between passive sampler values and the active monitor were consistent for five of the six weeks sampled (Figure 3 in Appendix). Passive sampler ozone concentrations for weeks 1 and 2 were about 10 ppb lower than the active monitor, week 3 was slightly higher, and weeks 4 through 6 were only slightly lower. Passive samplers at the three sites were generally in agreement for each of the six 7-day exposure periods with the exception of the sampler at the EPA site , which showed a slightly elevated value in the fourth week.

DISCUSSION

As in previous years, the period of highest mean hourly ozone concentrations occurred in the month of June. Ozone as a surface level photochemical pollutant in southwestern Vermont appears to show a seasonal trend whereby elevated concentrations can be expected in June, followed by higher concentrations again in August. This year saw fewer total hours exceeding the Green Line Screening Value than all other years in the period between 1989-1994. However, compared to the five previous seasons of ozone monitoring in southern Vermont, concentrations exceeding 50 ppb for sustained periods were more common than in 1989, 1990, and 1993. Foliar effects of ozone on native vegetation were not studied sytematically in 1994 as in previous years, so conclusions can not be drawn concerning possible wide-spread effects on native plant species in the region for 1994. Ozone injury on red-fruited elderberry (*Sambucus pubens*) and prickly lettuce (*Lactuca scariola*) were noted along the road leading to Prospect Rock.

Using a new passive sampler, agreement with the ozone monitor was significantly improved from results of 1992 and 1993. Results from passive samplers exposed to ambient ozone were relatively good compared to actual ozone concentrations as determined by the active monitor. If the results prove to be consistent with further testing, these devices may be of great value for environmental monitoring at increased sampling intensities and reduced cost. Simple, reliable sampling devices for ozone and other atmospheric pollutants such as sulfur dioxide and nitrogen compounds would be particularly useful for application in remote sites and difficult terrain, such as the mountainous areas of the northeastern United States. Continued evaluation of passive samplers used for monitoring ozone should be done in conjunction with the active monitoring program.

PLANS FOR 1995

Depending upon available funding, the following activities are planned for 1995:

i) continuation of active monitoring (ozone monitor) of ozone at Mt. Equinox

ii) continued evaluation of passive ozone samplers, using increased numbers and locations in the southern Green Mountain region, Vermont

iii) surveys of vegetation near the active monitor and the passive samplers will also be conducted.

ACKNOWLEDGEMENTS

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APPENDIX

Monthly high-concentration ozone summary
Mt. Equinox Monitoring Site (549 m) 1989-1994

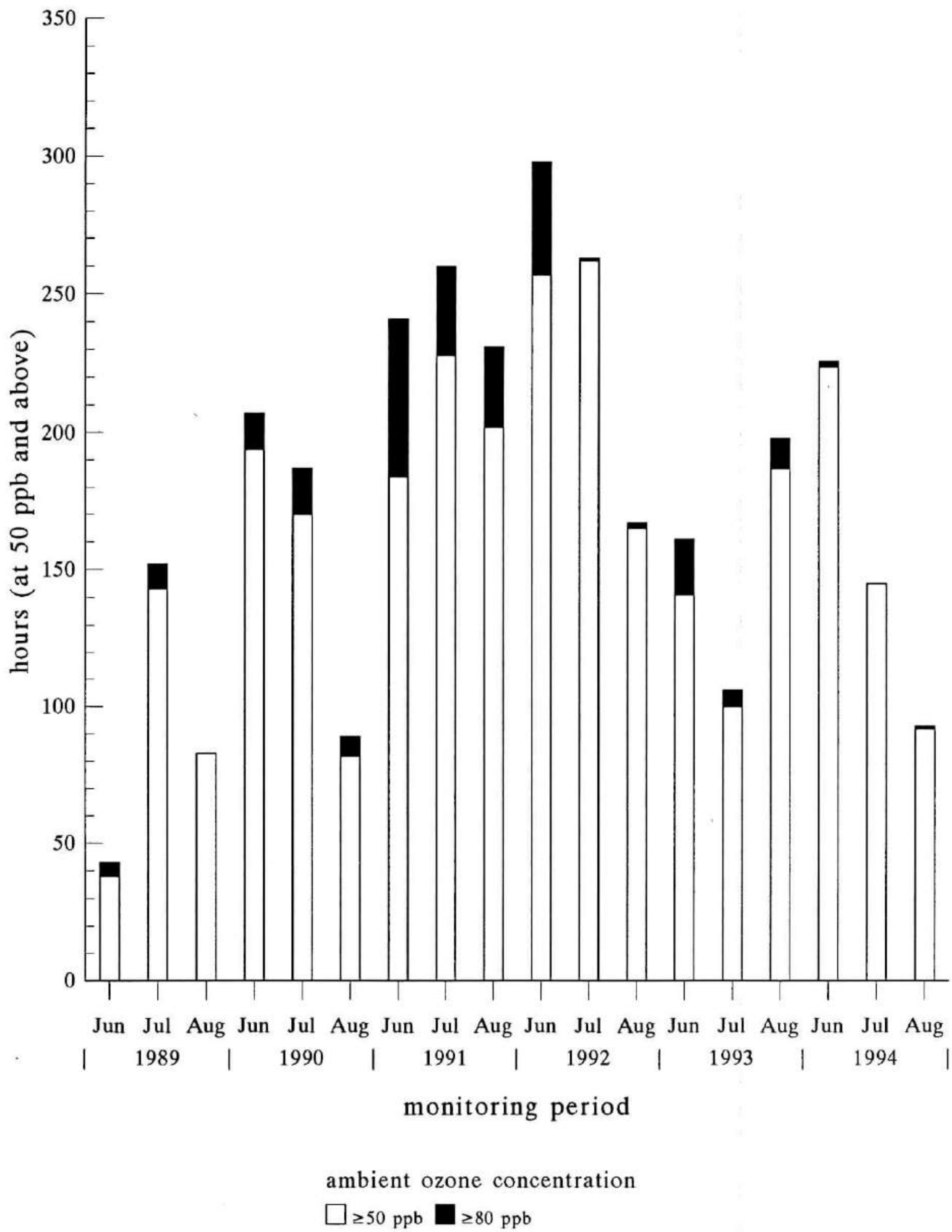
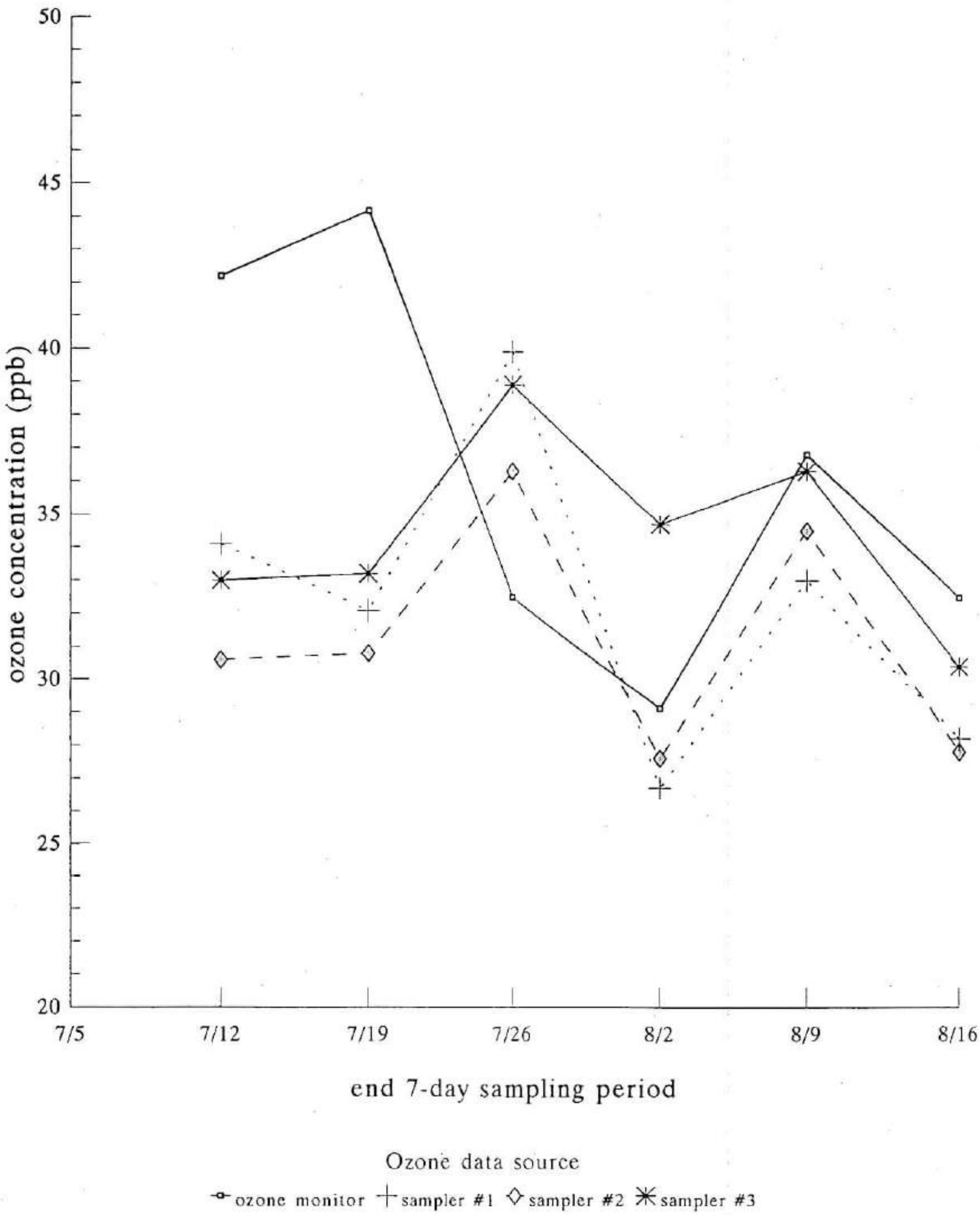


Figure 2

1994 7-day mean ozone concentrations for an active monitor and passive samplers at 3 sites

Green Mountain National Forest and Mt. Equinox, Vermont



monitor and sampler #1 co-located at Mt. Washington Auto Road Site (476 m)
sampler #2 located at Lowes Bald Spot, Mt. Washington (876 m)
sampler #3 located at Mt. Crawford summit (853 m)

Figure 3

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		MAY 30	MAY 31	JUN 1	JUN 2	JUN 3	JUN 4	JUN 5	JUN 6	JUN 7	JUN 8	JUN 9	JUN 10	JUN 11	JUN 12
HOUR	0		61.8	45.2	24.3	26.8	40.5	56.0	62.0	59.3	29.5	33.2	39.8	72.4	46.8
	1		65.7	47.4	23.8	29.4	40.7	76.3	66.8	44.9	32.4	37.7	41.3	67.7	49.2
	2		66.3	49.8	22.9	32.9	40.8	79.0	61.0	41.4	32.3	40.3	43.5	74.5	47.7
	3		69.1	45.7	23.4	34.9	40.9	70.5	56.0	37.8	32.5	42.2	43.2	68.2	45.3
	4		68.3	44.1	23.0	36.3	43.2	69.6	53.2	41.0	33.4	44.8	42.9	62.5	50.4
	5		67.8	44.3	19.9	40.0	46.5	72.7	51.4	46.0	34.5	45.7	43.1	65.2	52.7
	6		67.1	40.2	17.3	42.7	47.8	69.7	57.9	48.0	35.4	44.4	43.6	65.1	50.8
	7		69.7	38.1	17.3	41.6	48.0	73.7	58.8	47.6	35.5	42.3	44.6	61.6	50.6
	8		74.1	36.8	16.9	42.0	45.0	72.6	60.7	45.1	34.0	40.1	42.6	57.6	48.9
	9	67.2	75.2	41.5	16.2	38.5	44.3	55.4	69.5	49.4	31.1	39.9	37.4	56.8	44.2
	10	67.6	75.5	45.7	15.5	35.0	36.1	63.1	65.2	54.1	31.2	38.3	39.2	61.4	48.2
	11	68.8	74.8	41.3	17.8	30.4	32.5	50.8	57.9	54.1	32.2	35.1	38.6	59.2	44.4
	12	62.4	72.7	35.9	16.3	31.6	31.0	46.7	54.4	49.8	32.4	38.1	37.1	58.8	39.3
	13	65.0	68.8	31.9	19.5	31.8	31.6	52.2	53.9	49.7	31.0	38.4	35.9	67.5	39.5
	14	67.2	64.5	32.0	18.7	33.3	33.6	59.9	55.2	56.6	30.2	37.9	38.4	65.3	41.0
	15	62.7	57.3	30.1	17.5	32.8	29.9	51.0	55.5	54.9	30.1	36.5	35.0	53.1	37.2
	16	62.9	50.6	28.3	15.3	35.2	29.7	53.7	54.3	54.4	27.8	34.0	33.5	48.3	42.5
	17	62.3	48.5	26.3	12.9	34.6	31.5	49.7	55.2	44.9	24.7	31.4	34.0	44.2	34.6
	18	58.6	45.8	26.9	12.1	32.5	30.1	49.2	53.4	19.3	24.1	27.7	37.7	42.2	37.9
	19	55.6	44.3	26.4	10.8	32.3	27.2	54.4	53.8	19.9	23.2	29.5	35.4	40.4	37.3
	20	53.9	43.4	25.9	12.7	31.7	25.6	48.2	52.4	27.4	27.0	28.5	42.2	38.6	42.3
	21	55.3	40.0	25.3	16.4	36.1	24.6	52.9	49.8	33.8	30.0	31.6	62.6	36.0	47.3
	22	55.5	40.2	24.8	23.8	39.9	34.9	61.2	51.7	33.0	29.6	36.4	70.2	38.6	50.3
	23	59.2	43.1	24.2	24.9	39.9	40.9	62.8	54.1	29.2	31.2	38.7	70.5	42.6	54.3
		MAY 30	MAY 31	JUN 1	JUN 2	JUN 3	JUN 4	JUN 5	JUN 6	JUN 7	JUN 8	JUN 9	JUN 10	JUN 11	JUN 12
PPBH<30		0	0	8	24	2	5	0	0	4	7	3	0	0	0
30>=PPBH<40		0	0	6		18	8	0	0	3	17	14	12	3	6
40>=PPBH<50		0	7	10		4	11	4	1	11		7	9	5	12
50>=PPBH<60		6	2					9	17	6			0	5	6
60>=PPBH<70		9	10					5	6				1	9	
70>=PPBH<80			5					6					2	2	
80>=PPBH<90															
90>=PPBH<100															
100>=PPBH<110															
110>=PPBH<120															
TOTAL HOURS		15	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		JUN 13	JUN 14	JUN 15	JUN 16	JUN 17	JUN 18	JUN 19	JUN 20	JUN 21	JUN 22	JUN 23	JUN 24	JUN 25	JUN 26
HOUR	0	57.2	52.4	64.8	52.5	55.5	59.0	30.5	33.9	31.8	39.1	44.1	30.3	51.8	54.1
	1	58.0	62.7	62.7	55.4	56.0	63.9	28.6	34.1	32.5	40.3	49.3	35.4	49.6	57.3
	2	61.1	46.3	56.6	59.9	57.8	63.5	31.3	34.8	30.0	41.2	51.4	40.9	47.8	59.1
	3	61.5	43.9	52.6	58.7	57.6	62.2	36.1	34.2	32.5	41.5	48.5	51.4	48.4	60.2
	4	60.7	51.3	56.4	57.2	58.4	60.9	43.4	32.8	35.8	40.6	46.9	59.3	49.9	58.2
	5	61.2	50.6	51.6	56.9	55.3	62.1	39.2	37.5	38.2	38.7	41.9	58.8	55.1	57.4
	6	65.1	49.7	47.1	61.2	53.2	60.3	37.5	38.5	42.3	35.7	41.1	61.3	60.0	58.3
	7	67.6	50.4	39.0	64.6	48.5	62.7	35.9	36.7	41.6	33.4	42.5	61.2	59.4	58.1
	8	73.8	26.8	36.0	48.5	36.9	54.9	31.2	25.0	42.6	37.3	38.2	62.7	56.4	62.8
	9	86.0	27.1	26.4	40.6	38.6	47.0	30.6	31.3	45.6	36.7	35.5	63.3	54.2	68.5
	10	65.1	30.1	34.2	48.1	42.6	43.7	30.3	37.6	51.9	36.8	34.6	65.6	53.7	77.4
	11	59.1	28.5	33.9	45.5	46.0	39.7	35.7	39.8	50.2	36.9	32.8	69.0	53.9	80.9
	12	63.7	29.7	35.0	37.6	44.4	34.3	36.8	42.0	40.2	39.1	30.8	64.7	49.6	76.4
	13	55.8	31.1	35.9	40.0	41.5	33.8	36.0	51.6	39.2	40.5	29.5	67.8	46.7	70.2
	14	52.5	22.8	32.7	41.9	38.0	31.0	35.2	48.3	40.8	39.9	33.1	67.0	42.6	62.8
	15	55.4	17.7	28.8	41.7	39.1	26.2	35.6	44.1	37.2	40.3	29.2	65.6	39.4	60.8
	16	55.6	19.5	34.5	41.4	27.9	27.4	36.5	34.9	36.4	37.9	32.0	65.0	37.7	52.8
	17	48.0	20.2	36.4	42.2	26.0	29.8	35.7	28.9	35.3	37.4	29.4	64.7	36.7	46.7
	18	40.9	25.1	36.8	42.6	23.3	27.2	35.0	32.6	33.7	33.8	26.2	64.5	35.6	61.6
	19	42.0	32.4	34.1	33.1	20.2	25.7	32.5	34.0	34.7	32.1	20.2	61.5	36.4	60.0
	20	38.9	29.5	29.4	30.6	27.3	32.3	31.4	30.1	33.1	36.7	22.2	60.9	39.6	59.9
	21	38.9	54.5	49.4	44.6	39.0	33.3	31.5	29.1	33.9	42.3	19.9	57.8	43.3	56.8
	22	44.7	59.5	60.3	54.4	47.9	34.7	31.1	31.7	33.7	42.0	20.7	54.2	48.0	57.0
	23	44.8	63.4	57.8	55.7	54.3	30.0	34.9	33.2	37.3	40.8	31.7	52.8	51.0	57.4
		JUN 13	JUN 14	JUN 15	JUN 16	JUN 17	JUN 18	JUN 19	JUN 20	JUN 21	JUN 22	JUN 23	JUN 24	JUN 25	JUN 26
PPBH<30		0	10	3	0	5	5	1	3	0	0	8	0	0	0
30>=PPBH<40		2	3	11	3	5	8	22	17	16	15	8	2	6	0
40>=PPBH<50		5	3	2	11	6	2	1	3	6	9	7	1	9	1
50>=PPBH<60		7	6	5	8	8	2		1	2		1	6	8	12
60>=PPBH<70		8	2	3	2		7						15	1	7
70>=PPBH<80		1													3
80>=PPBH<90		1													1
90>=PPBH<100															
100>=PPBH<110															
110>=PPBH<120															
TOTAL HOURS		24	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		JUN 27	JUN 28	JUN 29	JUN 30	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5	JUL 6	JUL 7	JUL 8	JUL 9	JUL 10
HOUR	0	70.2	25.8	54.1	55.2	34.0	57.6	25.1	37.9	53.8	55.0	49.7	55.4	60.8	44.3
	1	62.8	27.8	60.6	56.9	35.0	61.4	26.7	38.3	57.5	57.4	57.4	58.0	63.0	43.5
	2	60.8	34	59.7	51.3	35.6	64.7	28.9	38.6	61.7	60.1	56.9	57.8	61.1	42.4
	3	52.8	38.3	56.5	50.6	38.7	63.2	32.1	38.9	63.3	55.1	56.1	56.5	61.4	42.1
	4	46.7	41.1	54.8	52.3	45.8	64.7	33.6	39.9	60.3	60.4	58.2	52.7	56.7	44.2
	5	61.6	43.9	48.6	49.3	46.7	63.8	35.3	39.2	58.2	58.9	61.9	53.4	52.6	43.9
	6	60.0	45	42.2	48.2	46.2	60.4	39.7	41.7	62.2	59.3	49.8	55.5	66.5	42.2
	7	59.9	42.4	54.1	44.1	45.0	61.6	37.1	40.6	68.2	58.5	50.1	54.8	67.7	33.1
	8	56.8	27.5	51.4	44.6	43.1	65.7	23.9	28.3	71.7	45.8	45.3	39.8	57.3	33.2
	9	57.0	16.9	57.3	42.8	32.7	68.6	23.5	24.3	75.7	46.7	35.9	50.4	50.8	33.4
	10	57.4	18.9	57.9	40.7	26.8	63.4	29.2	29.1	71.9	51.4	38.9	55.1	46.9	29.9
	11	59.4	19.4	56.8	38.3	26.1	61.7	32.6	30.8	65.0	50.8	37.5	40.0	50.5	23.6
	12	58.8	15.8	50.8	40.9	24.3	54.9	32.6	32.1	61.6	42.1	36.4	37.6	53.6	18.4
	13	60.3	14.8	48.2	43.8	26.5	47.0	29.4	36.3	60.3	39.3	31.8	50.6	50.7	16.3
	14	60.3	16.0	47.5	41.1	21.8	38.1	29.7	40.5	57.4	38.5	30.6	48.2	40.2	14.8
	15	58.7	18.9	37.6	41.6	23.2	48.5	32.1	50.1	56.5	30.4	28.7	53.4	34.2	16.0
	16	51.8	18.9	36.6	41.8	24.0	29.3	33.7	52.6	53.7	31.6	30.1	53.1	32.8	16.8
	17	43.6	17.8	46.6	41.9	20.8	17.4	34.6	51.4	53.1	32.7	28.6	44.0	31.5	16.2
	18	42.8	18.4	48.4	42.3	22.4	16.4	29.0	50.5	50.9	39.1	28.7	49.8	30.1	16.6
	19	46.2	16.2	43.6	41.2	25.7	12.3	23.3	50.5	48.1	35.0	23.8	42.9	30.4	16.6
	20	43.7	16.4	38.7	35.9	34.9	12.7	22.0	48.7	50.0	33.0	21.4	41.5	35.0	16.7
	21	43.5	42.7	44.8	33.6	42.6	16.4	22.4	48.0	52.5	40.0	43.0	55.0	35.4	16.4
	22	44.7	52.2	50.5	33.2	43.4	20.4	32.3	49.3	52.8	50.5	43.8	53.9	39.4	18.8
	23	42.6	55.3	51.7	32.9	52.6	22.7	36.0	49.5	52.4	51.2	52.1	58.1	42.1	21.4

	JUN 27	JUN 28	JUN 29	JUN 30	JUL 1	JUL 2	JUL 3	JUL 4	JUL 5	JUL 6	JUL 7	JUL 8	JUL 9	JUL 10
PPBH<30	0	15	0	0	10	8	12	3	0	0	5	0	0	14
30>=PPBH<40	0	2	3	5	6	1	12	9	0	8	7	2	8	3
40>=PPBH<50	8	5	8	14	7	2		7	1	4	5	6	3	7
50>=PPBH<60	9	2	12	5	1	2		5	12	10	6	16	7	
60>=PPBH<70	6		1			11			8	2	1		6	
70>=PPBH<80	1								3					
80>=PPBH<90														
90>=PPBH<100														
100>=PPBH<110														
110>=PPBH<120														
TOTAL HOURS	24	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		JUL 11	JUL 12	JUL 13	JUL 14	JUL 15	JUL 16	JUL 17	JUL 18	JUL 19	JUL 20	JUL 21	JUL 22	JUL 23	JUL 24
HOUR	0	16.6	41.5	68.7	23.3	39.6	32.8	28.8	47.8	47.8	31.1	30.9	39.8	24.1	22.5
	1	16.2	44.7	65.2	22.0	43.2	35.2	28.2	49.6	39.8	33.9	29.9	30.7	37.5	22.6
	2	17.1	42.1	61.6	21.4	39.3	37.3	26.4	61.0	45.9	36.0	29.9	24.2	36.9	22.1
	3	15	44.4	61.8	21.1	41.7	37.8	28.0	43.8	54.4	31.7	35.6	18.6	35.4	22.9
	4	17.2	47.5	61.5	17.6	42.5	38.3	24.2	42.2	53.0	30.3	33.2	16.7	36.1	22.8
	5	16.8	47.8	56.8	14.5	43.2	38.8	27.8	57.0	52.0	28.4	27.5	16.4	28.6	21.8
	6	18.5	48.4	54.9	22.9	46.8	40.8	34.2	57.1	49.5	24.3	28.1	17.0	27.7	20.7
	7	20.3	51.6	56.0	26.8	45.4	40.2	39.6	53.5	49.3	19.9	35.2	19.2	28.2	19.9
	8	19.9	50.6	56.8	32.6	45.0	43.5	40.8	33.9	51.5	22.2	42.1	19.7	26.1	21.5
	9	22.3	54.2	53.9	33.4	39.9	47.2	40.1	42.1	50.4	27.5	42.5	20.7	25.0	23.7
	10	25.4	54.7	57.9	34.1	35.7	47.6	36.6	49.5	55.2	43.7	44.1	22.0	24.0	27.7
	11	29.8	57.4	58.2	38.1	44.8	49.1	38.5	54.5	37.8	52.5	41.7	23.7	22.8	29.0
	12	31.6	58.6	58.3	34.7	34.5	41.0	34.0	54.9	44.4	55.7	41.2	26.9	27.2	30.4
	13	30.7	62.2	55.8	34.0	27.7	47.3	31.4	57.0	40.2	56.9	42.3	33.6	28.7	31.7
	14	30.4	66.0	52.0	31.5	29.7	44.8	32.8	58.8	46.4	55.9	46.9	36.6	30.0	33.4
	15	29.6	65.1	48.8	33.3	33.5	43.0	44.1	58.9	50.1	55.5	46.8	36.5	29.0	36.1
	16	31.9	64.9	47.3	37.5	36.0	41.6	49.9	58.6	49.4	55.0	41.2	35.0	27.8	36.5
	17	32.2	63.6	44.0	36.0	32.1	36.3	61.8	61.6	48.9	55.4	40.9	44.1	27.4	36.6
	18	27.2	59.1	42.3	36.5	22.1	31.6	66.8	57.3	47.9	54.3	45.0	45.1	29.7	34.3
	19		56.4	37.8	52.6	25.0	31.7	65.2	58.7	39.8	52.9	49.4	43.1	29.8	18.4
	20		59.4	33.4	53.6	30.8	29.1	62.3	60.8	30.6	45.8	48.4	46.8	30.0	17.1
	21		57.1	30.0	56.0	36.5	35.1	58.2	59.0	32.4	38.9	53.5	40.2	28.7	22.7
	22	36.3	61.6	25.2	49.0	31.6	27.7	56.6	58.5	33.0	29.3	63.2	31.8	26.3	20.3
	23	37.6	67.2	24.2	42.5	32.2	28.5	56.2	56.9	33.4	27.4	54.7	25.4	27.5	16.9
		JUL 11	JUL 12	JUL 13	JUL 14	JUL 15	JUL 16	JUL 17	JUL 18	JUL 19	JUL 20	JUL 21	JUL 22	JUL 23	JUL 24
PPBH<30		14	7	2	8	4	3	6	0	7	7	4	12	18	17
30>=PPBH<40		7	10	3	11	12	10	7	1	10	6	4	7	6	7
40>=PPBH<50			7	4	2	8	11	4	6	7	2	13	5		
50>=PPBH<60				10	3			3	14		9	2			
60>=PPBH<70				5				4	3			1			
70>=PPBH<80															
80>=PPBH<90															
90>=PPBH<100															
100>=PPBH<110															
110>=PPBH<120															
TOTAL HOURS		21	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		JUL 25	JUL 26	JUL 27	JUL 28	JUL 29	JUL 30	JUL 31	AUG 1	AUG 2	AUG 3	AUG 4	AUG 5	AUG 6	AUG 7
HOUR	0	19.6	19.4	21.2	15.9	11.8	16.0	24.3	20.6	11.4	31.1	46.9	65.1	16.4	15.4
	1	31.3	19.2	19.5	18.0	12.2	17.7	28.8	17.2	10.4	28.4	44.4	62.3	16.7	15.8
	2	19.8	18.2	19.6	16.2	17.5	14.6	29.5	15.3	10.7	26.8	32.9	58.8	15.5	15.6
	3	14.6	17.4	20.2	25.6	16.1	12.3	30.3	15.3	11.4	29.5	33.6	56.9	17.2	16.7
	4	14.9	26.5	19.0	36.0	12.9	11.2	28.3	15.1	11.3	28.9	26.3	56.8	17.3	15.2
	5	18.1	26.0	16.3	37.2	9.4	11.4	19.7	13.2	8.9	29.8	35.8	50.4	16.1	15.9
	6	15.6	27.4	13.8	35.6	12.6	21.2	25.8	13.9	11.1	47.4	43.8	44.1	17.2	16.1
	7	16.8	26.3	15.3	34.0	14.9	20.2	24.9	29.2	16.3	52.8	47.9	33.7	18.9	14.4
	8	25.7	26.4	17.7	28.1	16.8	37.8	30.9	35.2	20.7	49.8	57.7	29.4	20.4	25.8
	9	28.0	35.3	18.0	20.3	20.3	34.2	32.9	38.0	24.2	51.7	60.3	16.5	21.5	28.3
	10	29.8	38.8	18.4	19.2	26.6	31.9	32.0	42.4	27.7	54.1	65.8	12.4	24.2	28.3
	11	32.6	38.9	19.3	20.7	28.7	31.6	30.5	46.1	31.0	55.7	70.2	12.8	25.5	27.7
	12	34.3	44.2	20.6	23.0	29.9	32.4	30.3	47.7	31.4	57.0	70.9	14.5	25.9	28.0
	13	35.2	40.0	23.0	25.0	31.2	34.0	30.4	45.9	36.7	58.8	68.0	16.2	26.5	27.6
	14	38.3	38.2	24.4	20.8	30.9	35.5	31.4	45.3	69.9	61.9	71.5	19.2	25.8	28.4
	15	40.4	40.0	24.7	12.9	32.0	36.0	31.5	43.4	53.6	63.6	77.7	17.9	27.3	28.1
	16	28.5	49.8	19.3	12.3	31.7	34.9	27.6	42.5	39.6	61.1	79.8	19.0	27.7	26.1
	17	39.9	52.7	12.9	15.1	29.1	22.0	26.4	46.1	46.1	55.5	81.3	20.2	25.0	18.2
	18	40.1	44.7	10.1	15.9	18.2	22.0	18.8	44.9	47.8	40.5	76.5	19.8	20.1	14.2
	19	32.4	40.8	12.1	17.1	16.0	27.3	23.0	35.1	39.7	35.5	73.4	20.4	14.8	16.9
	20	24.4	39.9	13.3	14.9	19.7	36.0	25.2	26.0	32.7	36.6	79.9	20.3	15.3	17.1
	21	27.0	32.4	13.5	14.7	21.7	26.2	26.2	17.3	36.9	32.7	78.4	19.0	15.3	17.4
	22	24.6	26.2	15.1	18.2	19.8	26.6	25.0	19.6	35.6	28.8	72.1	16.6	16.0	19.3
	23	25.2	22.1	14.3	17.1	18.6	25.1	22.1	14.9	36.2	30.7	68.5	15.5	15.5	18.7
		JUL 25	JUL 26	JUL 27	JUL 28	JUL 29	JUL 30	JUL 31	AUG 1	AUG 2	AUG 3	AUG 4	AUG 5	AUG 6	AUG 7
PPBH<30		15	11	24	20	20	14	15	12	11	6	1	16	24	24
30>=PPBH<40		7	6		4	4	10	9	3	9	5	3	1		
40>=PPBH<50		2	6						9	2	3	4	1		
50>=PPBH<60			1							1	7	1	4		
60>=PPBH<70										1	3	4	2		
70>=PPBH<80												10			
80>=PPBH<90												1			
90>=PPBH<100															
100>=PPBH<110															
110>=PPBH<120															
TOTAL HOURS		24	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		AUG 8	AUG 9	AUG 10	AUG 11	AUG 12	AUG 13	AUG 14	AUG 15	AUG 16	AUG 17	AUG 18	AUG 19	AUG 20	AUG 21
HOUR	0	19.1	58.5	43.6	17.1	16.3	44.4	39.7	28.1	17.2	17.4	13.0	19.7	7.4	64.6
	1	20.0	42.7	41.4	16.0	17.0	42.3	41.9	25.8	19.8	17.8	23.0	19.2	7.2	58.5
	2	23.4	39.9	38.3	16.4	14.1	37.1	44.0	23.4	17.3	25.3	23.9	19.0	15.4	50.8
	3	24.6	37.5	34.0	16.1	19.6	40.1	45.8	22.8	15.0	21.4	23.3	17.7	13.3	49.0
	4	23.8	33.9	30.9	15.8	20.5	46.4	45.5	22.9	15.1	22.4	25.3	16.5	11.5	48.3
	5	19.7	31.6	23.6	14.8	20.5	49.4	46.1	23.2	13.2	19.9	26.4	13.2	15.4	46.9
	6	18.7	52.4	21.0	16.6	17.6	38.4	45.1	20.2	11.9	23.2	27.8	15.0	19.8	47.2
	7	36.6	63.5	20.2	25.6	19.7	39.1	45.6	18.8	22.9	18.7	28.8	16.9	28.2	47.6
	8	39.0	63.4	20.5	24.7	30.9	40.3	45.4	18.4	26.3	25.6	30.0	18.5	34.8	45.0
	9	38.8	63.7	21.4	25.0	34.0	46.9	43.8	19.3	28.3	41.2	24.1	20.2	41.3	43.8
	10	40.4	62.9	24.8	23.6	37.2	50.0	40.8	21.0	30.1	42.2	24.3	20.1	49.4	44.2
	11	41.6	64.3	29.7	26.4	38.2	49.6	38.4	20.9	32.9	41.8	24.7	19.5	52.4	43.2
	12	42.8	65.4	30.6	29.0	39.5	47.8	39.8	21.7	36.9	40.9	26.2	21.7	56.8	45.0
	13	46.9	67.6	30.6	30.2	41.1	49.1	40.1	20.4	42.4	43.9	20.9	23.0	61.0	41.9
	14	49.6	67.6	30.6	33.0	43.6	44.4	39.2	19.6	45.6	42.7	21.2	22.5	64.8	42.1
	15	52.3	58.4	32.3	37.8	42.2	42.3	38.4	19.6	46.0	41.1	18.1	22.0	60.6	41.8
	16	53.1	52.0	29.2	39.3	44.4	40.7	35.4	20.8	45.8	34.7	19.1	21.8	62.0	41.5
	17	40.9	52.9	23.0	35.6	35.3	38.3	30.0	21.0	37.6	31.0	20.1	21.9	62.2	36.4
	18	32.1	43.9	15.2	29.6	26.2	37.8	29.8	20.4	23.9	23.2	20.4	19.1	62.3	28.5
	19	36.3	54.2	14.8	25.3	38.2	38.3	33.2	19.4	21.0	19.1	21.7	12.8	64.7	23.3
	20	32.4	46.2	19.1	20.0	41.3	40.3	31.9	21.3	20.7	11.9	19.4	13.1	62.9	22.5
	21	29.7	49.5	17.8	19.6	51.4	40.8	30.0	21.5	19.0	10.8	20.6	11.3	68.0	20.7
	22	32.5	49.9	16.4	19.3	53.7	39.4	29.0	16.9	16.7	12.9	20.0	7.9	60.9	15.6
	23	47.9	45.4	15.7	16.4	49.8	39.8	28.4	18.8	18.1	10.4	15.9	7.9	57.5	16.6
		AUG 8	AUG 9	AUG 10	AUG 11	AUG 12	AUG 13	AUG 14	AUG 15	AUG 16	AUG 17	AUG 18	AUG 19	AUG 20	AUG 21
PPBH<30		8	0	15	19	9	0	3	24	16	15	23	24	8	6
30>=PPBH<40		7	4	7	5	7	8	10		4	2	1		1	1
40>=PPBH<50		7	6	2		6	15	11		4	7			2	14
50>=PPBH<60		2	6			2	1							3	2
60>=PPBH<70			8											10	1
70>=PPBH<80															
80>=PPBH<90															
90>=PPBH<100															
100>=PPBH<110															
110>=PPBH<120															
TOTAL HOURS		24	24	24	24	24	24	24	24	24	24	24	24	24	24

Mt. Equinox, VT Mean Hourly Ambient Ozone Levels for 1994

DATE		AUG 22	AUG 23	AUG 24	AUG 25	AUG 26	AUG 27	AUG 28	AUG 29	AUG 30	AUG 31	SEP 1	
HOUR	0	17.4	21.7	19.9	21.4	27.8	32.7	20.6	39.7	29.8	20.3	23.9	
	1	28.3	22.7	17.9	19.8	31.8	34.5	19.3	33.6	28.1	18.5	24.0	
	2	35.4	21.2	19.1	18.5	32.8	41.5	18.5	29.3	25.0	18.2	25.8	
	3	30.6	20.7	22.7	21.9	21.3	41.1	23.1	26.4	20.7	17.0	23.9	
	4	26.9	15.1	22.0	22.8	20.4	38.1	15.6	25.4	17.4	18.9	24.1	
	5	25.2	11.5	19.7	22.1	17.1	35.8	16.2	24.8	15.6	19.5	23.9	
	6	21.6	12.0	19.8	32.2	19.8	33.5	13.9	22.8	14.6	17.3	22.4	
	7	21.6	19.8	18.9	49.2	39.4	33.1	30.2	23.4	19.2	22.8	21.6	
	8	22.1	21.4	20.1	55.6	40.0	36.0	40.2	23.0	22.6	24.4	22.7	
	9	19.3	22.7	30.0	58.0	40.8	37.5	42.2	24.0	59.5	28.3	18.7	
	10	17.3	26.5	30.5	58.0	41.2	38.6	49.1	24.7	26.6	29.1	15.1	
	11	17.2	26.6	30.3	58.4	43.0	39.9	49.7	25.0	27.9	32.3	17.6	
	12	17.4	27.1	31.9	60.5	47.1	39.7	49.0	25.2	27.8	32.7	23.3	
	13	17.1	27.7	30.8	63.5	48.7	38.0	51.5	25.8	27.6	31.5	24.3	
	14	16.0	29.2	32.1	64.4	50.8	37.9	50.4	27.4	29.2	34.2	27.5	
	15	16.4	29.5	32.6	60.8	54.8	38.3	50.6	26.9	29.2	20.2	27.9	
	16	16.5	29.0	30.6	50.3	56.8	33.1	52.7	27.5	28.7	12.9		
	17	17.7	23.8	16.6	60.6	59.1	26.4	55.5	26.5	30.2	21.3		
	18	24.5	14.4	14.9	44.7	35.0	14.9	56.2	26.5	26.3	16.7		
	19	29.1	23.2	16.6	45.1	27.6	18.7	55.3	26.2	21.7	17.6		
	20	22.6	22.0	17.4	45.2	24.8	17.6	54.4	27.8	19.0	25.5		
	21	20.0	18.8	16.2	47.3	20.3	19.0	50.1	29.7	19.0	16.0		
	22	18.3	15.3	17.5	44.7	29.5	21.9	49.9	29.9	18.4	32.2		
	23	20.2	16.6	19.7	31.7	39.3	22.2	45.5	30.8	18.7	29.9		
		AUG 22	AUG 23	AUG 24	AUG 25	AUG 26	AUG 27	AUG 28	AUG 29	AUG 30	AUG 31	SEP 1	SUM BY ROW
PPBH<30		22	24	16	6	9	7	7	21	22	19	16	816
30>=PPBH<40		2		8	2	5	15	1	3	1	5		532
40>=PPBH<50					6	6	2	7		0			415
50>=PPBH<60					5	4		9		1			294
60>=PPBH<70					5								167
70>=PPBH<80													33
80>=PPBH<90													3
90>=PPBH<100													0
100>=PPBH<110													0
110>=PPBH<120													0
TOTAL HOURS		24	24	24	24	24	24	24	24	24	24	16	2260

SOIL TEMPERATURE GRADIENTS IN A NORTHERN

HARDWOOD FOREST

1994

Carl Waite and Tim Scherbatskoy
School of Natural Resources
University of Vermont

Cooperators:

Deane Wang and Joanne Cummings, UVM School of Natural Resources

ABSTRACT

A study was initiated in January 1993 to continuously monitor soil temperature at several depths in a northern hardwood forest stand located at the Proctor Maple Research Center in Underhill, VT. In 1993 and 1994 treatments applied to these plots were designed to examine the effects of snow cover on soil temperature within a hardwood forest. Overall seasonal trends were similar in both years with soil temperatures increasing with increasing soil depth during fall and winter and decreasing with increasing depth in spring and summer. During winter, soil temperatures in snow-free plot were generally more responsive to ambient air temperature than those in snow-covered plots, and were consistently 1 to 5° C (1993) and 3 to 9° C (1994) lower than those measured at corresponding depths in snow-covered plots. In 1994, soil temperature at all subsurface depths (-30, -15, and -5 cm) on snow-covered plots remained above freezing throughout winter, while in 1993, only at -30 cm was soil temperature consistently above freezing. On snow-free plots average daily soil temperature reached lows of -2, -4.5, and -9° C at depths of -30, -15, and -5 cm, respectively. When a continuous snow pack develops in December, it appears that soil temperatures tend to stay above freezing even at depths as shallow as -5 cm. When averaged over the two years, below freezing temperatures (1 February-15 April) occurred only 0.5% of the time at -30 cm when snow cover was present, but 92% of the time when snow was absent.

INTRODUCTION

In January 1993 a study was initiated to continuously monitor soil temperatures at several depths within a northern hardwood forest. This monitoring will provide basic data on soil temperature gradients within the forest and address questions about the frequency of freezing in the forest soil rooting zone. Soil thermocouples were installed within the upper rooting zone in two sets of paired, m^2 plots located near the VMC canopy research tower at the Proctor Maple Research Center in Underhill, VT. The paired-plot approach allows treatment of one plot in each pair while maintaining the second plot as a control. Over time, this instrumentation will allow us to add soil temperature information under a variety of environmental conditions to the ever-increasing database being generated at the tower site.

In 1994 treatments of snow-covered vs. snow-free plots were continued to again look at the effects of snow cover on soil temperatures during winter and early spring. Snow was allowed to accumulate naturally on one plot in each pair while the other plot was kept free of snow throughout winter.

Objectives

The overall goals of this project are to increase our understanding of soil temperature dynamics within the upper rooting zone of a northern hardwood forest and to examine the effects of snow cover on forest soil temperatures. Specific goals are to:

1. continuously monitor soil temperature at several depths within the upper rooting zone of a northern hardwood forest,

2. examine the effects of snow cover on soil temperature at various depths within the upper rooting zone of a northern hardwood forest, and

3. relate meteorological variables such as ambient temperature, total irradiance, and wind speed to soil temperature.

METHODS

On 15 January 1993 four-point, averaging thermocouples were installed 2 cm above and 5, 15 and 30 cm below the soil surface (2, -5, -15, and -30 cm) in each of the four plots (two sets of paired plots). Subsurface thermocouples were installed by excavating a small pit with a smooth vertical face and inserting the four ends of each thermocouple set horizontally into the face of the soil approximately 10 cm apart at each depth and 7 cm deep into the soil face. Thermocouples were patterned after commercially available ones sold by Campbell Scientific Inc. (CSI), but were made by us from bulk teflon-coated 22 gauge copper-constantan thermocouple wire. The actual thermocouple junctions were waterproofed by applying clear heat shrink tubing over which several coats of clear commercial plasti-dip were applied. Thermocouples were calibrated and referenced to

National Institute of Standards and Technology (NIST) traceable thermometers prior to installation, with individual temperature corrections developed for each thermocouple. Plots were randomly designated as snow-covered (snow) or snow-free treatments. Data from one set of plots were recorded as 15 min averages to the CSI 21X datalogger located at the VMC research tower. Because of a shortage of available channels on the datalogger, data from the second set of plots were recorded directly to a computer, also as 15 min averages, by means of an analog to digital converter (ADC "blue box") and a Turbo Pascal program.

The first snowfall of the 1993-94 season occurred on 1 November 1993, but 4 cm of snow on 30 November marked the beginning of a continuous snow pack which lasted into late April 1994. Average snow depths on all plots were measured and recorded and snow was cleared from snow-free plots after each snowfall, as was done in 1993. In keeping with the yearly format of the VMC annual reports, data presented here will begin on 1 January 1994.

RESULTS

In 1994 overall seasonal trends in soil temperature were similar to those found in 1993. Soil temperature generally increased with depth during fall and winter and decreased with depth in spring and summer (Fig. 1). Soil temperatures at all three subsurface depths came into equilibrium with air temperature near the soil surface in mid March and again in early September, with both points being slightly earlier than in 1993. These times represent the transition from soil temperatures warmer than ambient air in fall and winter to those cooler than ambient air in spring and summer and back to warmer than ambient air. Seasonal soil temperatures increased sharply from April to June, then continued to increase at a slower rate until mid July. Soil temperatures then began to decrease gradually in response to the decrease in ambient air temperatures from mid August through early November and then more rapidly through the end of December. Average monthly soil temperatures fluctuated by 12 °C from February until July at -30 cm and 16° C at -5 cm, again very close to 1993 values. Significant differences in temperature related to soil depth were found during all seasons of the year.

During the period of continuous snow cover (late November to late April) soil temperatures in snow-free plots were generally more responsive to ambient air temperature than those in snow plots (Fig. 2). Soil temperature at all subsurface depths on snow-free plots, including -30 cm, were below freezing from mid January until late March. Average daily temperatures at -30, -15, and -5 cm on snow-free plots reached lows of -2, -4.5, and -9° C, respectively. Hourly average temperature at -5 cm on snow-free plots reached a low of -12° C in late January. Average daily temperatures of soil on snow-covered plots, on the other hand, remained above freezing at all depths, although only slightly above at -5 cm, throughout the entire snow-covered period. Average daily soil temperatures at -30, and -15 cm on snow-covered plots did not drop below 0.4° C, but soil temperature at -5 cm did approach freezing and some hourly averages did reach 0° C between mid February and early March.

Figure 1. Average monthly soil temperature measured 2 cm above and 5, 15, and 30 cm below the soil surface in a northern hardwood forest stand at the Proctor Maple Research Center in Underhill, VT.

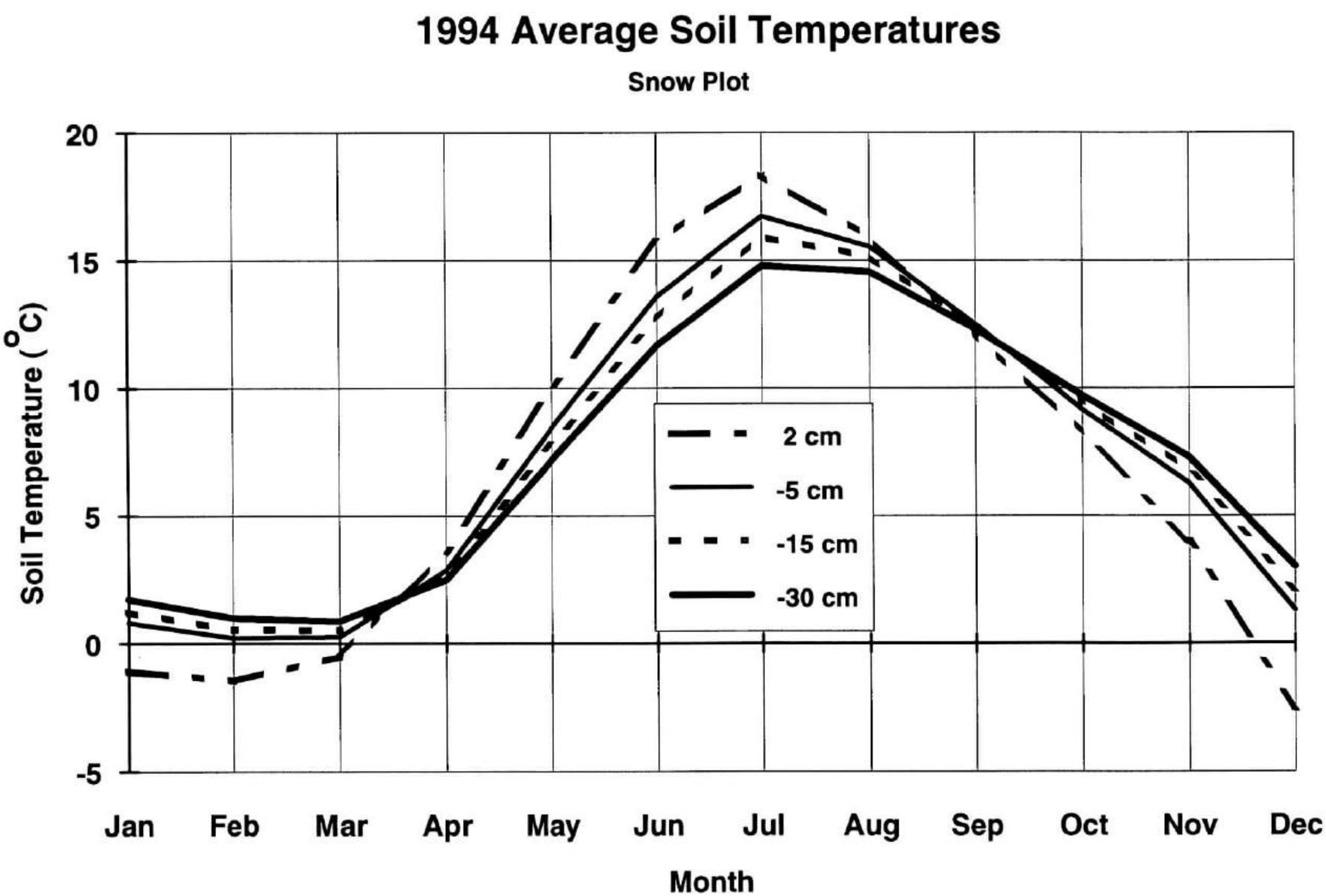
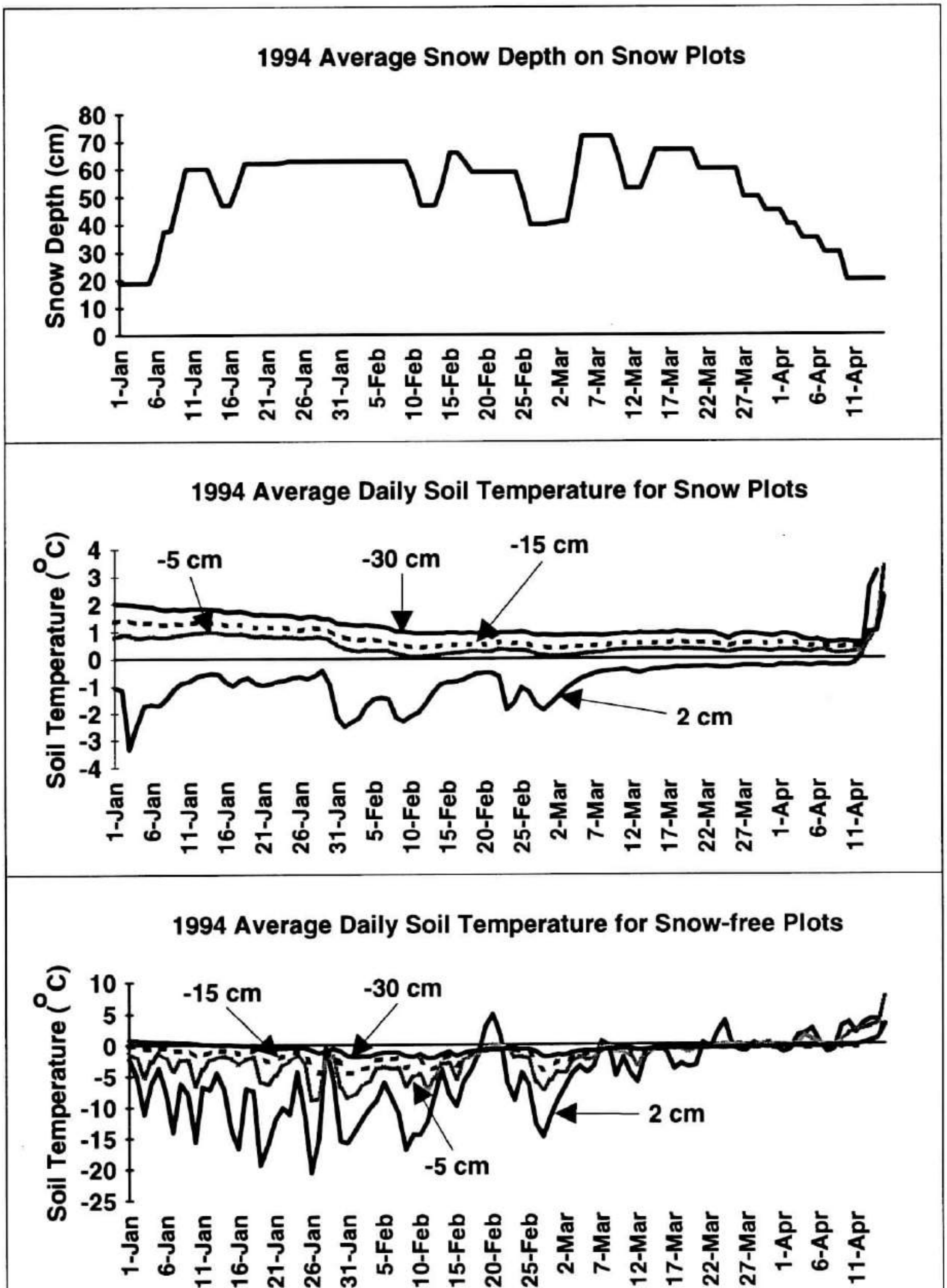


Figure 2. Average snow depth and average daily soil temperature for snow-covered (snow) and snow-free plots from 1 January to 15 April 1994 measured in a northern hardwood forest stand at the Proctor Maple Research Center in Underhill, VT.



Specific results show that soil temperatures at -30 cm were 1 to 2° C above freezing in the snow-covered plots and ranged from 1° C above to 2° C below freezing (1 to -2° C) in snow-free plots (Fig. 3). At -15 cm soil temperatures in snow plots were 0.5 to 1.5° C above freezing throughout the entire period (1 January to 14 April). In contrast, soil temperatures in snow-free plots at -15 cm were consistently below freezing (-0.25 to -4.5° C) before increasing rapidly in early to mid April. Daily average soil temperatures at -5 cm remained above freezing in snow-covered plots, although only slightly at times, and hourly averages did reach 0° C. In contrast, temperatures at -5 cm in snow-free plots tended to vary with ambient temperatures (2 cm), although not to the same magnitude, and remained consistently below freezing until late March to early April. Temperatures in snow-free plots at -5 cm fluctuated between -1 and -9° C until early to mid April when temperatures in both snow and snow-free plots began to rise rapidly in response to warming ambient air temperatures.

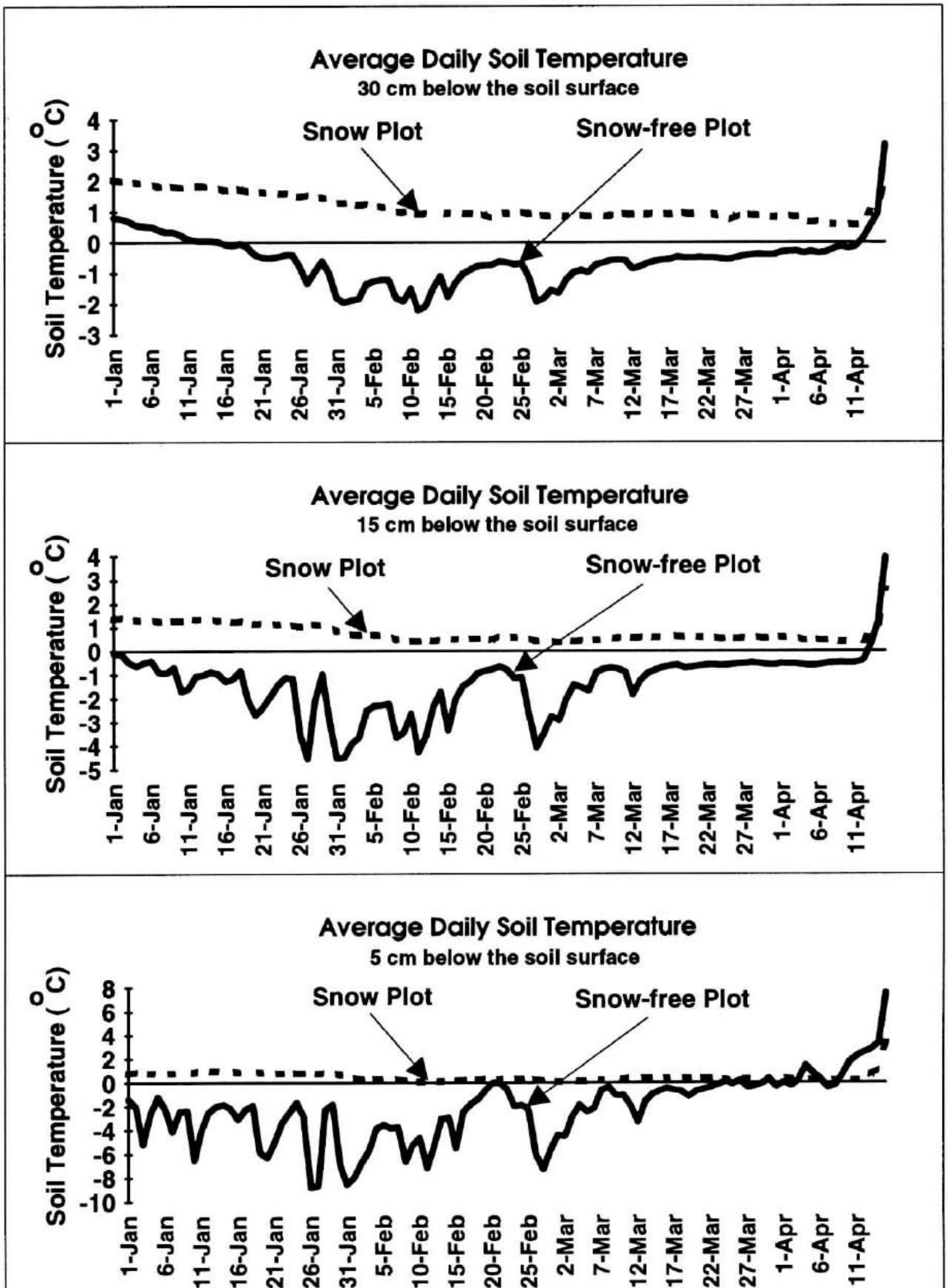
Although, trends for snow-free plots were quite similar in 1993 and 1994, some major differences were noted in the performance of snow-covered plots. In 1993 soil temperatures at all depths except -30 cm remained below freezing throughout most of the winter. In that year temperatures at -30 cm went above-freezing only after a snow pack of about 30 cm had accumulated and never reached 1° C throughout the entire snow-covered period. In contrast, 1994 soil temperatures on snow-coverd plots remained above freezing at all subsurface depths throughout the entire period (1 January to 15 April), although daily average temperatures at -5 cm did approach freezing. Soil temperatures in 1994 at -30 cm remained 1 to 2° C above freezing throughout winter.

The number of hours (1 February to 15 April) in 1993 and 1994 that temperatures remained below freezing, at the various depths, in snow and snow-free plots is summarized in Table 1.

Table 1. Number of hours and % of time that subfreezing soil temperatures occurred, at various depths, between 1 February and 15 April 1993 and 1994, in snow-covered and snow-free plots.

Soil Depth	Snow-covered				Snow-free			
	1993		1994		1993		1994	
cm	hrs	(%)	hrs	(%)	hrs	(%)	hrs	(%)
2	1572	(89)	1693	(95)	1331	(75)	1277	(72)
-5	1473	(83)	3	(0.2)	1448	(82)	1496	(84)
-15	1100	(62)	0	(0)	1579	(89)	1712	(96)
-30	23	(01)	0	(0)	1581	(89)	1691	(95)

Figure 3. Average daily soil temperature from 1 January to 15 April 1994 measured at 30, 15, and 5 cm below the soil surface on snow-covered and snow-free plots within a northern hardwood stand at the Proctor Maple Research Center in Underhill, VT.



In both years the number of hours of subfreezing temperatures decreased with soil depth in snow-covered plots and generally increased with depth in snow-free plots. The most striking difference between the two years is the significant reduction in hours of subfreezing temperatures (1994) in snow-covered plots at -5,-15, and -30 cm. This reduction in hours of subfreezing temperatures is apparently due to the much earlier snowfall and development of a continuous snow pack in 1994, although maximum snow depths were similar (about 70 cm) in both years. The insulating layer of snow (snow plots) increased the number of hours of subfreezing temperatures near the soil surface (2 cm) in both years, compared to snow-free plots. When averaged over both years, below freezing temperatures occurred only 0.5% of the time at -30 cm when snow cover was present, but 92% of the time when snow was absent.

DISCUSSION

Soil temperature is an important factor affecting establishment, growth and productivity, and survival of forest trees. In winter, soil temperature influences the degree of cold hardiness in roots of woody plants, regulates the supply of available moisture, and affects insect populations (i.e., pear thrips) and other soil-dwelling organisms. Winter desiccation, a particular problem in some conifer species, results when plants are deprived of moisture due to frozen soils and possibly frozen roots at the same time water is being lost through transpiration. In winter, length and frequency of soil freeze-thaw cycles, as well as depth of freezing, influence the severity of physiological and physical perturbation to trees and other biota. Extremes in high as well as low soil temperatures can also have detrimental effects on many forest organisms. In mature sugar maple (*Acer saccharum* Marsh.) it has been shown that when roots were exposed to freezing temperatures (-6° C) to a depth of 20 cm, that a significant reduction in sap flow rates, total sap volumes, and total sugar per tree occurred (Robitaille et al. 1995). These perturbations persisted for at least two years after treatment and were accompanied by increased canopy transparency (dieback).

We now have temperature data at differnt depths for two winters in soils beneath a northern hardwood forest. The two winters were quite different in the timing of snowfall and duration of a continuous snow pack. In 1994, snowfall and the associated snow pack began in late November and persisted until mid to late April. No significant snowfall occurred until mid January in 1993 and a continuous snow pack did not develop until early February. Despite the difference in timing of snow events, similar maximum depths of snow were recorded in both years (about 70 cm). Data from both winters show that in the absence of snow cover, soil temperatures can be below freezing to a depth of -30 cm for a significant part of the winter. At lesser depths of -5 and -15 cm, soil temperature in the absence of snow cover can be as low as -12 and -6° C (based on hourly averages), respectively. These depths encompass the major rooting zone for many tree species, subjecting roots (and other soil biota) to significant freezing events. These conditions usually occur during winters with extended periods of little or no snow cover. With snow present in December, soil temperatures remained above freezing for the entire winter even at depths as shallow as -5 cm. In 1993 when significant snowfall occurred late, we found that soil temperatures dropped below freezing even to depths of -30 cm. When snow-cover did occur in 1993, soil temperatures began to rise very gradually over the winter, but still remained below freezing at all depths except -30 cm.

Soil temperatures well below freezing are certain to cause freezing of soil water, but it is unclear if temperatures slightly below freezing also cause soil water to freeze. It seems probable that matric and solute forces in soil water may prevent freezing at temperatures -1 or -2° C. Once winter acclimated, most tree tissues are protected to temperatures well below freezing, but root tissues may not be so well protected (A. Auclair, pers. comm.). There is a need for more information about the effects of freezing degree and frequency on root physiology, as well as about the occurrence of freezing and high temperature events in soils. There are limited continuous multi-depth data on soil temperatures available, so these data provide valuable information about this fundamental property of soils and its important effects on plant roots and soil biota.

FUTURE PLANS

We plan to continue the experiment over several winters in an attempt to characterize soil temperature patterns under a variety of winter climatic conditions. Additional analyses will be done to examine number and timing of freeze-thaw cycles and extremes in high soil temperature.

FUNDING SOURCES

Support for this project comes from the VMC, the U.S. Forest Service Northeastern Forest Experiment Station (cooperative agreement #23-758), the UVM School of Natural Resources (SNR), and SNR McIntire-Stennis program.

LITERATURE CITED:

Robitaille, G., Boutin, R., and Lachance, D. 1995. Effects of soil freezing stress on sap flow and sugar content of mature sugar maples (Acer saccharum). Can. J. For. Res. 25: 577-587.

VARIATION IN ENVIRONMENTAL GRADIENTS AND OZONE UPTAKE IN A DECIDUOUS FOREST CANOPY

1994

Carl Waite and Tim Scherbatskoy
School of Natural Resources
University of Vermont

Cooperators:

Deane Wang, Joanne Cummings, and Alison Berry, UVM School of Natural Resources
David Ellsworth, Brookhaven National Laboratory, Upton, L.I., NY

ABSTRACT

From January to December 1994 meteorology and ozone (O_3) data were continuously collected at five elevations (0.5, 7.5, 12, 16, and 24 m above the ground) from the VMC research tower at the Proctor Maple Research Center (PMRC) in Underhill, VT. Examination of the O_3 data for 1994 revealed a similar pattern to that observed in 1992 and 1993. Ozone concentrations generally increase with height in the canopy, but the largest and only significant difference occurred between 0.5 m (just above the forest floor) and all other elevations with O_3 levels being lowest at 0.5 m. On average over the entire sampling season (mid May-mid November), O_3 concentrations were 23% lower at 0.5 than at 24 m, compared to 21% lower in 1993. This reduction in O_3 concentration just above the forest floor may result from inadequate mixing of air due to a boundary layer effect and lower air velocities at this level or the physical or chemical destruction of O_3. When number of hours of O_3 exposure at certain threshold concentrations during June, July, and August were tabulated for 1994, it was found that the number of hours of exposure at all concentrations were 20 to 100% lower in 1994 than in 1993. Examination of average seasonal diurnal patterns revealed that O_3 concentrations reach a daily low in early morning (around 7:00 AM) and maximums around midday to early afternoon. Stomatal conductance in sugar maple (*Acer saccharum* Marsh.) was found to generally increase with height in the canopy and decrease through the day. Leaf area index (LAI) was found not to vary in a linear pattern, but instead, was greatest near the top of the canopy (16 m) and at the bottom of the canopy (4 m) while intermediate strata had the lowest LAI values. Ozone uptake rates were estimated using the relationship: Ozone uptake = (stomatal conductance / 1.68) x ozone concentration x LAI. Rates of O_3 uptake by the forest canopy were found to be greatest near the top of the canopy and greater at noon than at 5 PM. Canopy structure and meteorological variables that influenced stomatal conductance appear to play key roles in controlling rates of O_3 uptake by the forest canopy.

INTRODUCTION

Collection of meteorological and ozone (O_3) data from five elevations on the VMC research tower located at the Proctor Maple Research Center (PMRC) in Underhill, VT continued throughout 1994. A continuous record of temperature, relative humidity, wind speed and direction, surface wetness, total solar irradiance, photosynthetically active radiation (PAR), ultraviolet-B (UV-B), and O_3 began in 1992 (1993 for UV-B) for both monitoring and research purposes.

These meteorological and O_3 data from different vertical heights throughout the canopy provide the basic information necessary to begin "scaling up" from the individual leaf to the whole-tree, stand/community, and even ecosystem levels. Micro-meteorological flux measurements often are not available and preclude effective scaling and model verification (Baldocchi and Harley, 1995). The spatial (horizontally and vertically through the canopy) and temporal distribution of pollutants such as O_3 would not be expected to be homogenous throughout the forest or even within any single stand. Current instrumentation and data collection on the forest research tower allowed us to begin looking at the vertical distribution of O_3 within a northern hardwood forest canopy.

Tropospheric O_3 is one of several pollutants of regional importance that is thought to be a stressor in forest canopies (Wang and Schaap, 1988; Smith, 1981). Trees act as an important filter for gases and aerosols because of their abundance and large surface areas for gaseous exchange. Although, the air in the interior of forest stands is generally less polluted than air over the surrounding open area due to this filtering action (GroB, 1993), few studies have measured pollutants at multiple locations in the canopy (Cavender and Allen, 1990; Lindberg and Lovett, 1985). The vertical distribution of pollutants in different forest communities is likely to vary widely.

The obvious pathway for gaseous pollutants such as O_3 to enter trees is through open stomata in the leaves. Uptake of O_3 or other gaseous pollutants through the stomata is regulated by stomatal conductance (Reich, 1987). Ozone in turn can impair stomatal function (Tjoelker, Volin, Oleksyn, and Reich, 1995; Reich, 1987) and affect the pattern of uptake into leaves and to leaf surfaces, ultimately influencing the distribution of O_3 concentrations in the canopy. Interactions with O_3 at the canopy-atmosphere interface have the potential to affect metabolism, reduce growth, and negatively impact the ability to respond to biotic and abiotic stresses (Tjoelker *et al.*, 1995; Chameides and Lodge, 1992; Chappelka and Chevone, 1992; Sasek and Richardson, 1989; Wang, Bormann, and Karnosky, 1986). Significant economic losses can result when a commercially important species such as sugar maple (*Acer saccharum* Marsh.) is affected. Tjoelker *et al.* (1995) found that when upper canopy branches of mature sugar maple were exposed to O_3 concentrations averaging 95 ppb for 6 hours per day throughout the growing season, that light-saturated rates of net photosynthesis were reduced by 56% while dark respiration was increased by 40%.

Objectives

The goal of this research is to improve our knowledge of variation in canopy-atmosphere interactions and begin scaling up from the individual leaf to the whole-tree and stand levels of forest structure. We are using a 22 m research tower, located in a mature hardwood stand, at the PMRC to collect basic meteorological and O_3 concentration data. At heights of 0.5, 7.5, 12, 16, and 24 m above the ground (from ground-level to above the canopy) we are:

1. monitoring ambient environmental conditions (meteorology and O_3) beneath, within, and above a northern hardwood forest canopy. Meteorological variables continuously measured and recorded as 15 minute means at all five heights include: temperature, relative humidity, wind speed and direction, and surface wetness. Variables continuously measured (recorded as 15 min means) above the canopy (22 m) include: total solar irradiance (400-1100 nm), PAR (400-700 nm), and UV-B (290-320 nm).

2. quantifying canopy structure and canopy-light relationships by measuring leaf area distribution (leaf area index, LAI) and PAR.

3. quantifying stomatal conductance of sugar maple leaves at different heights in the canopy in an effort to examine spatial and temporal variation in O_3 flux and begin scaling up to the stand level of forest structure.

4. testing the hypothesis that within-canopy O_3 concentration and O_3 uptake are a function of meteorology and canopy structure.

METHODS

Throughout 1994 meteorological variables including ambient temperature, relative humidity, wind speed and direction, and leaf surface wetness were continuously collected at five elevations alone a vertical gradient on the VMC research tower. Elevations sampled include: 0.5 m (just above the soil surface), 7.5 m (below the main canopy), 12 m (within the canopy), 16 m (top of the canopy), and 24 m (ambient). Ozone concentrations in parts per billion (ppb) at each of these five elevations were also recorded from 11 May to 9 November. Concentrations of O_3 were tabulated by hour-of-the-day (11 May-31 August) to look at the average seasonal diurnal pattern in concentration at all five heights. Total solar irradiance, PAR, and UV-B (starting on 25 July 1993) data were collected only at the 22 m level. All data were stored as 15 min averages by a Campbell Scientific 21X datalogger or directly to a computer. For further details about instrumentation, please see the 1992 VMC Annual Report.

Stomatal conductance measurements were made on several dates during mid July and August 1994, at 5 heights [4, 9, 11, 13, and 16 m (top of the canopy)], on two sugar maple trees accessible from the 22 m research tower at PMRC. Due to weather and equipment related interruptions in measurements, complete data sets for spatial and temporal analysis were obtained for only two days. A LI-COR 1600 steady state porometer was used to make one-sided stomatal conductance measurements (mmol H_2O $m^{-2} s^{-1}$). The instrument was calibrated for flow rate and relative humidity prior to each set of measurements. Measurements were stratified by leaf-age classes and position (sun or shade leaves) over the vertical distribution of the canopy over time.

Estimates of expected O_3 uptake into plant leaves through stomata were based on physiological models similar to those elucidated by Farquhar, Dubbe, and Raschke (1978) and Cowan (1977). Gas exchange rates were estimated using diffusion gradients based on negligible leaf-internal O_3 concentration (Wang, Hinckley, Cumming, and Braate, 1995; Laisk, Kull, and Moldau, 1989). The following relationship was used to estimate expected O_3 uptake.

Ozone uptake = (stomatal conductance / 1.68) x ozone concentration x LAI

The expected rates for O_3 uptake were estimated using stomatal conductance and O_3 concentration data from the top of the canopy (16 m) and total LAI. Expected rates were then compared to observed O_3 uptake calculated as the sum of uptake for the five individual canopy heights.

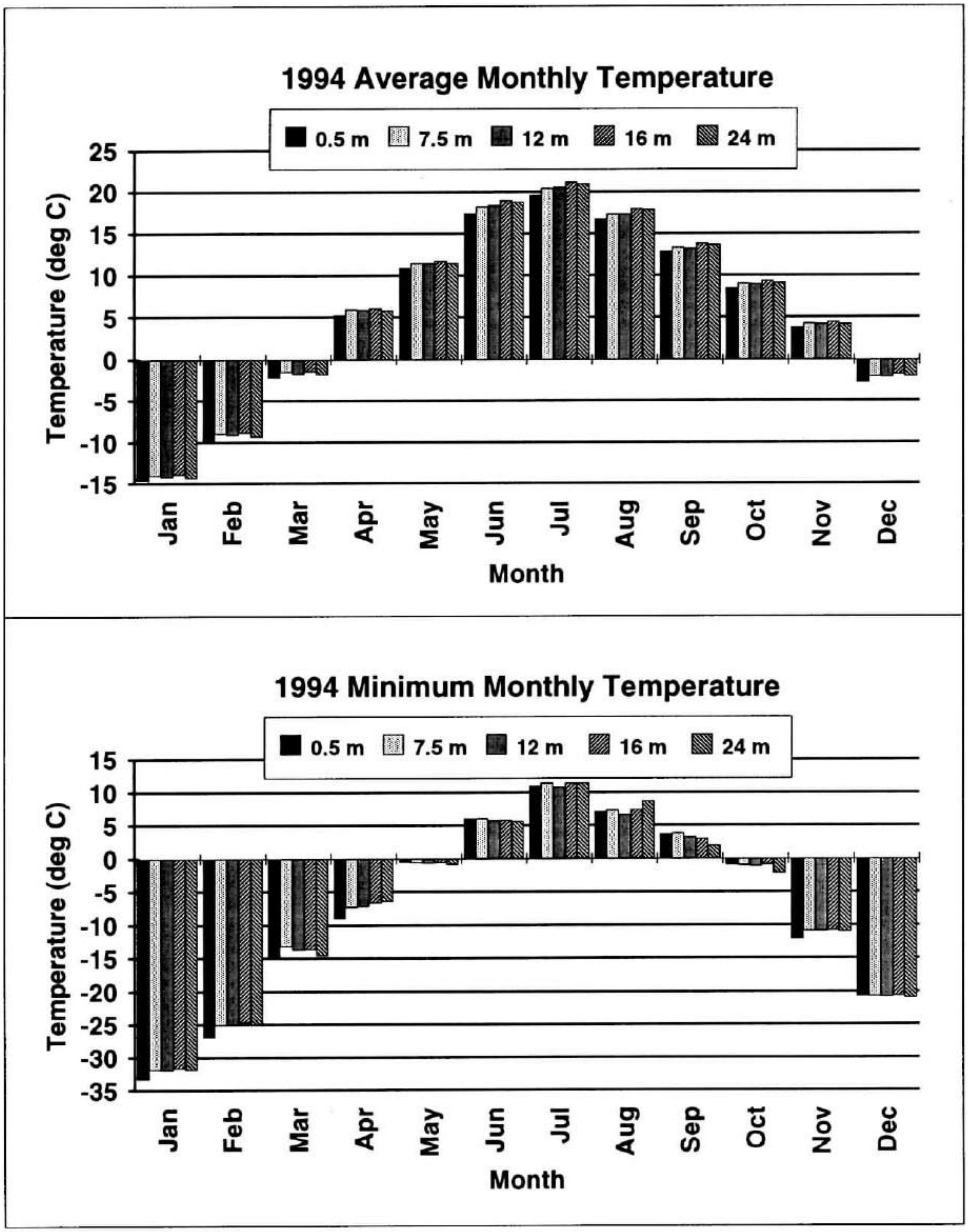
In August 1994 LAI was estimated from PAR attenuation data collected from the forest canopy research tower using a Sunfleck Ceptometer (Decagon Devices, Pullman, WA). Measurements were made at 4, 9,11, 13, and 16 m above the forest floor at the same heights that stomatal conductance data were collected. In addition to enhancing the long-term record of LAI at the forest tower, these data were used to estimate O_3 uptake by the forest canopy.

RESULTS AND DISCUSSION

Meteorology. Meteorological data were collected from January to December 1994 at all five elevations on the research tower. The data are summarized in monthly files as 15 minute, hourly, and daily averages and are available to VMC cooperators or other researchers in Microsoft Excel, Lotus 123, or ASCII formats. Figure 1 shows examples of some of the data summarized on a monthly basis to look at overall annual trends.

Ozone. Examination of O_3 concentrations during 1994 at all five elevations on the research tower revealed a similar spacial (vertically up through the canopy) pattern to 1992 and 1993. Ozone concentrations generally increased with height in the canopy and concentrations near the forest floor (0.5 m) were significantly lower than those at any other height during much of the sampling season (mid-May to mid-November; Fig. 2). Concentrations of O_3 at the upper four heights (7.5, 12, 16, and 24 m) were not significantly different. In 1993 O_3 concentrations at 24 m (top of the tower) were significantly higher than those at 12, 7.5 and 0.5 m, but were only significantly higher than those at 0.5 m in 1994. The largest difference among heights in O_3 concentration was recorded in early July and occurred between the extremes in height (0.5 vs 24 m) and exceeded 26 ppb, compared to a 30 ppb maximum difference in 1993. When averaged

Figure 1. Average and minimum monthly temperature and average and maximum monthly wind speed at five elevations (0.5, 7.5, 12, 16, 24 m above the ground) along a vertical gradient and maximum monthly photosynthetically active radiation (PAR; 22 m only) on the VMC Research Tower at the Proctor Maple Research Center in Underhill, VT.



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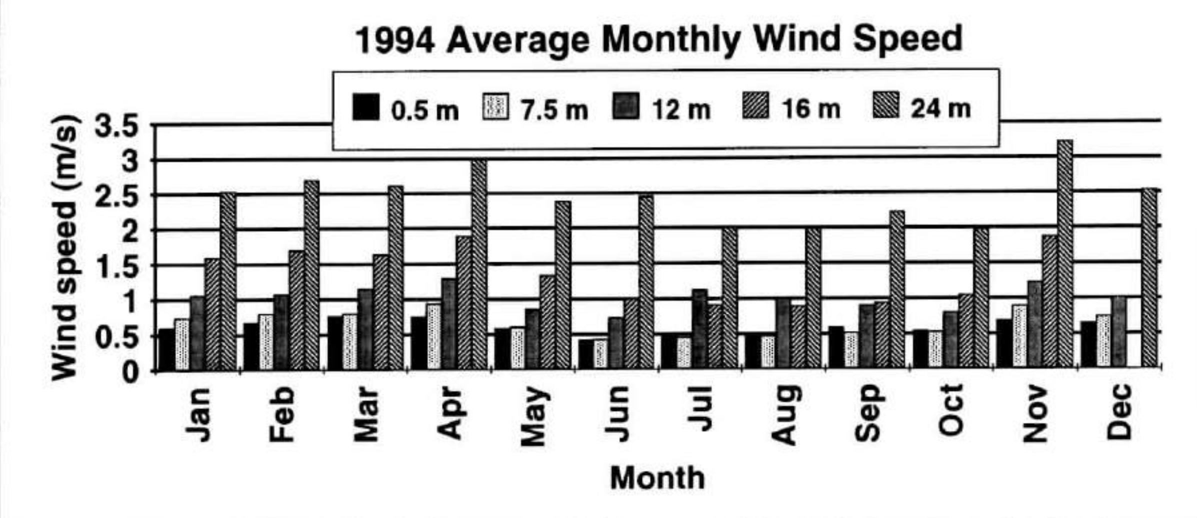
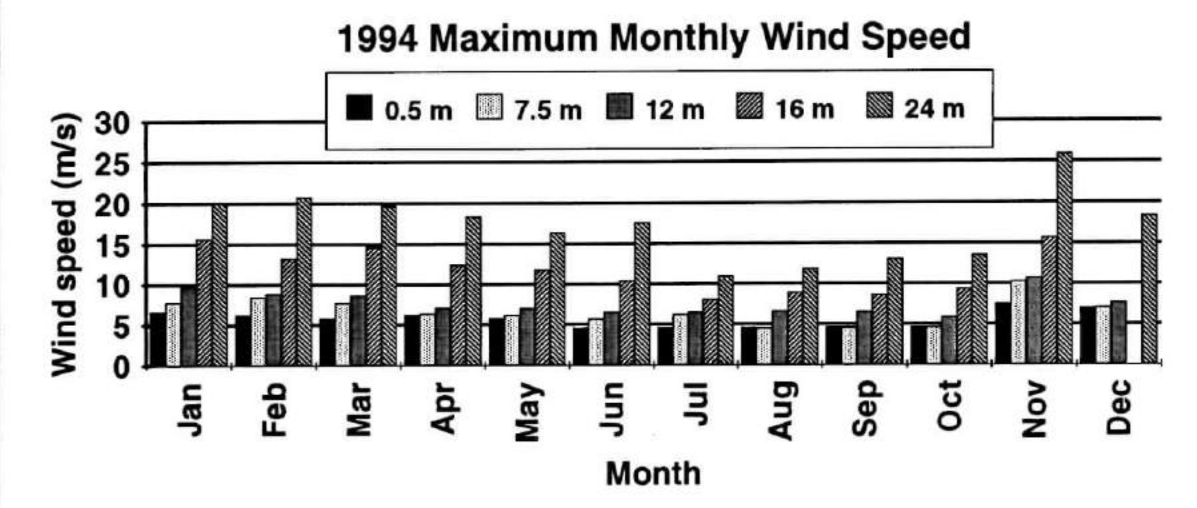




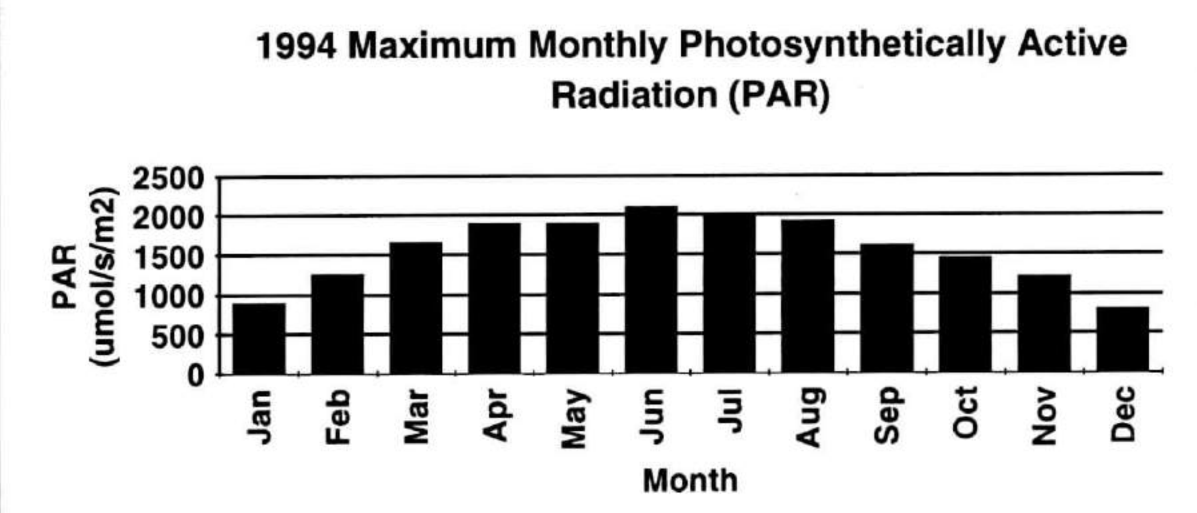
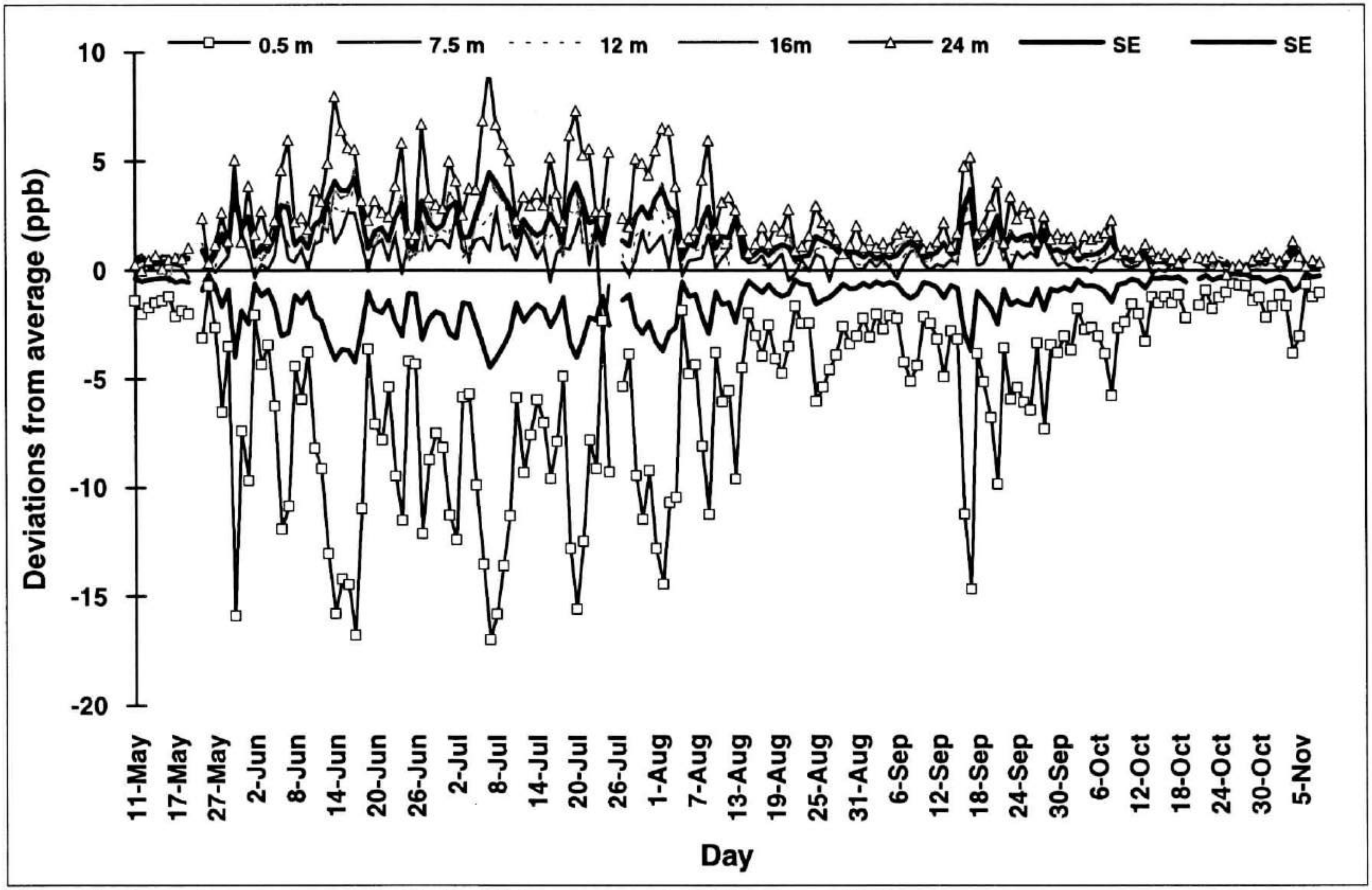


Figure 2. Variation in 7-hour-average (9 AM-4 PM) ozone concentration with height for 1994, measured at five elevations (0.5, 7.5, 12, 16, 24 m above the ground) along a vertical gradient on the VMC Research Tower at the Proctor Maple Research Center in Underhill, VT and expressed as deviations from average ozone concentration for all five heights.



Note: SE=standard error. The area inside the SE lines represents 2 SE's (+1 and -1 SE).

over the entire season, O_3 concentrations measured near the forest floor (0.5 m) were 23% lower than those recorded at the top of the tower, compared to 21% lower in 1993. When averaged over the entire season, O_3 concentrations were 10% lower in 1994 than 1993 and this reduction was consistent over all five sampling heights. As reported in 1993, O_3 concentrations have been previously shown to increase with elevation, but this phenomenon has usually been observed along elevational gradients on mountains where monitoring stations are separated by several hundred or even thousands of meters in elevation (Lefohn, 1992). We have speculated that lower concentrations of O_3 near the forest floor may be due either to a boundary layer effect caused by inadequate mixing of air near the soil surface during the growing season, the chemical destruction of O_3 in the presence of olefinic hydocarbons such as propylene and isoprene (Chameides & Lodge, 1992) or NO_x produced by soil micro-organisms, or the physical destruction of O_3 caused by O_3 coming in direct contact with leaf surfaces, bark, or soil.

In 1994 we also looked at the diurnal pattern of O_3 concentrations averaged over the season at all five heights (Fig. 3). Data from 11 May to 31 August 1994 were averaged by hour-of-the-day to arrive at an hour-by-hour seasonal summary of O_3 concentrations. These data were plotted and examined graphically to look at average diurnal patterns of O_3 concentrations at various height in the canopy. The trend of O_3 concentration generally increasing with height in the canopy was apparent. The diurnal pattern of O_3 concentrations was similar at all five elevations in the canopy with the most obvious difference being the lower magnitude of concentrations just above the forest floor (0.5 m). On average, O_3 concentrations near the forest floor were 9-12 ppb lower than at any other height in the canopy. Concentrations of O_3 at all heights reached a daily low at about 7:00 AM and then increase to peak concentrations between 1:00-3:00 PM with time to peak concentration also generally increasing with increasing height. That is, O_3 concentrations near the forest floor (0.5 m) reached peak daily concentrations at about 1:00 PM while concentrations at 24 m reach their maximum between 2:00-3:00 PM. Concentrations at all heights then decrease until about 4:00 PM when slight increases in concentrations at all levels were noted. By 9:00 PM, O_3 concentrations again begin to slowly decease during the night until they again reach their daily minimum at around 7:00 AM.

Total number of hours during June, July, and August that hourly average O_3 concentrations exceeded different thresholds were again examined in 1994 (Fig. 4). We found that the number of hours of exposure at concentrations between 60 to >100 ppb was down by 20 to 100% when compared to 1993. For example, at 60 ppb, a concentration which may cause injury to certain sensitive plants, we found that the forest floor was exposed for only 37 hours in 1994, compared to 77 hours in 1993. At the top of the forest canopy (24 m) the number of hours of exposure to concentration of 60 ppb or greater was down 20% from 1993. Only one hour of O_3 exposure at a concentration of 100 ppb or greater (at 7.5 m) was observed in 1994. This compares to at least 17 hours of exposure at this relatively high concentration at all levels of the canopy, except near the forest floor, in 1993.

Figure 3. Diurnal pattern of seasonal average ozone concentrations for the period of 11 May through 31 August, 1994 at five elevations (0.5, 7.5, 12, 16, and 24 m above the ground) along a vertical gradient on the VMC Research Tower at the Proctor Maple Research Center in Underhill, VT.

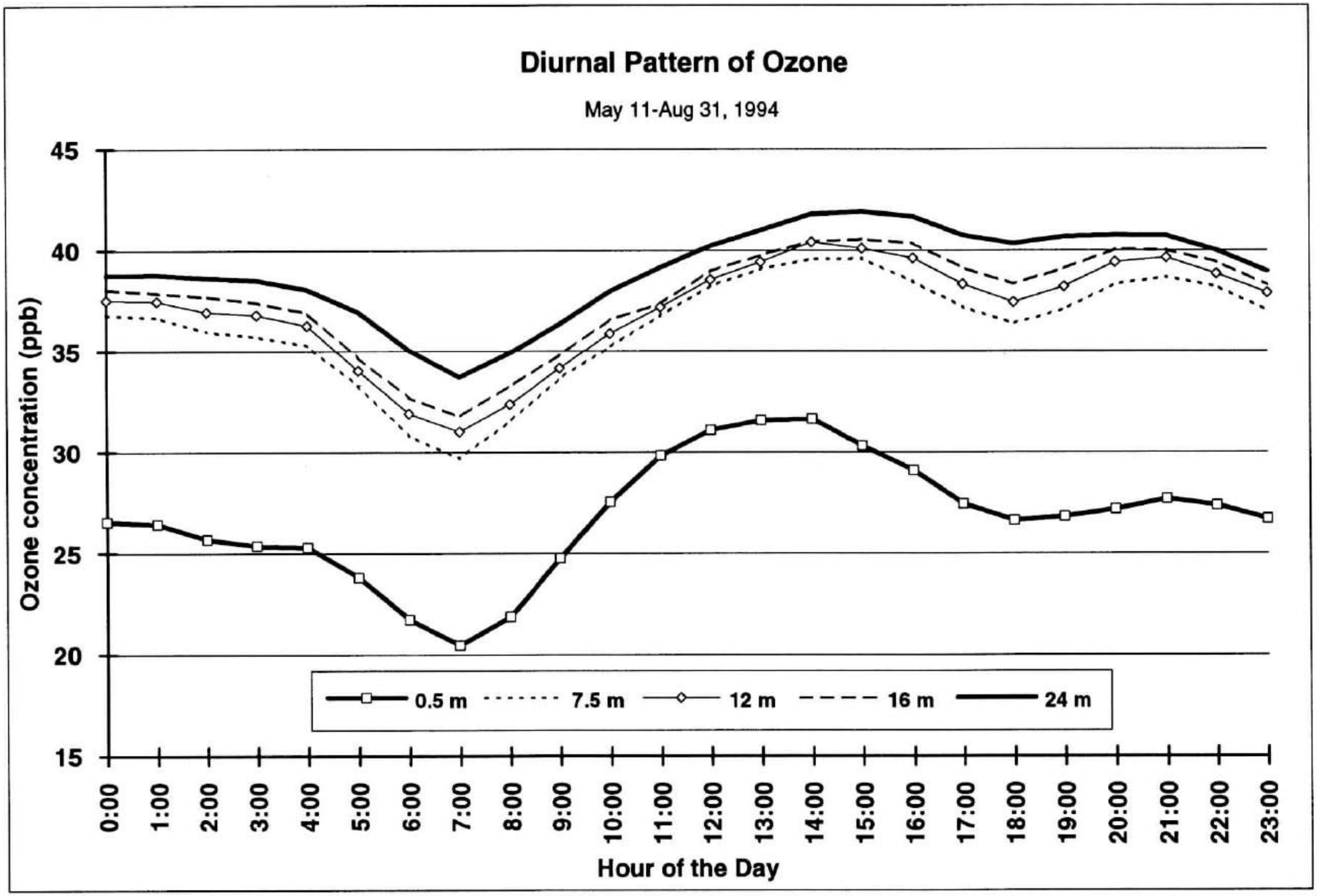
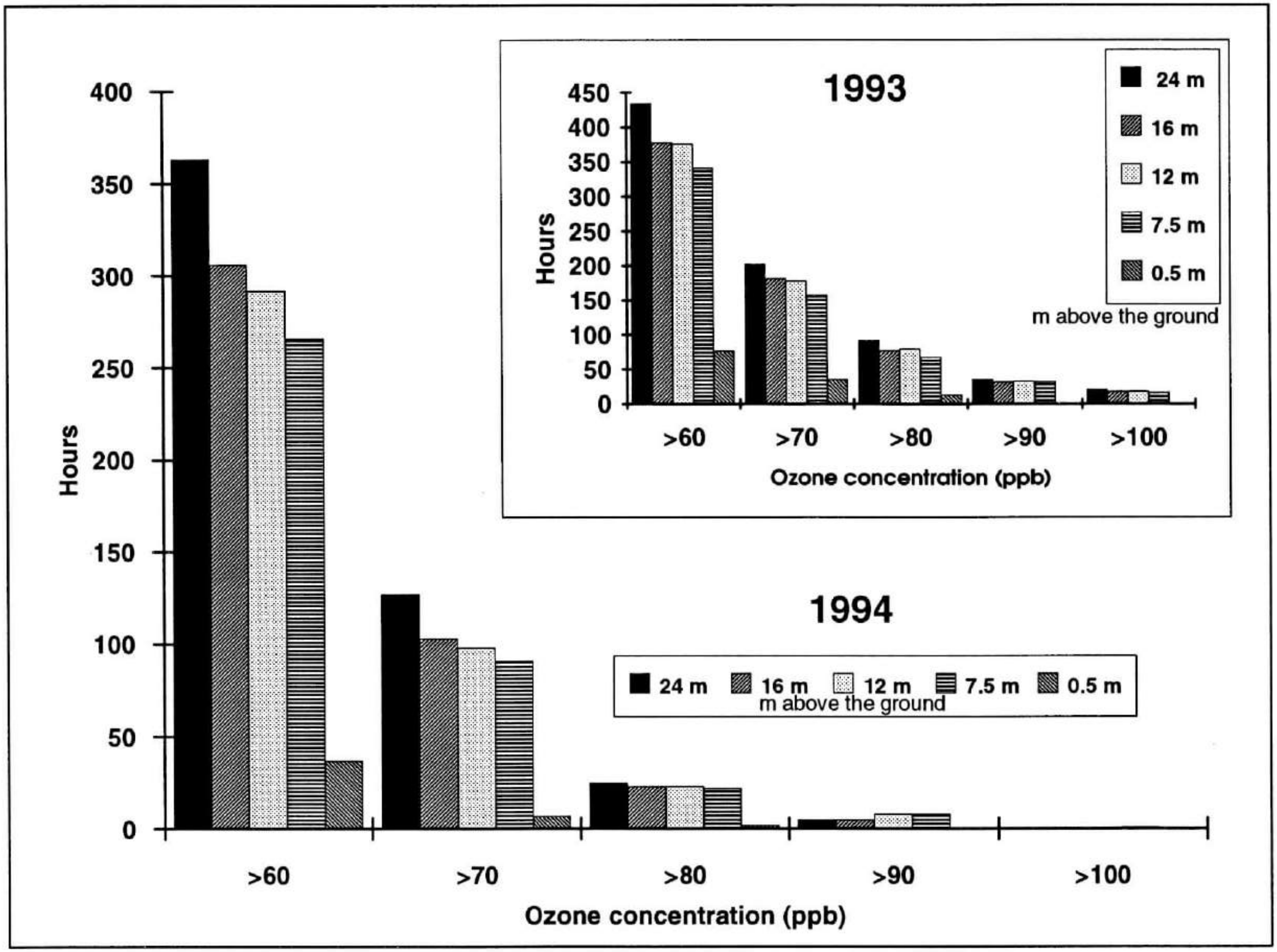


Figure 4. Number of hours during June, July, and August 1993 and 1994 that hourly ozone concentrations exceeded certain thresholds at five elevations (0.5, 7.5, 12, 16, and 24 m above the ground) along a vertical gradient on the VMC Research Tower at the Proctor Maple Research Center in Underhill, VT.



Stomatal conductance and leaf area index. On several dates in mid-July and August stomatal conductance measurements were made at five heights (4, 9, 11, 13, and 16 m) on leaves of sugar maple trees accessible from the forest research tower at PMRC. Stomatal conductance generally increased with height in the forest canopy and decreased through the day, with exceptions believed to be related to changing environmental gradients (Table 1). As a result on some occasions, on some sampling dates, the highest values were actually measured at the second highest level (13 m) rather than at the top of the canopy. Stomatal conductance is influenced by environmental factors such as available moisture, leaf temperature, relative humidity, and to a lesser degree, wind speed. Examination of meteorology data for 27 July and 11 August showed that relative humidity averaged 9% lower at the top of the canopy (16 m) than at the next lowest height (13 m). Leaf temperature presumably, was higher in direct sunlight (high radiation and slightly warmer air temperature) near the top of the canopy than lower down at the 13 m level. Low humidity and high leaf temperature both have a negative influence on stomatal conductance. Excessive temperatures may trigger a temporary partial closure of stomata during the middle of the day termed "midday closure" (Noggle and Fritz, 1983). This phenomenon helps prevent excessive water loss through the stomata and reduces the heat load on the leaf. These factors may help explain the reduction in conductance near the top of the canopy when compared to the next lowest height.

Table 1. Stomatal conductance and ozone measured in late July and early August 1994 and estimated LAI following full leaf-out in 1994 from five heights (4, 9, 11, 13, and 16 m) in a mature sugar maple stand at the Proctor Maple Research Center in Underhill, VT.

Height	Stomatal conductance		Ozone	LAI
	7/27/94 12 PM	8/11/94 5 PM		
(m)	(umol m^{-2} s^{-1})	(umol m^{-2} s^{-1})	(uliters)	
16	102	77	0.0344	1.6
13	113	123	0.0333	0.5
11	78	93	0.0328	0.3
9	80	79	0.0311	0.7
4	56	36	0.0302	1.2

Leaf area index (LAI) did not exhibit the same linear relationship as did stomatal conductance and ozone concentration. Instead, LAI was greatest near the top of the canopy (16 m) with an average value of 1.6, followed values of 1.2 and 0.7 at 4 and 9 m, respectively (Table 1). The intermediate heights of 11 and 13 m had the lowest LAI values. The thickness of the various canopy strata were not equal, so differences in LAI may be due either to differences in stratum thickness, foliage density, or leaf size.

Ozone uptake. In sugar maple, expected uptake of O_3 tended to be highest near the top of the canopy (14-16 m) and lowest at mid-canopy (11 m; Fig. 5). Because the upper canopy stratum did have greater leaf area (LAI) while actually having somewhat lower stomatal conductance on some sampling dates, when compared to the 13 m level, it appears that greater leaf area more than compensated for lower stomatal conductance and accounted for the higher O_3 uptake. When corrected for leaf area, lower canopy heights had similar rates of O_3 uptake to the upper canopy. Because neither stomatal conductance nor ambient O_3 concentrations were exceptionally low at mid-canopy on sampling days, lower leaf area (LAI=0.3) appears to explain the lower rates of uptake. This would indicate that canopy structure is an important factor in determining within-canopy O_3 concentrations. Ozone uptake was generally found to be similar to or lower at 5 PM than at noon (Fig. 5). This supports the theory that gas exchange generally reaches a maximum near midday and slows near the end of the day (Beadle et al., 1985; Iacobelli and McCaughey, 1993). The greatest differences between O_3 uptake at noon and at 5 PM were found in the highest (16 m) and lowest (4 m) canopy strata. Differences between midday and afternoon uptake rates were much smaller at the three intermediate heights. When averaged across all heights, expected values for O_3 uptake were found to be 13% higher than observed (Fig. 6). Differences in the way that expected and observed O_3 uptake rates were calculated may help explain this pattern. Expected O_3 uptake was estimated using stomatal conductance and ozone concentration data from the top of the canopy and total canopy LAI. Observed O_3 uptake rates were calculated as the sum of rates at individual canopy heights. Because conductance and O_3 concentrations were generally lower at lower heights in the canopy, expected uptake of O_3 was overestimated when based on upper canopy parameters.

CONCLUSIONS

In 1994 we began the process of scaling up from individual leaf measurements to the whole-canopy level. At the same time, we were able to begin testing the hypothesis that within-canopy O_3 concentration is a function of meteorology and canopy structure. The issue of scaling has become increasingly important with emphasis on an ecosystem approach to research and management and growing concerns about the impacts of global warming. Several recent studies have used rather complex gas-exchange models as tools for predicting flux and movement gases such as CO_2 and N and water vapor at the canopy level (Baldocchi and Harley, 1995; Leuning, Kelliher, DePury, and Schulze, 1995). The relationship (model) tested here, although relatively simple compared to others, did predict O_3 uptake quite well and differences between expected and observed uptake rates can be explained by within-canopy variation in leaf area and stomatal conductance and diurnal patterns in stomatal conductance. This would indicate that canopy structure and stomatal conductance are important determining factors in O_3 uptake. Stomatal conductance data

Figure 5. Estimated ozone uptake rates by a mature sugar maple canopy at 12 noon and 5 PM, in mid summer 1994, at five heights (4, 9, 11, 13, 16 m) along a vertical gradient on the VMC Research Tower at the Proctor Maple Research Center in Underhill, VT.

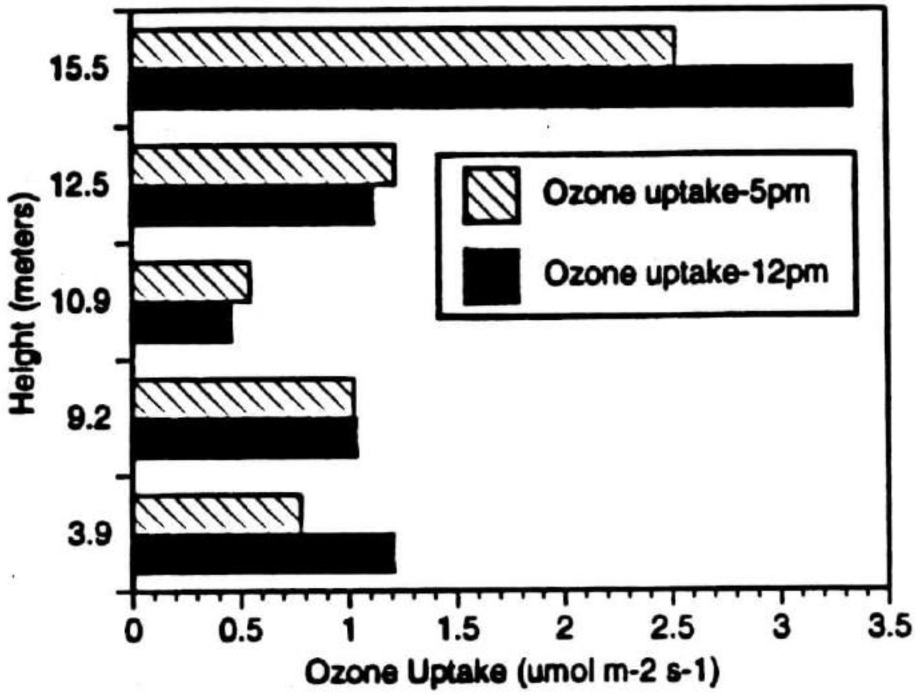
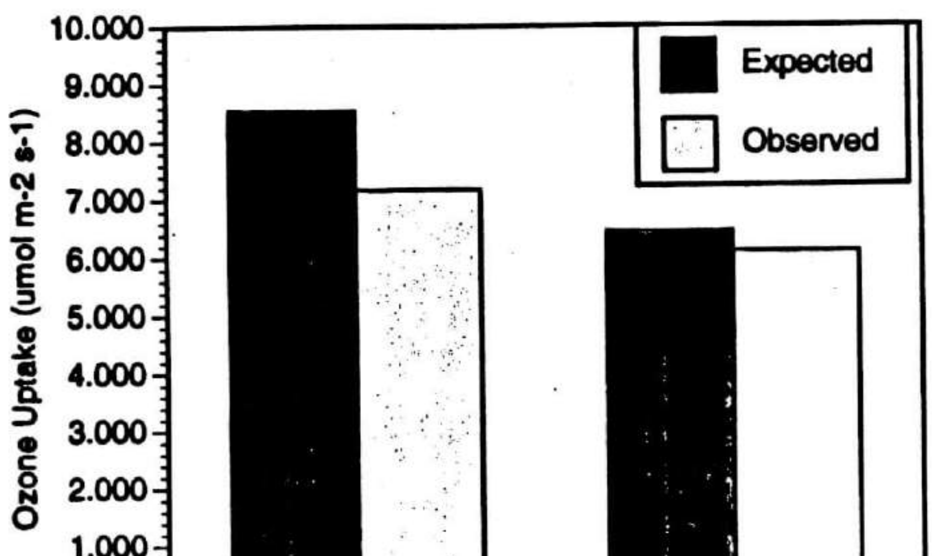


Figure 6. The average (averaged across height) difference between expected and observed ozone uptake at 12 noon and 5 PM, during mid summer 1994, in a mature sugar maple canopy at the Proctor Maple Research Center in Underhill, VT. Expected values were estimated using stomatal conductance and ozone concentration from the top of the canopy and total LAI. Observed values were calculated as the sum of ozone uptake at five canopy heights.



tends to show that meteorological variables such as relative humidity, air temperature, radiation, and leaf temperature influence stomatal conductance and affect O_3 uptake rates.

Although this was a relatively small experiment with limited data, several important points about O_3 uptake rates did emerge. Ozone is taken up at higher rates near the top of the canopy than at other heights. This portion of the canopy also had the greatest leaf area and relatively high, although not always the highest, rates of stomatal conductance. Despite relatively high leaf area at the lowest canopy level (4 m; LAI=1.2), stomatal conductance was lowest compared to all other heights and O_3 uptake rates were similar to mid-canopy heights (9 and 11 m) with the lowest leaf area and slightly higher rates of stomatal conductance. Ozone uptake was usually greater near midday and decreased toward the end of the day. This latter finding generally corresponds to the diurnal patterns for stomatal conductance and ozone availability. The smaller difference between expected and observed rates of O_3 uptake at 5 PM than at noon tends to indicate that biological and environmental gradients in the canopy are probably less in the afternoon than at midday.

On a seasonal basis, O_3 concentrations in 1994 were 10% lower than in 1993 and this reduction was consistent across all five sampling heights. This reduction was also reflected in hours of O_3 exposure at different concentrations during June, July, and August. Maximum hours of exposure at 100 and 90 ppb or greater were 1 and 8 hours, respectively in 1994 compared to 21 and 32 hours in 1993. Tjoelker *et al.* (1995) found that when upper canopy branches of mature sugar maple were exposed to O_3 concentrations averaging 95 ppb for 6 hours per day throughout the growing season, a significant reduction in light-saturated rates of net photosynthesis and increase in dark respiration occurred. While concentration of O_3 at PMRC rarely approach or exceed this experimental concentration and length of exposure (dose) are much lower than those imposed in this experiment, it is not known what if any effects, long-term exposure to lower O_3 concentrations (50-60 ppb) may have on sugar maple growth and health.

FUTURE PLANS

As in the past, this data will continue to be available upon request to VMC cooperators and other researchers. Collection of meteorology and O_3 data at the VMC research tower will continue through December 1995.

FUNDING SOURCES

Support for this project comes from the UVM Research Advisory Council, the VMC, the U.S. Forest Service Northeastern Forest Experiment Station (cooperative agreement #23-758), the UVM School of Natural Resources (SNR), and the SNR McIntire-Stennis program.

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Vermont Acid Precipitation Monitoring Program

Data Summary Report 1980-1994 for Underhill and Mt. Mansfield

Heather Pembrook
Vermont Department of Environmental Conservation
Biomonitoring and Aquatic Studies Section

Cooperators:

UVM Proctor Maple Research Center: Joanne Cummings and Sumner Williams
WCAX-TV Mt. Mansfield Transmitter Station: Michael Rainey.

Abstract:

The VMC monitoring stations located at Underhill and Mt. Mansfield are included in the Vermont Acid Precipitation Monitoring Program (VAPMP). The majority of bulk precipitation in Vermont is unquestionably acidic. Forty-nine percent of all events occur between the pH of 4.1 - 4.6. Ninety-four percent of all precipitation events have a pH of less than 5.60, the theoretical pH of unpolluted rain. Typically, both sites have lower volume-weighted pH means in the summer than in the winter. Mt. Mansfield, Underhill and a site located in Morrisville were examined for elevational and spatial variations. The sites can be characterized from lowest to highest pH; Mt. Mansfield, Underhill and Morrisville. In addition, a lower pH can be expected on the west side of the Green Mountains due to storm fronts moving west to east.

Introduction:

The Department of Environmental Conservation (DEC) began monitoring precipitation events via the Vermont Acid Precipitation Program (VAPMP). The program was initiated in 1980 to assess the impact of the 1970 Clean Air Act, which mandated the improvement of air quality in the vicinity of midwestern and southeastern fossil fuel burning plants. Precipitation samples are collected on an event basis by dedicated volunteers at six sites throughout Vermont (Mt. Mansfield, Underhill, Morrisville, Concord, St. Johnsbury and South Lincoln).

Methods:

Bulk precipitation is collected and measured on an event basis. Precipitation amount and pH are measured for each event. The pH is measured with a Cole Parmer digital pH meter model 5987 and a Cole Parmer combination electrode with a calomel reference.

Rainfall is intercepted by a funnel with a polyethylene screen (1241 micron mesh) at its vortex and passes through a length of tygon tubing until it reaches and is collected in a one gallon polyethylene jug. The entire apparatus is housed in a wooden box, one foot in width and four feet in height. Snow is collected in a five gallon polyethylene bucket and brought indoors to completely melt before the pH is measured.

The collectors are located in flat open areas, away from roads, point sources, heavily urbanized and/or agricultural areas, trees and overhead wires.

All monitors are trained by the DEC and the monitor's techniques are observed bi-annually. There has been a low turnover of monitors, which has contributed to consistency in the data collection.

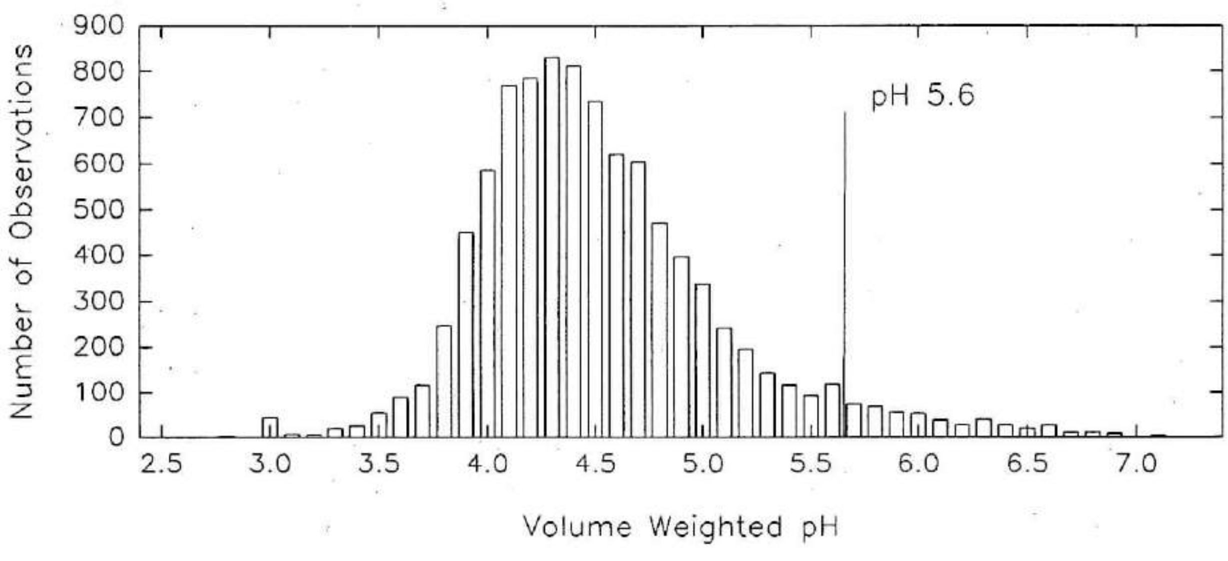
The pH meters are calibrated with buffers 4.00 and 7.00 prior to each use. To ensure that the electrodes are working properly, the monitors are supplied with a check sample of pH 4.70+/-0.10 at 25°C. The pH meters are professionally calibrated every year and the electrodes are replaced when they show signs of slow response or failure. The pH and the amount of precipitation is recorded on a monthly report sheets along with comments about duration of event, type of precipitation, time and date of analysis, use of pH check sample and presence of visible contaminants in the sample. The bulk collector jugs and snow buckets are rinsed with distilled water three times after each precipitation event.

Results:

Frequency of Distribution

The highest frequency of precipitation pH occurrence falls between 4.1 - 4.6. Ninety-four percent of all precipitation events from July 1980 to December 1994 are less than pH 5.60, the theoretical pH for unpolluted precipitation. Eighty-five percent of all precipitation events are between 3.00 - 5.00. The most extreme pH observations, both high and low, appear to be associated with low-volume precipitation events while high-volume events tend to have pH's toward the median of the distribution. (Graph 1.)

Graph 1. VAPMP Frequency Distribution for all stations, 1980–1994
9354 Observations



Mt. Mansfield recorded substantially lower annual volume-weighted pH in 1980, 1981, 1991, 1992 and 1994 (Table 1). In comparison to other VAPMP sites, Underhill and Mt. Mansfield usually have the lowest annual volume weighted pH.

Seasonal Variation

Summer volume-weighted means tend to be slightly lower than the winter volume-weighted means (Table 2). However, there is not a significant trend indicating that the summer means are consistently lower than the winter means.

Table 1. Annual Volume-Weighted Mean pH for 3 Continuously Operating Sites.

SITE	1980	1981	1982	1983	1984	1985	1986	1987
Mt. Mansfield	3.86	4.09	4.28	4.41	4.30	4.35	4.43	4.42
Underhill	ND	ND	ND	4.37	4.29	4.27	4.36	4.32
Morrisville	4.78	ND	4.37	4.51	4.44	4.49	4.51	4.37

SITE	1988	1989	1990	1991	1992	1993	1994
Mt. Mansfield	4.49	4.26	4.28	4.14	4.03	4.25	4.13
Underhill	4.32	4.34	4.46	4.41	4.46	4.28	4.31
Morrisville	4.39	4.44	4.38	4.49	4.64	4.50	4.47

ND = No Data

Table 2. Seasonal Volume-Weighted pH 1981-1994.

SITE	1981		1982		1983		1984		1985		1986	
	W	S	W	S	W	S	W	S	W	S	W	S
Mt.Mansfield	4.32	4.00	4.37	4.25	4.45	4.40	4.21	4.21	4.20	4.24	4.52	4.39
Underhill	ND	ND	ND	ND	ND	4.25	4.44	4.14	4.30	4.25	4.37	4.32

SITE	1987		1988		1989		1990		1991		1992	
	W	S	W	S	W	S	W	S	W	S	W	S
Mt. Mansfield	4.53	4.42	4.38	4.51	4.36	4.29	4.22	4.24	4.32	4.29	3.69	4.60
Underhill	4.40	4.36	4.12	4.23	4.12	4.50	4.35	4.53	4.44	4.50	4.33	4.62

SITE	1993		1994	
	W	S	W	S
Mt. Mansfield	4.24	4.31	4.27	4.14
Underhill	4.25	4.25	4.41	4.19

W = Winter, S = Summer, ND = No Data

Elevational and Spatial Variation

In comparing Mt. Mansfield (3800') with Underhill (1300'), and Morrisville (700') there appears to be a pattern of decreasing pH with increasing elevation. In comparing spatial relationships, Underhill, located to the west of Mt. Mansfield, has a lower yearly mean weighted pH than does Morrisville, located on the east side of Mt. Mansfield. (Table 1.)

Discussion:

The majority of bulk precipitation in Vermont is unquestionably acidic. However, based on this network there has been no clear trend indicating a statistical change in pH since 1980 in Vermont. It has been suggested that if sulfur emissions decreased, then pH would increase. The VAPMP data does not support this hypothesis. This may be due to the importance of nitrate in atmospheric chemistry, which has not been regulated as strictly as sulfur emissions. In addition, there has been a reduction of base cations in the atmosphere, which provides an atmospherically deposited buffer. This is due in part to the removal of dust particulates from emissions.

Although the summer volume weighted means tend to be slightly lower than the winter volume weighted means, there is no significant trend. In addition, from 1989-1994, summer means appear to be higher than the winter means. In general, a lower pH is expected in the summertime due to increases in sunlight, temperature, humidity and photochemical oxidants which enhance the chemical transformation of sulfur dioxide (SO_2) into sulfuric acid (H_2SO_4) (Allan and Mueller, 1985; Bowersox and Stensland, 1985).

Several spatial relationships have been suggested in reference to precipitation and pH in Vermont. 1) There is a decrease in pH with increasing elevation, mainly due to acidic fog; 2) a lower pH is expected to occur west of the Green Mountains as a result of storm fronts moving west to east, depositing more acidic and concentrated pollutants as they rise over the mountains (Scott, 1987). The VAPMP data support these suggested relationships.

Future plans:

The VAPMP will continue to monitor sites around Vermont with new site(s) being brought into the program. In addition, the Department of Environmental Conservation plans on rigorously testing the data to determine any significant trends.

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Surface Waters

A Biological and Chemical Survey of Selected Surface Waters in the Lye Brook Wilderness Area, Vermont

By
James H. Kellogg
Steven L. Fiske
Richard W. Langdon

For
The U.S. Forest Service - Green Mountain National Forest

Vermont Agency of Natural Resources
Department of Environmental Conservation
Biomonitoring and Aquatic Studies Unit

June 1995

Excerpts from this interim report to the GMNF are included here. A final report will be available in 1996 when this study is completed.

Table 1. Chemistry of Lye Brook Wilderness Study Lakes - 1994

Lake	Depth (m)	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Bourn	1	10-May-94	11.2	5.07	0.01	14.8	64	60	0.25	0.11	3.03	0.82	0.29	0.44	0.33	252	42	69	4.52
Bourn	1	20-Jul-94	22.6	5.28	0.26	14.0	112	> 70	0.23	<0.01	3.29	0.70	0.30	0.48	0.32	312	27	63	5.43
Bourn	8	20-Jul-94	8.0	5.34	1.07	14.9	128	> 70	0.24	<0.01	3.09	0.79	0.31	0.47	0.36	279	9	77	5.52
Bourn	1	29-Sep-94	13.0	5.36	0.79	15.6	67	> 70	0.26	<0.01	3.22	0.76	0.33	0.49	0.34	195	24	49	5.43
Branch	1	10-May-94	9.8	4.67	-0.85	19.0	88	> 70	0.28	0.12	3.36	0.74	0.24	0.42	0.34	315	95	68	5.30
Branch	1	20-Jul-94	21.7	4.76	-0.67	19.7	71	55	0.36	0.03	4.02	0.61	0.24	0.53	0.35	252	79	57	4.85
Branch	9	20-Jul-94	4.3	4.76	-0.68	20.3	91	65	0.32	0.12	3.81	0.70	0.24	0.53	0.44	292	99	69	4.88
Branch	1	29-Sep-94	12.4	4.68	-0.74	21.3	77	> 70	0.33	0.04	3.97	0.71	0.24	0.50	0.41	270	69	51	5.12

Parameter:

[0]Cond - Conductivity
[1]DC2 - Filtered Color
[2]TC - Unfiltered Color
[3]DCL - Dissolved Chloride
[4]DNO_3 - Dissolved Nitrate
[5]DSO_4 - Dissolved Sulfate
[6]DCA - Dissolved Calcium
[7]DMG - Dissolved Magnesium
[8]DNA - Dissolved Sodium
[9]DK - Dissolved Potassium
[10]DAL - Dissolved Aluminum
[11]IMAL - Inorganic Monomeric Aluminum (most toxic form to aquatic biota)
[12]OMAL - Organic Monomeric Aluminum
[13]DOC - Dissolved Organic Carbon

Table 2. Chemistry of Lye Brook Wilderness Study Streams 1994

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[1] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Bourn (Upper)	20-Sep-94	9.0	5.97	1.85	18.3	169	> 70	0.48	0.03	3.46	1.29	0.59	1.04	0.58	348	12	120	9.03
Bourn (Lower)	14-Apr-94	1.5	4.85	-0.41	20.1	84	65	0.23	0.26	3.58	1.13	0.38	0.41	0.46	306	60	91	6.54
Bourn (Lower)	28-Apr-94	4.0	4.80	-0.55	17.7	104	> 70	0.20	0.13	3.23	1.01	0.32	0.36	0.33	303	26	107	6.90
Bourn (Lower)	19-May-94	6.5	5.33	0.43	17.2	81	60	0.24	0.07	4.14	1.32	0.44	0.49	0.41	299	55	101	5.91
Bourn (Lower)	08-Aug-94	17.5	6.70	4.92	26.6	97	70	0.40	0.19	4.23	2.31	0.93	0.86	0.65	204	0	80	6.50
Bourn (Lower)	20-Sep-94	10.5	6.76	4.68	24.9	81	55	0.42	0.08	4.39	2.20	0.91	0.93	0.61	80	5	58	5.03
Branch Pond Bk.	06-Apr-94	1.0	4.73	-0.65	22.9	55		0.29	0.28	4.24	1.02	0.36	0.68	0.47	279	79	79	4.30
Branch Pond Bk.	13-Apr-94	1.0	4.66	-1.28	25.2	58	50	0.24	0.32	3.87	0.91	0.31	0.53	0.41	303	82	78	5.07
Branch Pond Bk.	28-Apr-94		4.61	-1.26	19.8	93	> 70	0.17	0.20	3.01	0.73	0.24	0.39	0.31	314	61	90	6.56
Branch Pond Bk.	11-May-94	8.5	4.76	-0.72	18.7	84	65	0.23	0.06	3.71	0.87	0.27	0.54	0.38	309	26	127	5.84
Branch Pond Bk.	18-May-94	9.0	4.58	-1.05	20.1	88	70	0.22	0.06	3.84	0.89	0.27	0.52	0.34	315	89	100	6.46
Branch Pond Bk.	01-Aug-94	14.5	5.17	0.47	15.2	155	> 70	0.26	0.01	2.73	0.82	0.30	0.88	0.41	312	25	114	8.75
Branch Pond Bk.	14-Sep-94	11.5	5.22	0.45	21.6													
Branch Pond Bk.	19-Sep-94	10.5	5.41	0.53		117												
Branch Pond Bk.	03-Oct-94	5.5	5.22	-0.29	20.8	86	65	0.39	<0.01	4.45	0.98	0.34	0.72	0.44	309	56	108	7.79
Lye (Upper)	28-Apr-94	4.0	4.46	-1.99	22.4	162	> 70	0.18	0.09	3.07	0.58	0.20	0.35	0.36	342	89	134	9.31
Lye (Upper)	02-Oct-94	5.5	4.52	-1.56	29.4	194	> 70	0.47	0.02	4.59	1.06	0.41	0.62	0.47	504	98	98	13.90
Lye (Lower)	16-Mar-94	1.0	6.10	1.92	24.2			0.42	0.20	4.82	0.95	0.77	0.63	0.61	276			
Lye (Lower)	14-Apr-94	2.0	4.54	-1.36	25.8	139	> 70	0.26	0.22	3.65	0.87	0.36	0.37	0.48	456	119	101	9.09
Lye (Lower)	28-Apr-94	5.0	4.70	-0.82	18.8	163	> 70	0.56	0.08	3.22	0.81	0.34	0.34	0.35	348	103	109	9.47
Lye (Lower)	19-May-94	6.5	5.46	0.88	18.2	148	> 70	0.22	0.07	4.06	1.40	0.64	0.43	0.39	390	84	130	8.88
Lye (Lower)	20-Sep-94	10.5	6.77	5.56	30.6	137	> 70	0.50	0.11	4.27	2.42	1.22	0.83	0.54	276	13	83	7.99
Lye (Lowest)[14]	03-Aug-94	17.5	7.43	24.10	58.8	114	> 70	0.46	0.21	4.14	6.22	3.28	0.65	0.53	192	15	92	6.77

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[a] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Winhall	06-Apr-94	1.0	5.68	0.71	18.3	45		0.30	0.26	3.88	1.37	0.42	0.63	0.47	190	35	71	3.74
Winhall	13-Apr-94	1.0	5.40	0.34	18.6	42	45	0.24	0.27	3.52	1.28	0.37	0.55	0.44	214	41	72	4.14
Winhall	28-Apr-94		5.01	0.19	17.3	67	55	0.25	0.17	3.43	1.12	0.30	0.43	0.41	246	63	93	5.41
Winhall	11-May-94	10.0	6.14	1.10	16.2	59	50	0.27	0.07	3.83	1.33	0.35	0.58	0.45	230	10	100	4.56
Winhall	18-May-94	9.0	5.44	0.64	16.5	64	50	0.25	0.06	3.97	1.32	0.35	0.56	0.41	246	70	82	5.27
Winhall	01-Aug-94	18.5	6.56	3.06	18.9	83	60	0.31	0.08	3.14	1.59	0.51	0.95	0.55	168	3	82	6.17
Winhall	14-Sep-94	12.5	6.66	3.42	22.5													
Winhall	19-Sep-94	10.5	6.70	3.39		80												
Winhall	03-Oct-94	4.5	5.98	1.37	19.5	71	50	0.45	0.03	4.30	1.58	0.49	0.73	0.54	231	10	106	6.05

Parameter:

[a]Cond - Conductivity
[1]DC2 - Filtered Color
[2]TC - Unfiltered Color
[3]DCL - Dissolved Chloride
[4]DNO$_3$ - Dissolved Nitrate
[5]DSO$_4$ - Dissolved Sulfate
[6]DCA - Dissolved Calcium
[7]DMG - Dissolved Magnesium
[8]DNA - Dissolved Sodium
[9]DK - Dissolved Potassium
[10]DAL - Dissolved Aluminum
[11]IMAL - Inorganic Monomeric Aluminum (most toxic form to aquatic biota)
[12]OMAL - Organic Monomeric Aluminum
[13]DOC - Dissolved Organic Carbon

14 This Lye Brook sample was collected further downstream near the campsite just upstream from the parking area. The bedrock type is Dunham dolomite and imparts a considerable source of buffering. Lye Brook headwaters are located in an area of profound unconformity dominated by gneiss, quartzite and calc-silicate granulite. The lower site is located in Cheshire quartzite and between the upper and lower sites is the Dalton formation (a conglomerate found at the base of the southern Green Mountains).

Fish Community Summary for Lye Brook Wilderness Streams

Lye Brook (Station 1.8) - The same three species were collected in 1993 and 1994 in the same order of abundance (brook and brown trout and slimy sculpins). The 1994 sample was three times more dense, but still classifies as a low productivity reach.

Lye Brook (Station 3.4) - No fish were collected in either 1993 or 1994 most likely because of this reach's acidity and high levels of aluminum (see Table 2). The USFS sampling of Lye Brook Meadows in July of 1995 will determine if fish do exist upstream of this station. Based on the bedrock geology (see Table 2) chemical conditions should not be expected to be any better.

Bourn Brook (Station 1.6) - The same four species (blacknose dace, brook and brown trout and slimy sculpin) were collected in 1993 and 1994. The two dominant species (slimy sculpin and brook trout) had nearly the same densities both years.

Bourn Brook (Station 4.1) - As was observed in 1993, only brook trout were captured. This site is definately a very low productivity reach with marginal fish habitat.

Branch Pond Brook (Station 0.1) - As was observed in 1993, only brook trout were captured. The pH and aluminum levels are indicative of an acid stressed environment.

Winhall River (Station 8.1) - Seven species of fish were collected in 1994 with the capture of one creek chub in the final run versus six in 1993. Greater relative abundance of each species was found in 1994 with the exception of atlantic salmon where approximately 50% fewer were captured. The Winhall is the only stream where the VTIBI can be calculated because enough non-salmonids species were collected. The VTIBI was 43 and maintains its excellent population integrity.

Lye Brook Wilderness Area Macroinvertebrate Stream Communities

Four of the six sites sampled in the Lye Brook Wilderness aquatic resources study are in good to excellent conditions. Bourn Brook upper and lower; Lye Brook lower; and the Winhall River. The macroinvertebrate communities from these streams exhibit moderate densities, moderate to high numbers of taxa, and are dominated by clean water indicator taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT's). The Bio Index and EPT/EPT Chiro ratio biometrics are used to measure a community's tolerance toward organic loading (enrichment). Both metrics were rated in the good to excellent range for the four sites (BI values, < 1.75 and EPT/EPT Chiro ratio, $> .7$), indicating low levels of organic enrichment. Refer to Appendix 2 for an explanation of Vermont's biocriteria indices used for wadeable streams and rivers.

Two sites appear to be in less than optimal condition; Lye Brook upper, and Branch Pond Brook. The upper Lye Brook site rated poor due to very low densities (206), low taxa richness (20) and a low number of EPT taxa (13). The Bio index and EPT/EPT Chiro ratio were in the good-excellent range indicating that enrichment is not the cause for the poor condition of the biota at the upper Lye Brook site. The low densities, taxa richness and EPT values point toward a physical habitat or toxic limitation on the community. The habitat evaluation does not indicate that physical habitat is limiting at the site. The water quality, however, is low in pH ($x = 4.49$ std. units) and alkalinity ($x = -1.78$ mg/l), which is probably the reason for the poor community integrity at the site. This is supported by a very poor showing of the Ephemeroptera : 1-2 species and $\approx 5\%$ composition of the community. Dominance by the pH tolerant Plecoptera ($\approx 72\%$ composition) also points toward acidity as a probable cause for the impaired macroinvertebrate community. The site surprisingly still contains a population of crayfish (Cambarus bartoni bartoni) despite the very low calcium levels ($x = 0.82$ mg/l) in the water.

The Branch Pond site rated only fair primarily due to the lower number of taxa and sensitive EPT species as well as a slightly lower density. The site also seems to be impaired by low pH and alkalinity due to the poor number (1) and % composition (2) of Ephemeroptera in the community. The habitat evaluation also indicates that the substrate is carrying a higher than normal level of sand. Sand can limit the biological potential at a site by burying the cobble substate and physically limiting the available habitat for invertebrates. Sand embeddedness may also be contributing to the lower biological integrity of Branch Pond Brook.

The functional guild composition of a stream's macroinvertebrate community indicates where the stream community is receiving its energy (food) inputs. All the higher elevation stream sites; Bourn upper, Lye upper and Branch Pond Brook, are dominated by detritus shredders. This indicates that forest leaf breakdown is the most important energy source for these stream sites. The Winhall River contains the highest composition of collector gatherers and fewest percentage of detritus shredders, indicating this community is oriented toward processing fine particulate organic material already broken down in its headwaters and/or produced in the extensive wetlands and lakes in the drainage. To a lesser extent, the lower Lye Brook and Bourn Brook sites also have a higher proportion of collector gatherers . The scraper functional group reaches its greatest dominance in both Bourn Brook sites and Branch Pond Brook, indicating that diatom type periphyton growth is significant in these streams. Both Lye Brook sites contain very few scrapers (1-2%). This is especially unexpected at its lower site and is perhaps again due to the acidic nature of Lye Brook depressing the diatom community.

The biological data for all six sites is found in two attachments. The summary report shows the biometrics and dominant taxa for all dates sampled at a site and the sampling report includes a complete taxa list at each site for 1994.

Terrestrial Faunal

Amphibian Monitoring on Mt. Mansfield, Vermont

Stephen C. Trombulak
James Andrews
Department of Biology, Middlebury College

Abstract:

Populations of all amphibian species are monitored annually on Mount Mansfield to (1) document the occurrence of amphibian species in this area, (2) establish a baseline data set on their distributions and abundances for future analysis of changes in these species, and (3) monitor year-to-year changes in their status. Amphibians are targeted for this kind of study because their unique life-history characteristics, involving close association with both water and soil, as well as yearly breeding activity, makes them especially well suited as an indicator taxa of changes in environmental conditions in forest environments.

Highlights of our activities and results for 1994 include (1) continued abundance of spring peepers (Pseudacris crucifer), (2) an apparent increase in the density of redback salamanders (Plethodon cinereus), reversing a trend from 1992 to 1993, (3) an apparent decrease in wood frogs (Rana sylvatica), also reversing an earlier trend, (4) a continuation of the trend for poor reproduction in spotted salamanders (Ambystoma maculatum), with pH of vernal pools close to reported lethal limits, and (5) the start of measurements on size classes of individuals captured.

Introduction:

Amphibians such as frogs and salamanders are ideal indicators of forest health and water quality because their survival depends on clean water and a narrow range of soil and water acidity. Changes in amphibian populations over time may indicate changes in environmental quality that might only be discovered after much longer periods of time and with more expensive monitoring procedures. Also, different species of amphibians are sensitive to different conditions. Therefore, comparing the changes in different species may identify exactly what kind of environmental changes are occurring in the study area. The following report describes our results for 1994 as well as the overall design for our continued monitoring activity.

The purpose of this study is to (1) document the occurrence of amphibian species in this area, (2) establish a baseline data set on their distributions and abundances for future analysis of changes in these species, and (3) monitor year-to-year changes in their status. On-going monitoring of key indicator species will aid in the assessment of changes in their abundance over time.

Methods:

Since 1991, three techniques have been used to inventory the amphibian species in this area and to monitor their abundances. First, four drift fences have been built at three elevations on the west slope: 1200 feet (2 fences), 2200 feet (1), and 3200 feet (1). Each fence, with the exception of the fence at 3200 feet, is made of two 50-foot sections of 20-inch wide metal flashing buried 4 inches below the surface of the ground. The two sections are placed at right angles to each other, resulting in 100 feet of flashing set upright as a 16 inch high fence. Buckets are buried every 12.5 feet on both sides of the fence so that the top edges of the buckets are flush with the ground. The fence at 3200 feet is made of only one 50-foot section of flashing with buckets at 12.5-foot intervals. Amphibians that encounter a fence while moving through the forest will turn to one side and eventually fall into a bucket. The lids are taken off the buckets in the late afternoon on rainy days, and the captured amphibians identified and counted the following morning. The locations of these four sites are indicated on Figure 1.

Second, night-time road surveys are done on rainy nights in early spring to identify all amphibians seen on roads and calling in the vicinity of roads. By driving a set route at a constant speed (10 mph), standardized estimates of amphibian abundances and locations of breeding sites can be made throughout the entire area covered by roads. The roads used for these road surveys are indicated on Figure 2.

Third, selected breeding ponds in the area are searched during the breeding season for eggs and males calling for mates. The number of egg masses provide an index of the abundance of each species. In 1994, pools monitored for egg masses and water pH were the West Bank of Harvey Brook, the vernal pool below the PMRC, the pond behind the PMRC sugar shack, and the Lake of the Clouds.

In addition, active searches, involving turning over rocks and logs, are done irregularly during the day near the drift fences and other selected sites. The number of individuals of each species found in a given area in a given amount of time provide a direct measure of species presence and an index of species diversity and abundance. This technique is used when additional inventory is felt necessary for species or habitats not adequately inventoried by other methods. Furthermore, this year we began to measure the sizes of all amphibians handled at drift fences and on night-time road searches to begin developing a picture of changes in the age-class distributions of these species over time.

The distribution of the methods over the slope of Mount Mansfield is displayed in Figure 3.

Results and Discussion:

We have so far identified 13 species of amphibians from this area, from a total possible of 24 species known from Vermont, 21 of which show evidence of breeding in recent years (Figure 4). The list of species inventoried has not changed since 1992, and we are therefore confident that all species present have been identified. Six of these 13 are generally common, being observed or heard on almost all visits wherever suitable habitat is found:

Red-spotted newt: adults found in streams and ponds and terrestrial juveniles on roads and in the forest up to 3900 feet.
Redback salamander: found in the forest throughout most of the elevational range of the study area, but not observed above 3200 feet; extremely common.
Northern spring peeper: heard calling regularly from ponds throughout the area, mainly below 2000 feet.
Gray treefrog: heard calling regularly from ponds throughout the area, mainly below 2000 feet.
Wood frog: located up to tree line where breeding ponds occur.
Eastern American toad: concentrated below 2200 feet, but also occasionally found at elevations near 4000 feet.

Five species are locally common, being seen regularly in their limited appropriate habitat:

Spotted salamander: egg masses found in the spring in a few of the ponds in the area.
Northern dusky salamander: streams up to 2200 feet.
Northern spring salamander: streams up to 2200 feet.
Northern two-lined salamander: streams up to 3900 feet.
Green frog: heard calling regularly from ponds throughout the area, mainly below 2000 feet.

The pickeral frog is occasionally observed, but only below 2200 feet. The bullfrog is heard only rarely at a site along Pleasant Valley Road near 1200 feet.

We have only four years of data on these species (1991-94). It is too soon to draw any major conclusions on trends in their demography; however, the following summarizes what we have observed to date for the five best indicator species.

Spring peepers: commonly observed during both night-time road searches (Table 4) and surveys of breeding choruses (Table 3). They are by far the most common species observed on the roads and had many times the number of choruses (56) of any other species. Data from drift fences and choruses suggest a decrease from the previous year, but data from night-time road searches suggest a slight increase (Table 7). This is the opposite of the pattern reported in 1993.

Gray treefrogs: observed only four times during night-time road searches (Table 4), but this is expected due to their secretive behavior. Six choruses were noted (Table 3). Populations are probably too small to assess trends without many more years of data.

Redback salamanders: commonly found in drift fences (Table 1). There was a major increase in 1994 from the previous year (Tables 2 and 7) but this species is difficult to see on the roads at night, so our conclusions are based solely on numbers caught at drift fences.

Spotted salamanders: Fourteen individuals were found in drift fences (Table 1). Egg mass were located in all of the pools and the Lake of the Clouds, but we still don't know if any of them successfully hatched (Tables 5 and 6). Measurements of pH in these ponds indicate that most continue to be very close to the lethal pH for this species measured in other studies (4.0-4.5; Tables 5 and 6), suggesting a possible explanation for the low level of successful reproduction. The number of egg masses has shown a steady increase from 1992 (Table 6). This suggests an increase in the number of breeding adults over this three-year period; however, this is not supported by data at either drift fences (Table 1) or night-time road searches (Table 4).

Wood frogs: commonly observed on night-time road searches, surveys for choruses, and in drift fences (Tables 1, 3, and 4). Wood frogs successfully bred in at least two of the four ponds studied. Their populations appear to have decreased dramatically (Tables 2 and 7), reversing the trend noted in 1993.

Future plans:

We plan to continue monitoring the amphibian populations throughout this area following the techniques we have employed so far. We feel confident that we have a complete survey of the species in the study area; therefore, our efforts now focus exclusively on monitoring the populations, water quality, and breeding success of amphibians in vernal pools and lakes in the area.

Context:

This work on Mount Mansfield is part of a large survey and monitoring effort we are conducting throughout western Vermont. We have similar sites at several locations in the lowlands of the Champlain Basin, at Abbey Pond in the northern Green Mountain National Forest, and in the Lye Brook Wilderness Area of the southern Green Mountain National Forest. It is our hope that by conducting monitoring activity over a large geographic area over many years that long-term trends in the status of amphibian populations over regional spatial scales can be determined.

Acknowledgments:

Our work on Mt. Mansfield this year was helped a great deal by Mr. Robert Smith at Mt. Mansfield High School, and his students Jason McKnight, Ryan Walker, Joanne Cummings, and Rinda Gordon. We are extremely grateful for their interest in amphibians at Mt. Mansfield and all their hard work.

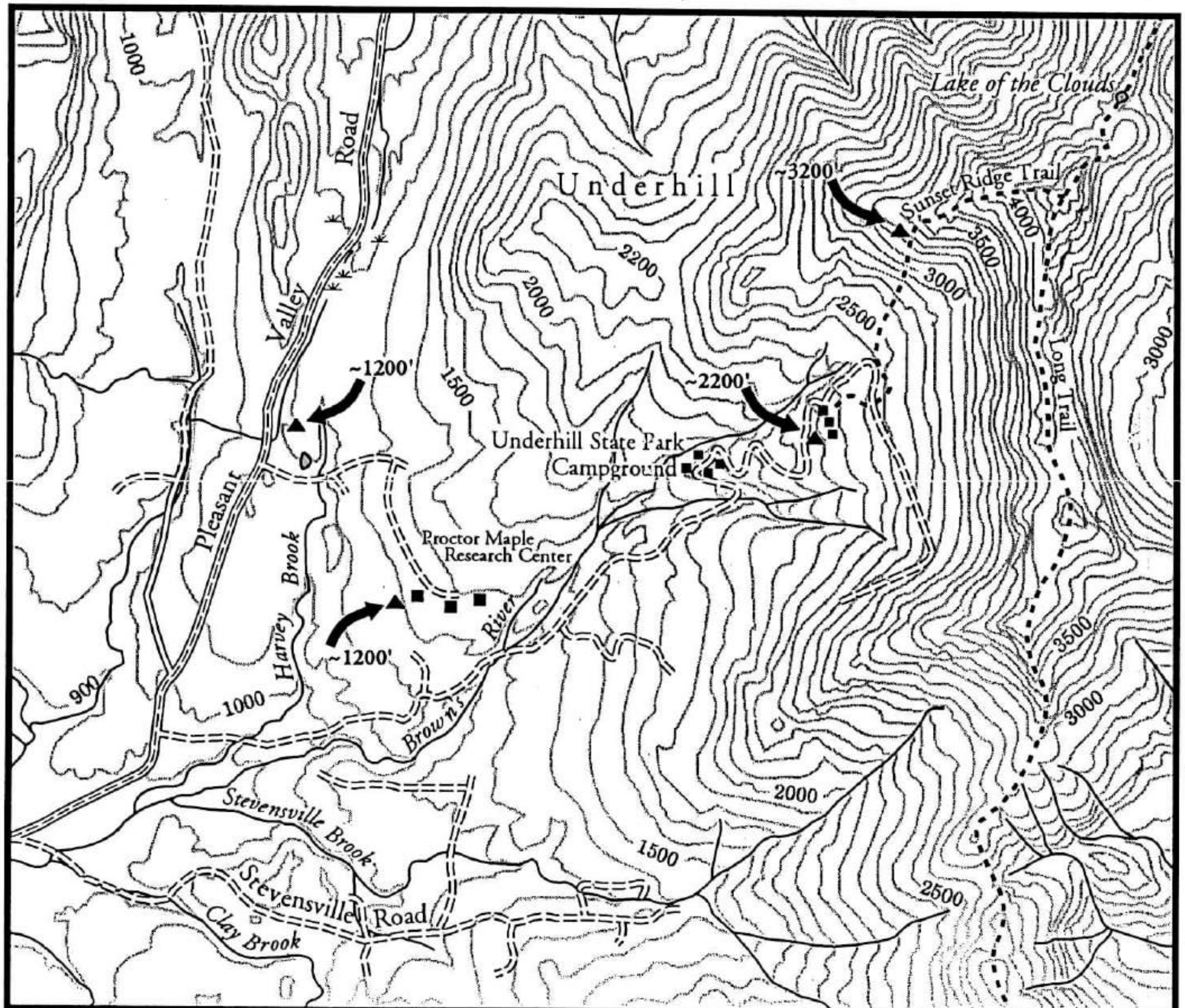


Figure 1.

Location of Drift Fences
on
Mount Mansfield
Underhill, Vermont

0 .5 1
kilometers
contour interval 100 feet

Drift fence

N
MN
15°

Figure 2.

Continued on following page

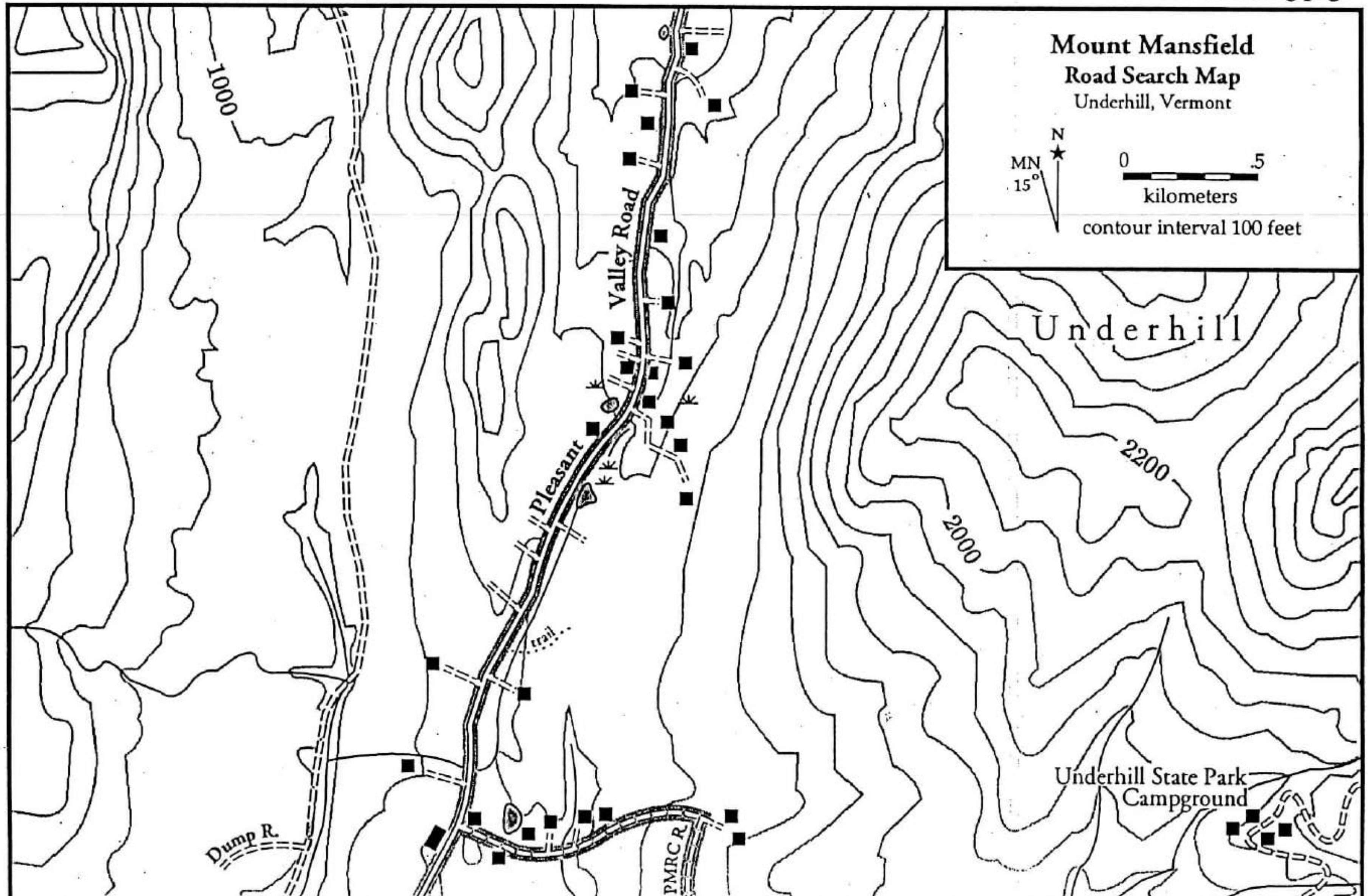


Figure 2 (cont).

Continued from previous page

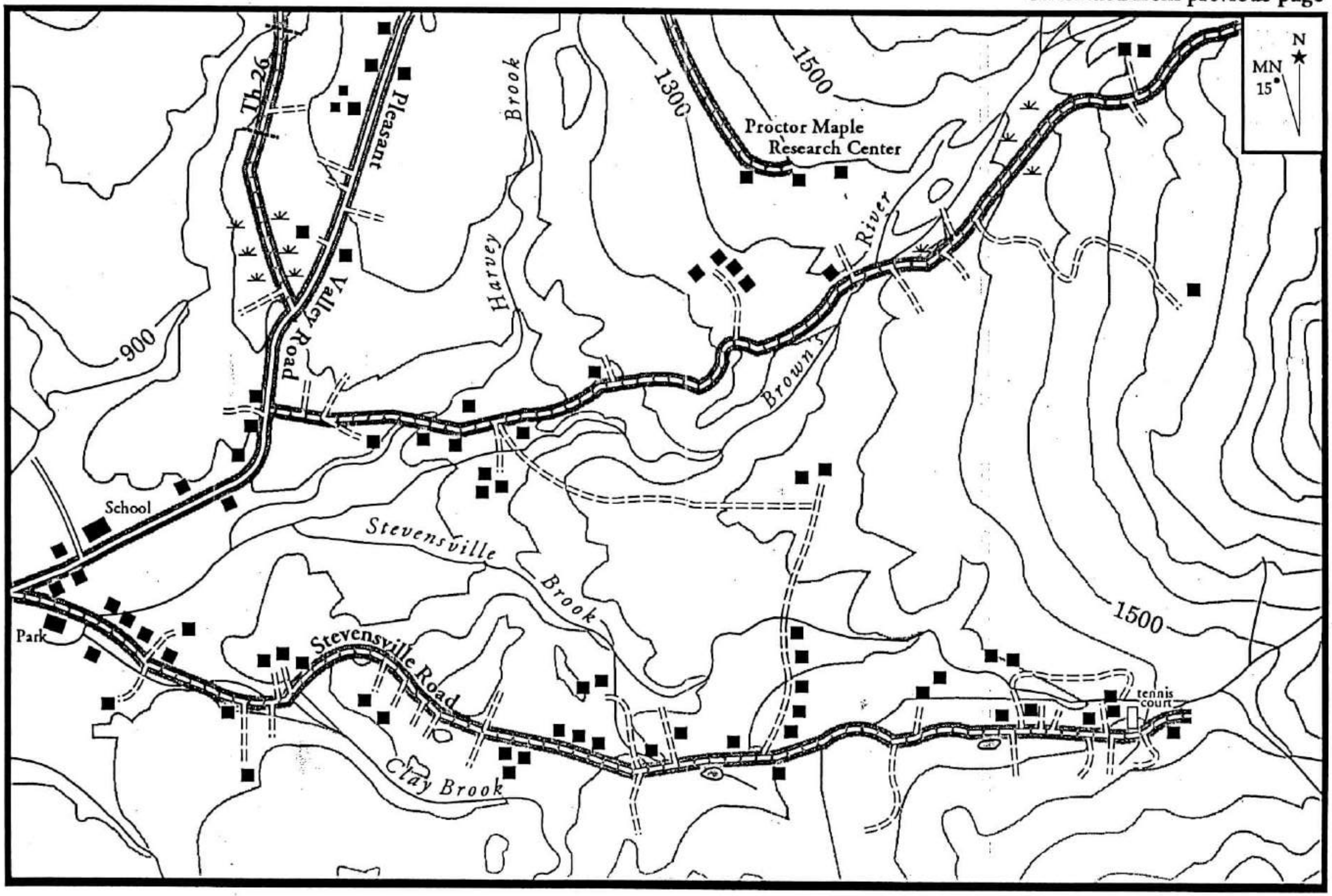
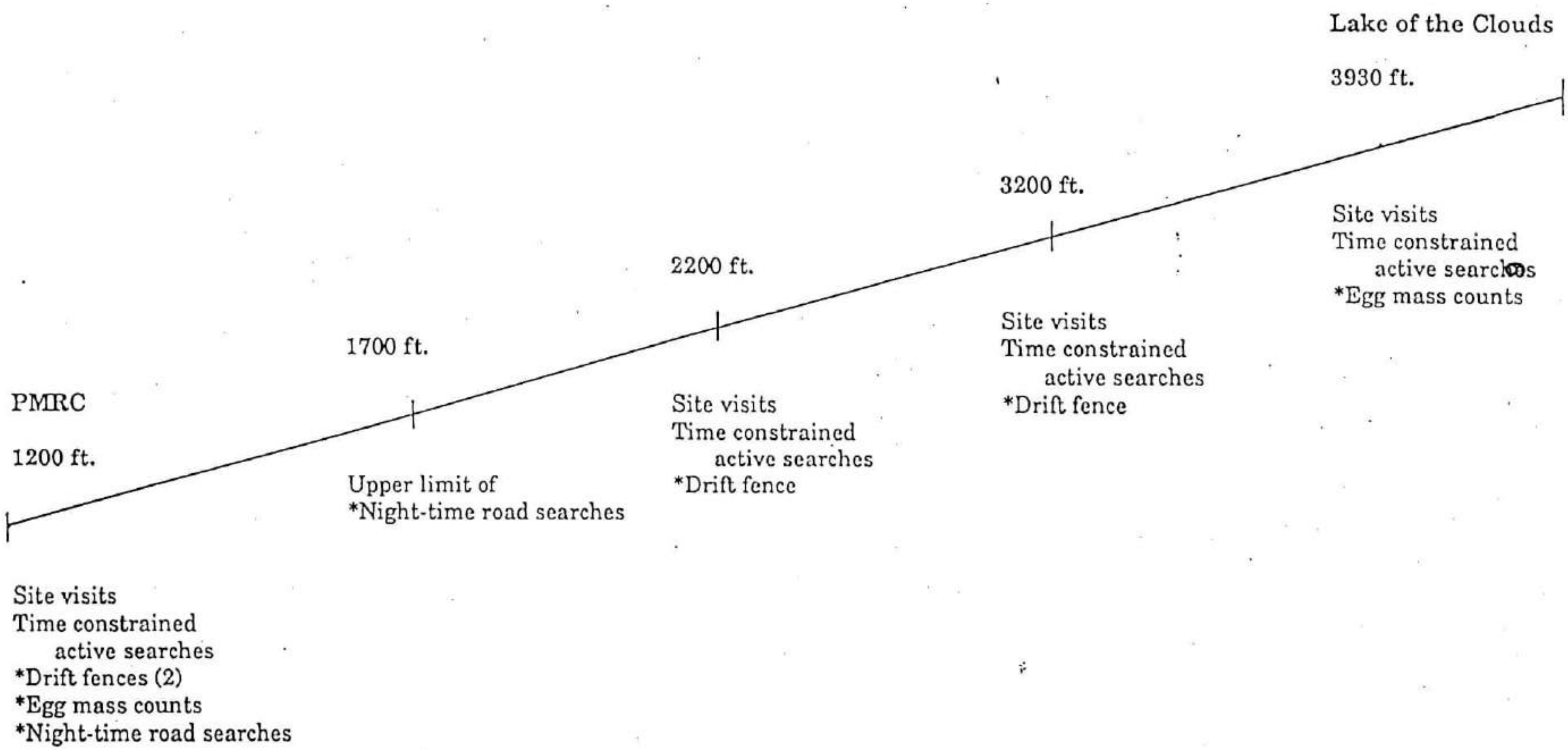


Figure 3.

Mt. Mansfield Inventory Methods by Elevation



*method to be continued for long-term monitoring

Table 1. A comparison of drift fence data from the 1993 and 1994 field seasons at Mt. Mansfield, Vermont using all data from the 1,200 ft. and 2,200 ft. drift fences.

Species name	Common name	# of ind.		# per trapping[1]		% of total catch	
		93	94	93	94	93	94
Caudates (Salamanders)							
Ambystoma maculatum	Spotted salamander	25	14	1.7	1.0	12	10
Desmognathus fuscus	Northern dusky salamander	5	4	0.3	0.3	2	3
Eurycea bislineata	Northern two-lined salamander	8	2	0.5	0.1	4	1
Gyrinophilus porphyriticus	Spring salamander	1	0	< 0.1	0.0	< 1	0
Notophthalmus viridescens	Red-spotted newt	20	17	1.3	1.2	10	12
Plethodon cinereus	Redback salamander	18	59	1.2	4.2	9	40
Anurans (Frogs and Toads)							
Bufo americanus	Eastern American toad	11	8	0.7	0.6	5	5
Pseudacris crucifer	Northern spring peeper	26	15	1.7	1.1	13	10
Rana clamitans	Green frog	1	3	< 0.1	0.2	< 1	2
Rana palustris	Pickerel frog	2	0	0.1	0.0	1	0
Rana sylvatica	Wood frog	84	24	5.6	1.7	42	16
	Totals	201	146	13.4	10.4	100	99

[1]Number per trapping are rounded to the nearest 0.1. All other figures are rounded to the nearest whole number. There were a total of 15 trappings counted in 1993 and 14 in 1994. Trappings counted are those nights where at least two of the three lower traps were opened under appropriate weather conditions for amphibian movement.

Table 2. An examination of the 1993 and 1994 trapping success of *Rana sylvatica* and *Plethodon cinereus* broken down by time period.

Species and Time Periods	Number of Trappings		Total Number Caught	
	1993	1994	1993	1994
Rana sylvatica				
April-May	4	4	29	7
June-August	5	5	6	5
Sept.-Nov.	6	5	49	12
Total	15	14	84	24
Plethodon cinereus				
April-May	4	4	4	10
June-August	5	5	4	3
Sept.-Nov.	6	5	10	49
Total	15	14	18	62

Table 3. A comparison of the number of choruses and calling anurans surveyed during night-time road searches April through June 1993 and 1994. In 1993 six searches took place during this time period: April 16, May 6, May 15, May 25, June 8, and June 18. In 1994 during this time period five searches took place: April 25, May 6, May 31, June 6, and June 13.

Species name	Common name	# of total choruses[1]		size of choruses[2]		# per NTRS[3]		% of total choruses	
		1993	1994	1993	1994	1993	1994	1993	1994
Bufo americanus	American toad	0	1	C-4 0-0 L-0 M-0 H-0	C-2 0-0 L-1 M-0 H-0	0	0.2	0	1
Hyla versicolor	Gray tree frog	4	6	C-7 O-0 L-3 M-1 H-0	C-6 O-0 L-0 M-0 H-0	0.7	1.2	5	8
Pseudacris crucifer	Northern spring peeper	73	56	C-38 O-5 L-27 M-37 H-4	C-15 O-6 L-12 M-33 H-5	12	11.2	89	74
Rana clamitans	Green frog	0	0	C-3 O-0 L-0 M-0 H-0	C-2 O-0 L-0 M-0 H-0	0	0	0	0
Rana sylvatica	Wood frog	5	13	C-0 O-0 L-5 M-0 H-0	C-6 O-2 L-7 M-4 H-0	0.8	2.6	5	17
	Totals	82	76	C-52 O-5 L-35 M-38 H-4	C-31 O-8 L-20 M-37 H-5	13.6	15.2	100	100

[1]not including calling individuals

[2]C = a calling individual
O = a chorus with occasional vocalizations
L = a continuous chorus of low intensity
M = a continuous chorus of medium intensity
H = a continuous chorus of high intensity

[3]Number per NTRS are rounded to the nearest 0.1. All other figures are rounded to the nearest whole number.

Table 4. Night-time road search data from Mt. Mansfield, Vermont, based on surveys from April through June in 1993 and 1994. All calling anurans are excluded from this table. Six searches took place during this time period in 1993 and five during 1994.

Species name	Common name	# of ind.		# per NTRS[1]		% of total catch	
		1993	1994	1993	1994	1993	1994
Caudates (Salamanders)							
Ambystoma maculatum	Spotted salamander	6	3	1.0	0.6	4	2
Gyrinophilus porphyriticus	Spring salamander	0	1	0.0	0.2	0	1
Notophthalmus viridescens	Red-spotted newt	24	9	4.0	1.8	14	7
Anurans (Frogs and Toads)							
Bufo americanus	Eastern American toad	25	38	4.2	7.6	15	28
Hyla versicolor	Gray treefrog	3	4	0.5	0.8	2	3
Pseudacris crucifer	Northern spring peeper	44	52	7.3	10.4	26	38
Rana catesbeiana	Bullfrog	1	0	0.2	0.0	1	0
Rana clamitans	Green frog	5	3	0.8	0.6	3	2
Rana palustris	Pickerel frog	3	2	0.5	0.4	2	1
Rana sylvatica	Wood frog	60	26	10.0	5.2	35	19
	Totals	171	138	28.5	27.6	102	101

[1]Number per NTRS are rounded to the nearest 0.1. All other figures are rounded to the nearest whole number.

Table 5. Spring 1994 egg mass data from Mt. Mansfield, Vermont.

Location/Date	Number of A. maculatum egg masses	Number of R. sylvatica egg masses	Mean pH N = 3	Site Notes	Water test results from Vermont DEC (J. Kellogg)[1]
West bank of Harvey Brook					
May 3	1	0		beaver dam	not tested
May 20	not	checked		broken and	
June 7	not	checked		deserted[2]	
Vernal pool below PMRC					
May 3	29	60	5.1[3]		conductivity 24.8
May 20	38	72 (all hatched)	5.0		color 35
June 7	25	0 (tadpoles)	4.6	water level up	alkalinity 0.09
June 30	9	0 (tadpoles with legs)		two puddles remaining ~ 20 cm deep	
July 19	0	0		dry	
Pond behind sugar shack at PMRC					
May 3	6	150	5.6[3]		conductivity 19.1
May 20	6 (~75% nonviable)	63 (many had hatched)	5.5		color 25
June 7	0	0 (many tadpoles)	5.2	water level up	alkalinity 0.57
June 30	0	0 (many tadpoles)		1 cm deep, almost dry	
July 19	0 (no larvae)	0 (no tadpoles)		1 cm deep	
Lake of the Clouds					
May 19	0	3	4.9 4.8[3]	snow patches	conductivity 19.2
June 6	14	6	4.7	no snow remaining	color 30
June 30	1	0	not sampled		alkalinity -0.60

[1]Conductivity (umhos/cm), total visual color (Pt.-co.), and alkalinity (mg/L) were measured by the Biomonitoring and Aquatic Studies Unit, Vermont Agency of Natural Resources, Department of Environmental Conservation.

[2]Rana sylvatica egg masses were found in a new dam immediately downstream of the old one.

[3]pH measurements from Vermont DEC

Table 6. A comparison of egg mass and pH data from 1992-1994 on Mt. Mansfield.

Site	Ambystoma maculatum			Rana sylvatica			Range of mean pH		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
West Bank, Harvey Brook	7	9	1	0	0	0	----	6.9	----
Vernal Pool below PMRC	18	12	38	36	36	72	----	4.3-5.1	4.6-5.1
Sugar Shack Pond at PMRC	3	6	6	----	82	150	4.4	4.8-6.2	5.2-5.6
Lake of the Clouds	2	12	14	22	46	6	4.6	4.9-5.0	4.7-4.9

Table 7. Summary of population changes of selected species, between the 1993 and 1994 field seasons as suggested by three indicators at Mt. Mansfield, Vermont. Species shown are only those species whose index changed by 1.0 or greater by any one method.

Species	Drift fences	NTRS choruses	NTRS individuals
Caudates (salamanders)			
P. cinereus	**up 3.0**	n/a	n/a
N. viridescens	down 0.1	n/a	**down 2.2**
Anurans (Frogs and Toads)			
B. americanus	down 0.1	up 0.2	**up 3.4**
P. crucifer	down 0.6	down 0.8	**up 3.1**
R. sylvatica	**down 3.9**	**up 1.8**[1]	**down 4.8**

[1]Egg mass counts of R. sylvatica at the same elevation as the night time road searches showed a mean increase of 91%, N = 2.

Forest Bird Surveys on Mt. Mansfield and Underhill State Park

Christopher C. Rimmer
Charles H. Darmstadt

Vermont Institute of Natural Science
RR 2 Box 532
Woodstock, VT 05091

Abstract: Censuses of breeding bird populations on two Mount Mansfield sites were conducted for a fourth year in 1994. One site in Underhill State Park at ca. 2200 ft elevation consisted of mature northern hardwoods, while the second site on the Mt. Mansfield ridgeline at ca. 3700 ft elevation consisted of subalpine spruce-fir. Ten-minute counts at each of 5 sampling points in the two habitats were conducted twice during June. Eighteen species were recorded at Underhill State Park, with a maximum of 101 individuals (70 in 1993) on 23 June and a mean of 90.5 (67.5 in 1993) for both visits. Eleven species were recorded on Mt. Mansfield, with a maximum of 81 individuals (104 in 1993) on 10 June and a combined mean of 68 (96 in 1993). Species diversity and numerical abundance were significantly higher at Underhill State Park, and significantly lower on Mt. Mansfield in 1994 than in 1993. The reasons for these changes, whether reflecting actual changes in bird populations or an artifact of differing sampling conditions between the two years, are not entirely clear.

Introduction

In 1994, breeding bird censuses were conducted for a fourth consecutive year on two permanent study sites on Mt. Mansfield, as part of a long-term Vermont Forest Bird Monitoring Program conducted by the Vermont Institute of Natural Science (VINS). This program was initiated in 1989 with the primary goal of conducting habitat-specific monitoring of forest interior breeding bird populations in Vermont and tracking long-term changes. As of 1994, VINS has selected, marked and censused 17 permanently protected sites of mature forest habitat in Vermont (Appendix 1). The specific objectives of the Mt. Mansfield study include: 1) adding a bird monitoring component to the integrated ecological research being conducted under the VMC; 2) adding two study sites to VINS' statewide monitoring program; and 3) sampling bird populations in the high elevation spruce-fir zone.

Methods

Survey methods were identical to those in previous years. Each site consists of a series of five sampling points spaced 200-300 meters apart. Preliminary site visits were made in late spring to check the condition of vinyl flagging and metal tree tags. Each site was censused twice during the height of breeding activities in June. Each census consisted of 10-minute counts of all birds seen and heard at each of the five sampling points. Field data were transcribed onto standardized forms and subsequently computerized, using DBASE3. Vegetation sampling was conducted at each census point on the Mt. Mansfield plot only, using a technique modified after the James and Shugart method. This sampling technique will be used at the Underhill State Park site in 1995, as well as at VINS' 15 other monitoring sites.

Results and Discussion

Overall numerical abundance and species diversity were at a four- year minimum on Mt. Mansfield in 1994 (Table 1). Only 11 species were recorded, with a maximum of 81 individuals (104 in 1993) on 10 June and a mean of 68 (96 in 1993) for both visits (Table 2). Numbers of three of the five most common species, Winter Wren, Blackpoll Warbler, and Bicknell's (Gray-cheeked) Thrush, fell to a four-year low (Table 1). Totals of eight species were below their 1991-1993 average. Only two species were at or above their three year average. Magnolia Warbler and Cedar Waxwing, both recorded in two of the previous three years, were absent in 1994. Adverse weather conditions on both count dates may have contributed to the low number of individuals detected.

The most pronounced declines occurred in Winter Wren, Swainson's Thrush, and Blackpoll Warbler populations. On average, Winter Wren declined 25% annually between 1991-1994 on Mt. Mansfield. This downward trend has also been recorded at VINS' other high elevation spruce-fir site on Camel's Hump, where the species declined at an average annual rate of 15% during the same period. At Underhill State Park, Winter Wrens declined at an average rate of 59% annually from 1992-1994, suggesting that the species may be experiencing widespread population losses. Blackpoll Warbler experienced a less dramatic, but steady annual decline of 11% on Mt. Mansfield. As in 1993, Swainson's Thrush was observed in low numbers in 1994, at 75% below its three-year average.

In contrast to the Mt. Mansfield site, overall numerical abundance and species diversity were at a four year maximum at Underhill State Park in 1994 (Table 3). Eighteen species were recorded, with a maximum of 101 individuals (70 in 1993) on 23 June and a mean of 90.5 (67.5) for both visits (Table 4). Only four species were below their 1991-1993 average, while 11 species were above their average for this period. Of the five species that have been recorded in each year since 1991, four were observed at levels at or above their four-year maximum. Red-eyed Vireo, Canada Warbler, and Ovenbird have all experienced a steady four-year increase.

Both the declines on Mt. Mansfield and the increases at Underhill State Park must be interpreted cautiously. With only 4 years of data available, detection of meaningful population trends is yet not possible. Changes in population trends may simply reflect natural fluctuations and/or variable detection rates. Census data may be particularly susceptible to variation in detectability on Mt. Mansfield, where weather conditions are often extreme or subject to rapid change. Natural populations are also dependent on a variety of dynamic factors, such as local prey abundance, overwinter survival, and habitat change. However, the steady decline recorded among most high elevation species on Mt. Mansfield warrants concern in light of documented threats to subalpine spruce-fir forests throughout the Northeast. Several years of additional data collection, their correlation with other VMC data, and comparison with census data from other ecologically similar sites will be necessary to elucidate population trends of various species at the Mansfield and Underhill sites.

Future plans include continued monitoring at both sites, as well as detailed sampling of habitat characteristics at Underhill State Park. Analysis of VINS' six-year forest bird monitoring database is planned to begin in 1995. This should enable future comparisons among sites and habitat types, information that will be critical to evaluating the significance of results from Mt. Mansfield and Underhill State park. Funding for VINS' 1994 work at these two sites was provided in large part by the VMC. Support for monitoring at VINS' additional 15 Vermont forest bird study sites was provided by VINS' general operating budget.

Appendix 1. Vermont Forest Bird Monitoring Sites - 1994

Site	Town	Habitat	Observer
1. Sandbar WMA	Milton	Floodplain	M. LaBarr
2 Pease Mountain	Charlotte	Oak-hickory	S. Staats
3. Cornwall Swamp	Cornwall	Maple Swamp	C. Darmstadt
4. Shaw Mountain	Benson	Oak-hickory	S. Morrical
5 Galick Preserve	West Haven	Hemlock-pine	N. Swanberg
6. Sugar Hollow	Pittsford	N. Hardwoods	S. Faccio
7. The Cape	Chittenden	N. Hardwoods	S. Faccio
8. Dorset Bat Cave	E. Dorset	N. Hardwoods	R. Stewart
9. Roy Mountain WMA	Barnet	Cedar-spruce	C. Rimmer
10. Concord Woods	N. Concord	N. Hardwoods	C. Rimmer
11. May Pond Preserve	Barton	N. Hardwoods	R. Renfrew
12. Wenlock/Buxton's	Ferdinand	Spruce-fir	C. Darmstadt
13. Bear Swamp	Wolcott	Spruce-fir	B. Pfeiffer
14. Underhill S.P.	Underhill	N. Hardwoods	C. Darmstadt
15. Mt. Mansfield	Stowe	Subalpine	C. Rimmer
16. Camel's Hump	Huntington	Subalpine	C. Fichtel
17. Merck Forest	Rupert	Maple-beech-oak	T. Johansson

Table 1. Maximum counts of individual birds recorded on Mt. Mansfield site, 1991-1994.

	Mansfield			
Species	91	92	93	94
Northern Flicker			1	
Hairy Woodpecker				1
Yellow-bellied Flycatcher			2	
Blue Jay		1		
Common Raven			1	
Red-breasted Nuthatch		2	3	1
Winter Wren	20	18	14	8
Ruby-crowned Kinglet		4		
Gray-cheeked Thrush	10	23	15	9
Swainson's Thrush	6	16	2	2
American Robin	2	7	2	4
Cedar Waxwing		1	4	
Nashville Warbler	4			
Magnolia Warbler	2	4		
Yellow-rumped Warbler	22	21	16	18
Blackpoll Warbler	20	18	18	14
Ovenbird			2	
Lincoln's Sparrow	4			
White-throated Sparrow	14	28	26	21
Dark-eyed Junco	8	17	10	4
Purple Finch	2	8	2	4
Pine Siskin		1		
Evening Grosbeak		2		
Number of individuals	114	171	118	86
Number of species	12	16	15	11

Table 2. Numbers of individual birds recorded on Mt. Mansfield in 1994. Maximum count for each species represents relative abundance index to be used in future analyses.

Species	10 June	23 June
Hairy Woodpecker	1	
Red-breasted Nuthatch	1	
Winter Wren	4	8
Gray-cheeked Thrush	9	6
Swainson's Thrush	1	2
American Robin	4	
Yellow-rumped Warbler	18	7
Blackpoll Warbler	14	13
White-throated Sparrow	21	18
Dark-eyed Junco	4	1
Purple Finch	4	
Number of individuals	81	55
Number of species	11	7

Table 3. Maximum counts of individual birds recorded at Underhill State Park, 1991-1994.

	Underhill			
Species	91	92	93	94
Northern Flicker			2	
Yellow-bellied Sapsucker		2		2
Hairy Woodpecker				1
Blue Jay				1
Common Raven				4
Brown Creeper				1
Black-capped Chickadee		2	1	
Winter Wren		12	4	2
Veery	2	2		
Swainson's Thrush		2		4
Hermit Thrush		7	2	11
Wood Thrush	1	2		
Solitary Vireo	1	4		
Red-eyed Vireo	5	8	8	12
Black-throated Blue Warbler	11	17	10	12
Yellow-rumped Warbler			4	4
Black-throated Green Warbler	9	14	12	14
Black-and-white Warbler		6	4	4
American Redstart		6		
Ovenbird	7	20	22	22
Canada Warbler	5	8	8	10
Rose-breasted Grosbeak	7	3		2
White-throated Sparrow	2		2	2
Dark-eyed Junco		6	2	6
Number of individuals	52	112	83	114
Number of species	11	18	14	18

Table 4. Numbers of individual birds recorded at Underhill State Park in 1994. Maximum count for each species represents relative abundance index to be used in future analyses.

Species	10 June	23 June
Yellow-bellied Sapsucker	2	
Hairy Woodpecker	1	
Blue Jay		1
Common Raven	4	
Brown Creeper		1
Winter Wren	2	2
Swainson's Thrush	4	2
Hermit Thrush	5	11
Red-eyed Vireo	2	12
Black-and-white Warbler	4	2
Black-throated Blue Warbler	10	12
Yellow-rumped Warbler	4	4
Black-throated Green Warbler	12	14
Black-and-white Warbler	6	4
Ovenbird	16	22
Canada Warbler	10	10
Rose-breasted Grosbeak	2	
White-throated Sparrow		2
Dark-eyed Junco	2	6
Number of individuals	80	101
Number of species	15	14

Insect Diversity on Mount Mansfield

J. R. Grehan and B. L. Parker

Entomology Research Laboratory
University of Vermont
P. O. Box 53400
Burlington, Vermont 05403

February 1995

Abstract

The insect biodiversity survey continued in 1994 for selected groups of Lepidoptera, and Coleoptera (Carabidae) at three elevations on Mount Mansfield. The Lepidoptera records are entered on a computer database for 1991-1994. Annual comparisons are now available for the Noctuidae, Geometridae, Tortricidae, Pyralidae and Notodontidae that are being sampled each year. Examples are presented here for some species that have a recognized pest status in Vermont forests. Biennial patterns of development are illustrated for the conifer swift moth, *Korscheltellus gracilis*, and the St Lawrence tiger moth, *Platarctia parthenos*. Elevation comparisons are presented for the unique species present at each of the sample sites to identify high elevation restricted species. The implications of biennial life cycles and elevation patterns for long-term ecosystem management and climate change are discussed.

Introduction

The Mount Mansfield insect biodiversity program comprises four years of consecutive survey and inventory for the ground dwelling ground beetles (Carabidae: Coleoptera), and night flying moths (Lepidoptera). A three year survey of Hymenoptera and Diptera in the forest canopy was carried out from 1991-1993, supplemented by a two month survey in May-June 1994 to document the spring fauna that may be involved with pollination of tree species.

Interim species lists have been presented for all groups in the 1991-1993 VMC annual reports. Taxonomic identification to species represents a continuing research activity that is nearly complete for the Carabidae represented by a total of 70 species. The species composition of Lepidoptera is documented for most taxonomic groups and families appropriate for long-term monitoring identified (1993 VMC report). Identification of Diptera and Hymenoptera is currently being carried out by J. Boone for his MS dissertation with assistance from available specialists. Fully curated voucher collections of Diptera, Hymenoptera, and Coleoptera from Mount Mansfield and other localities in Vermont have been completed by J. Boone at the Entomology Research Laboratory.

The 1994 insect survey was primarily concerned with the continued monitoring Carabidae and selected families of Lepidoptera at the permanent survey sites on Mount Mansfield. This report presents comparisons between years for some species of Lepidoptera, and seasonal records for the Carabidae, new Lepidoptera records, and comparison of species representation between sites for the Lepidoptera.

Methods

Sampling continued at the established survey sites in a sugar maple forest at 400 m elevation (Proctor Maple Research Center; PMRC), a mixed hardwood forest at 600 m (Underhill State Park; USP), and a sub-alpine balsam fir forest at 1160 m near the southern summit of Mount Mansfield (MMS).

Each survey site comprises five permanent 20 m diameter plots with a malaise trap installed in the canopy of one dominant sugar maple or fir tree (sub-alpine site) in each of the four outlying plots. Six pitfall traps are located around each plot at 60° intervals and a single light trap was located in the center plot. The 1993 survey covered the period from 9 May to 31 October. A detailed account of field and laboratory methods is outlined in the 1991 VMC Annual Report.

The 1994 Lepidoptera light trap survey was limited to the following groups: Noctuidae, Geometridae, Notodontidae, Arctiidae, Saturniidae, Sphingidae, Lymantriidae, Lasiocampidae, Drepanidae, and Limacodidae. Nearly all species in these families can be identified with confidence without specialist assistance or extensive dissection (see 1993 VMC report).

Baiting was carried out in late April when daytime temperatures reached the mid to high 50's (F). Baiting at USP was, however, delayed due to excessive snow on the access road, and interim baiting was carried out below the park entrance at about 500 m elevation (USPa). In the afternoon (approx. 3-4 pm) bait was applied with a brush to trunks of about 30 trees approximately 1.5 m above ground. Moths feeding at the bait were collected in vials at dusk for at least one hour.

Further baiting was carried out on 8 October at Proctor Maple Research Center to collect females of *Pachypolia atricornis* (Noctuidae). This moth is widespread, but usually rare even though it occurs in ordinary maple forests (Grehan et al., 1995). The host-plant is unknown, and the females are not attracted to lights.

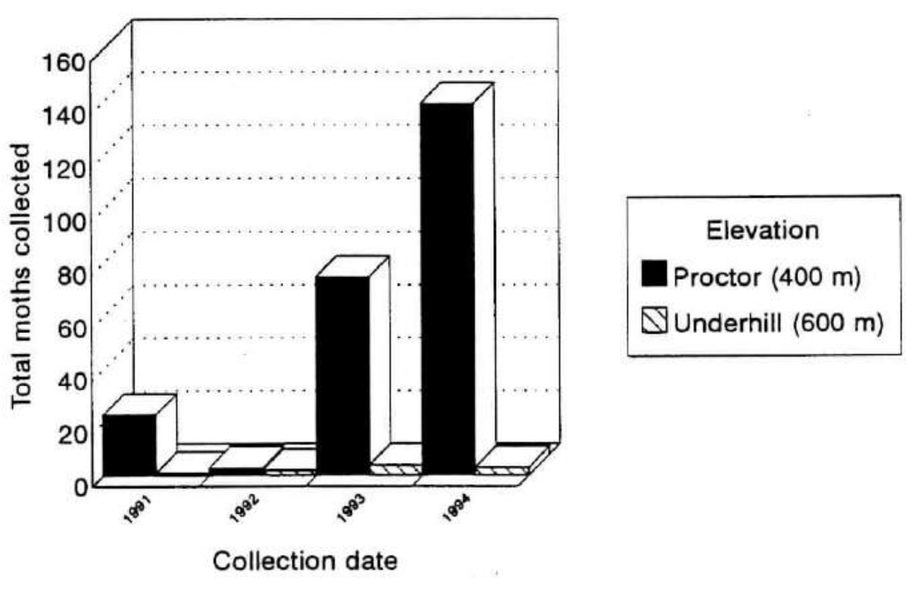
Results

Annual abundance of Lepidoptera

(i) Pest species

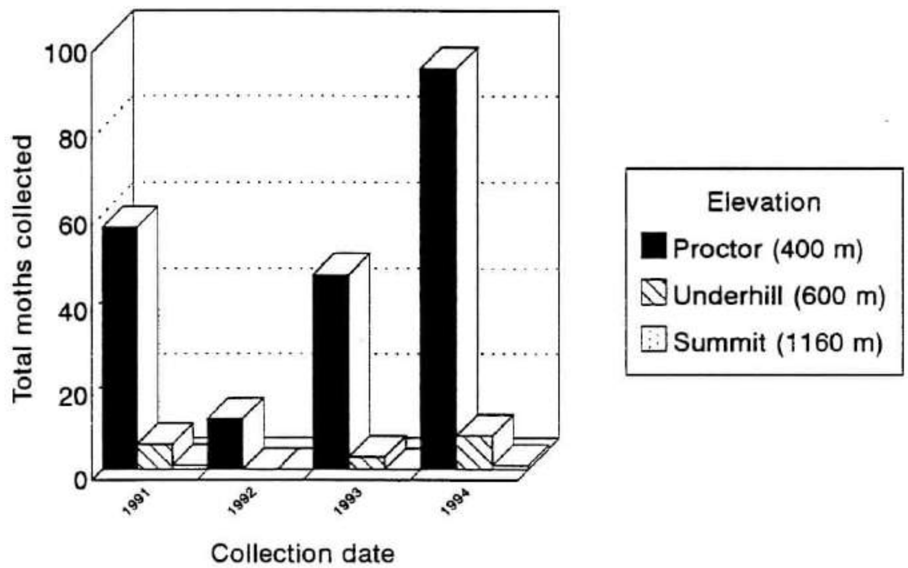
Population outbreaks of the forest tent caterpillar, *Malacosoma disstria*, occur 6-16 years apart and last only 3-6 years. High population numbers were last recorded in Vermont between the mid 1970's to the early 1980's (Parker et al., 1989). On Mount Mansfield higher numbers were collected at PMRC, with numbers being low in 1991 and decreasing in 1992 before showing a considerable increase in 1993 and 1994 (Fig. 1). No adults of forest tent caterpillar have been recorded from pheromone traps on Mount Mansfield during the last four years (see Wilmot et al VMC annual reports) and this contrast suggests that the pheromone is inactive. The eastern tent caterpillar, *Malacosoma americana*, is not a significant pest of forests in

Figure 1. Annual total number of adults of the forest tent caterpillar, *Malacosoma disstria*, collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center and Underhill State Park.



Vermont (cf. Parker et al., 1989), but its population trends may provide a significant comparison because of its close phylogenetic relationship with the forest tent caterpillar and its similar biology. The eastern tent caterpillar is regularly collected at USP and PMRC. The numbers collected show a similar pattern to the forest tent caterpillar (Fig. 2).

Figure 2. Annual total number of adults of the eastern tent caterpillar, *Malacosoma americana*, collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center and Underhill State Park.



Adults of the bruce spanworm, *Operopthera bruceata*, are often observed flying above the forest floor during the daytime in early October at USP and PMRC. Light trap numbers are low (Fig. 3), even when many moths were observed flying in the habitat during the preceding afternoon. This species is either not strongly attracted to the lights, or poor weather conditions (e.g. low temperatures) late in the season reduce their flight activity after sundown.

The fall hemlock looper, *Lambdina fiscellaria*, is abundant at USP and PMRC, with declining numbers being collected from 1991 to 1994 (Fig. 4). The numbers collected per night in 1991 are comparable to densities recorded for *L. fiscellaria* in population outbreaks responsible for considerable defoliation of spruce and hemlock in Maine. There is no indication that *L. fiscellaria* is responsible for defoliation of spruce or hemlock at Mount Mansfield, and it is possible that the moth is feeding on hardwoods, but not at an intensity great enough to result in significant defoliation.

The flight season of *L. fiscellaria* is from September to early October (Grehan and Parker 1994). The spring hemlock looper, *L. athasaria*, is occasionally a significant pest of hemlock in Vermont (Grehan, Parker and Dearborn, in press), but is rare on

Figure 3. Annual total number of adults of the bruce spanworm, *Operopthera bruceata*, collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center and Underhill State Park.

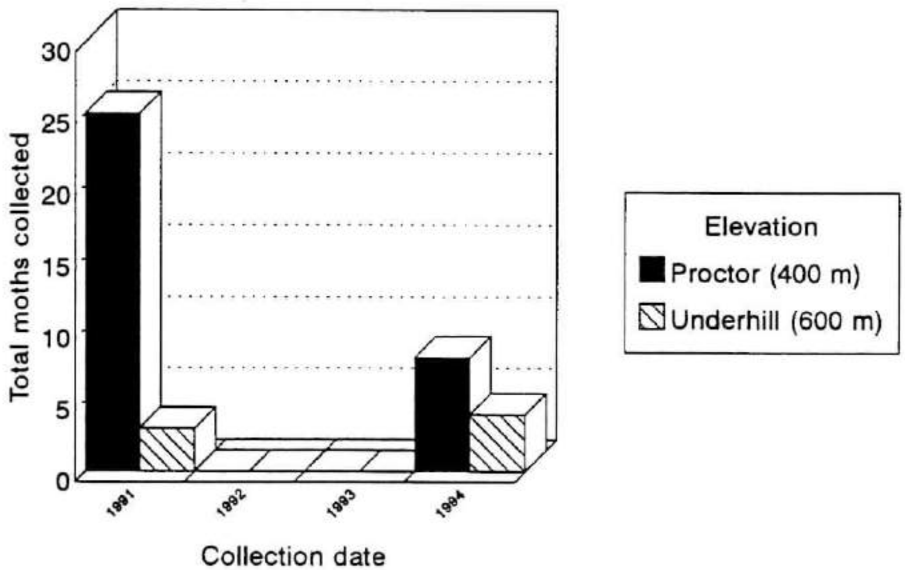
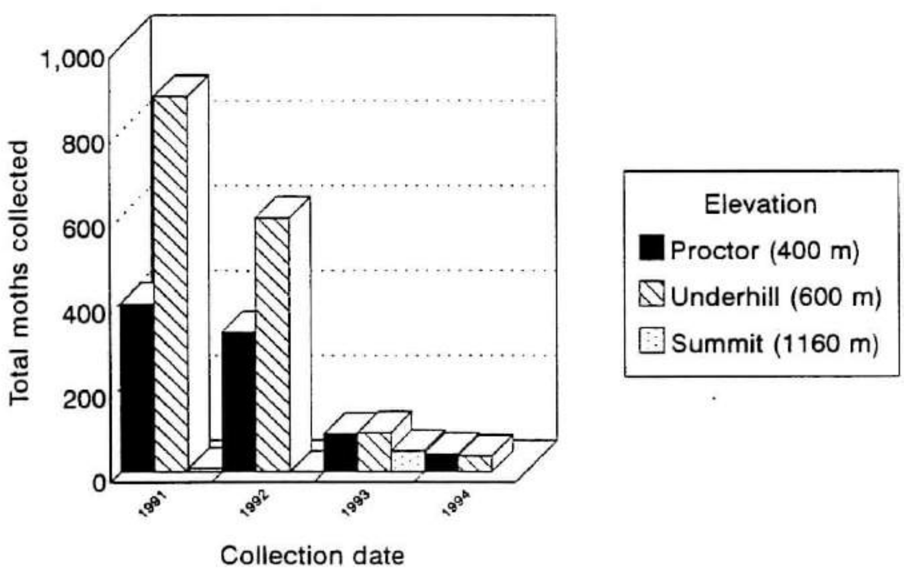


Figure 4. Annual total number of adults of the fall hemlock looper, *Lambdina fiscellaria* collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center, Underhill State Park, and near the Mountain summit.



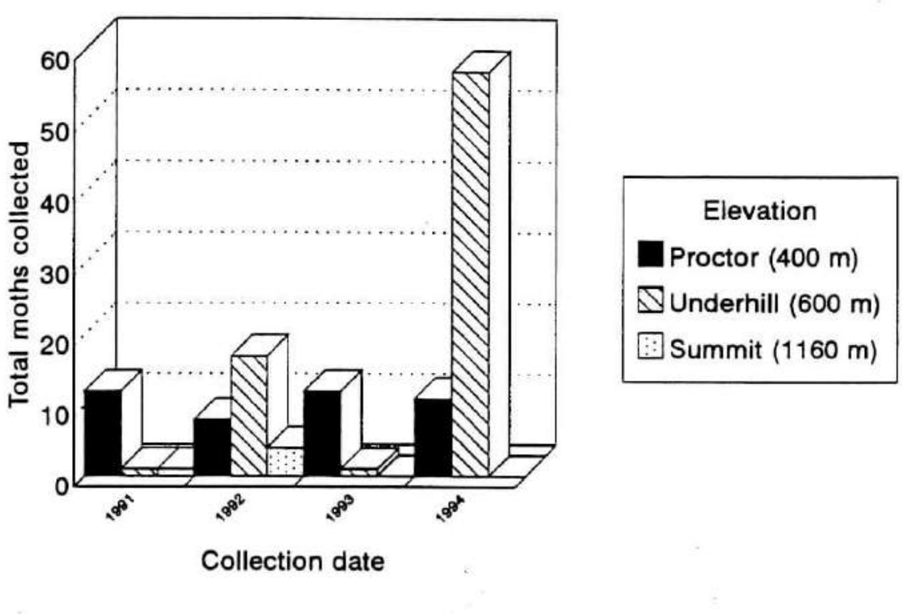
The spruce budworm, *Choristoneura fumiferana*, is recorded in pheromone traps each year at Mount Mansfield but it is rarely collected from the light traps. Only one specimen was recorded for 1994 and none in preceding years. The spruce budworm, like many other small moths, is either not strongly attracted to light or its flight behavior avoids becoming snared within the trap.

(ii) Biennial life cycles

Most Lepidoptera on Mount Mansfield have one or more generations each year, two species are known to exhibit synchronized biennial patterns of development. The periodicity of the conifer swift moth, *Korscheltellus gracilis*, has been extensively documented in the northeastern United States and Canada (Leonard and Parker, 1994). In Vermont most moths emerge on even numbered years, with a small minority flying on the odd numbered years. The species is attracted to light, but not very intensively, and population surveys have focused, therefore, on sticky traps which are effective at intercepting the swift, directional flight of the adult moths. Soil surveys and adult trapping suggest that the species is very abundant at mid to high elevations in the northeastern United States (Tobi et al., 1992).

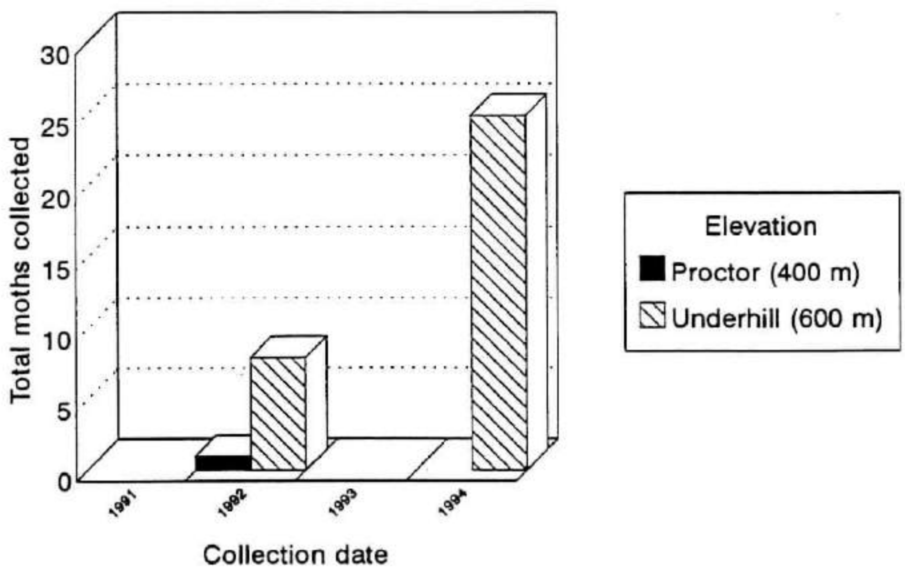
Only a small number of *K. gracilis* moths were collected each year in the light traps at Mount Mansfield, with no strong contrast between even and odd numbered years, with the exception of USP in 1994 where six times the usual number of moths was collected (Fig. 5). Light traps appear to provide an adequate record of the species' presence, but greatly underestimates its relative abundance.

Figure 5. Annual total number of adults of the conifer swift moth, *Korscheltellus gracilis*, collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center, Underhill State Park, and near the mountain summit.



In contrast to *K. gracilis*, the biennial development of the St Lawrence tiger moth, *Platarctia parthenos*, appears to be completely synchronized (Fig. 6). The species was first collected on Mount Mansfield in 1992 and again in 1994, coinciding with the main flight years of *K. gracilis*. The moth is recorded from a wide range of plants including alder, birches, willows and lettuce (Covell 1984), but does not represent a recognized forest pest.

Figure 6. Annual total number of adults of the St Lawrence tiger moth, *Platarctia parthenos*, collected from light traps over a four-year period on Mount Mansfield at Proctor Maple Research Center and Underhill State Park.



(b) Site representation of Lepidoptera

The 1991 annual report (Boone, Parker and Grehan 1992) reported on the similarity of total species numbers in the two lower elevation sites - PMRC and USP. This similarity is not surprising given their similar elevation, and the predominance of the same hardwood species in each area. This comparison can be further refined by considering the species unique to each site within Mount Mansfield, and the number of species shared between sites. The following comparisons were made for 1993 which covered all groups collected.

The largest number of unique species are present in PMRC, with a slightly lower number in USP (Fig. 7). The high elevation site (MMS) supported only 12 species not found at the other sites on Mount Mansfield (Table 1). Six of the high elevation species are known from other lowland localities in Vermont and are either strays or able to live in both high and low elevation habitats. Their host-plants suggests that they are not permanent elements of the high elevation fir forest habitat. The MMS site is located just below the WCAX television station where the habitat is highly modified.

seven species recorded only at MMS and USP represent known lowland species. The exception is represented by *Acleris variana* (Tortricidae) which comprises two forms, a grey-colored high elevation moth, and an orange-brown lowland moth (illustrated in Grehan et al. 1995). Each form may represent a separate species since the high elevation form feeds on balsam fir while the low elevation form feeds on eastern hemlock.

Table 1. Mount Mansfield Lepidoptera records unique to the summit survey site (1160 m) in 1993. The list is divided into (a) those known from low elevation records in Vermont, and (b) those not recorded from lowland habitats in Vermont.

(a) Low elevation representatives
Noctuidae
Amphipoea velata (grass feeder)
Anagrapha falcifera (herbs, horticultural pest)
Caripeta angustifolia (pine feeder)
Eurois occulta (feeds on tamarack)
Lithacodia albidula (grasses)
Papaipema sp
Tortricidae
Choristoneura pinus
Epinotia lindana

(b) High elevation representatives
Geometridae
Eulithis destinata (boreal distribution)
Eulithis flavibrunneata (boreal distribution)
Noctuidae
Melanchra adjuncta (trees and shrubs, alder, willow, elm and herbs)
Platypolia anceps
Xestia speciosa

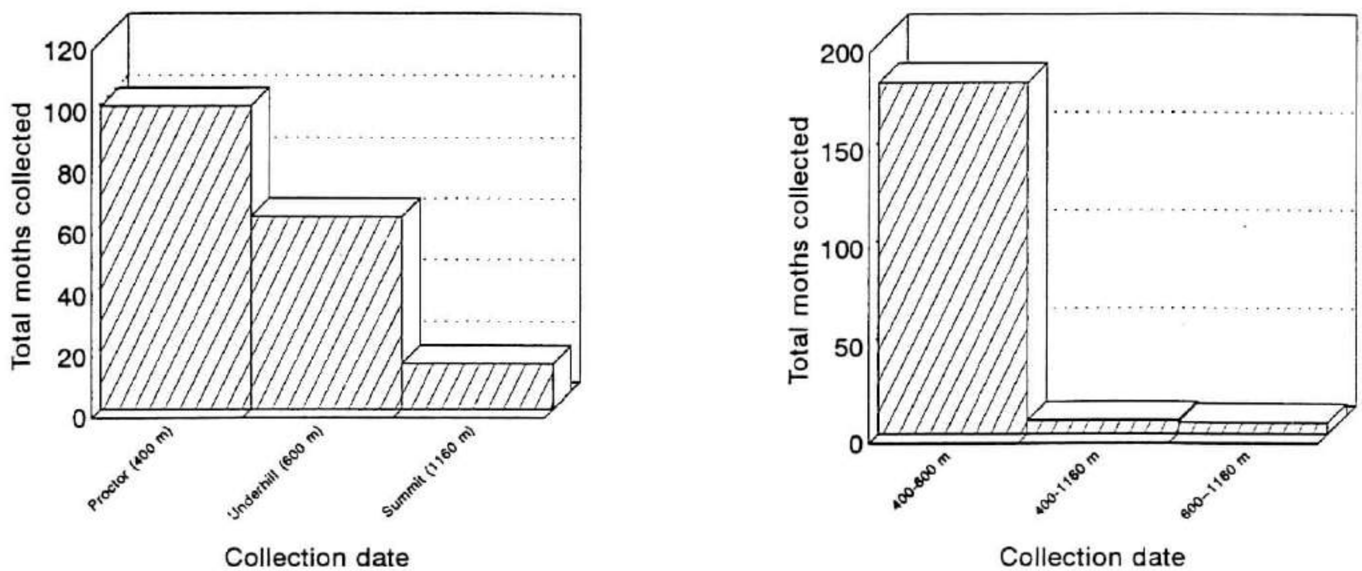
Table 2. Mount Mansfield Lepidoptera records unique to the summit survey site (1160 m) and Underhill State Park (600 m) in 1993. The list is divided into (a) those known from low elevation records in Vermont, and (b) those not recorded from lowland habitats in Vermont.

(a) Low elevation representatives
Noctuidae
Amphipyra tragopoginis (herbs)
Apamea amputatrix (very wide host range, includes vegetables)
Cryptocala acadiensis
Xestia smithii

(b) High elevation representatives
Noctuidae
Xestia rhaetica
Geometridae
Eulithis propulsata
Xanthorhoe iduata

Figure 7. Site comparisons of total number of Lepidoptera species collected at Mount Mansfield in 1993. **(a)** Number of species unique to each site; **(b)** total number of species shared between any two sites.

(a) **(b)**



(c) Bait sampling of Lepidoptera

Moths collected at bait are listed in Table 3. Sixteen species were not previously collected from the light traps. All species are already recorded in Vermont, and all should occur in both PMRC and USP. Five females of *Pachypolia atricornis* were collected at bait in September. The moths were fed a solution of water and apricot jelly. Eggs were deposited in rearing chambers comprising a surface of soft hand-towel. To obtain larvae for rearing and host-plant study in 1995 the eggs are being overwintered at the Entomology Laboratory and by other lepdiopterists.

(d) Seasonal patterns in Carabidae

When all carabid records are confirmed it will be possible to establish a statistical comparison of seasonal activity of adults that could be used to assess long-term environmental trends. The seasonal records will need to be interpreted in relation to the biology and ecology of each species. Overwintering may occur as adults, larvae, or both, and individual activity may be greatly reduced during unfavorable conditions such as hot, dry weather. Results from the 1991 season indicate that most adult carabids are collected in the early part of the summer, with considerable decline towards the beginning of fall.

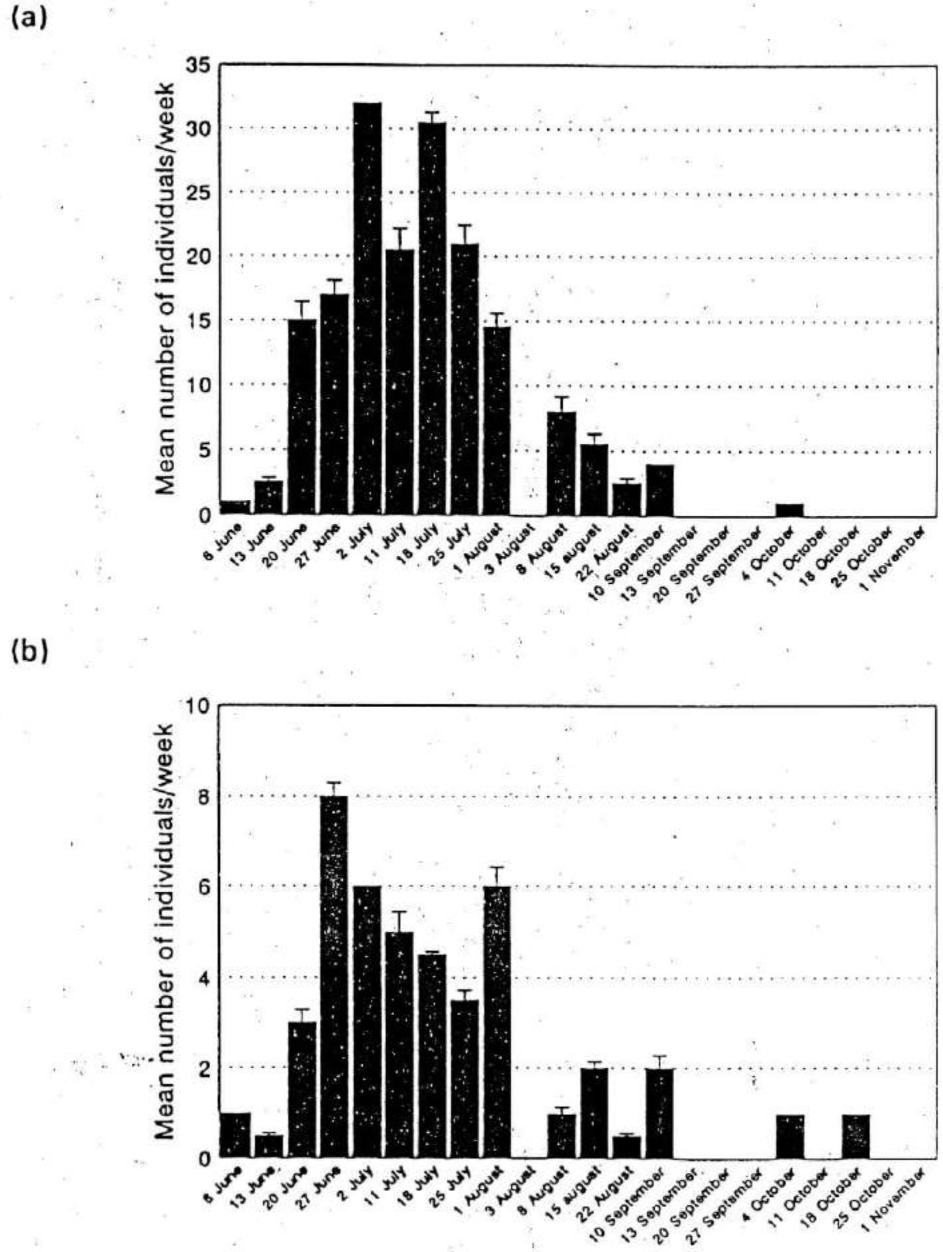
Table 3. Lepidoptera collected at bait at Mount Mansfield, April 1994. * - species not previously collected at light traps on Mount Mansfield. USPa - collected next to access road below entrance to Underhill State Park (500 m approx.). USP - Underhill State Park VMC site (600 m). PMRC - Proctor Maple Research Center VMC site (400 m).

	Collection Site		
Species	**USPa**	**USP**	**PMRC**
Noctuidae: Cuculliinae			
**Copivaleria grotei* Morr., 1874)			+
**Eupsilia devia* (Grt., 1875)		+	
Eupsilia morrisoni (Grt., 1874)	+	+	+
**Eupsilia vinulenta* (Grt., 1864)			+
**Eupsilia tristigmata* (Grt., 1877)	+	+	+
Lithophane baileyi Grt., 1877	+	+	+
Lithophane fagina Morr., 1874			+
**Lithophane gotei* Riley, 1877		+	
**Lithophane hemina* Grt., 1874	+		+
**Lithophane innominata* (Sm., 1893)	+	+	+
**Lithophane petulca* Grt., 1874)	+		+
**Lithophane unimoda* (Lint., 1878)			+
**Pyreferra pettiti* (Grt., 1874)			+
**Xylena curvimacula* (Morr., 1874)			+
Noctuidae: Hadeninae			
Achatia distincta Hbn., 1813			+
**Egira dolosa* (Grt., 1880)			+
**Orthosia hibisci* (Gn., 1852)			+
**Orthosia revicta* (Morr., 1876)			+
Orthosia rubescens (Wlk., 1865)			+
Noctuidae: Noctuinae			
Cerastis tenebrifera (Wlk., 1865)			+
Notodontidae			
Gluphisia lintneri (Grt., 1877)			+
Tortricidae			
**Acleris cerviana* (Fern., 1882)			+
**Acleris flavivittana* (Clem., 1864)			+
Thyatiridae: Thyatirinae			
Euthyatira pudens (Gn., 1852)			+

The elevational distribution of the carabid *Synuchus impunctatus* is an example of a mid and lower elevation species where most adults were collected between June and mid September (Fig. 8). This species usually overwinters in the larval stage and the lack of adults at the end of this season may reflect this pattern of development.

Adults of *Pterostichus rostratus* are most abundant at USP between June and August with only a few

Figure 8. Seasonal distribution of *Synuchus impunctatus* adults collected from pitfall traps on Mount Mansfield in 1991. (a) Underhill State Park, 600 m; (b) Proctor Maple Research Center, 400 m.



adults collected towards the end of the sampling season (Fig. 9). Although this species may overwinter in the adult stage, it is possible that the activity level of fall adults is very low and specimens are rarely collected in the pitfall traps. The high elevation species occur in lower numbers than USP or PMRC and population trends may be less evident. Records of *Pterostichus brevicornis* fluctuate considerably, but no adults occur beyond the end of August although the species probably overwinters in the adult stage (Fig. 10).

Figure 9. Seasonal distribution of *Pterostichus rostratus* adults collected from pitfall traps on Mount Mansfield in 1991 at Underhill State Park, 600 m.

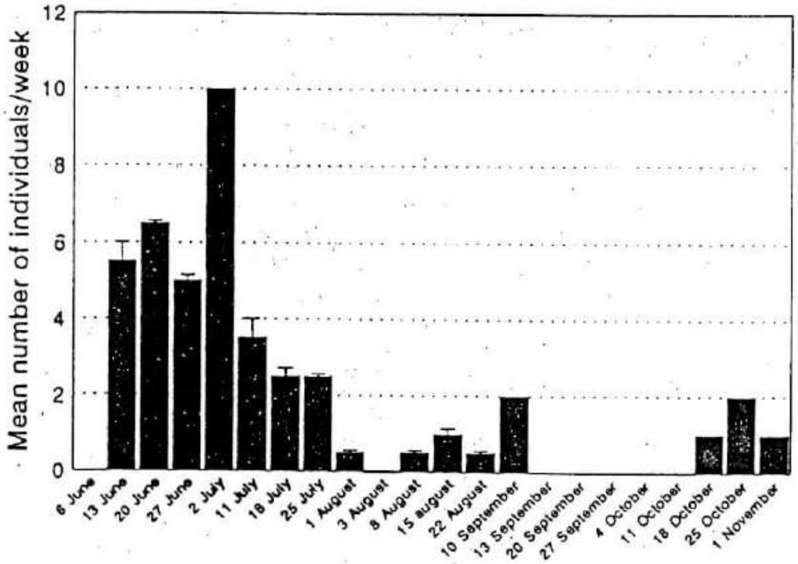
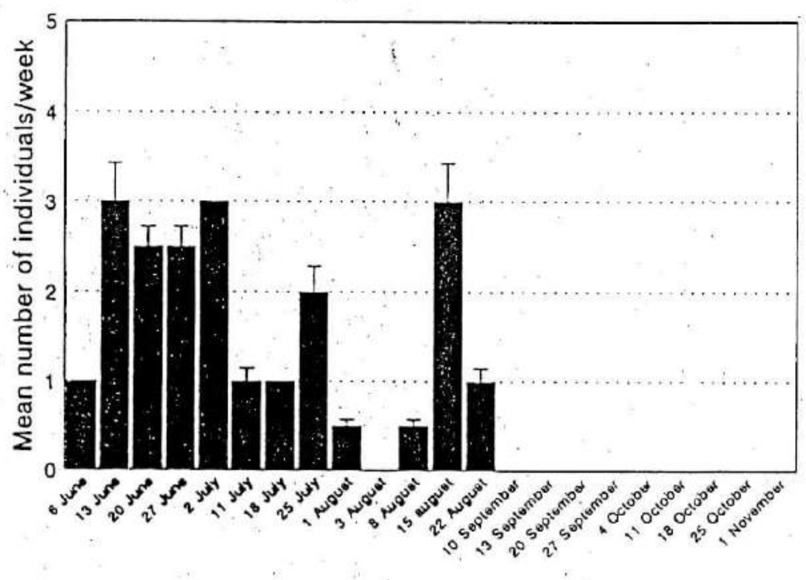


Figure 10. Seasonal distribution of *Pterostichus brevicornis* adults collected from pitfall traps on Mount Mansfield in 1991 at Underhill State Park, 600 m.



Discussion

Annual and seasonal Lepidoptera records cannot be compared on a statistical basis, and this will limit the significance of annual and seasonal patterns. The traps will, however, provide information on species representation not available from other techniques at present, and provide an alternative check to pheromones for pest species such as the forest tent caterpillar. The species composition is currently being developed into a biodiversity list that will relate species to their host-plant associations to provide an ecological measure of lepidopteran biodiversity at Mount Mansfield. Biennial species may be particularly significant for forest ecosystem management. Where development is completely synchronized the impact of forest management at the adult or larval year could be completely different, and have a major impact on the local survival of that species.

Species with limited elevational ranges may have the most significance for assessment of long-term ecological and climatic trends on Mount Mansfield. The high elevation species may provide the most sensitive indicators of changes affecting the elevational limits of species. Because most insects have at least an annual turnover between generations, they may show a rapid response to changes in ecological or climatic variables (including management techniques). At present there is a considerable distance in elevation between MMS and USP sites so the precise distributional limits are not known. Further sampling at 1000 m could be very informative. This elevation is closer to the MMS site, but represents an transitional area of mixed spruce, fir, and paper birch.

The low elevation species *Pachypolia atricornis* may prove to qualify as an indicator species for forest management and health when its host-plant relationships are determined. The species appears to be strongly associated with sites with fertile soil and dominated by sugar maple (D. F. Schweitzer, personal communication). Attempts will be made in 1995 to rear larvae emerging from eggs.

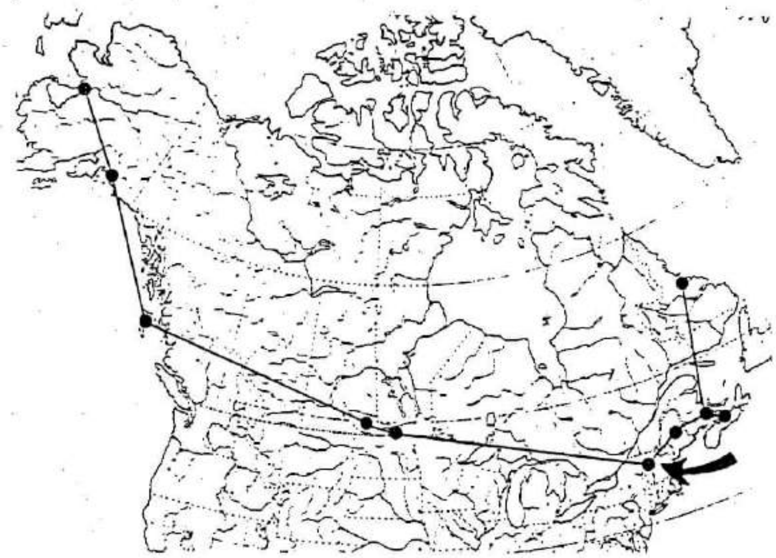
Future Plans

A regional context should be developed for the insect diversity at Mt Mansfield. This effort would be limited to species where regional geographic records are available. Rather than attempting to cover all species (some with very widespread distributions may be redundant) it could be targeted to those that qualify as local indicators. The geographic track of the high elevation species *Eulithis flavibrunneata* (Lepidoptera: Geometridae), for example, has a "boreal" range across Canada (Fig. 11). The Mount Mansfield locality represents a node that may be close to the southern range limit of the species along the Appalachian system.

We anticipate that a primary monitoring program of the current taxa from pitfall and light traps will continue with possible modification of the upper elevation sites to develop a more precise map of species distribution on the mountain. Replication for the Lepidoptera survey is desirable and this may be initiated for 1995. Other sources of biodiversity information are being considered, including the use of tree-trunk traps that may provide important information on the ecological and diversity relationships between invertebrates on the forest floor and the tree canopy.

Detailed statistical comparisons of biodiversity are too be developed by J. Boone for the carabids and selected Diptera and Hymenoptera. Once these methods are available, long-term assessment will be feasible for these groups. Analysis of seasonal patterns will also be carried out to provide a basis for correlation between insect activity and physical/climatological parameters currently documented by VMC.

Figure 11. Geographic track of the "boreal" moth *Eulithis flavibrunneata*. Mount Mansfield (arrow) is represented by a high elevation population at 1160 m. (Distribution data from the Smithsonian Institution).



Acknowledgements

We are grateful for the continued support of Ross and Joyce Bell (University of Vermont) and Bob Davidson (Carnegie Museum of Natural History) with identification of Carabidae and other Coleoptera. Data collection was assisted by Parras Kumar (University of Vermont Research Program). Data processing and database entry was facilitated by David Barnes, Pete Pfenning and Dave Marcaux (St Albans). Access to the Smithsonian Institution collection was kindly facilitated by D. C. Ferguson.

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Population structure and gene flow in a long-distance migrant bird, the Bicknell's Thrush (*Catharus bicknelli*).

Walter G. Ellison, Dept. of Biological Sciences, The University at Albany, Albany, NY 12222; Phone: (518) 442-4320, Fax: 442-4767
E-mail: well90@csunix.albany.edu

Abstract

Isolation of populations may lead to interruption of gene flow among them. I plan to assess how much gene flow occurs among apparently isolated populations of Bicknell's Thrush. This bird nests above 900 m in several mountain ranges in upstate New York and northern New England. I will use microsatellite DNA variation to determine genetic distances among Bicknell's Thrush populations of the Catskills, Adirondacks, Green and White mountains. I hope to test the effectiveness of long-distance migration in bridging geographic and habitat gaps in this bird's range. Patterns of microsatellite DNA variation from Mt. Mansfield thrushes will be compared with patterns from other ranges and other peaks in the Green Mountains. As a control I plan to examine population structure of the continuously distributed and more numerous Gray-cheeked Thrush (*C. minimus*) in northern Québec and Labrador. Eleven thrushes were captured on Mt. Mansfield in June of 1993 (4) and 1994 (7). All four birds caught in 1993 were seen in 1994 demonstrating strong site faithfulness. DNA has been extracted from most samples and three polymerase chain reaction (PCR) primer sets amplify Bicknell's Thrush DNA. My study should have important implications for models of gene flow in mobile organisms, and conservation of migratory birds.

Introduction

The geographic isolation of fragments of habitat may interrupt gene flow among populations of organisms spread out among such fragments (Milligan *et al.* 1994). These processes can be modeled but are generally difficult to demonstrate under field conditions. Developments in molecular biology such as polymerase chain reaction (PCR) amplification of specific genetic loci have provided inferential tools for attacking problems in evolutionary biology including the genetic effects of habitat fragmentation and isolation (Avise 1994).

Short motif repetitive segments of nuclear DNA called microsatellites show promise for measuring fine-scale geographic variation among populations (Queller *et al.* 1993, Bowcock *et al.* 1994, Morin *et al.* 1994). I propose to use microsatellite DNA variation to examine patterns of microgeographic differentiation in a bird with a highly fragmented breeding range and small overall population, Bicknell's Thrush, and to compare these results with a control sample from the closely related, but more common and continuously distributed, subarctic Gray-cheeked Thrush.

The breeding range of Bicknell's Thrush is confined to southeastern Canada, northern New England and upstate New York (Ouellet 1993, Rimmer *et al.* 1993). In its United States range it is almost entirely found at high elevations in stunted subalpine spruce-fir forest. It is migratory, wintering in the Greater Antilles (Wallace 1939, Ouellet 1993). Concern has recently been expressed over the conservation status of this bird (Rimmer *et al.* 1993). Does the fragmented distribution of Bicknell's Thrush cause genetic partitioning of its populations? Long-distance migration might provide an important avenue for gene exchange among seemingly isolated populations. On the other hand, many migratory animals exhibit a high degree of natal philopatry, it is therefore necessary to assess the importance of migration in promoting gene flow among isolated populations of very mobile organisms such as Bicknell's Thrush.

Methods

I capture thrushes in 6 m nylon mist nets by inducing aggressive behavior with a tape of territorial songs and calls. I band and take several morphometric measurements from each bird. I then remove 100 µl of blood from the humeral wing vein before releasing the bird. I transfer the blood to a lysis buffer solution to preserve DNA (Seutin *et al.* 1991). I obtain DNA from my samples with phenol-chloroform extraction (Kirby 1991). Three sets of PCR primers that amplify microsatellite loci in Long-tailed Manakins (*Chiroxiphia linearis*) (McDonald and Potts 1994, Shou-hsien Li, pers. comm.) also amplify Bicknell's Thrush loci, therefore I can use these to examine allelic variation among thrush populations. I will calculate population structure (F_{ST}; Wright 1978), and gene flow (Nm; Slatkin 1987) indices from polyacrylamide gels showing band patterns from the thrush populations I have sampled.

Results

I have captured and sampled 11 total Bicknell's Thrushes on Mt. Mansfield. Four were caught in June 1993, and a further seven were netted in June 1994 in joint netting with Christopher Rimmer of the Vermont Institute of Natural Science. At present I have met my minimum sample needs for Mt. Mansfield, however if variances in allele frequencies prove high I may need to add more individuals to aid in analyses of population structure, inbreeding coefficients, and gene flow. All four birds banded in 1993 were encountered in 1994 indicating site faithfulness. However three of the four were at new locations in 1994. Birds moved from 0 to 595 m between years. The bird that moved over one-half km was a one-year-old in June 1993. I have extracted DNA from six of the eleven Mt. Mansfield samples and I intend to complete extracting these samples in August 1995.

Context

My Mt. Mansfield work is a portion of my broader study of population structure in Bicknell's and Gray-cheeked thrushes in northeastern North America. I still need to increase my samples in the Adirondacks (n=8), and White Mountains (n=5) in 1995. I also will be collecting blood samples from Gray-cheeked Thrushes in northern Canada from late June through July 1995. I am hoping to use a short-term visitor award at the National Zoological Park Genetics Laboratory to develop more primers for microsatellite loci in Bicknell's Thrush by working with Dr. Robert Fleischer who is developing primers for the closely related Omao (*Phaeornis obscurus*).

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Population Studies of Bicknell's Thrush (*Catharus bicknelli*) on Mount Mansfield, Vermont

Christopher C. Rimmer
Kent P. McFarland

Vermont Institute of Natural Science
RR 2, Box 532
Woodstock, VT 05091

Abstract: Research on the population ecology of the Bicknell's Thrush (*Catharus bicknelli*) in Mt. Mansfield's subalpine spruce/fir forest was continued in 1994. Studies were concentrated on a 8.8 ha plot established in 1992 at 1160-1200 m elevation. Intensive spot mapping of territorial males yielded similar density estimates in all 3 years (36-52 pairs/40 ha in 1992, 50-59 pairs/40 ha in 1993, 55-65 pairs/40 ha in 1994). To examine questions of population stability, territory size, movements, site fidelity, territorial turnover, productivity, and survivorship, a concerted effort was made to capture and band all thrushes occurring on the study plot. A total of 57 thrushes (31 adult males, 10 adult females, 16 juveniles) were banded over three years on or near the study plot yielding a survivorship of 42.8 percent. Nest searching and monitoring produced 8 nests (4 active) over the 3-year period. Two nests were abandoned, one was predated and one fledged two young. Analysis of nest site microhabitat data indicated that nest site selection appears to be keyed to high shrub stem (woody plant with DBH <8cm and >0.5 m tall) density. Seven of 8 nest trees were live, healthy balsam firs 1.85-2.80 m tall. Nests tended to be located in the southeastern quadrant of the tree against the trunk. Long-term habitat monitoring plots were established and sampled within the study area.

Additionally, long-term monitoring of the entire avian community was initiated during 1994, using the continent wide constant-effort mist-netting program, Monitoring Avian Productivity and Survivorship (MAPS). Six mist nets were used in this trial year. An additional four mist nets will be placed in 1995 to complete the establishment of the study station. Mist netting was conducted for 6 morning hours in nine 10-day periods throughout the breeding season for a total of 329 hrs of netting. Sixty-five birds (39 adults, 26 juveniles) of 15 species were captured and banded. Six banded individuals were recaptured.

Anticipated plans for 1995 research on Mt. Mansfield include: 1) continued monitoring of Bicknell's Thrush using existing field protocols; 2) monitoring several individuals with radio telemetry; 3) completing the second year of MAPS monitoring using four additional mist nets; 4) monitoring fall passerine migration on Mt. Mansfield using banding and censusing to assess stopover usage of the subalpine spruce/fir forest; and 5) monitor transmission tower strikes by birds during fall migration to assess the extent of mortality.

Introduction

The Bicknell's Thrush (*Catharus bicknelli),* recognized as a subspecies of the Gray-cheeked Thrush (*Catharus minimus*) since its discovery on Slide Mountain in the Catskills of New York in 1881, has recently been given full species status and listed as a Category 2 species under the Federal Endangered Species Act. The Bicknell's Thrush is the only songbird endemic to the high altitude forests of the Northeast, qualifying it as a potentially valuable indicator species for the subalpine avian community and forest habitat health.

In 1992 VINS established an 8.8 ha long-term study plot on Mt. Mansfield to examine the population ecology of Bicknell's Thrush. In 1994 research was expanded to examine the entire avian community. The purpose of the study was to: 1) monitor the density of breeding pairs of Bicknell's Thrush; 2) mist net and color band thrushes to examine site fidelity, survivorship and population stability; 3) locate and monitor Bicknell's Thrush nests to determine site selection and productivity; 4) conduct standardized mist-netting of all breeding bird species to monitor productivity and survivorship; 4) select and implement a vegetation sampling protocol for habitat monitoring.

Methods

Studies were concentrated on an 8.8 ha permanent study plot along the summit ridge (1160-1200 m elevation). Spot mapping has been completed since 1992. For each bird seen or heard a compass bearing and distance estimate was recorded from marked vantage points. The data were plotted on a base map of the study area. Simultaneous registration of two or more vocalizing birds was used as the primary means of discriminating between adjacent territories. Sightings of color banded birds were recorded and mapped in the same manner in an attempt to identify each territory with a known identity bird.

Using strategically placed mist nets in combination with tape recorded playbacks of Bicknell's Thrush vocalizations and a life-like wooden decoy, an attempt was made to capture and color band all known breeders on the study area. Up to 10 mist nets were used simultaneously to passively capture thrushes as a complement to the use of vocal and visual lures. This facilitated the capture of females, which are not readily lured into nets. Detailed mensural (e.g., wing chord, weight) and body condition (e.g., subcutaneous fat, molt, feather wear) data were recorded for all captured birds. Capture locations were plotted on a master study plot map. Site fidelity, territorial turnover, survivorship, and population stability were investigated on Mt. Mansfield by searching for color banded birds.

From early June to mid-July, careful searching of the study plot was conducted to locate active and recently used nests. Each nest location was mapped. For active nests chronology and success were monitored, and nestlings were banded. Nest monitoring was conducted according to the guidelines established by the Breeding Biology Research & Monitoring Database Program (BBIRD 1994). After fledging, nest site selection and microhabitat data were collected in accordance with BBIRD (1994).

Twenty vegetation monitoring plots were permanently marked and sampling was conducted in August and September 1994. Protocols followed those prescribed by BBIRD (1994) and were a modification of the standard James and Shugart (1970) method.

Research was initiated in 1994 to monitor the productivity and survivorship of the entire avian community as part of the continentwide Monitoring Avian Productivity and Survivorship Program (MAPS). Six mist nets were utilized in our study plot for this first year trial. We plan to use an additional four nets in 1995 to complete the study plot establishment. This study must be relatively long-term in order to gain statistically valid and meaningful results. We captured birds during one morning in each of nine 10-day periods from May 31 to August 28. For each bird captured and recaptured we recorded net location, age and sex, degree of skull pneumatization, unflattened wing chord, fat class, mass, cloacal protuberance or brood patch class, and molt condition.

Results

Density estimates : Spot mapping of vocalizing males yielded density estimates for Bicknell's Thrush of 36-52 pairs/40 ha in 1992, 50-59 pairs/40 ha in 1993, and 55-65 pairs/40 ha in 1994 (Figure 1). The territories of 8, 11, and 12 pairs were located entirely within the borders of the study plot in 1992, 1993, and 1994, respectively. The total number of territories on the plot was estimated at 11.5 in 1992, 13.0 in 1993, and 14.25 in 1994. Independent evaluation of our data by an individual experienced in spot mapping but unfamiliar with the plot yielded estimated totals of 11.75 territories in 1992, 13.25 territories in 1993, and 12.5 territories in 1994. For the purpose of these calculations, the maximum density values were obtained by including percentages of territories estimated to be located within the boundaries of the study plot. The minimum density values were calculated by excluding all "partial" territories from consideration.

Location of Color Banded Birds : Only nine individual color marked thrushes were visually identified in over 1,000 people hours on the study plot in 1994, illustrating the difficulty in sighting birds in the dense habitat.

Mist Netting : We captured 22 unbanded birds and 23 previously banded Bicknell's Thrushes on Mt. Mansfield in 1994, 24 unbanded and 11 recaptures in 1993, and 11 unbanded and none recaptured in 1992 (a pilot year) for a total of 57 banded thrushes in three years. Survivorship was calculated using capture-recapture data and observations of color banded birds from 1992-1994 (Table 1).

Nest Monitoring : Despite many hours of systematic searches on the Mt. Mansfield study area we found only two active nests, two recently fledged nests, and two nests from previous breeding seasons in 1994. In both 1992 and 1993 one active nest was found. Only one of the four active nests produced fledglings (Table 2). It remains unclear why the two 1994 nests were abandoned. Nests were found to be placed abutting the trunk of a tree or very close to the trunk. There was a tendency for nests to be placed on the southeastern side of trees.

Seven of 8 nest trees were balsam fir (*Abies balsamea*). One nest was located in a red spruce (*Picea rubens*). Nest trees were small (1.85-2.80 m tall and 2.8-7.9 cm DBH) with the nest located between 1 and 1.60 m high. Nests were supported by one to four small branches (0.3-1.5 cm diameter). The amount of vegetation obscuring the nest in each cardinal direction in a 25 cm radius circle centered at the nest was usually very high (+60% coverage) on at least two sides of the nest and low on two sides. Nests were invariably found in a live portion of the tree and usually in healthy trees.

We compared vegetation surrounding the eight nest sites with eight randomly selected non-use (no nest) sites. Five-meter radius plots examined the shrub stem densities (defined as woody plants with a DBH <8 cm and > 0.5 m high). Densities were significantly higher in the nest plots for both small stems ($x^2 = 25.2$, $P < 0.001$) and large stem densities ($x^2 = 18.06$, $P < 0.001$). Except for small mountain holly (*Nemopanthus mucronata*) stems and small dead stems, the relative densities of each species were similar on nest sites and non-use sites. Small mountain holly was nearly twice as dense in non-use sites and small dead stems were twice as prevalent in nest sites.

Tree densities were examined on 11.3 meter plots around the nests and in randomly chosen non-use sites. There were significantly more trees in the 8-23 cm DBH class on the non-use sites ($x^2 = 4.01$, $P < 0.05$). Balsam fir trees were the dominant species in this size class. There was no significant between-site difference in density in the >23 cm DBH tree class. However, there were a significantly greater number of dead than living trees in the non-use site in this class ($x^2 = 7.54$, $P < 0.01$). Relative densities were similar in the small DBH class. Balsam fir dominated the large tree class on nest sites, while dead trees dominated the large tree class on non-use sites.

Ocular estimates for nine categories of ground cover and vegetation were estimated within the 5 meter radius plots for both nest sites and non-use sites. The averages of three of these categories (ferns, moss, and leaf litter) differed considerably between the two types of site. Fern and moss average cover was lower and average leaf litter cover was higher in the nest sites.

Long-Term Habitat Monitoring Plots : 1994 was the first year of long-term monitoring of the vegetation in the study area on Mt. Mansfield. These data will yield more meaningful insights in 3 years when the same plots are resampled.

Monitoring Avian Productivity and Survivorship : Mist netting was completed for six consecutive morning hours in nine 10-day periods throughout the breeding season for a total of 329 net hours. Sixty-five birds of 15 species were captured during this time for a total of 4.7 birds captured per net hour (Table 3). Six individuals were recaptured. These results are not amenable to analysis after only one year of data collection. Several additional years of data collection will be necessary to make conclusions based on capture-recapture models.

Discussion

Spot mapping data since 1992 have shown an increase of four territories on the Mt. Mansfield study plot. We believe our spot mapping data, from which two independent observers calculated similar numbers of territories in 1992-1994, closely approximated actual Bicknell's Thrush densities on the study plot. On 11 July we observed a color banded bird counter calling five times with other birds. The locations of this bird coincided closely with a territory plotted from spot-mapping data. These observations appear to support the accuracy of our spot-mapping data. Some birds wandered over a large area. These individuals were almost always captured in mist nets and not observed singing or calling. Most nomadic behavior occurred early (territory establishment phase) and late (post-breeding dispersal) in the breeding season. This suggests that territorial boundaries "relax", or break down, outside the height of breeding activities.

Wallace (1939) reported that Bicknell's Thrush territories on Mt. Mansfield "may apparently cover an acre or more". Assuming densely packed territories of about 0.6 ha (1.5 ac) in size, Wallace's suggestion would yield density estimates of approximately 65 pairs/40 ha. This is similar to our maximum estimates and may reflect unusually high densities on Mt. Mansfield, which we believe supports 250+ pairs.

A significant, but still preliminary, finding is that the survivorship and return rates (site fidelity) of adult Bicknell's Thrushes appear to be very high. Survivorship calculations represent conservative estimates because of the difficulty in capturing birds and sighting color bands in the dense habitat. We have not documented the return of a juvenile, or hatch year (HY), bird in a successive year. Adult birds appear to have higher survivorship, based on their observed return rates. However, sample sizes of HY birds have been small (1992=2, 1993=2). We captured 13 HY birds in 1994 and hope to obtain data in 1995 on survivorship and site fidelity of young birds.

Similar breeding densities in 1992-1994, coupled with high adult site fidelity and survivorship, suggest that Mt. Mansfield's breeding population may be relatively stable. However, the demographics of this relatively large population may not reflect those on the many smaller, more isolated peaks occupied by this species. We are comparing Bicknell's Thrush demographics and population stability on peaks with both extensive and limited subalpine spruce-fir habitat as part of our overall research on the status of the species.

Nest monitoring was largely unsuccessful in 1994 because of the small number of nests found and the abandonment of the only two active nests during incubation. The nests may have been abandoned because of human disturbances from excessive traffic on nearby trails. Five Blackpoll Warbler (*Dendroica striata*) nests, one Myrtle Warbler (*Dendroica coronata*) nest, and a Purple Finch (*Carpodacus purpureus*) nest were discovered and monitored in a similar manner, yet all seven nests fledged young.

It is possible that either or both incubating females were predated. Both were color banded, but neither was captured or observed following its nest abandonment. Possible predators of adults and nests that were observed during the 1994 season included: Blue Jay (*Cyanocitta cristata*), numerous Northern Ravens (*Corvus corax*), one *Accipiter* species, red squirrel (*Tamiasciurus hudsonicus*), and raccoon (*Procyon lotor* ; two sets of tracks noted on the Amherst Trail).

Nest site selection appeared to be based primarily on shrub stem densities. Areas that had high shrub densities were characterized by thick patches of young balsam fir trees and very few large, mature trees. Non-use sites generally had higher densities, although widely spaced, mature trees.

The long-term habitat monitoring plots on Mt. Mansfield may enable an understanding of changes that occur in the habitat over time. Several studies have documented severe declines of red spruce throughout the Northeast since the early 1960's (e.g., Siccama et al. 1982, Foster and Reiners 1983, Battles et al. 1992, Miller-Weeks and Smoronk 1993), as well as heavy mortality of balsam fir (Miller-Weeks and Smoronk 1993). Most of the hypotheses proposed to account for this decline involve the effects of atmospheric deposition and include: 1) soil acidification/aluminum toxicity; 2) spruce needle damage and disease; 3) general stress from reduced photosynthetic activity and secondary metabolite production; 4) excess nitrogen deposition; 5) complex high-elevation disease from the combined effects of high ozone concentrations, acid deposition and nutrient deficiencies; and 6) organic air pollutants (e.g., Krahl-Urban et al. 1989). The possible impacts of this habitat degradation on populations of Bicknell's Thrush and other subalpine bird species are unknown Detection of such impacts will require long-term monitoring of both vegetation and avifauna.

Future Plans

Research will continue on the Mt. Mansfield study plot in 1995. We plan to use radio telemetry to monitor several individual thrushes on the study plot. Additionally, passerine migration will be monitored in the fall using mist nets, censusing, and examination of transmission tower strikes to assess the use of the subalpine forest by migrants during migration on Mt. Mansfield and one other site in Vermont to be determined.

In 1995 we plan to expand our monitoring of high-elevation bird populations to other study plots in the Green Mountains, Adirondacks and the Catskills using point counts, five MAPS stations, and two BBIRD stations. Bicknell's Thrushes will also be studied on the five new study plots using similar protocols as on Mt. Mansfield.

Acknowledgments

We thank Chip Darmstadt, Clare McFarland, Will Richardson, Laura Nagy, and Steve Faccio for their invaluable field assistance. Rick Paradis of the University of Vermont, William Kemp of the Mt. Mansfield Co., and the summit caretakers of the Green Mountain Club all provided logistical support. Trevor Lloyd-Evans independently plotted spot-mapping data for each year. This project was supported financially by Vermont Monitoring Cooperative, the U.S. Fish and Wildlife Service, the Wharton Trust, and the members and trustees of the Vermont Institute of Natural Science and Manomet Observatory for Conservation Sciences.

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Table 1. Survivorship estimates based on capture-recapture data and observations of color banded birds from 1992-1994 on Mt. Mansfield, VT.

Years	Total Banded	Total Recaptured	Percent Survivorship
Female			
1992-1993	3	2	66.7
1993-1994	5	3	60.0
1992-1994	8	4	50.0
Male			
1992-1993	6	2	33.3
1993-1994	5	3	52.9
1992-1994	23	11	47.8
Total			
1992-1993	11	4	36.3
1993-1994	28	15	53.6
1992-1994	35	15	42.8

Table 2. History of four active nests found on Mt. Mansfield, VT, 1992-1994.

Nest	Date	# Eggs	# Young	Notes
92A	6 July 92	1	2	Chicks approx. 6 days old. Banded nestlings (908, 909).
	13 July 92			Nest empty, intact. Assumed fledged two.
93A	24 June 93	4		Female flushed from nest.
	29 June 93	1	3	Approximately 1 day old.
	30 June 93		4	
	6 July 93		3	
	7 July 93			Nest empty. Presumed predated. Red squirrel seen in area at 0930. Nest checked at 1315.
94A	22 June 94	4		Flushed adult from nest. Silent
	23 June 94			Female went to nest while watched from trail 5 meters away.
	27 June 94	4		Female not seen. Watched for 20 minutes. Several males calling and singing nearby.
	29 June 94	4		Female not seen. Watched 5 minutes.
	30 June 94	4		Eggs cold. Estimated to be 7 days old. Female has abandoned.
94B	22 June 94	4		Flushed adult from nest. Silent. Later netted female (921).
	23 June 94	4		Female on nest.
	27 June 94	4		Observing from trail periodically female not seen all A.M. Checked nest. Eggs cold. Female abandoned.

Table 3. Number of individuals of each species of birds captured during MAPS banding periods.

Common Name	Scientific Name	Total Adults	Total Juveniles
Ruby-throated Hummingbird	*Archilochus colubris*	1	0
Yellow-bellied Flycatcher	*Empidonax flaviventris*	1	0
Ruby-crowned Kinglet	*Regulus calendula*	0	1
Bicknell's Thrush	*Catharus bicknelli*	2	0
Swainson's Thrush	*Catharus ustulatus*	0	1
American Robin	*Turdus migratorius*	1	0
Black-throated Blue Warbler	*Dendroica caerulescens*	0	4
Myrtle Warbler	*Dendroica coronata*	8	3
Blackpoll Warbler	*Dendroica striata*	11	8
American Redstart	*Setophaga ruticilla*	0	1
Canada Warbler	*Wilsonia canadensis*	1	0
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0	1
White-throated Sparrow	*Zonotrichia albicollis*	11	3
Slate-colored Junco	*Junco hyemalis*	2	4
Purple Finch	*Carpodacus purpureus*	1	0
Number of individuals		39	26
Number of species		10	9

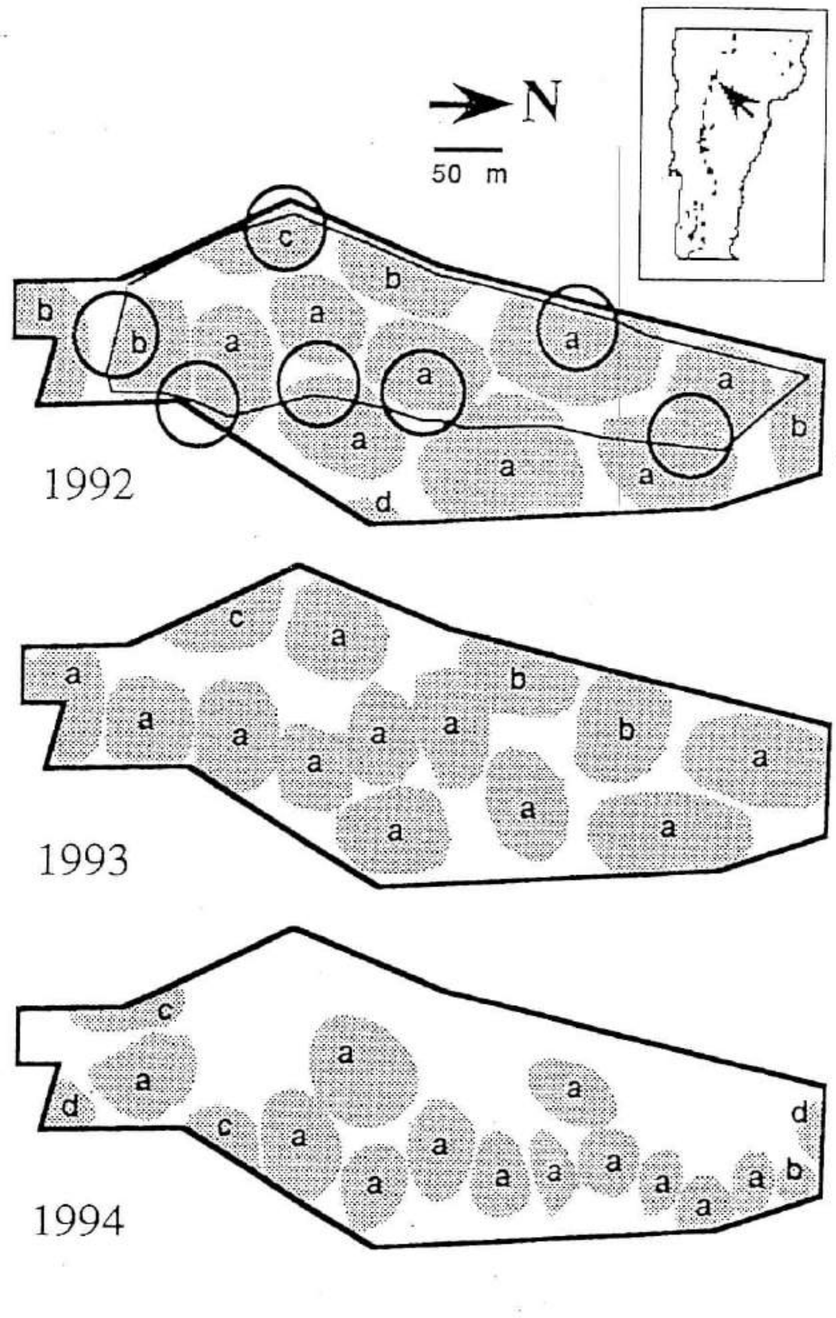

Figure 1. Locations of spot-mapped Bicknell's Thrush territories on Mt. Mansfield study plot. The 1992 map indicates point count locations (circles) and the transects used for spot-mapping. Inset map shows approximate location of high elevation (> 915 m) land in Vermont, and the arrow indicates location of Mt. Mansfield. Letters indicate percent of territory estimated to be located within the boundaries of the plot: a - 100%; b - 75%; c - 50%; d - 25%.

Small Mammals on Mt. Mansfield, Vermont

Stephen C. Trombulak
Department of Biology, Middlebury College

Abstract: An inventory and monitoring project on small mammals on the west slope of Mt. Mansfield was begun during the spring of 1994. Four techniques were used to determine what species were found across the elevational gradient: live trapping, pitfall trapping, walking transects, and road surveys. These techniques were biased towards detection of rodents and insectivores, and to a lesser extent rabbits, marsupials, medium-sized carnivores, and large herbivores. Bats and large carnivores were not sampled at all. Fourteen species of mammals were identified in this area, including 9 species of rodents, 2 insectivores, 1 rabbit, 1 carnivore, and 1 large herbivore. Inventory efforts in 1994 were restricted to between 1200 and 2200 feet, and no significant elevational trends were seen over that range. Pitfall trapping was the most complete of all the techniques used to inventory the small mammal population (8 of 11 species of rodents and insectivores, only failing to note three diurnal or large-bodied rodents), and future work at the elevations where drift fences have been set up will be restricted to this technique. Future work will include trapping up to the summit of Mt. Mansfield to better identify such potential trends, and identification of small mammals captured at in pitfall traps at drift fences from 1991 to 1993.

Introduction

During the late spring of 1994, I began an inventory of the small mammals on the west slope of Mt. Mansfield, an area within the study region of the Vermont Monitoring Cooperative. The purpose of this work was to identify the species of small mammals that live in this region and to establish a methodology that will allow for standardized replicate sampling in this area at intervals throughout the coming years. In 1994, inventory effort was restricted to the elevations between 1200 and 2200 feet in order to assess the effectiveness of a range of inventory techniques. No effort was made to establish a methodology to answer questions associated with the demography of resident populations.

For the purposes of this study, the small mammal fauna is considered to be composed of the insectivores and rodents. Bats, all carnivores, and all large-bodied mammals were excluded from this inventory effort. However, an attempt was made to collect anecdotal information on rabbits and medium to large-sized herbivores and carnivores at the lowest elevations of the study region, primarily along roads.

Methods

Four techniques were used to inventory the small mammal species on Mt. Mansfield. The first was night-time live-trapping. On 9 nights, Sherman live traps (7.7 cm x 9.0 cm x 23.0 cm) were set in two locations within the VMC monitoring area: 1200 feet and 2200 feet elevation. The 1200 foot location is to the east of and adjacent to the lower 1200 foot amphibian drift fence, and the 2200 foot location is to the south of and adjacent to the 2200 foot amphibian drift fence (Figures 1 and 2). At each site, forty traps were set in a 4 x 10 trap pattern at 10 m intervals. Traps were set in the early evening hours, baited with rolled oats and peanut butter, and checked again the following morning. All animals captured were identified to species and sex and then released unharmed at the point of capture. Traps were set on 9 evenings at each site, resulting in 720 trap-nights from 2 June to 25 July.

The second technique was pitfall traps at drift fences. These traps are associated with the amphibian drift fences, 2 fences at 1200 feet and one at 2200 feet. Pitfall traps were opened on evenings that seemed to be good for amphibian activity (e.g., warm and wet) and checked again the following morning. Animals that were in the pits the following morning, including small mammals, were identified and, if dead, frozen and returned to the laboratory. During 1994, the pitfall traps were open on 12 evenings between 18 May and 1 November.

The third technique was morning transect walks. An observer slowly walked over a known route recording all small mammal activity either on the ground or in nearby trees. Two transects were used, one along the road heading east and south from the 2200 foot trapping site (0.50 mile) and the other along the trail extending west from the 1200 foot trapping site (0.25 mile) (Figures 1 and 2). During 1994, each transect was walked 9 times, once each week between 3 June and 26 July.

The fourth technique was road surveys. A set route of 9.8 miles in the western part of the VMC monitoring area (Figure 1) was driven during mid-day, and all mammals living or dead (roadkills) were recorded. The road survey route was driven 9 times, once each week between 3 June and 26 July.

Results and Discussion

Species richness. All techniques combined identified 11 species of insectivores and rodents of a possible 29 known from the state (Tables 1-3). Three additional species, Eastern cottontail, coyote, and white-tailed deer, were also observed (Tables 2, 4). The only apparent difference in the small mammal fauna between these two sites is the presence of the meadow jumping mouse (Zapus hudsonicus) at 1200 feet, which is probably related to the absence of appropriate habitat near the drift fence at 2200 feet.

Analysis of techniques. Of the two trapping techniques used, by far the most useful was the pitfall traps at the drift fences. The pitfall traps caught eight identifiable species, whereas the Sherman traps only caught five at any one site, which were a complete subset of those found in the pitfall traps. Further, the Sherman traps caught fewer individuals of many species, especially jumping mice, voles, and masked shrews. The transect walks were useful at locating a small number of diurnal and arboreal species, like squirrels, porcupines, and rabbits, that normally are not found in traps, but only accounted for three species not found in the pitfall traps. It is apparent that the road surveys are not a useful technique. Despite the susceptibility of many mammalian species to being killed by cars, it does not appear that traffic in the VMC study area is sufficiently high or fast enough to kill animals that cross the road with any regularity.

Future plans

Priorities for 1995 are as follows:

1. Replicate the 1994 pitfall trapping at the 1200 foot and 2200 foot sites: Because populations of many species of small mammals demonstrate three to five year cycles, repeat trapping will increase the confidence we can place in the inventory. Pitfall trapping was the most complete inventory technique used in 1994, so only this technique will be used in 1995 at these elevations.

2. Trap for small mammals above the 2200 foot elevation site. I plan to trap at both the 3200 foot amphibian drift fence and at locations near the summit of the mountain.

3. Identify the small mammals caught in the pitfall traps from 1991 to 1993. These animals are still frozen in my laboratory. Preliminary identification suggests that at least five species not recorded in 1994 are represented in this collection.

Context

This study is unique. It is the only site in Vermont at which this full range of inventory techniques is being used to look for the presence of small mammals species over a large area. It is also the only site at which a long-term monitoring program for small mammals has been implemented. At one other site in the Champlain Basin and at one site in the Battenkill River watershed (Lye Brook Wilderness Area), small mammals are captured in pitfall traps incidental to amphibian trapping. At two sites in the Champlain Basin (Camel's Hump and the Bread Loaf Wilderness area), small mammals are regularly live trapped to assess their status, particularly with regard to changes in vegetation over time.

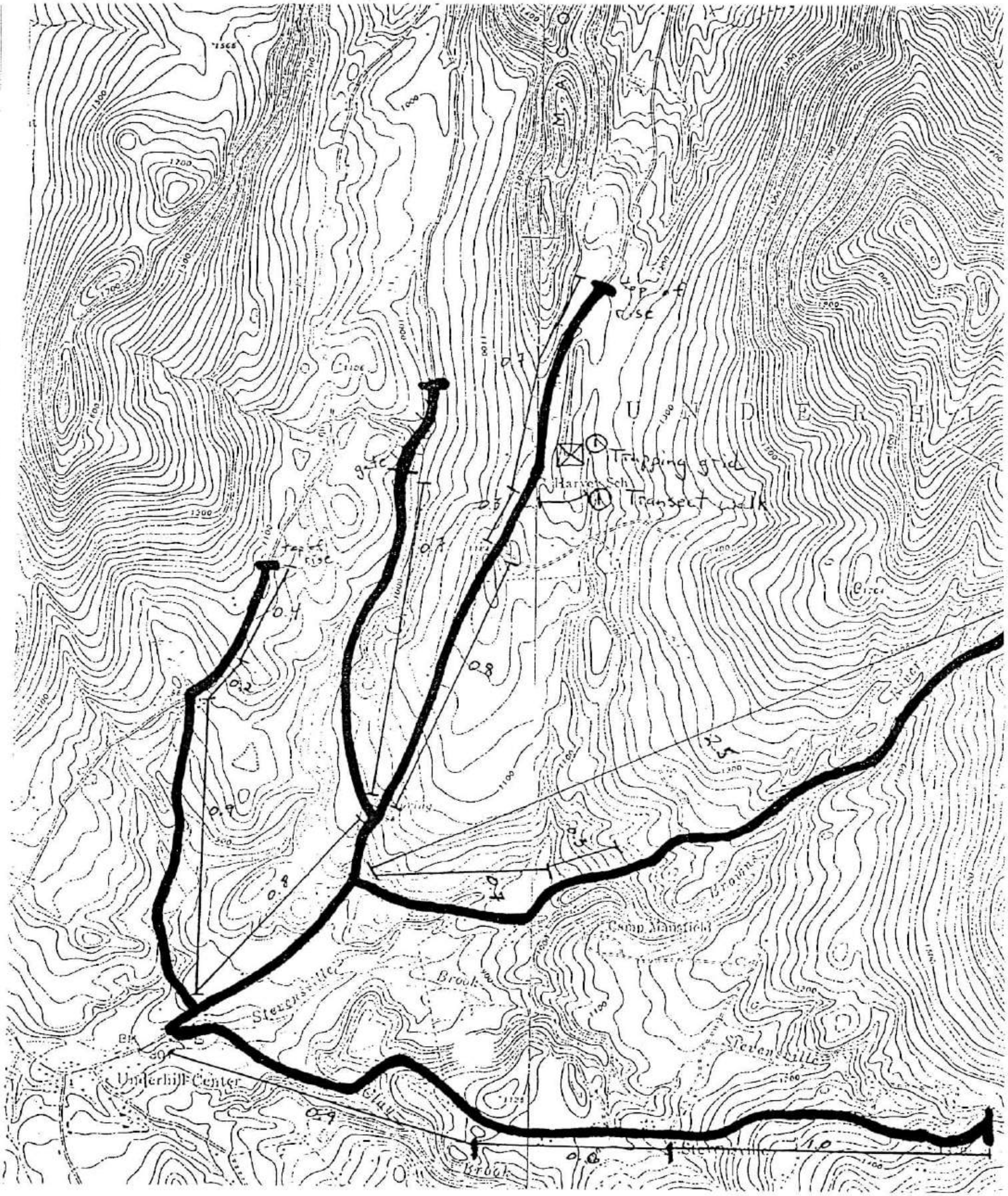

Figure 1. Map of lower portion of Brown's River drainage showing routes of road surveys, location of the 1200′ trapping grid, and route of 1200′ walking transect.

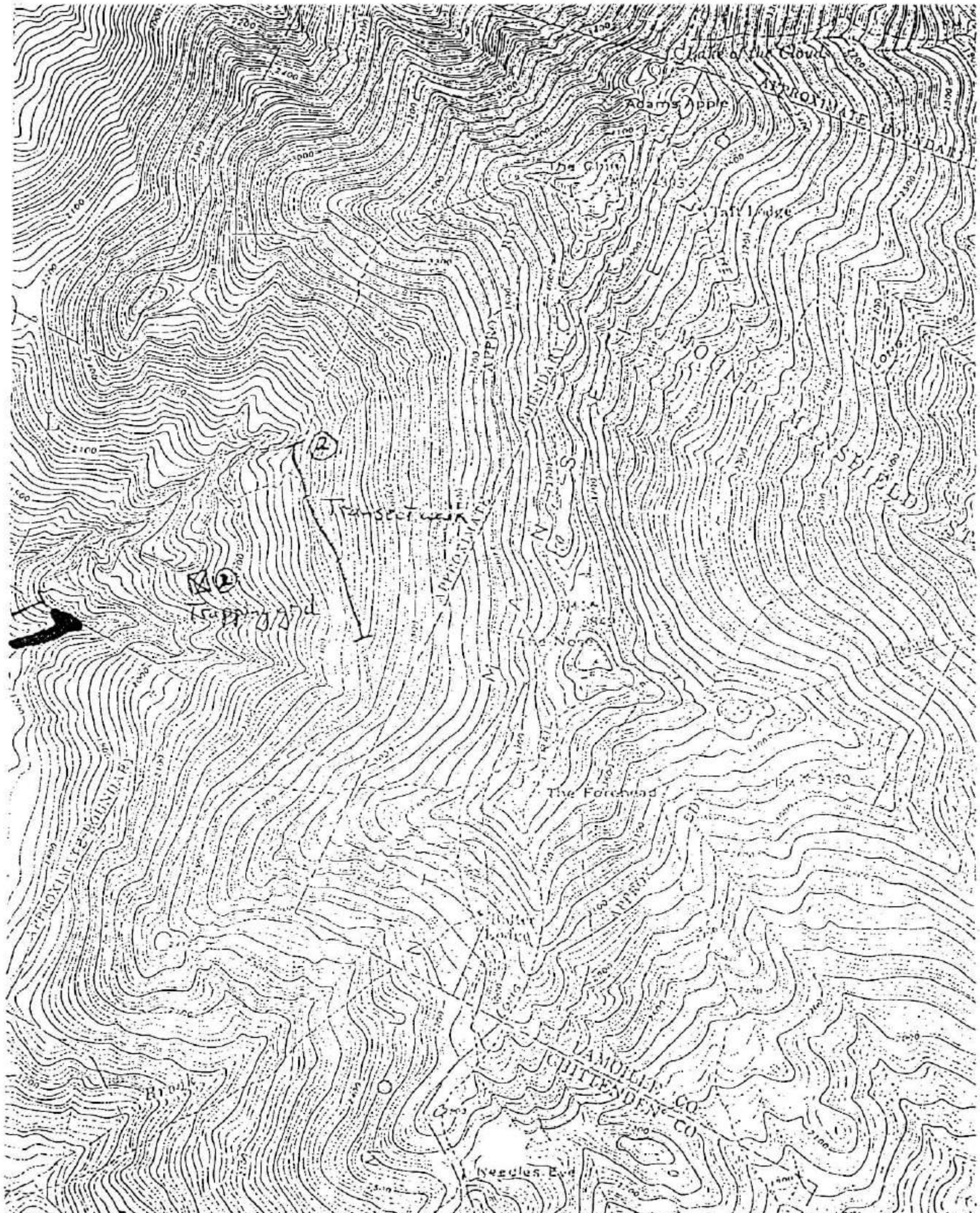

Figure 2. Map of upper portion of Brown's River drainage showing route of 2200′ walking transect and 2200′ trapping grid.

Table 1. Number of individuals of each species captured at 1200 feet and 2200 feet by pitfall traps and Sherman live traps during 1994.

	1200 feet		2200 feet	
	Pitfall	**Sherman**	**Pitfall**	**Sherman**
Peromyscus maniculatus	5	10	4	6
P. leucopus	5	7	2	7
Zapus hudsonicus	4	--	--	--
Napaeozapus insignis	1	--	3	1
Unidentified jumping mouse	13	--	2	--
Clethrionomys gapperi	2	1	1	--
Microtus pennsylvanicus	4	--	1	1
Unidentified vole	2	--	4	--
Sorex cinereus	32	1	35	--
Blarina brevicauda	9	10	6	10
Unidentified shrew	2	--	--	--
Unidentified mole	1	--	--	--

Table 2. Mammalian species observed on either transect walks or road surveys.

Species	Notes
Tamias striatus	Commonly observed on transect walks on ground at both elevations
Castor canadensis	Ad hoc observation; beaver activity noted along Harvey Brook during related field work
Erithozon dorsatum	Porcupine damage to trees noted at both elevations
Sylvilagus floridanus	Several noted on occasion feeding on the lawns of the Underhill State Park
Canis latrans	Scat noted on the transect walk at 2200 feet
Odocoileus virginianus	Individuals noted during road surveys

Table 3. Checklist of insectivores and rodents in Vermont, and their status on the west slope of Mt. Mansfield in the Vermont Monitoring Cooperative study area. Information current to Summer 1994.

Latin name	Common name	S[a]	C[b]
Sorex cinereus	Masked shrew	K	A
Sorex palustris	Water shrew	S	--
Sorex fumeus	Smokey shrew	S	--
Sorex dispar	Long-tailed shrew	S	--
Microsorex thompsoni	Thompson's pygmy shrew	S	--
Blarina brevicauda	Short-tailed shrew	K	A
Parascalops breweri	Hairy-tailed mole	S	--
Condylura cristata	Star-nosed mole	S	--
Tamias striatus	Eastern chipmunk	K	A
Marmota monax	Woodchuck	S	--
Sciurus carolinensis	Gray squirrel	S	--
Tamiasciurus hudsonicus	Red squirrel	S	--
Glaucomys volans	Southern flying squirrel	S	--
Glaucomys sabrinus	Northern flying squirrel	S	--
Castor canadensis	Beaver	K	O
Peromyscus maniculatus	Deer mouse	K	A
Peromyscus leucopus	White-footed mouse	K	A
Clethrionomys gapperi	Gapper's red-backed mouse	K	A
Microtus pennsylvanicus	Meadow vole	K	A
Microtus chrotorrhinus	Rock vole	S	--
Microtus pinetorum	Pine vole	S	--
Synaptomys cooperi	Southern bog lemming	S	--
Ondatra zibethicus	Muskrat	U	--
Mus musculus (I)	House mouse	S	--
Rattus rattus (I)	Black rat	S	--
Rattus norvegicus (I)	Norway rat	S	--
Zapus hudsonicus	Meadow jumping mouse	K	A
Napaeozapus insignus	Woodland jumping mouse	K	A
Erithizon dorsatum	Porcupine	K	O

a: status, based on field work in the VMC study area, on the known geographic distribution of mammals in Vermont, and the natural history of the species:

U = unlikely

K	=	known
S	=	suspected, based on published range maps

b: observed commonality at the VMC study area

A	=	abundant, present in most appropriate habitats and observed on most visits
LC	=	locally common, found regularly but in only a few areas
O	=	occasional, found uncommonly
R	=	rare, observed only once or twice

Total in Vermont =		29
At VMC site:	abundant	9
	locally common	0
	occasional	2
	rare	0

Table 4. Checklist of marsupials, chiropterans (bats), lagomorphs (rabbits and hares), carnivores, and artiodactyles (even-toed ungulates) in Vermont, and their status on the west slope of Mt. Mansfield in the Vermont Monitoring Cooperative study area. Information current to Summer 1994.

Latin name	**Common name**	**S[a]**
Didelphis virginiana	Virginia opossum	S
Myotis lucifugus	Little brown bat	S
Myotis septentrionalis	Northern long-eared bat	S
Myotis sodalis	Indiana bat	S
Myotis leibii	Eastern small-footed bat	S
Lasionycteris noctivagans	Silver-haired bat	S
Pipistrellus subflavus	Eastern pipistrelle	S
Eptesicus fuscus	Big brown bat	S
Lasiurus borealis	Eastern red bat	S
Lasiurus cinereus	Hoary bat	S
Sylvilagus floridanus (I)	Eastern cottontail	K
Sylvilagus transitionalis	New England cottontail	S
Lepus americanus	Snowshoe hare	S
Canis latrans	Coyote	K
Vulpes vulpes	Red fox	S
Urocyon cinereoargenteus	Gray fox	S
Ursus americanus	Black bear	S
Procyon lotor	Raccoon	S
Mustela erminea	Ermine	S
Mustela frenata	Long-tailed weasel	S
Mustela vison	Mink	S
Martes pennanti	Fisher	S
Martes americana	Marten	S
Mephitus mephitus	Stripped skunk	S
Lutra canadensis	River otter	U
Lynx rufus	Bobcat	S
Lynx canadensis	Lynx	U
Felis concolor (E?)	Mountain lion	U
Odocoileus virginianus	White-tailed deer	K
Alces alces	Moose	S

a: status, based on field work, known geographic distribution of mammals in Vermont, and the natural history of the species:

- U = unlikely
- K = known
- S = suspected, based on published range maps
- R = rare, observed only once or twice

Total in Vermont = 30
Known at VMC site = 3

Terrestrial Flora

ANNUAL ASSESSMENT OF FOREST HEALTH IN THE LYE BROOK WILDERNESS AREA 1994

Vermont Department of Forests, Parks and Recreation
Sandra H. Wilmot

Cooperators

Brent Teillon, Jay Lackey, and Ron Wells, Department of Forests, Parks and Recreation; and Susan Cox, USDA Forest Service-Forest Health Protection, Durham, NH.

Abstract

Forest health monitoring plots were established in the Lye Brook Wilderness Area, in the towns of Manchester, Sunderland and Winhall, Vermont. The design and measurements used are the same as in the National Forest Health Monitoring Program (NFHM), and one of the plots was previously established (1990) as part of that network. General measurements include: site characterization, mensuration, crown condition and damage. Tree condition measurements include crown dieback, density, live crown ration, crown width, and foliage transparency.

Most tree species at both elevations were in a healthy condition ($\leq$ 15% dieback). The exception was dominant and codominant yellow birch trees, where 26.7% of trees had more than 15% dieback. Black cherry at 1400' and red maple at 2200' had thin crowns. Black cherry is known to shed it's leaves when injured, so this may be one reason for the high transparency ratings on this species.

Paper birch, yellow birch and black cherry had high numbers of standing dead trees, 25, 11.1 and 9.1% respectively. Live paper birch trees seem to have recovered from past stresses, as is reflected in low dieback, high density and normal transparency ratings. Yellow birch and black cherry may still be in decline.

Introduction

Annual assessments of crown condition, mortality, and damage are conducted on permanent plots located at two elevations. The purpose of these plots is to document changes in tree health over time and will aid in the identification of causes for declines, if they occur.

Materials and Methods

Four long-term monitoring plots using the design and measurement variables of the National Forest Health Monitoring Program (NFHM) are used to represent forest health in the Lye Brook Wilderness Area (Tallent-Halsell, N.G. 1994). In 1990, one plot was established at 2300′ as part of the NFHM Program grid. One additional plot at the same elevation and 2 plots at 1400′ were established in 1994. These paired plots at these elevations were chosen to make them comparable to plots on Mt. Mansfield, the other VMC study site.

Results and Discussion

Most overstory tree species in the Lye Brook Wilderness area plots were in a healthy condition in 1994 ($\leq$ 15% dieback). Only 83.3% of yellow birch trees had less than or equal to 15% dieback. Average dieback for all tree species was low compared to other Vermont locations. High transparency ratings were observed for black cherry and red maple growing in plots at 2200′. Since black cherry is known to drop injured leaves, a high transparency rating may indicate the presence of an earlier season insect, disease, weather or air pollution foliage damage.

When all crown classes of trees are used, again most trees are generally healthy, with yellow birch and beech being the exception, 75 and 80% of trees healthy, respectively. Poor transparency ratings are consistent on black cherry and red maple at 2200′. High numbers of dead trees are recorded for paper birch, yellow birch and black cherry. Paper birch seems to have experienced a previous stress responsible for tree mortality, but current condition of trees is good as indicated by low dieback, high density and normal transparency ratings. Yellow birch and black cherry seem to remain in decline on these plots. Indicators of decay were present on many of the yellow birch boles, an added sign of poor health. The black cherry trees had very small crowns, with average crown ratios of 33%.

No clear differences occurred in tree condition between the two elevations. A higher diversity of tree species was present in the 1400′ plots as compared with the 2200′ plots, 11 and 5 species, respectively.

Figure 1. Crown condition measurements for overstory trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area for 1994.

Species	Elevation	Dieback (%)	Transparency (%)	Density (%)	Healthy (%)
Balsam Fir	2200	1.0	18.3	48.3	100
Black Cherry	1400	6.7	25.6	45	100
Paper Birch	1400	3.3	15.6	58.3	100
Red Maple	1400	3.8	14.2	55.2	98.4
	2200	6.0	20.8	47.2	100
Red Spruce	2200	1.1	16.6	51.1	100
Yellow Birch	1400	6.7	19.2	49.2	83.3
All Species	1400	5.2	17.0	53.0	94.6
	2200	3.4	18.9	48.4	100

Healthy = trees with $\leq$ 15% dieback

Figure 2. Tree condition measurements for all crown classes of trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area for 1994.

Species	Elevation	Dieback (%)	Transparency (%)	Density (%)	Healthy (%)	Dead (%)
Balsam Fir	2200	1.2	18.8	46.6	100	2.9
Beech	1400	8.5	15.5	50	80	0
Black Cherry	1400	6.5	24.5	45	100	9.1
Paper Birch	1400	3.3	15.6	58.3	100	25.0
Red Maple	1400	3.6	14.2	55.2	98.5	1.5
	2200	6.6	20.7	44.9	100	2.6
Red Spruce	2200	1.4	17.9	47.1	100	5.4
Sweet Birch	1400	1.2	15	55	100	0
Yellow Birch	1400	9.4	18.2	45	75	11.1
All Species	1400	5.0	16.6	52.5	94.6	8.7
	2200	3.4	19.1	46.3	100	7.8

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ANNUAL ASSESSMENT OF FOREST HEALTH ON MOUNT MANSFIELD 1994

Vermont Department of Forests, Parks and Recreation
Sandra H. Wilmot

Cooperators

H. Brenton Teillon, Thomas Simmons, Pete Reed, Bernard Barton, Jay Lackey, Bradley Greenough, and Ronald Wells, Vermont Forestry Division; and the North American Maple Project.

Abstract

Forest health is monitored annually using two different methods. One plot-cluster of the North American Maple Project (NAMP) monitors trends in the condition of sugar maple at an elevation of 415 m (1360'). Site characterization, crown condition, and bole and crown damage are measured. In addition, 8 plots have been established following the design and measurement variables of the National Forest Health Monitoring Program. These are located on the west slope of the mountain along an elevation gradient, with pairs at 1400, 2200, 3000 and 3800 feet. Measurements taken on these plots are used to determine current tree health and to create a baseline for long-term monitoring.

NAMP data on sugar maple condition has been recorded since 1988 and shows a general improvement from 1988 to 1989, then a stable and generally healthy condition thereafter. In 1994, 95.8% of trees were considered healthy (≤ 15% dieback), average dieback was 7.6%, transparency of foliage was 10.4, and no new mortality was observed. Denser foliage can be attributed to a reduction in pear thrips defoliation from 1993 and generally favorable growing conditions. Light defoliation on lower canopy foliage was observed from Bruce spanworm feeding.

Tree health data from the other forest health plots also showed an improvement or stable condition of most dominant or codominant trees. Exceptions were seen in balsam fir trees at 3000' and sugar maple at 2200' elevations, which both have shown a trend towards increasing dieback over the last 3 years. Most of these trees, however, had less that 15% dieback, as reflected in the 92 and 86% of trees considered healthy, respectively. Noteworthy is a trend in improving condition of red spruce in the 3000' elevation plots since 1992.

Introduction

Annual assessments of crown condition, mortality, and damage are conducted on permanent plots located at four elevations. The purpose of these plots is to document changes in tree health over time and will aid in the identification of causes for declines, if they occur.

Two types of plots are used: one plot at low elevations is part of the North American Maple Project (NAMP) plot system, 8 additional plots use the design and measurement variables of the National Forest Health Monitoring Program (NFHM).

NAMP Plot Methods

Plot establishment, site characterization and annual tree evaluations follow standardized NAMP protocols (Millers et al, 1991). Annual evaluations of tree condition and foliage damage require two - three visits to the plot to determine extent of injury from early-, mid-, and late-season defoliators: one in mid-to-late June, July, and early September. Evaluators are trained and certified with other state and provincial field crews to maintain high Quality Control. Between-crew and between-state remeasurements are done on 12 % of the plot-clusters and with each field crew. Data entry is completed in-state, and statewide data is acquired following quality check by the NAMP data analyst at SUNY in Syracuse, NY. Metric units are used for data collection and analysis.

NAMP Plot Results and Discussion

Sugar maple tree health continued to be good in 1994, with 95.8% of trees considered healthy ($\leq$ 15% dieback) (Table 1). Average dieback and transparency were slightly better in 1994 than in the previous 2 years. No new mortality occurred.

Denser foliage in 1994 may be attributed to a lack of pear thrips defoliation, as observed in 1993, and generally good growing conditions. Some defoliation from Bruce spanworm was observed on lower canopy foliage of sugar maples. An abundance of flowers were observed in the spring, but no significant seed production followed.

YEAR	DIEBACK (%)	TRANSPARENCY (%)	MORTALITY (%)	% HEALTHY TREES
1988	11.3	27.3	0	88.6
1989	7.1	23.0	0	91.4
1990	7.6	14.0	0	91.4
1991	3.0	10.9	0	97.1
1992	8.1	14.3	0	94.3
1993	8.2	14.3	0	91.5
1994	7.6	10.4	0	95.8

Table 1. Tree health results for the NAMP plot at 415 m (1360 ft) at the Proctor Maple Research Center, Mount Mansfield, Vermont. Average crown dieback, average foliage transparency (the amount of light coming through the foliated portions of the crown), mortality, and percent of trees healthy are all used to assess the health of dominant and codominant sugar maple trees in this plot.

Forest Health Plot Methods

Eight permanent plots are used to monitor the health of forests on the west slope of Mount Mansfield. Two plots at each of four elevations (1400, 2200, 3000 and 3800 feet) were established following the design and measurement variables of the NFHM program (Tallent-Halsell 1994). At each elevation, except 3800 ft, one plot is located in each of the two watersheds: Browns River and Stevensville Brook. In the Stevensville Brook watershed, no canopy trees were present at the 3800 foot elevation, so both plots at this elevation are in the Browns River watershed. English units are used for data collection and analysis.

Forest Health Plot Results and Discussion

A stable or improving trend in tree condition occurred for most species in 1994 (Table 2a & 2b). Noteworthy is that red spruce at 3000 foot elevation has shown a trend towards improving condition over the last 3 years as indicated by decreasing average dieback (Table 2a). Conversely, balsam fir at 3000' and sugar maple at 2200' have shown an increase in average dieback over the same period. Most of these trees, however, had less than 15% dieback, as reflected in the 92% and 86% of trees considered healthy, respectively (Table 2b).

Table 2a. Average dieback for overstory trees of species growing on monitoring plots at different elevations on Mt. Mansfield from 1992 through 1994.

SPECIES	ELEVATION	1992 DIEBACK (%)	1993 DIEBACK (%)	1994 DIEBACK (%)
BALSAM FIR	3000	5.6	6.8	8.2
	3800	18.8	20.5	20.3
RED SPRUCE	3000	15.6	11.1	7.1
RED MAPLE	1400	3.0	6.0	4.0
SUGAR MAPLE	1400	4.2	5.6	5.6
	2200	8.3	10.8	12.9
YELLOW BIRCH	1400	5.7	5.7	4.3
	2200	6.6	7.1	5.4
PAPER BIRCH	3000	9.6	8.4	6.1
ALL SPECIES	1400	5.3	6.1	5.4
	2200	8.6	9.4	8.3
	3000	9.0	8.4	9.2
	3800	18.8	20.2	20.7

Table 2b. The percentage of overstory trees of different species growing at different elevations on Mt. Mansfield that are considered healthy ($\leq$ 15% dieback) over a 3 year period, 1992 through 1994.

SPECIES	ELEVATION	1992 HEALTHY (%)	1993 HEALTHY (%)	1994 HEALTHY (%)
BALSAM FIR	3000	100	91.3	92
	3800	54.0	60.6	57
RED SPRUCE	3000	66.7	77.8	100
RED MAPLE	1400	100	100	100
SUGAR MAPLE	1400	100	100	100
	2200	83.3	100	86
YELLOW BIRCH	1400	100	100	100
	2200	94.7	94.7	100
PAPER BIRCH	3000	88.5	83.3	97
ALL SPECIES	1400	97.0	100	100
	2200	90.6	90.6	97
	3000	89.8	88.5	92
	3800	54.0	60.6	57

Data from 1992-1994 was combined to generate a baseline of tree condition on Mt. Mansfield (Figure 1-3). From this we will compare annual changes in tree condition and look at differences between elevations in measurements of tree health.

Tree health at 3800 feet continues to be a concern because of extremely high average dieback (20.3% in 1994) and only 57% of trees in a healthy condition (Table 2a &2b). When 3 years of data are combined, there is a statistically significant difference between average dieback at 3800 and all other elevations.

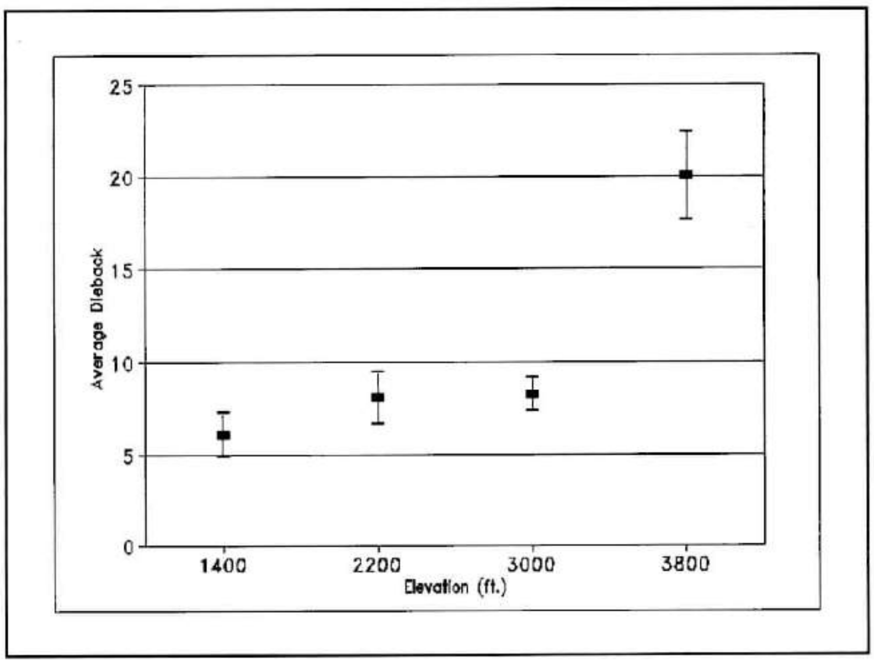

Figure 1. Average dieback of trees growing on monitoring plots at 4 elevations on Mt. Mansfield, 1992 through 1994. Trees at 3800' had significantly higher average dieback than at other elevations.

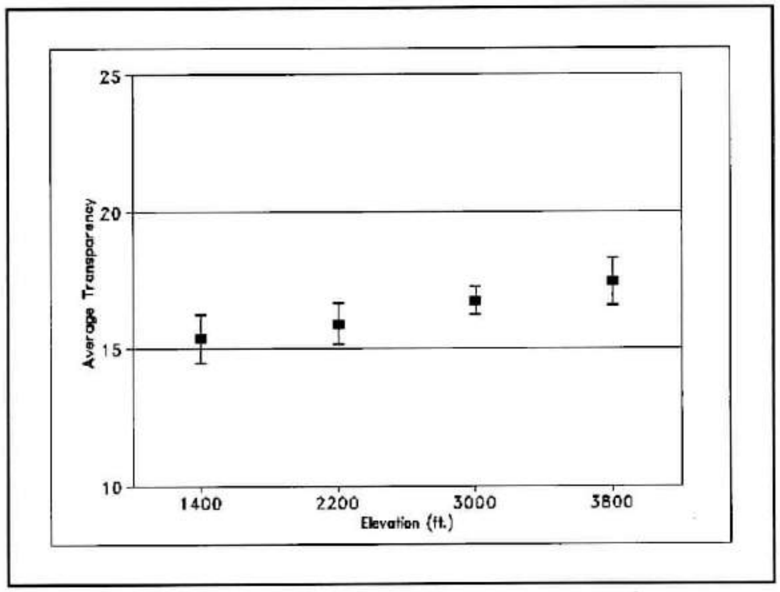

Figure 2. Average transparency of trees growing at different elevations on Mt. Mansfield, 1992-1994. There is no significant difference between transparency of trees at different elevations.

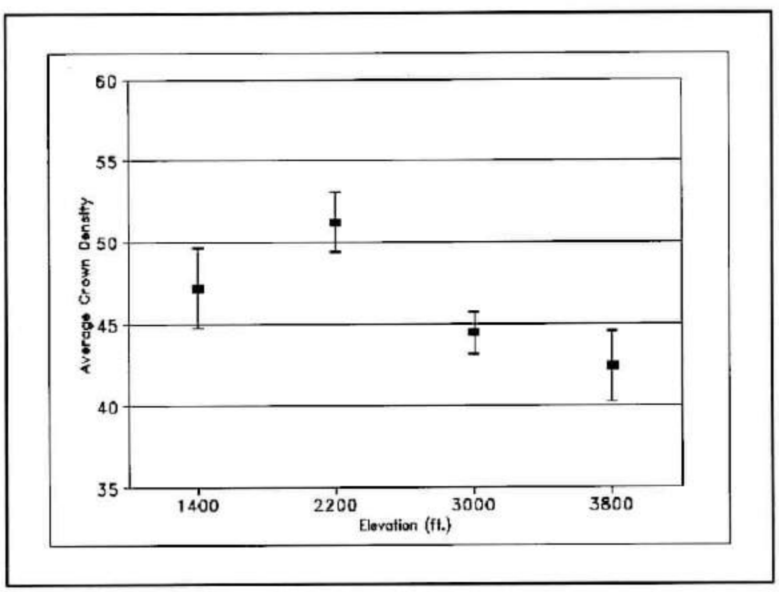

Figure 3. Average density of tree crowns on trees growing at different elevations on Mt. Mansfield, 1992 - 1994. Trees at 2200 feet have denser crowns than those growing at 3000 and 3800 feet.

Another measure of tree health, foliage transparency (how much light comes through the foliage), does not show a significant difference between trees at different elevations. Crown density is a measure of the density of the crown in terms of foliage, branches, and reproductive structures, and can be an indication of a lack of branches, dieback, or thin foliage. This measure showed no significant difference between trees at 1400 and 2200 foot elevations, but trees growing at 3000 and 3800 feet had significantly less dense crowns than those at 2200 feet. Some of this may be accounted for in the difference in tree species grow at these elevations. This will serve as a baseline to measure changes within and between elevations over time.

No new mortality occurred in plots at 1400, 2200, and 3000'. One balsam fir tree at 3800' with a previous dieback rating of 85% died in 1994, resulting in a 1.4% mortality rate at this elevation.

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Millers, I., D. Lachance, W. Burkman & D. Allen. 1991. North American Sugar Maple Decline Project: organization and field methods. Gen. Tech. Rep NE-154. Radnor, PA: U.S. Dept. of Agr., Forest Service, Northeastern Forest Experiment Sta. 26 p.

Tallent-Halsell, N.G. (ed.). 1994. Forest Health Monitoring 1994 Field Methods Guide. EPA/620/R-94/027. U. S. Environmental Protection Agency, Washington, D.C.

FOREST PEST MONITORING ON MOUNT MANSFIELD

Sandra Wilmot, Thomas Simmons and Trish Hanson
Vermont Department of Forests, Parks & Recreation

ABSTRACT

The forest on Mount Mansfield is monitored annually to detect changes in populations of major insect pests and to document the incidence of damage from insects, diseases, weather or air pollution. Techniques used include pheromone trapping of adult insects, damage assessments on individual trees, aerial surveys to detect damaged forested areas, and use of plant species sensitive to ozone injury.

Population levels of four of the six major insect pests monitored on Mount Mansfield decreased to or maintained a low population level in 1994. Spruce budworm adults trapped increased from 1993 levels. This trend was seen at other Vermont locations, but is not believed to represent the start of an outbreak since numbers are still relatively low, no defoliation has been observed, and the population cycle is 40 years between outbreaks (last outbreak in the early 1980's). Fall hemlock looper populations at low elevations (1400') rose slightly from 1993, but remained well below levels recorded in 1992. No defoliation was observed.

Light damage to sugar maple from Bruce spanworm and maple leaf cutter was visible but not serious. Ozone injury was detected on one of three bioindicator plant species (milkweed), with the severity of injury recorded as light, 1 on a scale of 0-5.

Areas of moderate and heavy dieback were mapped from aerial surveys. These correspond to areas of recent logging on private lands (northern area in Browns River watershed) and state lands mainly in the Clay Brook watershed south of the Stevensville Brook watershed.

INTRODUCTION

Damage to forest trees from insects, diseases and weather has played a major role in widespread tree declines in the past. Monitoring pest populations and tree damage is conducted annually on a statewide basis to understand trends in the occurrence of stress agents in relation to forest health. More recently, concerns about the role of air pollutants in forest health have prompted monitoring of injury to sensitive plants from ground level ozone.

Our objective, therefore, is to monitor trends in the populations of major insect pests, and to document the occurrence of damage to the forests on Mount Mansfield from any detectable stress agents.

METHODS

There are many different methods for measuring forest pest populations. Some forest pests do not yet have reliable, meaningful survey methods developed. At present, the forest pests monitored on Mount Mansfield include: pear thrips (PT), gypsy moth (GM), forest tent caterpillar (FTC), spring hemlock looper (SHL), fall hemlock looper (FHL) and spruce budworm (SBW). Defoliation is monitored on ground plots and from the air.

FOREST TENT CATERPILLAR, SPRING AND FALL HEMLOCK LOOPER, AND SPRUCE BUDWORM

These pests are monitored using pheromone traps [multipher traps with a biolure and a vaportape insecticide], which attract male moths during their flight period, indicating relative population levels in the area. FTC trapping is done using a 5 trap cluster in northern hardwood stands. Spring and fall hemlock looper trapping uses 1 trap per site placed in hemlock or balsam fir stands. SBW trapping uses a 3 trap cluster placed in spruce and fir stands. Protocols for these surveys is in accordance with that of other statewide surveys for these pests (Teillon et al, 1994).

Each trap type is deployed during the adult moth flight period. FTC traps are active between June 26 and August 15. SHL traps are placed out between May 19 and July 29. FHL catches are made from August 31 to October 31. SBW traps are deployed between June 22 and August 12. Trap catches are returned to the VT FPR Laboratory in Waterbury for identification and counting of target and non-target species.

PEAR THRIPS

PT are a relatively new pest to Vermont sugar maple trees, and therefore lack the depth of understanding in relating trap catches to population densities and subsequent damage. At present 2 different population assessment methods are in use for monitoring this pest: soil samples for fall and winter population estimates and yellow sticky traps for adult population estimates and flight period. Both methods are used at the PMRC [1360 ft. (415 m) elevation].

Soil samples are collected annually in the fall to estimate the overwintering pear thrips population. Field and laboratory protocols previously established for statewide and regional PT surveys are used (Parker et al, 1990). Basically, 5 sugar maple trees were identified in 1988 as reference points for soil sampling, using a bulb planter collecting tool, and resultant damage assessments.

Yellow sticky traps are used to monitor the timing and duration of adult PT activity above ground, as well as to monitor trends in adult populations over time. Standard protocols were developed under the CAPS program (Cooperative Agricultural Pest Survey Program) and consisted of placement of 4 yellow sticky traps at a 1-m height off the ground in the vicinity of 8 sugar maple trees to be used for monitoring bud phenology and PT damage. Weekly trap collections are made from April 1 through June 13, with trap catch counts verified by VT FPR Laboratory staff.

GYPSY MOTH

A gypsy moth population monitoring plot is used to monitor trends in GM egg masses counts over time. This plot is located in a small stand of quaking aspen, a preferred host of the GM. Protocols for this survey follow standards used in other Vermont GM focal areas. Burlap bands placed at DBH on live trees within a 1/5th acre plot attract egg bearing females, who tend to lay their egg masses under or near the burlap. Counts of egg masses in the fall are used to estimate the resident population.

AERIAL SURVEY OF FOREST DAMAGE

Aerial surveying of the mountain is conducted by trained FPR staff during the summer months. The purpose is to detect areas of defoliation, discoloration, heavy dieback or mortality, and determine the cause of this injury, if possible. Two observers sketch damaged areas onto topographic maps, indicate possible cause, then later conduct ground surveys to verify location, extent, and possible cause of injury. Procedures are standardized statewide and remeasurement is conducted on 10% of the area evaluated (Teillon et al, 1994).

OZONE BIOINDICATOR PLANTS

Plants sensitive to ground level ozone are monitored throughout the growing season as part of the National Forest Health Monitoring Program (Tallent-Halsell 1994). During the period of maximum exposure, August 7-23, 30 individuals of each sensitive species growing naturally in large openings are examined for symptoms of ozone injury. These include milkweed, black cherry and blackberry. Symptoms are verified by a regional expert in ozone injury identification as part of the NFHM.

RESULTS AND DISCUSSION

Four of the six major insect pest populations monitored on Mount Mansfield decreased to or maintained a low population level in 1994 (Table 1 & 2).

Pheromone traps failed to catch any FTC or SHL adults at any of the elevations, and no gypsy moth egg masses were observed in monitoring plot this year.

FHL populations at the 1400 and 2200' elevations increased in 1994, but were still below levels trapped in 1992. Populations at the top of the mountain remained low. No defoliation was observed on hemlock at any of the elevations.

SBW adults trapped also increased, and were the highest numbers recorded in the four years at these sites, at the population levels recorded at Mount Mansfield are higher than any of the other monitoring sites in the state. No defoliation was observed. These population levels are not believed to represent the start of an outbreak since numbers are still relatively low, no defoliation has been observed, and the population cycle is 40 years between outbreaks (last outbreak in the early 1980's).

PT populations were dramatically lower in 1994, with no insects recovered from soil samples, and only 4 adults trapped during the flight period. No defoliation was observed.

Other pests present and causing light defoliation included Bruce spanworm and maple leaf cutter. Both pests feed on sugar maple. Defoliation in scattered trees was moderate to lower foliage, but overall, only light defoliation occurred.

Ground level ozone caused detectable symptoms on sensitive plants (milkweed) growing in large openings at the Proctor Maple Research Center (Figure 1). Purple stipples rated as severity 1 (on a scale of 0 - 5)occurred on about 30% of the milkweeds observed during August. Drought conditions early in the summer probably reduced plant uptake of ozone, therefore avoiding extensive injury to plants. No damage from ozone was observed to trees at the Mount Mansfield site.

Moderate dieback in the northern part of the Browns River watershed was mapped from the air (Figure 2). This corresponds to previously mapped areas with thin crowns as a result of recent logging on privately owned lands. Also recorded was heavy dieback in the southern part of the Stevensville Brook watershed, adjacent to areas on State Lands logged in the past 5 years. No other damages were recorded from aerial surveys in June and August.

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Teillon, H.B., B.S. Burns and R.S. Kelley. 1994. Forest Insect and Disease Conditions in Vermont - 1994. Agency of Natural Resources, Dept. of Forests, Parks and Recreation, 103 So. Main St., Waterbury, VT 05671-0602. 132 pp.

Table 1. Survey results on six forest pests monitored on Mount Mansfield from 1991 to 1994. Results are in average population counted unless otherwise indicated. Blanks for 1991 indicate pests and elevations not included in the survey for that year.

TARGET PEST	SURVEY TYPE	ELEV.	1991	1992	1993	1994
Forest Tent Caterpillar	Pheromone traps	1400′	0	0	0	0
		2200′		0	0	0
		3800′		0	0	0
Spring Hemlock Looper	Pheromone traps	1400′		0	0	0
		2200′		0	0	0
		3800′		-	0	0
Fall Hemlock Looper	Pheromone traps	1400′		325	80	123
		2200′		521	-	133
		3800′		41	0	0
Spruce Budworm	Pheromone traps	1400′	19.7	29.0	16.0	53.0
		2200′		5.0	6.3	16.0
		3800′		2.3	1.7	18.7
Gypsy Moth	Burlap banded trees	1400′	3 e.m.	4 e.m.	1 e.m.	0 e.m.
Pear Thrips	Adult sticky traps	1400′	8	313	1472	4

e.m. = egg masses

Table 2. **Pear thrips soil populations and resulting damage to sugar maple foliage at 1400′ on Mount Mansfield from 1989 through 1994. Soil populations are recorded in units of pear thrips per bulb planter of soil to allow comparison between other Vermont sites.**

YEAR	SOIL POPULATION	RESULTING DAMAGE AFFECTING:				
		TREES			SAPLINGS	SEEDLING
		GENERAL DAMAGE RATING	DIEBACK	TRANS-PARENCY	GENERAL DAMAGE RATING	GENERAL DAMAGE RATING
1989	17.5	LIGHT			MOD.	---
1990	10.6	LIGHT			LIGHT	LIGHT
1991	0.6	LIGHT	15.0	17.0	LIGHT	LIGHT
1992	0.8	LIGHT	12.0	9.0	LIGHT	LIGHT
1993	8.1	LIGHT	22.0	19.0	MOD.	LIGHT
1994	0	NONE	6.0	11.0	NONE	NONE

Soil Population based on average number of thrips in 10 bulb planter sized samples
Light Damage = 1-30 % of leaves affected; Moderate Damage = 31-60 % of leaves affected
Dieback = average % of recently dead branches; Transparency = average % of light coming through the foliage

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Figure 1. Cumulative weekly ozone levels above 60 ppb from April through September compared with injury observed on sensitive plant species. Northern Vermont site = Underhill, southern Vermont site = Bennington & Rupert, Vermont, 1994.

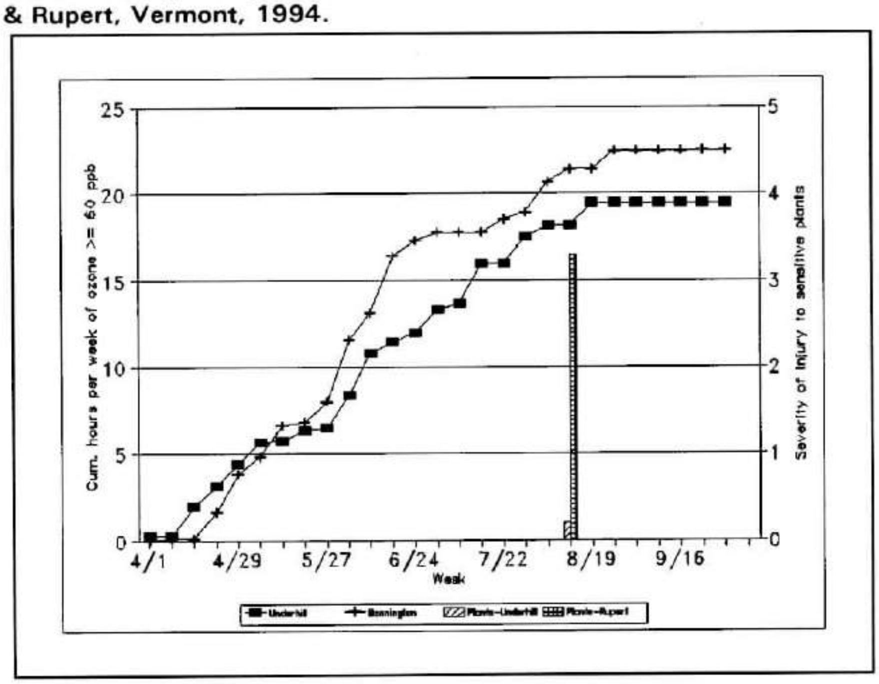
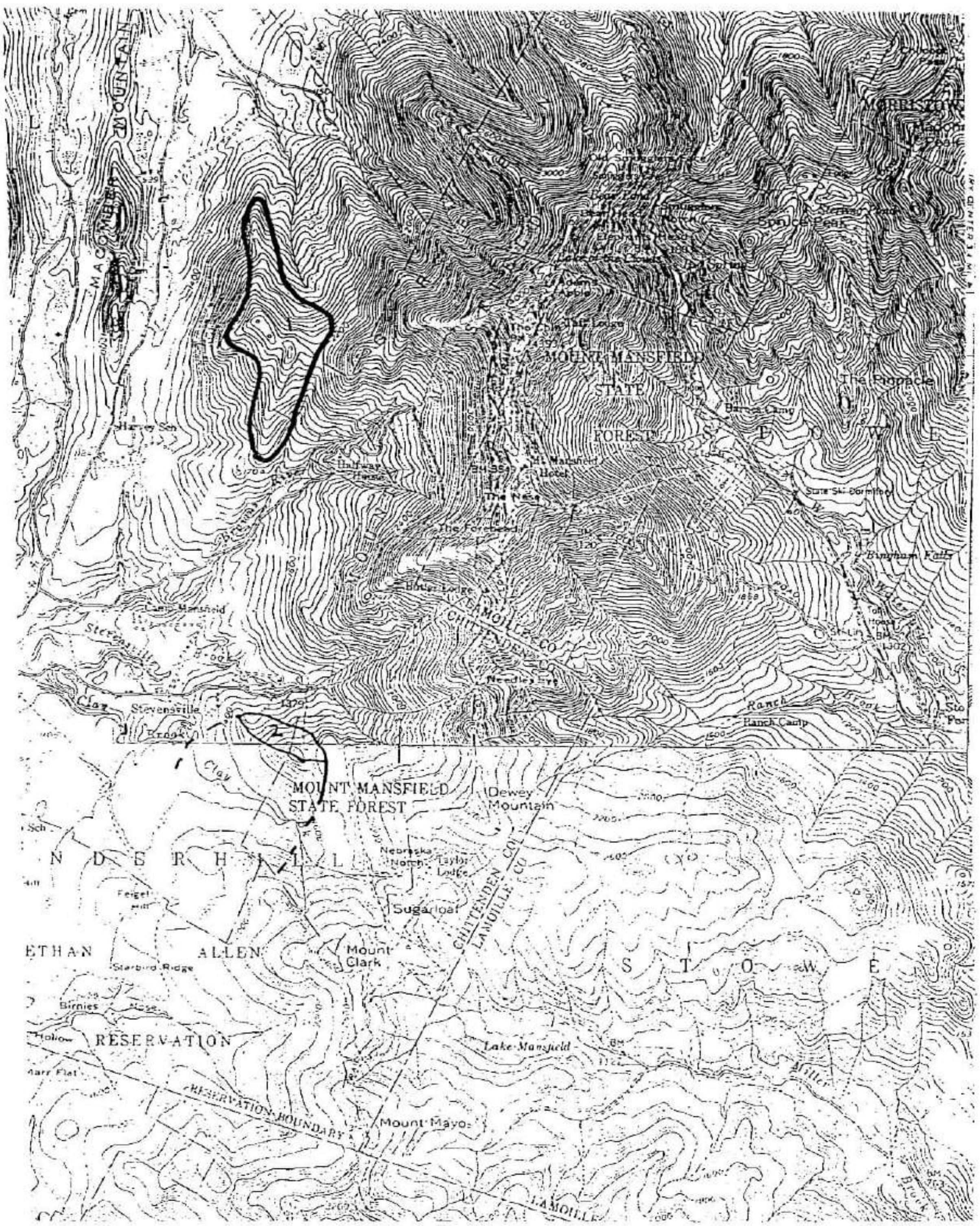


Figure 2. Forest Damage Mapped on Mt. Mansfield, 1994.



Damage 1 = Moderate dieback Damage 2 = Heavy dieback
Dotted line indicates that damage extends to adjacent watershed.

LICHENS AND AIR QUALITY

IN

LYE BROOK WILDERNESS

OF THE

GREEN MOUNTAIN NATIONAL FOREST

Excerpts from the Final Report

Prepared for

United States Department of Agriculture - Forest Service

Green Mountain National Forest

and

Northeastern Area State and Private Forestry

Forest Health Protection

Contract 42-649

by

Clifford M. Wetmore
Plant Biology Department
University of Minnesota
St. Paul, Minnesota 55108

March 1995

PREFACE

Under a contract from the USDA National Forest Service a lichen study was performed in the Lye Brook Wilderness Area (LBW) of the Green Mountain National Forest. The objectives were to survey the lichens of the wilderness area, produce an inventory of the lichen flora, collect and analyze lichens for chemical contents, and evaluate the lichen flora with reference to the air quality. This establishes baseline data to determine the future change in air quality. All work was done at the University of Minnesota with consultation with Mr. Manfred Mielke, and with personnel on the Forest.

The Forest Service personnel have been very helpful during the field work which has contributed significantly to the success of the project. The study was made possible by funds from the U. S. Forest Service, Green Mountain National Forest and NAS & PF Forest Health Protection. Dave Rugg, statistician with the NCFES did the statistical analysis. I would especially like to acknowledge the able assistance of Zhenfan Wang in the field and the laboratory. The assistance of all of these is gratefully acknowledged.

ABSTRACT

This study of the lichens of the Lye Brook Wilderness was designed 1) to collect lichens for a lichen species list, 2) to collect lichens for elemental analysis, 3) to study the health and distributions of species most sensitive to air pollution, and 4) to assess the effects of air quality on lichens. Eighteen localities were studied throughout the wilderness. Samples of three species were collected at four localities for elemental analysis.

The lichen flora is quite diverse. There were 126 species present including six species very sensitive to sulfur dioxide. The distributions of these sensitive species do not show patterns that would suggest directional air quality problems. All of the lichens found were in good health and with normal fertility. The lichens studied by elemental analysis show levels of all elements comparable to other clean areas. ANOVA analysis showed higher levels of thallus accumulation in LBW than in White Mt. Wilderness areas for the 1993 data. There seem to be no indications of threatening air quality problems (mainly sulfur dioxide) in the wilderness.

Recommendations are for periodic (5 year) restudy of the lichens by elemental analysis. A complete lichen restudy of the lichen flora should be done every 10-15 years. If construction or maintenance activities are planned within the wilderness, a lichenologist should be consulted to prevent loss of species.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so they must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by levels of sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13 μg/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 μg/cubic meter (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates.

Contrary to some published reports (Medlin, 1985) there is little evidence that most lichens are good indicators of acid precipitation. However, Sigal & Johnston (1986) have reported that one species of Umbilicaria shows visible damage due to artificial acid rain. They also report that similar symptoms were found in collections from various localities in North America. Lechowicz (1987) reported that acid rain only slightly reduced growth of Cladina stellaris but Hutchinson et al. (1986) reported that extremely acid precipitation (less than pH 3.5) killed or damaged some mosses and lichens. Scott & Hutchinson (1987) showed temporary reduction of photosynthesis in Cladina stellaris and C. rangiferina after artificial acid rain.

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air, and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

The Lye Brook Wilderness (LBW) is about 15,680 acres and is located in southern Vermont, about 20 miles north of Bennington. The wilderness is fairly steep and mountainous with some small lakes and streams. The elevations range from 900 to 2880 ft. The ridgetops have red spruce (Picea rubens) mixed with sugar maple (Acer saccharum), birch (Betula). Some of the hillsides have hemlock (Tsuga canadensis), beech (Fagus grandifolia) and sugar maple. In the low and wet areas there are some balsam for (Abies balsamea) and white ash (Fraxinus americana) and red maple (Acer rubrum). Rock outcrops are frequent on the ridges and hillsides and some of low areas have bogs. The Burning is an area that is quite different. It is a large area on the ridge that was burned around 1900 and is now heath with scattered red spruce with some white pines (Pinus strobus).

Most of the forest had been extensively logged prior to 1960 with only limited logging since. The last area to be logged was around Kelly Stand.

There probably has been no lichen collecting in the wilderness prior to this study and no literature references to lichen collections from the wilderness have been found.

METHODS

Field work was done during late July and August, 1993 when 565 collections were made at 18 localities. A complete list of collection localities is given in Appendix I and these are indicated on Fig. 1. Collection localities, about 2 acres in size, were selected first to give a general coverage of the wilderness, second, to sample all vegetational types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats (such as old logging roadsides and trails) were studied. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens. Lichen health was evaluated by looking for damaged or dying lichens on all of the trees where collections were made (at least 100 trees). The presence of many dead, dying, or abnormal thalli of particular species at a locality would indicate poor health, but an occasional damaged thallus is not significant.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium. All specimens deposited at the University of Minnesota have been entered into the herbarium computerized data base maintained there.

LICHEN FLORA

The following list of lichens is based on my collections. Species found only once are indicated by "Rare". In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983): S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50 μg per cubic meter. The Intermediate category includes those species present between 50 and 100 μg and those in the Tolerant category are present at over 100 μg per cubic meter. Those species without sensitivity designations have unknown sensitivity.

SPECIES LIST

I Alectoria sarmentosa (Ach.) Ach. :RARE
Anaptychia palmulata (Michx.) Vain.
1 unidendified species of Arthopyrenia
Bacidia chlorantha (Tuck.) Fink
Bacidia schweinitzii (Tuck.) Schneid.
Baeomyces rufus (Huds.) Rebent. :RARE
S Bryoria furcellata (Fr.) Brodo & Hawksw.
Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw.
Buellia arnoldii Serv. & Nadv. :RARE
I Buellia stillingiana Steiner
Calicium trabinellum Ach. :RARE
S-I Candelaria concolor (Dicks.) B. Stein
Candelariella efflorescens R. Harris & Buck
Cetraria oakesiana Tuck.
I Cetraria orbata (Nyl.) Fink
I Cetraria pinastri (Scop.) Gray
I Cetraria sepincola (Ehrh.) Ach.
Cetrelia olivetorum (Nyl.) W. & C. Culb.
Chaenotheca chrysocephala (Turn. ex Ach.) Th. Fr. :RARE
Chaenotheca laevigata Nadv. :RARE
Chaenotheca xyloxena Nadv. :RARE
Chaenothecopsis lignicola (Nadv.) Schmidt :RARE
Cladina arbuscula (Wallr.) Hale & W. Culb. :RARE
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo :RARE
Cladonia bacillaris Nyl. :RARE
Cladonia caespiticia (Pers.) Flörke
Cladonia chlorophaea (Flörke ex Somm.) Spreng. :RARE
Cladonia coccifera (L.) Willd.
I Cladonia coniocraea (Flörke) Spreng.
Cladonia cornuta (L.) Hoffm.
Cladonia crispata (Ach.) Flot.
I Cladonia cristatella Tuck. :RARE
Cladonia deformis (L.) Hoffm. :RARE
Cladonia digitata (L.) Hoffm.
Cladonia floerkeana (Fr.) Flörke
Cladonia furcata (Huds.) Schrad.
Cladonia grayi G. K. Merr. ex Sandst.
Cladonia merochlorophaea Asah.

Cladonia squamosa (Scop.) Hoffm.
Conotrema urceolatum (Ach.) Tuck.
Diploschistes scruposus (Schreb.) Norm. :RARE
I Evernia mesomorpha Nyl.
I Graphis scripta (L.) Ach.
Haematomma cismonicum Beltr.
Haematomma elatinum (Ach.) Mass.
Haematomma pustulatum Brodo & W. Culb.
Hypocenomyce friesii (Ach. in Lilj.) P. James & G. Schneid. :RARE
I Hypogymnia physodes (L.) Nyl.
S Hypogymnia tubulosa (Schaer.) Hav.
I Imshaugia aleurites (Ach.) S. F. Meyer
Julella fallaciosa (Stizenb. ex Arn.) R. Harris :RARE
I Lecanora chlarotera Nyl.
I Lecanora pulicaris (Pers.) Ach.
Lecanora thysanophora Harris ined.
Lecanora wisconsinensis Magn.
Lecidea helvola (Körb. ex Hellb.) Oliv.
2 unidendified species of Lecidea
Lecidella euphorea (Flörke) Hert.
Lepraria finkii (B. de Lesd. in Hue) R. Harris
Lepraria neglecta (Nyl.) Lett.
2 unidendified species of Lepraria
Leptogium cyanescens (Rabenh.) Körb. :RARE
Leptorhaphis epidermidis (Ach.) Th. Fr. :RARE
S Lobaria pulmonaria (L.) Hoffm.
Lobaria quercizans Michx.
I Lopadium pezizoideum (Ach.) Körb.
Micarea bauschiana (Körb.) V. Wirth & Vezda :RARE
2 unidendified species of Micarea
I Mycoblastus sanguinarius (L.) Norm.
Mycocalicium subtile (Pers.) Szat. :RARE
Ochrolechia pseudopallescens Brodo.
Ochrolechia trochophora (Vain) Oshio :RARE
Parmelia appalachensis W. Culb. :RARE
Parmelia aurulenta Tuck.
Parmelia caperata (L.) Ach.
Parmelia cumberlandia (Gyeln.) Hale :RARE
Parmelia galbina Ach. :RARE
I Parmelia olivacea (L.) Ach. :RARE
I Parmelia rudecta Ach.
I Parmelia saxatilis (L.) Ach.
I Parmelia septentrionalis (Lynge) Ahti
S Parmelia squarrosa Hale
S-I Parmelia subaurifera Nyl.
I Parmelia subrudecta Nyl.
I-T Parmelia sulcata Tayl.
1 unidendified species of Parmelia
I Parmeliopsis ambigua (Wulf. in Jacq.) Nyl.
I Parmeliopsis hyperopta (Ach.) Arn.
Peltigera canina (L.) Willd. :RARE
I Pertusaria amara (Ach.) Nyl.
Pertusaria consocians Dibb. :RARE
Pertusaria macounii (Lamb) Dibb.

I Pertusaria multipunctoides Dibb. :RARE
Pertusaria ophthalmiza (Nyl.) Nyl.
Pertusaria propinqua Müll. Arg. :RARE
Pertusaria trachythallina Erichs.
Pertusaria velata (Turn.) Nyl. :RARE
2 unidendified species of Pertusaria
Phaeocalicium polyporaeum (Nyl.) Tibell
Phaeophyscia chloantha (Ach.) Moberg :RARE
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Moberg
I Physcia aipolia (Ehrh. ex Humb.) Fürnr. :RARE
I Physcia millegrana Degel.
I Physcia stellaris (L.) Nyl. :RARE
I Physconia detersa (Nyl.) Poelt :RARE
Placynthiella icmalea (Ach.) Coppins & James
I Platismatia glauca (L.) W. & C. Culb.
Platismatia tuckermanii (Oakes) W. & C. Culb.
Porpidia albocaerulescens (Wulf.) Hert. & Knoph
Porpidia crustulata (Ach.) Hert. & Knoph
Porpidia macrocarpa (DC. in Lam. & DC.) Hert. & Schwab :RARE
Pseudevernia cladonia (Tuck.) Hale & W. Culb.
Pseudevernia consocians (Vain.) Hale & W. Culb.
Pyrenula pseudobufonia (Rehm.) R. Harris
Pyxine sorediata (Ach.) Mont. :RARE
Ramalina intermedia (Del. ex Nyl.) Nyl.
S Ramalina obtusata (Arn.) Bitt. :RARE
Rhizocarpon concentricum (Dav.) Beltram. :RARE
Rhizocarpon hochstetteri (Körb.) Vain.
Rinodina ascociscana Tuck.
Sarea resinae (Fr. ex Fr.) Kuntze :RARE
I Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda
Trapeliopsis flexuosa (Fr.) Coppins & James :RARE
Trapeliopsis granulosa (Hoffm.) Lumbsch. :RARE
Trapeliopsis viridescens (Schrad.) Coppins & James
Umbilicaria vellea (L.) Ach. :RARE
S Usnea filipendula Stirt. :RARE
S-I Usnea hirta (L.) Weber ex Wigg.
S-I Usnea subfloridana Stirt.
1 unidendified species of Verrucaria

DISCUSSION OF FLORA

This list of species presents the first listing of lichens from the Lye Brook Wilderness and includes 126 species found during this study. There are also 11 additional unidentified species, some of which are undescribed. The lichen flora is typical of the eastern deciduous forest. These hardwood forests have fewer lichens than conifer and mixed forests because the dense shade is not favorable to the growth of many species. Some of the most common species are Cetraria oakesiana, Hypogymnia physodes, Parmelia rudecta, P. subaurifera, Phaeophyscia rubropulchra and Graphis scripta.

The lichens of The Burning and in the swamp near Kelly Stand include several species rare in the LBW. Some of these rare species that are now present may be lost in the future due to natural causes as succession progresses in these areas.

None of the lichen distributions show unexpected patterns. Many of the species prefer wetter areas, such as bogs, and were only found in these bogs. Some of the species found only once are rare wherever they are found throughout their distributional range and might be found at other localities with further searching; and, others may require special substrates that are rare in the wilderness. The cases of rarity do not necessarily reflect sensitivity damage due from sulfur dioxide.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the wilderness. There are numerous species with blue-green algae, which are very sensitive to sulfur dioxide. One of the most sensitive lichens, Lobaria pulmonaria, was found twice in the LBW. These observations indicate that there is no air quality degradation in the wilderness due to sulfur dioxide that causes visible damage to the lichen flora.

This study found the following number of species in the different sensitivity categories.

Category	# of Species
Sensitive	6
S/I	4
Intermediate	30
I/T	1
Tolerant	0

Most lichen species are unknown as to sensitivity category. The absence of species in the more tolerant categories in LBW indirectly indicates the lack of sulfur dioxide problems. In areas of high sulfur dioxide these categories would have more species and the most sensitive categories would have fewer species. The RARE species in LBW are not related to air quality (see above). The only way to determine past air quality impacts on the present lichen species inventory is by comparison with historical data (from before the presumed impacts occurred). Since there are no historical species lists from this area it cannot be determined whether the present lichen flora has changed prior to this study.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the wilderness to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors. This method of assessing air quality is weak but occasionally is useful in detecting directional effects in an area.

Many of the lichens in the wilderness have known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983). There were six species in the most sensitive category. These species are usually absent when sulfur dioxide levels are above 50 μg per cubic meter average annual concentrations. The species that occur in the LBW in the most sensitive category are as follows.

Bryoria furcellata
Hypogymnia tubulosa
Lobaria pulmonaria
Parmelia squarrosa
Ramalina obtusata
Usnea filipendula

The distributions of these species are shown in Fig. 2-7. Although these species are not found at all localities and most are not common or rare, there is no indication that the voids in the distributions are due to high levels of sulfur dioxide. Some of the localities where collections were made do not have suitable habitats or substrates for some of these species. This is especially true for Lobaria pulmonaria that requires moist habitats.

ELEMENTAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

Four species of lichens were collected for elemental analysis in the LBW. At some localities not all species were present in quantities needed for the analysis.

METHODS

Lichens were collected in spunbound olefin bags at four localities in different parts of the wilderness for laboratory analysis (Fig. 1). Species collected were Cladina rangiferina, Evernia mesomorpha, Hypogymnia physodes, and Parmelia sulcata. These species were selected because they are locally present in abundance and relatively easy to clean. Cladina rangiferina was present at only two elemental analysis localities and was collected from the ground. Evernia mesomorpha was not present at one locality and was collected from conifer branches. Hypogymnia physodes and Parmelia sulcata were present at all four localities and were collected from conifer bark.

Four localities were selected for elemental analysis and are indicated on the map of collection localities (Fig. 1). These localities are: North of Little Mud Pond (9 Aug. 1993), Hill west of Lye Brook (8 Aug. 1993), West side of Bourn Pond (4 Aug. 1993), and North of Kelly Stand (30 July 1993). Full locality citations are given in Appendix I. Ten to 20 grams of each species were collected at each locality.

Lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples (replicates) of each collection were submitted for analysis. Because of the scarcity of Cladina rangiferina in LBW, these samples were submitted along with lichens from another study, where adequate material was available for parallel analytical splits. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis, a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled

Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. Values for National Bureau Of Standards Peach Leaves (NBS Peach) and a locally used lichen standard (Cladina stellaris) are also given. Lichens collected from hardwood bark sometimes have different accumulations than those collected from conifer bark. To reduce this substrate variable, all tree lichens were collected from conifer bark whenever possible. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the different species. Cladina rangiferina has lower levels of sulfur than the other species. None of the reported values were below the lower detection limits of the instruments.

All of the levels found in the LBW lichens are within typical limits for similar lichens in clean areas and the levels within each species are fairly uniform across all localities. At Kelly Stand two species showed higher accumulations but that may be due to historical effects rather than air quality. This shows that there is no point-source of pollution effecting one part of LBW.

The sulfur levels in lichens tested range from 535 to 1780 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980) for other species of lichens. Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. The sulfur levels in LBW are well within typical levels for clean areas as reported in the literature.

Table 1. Analysis of Lye Brook Lichens
Values in ppm of thallus dry weight

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
C. rangiferina	302	1083	207	170	157	173	47.8	54.6	17.1	1.6	0.4	2.9	0.7	0.3	0.1	535	Lye Brook
C. rangiferina	266	976	190	161	166	183	47.2	47.7	16.4	1.5	0.4	3.3	0.6	0.3	0.1	555	Lye Brook
C. rangiferina	269	1001	186	163	159	175	47.9	48.3	16.0	1.7	0.4	3.0	0.9	0.4	0.1	650	Lye Brook
C. rangiferina	312	1446	283	170	206	259	20.8	17.2	24.5	1.8	0.8	3.2	0.6	0.3	0.1	750	Bourn Pond
C. rangiferina	342	1637	235	175	183	229	19.3	15.0	24.6	2.0	0.8	3.1	0.5	0.3	0.1	750	Bourn Pond
C. rangiferina	332	1573	215	174	188	232	20.8	15.5	24.5	1.9	0.8	3.5	0.5	0.3	0.1	530	Bourn Pond
E. mesomorpha	653	2964	668	265	151	186	32.7	43.9	41.5	2.8	2.1	6.0	0.8	0.4	0.2	1330	Little Mud P
E. mesomorpha	646	2985	411	273	164	209	33.5	41.3	41.6	3.0	2.2	6.4	0.9	0.5	0.3	1330	Little Mud P
E. mesomorpha	738	2978	495	292	172	215	47.7	50.4	43.7	3.0	2.3	6.9	0.9	0.5	0.2	1430	Little Mud P
E. mesomorpha	456	1989	417	190	114	138	37.5	79.0	31.9	2.1	1.7	6.6	0.6	0.4	0.2	1070	Lye Brook
E. mesomorpha	449	1936	399	184	107	124	42.2	70.6	29.8	2.0	1.6	6.6	0.7	0.3	0.1	1035	Lye Brook
E. mesomorpha	439	1831	378	184	116	133	45.1	69.9	30.7	2.0	1.4	8.1	0.7	0.4	0.1	1070	Lye Brook
E. mesomorpha	422	1754	623	202	128	135	26.9	27.5	30.3	1.7	1.6	4.7	0.5	0.4	0.2	830	Bourn Pond
E. mesomorpha	463	1750	816	211	110	119	27.8	31.5	30.6	1.6	1.6	3.8	0.5	0.3	0.2	790	Bourn Pond
E. mesomorpha	464	1856	705	231	120	126	29.8	30.8	29.9	1.7	1.5	3.9	0.6	0.4	0.2	790	Bourn Pond
H. physodes	738	3862	8619	576	267	379	22.8	136.2	124.8	4.4	2.1	18.1	1.4	0.7	1.4	1380	Little Mud P
H. physodes	805	4416	5493	512	213	295	24.0	104.5	97.6	4.7	2.0	25.6	1.8	0.7	1.1	1380	Little Mud P
H. physodes	637	3807	8847	495	217	307	23.8	111.0	87.1	4.6	2.0	29.9	1.8	0.6	1.2	1420	Little Mud P
H. physodes	565	2743	7013	489	266	363	33.2	452.3	116.3	3.9	1.2	29.5	1.6	0.8	1.1	950	Lye Brook
H. physodes	694	3070	10832	507	252	322	51.0	506.4	116.7	3.5	1.3	33.7	1.2	0.7	1.4	1000	Lye Brook
H. physodes	619	2790	7764	492	243	322	70.5	508.1	121.4	3.4	1.3	25.8	1.1	0.7	1.2	1025	Lye Brook
H. physodes	813	3165	19606	653	191	229	30.0	281.7	88.1	3.6	2.8	17.5	1.0	0.6	0.9	1080	Bourn Pond
H. physodes	839	3127	21785	670	202	250	29.1	279.6	86.2	3.6	2.8	18.1	1.1	0.6	0.9	990	Bourn Pond
H. physodes	943	3414	17798	726	199	235	30.6	266.4	86.7	3.6	2.8	17.2	1.1	0.5	0.8	1020	Bourn Pond
H. physodes	2405	6348	6706	1008	521	794	57.1	139.8	102.3	6.0	3.1	25.7	2.4	1.1	0.7	1490	Kelly Stand
H. physodes	2037	5771	5686	901	544	814	58.2	110.6	96.4	5.5	2.8	26.1	2.4	1.1	0.5	1440	Kelly Stand
H. physodes	2336	6162	5900	932	542	807	55.5	120.7	100.4	6.4	2.8	43.5	2.3	1.1	0.6	1350	Kelly Stand
P. sulcata	1359	4517	1074	382	309	385	26.9	60.8	93.0	6.6	3.4	22.2	2.0	0.8	0.7	1550	Little Mud P
P. sulcata	1221	4222	1164	368	333	415	26.2	64.3	93.7	6.7	3.6	26.5	2.1	0.8	0.6	1530	Little Mud P
P. sulcata	1298	4442	1096	376	299	378	27.0	63.9	91.0	6.6	3.6	23.9	2.0	0.7	0.7	1780	Little Mud P
P. sulcata	1092	3547	1541	317	271	317	42.3	344.1	115.9	5.1	2.7	21.4	1.4	0.6	0.4	1080	Lye Brook
P. sulcata	664	2024	3587	405	301	326	16.9	181.7	94.5	5.1	2.8	24.1	1.7	0.7	0.4	1020	Bourn Pond
P. sulcata	663	2144	3357	384	326	356	29.2	183.5	96.8	5.0	2.8	23.1	1.8	0.8	0.4	1010	Bourn Pond
P. sulcata	689	2355	3036	357	318	352	18.1	162.2	85.0	4.6	2.6	22.7	1.8	0.8	0.4	1010	Bourn Pond
P. sulcata	1727	4364	2048	606	450	638	48.9	95.2	84.3	5.2	3.2	17.6	1.8	0.9	0.4	1360	Kelly Stand
P. sulcata	1724	4402	2064	599	443	634	40.7	98.9	87.6	5.5	3.4	17.5	1.8	0.9	0.4	1410	Kelly Stand
P. sulcata	1765	4516	2021	636	465	681	44.4	99.7	85.9	5.3	3.3	17.2	1.8	0.9	0.4	1480	Kelly Stand
Standards																	
C. stellaris	195	664	234	264	421	566	74.6	20.4	17.1	2.1	0.9	12.7	1.0	0.8	0.2	410	
C. stellaris	198	664	242	274	435	587	78.9	20.6	18.0	3.0	1.0	13.9	1.1	0.9	0.2	423	
C. stellaris	194	658	234	271	416	551	80.6	20.2	17.1	2.2	1.0	14.1	1.2	1.0	0.2	460	
NBS-Peach	1182	3695	4433	1164	459	177	17.3	686.6	71.3	2.8	17.1	10.8	1.5	1.9	0.2	NA	
NBS-Peach	1210	3718	4523	1199	467	178	24.1	702.1	64.6	3.3	17.5	12.0	1.7	2.1	0.3	NA	
NBS-Peach	1202	3675	4557	1208	459	177	20.0	696.8	66.1	3.2	17.4	12.6	1.9	2.2	0.3	NA	

Table 2. Summary of Analysis of Lye Brook Lichens
Values in ppm of thallus dry weight

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
<u>Cladina rangiferina</u>																	
Mean	279	1020	194	165	161	177	47.6	50.2	16.5	1.6	0.4	3.1	0.7	0.3	0.1	580	Lye Brook
Std. dev.	20	56	11	4	4	5	0.4	3.8	0.5	0.1	0.1	0.2	0.1	0.1	<.1	61	Lye Brook
Mean	329	1552	244	173	192	240	20.3	15.9	24.5	1.9	0.8	3.2	0.5	0.3	0.1	677	Bourn Pond
Std. dev.	15	97	35	3	12	17	0.9	1.2	0.1	0.1	<.1	0.2	<.1	<.1	<.1	127	Bourn Pond
<u>Evernia mesomorpha</u>																	
Mean	679	2976	525	277	162	203	38.0	45.2	42.3	2.9	2.2	6.4	0.9	0.5	0.2	1363	Little Mud P
Std. dev.	51	11	131	14	10	15	8.4	4.7	1.2	0.1	0.1	0.5	0.1	<.1	<.1	58	Little Mud P
Mean	448	1919	398	186	113	132	41.6	73.2	30.8	2.0	1.6	7.1	0.7	0.4	0.1	1058	Lye Brook
Std. dev.	9	81	20	3	5	7	3.8	5.1	1.1	0.1	0.2	0.9	<.1	<.1	<.1	20	Lye Brook
Mean	450	1787	715	215	119	126	28.2	29.9	30.3	1.6	1.6	4.1	0.5	0.4	0.2	803	Bourn Pond
Std. dev.	24	60	97	15	9	8	1.5	2.1	0.4	0.1	0.1	0.5	<.1	<.1	<.1	23	Bourn Pond
<u>Hypogymnia physodes</u>																	
Mean	727	4028	7653	527	232	327	23.5	117.2	103.1	4.6	2.0	24.5	1.7	0.6	1.2	1393	Little Mud P
Std. dev.	85	337	1874	43	30	45	0.7	16.8	19.4	0.1	0.1	6.0	0.2	0.1	0.1	23	Little Mud P
Mean	626	2868	8536	496	254	336	51.6	489.0	118.1	3.6	1.2	29.7	1.3	0.7	1.2	992	Lye Brook
Std. dev.	65	177	2023	10	12	24	18.6	31.8	2.8	0.3	<.1	3.9	0.3	0.1	0.2	38	Lye Brook
Mean	865	3235	19730	683	197	238	29.9	275.9	87.0	3.6	2.8	17.6	1.1	0.6	0.9	1030	Bourn Pond
Std. dev.	69	156	1996	38	5	11	0.8	8.3	1.0	<.1	<.1	0.5	<.1	<.1	0.1	46	Bourn Pond
Mean	2259	6094	6098	947	535	805	56.9	123.7	99.7	6.0	2.9	31.8	2.4	1.1	0.6	1427	Kelly Stand
Std. dev.	196	295	538	55	13	11	1.4	14.9	3.0	0.5	0.2	10.1	<.1	<.1	0.1	71	Kelly Stand
<u>Parmelia sulcata</u>																	
Mean	1293	4393	1111	375	314	393	26.7	63.0	92.6	6.6	3.5	24.2	2.1	0.7	0.7	1620	Little Mud P
Std. dev.	69	153	47	7	18	20	0.4	1.9	1.4	0.1	0.1	2.1	<.1	0.1	<.1	139	Little Mud P
Mean	672	2175	3326	382	315	345	21.4	175.8	92.1	4.9	2.7	23.3	1.7	0.7	0.4	1013	Bourn Pond
Std. dev.	15	168	277	25	12	16	6.7	11.8	6.3	0.3	0.1	0.7	0.1	0.1	<.1	6	Bourn Pond
Mean	1739	4427	2044	613	453	651	44.7	97.9	86.0	5.3	3.3	17.5	1.8	0.9	0.4	1417	Kelly Stand
Std. dev.	23	79	22	20	11	26	4.1	2.4	1.7	0.1	0.1	0.2	<.1	<.1	<.1	60	Kelly Stand
Standards																	
<u>Cladina stellaris</u>																	
Mean	196	662	237	270	424	568	78.0	20.4	17.4	2.4	1.0	13.5	1.1	0.9	0.2	431	
Std. dev.	2	3	5	5	10	18	3.1	0.2	0.5	0.5	0.1	0.7	0.1	0.1	<.1	26	
NBS Peach																	
Mean	1198	3696	4504	1190	462	177	20.5	695.2	67.3	3.1	17.3	11.8	1.7	2.1	0.3	NA	
Std. dev.	14	21	64	23	5	1	3.5	7.8	3.5	0.3	0.2	1.0	0.2	0.1	<.1	NA	

All of the other elements show normal levels for areas with low pollution or relatively clean air. The elemental levels in the same species in the White Mt. Wilderness areas are very similar but slightly lower than those in the LBW. In two species some elements are somewhat higher at the Kelly Stand.

Further statistical comparisons between Lye Brook Wilderness and White Mountains lichens have been omitted in this excerpt of the Final Report.

Statistical Analysis Conclusions

The levels of most elements are higher in the LBW than in the White Mt. wildernass areas. When comparing localities with the LBW, Kelly Stand was significantly higher in two species than the other localities. The levels at Bourn Pond were lowest in two species. The higer levels at Kelly stand may be due to historical activities in the area rather than air quality effects. LBW elemental levels are higher than clean areas in northen Minnesota in some species.

CONCLUSIONS

There is no indication that the lichens of LBW are being damaged by sulfur dioxide or the other elements studied. The lichen flora is diverse for such an area and there is no impoverishment of the lichen flora in any part of the the wilderness. There are six species in the most sensitive category to sulfur dioxide in the wilderness and most of these are rare. This rarity seems to be due more to ecological and climatic conditions than pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality. There is no geographical gradient of accumulations from north to south. Elemental levels are slightly higher than those in the White Mt. Wilderness areas.

RECOMMENDATIONS

Although there seem to be no sulfur dioxide effects or impacts from other elements monitored in LBW now, periodic restudy is recommended. Elemental analysis should be done every 5 years and compared to the levels reported in this study. A complete floristic restudy should be done every 10-15 years.

If plans are developed to do extensive trail construction or maintenance in the LBW, a lichenologist should be consulted to help design the work so that rare lichens are not lost.

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APPENDIX I

Lye Brook Wilderness collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by number and date of collection. All localities are in the Green Mountain National Forest, located in Bennington County, Vermont.

Green Mountain National Forest, Lye Brook Wilderness, Bennington County, Vermont

72507-72532 : Up the Lye Brook Falls Trail near talus slopes 3 miles southeast of Manchester Center. On west facing hillsides with maples, black spruce and some hemlock, elev. 1800 ft. 29 July 1993.

72533-72548 : Along Lye Brook Falls Trail 2 miles south of Manchester Depot. On ridge with maple and hemlock, elev. 1300 ft. 29 July 1993.

72549-72590 : North of Kelly Stand at southern end of wilderness along Branch Pond Brook. Along stream with balsam fir, maples and yellow birch, elev. 2250 ft. 30 July 1993. CHEMICAL ANALYSIS.

72591-72611 : Southeast of Branch Pond Brook in southern end of wilderness. On gentle hillside with beech, sugar maple and yellow birch, elev. 2520 ft. 30 July 1993.

72612-72648 : Four miles south of Manchester Center. In deep gully on north facing slope and ridge with yellow birch and some hemlock and maple, elev. 1700 ft. 31 July 1993.

72649-72676 : Upper part of Lye Brook Hollow below Lye Brook Trail. On banks above stream with maple, birch, red spruce and some balsam fir, elev. 2350 ft. 1 Aug. 1993

72677-72708 : 1.5 miles east of Sunderland. On west facing hillside among overgrown talus with birch, maple, hemlock and some red spruce, elev. 1600 ft. 3 Aug. 1993.

72709-72746 : West side of Bourn Pond. Near lake with balsam fir, red spruce, birch and maple, elev. 2540 ft. 4 Aug. 1993. CHEMICAL ANALYSIS.

72747-72777 : Half mile south of Bourn Pond. At edge of flooded red spruce swamp with some dead balsam fir, elev. 2580 ft. 4 Aug. 1993.

72778-72808 : North of Branch Pond, west of trail to Bourn Pond. On small hill with white and yellow birch, red maple and some young red spruce and balsam fir, elev. 2660 ft. 5 Aug. 1993.

72809-72842 : Northwest corner of Little Mud Pond (4 miles SE of Manchester). Along stream with beaver dams and red maple, red spruce, balsam fir and yellow birch, elev. 2250 ft. 6 Aug. 1993.

72843-72871 : North of Little Mud Pond above shelter. (3 miles of Manchester). In beech-maple woods on gentle slope with sugar maple, beech and some ash and young red spruce and balsam fir, elev. 2260 ft. 6 Aug. 1993.

72872-72910 : Hill west of Lye Brook (3 miles south of Manchester Center). On peak with red spruce, yellow birch and maples, elev. 2200 ft. 8 Aug. 1993. CHEMICAL ANALYSIS.

72911-72941 : North of Little Mud Pond. Near beaver swamps along old logging road with maples, red spruce and balsam fir, elev. 2330 ft. 9 Aug. 1993. CHEMICAL ANALYSIS.

72942-72985 : One mile east of Prospect Rock near trail junction. In beech-maple woods with some yellow birch and ash, elev. 2330 ft. 9 Aug. 1993.

72986-73014 : The Burning at southern end of wilderness (2 miles SE of Sunderland). On ridgetop southeast of pond in heath with red spruce and some white pine, elev. 2475 ft. 10 Aug. 1993.

73015-73046 : On hilltop east of main trail (3.5 miles E of Sunderland). In wet area with red spruce, balsam fir, some red maple and yellow birch, elev. 2600 ft. 13 Aug. 1993.

73047-73071 : Southwest corner of wilderness above Mill Creek. On gentle west slope with hemlock, maples and beech with few ash and oaks, elev. 1050 ft. 14 Aug. 1993.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in the Lye Brook Wilderness Area fall within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50 μg sulfur dioxide per cubic meter (average annual). Open circles on the maps are localities where the species was not found and solid circles are where it was found. Only the species in the Sensitive category are mapped.

Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the wilderness.

Fig. 2 Bryoria furcellata (Fr.) Brodo & Hawksw.
Fig. 3 Hypogymnia tubulosa (Schaer.) Hav.
Fig. 4. Lobaria pulmonaria (L.) Hoffm.
Fig. 5. Parmelia squarrosa Hale
Fig. 6. Ramalina obtusata (Arn.) Bitt.
Fig. 7. Usnea filipendula Stirt.

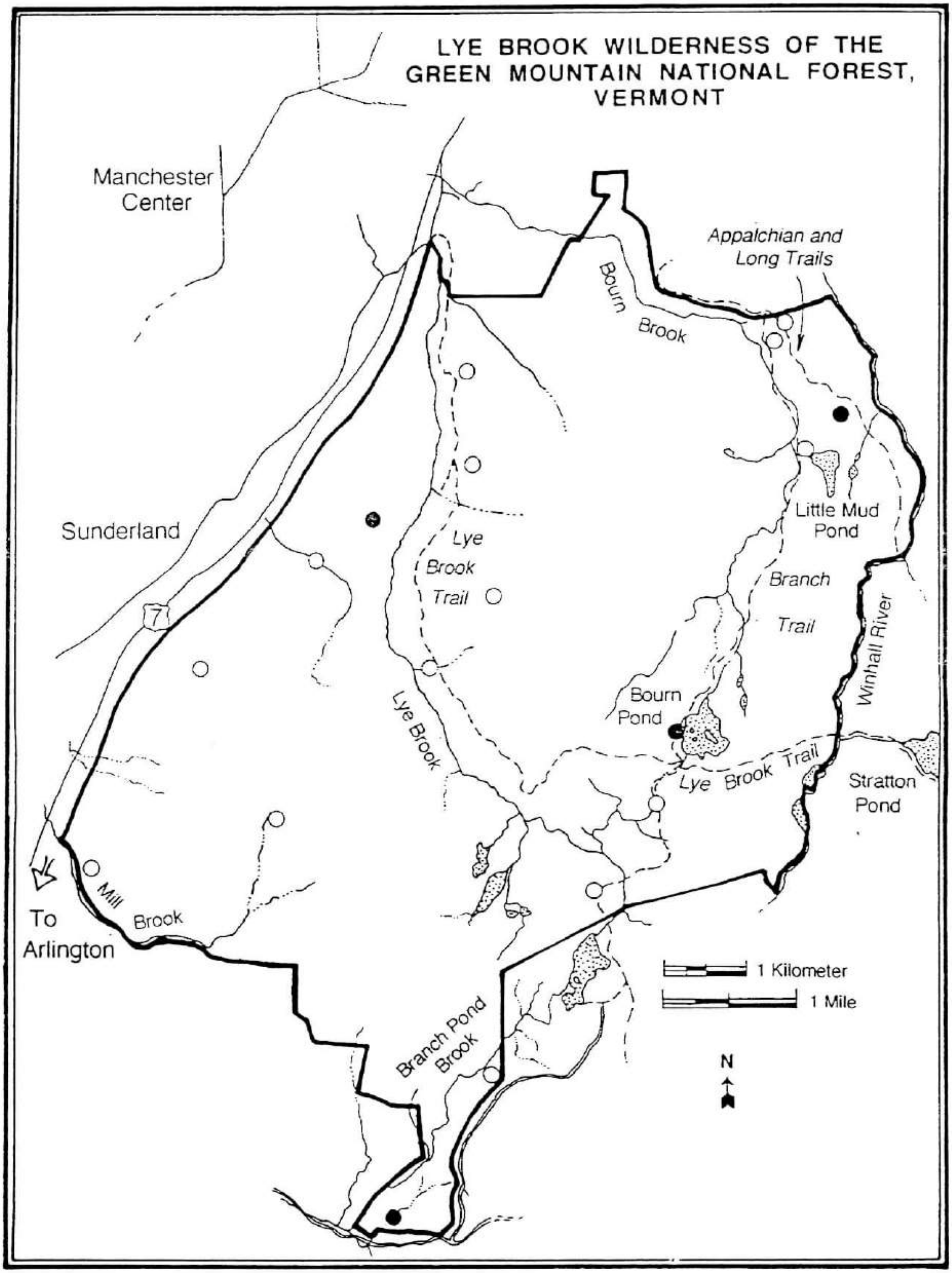

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities and collection localities.

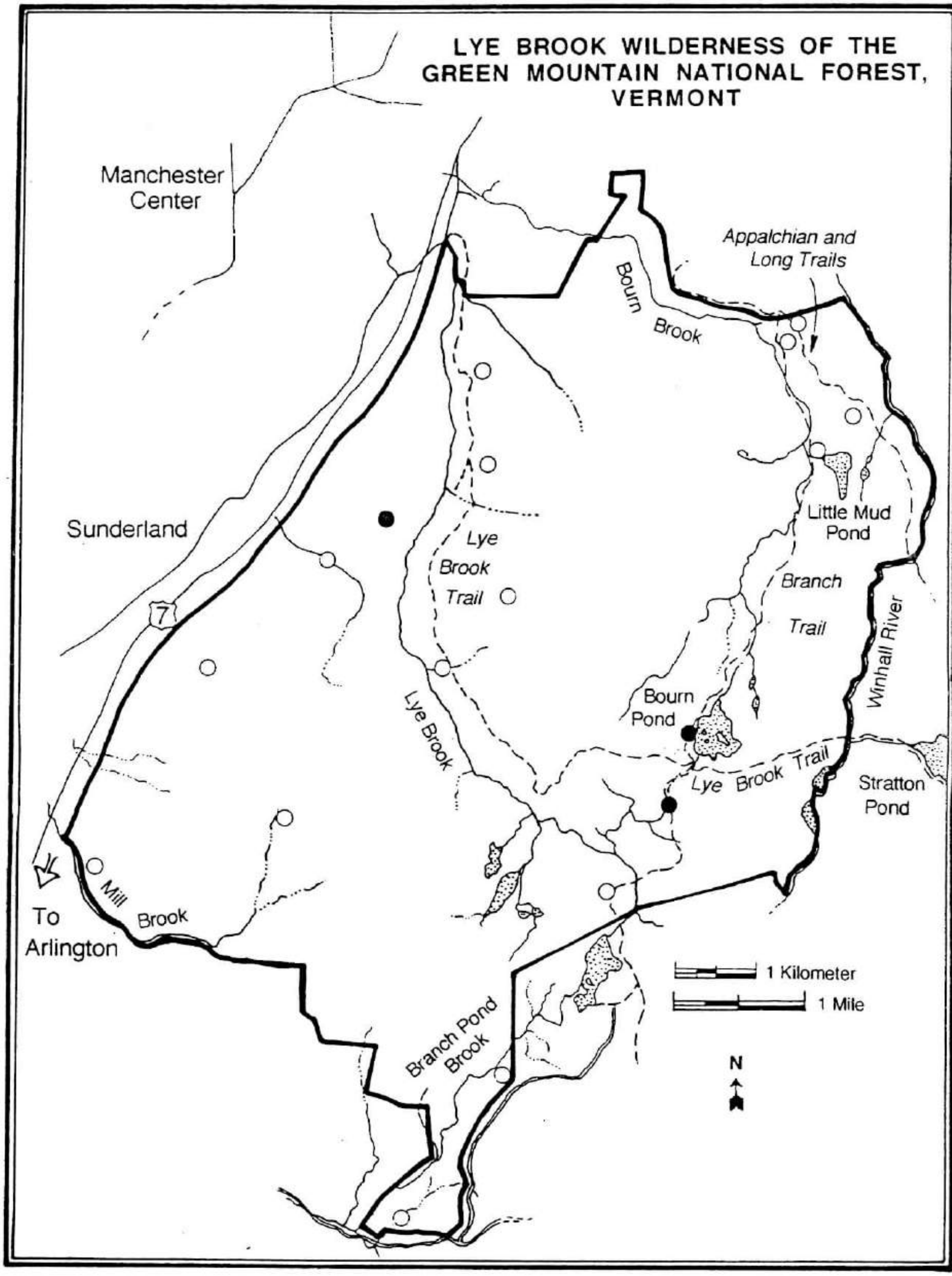

Fig. 2. Distribution of Bryoria furcellata.

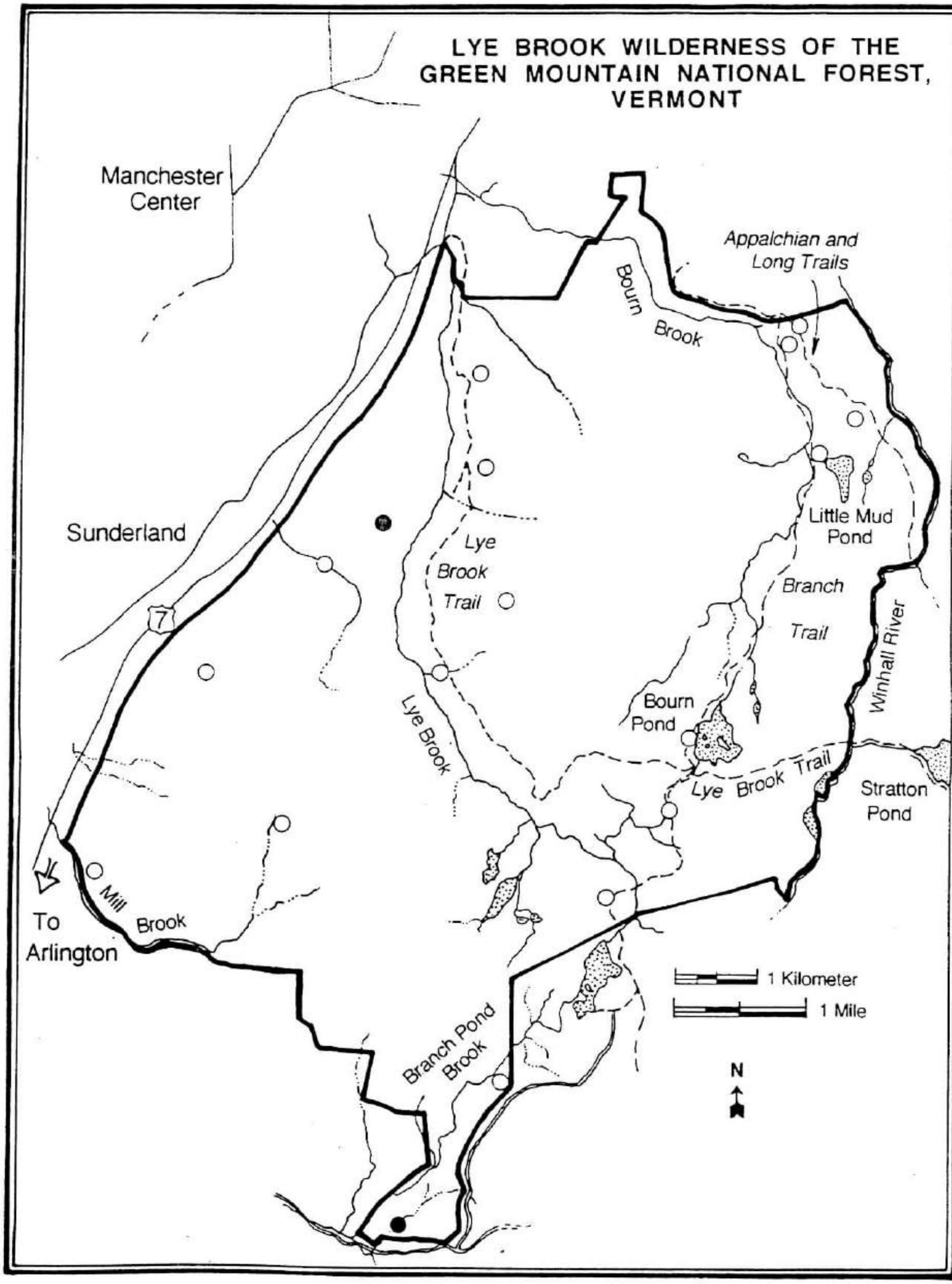

Fig. 3. Distribution of *Hypogymnia tubulosa*.

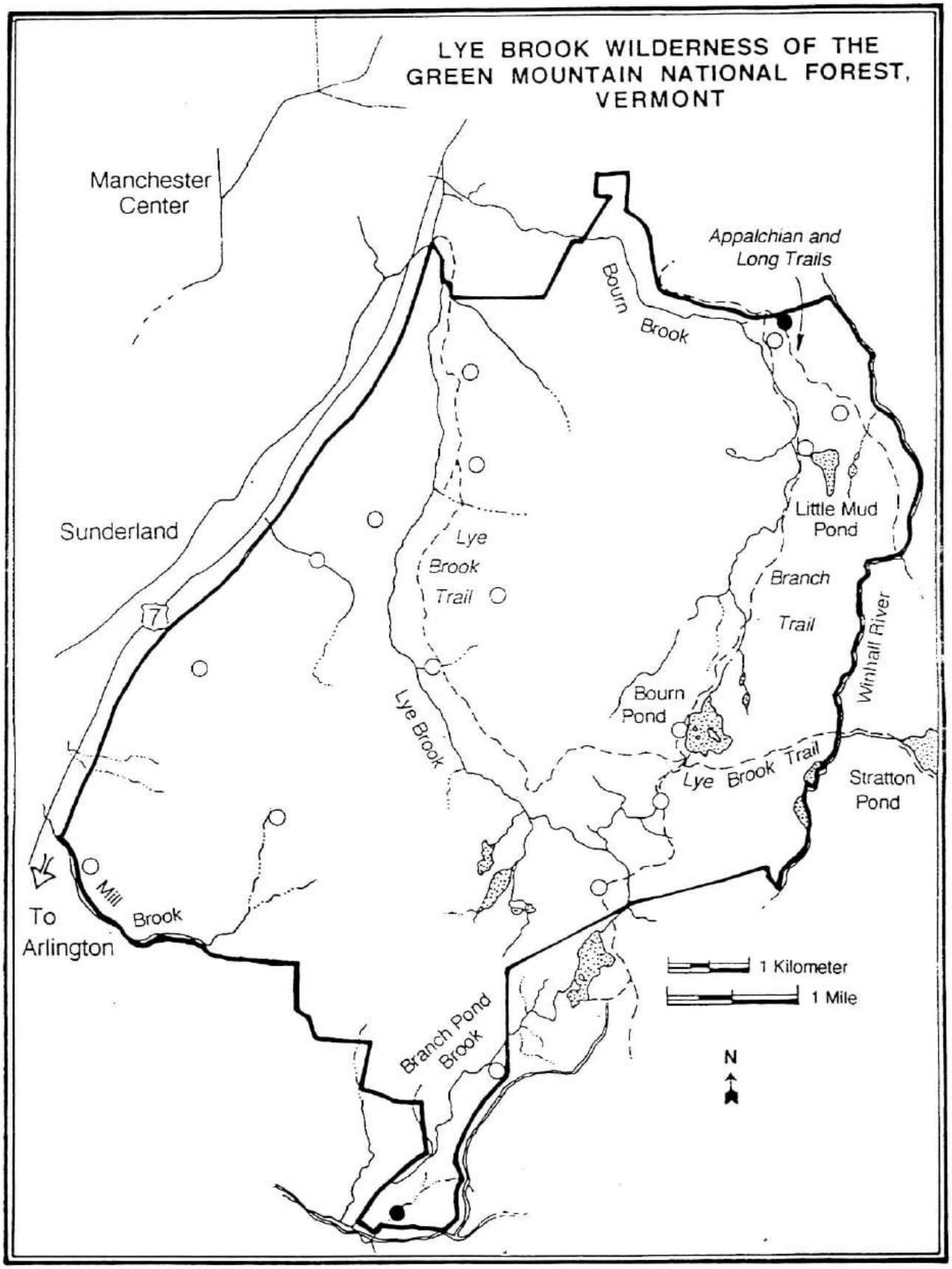

Fig. 4. Distribution of <u>Lobaria pulmonaria</u>.

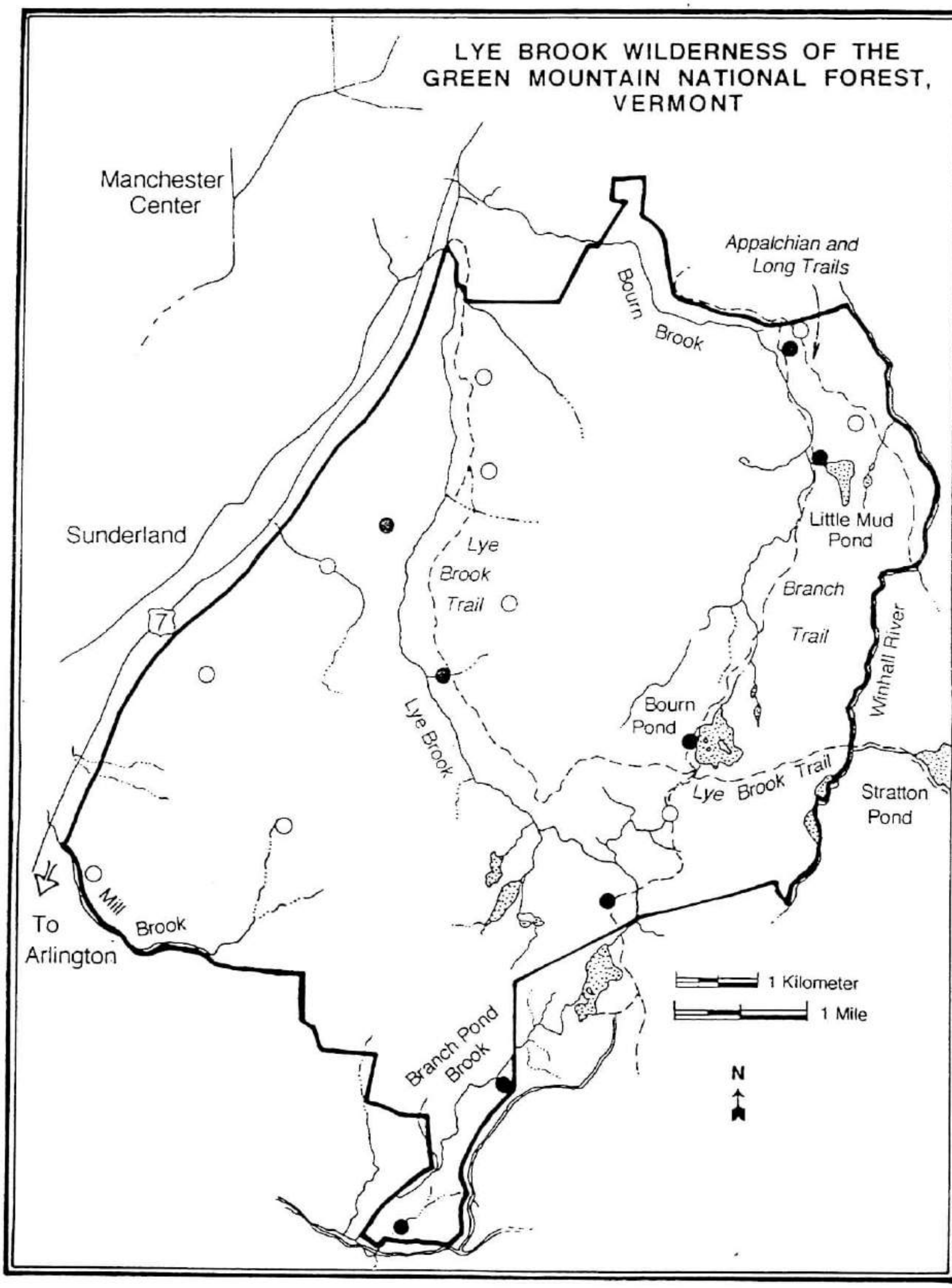

Fig. 5. Distribution of Parmelia squarrosa.

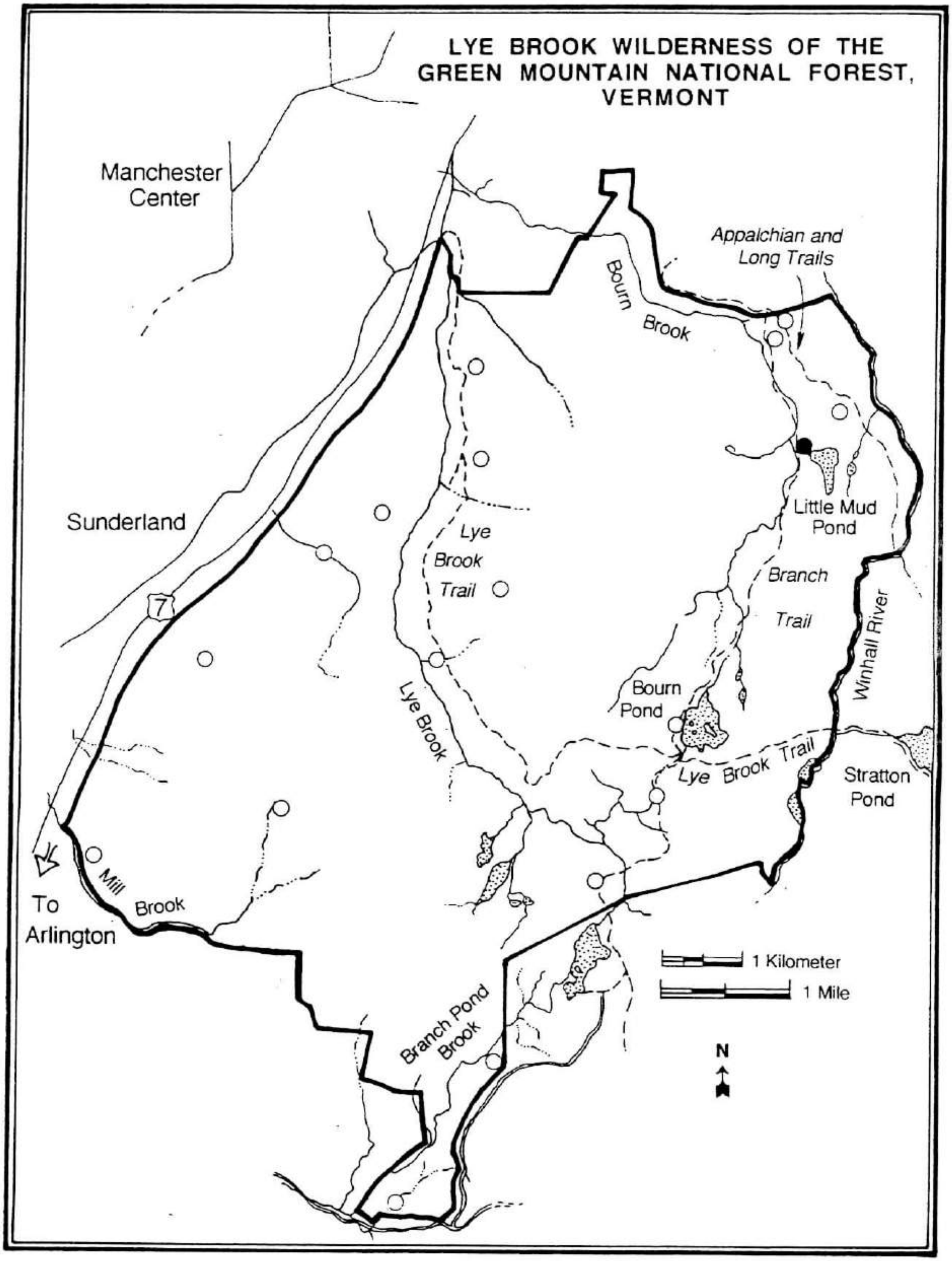

Fig. 6. Distribution of Ramalina obtusata.

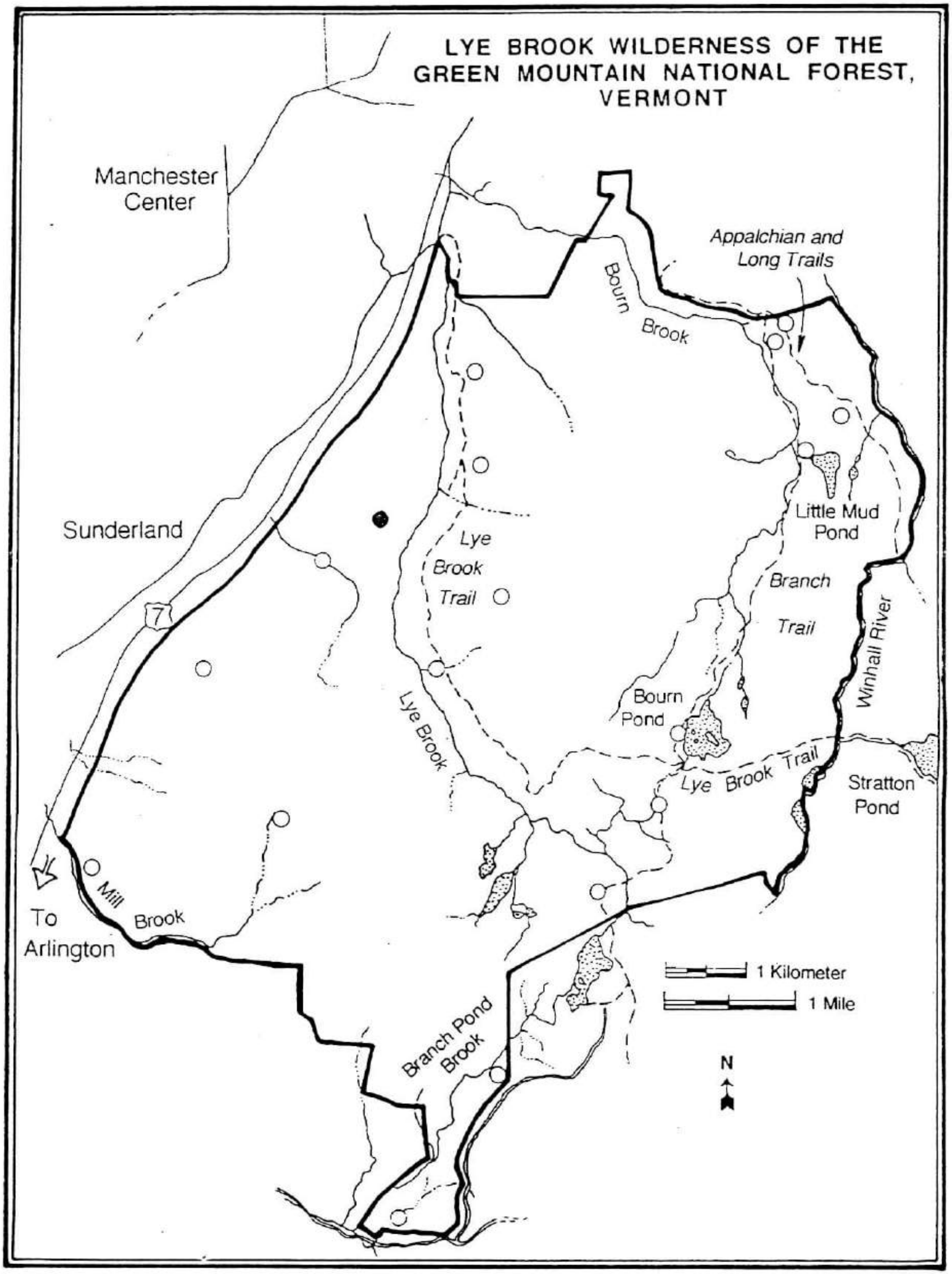

Fig. 7. Distribution of Usnea filipendula.

Sugar Maple Canopy Photosynthetic Responses to the Environment

David Ellsworth
Biosystems and Process Sciences Division
Brookhaven National Laboratory
Upton, N.Y. 11973

ABSTRACT Leaf photosynthetic responses to light and carbon dioxide (CO_2) supply were measured in sugar maple trees located near the Proctor Maple Research Center VMC tower. Leaf photosynthetic responses to environmental factors were determined by analysis of measurements of photosynthetic responses to short-term, experimental manipulations of leaf environmental conditions. Photosynthetic responses to light and to CO_2 supply inside of the leaf were determined for leaves at different canopy positions and in stands characterized by differences in soil fertility. There was a strong dependence of many physiological parameters on leaf nitrogen (N) status. A computer model based on the physiology and biochemistry of photosynthesis (called PHOTO-N) and using standard meteorological variables as inputs was produced to simulate leaf and canopy photosynthesis over time periods of days to weeks. The computer model can be used to examine possible changes in photosynthesis related to climate change and gaseous pollutants (elevated ozone or CO_2). While still only a research tool, it is envisaged that in the future stand productivity models may be useful in integrated assessment of potential environmental impacts on sugar maple forests in Vermont and elsewhere in the northeastern U.S.

INTRODUCTION

There is a critical need to develop methods to address issues of forest canopy productivity and the role of environmental conditions in regulating forest productivity. Recent observations of insect damage to sugar maple and reports of crown dieback or growth declines in northern hardwood forests (cf. Allen et al. 1992, Wilmot et al. 1995) have raised concern over the continued productivity of sugar maple forests.

The objective of my work on sugar maple physiology over the past few years has been to quantify key leaf photosynthetic responses of sugar maple that play an important role in regulating forest productivity. Another goal has been to formalize this understanding of sugar maple forest processes in a computer model designed to aggregate leaf responses to predict sugar maple forest canopy responses to the current environment and to anticipated changes in the environment.

METHODS

Sugar maple leaf photosynthesis was measured on intact leaves in the crowns of mature trees using a portable infra-red gas analyzer and photosynthesis system. Light was supplied to the measurement leaf by means of a metal halide projector lamp, and light levels were increased from darkness by removing progressive layers of shade cloth and neutral density filters shading the leaf. Under high light conditions, CO_2 supply to the leaf was changed by adding variable amounts of CO_2 from an external CO_2 source to the gas stream over a leaf. Care was taken to ensure that the leaf remained undamaged during measurements and that other environmental conditions in the leaf chamber such as air temperature and humidity were near optimal. Additional measurements of photosynthesis were made on leaves from trees in several Vermont sugarbushes that varied in soil acidity and nutrient conditions (see Ellsworth and Liu 1994).

Canopy structure was measured by a remote optical technique that uses fisheye sensor measurements of diffuse light within the forest canopy. Measurements were made at multiple levels within the forest to quantify the vertical distribution of leaf area in the sugar maple stand. Individual leaves measured for photosynthesis were harvested from multiple heights in the forest stand for analyses of leaf morphology and leaf nitrogen concentration.

RESULTS TO DATE

The vertical structure of the sugar maple forest near the PMRC tower is shown in Figure 1. The majority of the leaves in the stand are located between 10-13m height in the 17m tall forest stand. Canopy structure was remarkably similar between 1992 and 1993.

Figures 2 and 3 illustrate the typical response of leaf photosynthesis to light (Fig. 2) and leaf internal CO_2 (Fig. 3) in sugar maple. The curves in Figures 2 and 3 are from statistical fits to the data shown in the Figures. The photosynthetic light response curves showed lower saturation values for leaves in more shaded locations such as at 10-12m height. Leaf photosynthesis under high light and current ambient CO_2 conditions was closely related to total leaf nitrogen (N) content, as has been found previously for sugar maple (Ellsworth and Liu 1994). The initial slope of the CO_2 response curve, which is an indication of the biochemical capacity of the leaf to fix CO_2

in photosynthesis, was also closely correlated with leaf N content. I used the relationships between key physiological parameters such as leaf carboxylation capacity and leaf N to parameterize a computer model (PHOTO-N) based on leaf physiology and the biochemistry of photosynthesis that can simulate theoretical rates of leaf and canopy photosynthesis over time periods of days to weeks. Preliminary results from an early version of the model are shown in Figure 4. The data show a series of days in August 1993 the simulations were done using VMC meterological data. Days 2 and 3 were partly cloudy and show greater temporal variation in predicted photosynthesis than on Day 1, which was a clear sunny day. Photosynthesis is much lower for leaves at 8m than at 13.5m, largely due to the influence of shade in the forest. These results highlight the paramount importance of light in regulating photosynthesis in sugar maple.

FUTURE PLANS

I am developing a version of the model that predicts the impacts of chronic, low-level ozone exposure on leaf and canopy photosynthesis such as would be experienced in some years in Vermont. The model is parameterized using relationships between cumulative ozone dose and reductions in photosynthesis based on a field exposure of a mature sugar maple canopy to elevated ozone (Tjoelker et al. 1995). It is anticipated that the photosynthesis model will be revised to use more detailed assessments of spatial variation in stand leaf area and leaf characteristics. Analyses of model sensitivity to inputs and of model robustness are under way. A validation dataset is being assembled to test the model predictions. The model can be modified to use remotely sensed information on stand structure, leaf chemistry, and leaf area index for landscape units dominated by sugar maple so that complex spatial and ecological relationships between forest structure and canopy photosynthesis can be examined.

CONTEXT

Because data were collected from stands on a number of different soils, the measurements are likely to be applicable to sugar maple on spodic and other similar soils. Ellsworth and Liu (1994) showed that the physiological relationships examined in relation to leaf N compare favorably to those published for sugar maple in other regions within its natural range. The model was devised using fundamental physiological relationships to enable it to be parameterized for sugar maple growing throughout the northeastern U.S.

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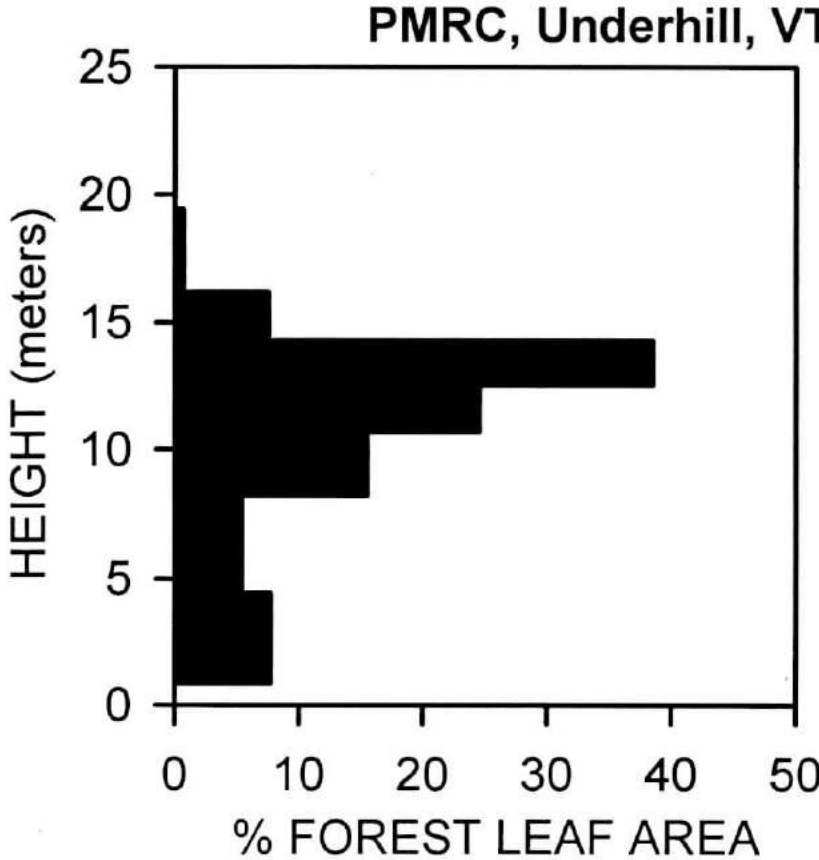


Figure 1. Structure of the forest in proximity of the Proctor Maple Research Center (PMRC) tower in July 1993. Each bar indicates the fraction of stand leaf area at a given level in the canopy.

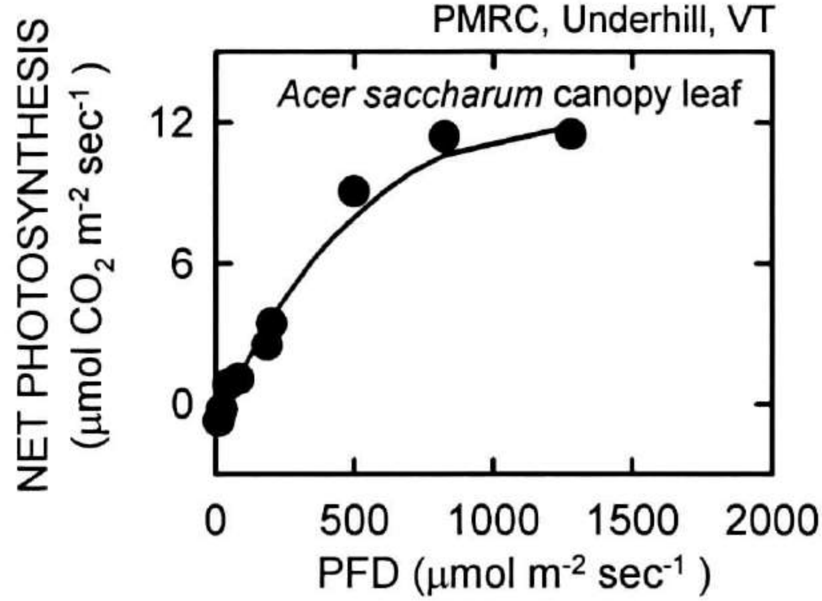


Figure 2. A typical photosynthetic light response curve for an intact leaf located at 16m in the canopy near the PMRC tower. PFD (photon flux density) is the flux density of light incident on the leaf.

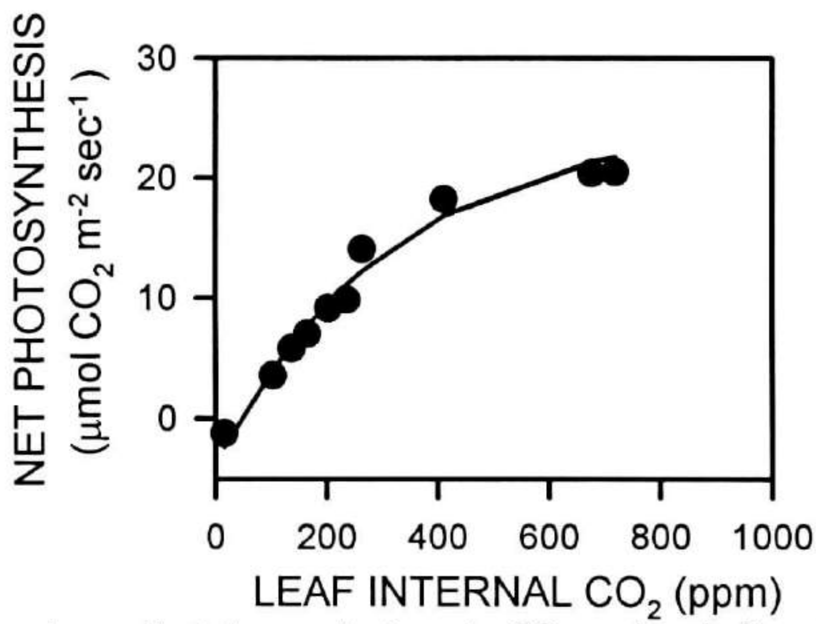


Figure 3. Dependence of leaf photosynthesis on the CO_2 supply to leaf internal air spaces. Measurements were made on an intact leaf of sugar maple at 16m height near the PMRC tower according to techniques in Ellsworth and Liu (1994).

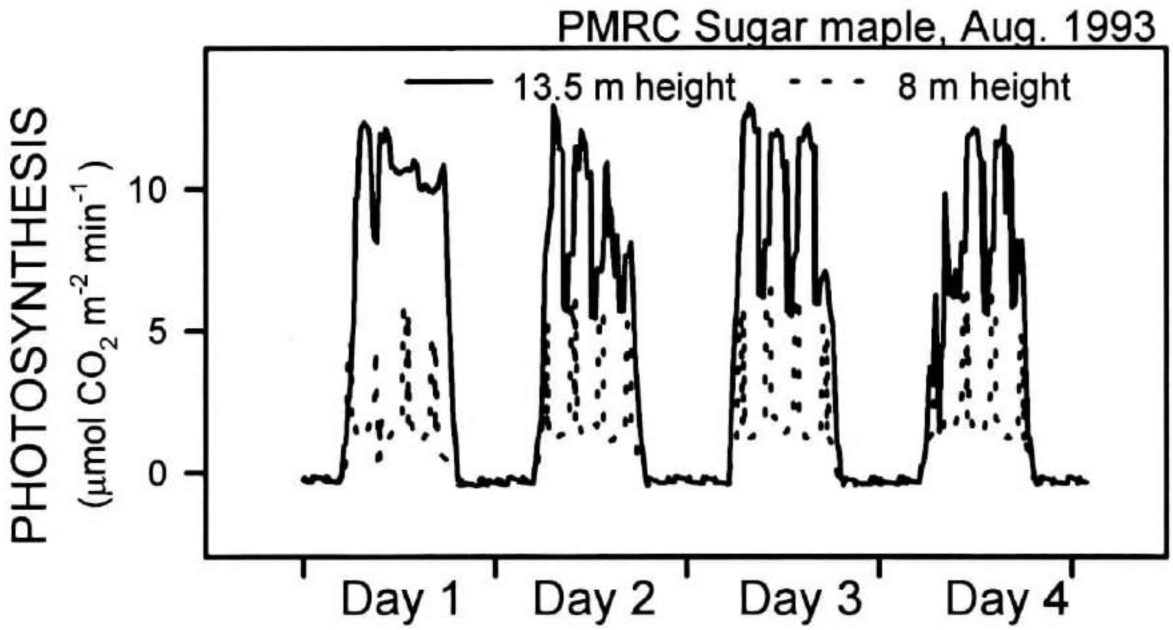


Figure 4. Time course of predicted photosynthesis for a representative leaf at two different canopy positions (13.5m height and 8m height). Data were generated by the photosynthesis model PHOTO-N using leaf and stand characteristics from data collected near the PMRC tower and using meteorological inputs from VMC monitoring.

TREE PHENOLOGY MONITORING ON MOUNT MANSFIELD - 1994

Sandra Wilmot and Thomas Simmons
Vermont Department of Forests, Parks and Recreation

ABSTRACT

Monitoring of bud development, leaf size, and fall color and leaf drop is conducted on three tree species growing at two elevations on Mount Mansfield. Yellow birch, American beech and sugar maple trees are monitored at 1400 and 2200' on the west slope of the mountain. The purpose of this monitoring effort is to begin gathering baseline information on these fundamental tree processes. In general, bud development at both elevations was slower and later than in 1992 and 1993. Conversely, fall color was earlier than normal especially at the 2200' elevation where in some cases full color came 2 weeks earlier than previous years. Three years of sampling leaves for leaf size has shown little within season size difference. Sugar maple leaves averaged 39.6 cm^2 and 40.7 cm^2 at the two elevations, respectively; yellow birch averaged 20.8 and 18.8; and beech averaged 30.9 and 28.3.

INTRODUCTION

Monitoring of bud development, annual leaf size, and fall color and leaf drop began in 1991 on sugar maple at one elevation (1400') on Mount Mansfield. The following year, a higher elevation was added (2200') and two additional hardwood species, yellow birch and American beech. The purpose of this monitoring effort is to begin gathering baseline information on these fundamental tree processes. Understanding the timing of developmental stages in relation to weather phenomena (such as early fall frost) and insect pest activity (such as pear thrips feeding in sugar maple buds) improves our knowledge of interrelations between tree physiology and stress events.

METHODS

BUD DEVELOPMENT

Bud development is recorded twice weekly from early April through mid-June using visual ratings as seen through a high powered spotting scope. Five mature trees and 5 saplings of sugar maple, yellow birch and American beech are monitored at two elevations (1400 and 2200') for a total of 30 trees and 30 saplings. Bud stages are recorded from the upper canopy, lower canopy and regeneration from dormancy through full leaf expansion (Table 1a & 1b). Descriptions of sugar maple bud stages (Skinner & Parker, 1994) have been modified for yellow birch and beech to allow between year comparisons of bud and leaf development. Flower bud stages are rated, but there are not enough flower buds on all sampling trees to present results for each year.

LEAF SIZE

Three mid-canopy leaf collections are made annually in late-June, -July, and -August using pole pruners. Ten leaves from 2 sides of each tree are collected, pressed, and measured for leaf area using a leaf area meter.

FALL COLOR AND LEAF DROP

Initial crown ratings are recorded on each tree and sapling in late July to establish a baseline for trees with full foliage. From mid-August through October, trees and saplings are rated for color and leaf drop. Color is rated in 5% categories using the North American Maple Project definitions for discoloration (color other than green). Leaf drop is measured using crown density, dieback and foliage transparency ratings as per the National Forest Health Monitoring Program. A measure of the density of the tree with no foliage (structural crown density) is taken late in the fall once all the leaves are gone, or in the spring before leaf out. Using both the full leaf-on and leaf-off density ratings, the percent leaf drop is calculated.

Leaf drop at each visit (%) =

((full leaf-on density - density at visit) /
(full leaf-on density - full leaf-off density)) X 100

In 1992 and 1993, dieback and transparency ratings were tested to measure leaf drop. Density was added in 11994, and more accurately measures leaf drop. In future years, density will replace dieback and transparency ratings in monitoring leaf drop.

Table 1a. Vegetative bud stages for sugar maple, yellow birch and American beech.

VEGETATIVE STAGE	SUGAR MAPLE	YELLOW BIRCH	BEECH
V0	dormant	dormant	dormant
V1	initial swell	initial swell	lengthening
V2	bud elongation		wide at bud base, exaggerated point at tip
V3	green tip stage		scales separating and bending back slightly
V4	bud break, leaf tips expanded beyond the bud tip	bud break, leaf tip exposed	bud break, leaf tips exposed
V5	extended bud break, leaves not yet spread apart	extended bud break	extended bud break
V6	initial leaf expansion	initial leaf expansion	initial leaf expansion
V7	leaves unfolded slightly,but individual leaves not yet expanded	leaves unfolded slightly	leaves unfolded slightly
V8	leaves expanded, may not be full size yet	leaves expanded, may not be full size yet	leaves expanded, may not be full size yet

Table 1b. Flowering bud stages for sugar maple, yellow birch and American beech.

FLOWER STAGES	SUGAR MAPLE	YELLOW BIRCH	BEECH
F0	dormant	dormant	dormant
F1	initial bud swell		
F2	bud elongation, buds more rounded at tip than vegetative buds	bud elongation	
F3	green tip stage	full bud elongation	
F4	bud break, flower tips show expanded beyond bud tip		
F5	initial flower expansion, flower bundle expands beyond bud scales	initial flower expansion	
F6	full flower expansion and pollen dispersal	full flower expansion and pollen dispersal	full flower expansion and pollen dispersal
F7	flower senescence and drop	flower senescence and drop	flower senescence and drop

RESULTS

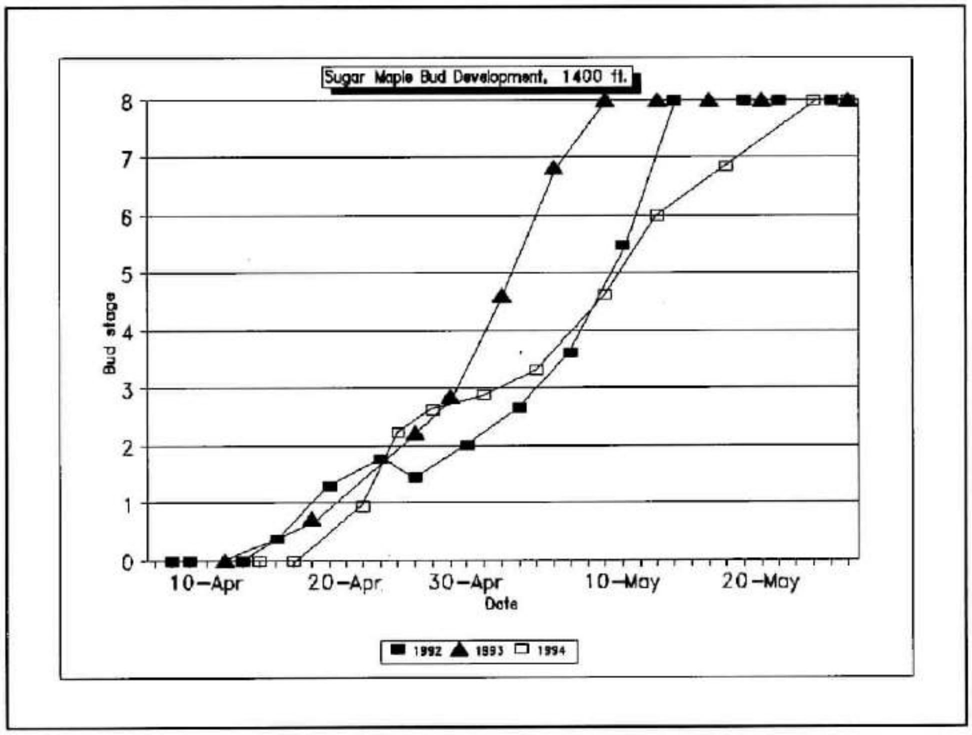
SPRING PHENOLOGY

Bud development in 1994 was in general later than previous years. Sugar maple bud development at 1400' was slow in the early stages of bud swell, and again from budbreak to full leaf expansion (10 days later than in 1992 and 2 weeks later than 1993)[Figure 1]. At the 2200' elevation, buds were slow to reach budbreak, nearly 2 weeks behind 1993, and full leaf expansion was also later than previous years.

Yellow birch buds at 1400' began swelling later than in 1992 and 1993, but by budbreak on May 2, had a similar developmental pattern as in 1992 (Figure 2). Full leaf expansion was observed by May 20. At the higher elevation, 2200', yellow birch bud development was later at all stages than in previous years. Budbreak occurred around May 16, and full leaves were developed by June 3.

Beech bud development at 1400' was much later than previous years (Figure 3). Initial bud swell was similar to 1993, but then in late april and early May, there was a long, slow period of development. Budbreak didn't occur until May 19, but then rapid leaf expansion produced full leaves by June 2. At the higher elevation, 2200', budbreak occurred around May 27, full leaf expansion by June 4, with an overall slower development than in 1992 and 1993.

Figure 1. Sugar maple bud development at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



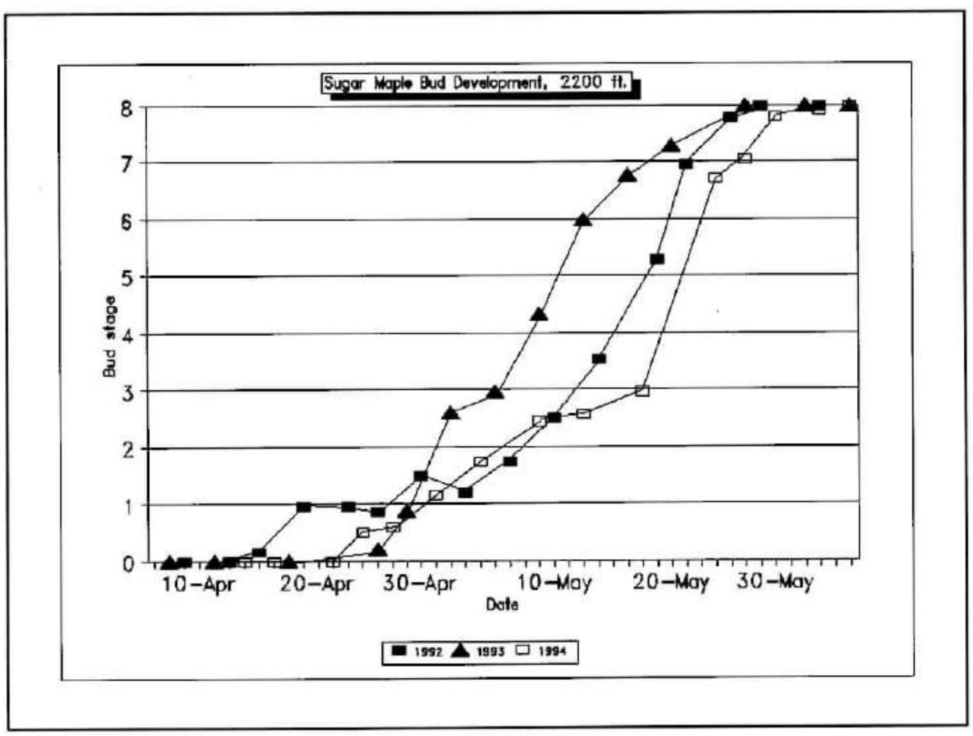
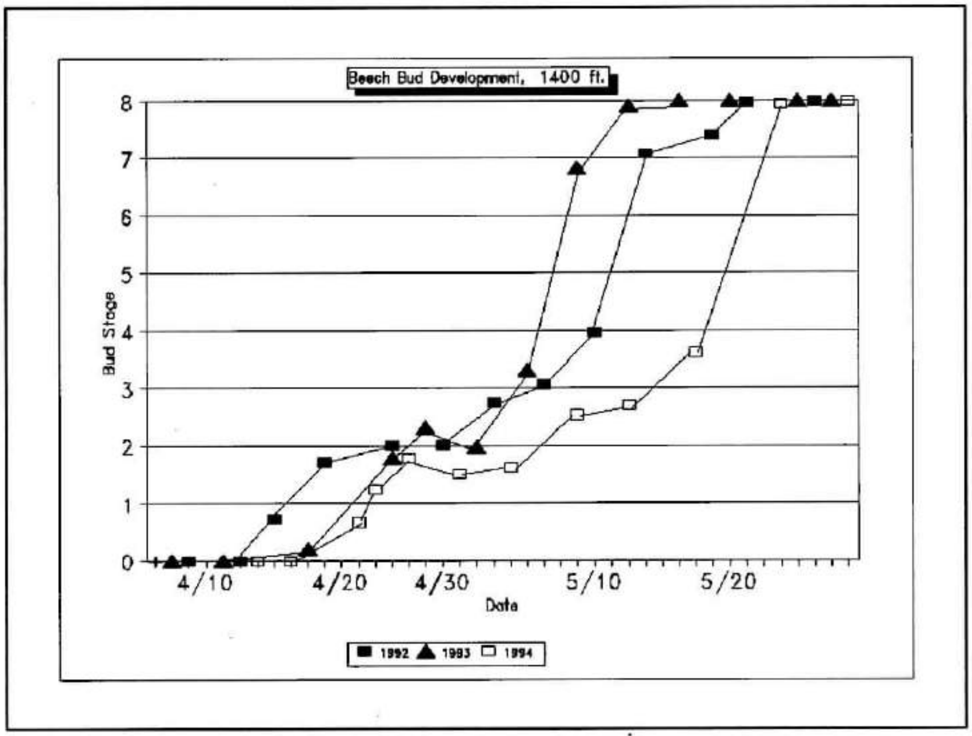


Figure 2. Beech bud development at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



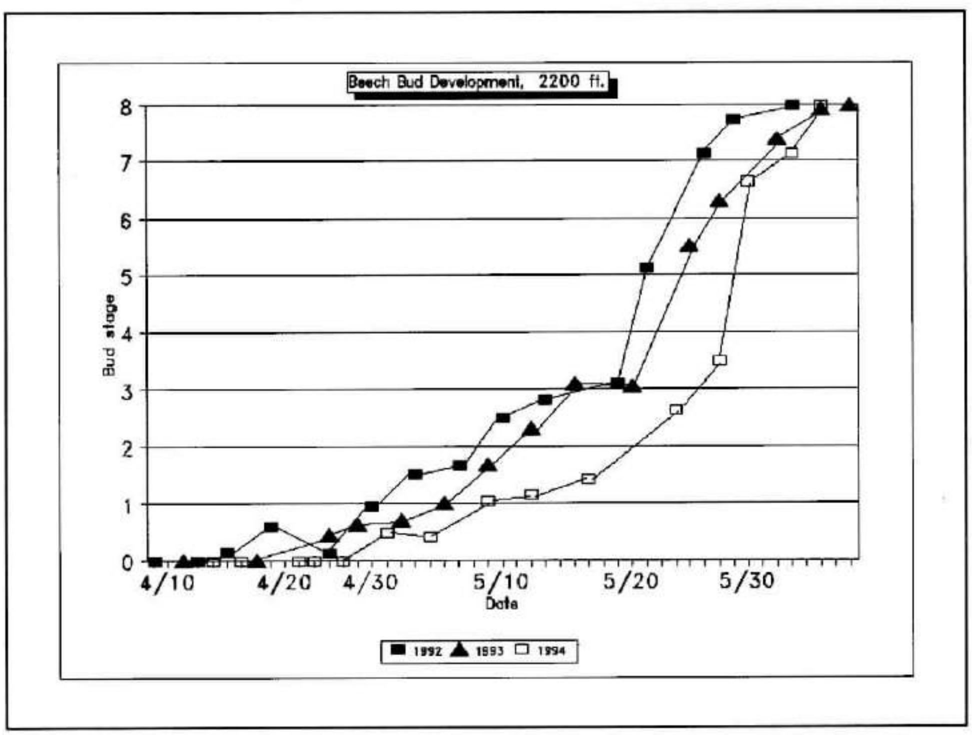
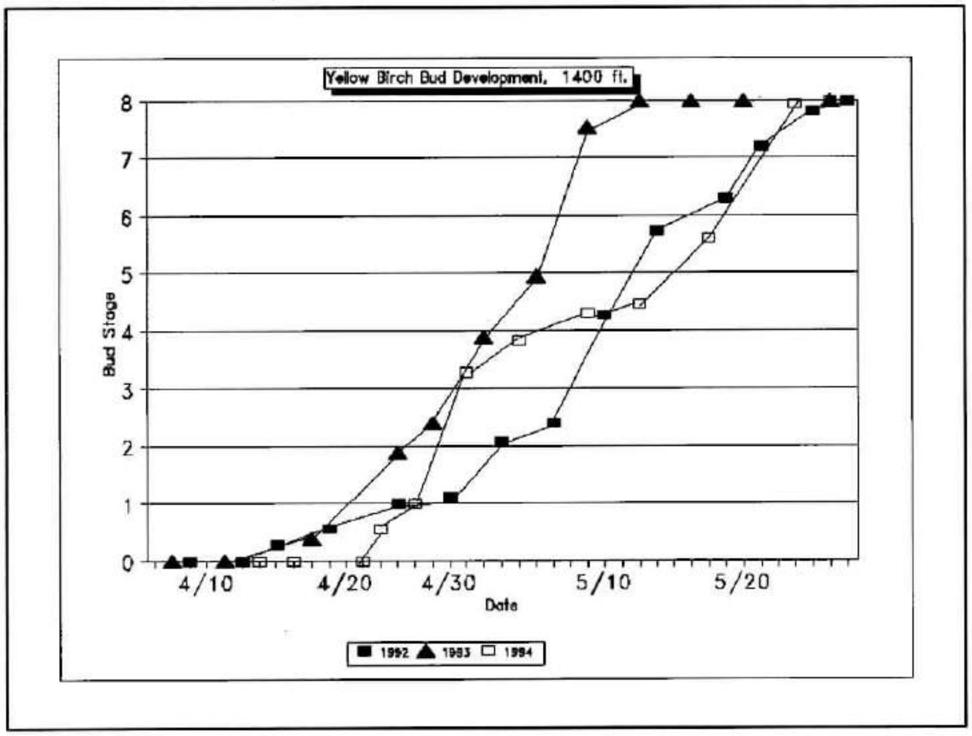
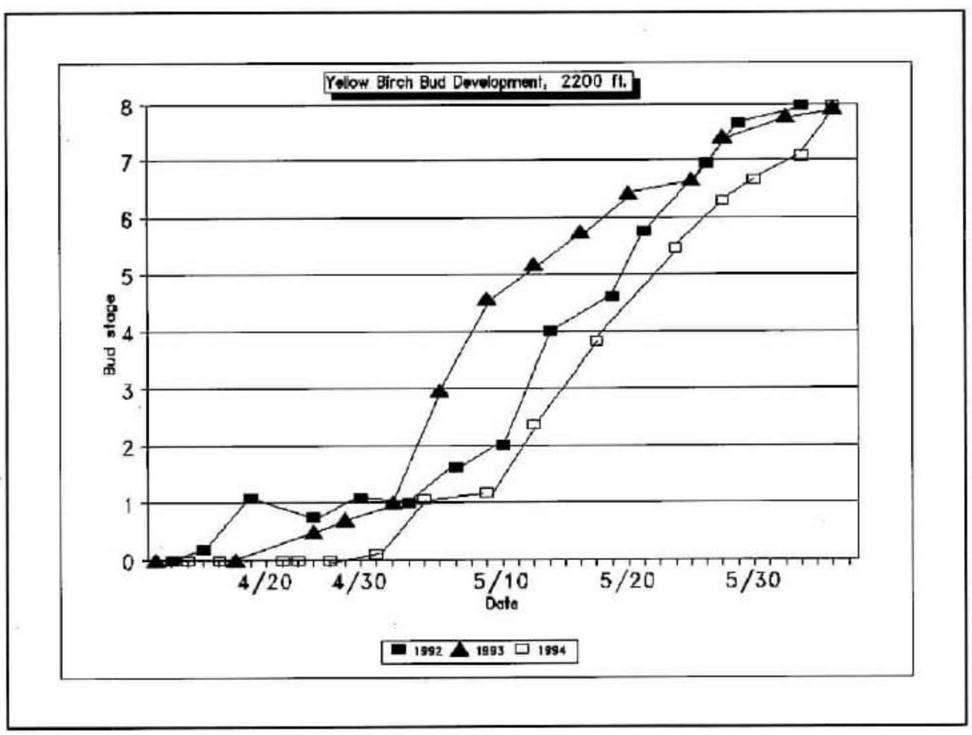


Figure 3. Yellow birch bud development at 1400 and 2200 feet on Mount Mansfield from 1992-1994.





LEAF SIZE

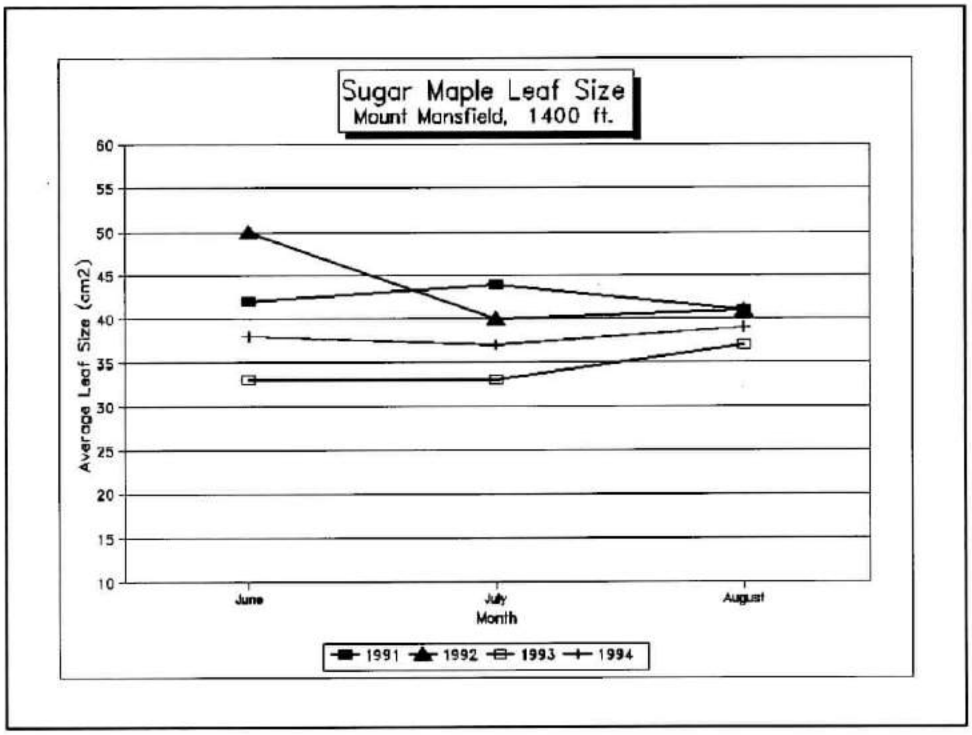
Within season leaf area measurements have shown similarities in between June, July and August (Figures 4-6). Early season sugar maple leaf size at the 1400 foot elevation has varied. Smaller than normal years in 1993 can be attributed to pear thrips damage.

Average leaf area for all years is presented in Table 2. Smaller leaf size was found at the higher elevation for yellow birch and beech, but no significant difference in size by elevation was found for sugar maple.

Table 2. Average leaf area of three hardwood species samples three times each season from 1992 through 1995 (sugar maple at 1400 feet was sampled from 1991-1995).

Species	Average Leaf Area (cm^2)	
	1400 ft.	2200 ft.
Sugar Maple	39.6	40.7
Yellow Birch	20.8	18.8
Beech	30.9	28.3

Figure 4. Sugar maple leaf area of trees growing at 1400 and 2200 feet on Mount Mansfield, measured during June, July and August of 1992-1994.



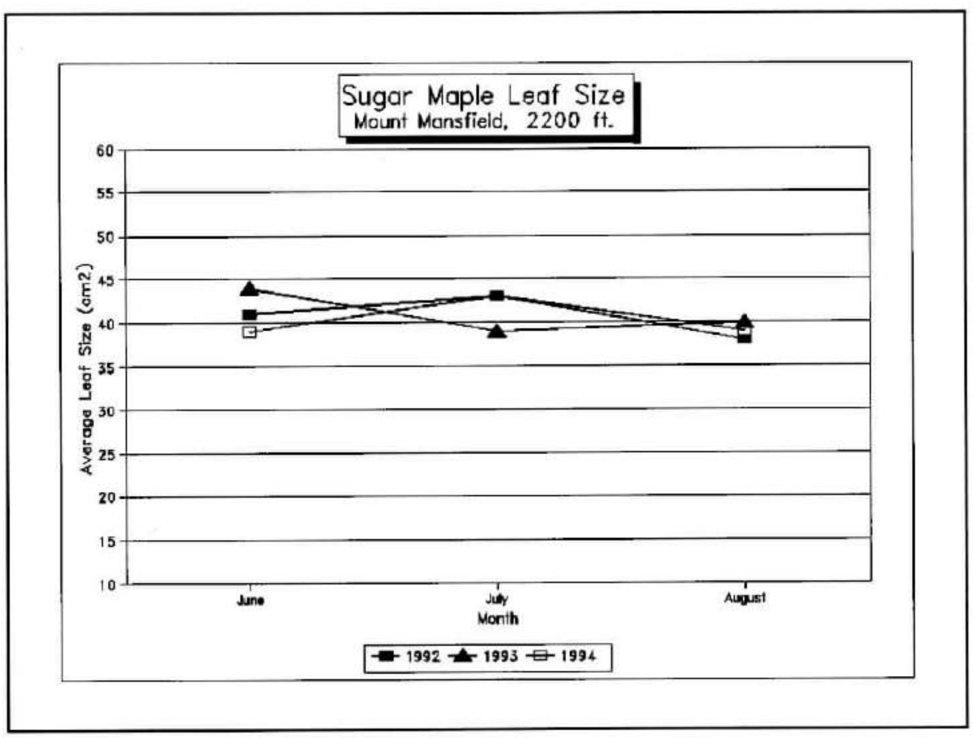
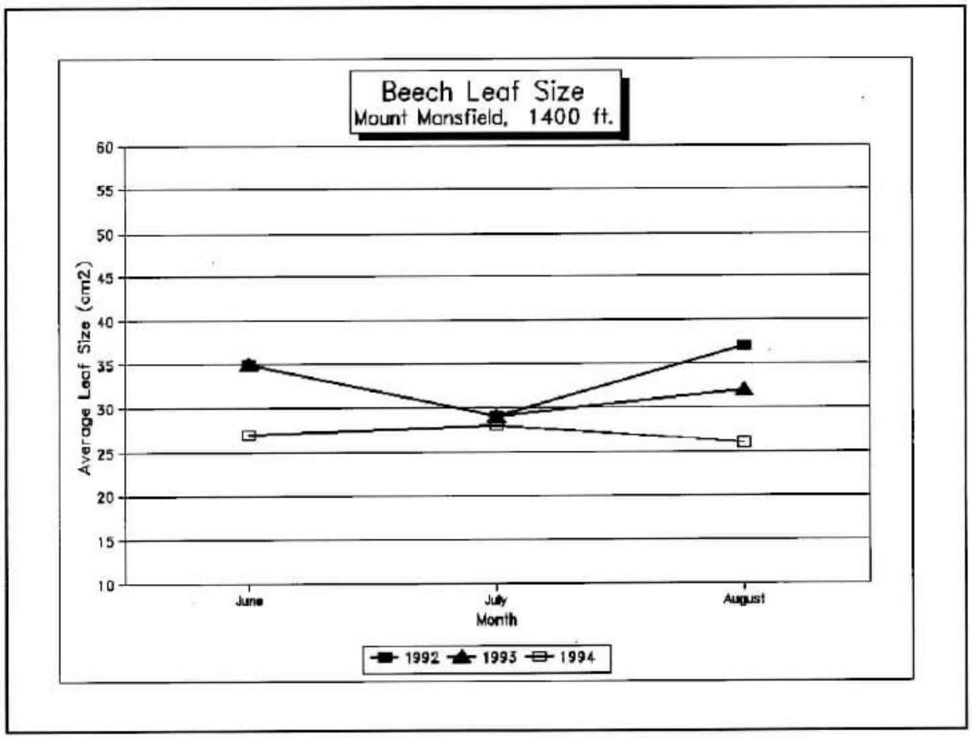


Figure 5. Beech leaf area of trees growing at 1400 and 2200 feet on Mount Mansfield, measured during June, July and August of 1992-1994.



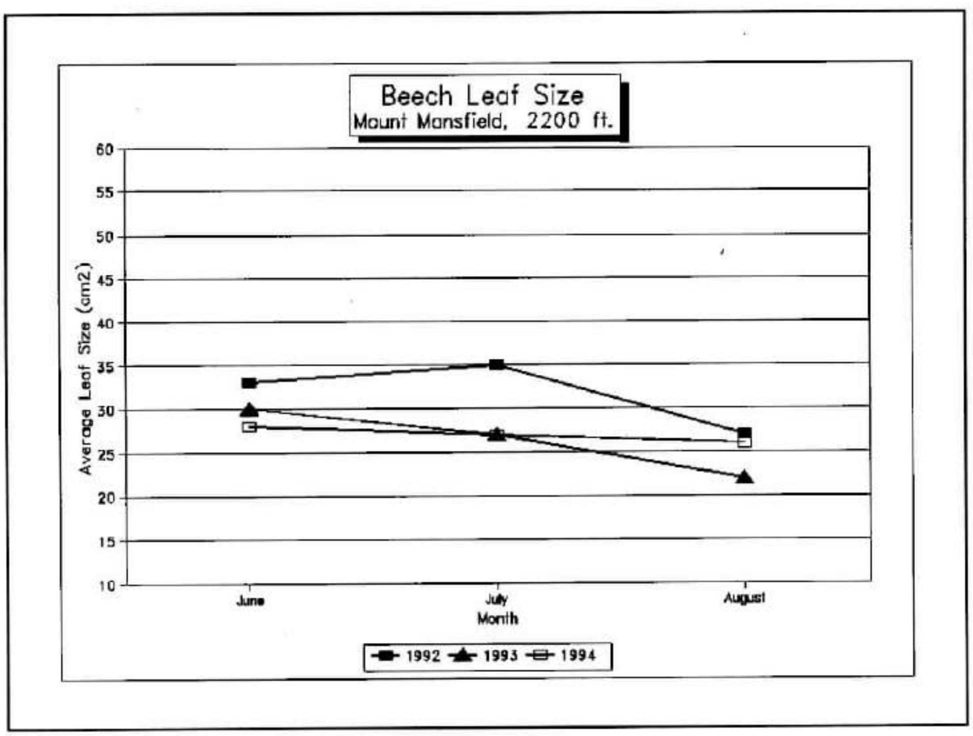
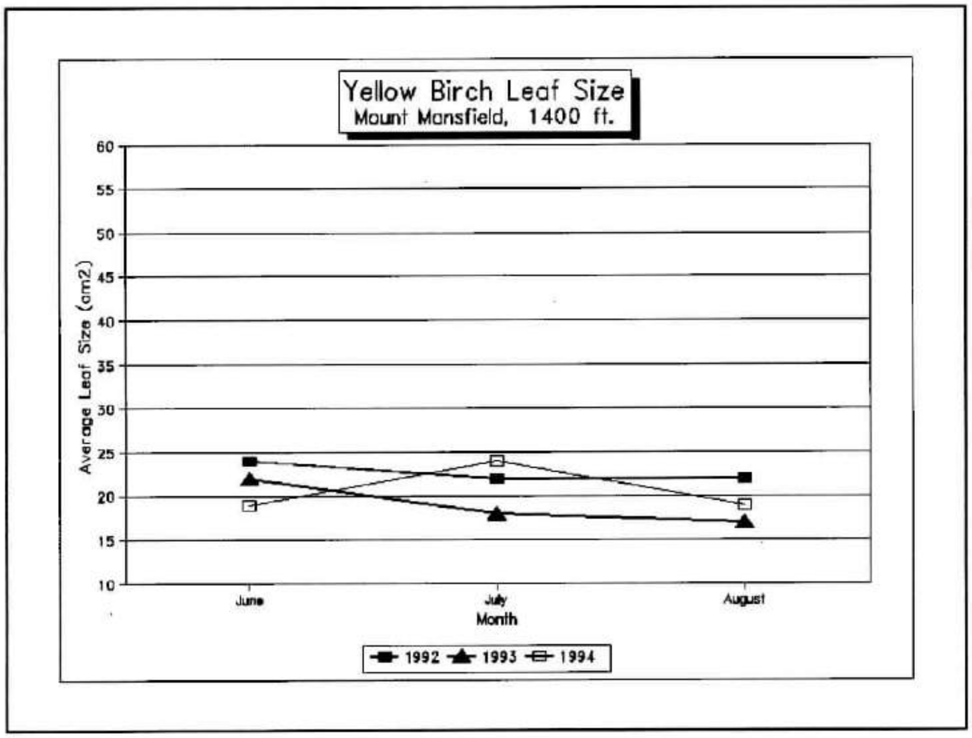
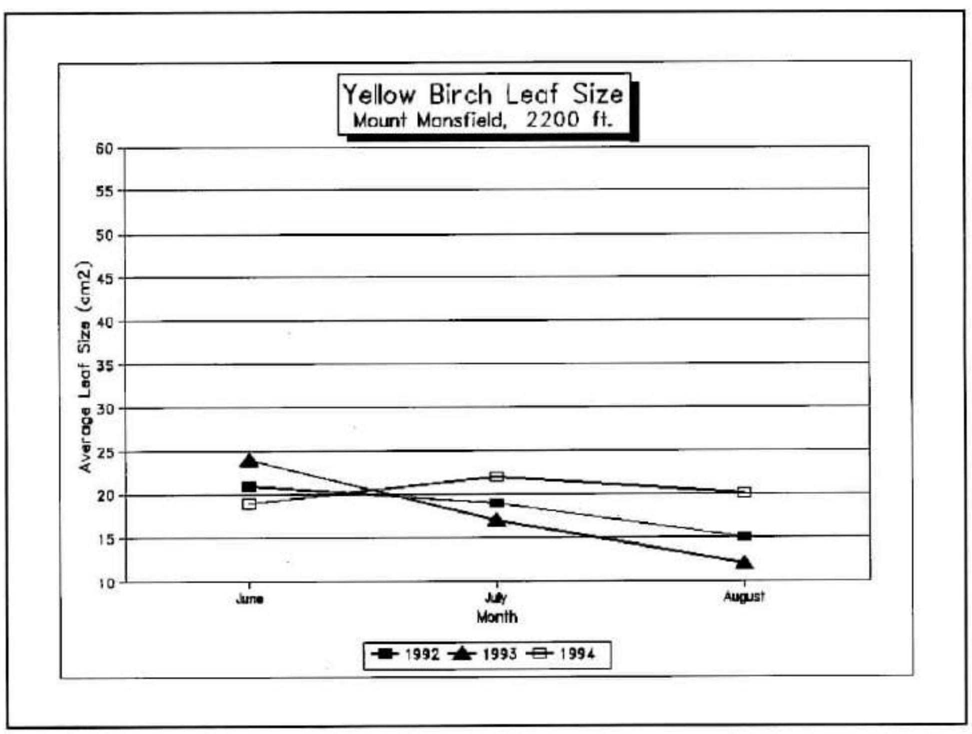


Figure 6. Yellow birch leaf area of trees growing at 1400 and 2200 feet on Mount Mansfield, measured during June, July and August of 1992-1994.





FALL COLOR AND LEAF DROP

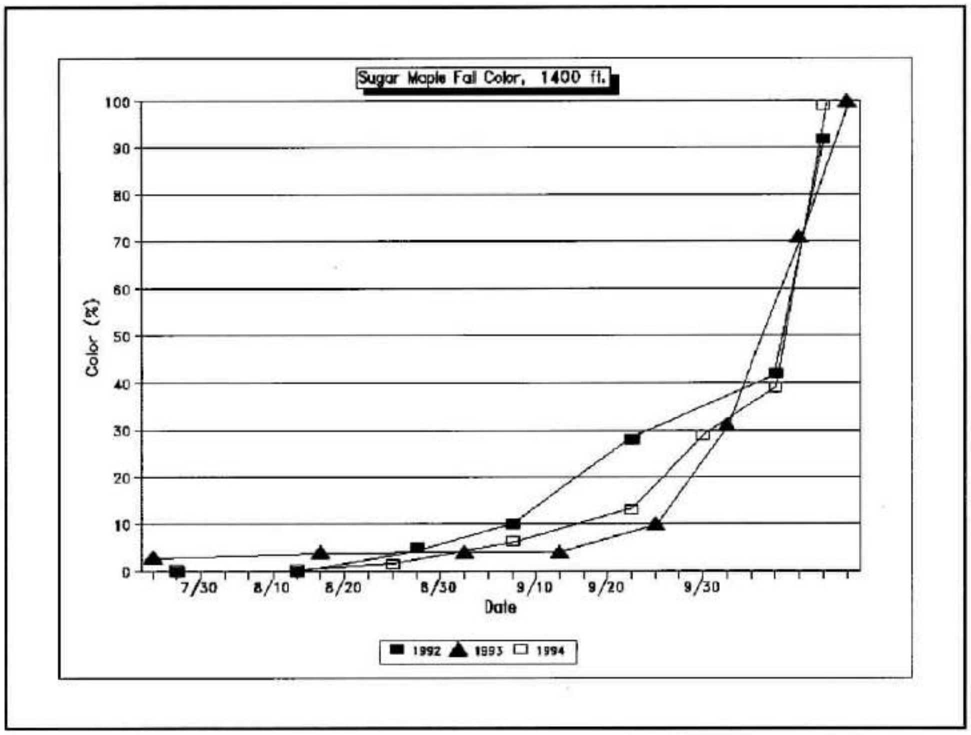
Fall color and leaf drop was earlier than normal for most tree species, especially at the higher elevation.

Sugar maple color at 1400' was similar to other years, with rapid color change the first week of October (Figure 7). At the higher elevation, 50% color was observed by September 20, 10 days earlier than in 1993. Leaf drop at lower elevations was similar to other years, but at the higher elevation, significant leaf drop (50%) was measured when leaves were still below 50% color.

Beech at 1400' reached 50% color slightly ahead of other years, while at the higher elevation, beech had full color nearly 2 weeks earlier than in 1992 and 1993 (Figure 8). Leaf drop began earlier in 1994, especially on higher elevation trees.

Yellow birch color was similar to other years (Figure 9). At 2200', birch had a rapid color change during the third week of September, resulting in 90% color well ahead of other years, 2 weeks earlier than in 1992. Significant leaf drop occurred at higher elevations well before October, with nearly 60% leaf drop on September 20, when only 15% color was measured.

Figure 7. Timing of sugar maple fall color at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



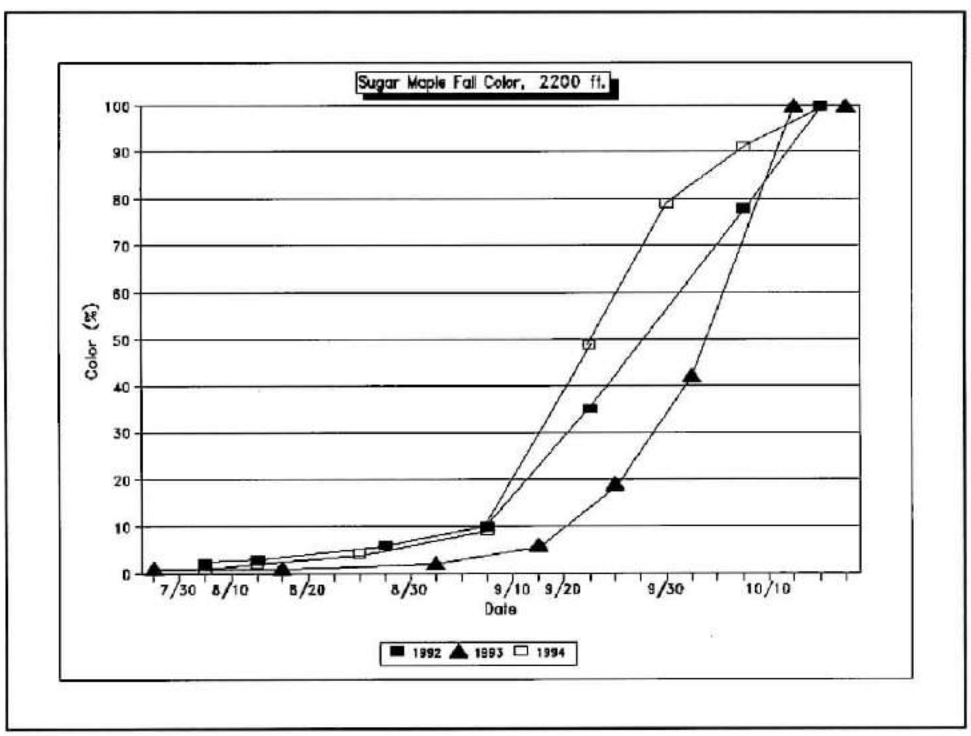
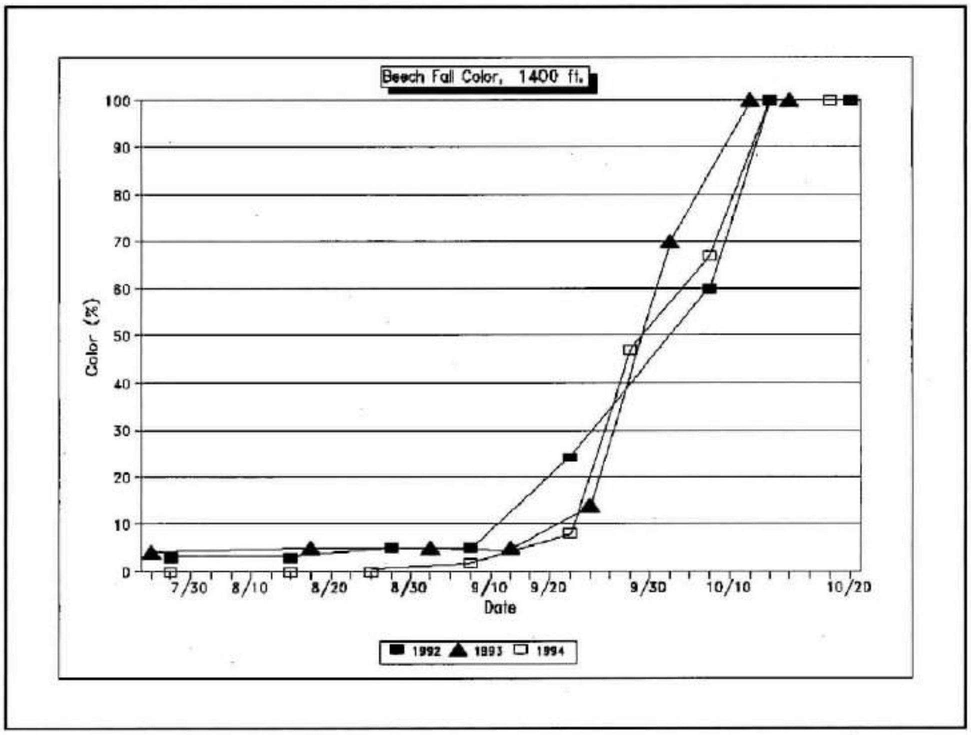


Figure 8. Timing of Beech fall color at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



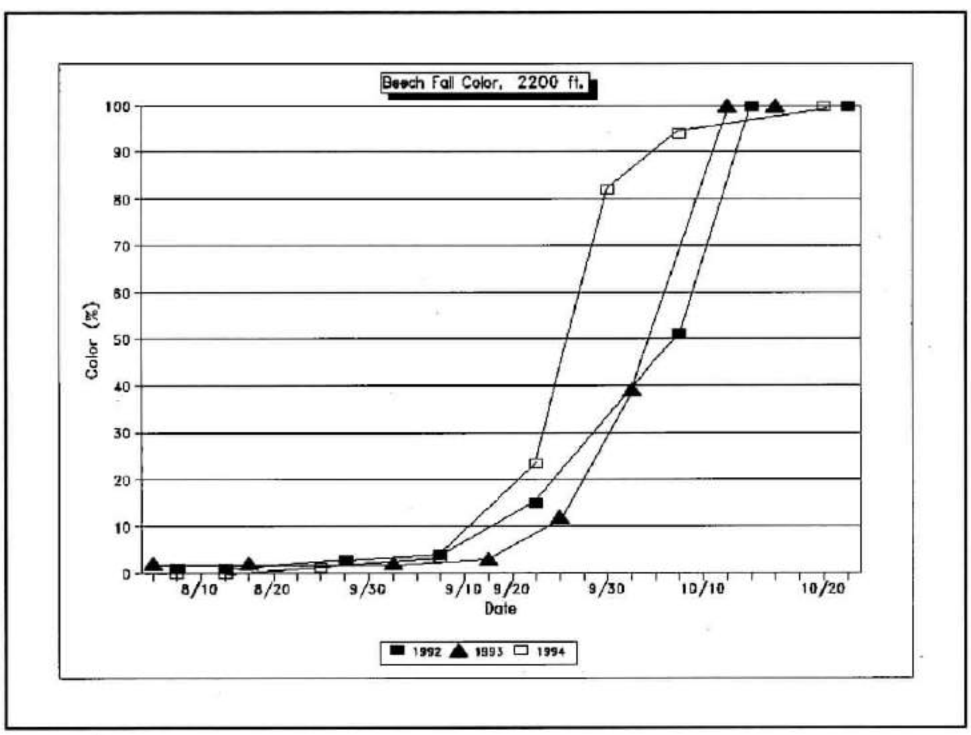
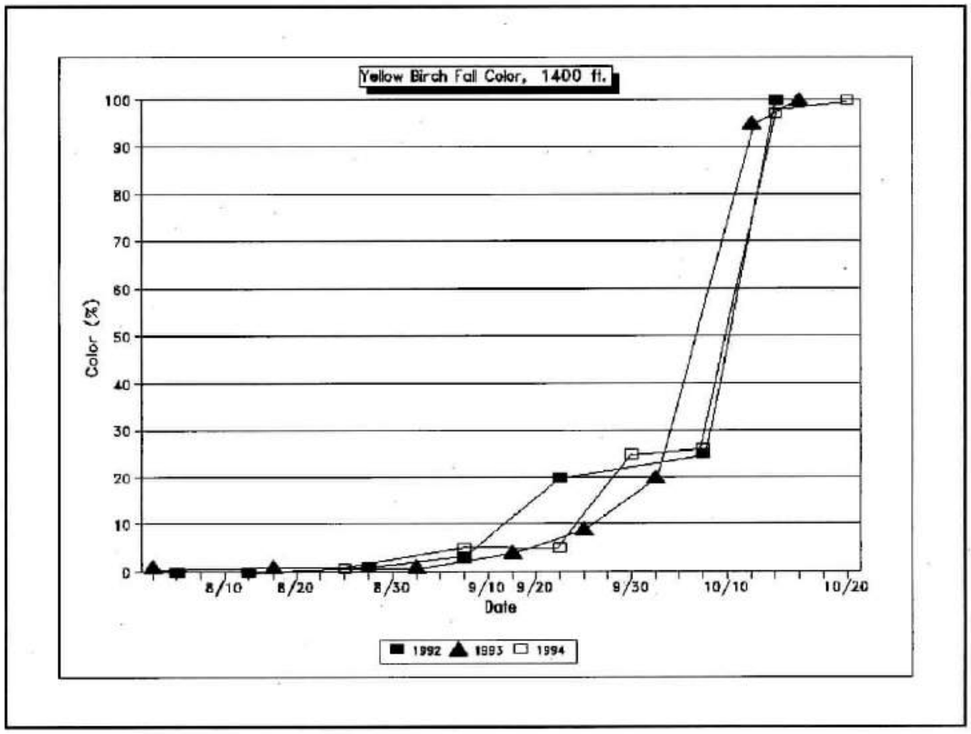


Figure 9. Timing of yellow birch fall color at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



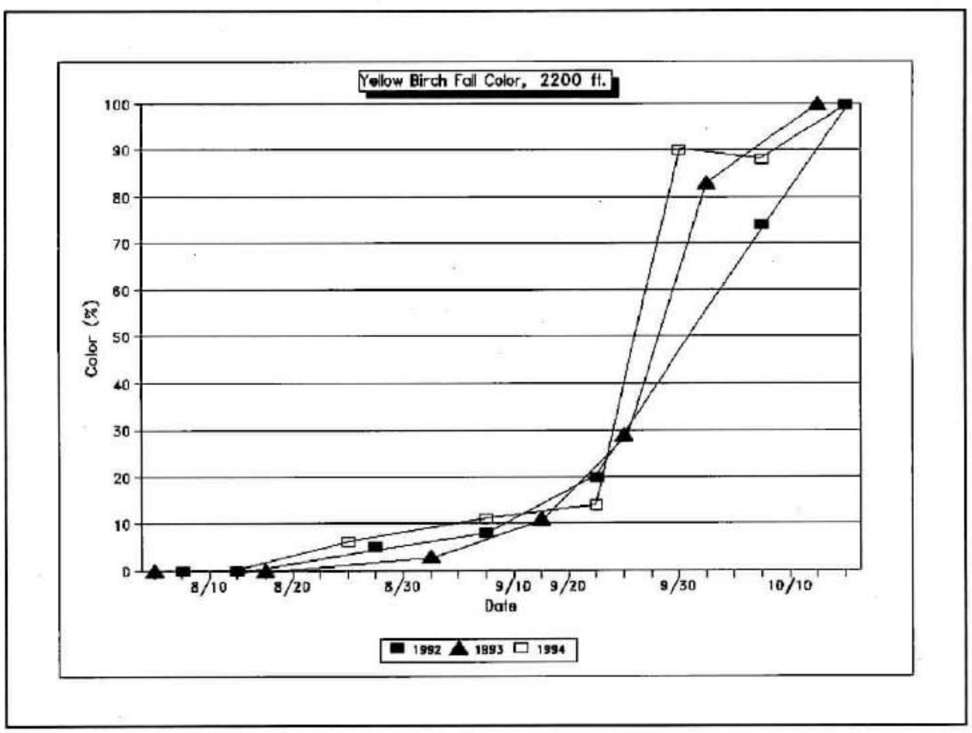
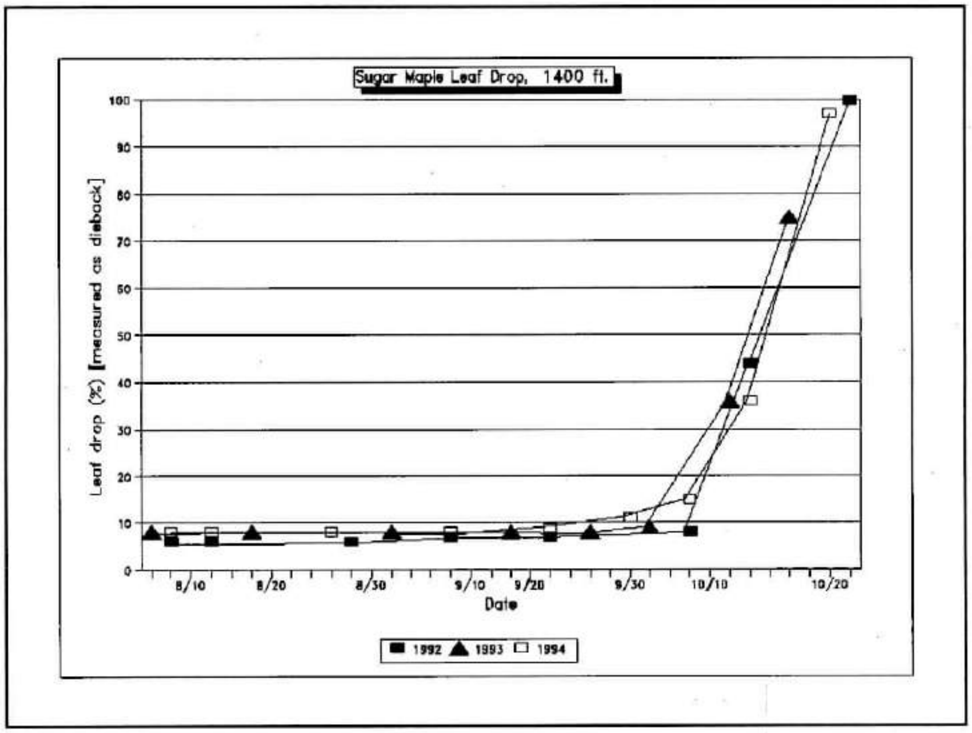


Figure 10. Timing of sugar maple leaf drop at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



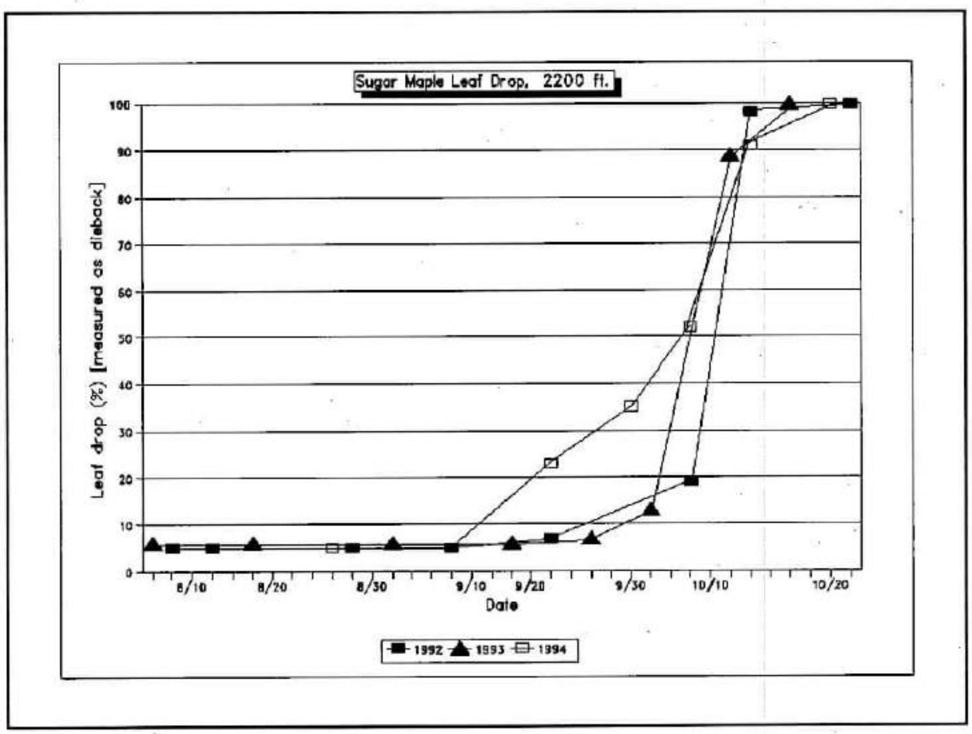
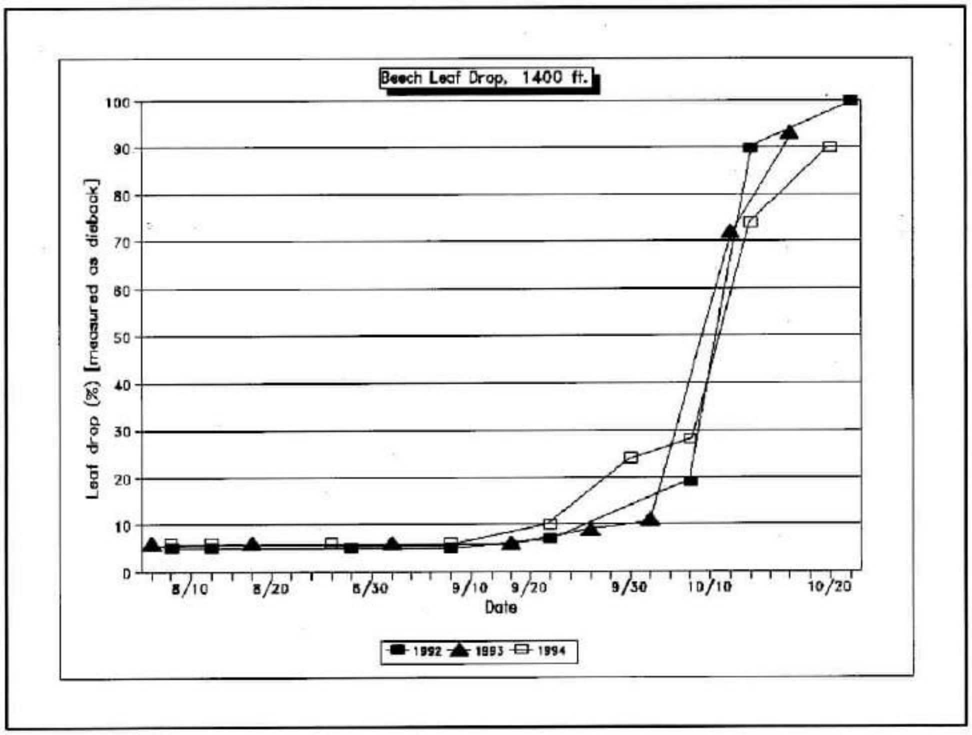


Figure 11. Timing of beech leaf drop at 1400 and 2200 feet on Mount Mansfield from 1992-1994.



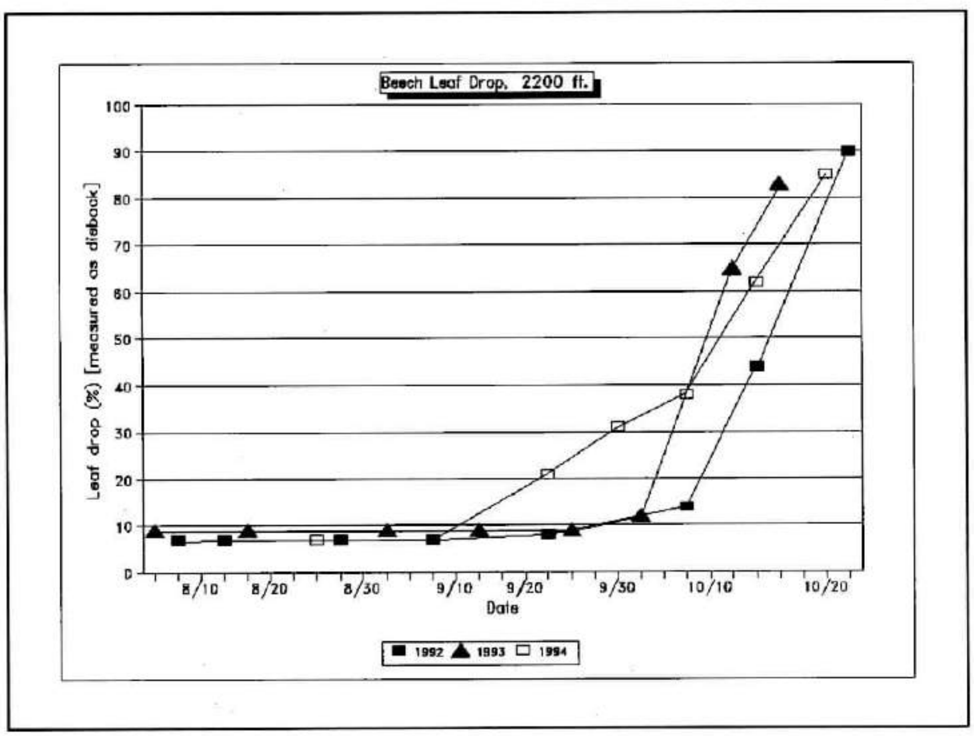
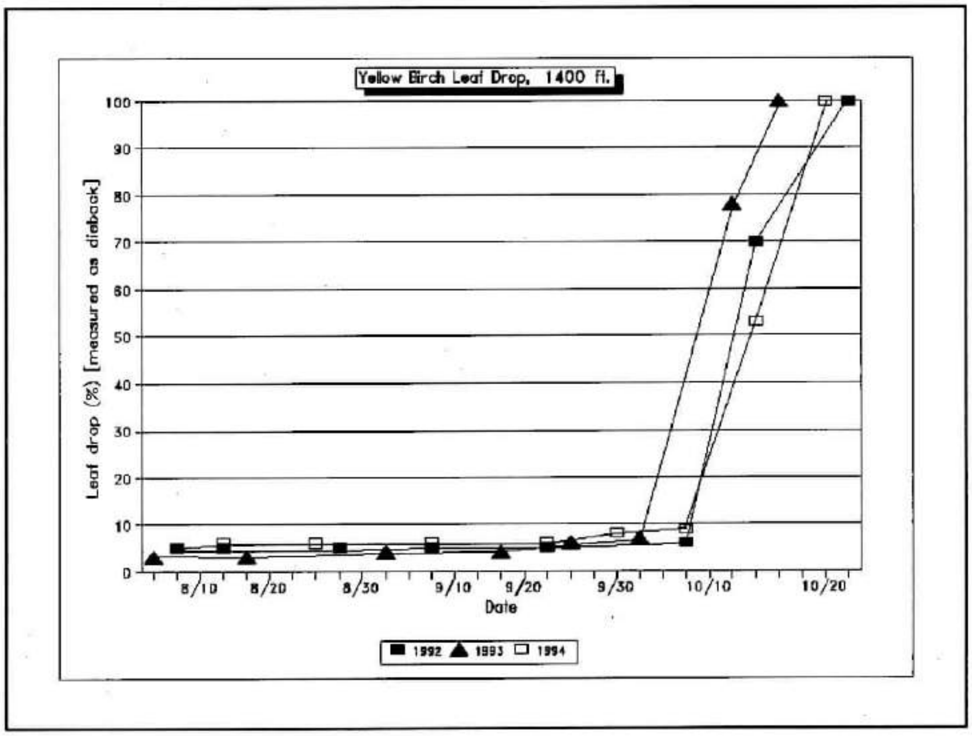
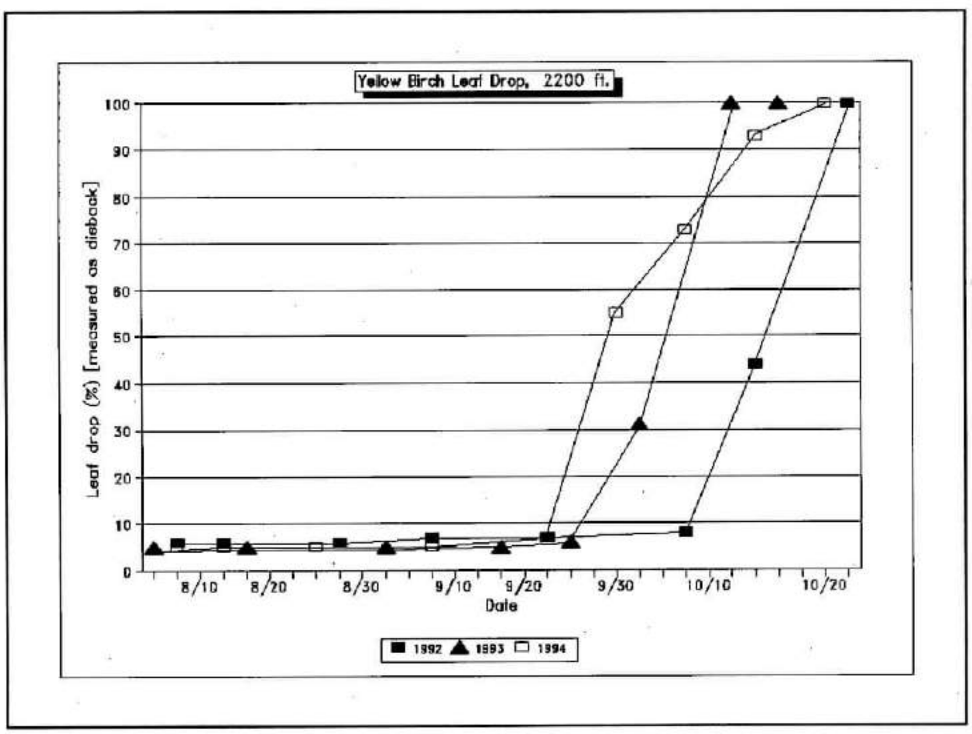


Figure 12. Timing of yellow birch leaf drop at 1400 and 2200 feet on Mount Mansfield from 1992-1994.





DISCUSSION

This growing season was shorter than usual with budbreak later than in the past few years, and fall color earlier than normal. A more extensive evaluation of bud development, fall color and weather relationships is available soon (Wilmot & Simmons, in press).

This concludes our baseline collection of leaf size. These results can be considered normal leaf size for sugar maple, yellow birch and American beech at this site. This baseline will be useful for future comparisons to assess defoliation or poor tree vigor resulting in leaf size reductions.

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Long-Term Vegetation Monitoring Data:

Mt. Mansfield, Vermont

Research Supported by
The Vermont Monitoring Cooperative

Completion Report

to the

Vermont Department of Forests, Parks and Recreation

under
Cooperative Grant Agreement
F-VMC/HOW-94-006

May 1995

William G. Howland

P.O. Box 527
Richmond, Vermont 05477

Abstract

Four long-term vegetation monitoring sites have been established in the summit area of Mt. Mansfield and located with reference to cadastral survey monuments. At each site a restricted random array of 10 permanent 1-meter quadrats was located, within which base-line vegetation data were acquired. Survey was done with a 5-second laser theodolite and recorded in a form to enable sites to be retrieved and re-examined in the future. Frequency and cover data were gathered for both higher vascular and cryptogamic taxa within forty 1-meter quadrats, and a comprehensive species list prepared. Soil depth, character, pH and surface morphology (slope and aspect) were recorded at each long-term site. Vegetation of the western slopes of Mt. Mansfield was also assessed, by trailside sampling at approximately 200 foot elevations. Vegetation data include a species list for twenty-five belt transects of 1 x 25 meters, and a frequency data within fifty 1-meter quadrats at random locations, two per belt transect.

Introduction

The Green Mountains of Vermont rest in the middle of the Northern Appalachian Mountain System and support a well known flora having strong affinities with that of montane habitats throughout New England, northern New York and the Gaspe region of Quebec. The summit of Mt. Mansfield, Vermont's highest peak, is blanketed with subalpine and alpine tundra; the lower slopes support boreal and mixed deciduous forest. Considering the long and active history of collections from the upper elevations of Mt. Mansfield (from Pringle, 1876 to Zika, 1991), surprisingly little is known of contemporary vegetation in the boreal, subalpine and alpine areas of the mountain.

Vogelmann, et. al. (1969) presented a summary description of the unique and vulnerable character of high elevation ecosystems in Vermont, including a brief description of montane vegetation. Countryman (1980) and Thompson (1989) have documented the threatened or endangered status of several species presently found on the mountain. Cogbill and White (1991) have reported on the boreal forest biogeography of the Appalachian mountain system, with many observations of direct relevance to the plant communities of the flanks of Mt. Mansfield. Zika (1991) has thoroughly reviewed the historical collections from the alpine zone and searched their contemporary populations. Zika (1992a) provides a current higher vascular species list for the mountain.

In recent years, a significant increase has occurred in the use of Mt. Mansfield by hikers crossing the summit on the Long Trail, from 40,000 per year (Peet, 1979), to an estimated 50,000 per year (Paradis, 1994). This heavy trail usage has inevitably increased the anthropogenic disturbance of the fragile plant communities of the alpine tundra zone. In addition, the eastern slopes of the mountain are managed extensively by a local ski area, and the middle peak (the 'Nose') supports several large communications towers, buildings and roadways. Finally, there is observational and anecdotal evidence that off-trail snowboarding occurs on the eastern side of the Chin, with attendant physical impact on vegetation that is particularly vulnerable and brittle in its frozen state.

Other regional contemporary anthropogenic impacts include acid precipitation and dry deposition (Bormann, 1985), with which Vogelmann et al. (1985) associated red spruce dieback on nearby Camels Hump. Changes in global climate associated with atmospheric CO_2 loading are also thought to contribute, through regional weather manifestations, to changing habitat conditions; an hypothesis relating historical declines in red spruce to climate change is examined by Hamburg and Cogbill (1988). Experimental research examining the recovery of disturbed sites on the summit ridge and the effects of nutrient treatments on revegetation vigor in selected alpine plant communities was reported by Vogelmann and Leonard (1982).

Insect predation and plant pathogens of significance to forest health are now monitored in the New England Region (Eager, et al. 1992) and on Mt. Mansfield by forest ecologists working in conjunction with the Vermont Monitoring Cooperative (Wilmot et al. 1994). Recent attention has focused on pathogenic and weather-induced stress in the spruce-fir forests of the northeast, that could well drive regional changes in species composition in montane plant communities (for example Burkman, et al., 1993; Cox and Miller-Weeks, 1991). Many studies have addressed the response of forest species to seasonal climatic stress (eg. DeHayes et al. 1989, 1990). Yet most of these important efforts attend primarily to the health of individuals or populations in species of direct economic importance, rather than to the condition or character of the natural vegetation as a whole.

Little research has treated natural vegetation patterns in the higher elevations of the Green Mountains, despite the steep environmental gradients and the attendent compression of ecotones that makes these places well suited to studies of natural and anthropogenic change. Consequently, at a time when it would be most useful, historical vegetation data for these sites is unavailable. There seems little prospect for the systematic recognition of either natural or anthropogenic changes in the vegetation of upper elevations in the Green Mountains until the associated base-line data are acquired and reported.

The present study has addressed this specific need by establishing several long-term study sites in the summit area of Mt. Mansfield, tabulating vegetation data within these sites, and also by acquiring vegetation data along the elevation gradient of the western slopes of the mountain. This completion report presents these data to the Vermont Department of Forests, Parks and Recreation which has supported the final field season of the study.

Objectives

This research program has addressed two objectives in assessing vegetation in the summit area and on the western slopes of Mt. Mansfield.

Part 1

The first objective was to establish four long term vegetation monitoring sites characteristic of the alpine tundra in the summit area of Mt. Mansfield, and to sample vegetation within each site. Specifically, under the terms of the Cooperative Grant Agreement, the work in each long term site was to include a characterization of soils, detailed location data for each sample site, and vegetation sample data characteristic of each, including a list of plant species identified.

Part 2

The second objective was to survey vegetation changes with elevation on the western slopes of Mt. Mansfield, through sampling along certain trails which provide access to the area, and including a list of plant species identified.

Methodology

Part 1 - Long-term Sites: Alpine Tundra, the Summit Area

Four long-term research sites were established for vegetation sampling, with adequate location control so that the sample quadrats within each site may be accurately relocated for re-study in future years for comparative purposes.

Spatial Sampling Method

The number of long-term sites to establish in the summit area reflects the scope of resources available for this project rather than an analytical optimum. The location and size (20 x 30m) of long-term sites in the summit area was made subjectively in consultation with the UVM Natural Areas Manager, to reflect the common sense requirements that they be off-trail to minimize visitor disturbance, and be characteristic of the more horizontally inclined slopes.

The alpine tundra vegetation within each long-term site in the summit area was examined in a restricted randomized array of ten one-meter squared quadrats.

Each 20 x 30 meter sample site was subdivided into a 10 by 10 grid of one hundred intersections, spaced 2 x 3 meters apart, as shown in the Site Maps (Figures 2 - 5). A random number array determined the x, y coordinates of grid intersections to be sampled for vegetation. The site stratification assured adequate distribution of samples; the random selection of sample locations within the stratification provided the component of objectivity required for many ecological analytic procedures.

Location Control

After long-term sites were generally located, one corner was selected as a geographic origin and a local point of reference for a subsequent site survey. For these corners, in each case on an outcropping of rock, a hole was drilled in the bedrock or a small paint mark was placed for reference through the survey period. Survey data were generated with respect to these local 'origin' locations, and the site was roughly set out with a tape and Brunton compass survey to ensure that it did not intersect trails or extend substantially off the cliffs in the area.

For the more demanding measurements required to establish sample locations, a laser theodolite (a Nikon DTM-5 Total Survey System) was used to survey each 20 x 30 meter site, and also each of ten randomized sample quadrats located within sites. Similarly, laser theodolite survey provided a linkage between samples sites and various permanent survey monuments in the summit area from previous cadastral surveys. Associated data are presented in Tables 1 - 5.

To locate 1-meter sample quadrats, coordinate pairs were specified by random numbers to identify ten grid intersections within each long-term site, with reference to a local grid survey origin. The chosen intersections determined the corner of the 1-meter sample quadrat frame closest to the survey origin of each long term site. For each long-term site, the survey origins are shown as the upper left corner (0,0) on Figures 2 - 5, and the approximate locations of each 1-meter sample quadrat are indicated by numbered squares distributed throughout.

After the field survey identified the nearest corner of the 1-meter sample, that corner and the opposite corner were marked with aluminum tags (or corresponding scratches in rock) for quadrat location reference through the vegetation analysis. Quadrat frame orientation was controlled by Brunton compass bearing, to make parallel the sides of the frame with the sides of the 20 x 30m sites. Tags marking corners were removed in two of the sites, and the balance of tags will be removed during the summer of 1995.

Floristic Sampling Method

A one-meter squared quadrat frame, divided by elastic cords into a 10-centimeter grid, provided the visual reference for generating frequency and cover scores for all species. Frequency was determined as the number of grid cells in which any parts of each taxon could be recognized. Cover was determined as the spatial extent of the plant canopy for each taxon, estimated with visual reference to the 1% area grid cells of the quadrat frame. Frequency and cover data were gathered in this way for ten fixed quadrats within each of four long-term sites. General observations of soil properties, local geomorphology, slope angle and aspect were also recorded at several quadrat locations within each long-term site.

Determinations of most cryptogams and several higher vascular plant vouchers from were obtained from regional botanical authorities. Selected voucher plant collections were prepared as herbarium specimens and catalogued.

Part 2 - Western Slopes Below Treeline

The sampling design for the investigation of the floristic composition of vegetation of the western slopes of Mt. Mansfield follows a random sampling scheme stratified by elevation.

Spatial Sampling Scheme

The number of sample sites examined on the western slopes reflects the scope of resources available for this project rather than an analytical optimum. Sample sites were restricted to areas adjacent to the existing trail network (which provided ease of access to the western slopes of the mountain) and located at aproximately 200 foot elevation intervals, by altimetric survey.

Location Control

Hand-held analog aneroid Peet and digital Avocet altimeters were used at various times to locate sampling sites. Altimeters were reset on each field excursion at the trail-heads or other elevation control points, to compensate for local atmospheric conditions. Usually calibrations were made early in the day but sometimes corrections were made at the end of the day.

The use of topographic maps as trailhead elevation controls suggests that an absolute accuracy of measurements of plus or minus one 200-foot interval is realistic, although the relative elevation measurements for any particular trail should be considerably more accurate. No analysis of accuracy or precision of elevation measurements was attempted.

At nominal 200 foot elevation intervals on various trails, belt transects were oriented normal to the trail and extending away from the trail at an azimuth recorded as 'transect azimuth'. Transects were extended on the upslope side of trails to avoid confounding the local vegetation conditions with the direct environmental effects of trail disturbance (which mostly occurs downslope from the trail). The origin of each belt transect was located off the trailside by five meters on the upslope side in order to avoid invading ruderal species sometimes associated with trailside disturbance.

Floristic Sampling Method

Twenty-five belt transects of twenty-five meters in length and one meter in width were positioned upslope from and normal to the chosen locations on each sampled trail. Within each belt transect, comprehensive presence/absence data were collected for all visible species of the higher vascular flora, and also for the most abundant visible cryptogams.

At two random locations along each belt transect, additional vegetation sample quadrats of one square meter were positioned to survey the herb-level flora. Within each quadrat frame frequency and cover data for all visible species were gathered; 50 quadrats were assessed in this manner. For sampling conducted in 1994, a third random site was located on the belt transect, a ten-meter diameter area for sampling tall shrubs and trees was positioned. The data acquired in these samples included stem counts in two dbh classes: less than 2cm dbh and greater than 2cm dbh, by species.

Determinations of most cryptogams and several higher vascular plant vouchers were obtained from regional botanical authorities. Selected voucher plant collections were prepared as herbarium specimens and catalogued.

Results

Part 1 - Long-term Sites in the Summit Area

Site Location Data

Four long-term study sites have been established in the summit area by laser theodolite survey. They include one near the summit of the Chin, one on the highest part of the West Chin, and two between the base of the cliff at the West Chin and the trail junctions at Thunderbolt Gap (see Figure 1). All long-term sites except the West Chin Top site, (which is the most easily referenced to existing local survey monuments) have been informally monumented in one or more corners with small drilled holes in bedrock, into several of which were cemented steel bolts.

Ten vegetation sampling quadrats within each long-term sites were arrayed in a random scheme and mapped using Adobe software. A field survey of sample quadrats was done with the laser theodolite, following the radial coordinates calculated for each (see Tables 1 - 5). Because the terrain is not flat, the unpredictable vertical coordinates were measured in the field, and are tabulated either as X,Y,Z coordinates with reference to the Long-term site map or as angles and distances from the local coordinate origin of the site.

Vegetation Data

Vegetation sampling (species list, frequency and cover scores) was completed at 40 quadrats in the four long-term sites. The average field time required (on-site) to evaluate the vegetation of a quadrat is 3 hours, most of this time being in the examination of cryptogams. Determinations of cryptogams and a few of the higher vascular vouchers from were completed in early 1995. Several cryptogams species, while visually differentiable in the field, were subsequently not identifiable, due to the small amount of material collected or the sterile or obscure state of the collection.

Several cryptogams display such plasticity or morphological variations through various stages in their life history that they were scored and collected in the field as potentially separable taxa, and their scores were later combined following determination to the same species. This difficulty seems unavoidable, as the identification of many cryptogamic taxa requires laboratory analyses, mainly microscopic study and chemical tests. Consequently, the cryptogamic data do reflect revisions following determinations. For cases in which two sets of scores were found to represent a single taxon, the larger of the two frequency scores has been retained as the frequency datum, but the corresponding two cover scores were added to yield a combined cover score. This method results in conservative frequency scores but will avoid errors of overestimation. The corresponding errors of omission, in which two or more taxa were combined in the field and scored as a single taxon, remain unrecognized in this study; however, it is a virtual certainty that such errors have occurred despite efforts to avoid them.

Physical Site Data are presented in Table 15. The slope and aspect measurements are consistent with the apparent highly irregular surface in the summit area. Soil pH data indicate that the mountain soils are strongly acidic and that a similar soil series mantles the entire summit area; variations are minor. Data in Table 15 include mean pH scores to characterize alpha-type variations, in view of a single soil series being sampled, and median pH scores in view of the possibility of beta-type variations that would occur with more than one soil type in the area. The similarities of mean (as log mean antilog) and median scores suggest a limited variation in soil acidity in the summit area.

Part 2 - The Western Slopes

Site Location Data

Sample site location data are presented in Tables 10 - 14 together with the respective vegetation data.

Vegetation Data

Vegetation sampling (species list, frequency and cover scores) was completed at 50 quadrats in 25 belt transects on the Western Slopes. Determinations of cryptogams and a few of the higher vascular vouchers from were completed in early 1995. Several cryptogams and a few of the higher vascular plants were not identifiable due to the small amount of material collected or the sterile or obscure state of the collection. In Part 2 of the study especially, errors of omission are to be expected in the species list, as some ephemeral species may not have been visible among the ground flora of the montane forest at various sampling times.

Tables 10 - 14 list the taxonomic identity and associated presence data (belt transects) and frequency data (quadrat samples) by sample site, trail, and elevation. In these tables, the list of species without numeric scores (indicated **Pr**) comprise presence/absence data within the 25 x 1 meter belt transect.

Discussion

Vegetation of the Summit Area

This Cooperative Grant Agreement concerns the acquisition and transfer of data in the context of monitoring, and does not include a plant community analysis or gradient analysis *per se*. Nonetheless, it is clear that the tundra vegetation of Mt. Mansfield is characterized by two predominant vegetation types with variations from place to place. Moreover, the plant communities of the alpine zone of Mt. Mansfield appear to be rather different from those of peaks in either the adjacent White Mountains or the Adirondacks, particularly with regard to the following two plant associations.

Vaccinium - Cetraria - Carex Association.

Characterized in a general way by Bowley (1978) in the report of his research on lichen distributions in the area, the association of the Ericaceous shrub *Vaccinium uliginosum* and the lichen *Cetraria islandica* is apparent in the data from each site. These two taxa are generally found together, the lichen intertwined with the stems of the heath. Other frequent associates are *Carex Bigelowii* and *Vaccinium boreale*. In many areas adjacent to *V. uliginosum* colonies, *Polytrichum juniperinum* is prominent. The resulting association is characteristic of parts of the alpine zone in which organic soils are found to be relatively stable.

Rhizocarpon - Arctoparmelia - Lecanora - Mycoblastus Association

A second association of plant species in the alpine area is comprised of four common crustose lichen taxa, and predominates exposed rocky surfaces. Within this group, however, the distribution of each is not identical; they appear to be subtly controlled by the microclimatic conditions associated with microtopography

Rhizocarpon geographicum is typically found in the most exposed locations, associated by Bowley (1978) with typically less than 6-inches of snow in winter. *Lecanora* thrives in much the same conditions as *R. geographicum*. Conversely, *Arctoparmelia centrifuga* appears to be characteristic of sheltered rock facets offering some protection from the combined effects of wind and sun. *Mycoblastus sanguinarius* seems to thrive in a wide range of intermediate site conditions.

The rocky terrain of the summit area displays a microtopography in which rock facets of windward or otherwise extreme exposure, suitable for *Rhizocarpon*, are coupled with adjacent more protected facets, suitable for *Arctoparmelia*, and also microsites that are of intermediate exposure. Consequently, these four lichen taxa do actually form a characteristic association, despite the subtle differences in the habitat requirements of each. It is important to note that many other species of lichens are widely mixed throughout this association of four characteristic genera.

Soils of the Summit Area

A general characterization of soils in the long-term sites indicates that there is relatively little variation in soil properties within the summit area of Mt. Mansfield. Bowley (1978:13) discussed the parent rock in the study area and speculated on the related minerology of the alpine soils, especially with regard to vegetation responses. Little other information is available from the literature.

The schist which comprises the local bedrock (Christman, 1959) throughout the summit area is extensively weathered into boulders and cobbles which protrude from the thin veneer of soils, resulting in a rough microtopography. These boulders and adjacent outcroppings tend to be extensively colonized by crustose lichens except where there is a recent history of anthropogenic disturbance. Weathering has also reduced the local rock into platy particles and fragments which comprise the mineral component of soils.

The soils of the summit area are predominately organic in character, uniformly acidic, azonal in structure and dark in color. Soil pH data presented in Table indicates that acidic soils are the norm in the summit area. Characteristically, the organic soil overlies mineral fragments but the components are not well mixed, indicating an early stage in pedogenesis.

Soils are anything but uniform in depth in the four long-term sites. The deepest soils were found in microtopographic depressions, and often were immediately adjacent to windswept and soil-free rocky surfaces. In areas where soils are unvegetated due to visitor traffic, there is a tendency for desiccation and surface cracking in dry periods.

Data Character

While neither analysis of plant communities and associations nor gradient analyses are an intended part of this report, it is, however, important to note that the data herein are appropriate for that use. All data presented are suitable for direct gradient analysis, ordination techniques (as reviewed by Gaugh, 1985) and analytic routines to reveal relationships between species or vegetation types and environmental conditions. Floristic data, recorded as frequency and percent cover, provide importance values for each species in each sample quadrat. All vegetation sample data were acquired through a stratified random sampling method designed to satisfy that parametric requirement.

Location Control

As the purpose of carefully surveying long-term sites and the randomized quadrats that each contains was to ensure that future studies could retrieve the same locations, a partial resurvey of one site was conducted. The average variation between surveys for several quadrats was about 4 mm, and no error was greater than 1.0 cm.

Future Research

This study has generated biogeographic and ecological data which enable a better understanding of the character of the vegetation on the summit and western slopes of Mt. Mansfield. The data included in this report provide base-line research greatly needed both to recognize the existing vegetation and to enable an assessment of future changes should they occur. These data are expected to be widely applicable to conditions at similar elevations in many adjacent parts of the Green Mountains, for which there is also a paucity of data.

While the date presented in this study describe the vegetation of the long-term sites effectively and may prove to be very useful in future monitoring studies, they do concern only a very small part of the diverse tundra plant communities of the summit of Mt. Mansfield. In order to effectively monitor the status of the entire alpine zone of the mountain, a far more extensive sampling program is required. It is hoped that this study may be of benefit in the design of future efforts expanding vegetation research and monitoring into other parts of the unique Mt. Mansfield Alpine zone.

Cooperative Grant Deliverables

Deliverables under this Cooperative Grant Agreement include:

Part 1

1. Vegetation Tables for each of four Long-term Vegetation Quadrats
   Hard Copy and EXCEL spreadsheet on disk
2. General Soils Characterization for each Long-term Vegetation Quadrat
   Hard Copy and EXCEL spreadsheet on disk
3. A Map of Sampling Points within each Long-term Vegetation Quadrat
   Hard Copy
4. Detailed Location of Sample Sites
   Hard Copy and EXCEL spreadsheet on disk.

Part 2

1. Vegetation Data for sample sites arrayed on an elevation gradient along the western slopes of Mt. Mansfield.
   Hard Copy and EXCEL spreadsheet on disk.

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Figure 1
General Map of the Study Area

A section of the Green Mountain Club Map of the Mt. Mansfield Area and the Long Trail. Published by the Green Mountain Club, Waterbury, Vermont.

Approximate locations of long-term sites in the summit area are indicated in red.

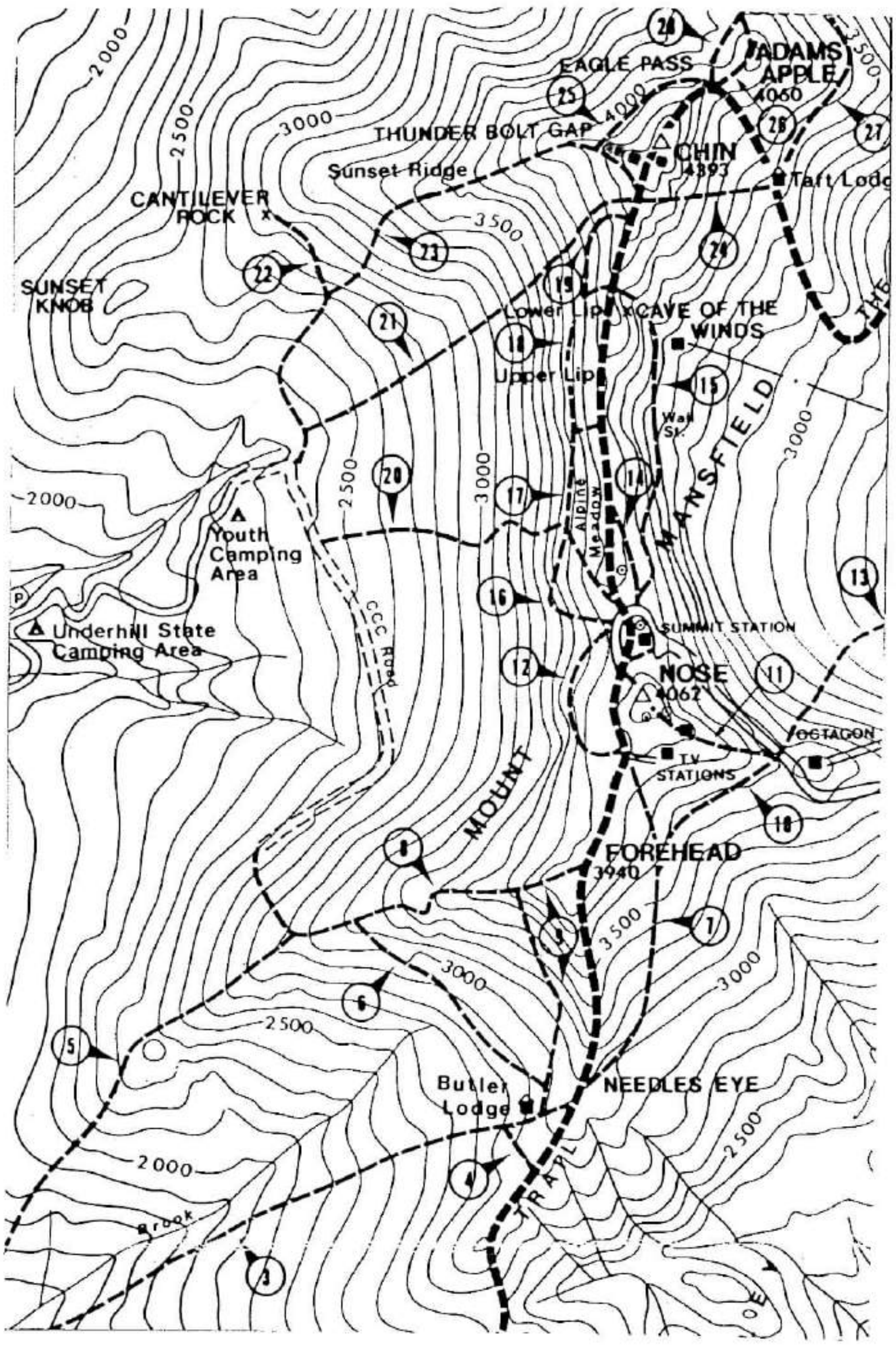

Figure 2
Summit Saddle Site - Quadrat Locations

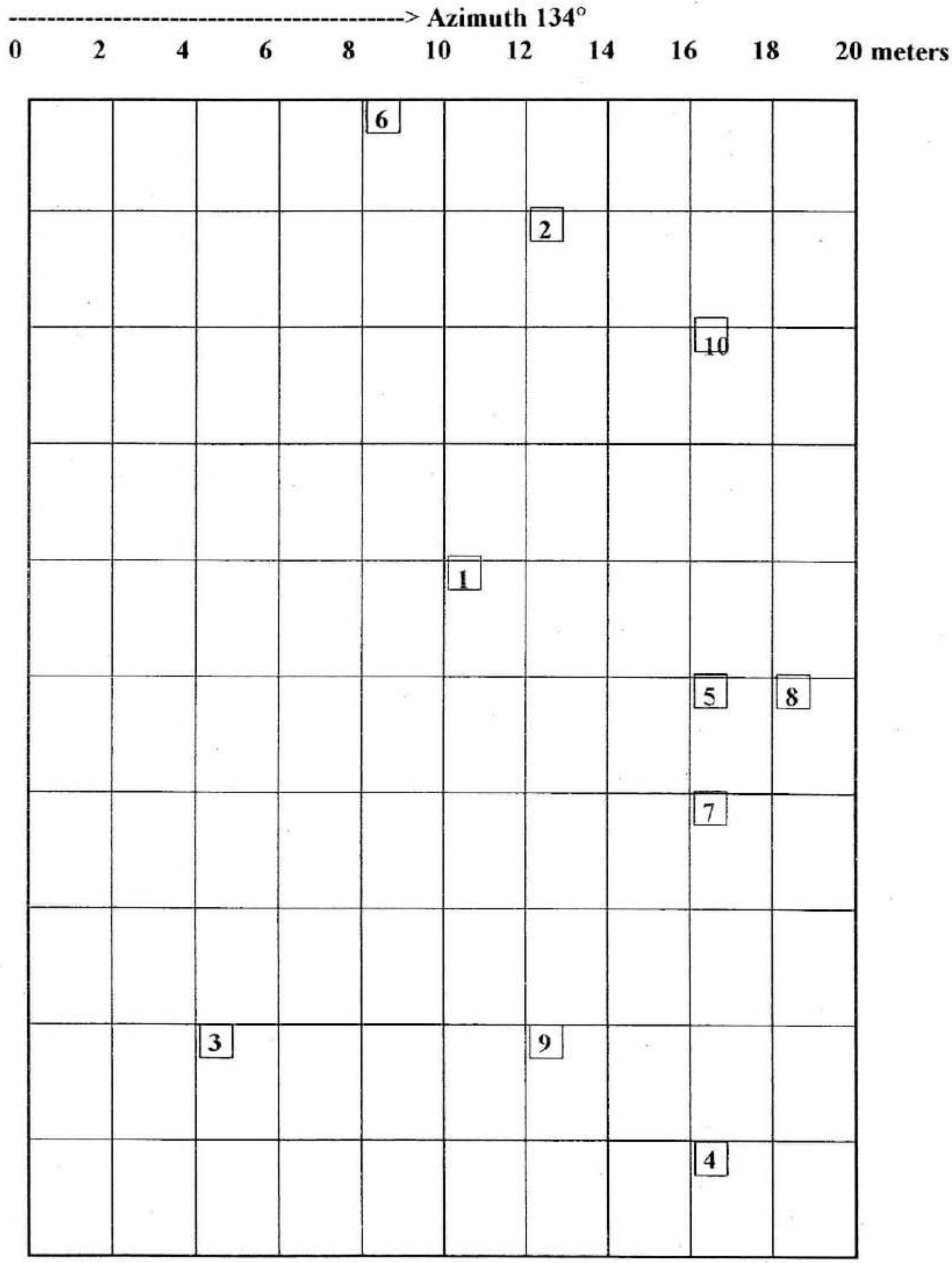

Figure 3
West Chin Top Site - Quadrat Locations

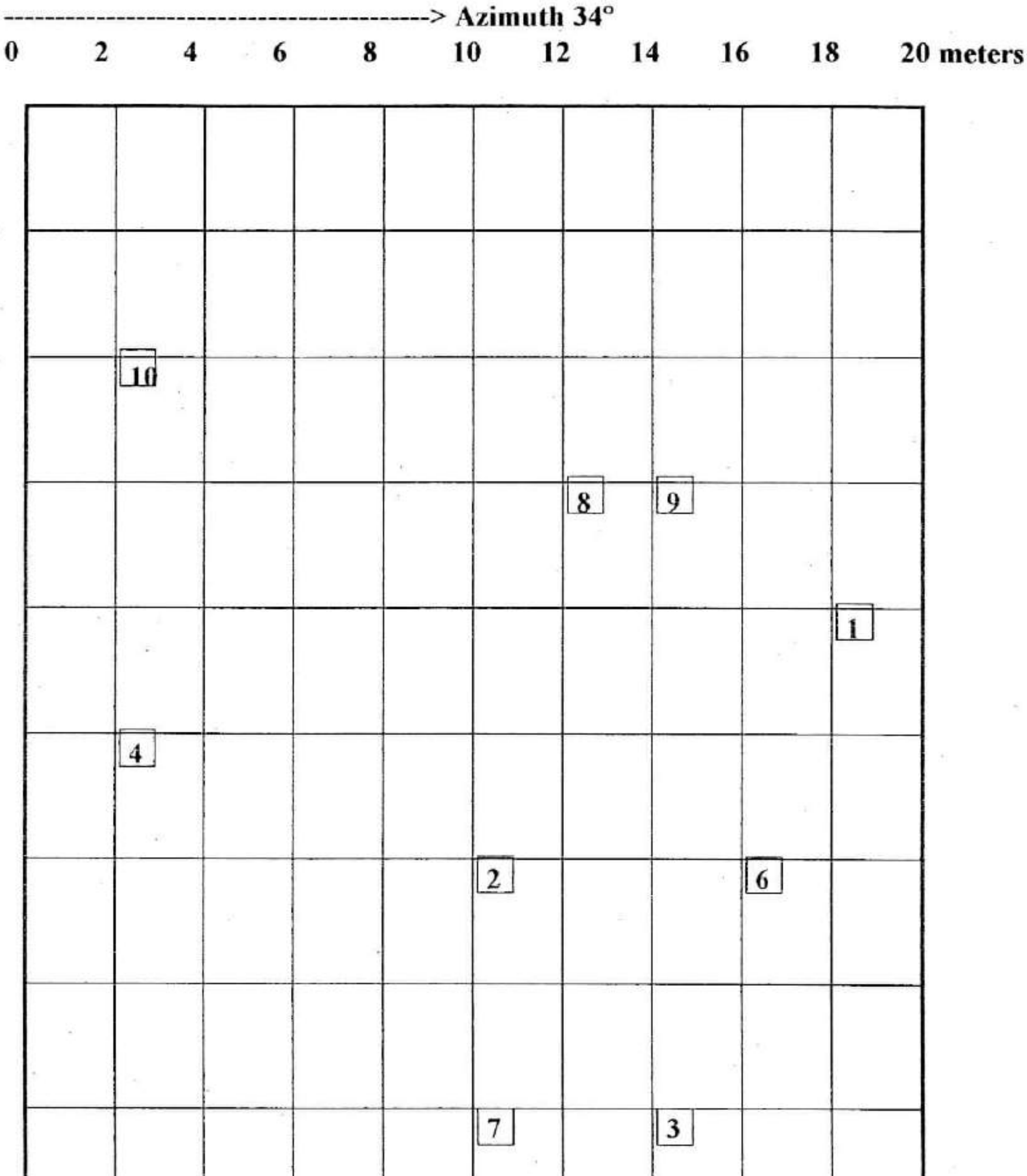

Figure 4
West Chin Low Site - Quadrat Locations

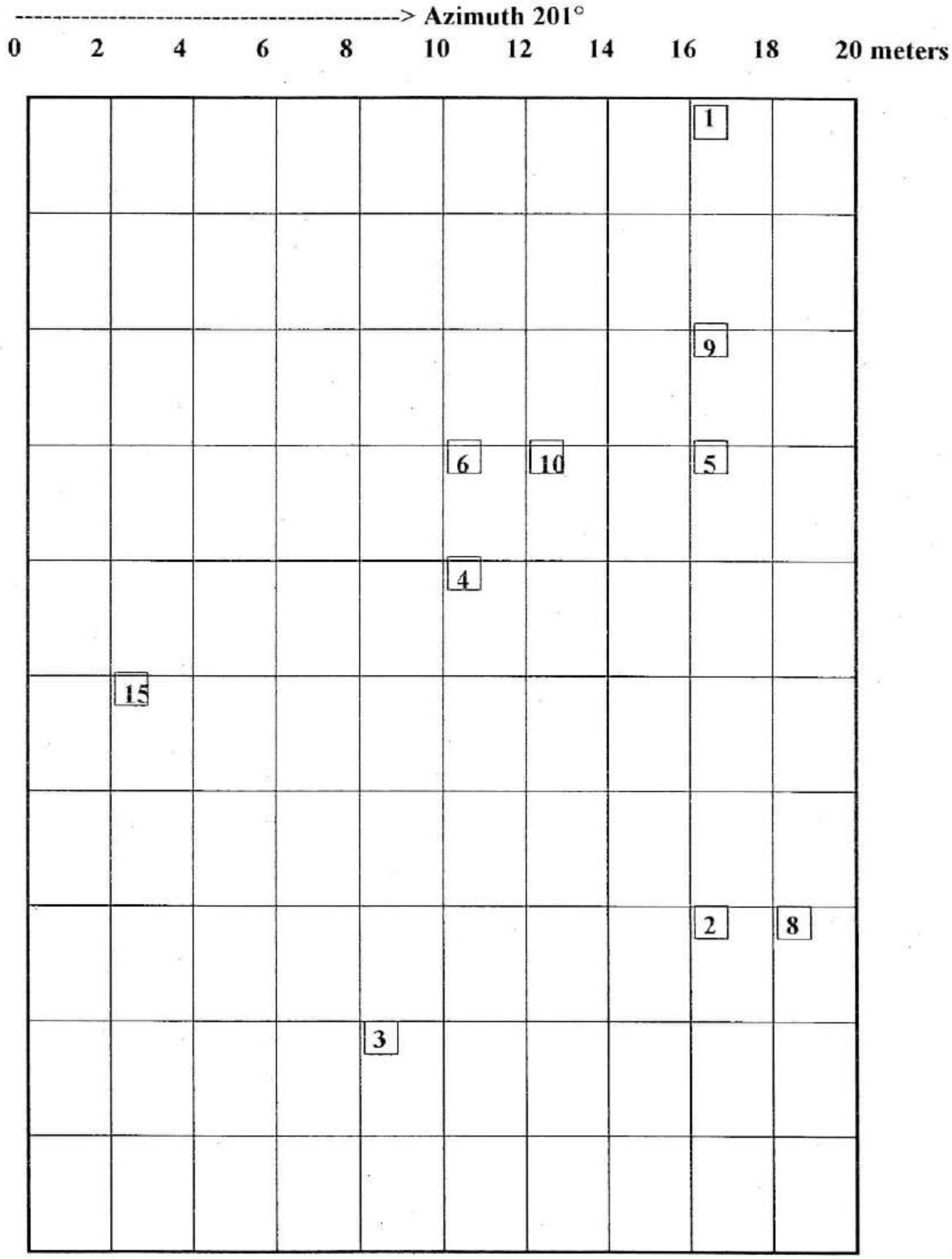

Table 1 -General Location Control Data

Based on NAD 1927

Theodolite Location	Target Location	Distance Meters	Vertical Angle DMS	Horiz. Angle DMS	H-Angle Reference DMS	UVM/VCS Northing Meters	UVM/VCS Easting Meters	UVM Trig Elevation	VCS Northing Meters	VCS Easting Meters
	CHIN (UVM- Triangle hole)					**745144.191**	**417937.917**	**4393.35**		
	Chin-USCGS Monument							**4393.349**	*745143.691*	*417937.917*
Chin-USCGS Monument	***MACBETH***	94.09	352.18.25	123.03.05	W-Chin Pass Point					
Chin-USCGS Monument	***SUNSET (monument hole)***	164.085	356.23.20	336.16.55	W-Chin Pass Point					
Chin-USCGS Monument	**W-Chin Pass Point**	**195.301**	**347.38.55**	**00.00.00**	**W-Chin Pass Point**					
Chin-USCGS Monument	***CHIN - UVM triangle/hole***	0.5	0	180 magn	magnetic north					
	TERRYBETHS (UVM)					**744737.883**	**417766.3**	**4359.6**	**744737.883**	**417766.3**
	SUNSET (UVM)					**744873.552**	**417472.865**	**4359.99**	**744873.552**	**417472.865**
	MACBETH (UVM)					**744874.695**	**417472.807**	**4351.2**	**744874.695**	**417472.807**
W-Chin Pass Point	**Origin West Chin Low**	**32.617**		**00.00.00**	**W. Chin Quad origin**					
W-Chin Pass Point	*Tower left*			54.28.15	W. Chin Quad origin					
W-Chin Pass Point	*Tower middle*			55.14.45	W. Chin Quad origin					
W-Chin Pass Point	*Tower right*			55.48.40	W. Chin Quad origin					
W-Chin Pass Point	*Origin Thunderbolt Gap Quad*	43.283		156.33.00	W. Chin Quad origin					

Summit Saddle - Long-term Site
Reference Survey

Table 2 - Summit Saddle Survey Data

Theodolite Location	Target Location	Distance Meters	Vertical Angle DMS	Based on NAD 1927 Horiz. Angle DMS	H-Angle Reference DMS	X-Coord	Y-Coord	Z-Coord	Rod H - Theo M
Chin-USCGS Monument	***MACBETH***	94.09	352.18.25	123.03.05	W-Chin Pass Point				0
Chin-USCGS Monument	***SUNSET (monument hole)***	164.085	356.23.20	336.16.55	W-Chin Pass Point				0
Chin-USCGS Monument	**W-Chin Pass Point**	**195.301**	**347.38.55**	**00.00.00**	**W-Chin Pass Point**				**0**
Chin-USCGS Monument	***CHIN - UVM triangle/hole***	0.5	0	180 magn	magnetic north				0
	TERRYBETHS (UVM)								
	SUNSET (UVM)								
	MACBETH (UVM)								
SUNSET (UVM, 1977)	**Summit Saddle NW Corner**	**107.745**	**0.26.20**	**00.00.00**	**0**				**0.4**
SUNSET (UVM, 1977)	*SW corner Summit Saddle Quadrat*	87.596	0.14.25	13.01.05	0				0.4
SUNSET (UVM, 1977)	*Chin Brass Monument*	164.662	3.42	337.21.10	0				0.4
SUNSET (UVM, 1977)	*TERRYBETHS (UVM)*	98.739	0.11.55	32.31.10	0				0.4
SUNSET (UVM, 1977)	*Base of microwave tower*		354.36.50	99.57.45	0				0.4
SUNSET (UVM, 1977)	*Summit Station Tower*			97.20.45	0				0.4
SUNSET (UVM, 1977)	*Nose Tower (tallest)*			96.37.00	0				0.4
Summit Saddle Origin	**NorthEast Corner from Origin**	**20**	**6.21.00**	**00.00.00**	**00.00.00**	**0**	**19.98**	**2.225**	**0.37**
Summit Saddle Origin	meter quad 1 - No-West Corner	15.621	355.13.00	50.11.40	20-meter 0-line	11.968	9.95	-1.301	0.37
Summit Saddle Origin	meter quad 2 - No-West Corner	12.369	1.44.25	14.02.10	20-meter 0-line	3.006	11.992	0.376	0.37
Summit Saddle Origin	meter quad 3 - No-West Corner	24.331	359.34.50	80.32.15	20-meter 0-line	24.249	4.03	-0.175	0.37
Summit Saddle Origin	meter quad 4 - No-West Corner	31.384	2.2625	59.21.00	20-meter 0-line	26.989	15.96	1.336	0.37
Summit Saddle Origin	meter quad 5 - No-West Corner	21.932	357.51.30	43.09.10	20-meter 0-line	15.287	16.275	-0.835	0.37
Summit Saddle Origin	meter quad 6 - No-West Corner	8	5.51.40	00.00.00	20-meter 0-line	0	7.958	0.817	0.37
Summit Saddle Origin	meter quad 7 - No-West Corner	24.083	358.52.15	48.22.00	20-meter 0-line	17.954	15.95	-0.474	0.37
Summit Saddle Origin	meter quad 8 - No-West Corner	23.431	358.56.30	39.48.20	20-meter 0-line	15.162	18.201	-0.438	0.37
Summit Saddle Origin	meter quad 9 - No-West Corner	26.833	1.44.00	63.26.05	20-meter 0-line	24	11.989	0.811	0.37
Summit Saddle Origin	meter quad 10 - No-West Corner	17.088	2.07.10	20.33.20	20-meter 0-line	6.111	15.874	0.629	0.37
Summit Saddle Origin	*SUNSET 1970 (UVM, 1977)*	107.745	359.57.40	129.33.00	20-meter 0-line	83.079	-68.608	-0.071	0.37

West Chin Top - Long-term Site
Reference Survey

Table 3 - West Chin Top Survey Data

				Based on NAD 1927					
Theodolite Location	**Target Location**	Distance Meters	Vertical Angle DMS	Horiz. Angle DMS	H-Angle Reference DMS	X-Coord	Y-Coord	Z-Coord	Rod H - Theo M
	CHIN (UVM- Triangle hole)								
	Chin-USCGS Monument								
Chin-USCGS Monument	***MACBETH***	94.09	352.18.25	123.03.05	W-Chin Pass Point				0
Chin-USCGS Monument	***SUNSET (monument hole)***	164.085	356.23.20	336.16.55	W-Chin Pass Point				0
Chin-USCGS Monument	***CHIN - UVM triangle/hole***	0.5	0	180 magn	magnetic north				0
SUNSET (UVM, 1977)	**Summit Saddle NW Corner**	**107.745**	**0.26.20**	**00.00.00**	**0**				**0.4**
SUNSET (UVM, 1977)	*SW corner Summit Saddle Quadrat*	87.596	0.14.25	13.01.05	0				0.4
SUNSET (UVM, 1977)	*Chin Brass Monument*	164.662	3.42	337.21.10	0				0.4
SUNSET (UVM, 1977)	*TERRYBETHS (UVM)*	98.739	0.11.55	32.31.10	0				0.4
SUNSET (UVM, 1977)	*Base of microwave tower*		354.36.50	99.57.45	0				0.4
SUNSET (UVM, 1977)	*Summit Station Tower*			97.20.45	0				0.4
SUNSET (UVM, 1977)	*Nose Tower (tallest)*			96.37.00	0				0.4
W-Chin Top Origin	**NorthWest Corner from Origin**	**20**		**00.00.00**	**Corner**	**0**	**20**		
W-Chin Top Origin	*Ben's 1991 WChin origin (old)*	2.427		315.08.50	20-meter 0-line	-1.692	1.698	-0.336	0
W-Chin Top Origin	*SUNSET (monument hole)*	18.778		262.23.20	20-meter 0-line	-18.622	-2.438	0.347	0
W-Chin Top Origin	*TerryBeths UVM Monument*	78.85		86.22.50	20-meter 0-line	78.705	fog	fog	0
W-Chin Top Origin	*Chin USCGS monument*	152.94	3.58.05	24.44.20	20-meter 0-line	63.857	fog	fog	0.02
W-Chin Top Origin	*Summit Saddle Origin*	90.823	0.31.30	47.07.35	20-meter 0-line	66.55	61.785	0.833	0
W-Chin Top Origin	meter quad 1- So-West Corner	22.016		33.29.45	20-meter 0-line	12	18.14	-3.468	0
W-Chin Top Origin	meter quad 2- So-West Corner	22.709		60.56.55	20-meter 0-line	19.667	10.928	-3.061	0
W-Chin Top Origin	meter quad 3- So-West Corner	27.912		59.44.40	20-meter 0-line	23.909	13.942	-3.521	0
W-Chin Top Origin	meter quad 4- So-West Corner	15.11		84.24.20	20-meter 0-line	14.745	1.967	-2.626	0
W-Chin Top Origin	meter quad 5- So-West Corner	32.504		56.18.35	20-meter 0-line	26.888	17.929	-3.498	0
W-Chin Top Origin	meter quad 6- So-West Corner	24.083		48.21.60	20-meter 0-line	17.819	15.838	-2.694	0
W-Chin Top Origin	meter quad 7- So-West Corner	25.902		67.22.50	20-meter 0-line	23.688	9.87	-3.548	0
W-Chin Top Origin	meter quad 8- So-West Corner	15.069		36.52.10	20-meter 0-line	8.975	11.972	-1.802	0
W-Chin Top Origin	meter quad 9- So-West Corner	16.623		32.44.10	20-meter 0-line	8.962	13.886	-1.887	0
W-Chin Top Origin	meter quad 10- So-West Corner	6.325		71.33.55	20-meter 0-line	5.752	1.924	-1.78	0

Table 4 - West Chin Low Survey Data

Based on NAD 1927

Theodolite Location	*Target Location*	Distance Meters	Vertical Angle DMS	Horiz. Angle DMS	H-Angle Reference DMS	X-Coord	Y-Coord	Z-Coord	Rod H - Theo M
	CHIN (UVM- Triangle hole)								
	Chin-USCGS Monument								
Chin-USCGS Monument	***MACBETH***	94.09	352.18.25	123.03.05	W-Chin Pass Point				0
Chin-USCGS Monument	***SUNSET (monument hole)***	164.085	356.23.20	336.16.55	W-Chin Pass Point				0
Chin-USCGS Monument	**W-Chin Pass Point**	**195.301**	**347.38.55**	**00.00.00**	**W-Chin Pass Point**				**0**
Chin-USCGS Monument	***CHIN - UVM triangle/hole***	0.5	0	180 magn	magnetic north				0
W-Chin Pass Point	**Origin West Chin Lower Quad**	**32.617**		**00.00.00**	**W. Chin Quad origin**				**0**
W-Chin Pass Point	*Tower left*			54.28.15	W. Chin Quad origin				
W-Chin Pass Point	*Tower middle*			55.14.45	W. Chin Quad origin				
W-Chin Pass Point	*Tower right*			55.48.40	W. Chin Quad origin				
W-Chin Pass Point	*Origin Thunderbolt Gap Quad*	43.283		156.33.00	W. Chin Quad origin				
West Chin Low Origin	**SouthEast Corner from Origin**	**20**	**351.31.10**	**00.00.00**	**0**				**0**
West Chin Low	NorthWest Corner from Origin	30	334.42.30	90.00.00	0				0
West Chin Low	meter quad 1- No-East Corner	16	351.42.55	00.00.00	0				0
West Chin Low	meter quad 2- No-East Corner	26.401	333.59.35	52.41.45	0				0
West Chin Low	meter quad 3- No-East Corner	25.298	333.40.40	71.33.55	0				0
West Chin Low	meter quad 4- No-East Corner	15.621	335.12.25	50.11.40	0				0
West Chin Low	meter quad 5- No-East Corner	18.358	338.27.05	29.21.30	0				0
West Chin Low	meter quad 6- No-East Corner	13.454	333.48.20	41.59.15	0				0
West Chin Low	meter quad 7- No-East Corner	15.133	332.26.50	82.24.20	0				0
West Chin Low	meter quad 8- No-East Corner	27.659	334.19.15	49.23.55	0				0
West Chin Low	meter quad 9- No-East Corner	17.088	342.09.55	20.33.20	0				0
West Chin Low	meter quad 10- No-East Corner	15	336.27.10	36.52.10	0				0

Thunderbolt Gap - Long-term Site
Reference Survey

Table 5 - Thunderbolt Gap Survey Data

				Based on NAD 1927					
Theodolite Location	***Target Location***	**Distance Meters**	**Vertical Angle DMS**	**Horiz. Angle DMS**	**H-Angle Reference DMS**	**X-Coord**	**Y-Coord**	**Z-Coord**	**Rod H - Theo M**
	CHIN (UVM- Triangle hole)								
	Chin-USCGS Monument								
Chin-USCGS Monument	***MACBETH***	94.09	352.18.25	123.03.05	W-Chin Pass Point				0
Chin-USCGS Monument	***SUNSET (monument hole)***	164.085	356.23.20	336.16.55	W-Chin Pass Point				0
Chin-USCGS Monument	**W-Chin Pass Point**	**195.301**	**347.38.55**	**00.00.00**	**W-Chin Pass Point**				**0**
Chin-USCGS Monument	***CHIN - UVM triangle/hole***	0.5	0	180 magn	magnetic north				0
W-Chin Pass Point	**Origin West Chin Lower Quad**	**32.617**		**00.00.00**	**W. Chin Quad origin**				**0**
W-Chin Pass Point	*Tower left*			54.28.15	W. Chin Quad origin				
W-Chin Pass Point	*Tower middle*			55.14.45	W. Chin Quad origin				
W-Chin Pass Point	*Tower right*			55.48.40	W. Chin Quad origin				
W-Chin Pass Point	*Origin Thunderbolt Gap Quad*	43.283		156.33.00	W. Chin Quad origin				
Thunderbolt Gap Origin	**South East Corner from Origin**	**20**		**00.00.00**	**Corner**	**0**	**20**		
Thunderbolt Gap Origin	*West Chin Bottom Origin*	75.486	25.47.40	279.53.40	20-meter 0-line				0
Thunderbolt Gap Origin	meter quad 1- No-East Corner	20.125	342.35.00	26.33.55	20-meter 0-line	8.596	17.193		0.3
Thunderbolt Gap Origin	meter quad 2- No-East Corner	7.211	338.41.50	82.47.20	20-meter 0-line	5.594	3.729	-2.662	0.3
Thunderbolt Gap Origin	meter quad 3- No-East Corner	27.65	340.18.30	49.23.55	20-meter 0-line	19.766	16.943	-9.32	0
Thunderbolt Gap Origin	meter quad 4- No-East Corner	6.325	337.13.30	71.33.55	20-meter 0-line	5.521	1.84	-2.444	0.3
Thunderbolt Gap Origin	meter quad 5- No-East Corner	13.454	338.14.30	41.59.15	20-meter 0-line	8.347	9.275		0.3
Thunderbolt Gap Origin	meter quad 6- No-East Corner	28.884	340.21.15	56.18.35	20-meter 0-line	22.64	15.093	-9.714	0.3
Thunderbolt Gap Origin	meter quad 7- No-East Corner	16.971	337.56.35	45.00.00	20-meter 0-line	11.12	11.12		0.3
Thunderbolt Gap Origin	meter quad 8- No-East Corner	17.63	338.46.25	38.36.05	20-meter 0-line	11.145	13.096		0
Thunderbolt Gap Origin	meter quad 9- No-East Corner	18	335.57.35	90.00.00	20-meter 0-line	16.441	0		0.3
Thunderbolt Gap Origin	meter quad 10- No-East Corner	24.8	339.47.40	48.21.60	20-meter 0-line	16.914	15.035	-8.329	0

Table 6	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum
Summit Saddle Site Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C
Field Study Year	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Arenaria groenlandica			4	0.5	2	0.3														
Carex Bigelowii	100	21	94	37	25	3	70	8	80	8	42	17	97	12	37	3	96	15	65	26
Vaccinium uliginosum	100	77	51	35	40	21	1	0.3	46	11	11	2	100	33	22	6	57	14	73	27
Vaccinium Vitis-Idaea																	2	0.1		
Lycopodium selago			9	0.5	3	0.1														
Arctoparmelia centrifuga			17	2	38	10	15	0.5	18	1	19	2	4	0.8	3	0.3	3	0.3	1	0.1
Ceratodon purpureus							19	0.5												
Cetraria islandica	77	13			35	14	64	14	25	4	44	11	93	20			59	2	44	25
Cladina rangifernia							5	0.1									16	0.1		
Cladonia coccifera					2	0.1									39	1				
Cladonia gracilis									13	0.8										
Cladonia pleurota			32	0.3	10	0.3	33	0.5	61	1	20	1	22	0.3			20	0.1	2	0.1
Cladonia squamosa var. squamosa					2	0.1														
Cladonia uncialis											12	5	10	0.3	22	1	34	4	8	0.5
Fuscidia kochiana					8	0.3											2	0.1		
Lecanora intricata					34	6	12	0.3	11	0.5			6	0.1	41	0.5	6	0.1		
Lecidea platycarpa													4	0.5						
Mycoblastus sanguinarius					7	0.3	9	0.4	3	3.3					11	0.3	4	0.1		
Ophioparma lapponica															3	0.3				
Rhizocarpon geographicum			9	1	64	13	14	0.3	11	2	72	50	1	0.1	36	3	5	0.3	21	3
Rhizocarpon hochstetteri			8	0.3							56	3							21	4
Umbilicaria hypeborea			6	0.3			3	0.1			55	3			3	0.1	3	0.1	11	0.3
Umbilicaria deusta					42	NA			4	0.3			2	0.1	21	0.5				
Porpidia macrocarpa									2	0.3										

Summit Saddle Site -Page 2	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum
Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C
Stereocaulon glaucescens					2	0.1														
Stereocaulon paschale					7	0.5											1	0.1		
Crustose lichens - undetermined					30	4			6	1			4	0.3	55	10	1	0.1		
Dicranella sp.																				
Dicranium fuscescens	20	2															14	1		
Pleurozium schreberi	6	0											2	0.1						
Polytrichastrum alpinum					8	1														
Polytrichum formosum													62	2						
Polytrichum juniperinum			47	23			84	33	85	28	9	3.5	57	6	29	2	86	38		
Moss - undetermined					2	0.1							78	4						

Table 7	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT
West Chin Top Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q4	Q4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C
Field Study Year	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
Arenaria groenlandica	7	0.5	2	0.1							3	0.25			17	0.5	2	0.13	33	4
Betula papyrifera					3	0.5														
Carex Bigelowii			23	1	99	15	64	14	44	4.5			95	11	71	4	62	6	77	19
Ledum groenlandicum					1	0.13	1	0.1												
Vaccinium boreale			63	21			31	1.5												
Vaccinium uliginosum	60	38	32	15	49	23	76	54	97	73	9	4	56	31	64	42	75	69	60	29.5
Juncus trifidus	12	1.75	16	4							12	2			24	8			6	0.5
Picea rubens			2	2																
Lycopodium selago															7	0.13				
Lophozia sp.											2	0.33							2	0.5
Arctoparmelia centrifuga	32	3	6	0.5	1	0.1			4	0.13	41	5	2	0.25	4	0.13	28	4		
Cetraria cucullata			2	0.1																
Cetraria islandica	46	13	38	7	43	4.5	51	15.5	88	31	12	2.5	19	2	33	8	65	42	9	1
Cladina rangiferina	35	10					13	1	1	0.1							18	2		
Cladonia coccifera	15	0.25			41	4	21	1	10	0.5			4	0.1					1	0.1
Cladonia pleurota											11	0.1								
Cladonia pocillum																			12	0.5
Cladonia uncialis	30	8	2	0.1	2	0.1	7	1	20	1	1	0.1	2	0.1	8	0.5	1	0.13		
Fuscidia kochiana	4	0.06									18	0.75			5	0.25	8	0.25		
Lecanora intricata			26	1			3	0.1	12	1	40	2	6	0.25	13	0.6	3	0.1	14	1
Lecidea platycarpa					2	0.1									21	0.5				
Mycoblastus sanguinarius	5	0.33	28	3					12	1	15	2	11	2			5	0.25	11	1.25
Normandina pulchella							11	0.25												
Ophioparma lapponica											6	1								

West Chin Top - Page 2	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT	WCT
Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q4	Q4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C	%Fr	%C
Orphniospora moriopsis											48	8					9	0.5		
Porpidia macrocarpa											1	0.1								
Rhizocarpon geographicum	30	3	28	1			4	0.25	6	0.25	90	17	4	0.1	17	1.5	35	4	36	5.5
Stereocaulon glaucescens	1	0.1	6	0.33			1	0.06			7	0.5			1	0.13				
Trapeliopsis gelatinosa											1	0.33								
Trapeliopsis granulosa																			22	4
Umbilicaria hyperboria			24	1.5	1	0.1					10	0.5								
Umbilicaria deusta	10	0.1	14	0.25							45	2	4	0.1	20	0.06	18	0.25	5	0.1
Crustose lichens Undetermined	13	1	7	0.33					7	0.25	22	1.5	6	0.25			8	0.13	40	2.5
Andraea rupestris											5	1								
Dicranella heteromalla cf.																			7	0.25
Dicranella sp.							2	0.25			6	0.5							1	0.1
Dicranum fuscescens	7	0.25					2	0.1	31	2.13							1	0.1		
Dicranum montanum (?)	5	0.1													14	0.06	4	0.1		
Ditrichum sp.																			2	0.06
Pleurozium schreberi							21	4									5	0.1		
Polytrichum formosum			17	2									16	0.5						
Polytrichum juniperinum	13	0.06	15	9	88	37							70	41	11	1	2	0.06	13	2
Polytrichum pallidisetum							46	3												
Moss undetermined					2	0.1														

West Chin Low Long-term Site
Vegetation Data

Table 8	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes
West Chin Low Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C
Field Study Year	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Arenaria groenlandica	21	3											3	0.13			1	0.05		
Betula papyrifera var. cordifolia									1	0.1										
Carex Bigelowii	97	23	21	0.75			38	9	14	1			87	15	65	3			17	0.5
Carex sp.											1	0.13								
Juncus trifidus	3	0.33	11	0.75			15	0.5					48	3	45	2				
Ledum groenlandicum											1	0.13								
Potentilla tridentata	10	0.5																		
Trientalis borealis	1	0.06											1	0.1						
Vaccinium angustifolium .											17	3			98	12			2	0.1
Vaccinium uliginosum	27	13	88	58	3	0.5	82	39	100	95	96	80	73	40	21	5			87	42
Vaccinium Vitis-Idaea	9	0.25	66	4					92	4	52	9	52	3.5	96	9			54	3
Lycopodium selago							1	0.25												
Andreaea rupestris																	38	1.5		
Arctoparmelia centrifuga					68	9	7	0.25			22	2							25	2
Cetraria islandica			65	5	6	0.5	18	6	40	5	85	80	53	15	93	28			80	50
Cladina rangiferina											8	2			51	7				
Cladonia coccifera			21	0.25	2	0.5					6	0.25								
Cladonia pleurota									4	0.1			39	1	28	0.25				
Cladonia pocillum																	1	0.1		
Cladonia uncialis	0.1	0.1													3	0.06				
Fuscidea kochiana			8	0.08	26	3									3	0.1	97	9		
Lecanora intricata			22	2	29	0.5	18	0.1					2	0.1	5	0.1	79	6		
Mycoblastus sanguinarius			11	0.1	10	1	11	0.06					3	0.25						
Ophioparma lapponica					2	0.1											17	1	8	0.1

West Chin Low - Page 2	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes	Wes
Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C	% Fr	% C
Orphniospora moriopsis					37	4									2	0.1	85	10	13	0.33
Rhizocarpon geographicum			2	0.06	90	11	14	1			14	2	3	0.1	4	0.33	98	18	17	0.5
Rhizocarpon hochstetteri							10	0.13					2	0.1						
Stereocaulon paschale					36	6											6	0.5		
Trapeliopsis granulosa													15	1	13	0.5				
Umbilicaria deusta					25	0.5	4	0.1			6	0.5			3	0.13	23	1		
Umbilicaria hyperborea					1	0.1													10	0.13
Umbilicaria proboscidia											2	0.25								
Umbilicaria vellea																	19	1		
Crustose lichens - undetermined					19	3					25	4					59	3		
Dicranella heteromalla					3	1					9	1								
Mnium marginatum var. riparium	38	1																		
Pallidisetum sp.							20	5					40	12			1	0.1		
Polytrichum formosum											8	0.25								
Polytrichum pallidisetum					7	2.5														
Polytrichum sp.	73	24			2	0.33														
Moss - undetermined			16	0.1											5	0.1				

Table 9	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Thunderbolt Gap Site Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C
Field Study Year	94	94	92	92	94	94	92	92	92	92	94	94	92	92	94	94	94	94	94	94
Abies balsamea	100	91	1	0.1					3	0.5					41	36				
Arenaria groenlandica			4	0.1			20	2	11	0.3	6	0.1					15	0.5		
Betula papyrifera			2	0.3					9	1										
Betula papyrifera var. cordifolia	29	15					2	0.3					4	1						
Carex Bigelowii			43	4			27	3					22	1			5	0.5		
Carex brunnescens									23	3										
Juncus trifidus			25	1									7	0.5			7	1		
Ledum groenlandicum	3	0.1																	100	23
Vaccinium boreale			12	0.5	90	33			32	3			70	5	80	10			91	25
Vaccinium uliginosum	41	9	100	21	53	28	54	24	59	13	13	4.5	98	31	74	36	34	8	100	37
Vaccinium Vitis-Idaea			19	0.5	18	1	8	0.3					28	1.5					50	3
Lycopodium annotinum	16	1											70	11	82	21			90	28
Lycopodium selago			9	0.3			20	2	16	0.3							2	0.1		
Bazzania trilobata													2	0.1						
Arctoparmelia centrifuga							15	1	12	1	42	4	9	1			9	2.5		
Ceratodon purpureus							2	0.3									35	6		
Cetraria islandica	1	0.1	58	21	*82*	*34*	30	19	36	7	30	1	78	36	71	55	22	6	*28*	*6*
Cladonia coccifera													2	0.1			26	0.5		
Cladonia pleurota			22	0.1			14	0.1	13	0.5			*20*	*1*						
Cladonia squamosa													1	0.1						
Cladonia uncialis											4	0.1								
Cladina rangifernia					*82*	*34*			8	1			*20*	*1*	45	4			*28*	*6*
Fuscidea recensa									7	0.3										
Hypogymnia physodes	5	0.1																		
Lasallia papulosa											2	0.1								
Lecanora intricata			5	0.1			21	1.3	8	0.3	17	1	9	0.5			32	5		
Lecidea platycarpa			9	0.5			24	2												
Mycoblastus sanguinarius			2	0.1			3	0.1			19	2					32	5		
Orphniospora moriopsis											7	0.3								
Propidia macrocarpa									16	1.5										
Protoparmelia badia											19	1								

Thunderbolt Gap - Page 2	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur	Thur
Quadrat #	Q 1	Q 1	Q 2	Q 2	Q 3	Q 3	Q 4	Q 4	Q 5	Q 5	Q 6	Q 6	Q 7	Q 7	Q 8	Q 8	Q 9	Q 9	Q 10	Q 10
SPECIES LIST	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C	% F	% C
Crustose lichens - undetermined			1	0.1			10	0.5	14	1.5			13	1.8						
Rhizocarpon geographicum			2	0.1			22	2.5	20	3	72	13	33	4			21	3		
Rhizocarpon badioatrum																	25	0.5		
Rhizocarpon hochstetteri							20	2	14	0.3	7	1	8	0.1						
Stereocaulon paschale							4	0.3					2	0.1						
Umbilicaria deusta							32	1.5	22	0.5	46	6	8	0.3			7	1		
Umbilicaria hyperborea							10	1					2	0.3						
Umbilicaria proboscidia																	1	0.1		
Dicranella sp.									27	1										
Dicranum montanum											26	1								
Dicranella heteromalla											6	0.3								
Pholia sp.																	12	1		
Pleurozium schreberi																			16	3
Pogonatum dentatum			5	0.1																
Polytricastrum alpinum																	7	0.1		
Polytrichum juniperinum					19	1											24	5		
Mushroom - undetermined																	1	0.1		

TABLE 10 - Sites 1 - 5
Western Slopes of Mt. Mansfield

Sample Site Number	**1**			**2**			**3**			**4**			**5**		
Trail .	Sunset Ridge			Sunset Ridge			Sunset Ridge			Sunset Ridge			Sunset Ridge		
Elevation AMSL	2500ft			2700ft			2900ft			3000ft			3300ft		
Date	1-Jul-91*			1-Jul-91*			1-Jul-91*			2-Jul-91*			2-Jul-91*		
Taxon	P/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2
Azimuth | Rnd#1 | Rnd#2	57	24	20	123	11	5	167	2	19	95	13	5	140	25	22
Abies balsamea	Pr			Pr		18	Pr	2		Pr			Pr		15
Acer pensylvanicum	Pr									Pr					
Acer rubrum	Pr														
Acer spicatum	Pr		14	Pr			Pr			Pr	22	3			
Aralia nudicaulis													Pr		
Betula alleghaniensis	Pr			Pr		6									
Betula papyrifera				Pr			Pr			Pr			Pr		
Carex intumescens										Pr					
Cladonia squamosa															
Clintonia borealis	Pr		26	Pr			Pr			Pr	16	12	Pr	6	24
Cornus alternifolia				Pr		10									
Dennstaedtia puntilobula							Pr			Pr	100	48			
Dryopteris spinulosa	Pr	6	16	Pr	23	17	Pr	20	15	Pr	4		Pr	74	81
var. intermedia										Pr					
Juncus													Pr		
Lycopodium lucidulum	Pr	96	55	Pr	41		Pr								
Maianthemum canadense	Pr		52	Pr	26		Pr	72	64				Pr		59
Oxalis montana	Pr	27	87	Pr	39		Pr						Pr	90	8
Picea mariana				Pr			Pr						Pr		
Polypodium vulgare				Pr		1									
Prunus serotina										Pr		25			
Pteridium aquilinum				Pr											
Ribes cynosbati				Pr		35									
Rhus typhina				Pr											
Rubus allegheniensis	Pr														
Smilacina racemosa				Pr											
Solidago macrophylla				Pr	10		Pr			Pr			Pr		
Sorbus americana										Pr			Pr	2	
Sorbus decora										Pr		23	Pr		
Streptopus amplexifolis	Pr	3		Pr											
Thalictrum polygamum				Pr											
Tiarella cordifolia				Pr											
Trientalis borealis	Pr		4												
Trillium cernuum				Pr			Pr			Pr					
Trillium grandiflorum	Pr														
Tsuga canadensis	Pr														
Veratrum viride				Pr						Pr		9			
Viburnum alnifolium	Pr	20		Pr	14		Pr								

Table 11 - Sites 6 - 10
Western Slopes of Mt. Mansfield

Sample Site Number	**6**			**7**			**8**			**9**			**10**		
Trail,	**Sunset Ridge**			**Sunset Ridge**			**Sunset Ridge**			**L.Mansfield**			**LongTrail**		
Elevation AMSL,	**3500ft**			**3490ft**			**3700ft**			**1840ft**			**1900ft**		
Date	**2-Jul-91***			**9-Jul-91***			**9-Jul-91***			**16-Jul-91***			**16-Jul-91***		
Taxon	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**
Abies balsamea	Pr	84	100	Pr	27	100	Pr			Pr					
Acer pensylvanicum										Pr	1		Pr		
Acer rubrum										Pr					
Acer spicatum										Pr			Pr		
Arenaria groenlandica							Pr								
Betula alleghaniensis										Pr	3		Pr		
Betula papyrifera	Pr	12		Pr											
Brotherella recurvans													Pr		
Calamagrostis canadensis							Pr								
Carex sp.	Pr														
Cladonia coniocraea													Pr		
Cladonia cristatella				Pr											
Cladonia sp							Pr	2							
Clintonia borealis	Pr			Pr	6	7	Pr			Pr	16	10	Pr		17
Coptis groenlandica	Pr			Pr	18	8				Pr					
Cornus canadensis	Pr			Pr			Pr								
Dennstaedtia puntilobula	Pr														
Dryopteris spinulosa						14									
var. americana				Pr											
var. intermedia										Pr	32	9	Pr	91	45
Gaultheria hispidula	Pr														
Hypnum pallescens													Pr		
Hylocomium splendens													Pr		3
Lichen - undetermined				Pr	19		Pr	66							
Lycopodium annotinum				Pr			Pr	3	24						
Lycopodium lucidulum										Pr	75	100	Pr	13	41
Maianthemum canadense	Pr			Pr		27				Pr	65	91			
Monotropa uniflora										Pr		1			
Moss - undetermined				Pr	85	82									
Nemopanthus mucronata				Pr		16									
Oxalis montana				Pr						Pr	62	74	Pr	12	74
Picea mariana															
Picea rubens										Pr					
Plagiothecium laetum													Pr		

Table 11 - Sites 6 - 10
Western Slopes of Mt. Mansfield

Sample Site Number	**6**			**7**			**8**			**9**			**10**		
Trail,	**Sunset Ridge**			**Sunset Ridge**			**Sunset Ridge**			**L.Mansfield**			**LongTrail**		
Elevation AMSL,	**3500ft**			**3490ft**			**3700ft**			**1840ft**			**1900ft**		
Date	**2-Jul-91***			**9-Jul-91***			**9-Jul-91***			**16-Jul-91***			**16-Jul-91***		
Taxon	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**
Potentilla tridentata							Pr								
Salix sp.	Pr														
Sorbus americana	Pr			Pr	2										
Spirea latifolia							Pr								
Streptopus amplexifolis													Pr	4	24
var. perspectus										Pr					
Thelypteris Phegopteris													Pr	2	
Thuidium delicatulum													Pr		
Trientalis borealis				Pr						Pr					
Trillium cernuum										Pr			Pr	11	
Trillium undulatum													Pr		
Vaccinium angustifolium	Pr														
var. *angustifolium*				Pr			Pr	94	100						
var. *laevifolium*				Pr		100									
Vaccinium uliginosum							Pr		33						
Vaccinium vitis-idaea							Pr								
Viburnum alnifolium										Pr			Pr	1	1

Table 12 - Sites 12 - 15
Western Slopes of Mt. Mansfield

Sample Site Number	**12**			**13**			**14**			**15**		
Trail,	**Halfway House**			**Halfway House**			**Halfway House**			**Halfway Hous**		
Elevation AMSL,	**3800ft**			**3600ft**			**3400ft**			**3200ft**		
Date	**17-Jul-91***			**17-Jul-91***			**18-Jul-91***			**18-Jul-91***		
Taxon	**Pr/Ab**	**Q1**	**Q2**	**Pr/Ab**	**Q1**	**Q2**	**Pr/Ab**	**Q1**	**Q2**	**Pr/Ab**	**Q1**	**Q2**
Azimuth|Rnd#1|Rnd#2	**163**	**15**	**8**	**204**	**16**	**6**	**185**	**25**	**22**	**33**	**17**	**23**
Abies balsamea	**Pr**	**31**	**25**	**Pr**	**16**		**Pr**			**Pr**	**7**	**1**
Aster acuminatus				**Pr**		**6**	**Pr**			**Pr**		
Aulacomnium palustre												
Bazzania trilobata							**Pr**					
Betula papyrifera	**Pr**			**Pr**	**30**		**Pr**			**Pr**		
Brotherella recurvans	**Pr**			**Pr**		**13**	**Pr**	**8**	**14**	**Pr**	**50**	**57**
Carex intumescens				**Pr**								
Carex trisperma				**Pr**								
Cladonia chlorophaea	**Pr**	**37**										
Cladonia coniocraea							**Pr**					
Cladonia macilenta	**Pr**											
Cladonia squamosa	**Pr**		**9**				**Pr**					
Clintonia borealis	**Pr**	**21**	**59**	**Pr**		**54**	**Pr**	**63**	**23**	**Pr**	**8**	**4**
Coptis groenlandica	**Pr**		**25**									
Cornus canadensis	**Pr**			**Pr**		**21**						
Dennstaedtia puntilobula										**Pr**		
Dicranum fuscescens							**Pr**			**Pr**	**24**	
Dicranum montanum							**Pr**					
Dicranum scoparium	**Pr**		**80**				**Pr**	**4**				
Ditricum pallidum							**Pr**	**3**				
var. americana	**Pr**		**23**	**Pr**		**60**	**Pr**	**79**	**53**	**Pr**	**11**	
Eupatorium maculatum												
Grass - sterile				**Pr**	**61**							
Hypogymnia physodes	**Pr**	**4**					**Pr**					
Lycopodium lucidulum	**Pr**			**Pr**		**18**	**Pr**	**22**	**15**	**Pr**	**2**	**32**
Brotherella recurvans	**Pr**	**2**										
Polytrichum commune				**Pr**	**64**							
Nemopanthus mucronata	**Pr**											
Nowellia curvifolia										**Pr**	**13**	
Oxalis montana	**Pr**	**27**	**4**	**Pr**	**3**	**84**	**Pr**	**93**	**80**	**Pr**	**66**	**98**
Picea rubens										**Pr**		
Pleurozium schreberi							**Pr**					
Polytrichum commune				**Pr**								

Table 12 - Sites 12 - 15
Western Slopes of Mt. Mansfield

Sample Site Number	12			13			14			15		
Trail, Elevation AMSL	Halfway House			Halfway House			Halfway House			Halfway Hous		
	3800ft			3600ft			3400ft			3200ft		
Page 2 - Date	17-Jul-91*			17-Jul-91*			18-Jul-91*			18-Jul-91*		
Taxon	Pr/Ab	Q1	Q2	Pr/Ab	Q1	Q2	Pr/Ab	Q1	Q2	Pr/Ab	Q1	Q2
Azimuth|Rnd#1|Rnd#2	163	15	8	204	16	6	185	25	22	33	17	23
Polytrichum ohioense	Pr			Pr		18	Pr	4	6			
Prunus pennsylvanica	Pr											
Ribes glandulosum				Pr						Pr		
Rubus allegheniensis	Pr	11										
Scapania nemorosa				Pr								
Solidago mucronata	Pr		1									
Sorbus americana	Pr	8		Pr	25		Pr			Pr	5	1
Sphagnum girgensohnii	Pr	73		Pr	67	20	Pr					
Sphagnum russowii				Pr			Pr					
Sphagnum squarrosum				Pr								
Thelypteris Phegopteris				Pr						Pr		
Trientalis borealis	Pr		81									
Trillium undulatum							Pr					

Table 13 - Areas 16 - 20
Western Slopes of Mt. Mansfield

Sample Site Number	**16**			**17**			**18**			**19**			**20**		
Trail,	**Sunset Rdg**			**Butler Lodge**			**Proctor Ctr**			**Proctor Ctr**			**Maple Rdg**		
Elevation AMSL,	**3910ft**			**2800ft**			**1400ft**			**1400ft**			**3600ft**		
Date	**31-Jul-91***			**1-Aug-91***			**2-Aug-91***			**2-Aug-91***			**12-Aug-91***		
Taxon	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**	**Pr/A**	**Q1**	**Q2**
Azimuth|Rnd#1|Rnd#2	**45**	**12**	**18**	**183**	**11**	**17**	**101**	**19**	**23**	**54**	**5**	**17**	**225**	**5**	**13**
Abies balsamea	**Pr**	**65**	**37**	**Pr**			**Pr**			**Pr**			**Pr**	**66**	**100**
Acer pensylvanicum				**Pr**	**4**	**3**	**Pr**								
Acer saccharum							**Pr**		**4**	**Pr**					
Acer spicatum				**Pr**			**Pr**		**3**						
Aralia nudicaulis				**Pr**											
Arenaria groenlandica	**Pr**														
Aster acuminatus				**Pr**									**Pr**		
Athyrium Filix-femina							**Pr**		**96**	**Pr**					
Athyrium thelypteroides							**Pr**			**Pr**					
Betula alleghaniensis				**Pr**			**Pr**			**Pr**		**1**			
Betula papyrifera	**Pr**			**Pr**			**Pr**			**Pr**			**Pr**		
Brotherella recurvans				**Pr**	**8**								**Pr**		**6**
Calamagrostis canadensis							**Pr**								
Carex intumescens				**Pr**											
Cetraria islandica	**Pr**	**25**	**95**												
Cichorium intybus										**Pr**					
Cladina rangiferina	**Pr**	**25**	**95**										**Pr**		
Cladonia alpestris	**Pr**														
Clintonia borealis				**Pr**	**15**	**94**									
Cornus canadensis	**Pr**														
Deschampsia flexuosa	**Pr**														
Dicranum fuscescens													**Pr**		**100**
Dicranum scoparium													**Pr**	**20**	
Dryopteris spinulosa										**Pr**		**27**			
var. americana				**Pr**	**73**	**23**									
Fagus grandifolia				**Pr**			**Pr**			**Pr**					
Impatiens capensis							**Pr**			**Pr**					
Juncus trifidus	**Pr**	**6**													
Lycopodium annotinum	**Pr**														
Lycopodium lucidulum	**Pr**			**Pr**	**26**	**13**									
Lycopodium obscurum										**Pr**					
Lycopus uniflorus							**Pr**			**Pr**					
Maianthemum canadense				**Pr**	**95**	**88**	**Pr**			**Pr**		**1**			
Mitchella repens										**Pr**	**4**				
Onoclea sensibilis							**Pr**	**I**		**Pr**					

Table 13 - Areas 16 - 20
Western Slopes of Mt. Mansfield

Osmunda Claytoniana							Pr	48							
PAGE 2	16			17			18			19			20		
Trail,	Sunset Rdg			Butler Lodge			Proctor Ctr			Proctor Ctr			Maple Rdg		
Elevation AMSL,	3910ft			2800ft			1400ft			1400ft			3600ft		
Date	31-Jul-91*			1-Aug-91*			2-Aug-91*			2-Aug-91*			12-Aug-91*		
Taxon	Pr/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2	Pr/A	Q1	Q2
Azimuth|Rnd#1|Rnd#2	45	12	18	183	11	17	101	19	23	54	5	17	225	5	13
Oxalis montana				Pr	46	74									
Picea rubens				Pr			Pr			Pr					
Pleurozium schreberi													Pr		100
Polytrichum juniperinum				Pr											
Polytrichum ohioense				Pr	8										
Potentilla tridentata	Pr														
Ptilidium ciliare													Pr	14	
Rhizocarpon geographicum	Pr														
Solidago macrophylla				Pr		6	Pr								
Sorbus americana				Pr											
Sphagnum squarrosum				Pr		17									
Streptopus roseus				Pr			Pr								
Thelypteris Phegopteris				Pr						Pr					
Tiarella cordifolia							Pr		46						
Trillium cernuum							Pr								
Trillium undulatum				Pr		7									
Uvularia sessifolia										Pr					
Vaccinium angustifolium	Pr	2											Pr	1	
var. *angustifolium*													Pr		
var. *laevifolium*													Pr		
Vaccinium uliginosum	Pr	72	85												
Viburnum alnifolium				Pr											

Table 14 - Areas 21 - 26
Western Slopes of Mt. Mansfield

Sample Site Number	21			22					23					24					25					26				
Trail,	Maple Rdg			Halfway House					Halfway House					Maple Rdg					Maple Rdg					Laura Cowles				
Elevation AMSL,	3400ft			2600ft					2800ft					3200ft					3000ft					3800ft				
Date	12-Aug-91*			25-Jul-94*					14-Sept-94*					15-Sept-1994*					12-Aug-91*					19-Sept-94*				
Taxon	Pr/A	Q1	Q2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2
Azimuth | Rnd#1Rnd#2 | Rnd#3	0	5	20	155	3	22		24	0	2	9		3	335	3	18		19	30	9	17		7	110	7	10		25
Abies balsamea	Pr	6	47				2	1	Pr		1	10	4	Pr	2		5	22	Pr	2	8	10	37	Pr	7	9	14	7
Acer pensylvanicum				Pr	1							3	2															
Acer spicatum				Pr				15	Pr	2	1	1	8															
Aralia nudicaulis									Pr																			
Aster acuminatus				Pr		1								Pr	1									Pr				
Athyrium Filix-femina				Pr																								
Bazzania trilobata																			Pr	10								
Betula alleghaniensis				Pr	1	3	4		Pr		1	1																
Betula papyrifera	Pr	3	30	Pr			5		Pr			3		Pr			13						1	Pr	2	2		2
Brotherella recurvans	Pr	15																										
Carex inflata				Pr	7																							
Cladonia grayi																			Pr	28								
Cladina rangiferina	Pr		12																Pr	2								
Cladonia alpestris																												
Cladonia chlorophaea	Pr	5																										
Cladonia cristatella																								Pr		98		
Cladonia furcenta				Pr	1																							
Cladonia merochlorophaea																								Pr	12			
Cladonia ochrochlora						2								Pr		6			Pr	4				Pr	4			
Cladonia pleurota	Pr		8																									
Cladonia squamosa																			Pr	8								
Clintonia borealis	Pr			Pr	9	27			Pr	16	1			Pr	5	12								Pr	26			
Coptis groenlandica	Pr													Pr										Pr				
Cornus canadensis	Pr	2												Pr	8						1							
Dennstaedtia puntilobula				Pr	4	3																						
Dicranum fuscescens	Pr	79																										
Dicranum montanum	Pr	5		Pr	4	11																						

Table 14 - Areas 21 - 26
Western Slopes of Mt. Mansfield

PAGE 2	21			22					23					24					25					26				
Trail, Elevation AMSL	MRT 3400ft			HHT 2600ft					HHT 2800ft					MRT 3200ft					MRT 3000ft					LCT 3800ft				
Trail,	Maple Rdg			Halfway House					Halfway House					Maple Rdg					Maple Rdg					Laura Cowles				
Elevation AMSL,	3400ft			2600ft					2800ft					3200ft					3000ft					3800ft				
Taxon	Pr/A	Q1	Q2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2	Pr/A	Q1	Q2	>2	<2
Dicranum polysetum																			Pr	27								
Dicranum scoparium				Pr	1									Pr					Pr	12	26							
Gaultheria hispidula	Pr		5																Pr	1								
Lycopodium lucidulum				Pr	7	85			Pr	91	85			Pr														
Maianthemum canadense	Pr			Pr	58	26								Pr														
Monotropa uniflora				Pr	1				Pr					Pr							4							
Nemopanthus mucronata														Pr		2												
Oxalis montana				Pr		32			Pr		88			Pr										Pr	2			
Paraleucobryum longifolium				Pr																								
Picea rubens	Pr			Pr	2		1		Pr		1	1	2	Pr	3	6	21		Pr	2		10	37					
Plagiothecium laetum														Pr	20													
Pleurozium schreberi	Pr																											
Polytrichum pallidisetum				Pr																								
Ptilidium ciliare	Pr	7																				2	2					
Sambucus pubens								2																				
Sorbus americana	Pr			Pr	2		5		Pr			3		Pr	3	2	5	13	Pr		1			Pr				
Sphagnum girgensohnii																								Pr	91			
Streptopus amplexifolis				Pr																								
Thelypteris Phegopteris				Pr																	1							
Trientalis borealis				Pr	1									Pr										Pr				
Trillium erectum				Pr																								
Trillium undulatum									Pr																			
Vaccinium angustifolium	Pr		31																									
Vaccinium myrtilloides	Pr		17																Pr	1	1							
Viburnum alnifolium				Pr	1	6		20	Pr	11	3																	
sphagnum sp.														Pr		2												
moss - undetermined																			Pr	33								

Table 15
Physical Site Conditions

Quadrat #	Summit Saddle Measured Soil pH	Summit Saddle Max soil depth - cm	Summit Saddle Slope Angle	Summit Saddle Slope Aspect	West Chin Top Measured Soil pH	West Chin Top Max soil depth - cm	West Chin Top Slope Angle	West Chin Top Slope Aspect
1						105	20	25
2	3.86	12	8	285	3.96	100	18	115
3		12.5	20	340	3.57	130	4	220
4	3.93	17	66	11	3.72	70	15	250
5	3.82	16.5	9	340		116	4	15
6	3.93	30	18	255		80	15	45
7	3.87	12	4	10	3.76	125	0	0
8		8.5	variable	variable		115	4	30
9	3.82	18	11	25	4.32	9	15	30
10	3.92	12	24	278		1.4	variable	variable
Log Mean pH Antilog		3.88			3.80			
Median pH		3.87			3.76			

Quadrat #	Thunder-bolt Gap Measured Soil pH	Thunder-bolt Gap Max soil depth - cm	Thunder-bolt Gap Slope Angle	Thunder-bolt Gap Slope Aspect	West Chin Low Measured Soil pH	West Chin Low Max soil depth - cm	West Chin Low Slope Angle	West Chin Low Slope Aspect
1	4.22	25	25	272	3.74	20	8	290
2	4.14	12	26	265	3.89	10	15	252
3		9	4	254		0	15	280
4	3.9	10	24	307	4	21	39	255
5		20	24	280	4.13	28	37	265
6		10	4	254	3.65	10	6	285
7	4.57	15	13	190		13	16	275
8	4.1	18	23	237		17	20	250
9		13	19	290	3.79	0	27	280
10	4.05	26	8	280	4.48	15	10	270
Log Mean pH Antilog		4.12			3.89			
Median pH		4.09			3.89			