Vermont Forest Ecosystem Monitoring

(formerly Vermont Monitoring Cooperative)

Annual Report for 1996

Sandra Wilmot and Timothy Scherbatskoy
(Editors)

The VForEM is Vermont's Cooperative Forest Ecosystem Monitoring and Research Program, administered by the Vermont 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, North-eastern Area State and Private Forestry.

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Introduction

The purpose of the VForEM Annual Report is to provide annual documentation of results from studies conducted at the two VForEM sites at Mount Mansfield and the Lye Brook Area. Cooperating scientists working at the two study sites are invited to submit their findings (preliminary or otherwise) for the year in a form that is easily understood by non-experts with an interest in forested ecosystems. A broader goal of this publication is to stimulate further exchange of information and ideas that expand our understanding of forest ecosystems, and result in scientific conclusions that lead to more ecologically based natural resource management.

This document begins with an overview of program activities for 1996, then proceeds to specific study results. Results are organized by the type of information collected (atmospheric, flora, fauna, etc), and includes studies conducted at Mount Mansfield and the Lye Brook Area sites.

Program Activity Summary

A unified, clearly defined program was articulated in a Memorandum of Understanding among the State Agency of Natural Resources, the University of Vermont, the USDA Forest Service: Green Mountain National Forest, Northeastern Area State and Private Forestry, and Northeast Forest Experiment Station in August, 1996. This document provides a clear understanding of how truly cooperative the VForEM program is, with each partner playing a crucial role in maintaining an integrated forest ecosystem monitoring and research program for Vermont.

Reductions in federal funding to support monitoring and research at the two study sites prompted the Coordination Committee to conduct a program review and make recommendations to the Steering Committee through a draft Planning Document ~ 1996 -2001. The Steering Committee, which provides oversight to the program, suggested broadening funding sources by establishing a non-profit organization. In the process of becoming incorporated, the name Vermont Monitoring Cooperative changed to Vermont Forest Ecosystem Monitoring. The strengths of the program would be maintained, i.e. long-term monitoring data collection, program coordination and information management and services. Strategies for improving stable funding for base monitoring included increased contribution by the State, with continuation of federal support from the USDA Forest Service. No new state appropriations were awarded, and many monitoring efforts had to be scaled back. However, an environmental fine from the Mt. Mansfield Company was awarded to the program through the University of Vermont in three installments over a two year period. This was used to support long-term monitoring and research on Mt. Mansfield.

A centralized data management structure was initiated in 1995 and was expanded in 1996. Current and historical data and metadata (information about the data) are being standardized and stored in the VForEM Data Library, and cataloged in a VForEM Card Catalog for easy search and retrieval. Data requests are made through the Data Manager, with the goal of eventually having data, metadata and reports available through the VForEM web site on the internet (http://www.uvm.edu/~snrdept/vmc).

The VForEM Data Manager was invited to instruct international students on data management and integration at a Smithsonian Institute-sponsored 3-week course on Ecological Research and Monitoring in Forested Ecosystems. VForEM has been recognized as having a unique data management system that facilitates integration of disparate data sets, common among ecological studies. The course was held at the Kejimkujik National Park in Nova Scotia.

The Annual Cooperators Meeting in March was attended by 56 interested persons. This event allowed program participants an opportunity to exchange information and network with other groups working in Vermont. It featured presentation of results by cooperators followed by panel presentations on opportunities for information outreach to educators and students, and possible funding sources for such endeavors.

VForEM Cooperators also contributed to in the Agency of Natural Resources "Environment 1997" publication. This annual publication documents the status and trends in Vermont's natural resources. That year's issue focused on the watersheds in the Lake Champlain Basin (which includes Mount Mansfield) and their human, ecosystem and economic health. Air and water quality information from Underhill was woven throughout the document, with special attention given to mercury.

A joint UVM School of Natural Resources and Vermont Agency of Natural Resources workshop was held to stimulate discussion on issues of mutual interest aimed at enhancing communication and opportunities for shared activities between organizations. VForEM served as a model for the workshop on collaborative research and management activities, and our information was well represented in the discussions.

The VINS sponsored Vermont Bird Conference was held at Mount Mansfield this year and highlighted much of the ecological studies in the high elevation alpine forest and tundra. Workshops included VINS bird studies with the Bicknell's Thrush and other high elevation forest birds, Middlebury College's amphibian monitoring and alpine tundra ecology. A panel on "Balancing multiple uses in high elevation forests" provided the hundred plus participants with an opportunity to discuss the intricacies of trying to accommodate many interests on Mount Mansfield.

A new VForEM display was created highlighting monitoring and research conducted through our program. Some interactive features allow audiences to think about results in new ways. It was featured at the Lake Champlain Science Center for 2 weeks over the summer, and presented at numerous winter meetings of resource managers and scientists around the state.

Forest inventory data collection for the Forest Ecosystem Management Demonstration Project (EM Demo) continued on Mount Mansfield. This will form the background information needed in designing the comprehensive study. Tree health and understory plant diversity data were collected this year to augment basic mensurational data collected in 1995. The new expanded version of forest inventory implemented under this project was presented at the annual statewide foresters meeting to stimulate interest in expanding the normal forest inventories to include a broader array of ecosystem data.

The Department of Forests, Parks and Recreation began the process for updating the State Land Management Plan for the Mount Mansfield State Forest. This effort has brought together the various user groups, including state and local government organizations, to create a plan that accounts for the growing use of this limited resource. A Steering Committee with diverse representation, initiated discussions by serving as a forum for information exchange on environmental issues, land use allocations, policies, ecological constraints, etc. The committee will advise the Department on balancing multiple uses for the future in developing its resource manangement plan. Research and monitoring interests under VForEM have been represented by the Monitoring Coordinator at meetings of this committee.

Atmospheric

Meteorological Conditions at VForEM Sites in 1996

Judy Rosovsky And Tim Scherbatskoy
VForEM and School Of Natural Resources, University Of Vermont

Cooperators: UVM Proctor Maple Research Center (PMRC), VT Department of Environmental Conservation (DEC), WCAX-TV staff at Mt. Mansfield transmitter station, 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 basic meteorological data has been conducted at several VForEM sites. Continuous hourly meteorology data from Proctor Maple Research Center (PMRC) 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. This report is based on the PMRC air quality monitoring station data (PMRC AQ, 400 m) and on the data made available to VForEM in 1996 from stations at Colchester Reef (ColchReef) and Clear Air Status and Trends Network (CASTNET) in the Lye Brook Wilderness (LYE145).

METHODS:
Air temperature, relative humidity, mean resultant and horizontal wind speed and direction are monitored at four VForEm sites. Data from the Mount Mansfield 2900' site (MM2900) will be available as of 1997. Precipitation is recorded from PRMC AQ, CASTNET and MM2900. Barometric pressure is monitored at the Colchester Reef and PMRC AQ sites; pyranometer reading are collected from Colchester Reef and MM2900. Photosynthetically active radiation is available from the CASTNET site; and water temperature is monitored at Colchester Reef.

Minimum and maximum values are calculated and the number of sample dates are given. Data from 1996 is available from Colchester Reef as of July and from CASTNET for November and December. In addition, meteorological conditions are monitored within the forest at the canopy research tower and the Nettle Brook gauging station; these provide continuous mnitoring at within-forest sites. Although not reported here, these data are available from the VForEM data manager. VForEM has access to National Weather Service (NWS) data; there are 77 NWS stations currently active in Vermont.

The PMRC AQ 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 VForEM as spreadsheets (Lotus, Excel), and in Voyager format. Station supervision is by Tim Scherbatskoy and operated by Miriam Pendleton and Carl Waite. Consolidation of the historic and current basic meteorology data from the VForEM 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 VForEM Data Manager.

RESULTS AND DISCUSSION:
Monitoring occurs at 15 minute intervals at Colchester Reef and MM2900; and as of 1998 at PMRC AQ, too. Data is averaged to generate hourly means. Monitoring at hourly intervals takes place at LYE145 and PMRC AQ; all hourly data is summarized to create daily means. Yearly and monthly means are calculated from the daily data. The principle goal of these projects is to provide a high-quality, long-term comparative database on meteorological conditions for use by VForEM cooperators and others.

Visual analysis of trends and relationships in these projects is presented graphically. Complete meteorological monitoring data from these four VForem sites began at the end of 1996; only the PMRC air quality station has a complete year of data.

Yearly and monthly summaries.for each site are presented in tables 1 and 2. Four basic meteorological variables summarized by month are displayed for site to site comparison (Figure 1); note that the Y-axis scale varies. Statistical analysis of these comparisons will be made in 1997, when full data sets are available. Comparison of multiple meteorological variables on individual sites can be seen in Figure 2. Daily total precipitation is summarized in Figure 3; note that the Y-axis scale has been standardized to facilitate comparisons across time. Daily mean, minimum and maximum temperature from PMRC AQ is shown in Figure 4. The X-axis crosses the Y-axis at 0 degrees Celsius to better visualize fluctuations, and note the standardized Y-axis scale.

Cumulative growing degree days based on start temperatures of 32 and 50 degrees Farhenheit are plotted together on Figure 6. Growing degree day temperature thresholds of 32 and 50 degrees Farhenheit represent those of plants and insects, respectively.

Table 1: VForem Yearly Data Comparisons For 1996

Site	Air Temp	Barom Press	Rel Humd	Precip	Pyranom	H2O Temp	Wind Speed: Max	Wind Speed: Mean Resultant	Wind Speed: Mean Horizontal	Wind Direction: Mean Resultant	Wind Direction: Std Dev
	deg C	mb	%	mm	watts/m2	deg C	m/second			degrees	
Castnet											
Mean	-3.13		87.02	0.20	26			2.69	3.00	204	4.00
Max	10.6		99	10.4	534		0	5.41	6	326	18
Min	-23.7		34	0	1		0	1.02	1	76	2
N	41		41	41.00	41		0	41	41	41	41
Sum											
ColchReef											
Mean	10.49	1014.04	76.87		111	13.00		6.38		187	8.00
Max	28.96	1044	102.2		982	29	20	18.86		360	78
Min	-17.58	989	32.65		0	1	0	0.06		0	1
N	156	156	156		156	156	156	156		156	156
Sum											
PMRC AQ											
Mean	5.96	931.03	56.72	3.53				1.83	0.00	0	0.00
Max	27.9	984	99.2	9.7			0	8.30	0	0	0
Min	-26.4	0	0	0			0	0.00	0	0	0
N	357	357	357	357.00			0	357	0	0	0
Sum											

Table 2: VForem Meteorological Monthly Data Comparisons Fo 1996

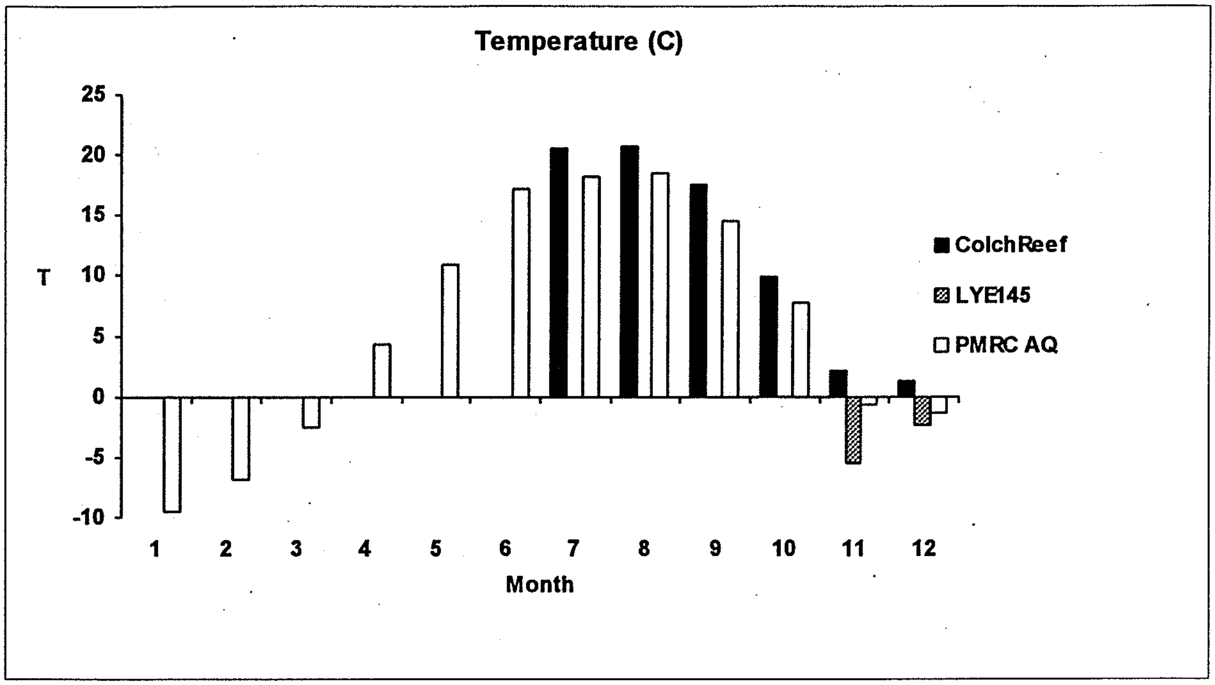
Site Month	Air Temp	H2O Temp	Barom Press	Rel Humd	Precip	Pyranom	Wind Speed: Max	Wind Speed: Mean Resultant	Wind Direction: Mean Resultant	StDev
		degrees C	mb	%	mm	watts/m2	m/second		degrees	
ColchReef										
Jul										
Mean	20.51	20		79.67		104		6.59	175.00	
Max	25.03	22		95.6		622	13.23	12.33	244.10	
Min	16.98	19		60.18		0	1	0.81	48.88	
N	3	3	3	3	0	3	3	3		
Sum										
Aug										
Mean	20.69	21	1014.80	79.05		226		4.81	183.00	
Max	28.96	25	1025	100.8		982	14.45	13.08	360.00	
Min	13.77	16	1004	32.65		0	0	0.11	0.01	
N	31	31	31	31	0	31	31	31		
Sum										
Sep										
Mean	17.46	18	1010.71	78.79		152		5.82	182.00	
Max	26.51	29	1026	98.3		896	18.51	17.35	359.80	
Min	7.8	8	1001	38.65		0	0	0.17	0.02	
N	30	30	30	30	0	30	30	30		
Sum										
Oct										
Mean	9.88	10	1013.58	72.97		99		7.36	193.00	
Max	19.16	19	1037	98.7		672	18.78	17.44	359.80	
Min	0.69	2	991	33.87		0	0	0.06	0.01	
N	31	31	31	31	0	31	31	31		
Sum										
Nov										
Mean	2.12	8	1017.27	73.26		48		6.45	199.00	
Max	17.94	13	1044	102.2		552	20.25	18.86	359.90	
Min	-9.25	1	989	37.72		0	1	0.06	0.20	
N	30	30	30	30	0	30	30	30		
Sum										

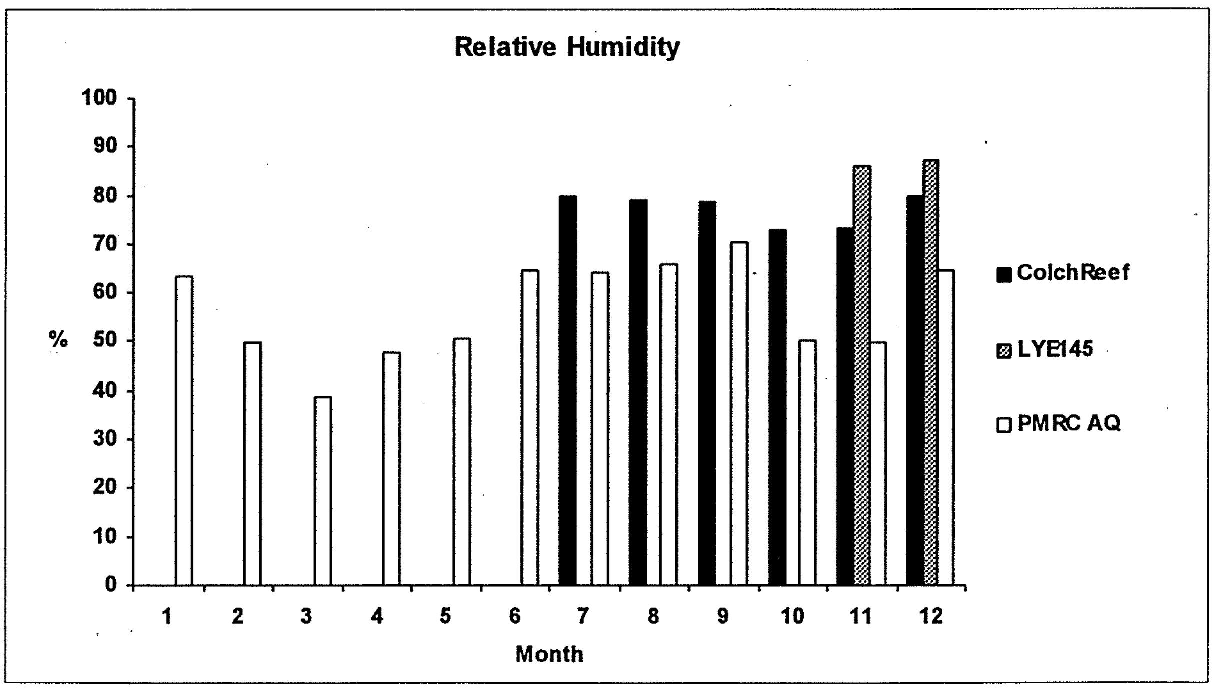
Site / Month	Air Temp	H2O Temp	Barom Press	Rel Humd	Precip	Pyranom	Wind Speed: Max	Wind Speed: Mean Resultant	Wind Direction: Mean Resultant	Wind Direction: StDev
		degrees C	mb	%	mm	watts/m2	m/second		degrees	
ColchReef										
Dec										
Mean	1.30	7	1014.25	79.96		28		7.45	181.00	
Max	12.17	7	1032	100.4		458	19.39	18.11	359.80	
Min	-17.58	3	993	40.66		0	1	0.16	0.36	
N	31	31	31	31	0	31	31	31		
Sum										
LYE145										
Nov										
Mean	-5.44	0		85.84	0.17	36		1.98	241.00	10.49
Max	5.4	0		99	8.1	534		3.21	325.63	15.66
Min	-13.8	0		44	0	1	0	1.24	171.33	4.27
N	30	0		30	30	30		10	10	10
Sum					39.7					
Dec										
Mean	-2.38	0		87.40	0.21	23		2.92	192.00	7.50
Max	10.6	0		99	10.4	418		5.41	283.46	18.29
Min	-23.7	0		34	0	1	0	1.02	75.58	2.43
N	31	0		31	31	31		31	31	31
Sum					157.9					
PMRC AQ										
January										
Mean	-9.44		945.25	63.30	2.76	0		2.18	0.00	28.91
Max	13.5		977	99.1		0		8.30	360.00	88.80
Min	-26.4		0	0		0	0	0.00	0.00	0.00
N	31			0	0	0	31	31	31	31
Sum					85.7					
February										
Mean	-6.88		953.30	49.89	2.04	0		2.29	0.00	27.64
Max	9.8		972	88		0		7.20	360.00	85.80
Min	-23.1		930	20.1		0	0	0.00	0.00	6.60
N	28			0	0	0	28	28	28	28
Sum					57					

Site Month	Air Temp	H2O Temp	Barom Press	Rel Humd	Precip	Pyranom	Wind Speed: Max	Wind Speed: Mean Resultant	Wind Direction: Mean Resultant	Wind Direction: StDev
		degrees C	mb	%	mm	watts/m2	m/second		degrees	
PMRC AQ										
March										
Mean	-2.52		954.71	38.65	0.93	0		2.11	0.00	28.64
Max	14.2		982	84.4		0		6.10	360.00	84.50
Min	-16.8		934	10		0	0	0.20	0.00	8.60
N	29			0	0	0	29	29	29	29
Sum					27					
April										
Mean	4.19		947.04	47.55	7.11	0		2.38	0.00	30.59
Max	19.6		970	92.4		0		7.60	360.00	78.90
Min	-8.3		927	11.7		0	0	0.00	0.00	9.70
N	30			0	0	0	30	30	30	30
Sum					213.2					
May										
Mean	10.96		955.03	50.52	4.93	0		1.92	0.00	30.36
Max	25.8		973	88.8		0		5.20	360.00	93.30
Min	0.1		921	16.9		0	0	0.10	0.00	3.80
N	31			0	0	0	31	31	31	31
Sum					152.9					
June										
Mean	17.12		956.45	64.59	3.93	0		1.36	0.00	38.36
Max	27.2		971	87.2		0		5.20	359.00	79.80
Min	8.1		939	21.6		0	0	0.10	2.00	5.70
N	29			0	0	0	29	29	29	29
Sum					113.9					
July										
Mean	18.18		951.55	64.32	5.65	0		1.52	0.00	38.98
Max	25.7		966	83.9		0		5.80	360.00	89.00
Min	10.4		936	33.4		0	0	0.10	1.00	4.80
N	31			0	0	0	31	31	31	31
Sum					175.3					

Site *Month*	*Air Temp*	*H2O Temp*	*Barom Press*	*Rel Humd*	*Precip*	*Pyranom*	*Wind Speed:* *Max*	*Wind Speed:* *Mean Resultant*	*Wind Direction:* *Mean Resultant*	*Wind Direction:* *StDev*
		degrees C	*mb*	*%*	*mm*	*watts/m2*	*m/second*		*degrees*	
PMRC AQ										
August										
Mean	18.54		960.52	65.82	1.54	0		1.27	0,00	34.32
Max	27.9		972	87.5		0		3.50	360.00	88.90
Min	8.1		943	37.9		0	0	0.10	0.00	3.70
N	31			0	0	0	31	31	31	31
Sum					47.6					
September										
Mean	14.59		946.47	70.39	2.11	0		1.33	0.00	40.46
Max	25.1		970	93.5		0		5.10	360.00	85.90
Min	3.3		778	36.2		0	0	0.10	1.00	3.80
N	29			0	0	0	29	29	29	29
Sum					61.1					
October										
Mean	7.80		917.19	50.20	4.89	0		1.89	0.00	34.47
Max	20.1		975	99.2		0		6.20	360.00	84.40
Min	-3.9		769	0		0	0	0.20	1.00	4.60
N	29			0	0	0	29	29	29	29
Sum					141.9					
November										
Mean	-0.73		879.47	49.99	2.72	0		1.67	0.00	29.63
Max	19.2		984	88.7		0		7.50	360.00	85.30
Min	-15.2		771	9.4		0	0	0.10	0.00	5.40
N	30			0	0	0	30	30	30	30
Sum					81.7					
December										
Mean	-1.41		801.31	64.52	3.59	0		2.04	0.00	28.69
Max	10.8		966	89.8		0		6.50	360.00	80.00
Min	-24.3		781	18.2		0	0	0.00	0.00	0.00
N	29			0	0	0	29	29	29	29
Sum					104.1					

Figure 1: Meteorological Variables Summarized By Month At VForEM Sites





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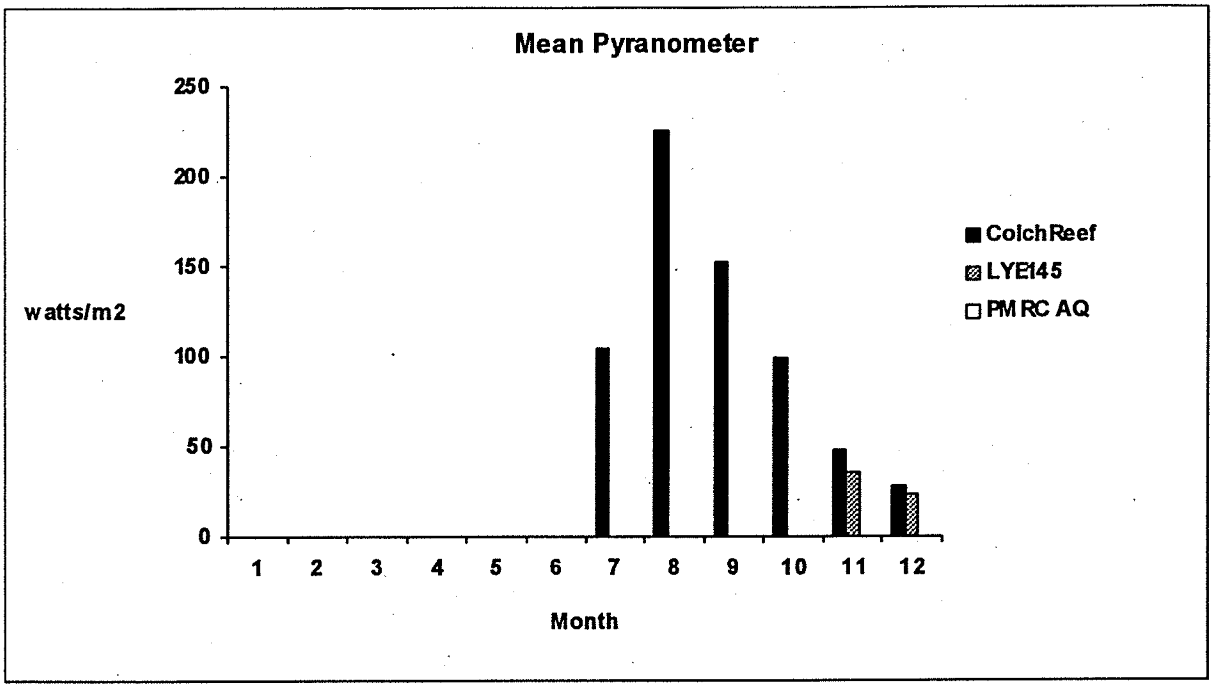


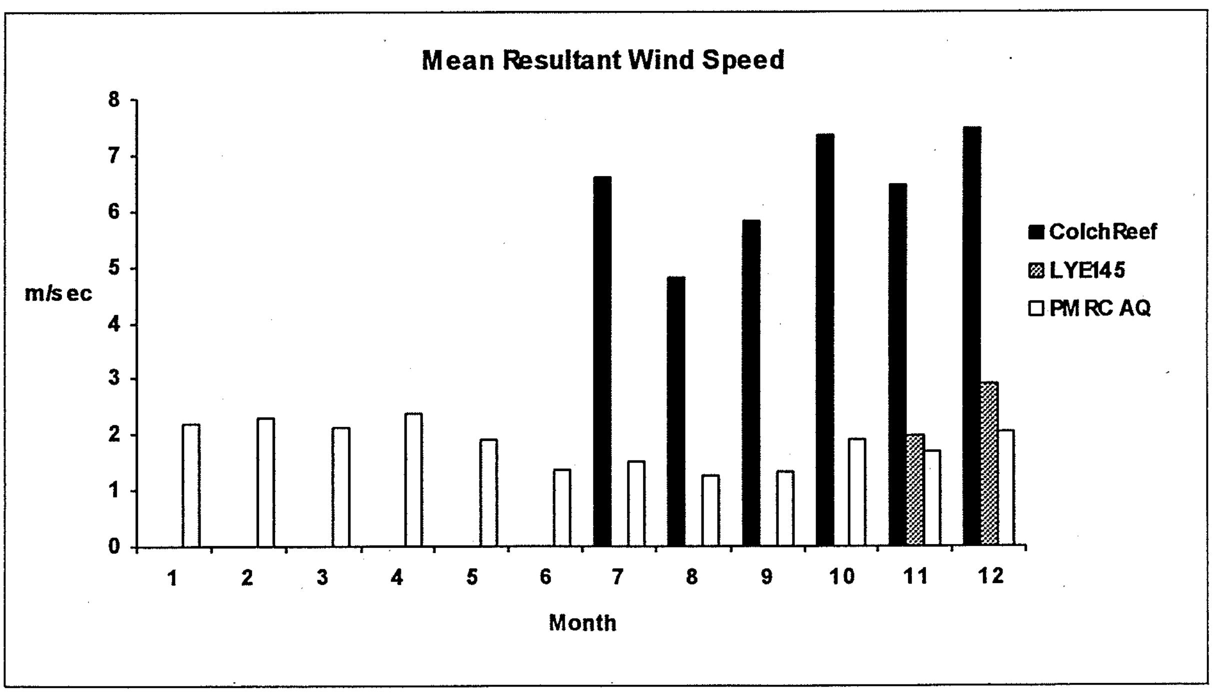
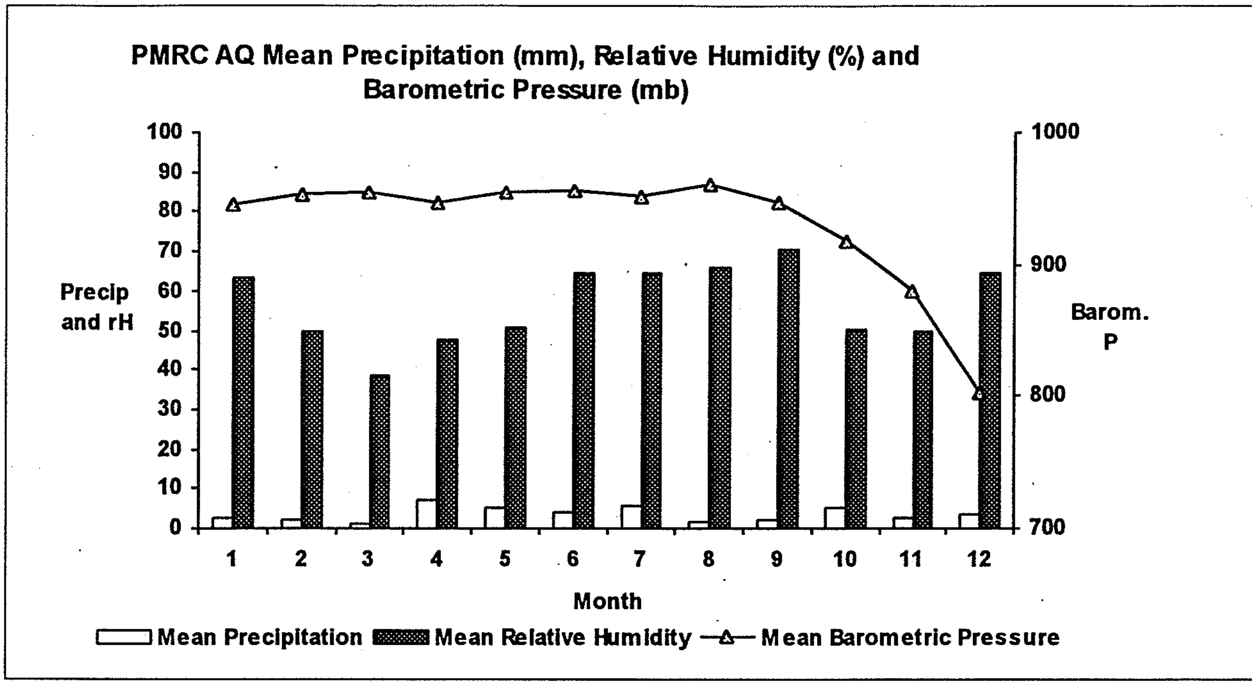


Figure 2: Meteorological Variables Summarized By Month On Individual Sites



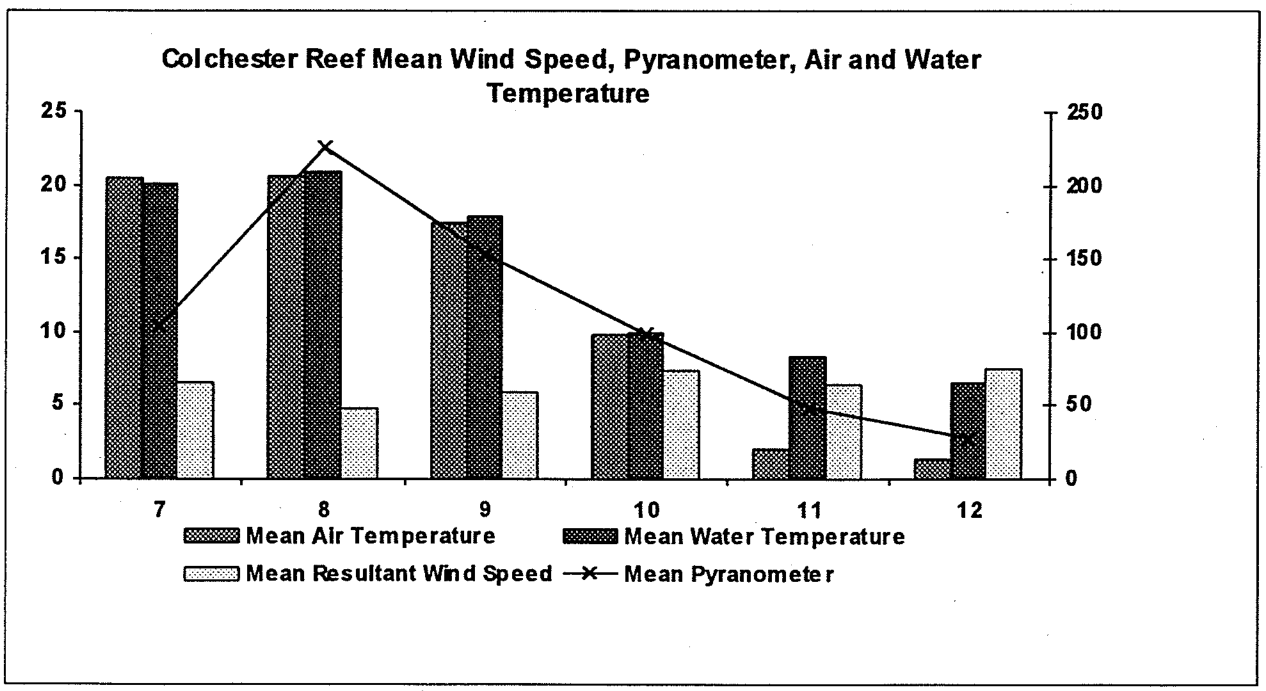


Figure 3: PMRC AQ Total Daily Precipitation

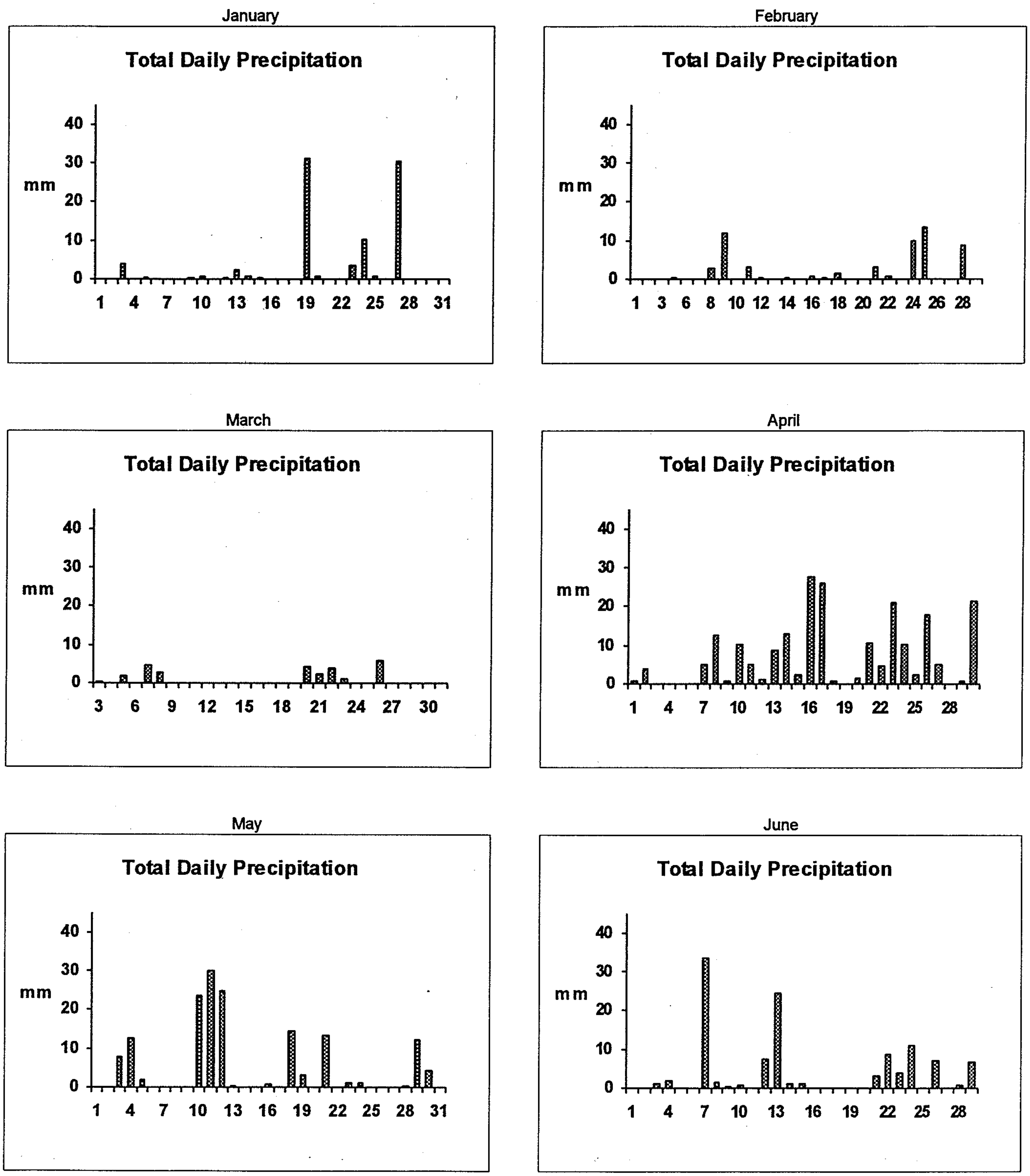


Figure 3: PMRC AQ Total Daily Precipitation

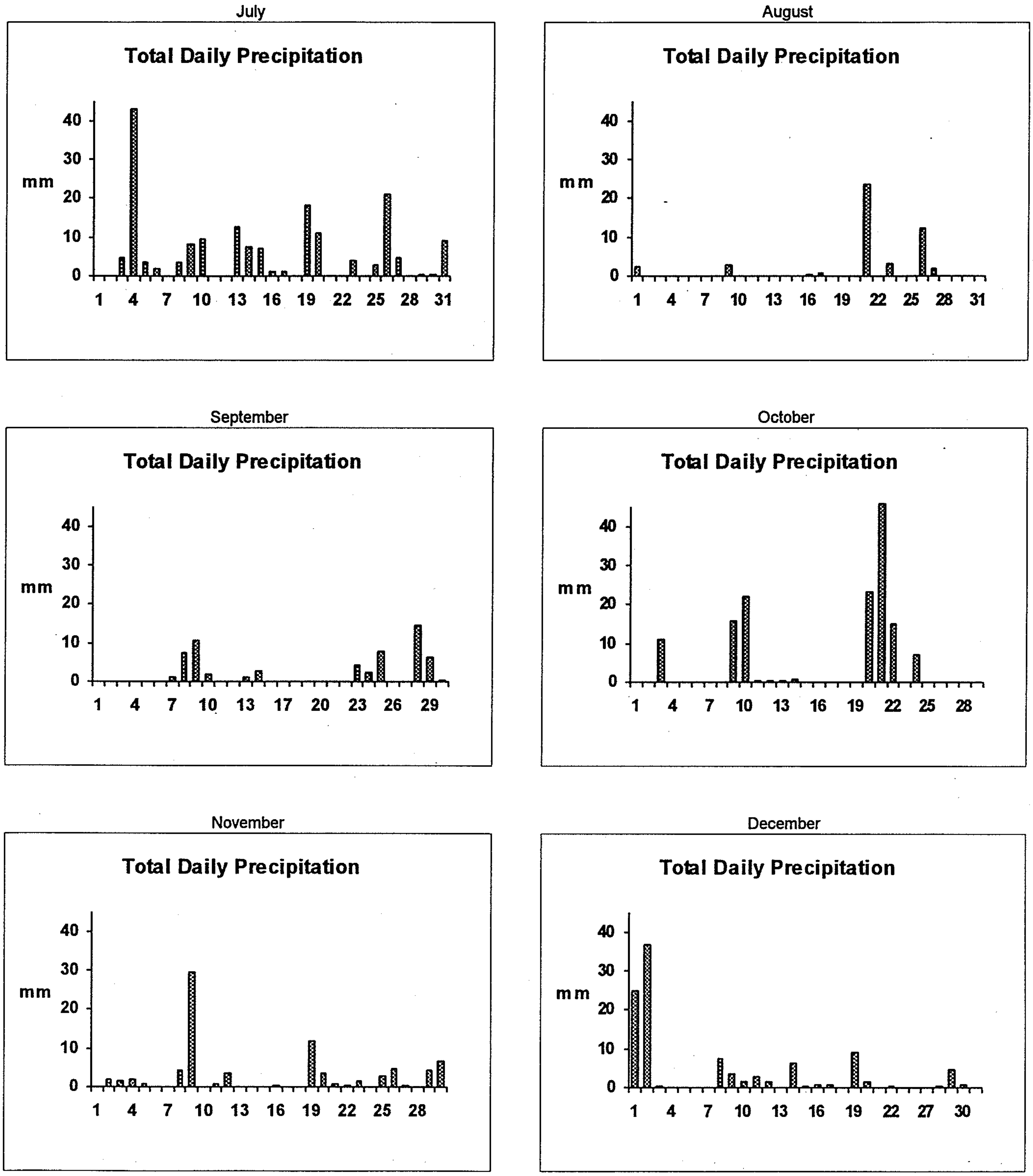


Figure 4: PMRC AQ Daily Temperature

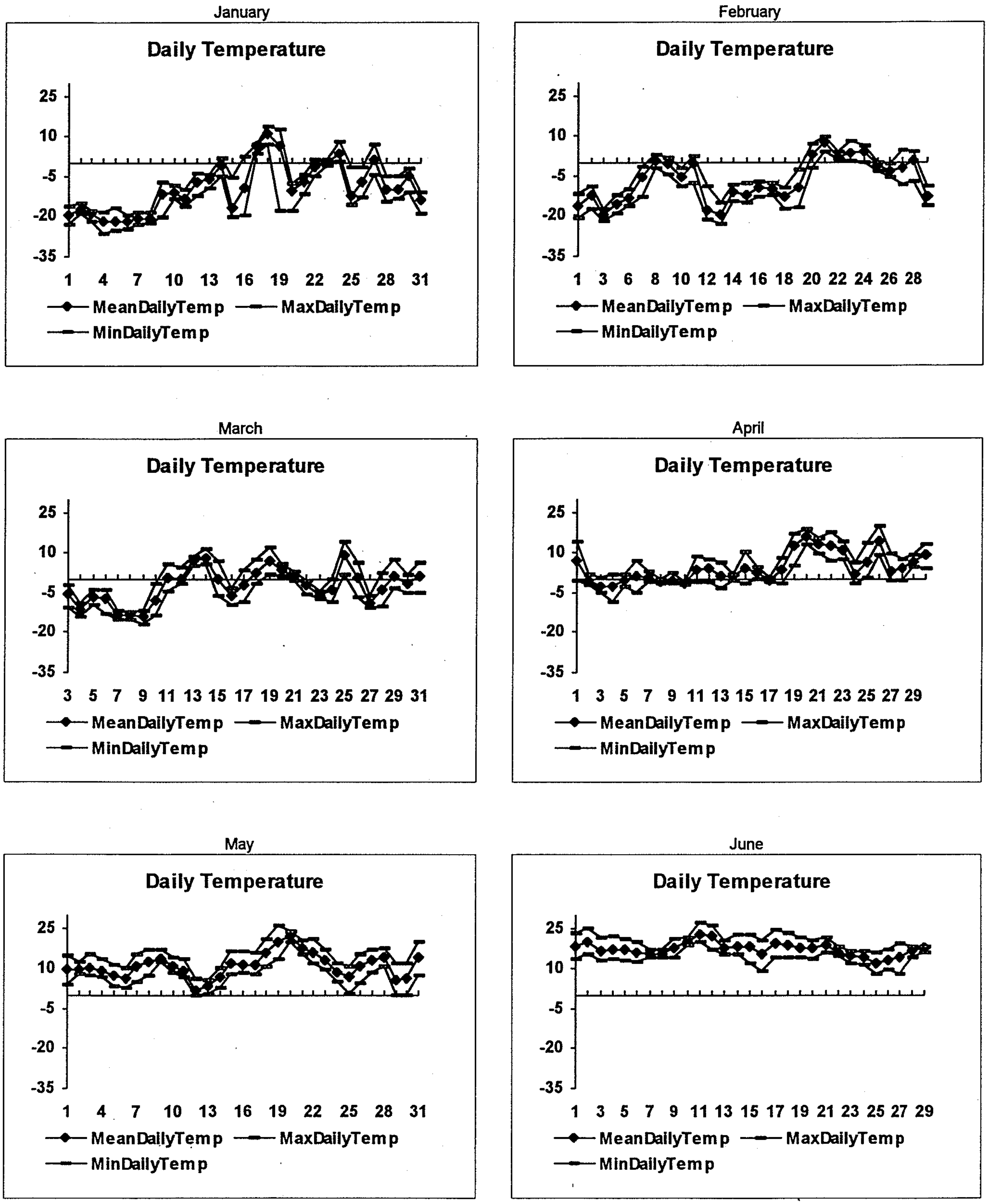
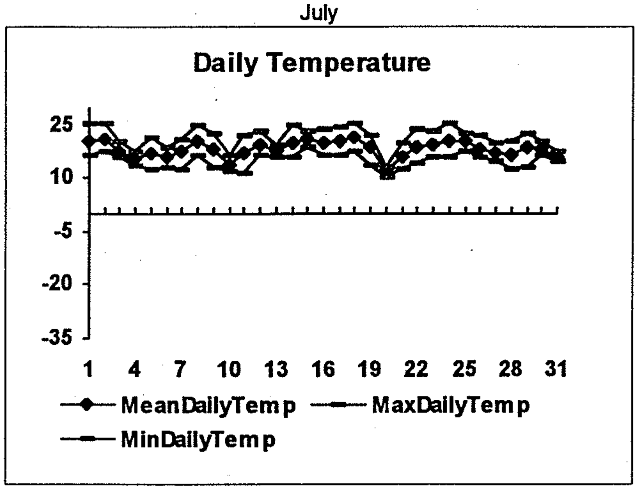
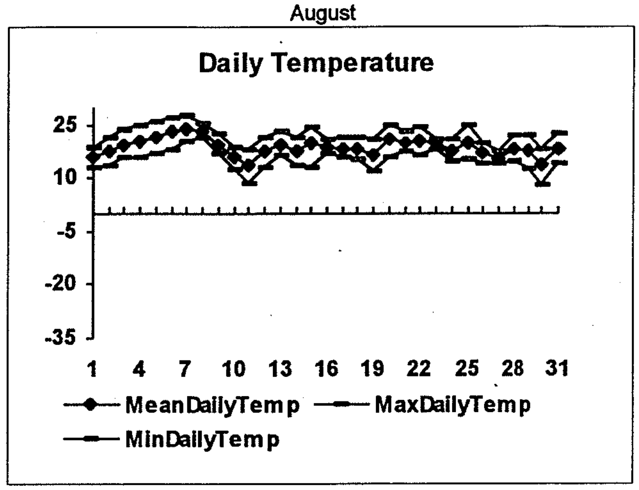


Figure 4: PMRC AQ Daily Temperature

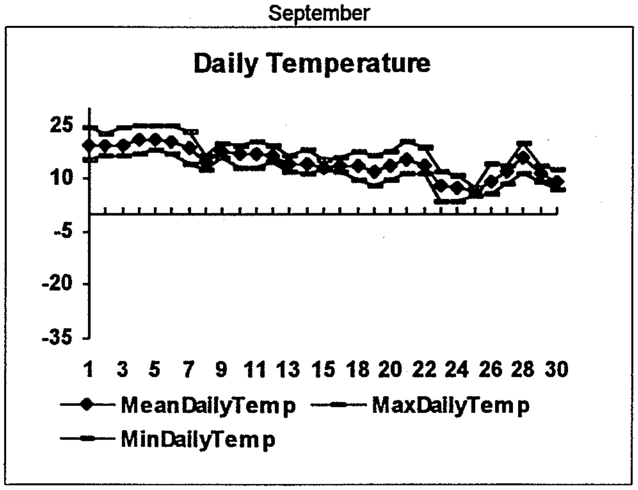
July



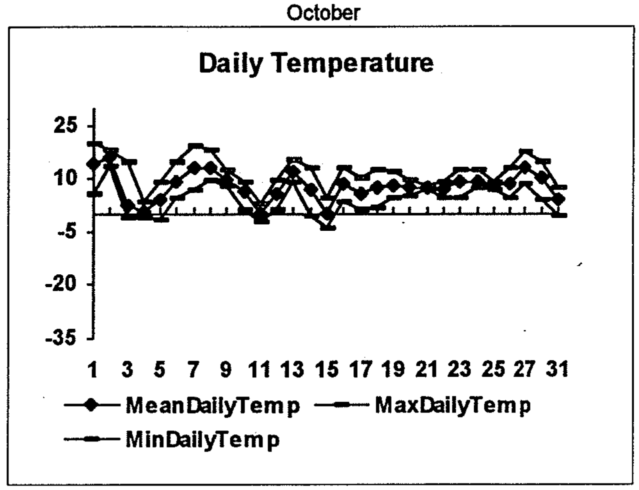
August



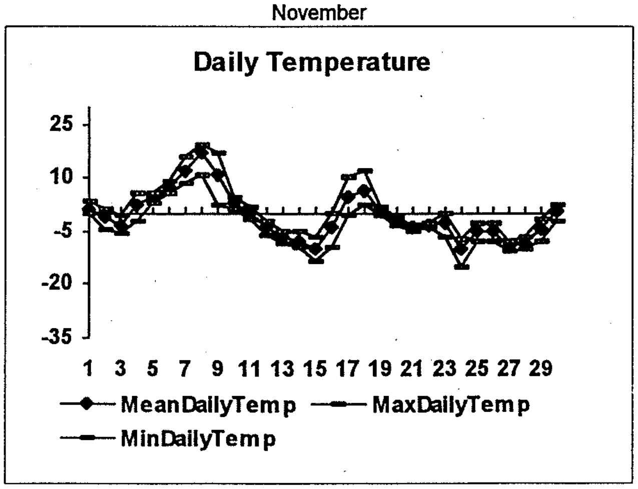
September



October



November



December

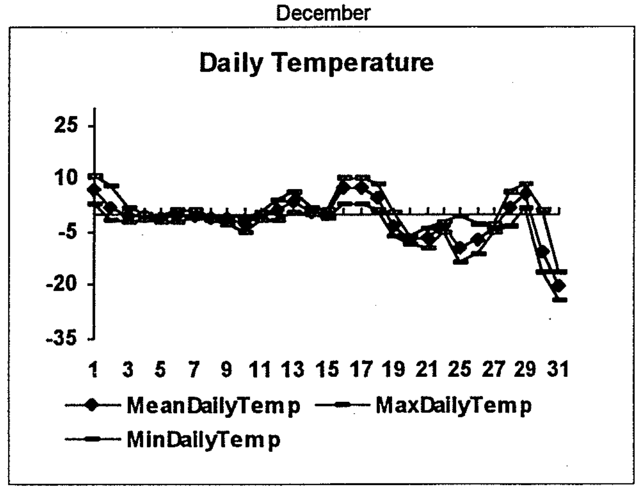
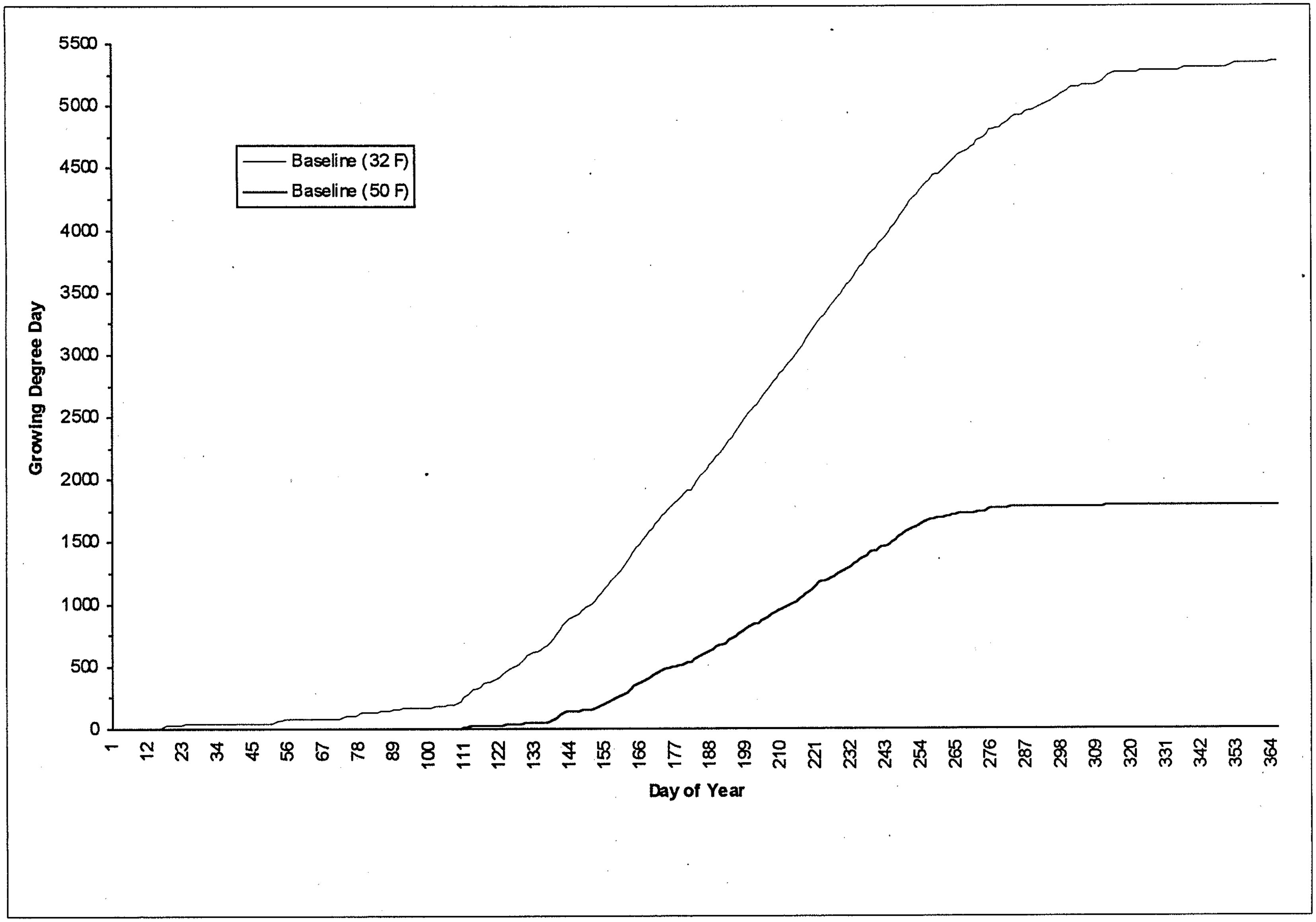


Figure 6: PMRC AQ Cumulative Growing Degree Days



Vermont Acid Precipitation Monitoring Program

Data Summary Report 1980-1996 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
Stowe Mountain Resort and Simon Operating Systems: Michael Bernadine

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.

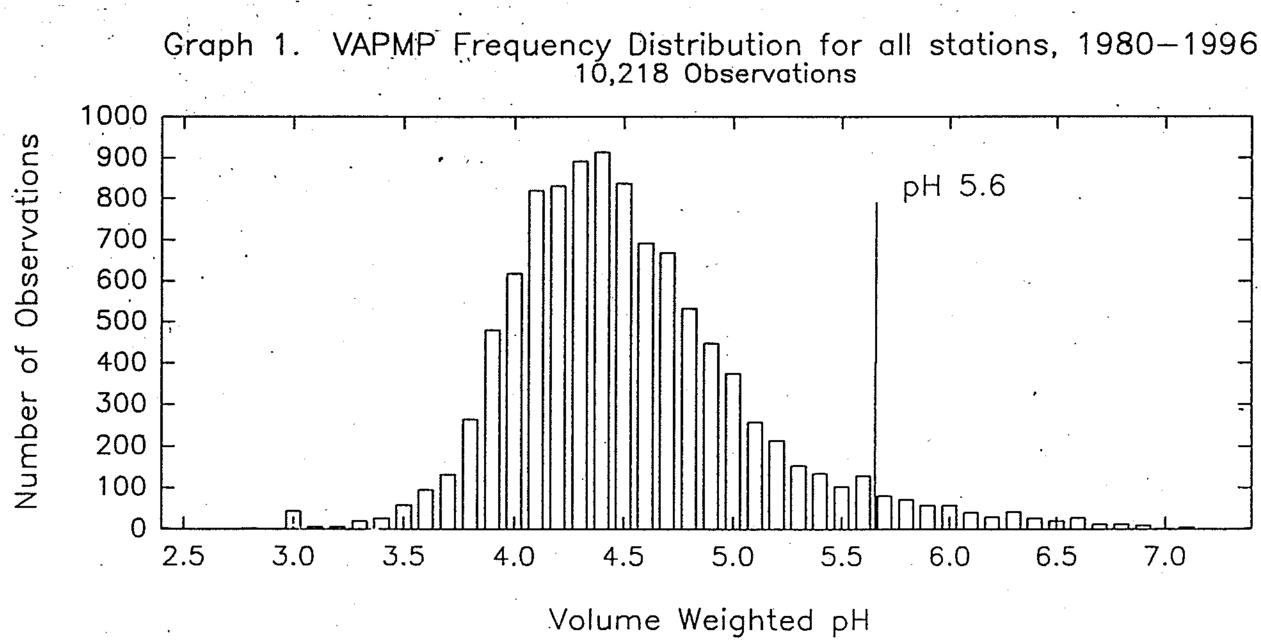
All monitors are trained by the DEC and the monitor's techniques are observed bi-annually. There has been a low turnover of monitors, which has contributed to consistency in the data collection.

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 1996 are less than pH 5.60, the theoretical pH for unpolluted precipitation. Eighty-four 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.)



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 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	1995	1996
Mt. Mansfield	4.49	4.26	4.28	4.14	4.03	4.25	4.13	ND	ND
Underhill	4.32	4.34	4.46	4.41	4.46	4.28	4.31	4.38	4.52
Morrisville	4.39	4.44	4.38	4.49	4.64	4.50	4.47	4.54	4.63

ND = No Data

Table 2. Seasonal Volume-Weighted pH 1981-1996.

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		1995		1996	
	W	S	W	S	W	S	W	S
Mt. Mansfield	4.24	4.31	4.27	4.14	4.38	ND	ND	ND
Underhill	4.25	4.25	4.41	4.19	4.36	4.36	4.37	4.46

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. With the implementation of Phase II of the 1990 Clean Air Act, nitrate emissions will be reduced, possibly improving the pH of precipitation. However, Utility Restructuring may have a profound effect on Vermont's precipitation chemistry. Older coal-powered utility plants which were grandfathered in the Clean Air Act may begin to run at full capacity. These plants are able to produce cheap energy without installing pollution prevention devices. The State of Vermont has pending legislation requiring each utility to purchase a portion of renewable energy and meet certain environmental criteria.

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 Mount Mansfield station is once again up and running. For over a year and a half, we tried to deal with electromagnetic surges at the summit. Now, the Mt. Mansfield Corporation and Simon Operating Services are performing the pH measurments at the base of the mountain while the collection is still being handled at the historic summit site. The VAPMP will continue to monitor sites around Vermont with new site(s) being brought into the program.

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Surface Waters

AQUATIC MACROINVERTEBRATE MONITORING AT THE VERMONT FOREST ECOSYSTEM MONITORING RESEARCH SITE UNDERHILL, VERMONT

by the
Vermont Department of Environmental Conservation

Summary

Aquatic macroinvertebrates have been sampled by the Vermont Department of Environmental Conservation at two sites in the upper Brown's River drainage basin using standardized sampling methods. 1996 marked the sixth year of sampling. Samples are collected once annually during the fall period. Long-term sampling is undertaken at these sites, which are essentially unimpacted by land-based human activity, in order to gather data describing the natural variability of macroinvertbrate communities from year to year. Data show that macroinvertbrate community characteristics show considerable variability between years and that natural forces exert a great deal of influence on those measures of variability. This report describes sampling methods in some detail and some observations are made from the data collected over the past six years.

INTRODUCTION:

The Vermont Department of Environmental Conservation (DEC) maintains a Statewide biological monitoring program which samples aquatic biological communities in rivers and streams at 50-70 sites annually. There is a core if sites that are sampled every year during the late summer/fall period for the purpose of evaluating temporal variability and tracking long-term trends in biological integrity at those sites. Other sites are sampled for the purpose of making site-specific water quality evaluations related to the effects of watershed disturbance. In 1991, DEC initiated sampling at two sites at the Vermont Forest Ecosystem Monitoring (VForEM) research area in Underhill, on the western slope of Mt. Mansfield. These two sites, located on the Browns River and Stevensville Brook, have been sampled every fall since 1991. This report will discuss some observations related to temporal variability in aquatic macroinvertebrate communities at these two sites.

BACKGROUND

The two sites are located in the upper reaches of the Brown's River watershed - one on Stevensville Brook and one on the Brown's River upstream of its confluence with Stevensville Brook. Both sampling sites are located at an elevation of 1400 feet. The Stevensville Brook site is located about 50 m above the bridge at the parking lot for the Nebraska Notch trail and drains approximately 5.2 km^2 of forested watershed. The Brown's River site is located about 100 m above the last bridge before the State park gate and drains approximately 6.1 km^2 of forested watershed. Physical characteristics of the two sites are very similar: stream substrate composition is similar with 35% boulder, 30% cobble, 20% course gravel, 10% gravel, and 5% sand; canopy cover (shading) is approximately 80% at both sites; sampling depth averages 0.2 m at both sites.

METHODS

All field methods used to collect aquatic macroinvertebrates for this project are documented in the Vermont Department of Environmental Conservation Field Methods Manual (DEC, 1989). All macroinvertebrate samples are collected during the late-Summer, early-Fall index period, from September to mid-October. A two-person field crew selects a representative stream section in the area to be sampled. The preferred habitat if present is "riffle". Physical characteristics recorded at the selected site include: stream width, depth, water velocity, water temperature, specific conductance, weather conditions, substrate composition, substrate embeddedness (riffle sites only), canopy cover, stream bank condition and immediate upstream land use. All data are entered onto a field sheet with appropriate site and sampling event identifiers, along with additional comments that may be pertinent to the site evaluation. A water sample is collected for pH and alkalinity determination and placed on ice for return to the laboratory.

Samples are collected using an 18 inch wide x 12 inch high D-frame net with a 500 u mesh size. One person operates the net while the second operates a stop watch. The net is placed in the riffle at an appropriate location and an area immediately upstream of the net is thoroughly disturbed by hand, ensuring that all pieces of substrate are moved and rubbed clean of attached organisms. Moving up-stream, this is repeated at 4-5 different locations within the riffle, representing a range of velocity and substrate type characteristic of that riffle. Actual sampling activity, ie substrate disturbance, is timed with the stop watch. Each specific location is actively sampled for about 30 seconds, and active sampling is terminated at the end of two minutes. Time spent relocating to a new location within the riffle is not counted as part of the two minutes. The contents of the net are washed into a quart mason jar and preserved with 75% ethanol. The process is repeated, being careful to avoid areas previously disturbed. This "composite" sampling methodology effectively collects samples representative of the macroinvertebrate community of that riffle [1]. This sampling protocol is most comparable to the riffle/run sampling portion of Rapid Bioassessment Protocol III (RBPIII) as described in Plafkin et al, 1989.

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[1] This sampling methodology is nominally identified as a kick net sample. This is technically a mis-nomer as no "kicking" is actually done. All substrate manipulation is done by hand. It is our opinion that this method of substrate manipulation, combined with the moving to different locations within the riffle, increases the representativeness of the sample and the precision of the sampling method. Sampling effort is extremely reproducible. It has been our experience that it is very unusual for the percent standard error of total organism abundance and taxa richness estimates using this methodology (combined with associated sample processing methods) to exceed 40% and 20% respectively. Data precision will be discussed separately.

All methods used to process aquatic macroinvertebrate samples for this project are documented in the Vermont Department of Environmental Conservation Field Methods Manual (DEC, 1989). All sample processing is done in a laboratory setting. Processing includes picking organisms from the sample, sorting organisms into taxonomic groups, identifying organisms to lowest possible taxonomic level, and entering data into the data management system.

An entire sample is thoroughly washed through a 30-mesh (560 micron) brass sieve. The sample is then backwashed into a 12 x 18 inch white enamel tray that has been marked so as to delineate 24 numbered equal squares. The sample is spread evenly over the tray surface. A random number between 1 and 24 is selected and picking is started on that tray square. All organisms are removed from that square. Picking continues into subsequently numbered squares until a minimum of six squares (25 percent of the sample) have been picked. If less than 300 organisms have been picked at this point, picking continues until a total of 300 organisms have been removed or the entire sample has been picked, whichever comes first. Sub-sampling details are recorded on bench sheets. Removed organisms are sorted to order and placed in appropriately labeled vials in alcohol for further identification. If the sample has not been totally picked, the remaining sample is qualitatively examined for Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa not found in the sub-sample. Organisms are removed, labeled, and stored separately from the sub-sampled organisms.[2]

All organisms are subsequently identified to the lowest practicable taxonomic level by staff specializing in specific order taxonomy. Identifications are recorded on laboratory bench sheets. Raw counts and sub-sampling details are entered into the PARADOX data management system. The data management system normalizes all abundance data to a standard sampling effort to account for variations in sub-sampling procedures. The data management system uses scripts to calculate and report out the mean percent composition and density of all taxa, the standard error (based on the minimum of two replicates) of all taxon abundance estimates, the functional group percent composition, and a wide range of community biometrics for each sampling event in a sample summary report. Taxa richness is manually adjusted for each sample to account for differing levels of taxonomic identification within a sample[3]. The biometrics are electronically transferred to a macroinvertebrate metrics data table and the adjusted taxa richness values are inserted. From this table a site summary report is generated, which includes all sampling events from a site over time.

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[2] Organisms removed from the sample as part of the EPT scan are not used in subsequent calculations of organism abundance or associated metrics calculated from abundance estimates. They are used in calculations of taxonomic richness and the family of metrics derived from measures of taxonomic rishness.

[3] For example, the taxonomic bench sheet may list *Baetis tricaudata* and *Baetis* immature. The management system script will count two taxa when calculating taxa richness, whereas it is more likely that the immature organisms are of the same taxon as the identified species; counting two species would overestimate the real taxonomic richness. We haven't figured out how to make this correction electronically yet as some judgement is required.

The following practices provide a means of evaluating the precision, accuracy, comparability, and representativeness of the macroinvertebrate data used in this project. These activities are documented in"Vermont DEC Ambient Biomonitoring Activities - Work/QA Project Plan" (DEC, 1994).

- Precision is determined by field replication. All samples are collected, at a minimum, in duplicate. The mean of replicate samples is the value used for incorporation into the working data base. Samples with a relative standard error (RSE) of greater than 40% for abundance estimates and 20% for taxa richness are eliminated from the data base.

- Accuracy in the field is assured through standardized sampling effort conducted by experienced aquatic biologists. All field methods used to collect aquatic macroinvertebrates for this project are documented in the Vermont Department of Environmental Conservation Field Methods Manual (DEC, 1989). In the lab, all samples picked are checked for completeness by a second biologist. Standard taxonomic keys are used for all identifications and each ID is assigned a confidence level. A reference collection of all species identified is maintained and all samples are archived in their entirety forever. ID's are corroborated in-house as well as through external experts when appropriate. A random sub-sample of completed samples are re-identified to check consistency.

- Comparability and representativeness are assured by maintaining consistent standardized sampling and processing methods, and always sampling only during the fall index period.

RESULTS AND DISCUSSION

The watersheds of these two sites are essentially undisturbed by significant human activity. The six years of data collected from these two sites present an opportunity to examine the variability in biological communities and in the various measures of community structure and function as influenced by the forces of nature. Information regarding natural variability is critical when using biological data to evaluate water quality impacts related to watershed activities. Without natural variability information, it can be difficult to determine if observed biological conditions at a particular site are a result of watershed perturbation or are within the bounds of natural variability. This report will discuss observations in temporal variability of the following measures of macroinvertebrate community structure and function, which DEC uses on a regular basis to evaluate water quality condition:

- *Relative density*: a measure of the number of organisms collected during a standardized sampling effort; density can be affected by a number of chemical, physical, and biological conditions and can be a good indicator of general trophic status.

- *Mean Taxa Richness*: a measure of the number of "species" per sample; a simple diversity indicator that is a good indicator of general biological health.

- *Percent Mayflies and Stoneflies*: these are the dominant organisms in these streams and are generally very intolerant of environmental disturbance; good indicators of general biological health.

- *Percent Shredder Functional Group*: a measure of the percent of organisms in a sample that process detrital material originating outside the stream banks (eg heterotrophic materials such as leaf litter) as their primary source of energy; a good indicator of the primary source of energy in the stream system.

Relative density at the two sites over the six years of sampling is shown in Figure 1. As can be seen, there was a considerable degree of variability from year to year in the estimate of relative density. The relative density of aquatic organisms is particularly sensitive to annual or seasonal variations in hydrological and meteorological events. Heavy precipitation and high flows can scour streams and dislodge many of the organisms less adapted to finding refuge during stressful hydrological periods. Other factors, such as temperature, level of predation, food availability, and recruitment success can strongly affect faunal density on a year to year basis. Outstanding recruitment in any given year by a particular species can influence annual estimates of faunal density. As can be seen in **Figure 1**, density ranges are within the ranges of similar sites located in different areas of the state. With the exception of 1994, macroinvertebrates have been more abundant and show greater abundance variability in the Brown's River than in Stevensville Brook. In 1992, a year of relatively high abundance for both streams, the mayfly *Baetis sp.* and the dipteran *Micropsectra sp.* were quite abundant. *Micropsectra sp.* Made up 38% of the community in Brown's River and nearly 10% in Stevensville Brook; since that time, this organism has not exceeded 1% of the community composition in either stream.

Figure 1: Macroinvertebrate Density

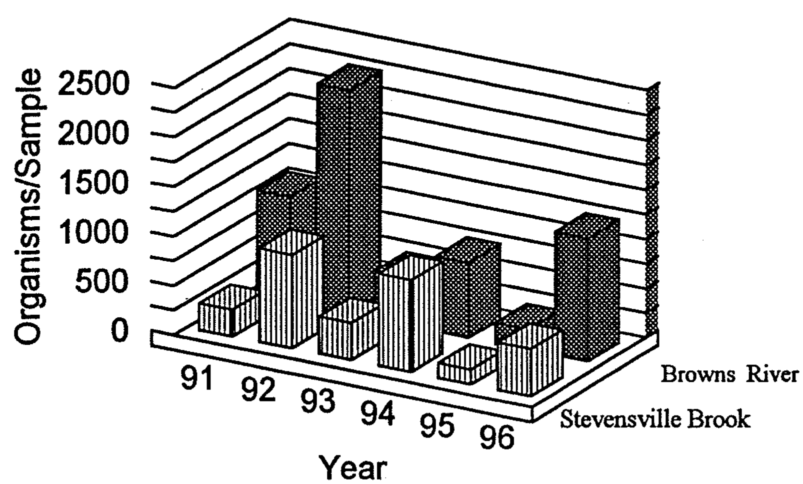


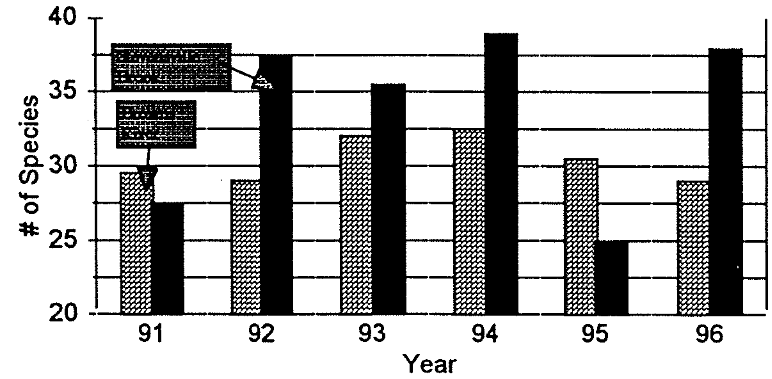
Table 1: Range of macroinvertebrate measurements at the two study sites and at a number of similar undisturbed sites statewide.

Attribute	Statewide Range	Stevensville 1991-1996	Relative Standard Deviation	Brown's 1991-1996	Relative Standard Deviation
Relative Density	100-2400	151-945	65%	208-2262	72%
Mean Taxa Richness	21-48	25-39	18%	29-32.5	6%
% Stoneflies	13-79	38-76	36%	13-55	36%
% Mayflies	0-45	1-40	123%	11-29	41%
% Shredders	3-55	20-70	45%	7-40	46%

This is a clear example of a highly successful recruitment year for a couple of species. Because these organisms feed primarily on algae, it is reasonable to conclude that at the time of sampling in 1992, there was more algal growth present than in other years. Algal populations in turbulent streams are likely to be quite ephemeral and subject to hydraulic scouring, exhibiting extreme short term variations. Fauna associated with those algal populations will be subject to the same short term variability factors, although macroinvertebrate recolonization occurs more slowly than algal recolonization.

Mean taxa richness at the two sites over the last six years is shown in **Figure 2.** Taxa richness appears to be more variable in Stevensville Brook than in the Brown's River, but is much less variable than abundance **(Table 2)**. Over the six years of sampling, nineteen taxa in Brown's River have at one time or another occurred at densities making up more than three percent of the community composition. Seven of those taxa have appeared at that level in only one year. Two taxa have appeared at the greater than three percent level in all six years.

Figure 2: Mean Taxa Richness
of "species" in sample



Similarly in Stevensville Brook, eighteen taxa have appeared at the three percent level, with five appearing only once at that level and three taxa at the greater than three percent level in all six years.

These two streams are dominated by mayflies and stoneflies. Recent evaluations conducted by DEC of similar streams throughout Vermont show this to be a very typical scenario for small, high elevation cold turbulent streams **(Table 1)**. **Figures 3 and 4** show the percent composition of mayflies and stoneflies at the two streams.

Figure 3: % Mayflies and Stoneflies
Stevensville Brook

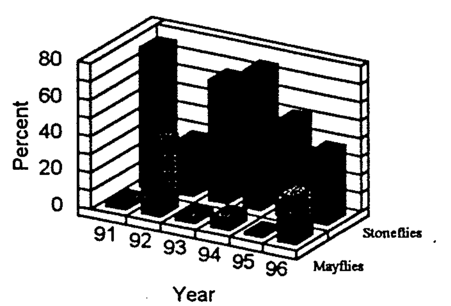
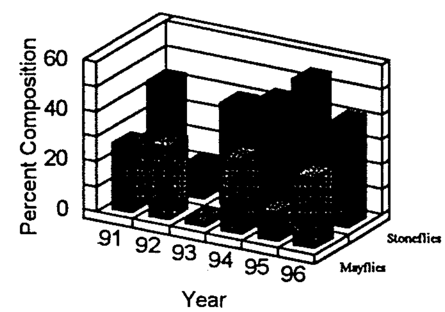


Figure 4: % Mayflies and Stoneflies
Browns River



1993 was a tough year for mayflies as % composition dropped sharply in both streams that year. Populations remained depressed in Stevensville Brook in subsequent years, but rebounded to previous levels in Brown's River the following year. Mayflies are a much more significant and consistent component of the Brown's River fauna than the fauna of Stevensville Brook, which is definitely a "stonefly" stream. The two orders regularly make up more than 60% of the fauna at both sites, ranging up to 80% at Stevensville Brook and 73% at Brown's River. The mayflies show somewhat greater variability between years than the stoneflies, particularly in

Stevensville Brook (see **Table 1**) where relative standard deviation exceeds 100%. **Figures 5 and 6** compare stonefly and mayfly percent composition across streams.

Figure 5: Percent Stoneflies

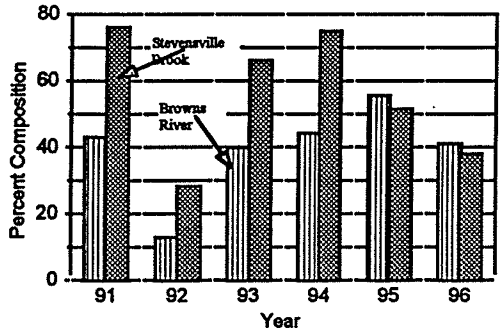
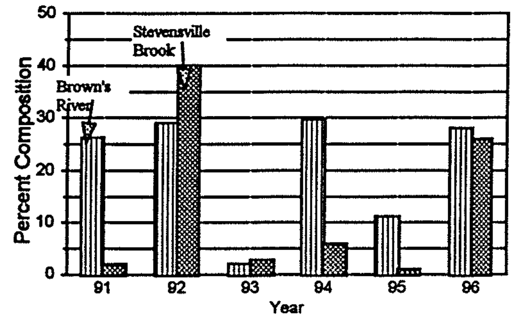


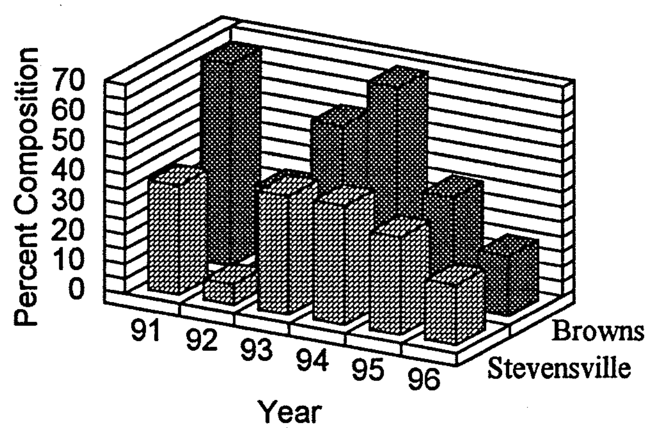
Figure 6: Percent Mayflies



The **detrital shredder functional group** makes up a significant portion of both stream macroinvertebrate communities, although some variability between years is indicated. **Figure 7** shows the percent composition of detrital shredders in the two streams from 1991 to 1996. A dominance by

Figure 7: % Detrital Shredders

Brown's River/Stevensville Brook



detrital shredders is a general indication of the extent to which heterotrophic, rather than autotrophic energy sources dominate the aquatic food chain. Heterotrophic means that the energy source originates outside the aquatic system. An example of a heterotrophic energy source is leaf litter that falls into the stream and is consumed by detrital shredders. Autotrophic means that the primary energy for the system is derived from instream processes, an example being periphyton growth in the stream that is consumed by algal grazers. It is typical for small mountain streams to be dominated by heterotrophic processes as primary production in the stream is often limited by various chemical and physical constraints and there is usually a good supply of organic material from the watershed falling into the streams. In comparing these two streams, Stevensville Brook appears to have a more significant detrital shredder component than the Brown's River. Stevensville is consistently dominated by the shredding *Leuctridae* and *Peltoperlidae* stoneflies and less by the algal-grazing mayflies (*Baetis spp* and *Epeorus sp*) and caddisflies (*Lepidostoma spp*) of the Brown's River. As with other measurements evaluated at these sites, the percent shredders indicate that 1992 was an unusual year, with a low percentage of shredders in both streams.

Observations of six years of macroinvertebrate monitoring data from these two streams can lead to a number of inferential conclusions regarding the character of these two streams:

- The macroinvertebrate communities of these two streams appear to be typical of similar streams throughout the state, although some of the community characteristics border on the extreme range for their stream type.

- The measured characteristics of the macroinvertebrate communities show considerable variability from year to year. Individual species show high variability in relative abundance from year to year. Because these streams are relatively unimpacted by human activity, this variability can be assumed to be due to natural causes.

- The data indicate some differences between the two streams. Stevensville appears to have a more hydraulically rigorous environment than the Brown's River. This is indicated by wider ranges in most measurements and an apparent lower level of primary production as indicated by relatively greater dominance by detrital shredders. In addition, the dominant species are those able to resist hydraulic scouring to a greater extent some of those common to the Brown's River.

The Vermont Forest Ecosystem Monitoring Research Area offers a unique opportunity to investigate the factors that influence variability in these streams and to validate the inferences that can be made from the biological data. Additional data being gathered by cooperating researchers on the site, including streamflow, stream chemistry, precipitation quantity and chemistry, the timing of leaf litter inputs to the streams, and land typing and use mapping will be integrated into further investigations regarding the forces which shape natural variability in the biological components of aquatic systems.

Acknowledgments: The staff of the Biological Monitoring and Aquatic Studies Section of the Vermont DEC - Steve Fiske, Rick Levey, Jim Kellogg, Rich Langdon, Heather Pembrook, Jessica Rykken - are responsible for the gathering and analysis of the stream monitoring data presented in this report. Much appreciated encouragement and assistance from Tim Sherbatskoy, Sandy Wilmot, and Phil Girton of VForEM.

METHODS DEVELOPMENT FOR SAMPLING MERCURY IN SOIL WATER IN FORESTED WATERSHEDS

1996

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Health warnings about mercury (Hg) concentrations in Lake Champlain fish have prompted public concern and created an interest in studying the mechanisms of Hg transport in the environment. Results of previous studies have suggested that forest soils may play an important role in the loading of Hg into surface waters, but little is known about the rivers draining into Lake Champlain. A study comparing the chemistry of soil water with that of stream water on the western side of Mt. Mansfield is under way to test several hypotheses.

Work in 1996 was completed to identify a suitable device with which to collect soil water for the 1997 field season. For this study, two different soil water sampling devices were tested. Laboratory tests compared the amount of Hg in water poured through the devices with the amount of Hg in control samples. Soil water collectors of each kind were installed in the field, and the volumes of water collected during several rain storms were compared. Ultimately, the fiberglass wick device was chosen for our study over the zero-tension lysimeter.

INTRODUCTION

Currently there is concern about the level of mercury (Hg) in fish in Lake Champlain and in other, more remote lakes in the northeastern U.S. It is generally thought that most environmental Hg originates from industrial emission sources and is transported in the atmosphere. Studies in the U.S. and Sweden indicate that some of the Hg in lakes most likely comes from the watershed. The movement of Hg in forest soils may therefore play an important role in the loading of Hg into surface waters draining into Lake Champlain. We are conducting a study comparing the chemistry of soil water and stream water to test several hypotheses about Hg transport in an upland watershed.

Research activity is taking place in three areas along two streams on the western side of Mount Mansfield: one area (at approximately 850 m in elevation) along "Stream 10" near the intersection with the CCC Road, and two areas (at elevations of 520 and 550 m) along "Nettle Brook" near the Butler Lodge Trail. Both streams are currently being monitored as part of other VForEM work. Soil water and stream water samples will be collected during storm events in the spring and summer of 1997. Samples will be analyzed for total Hg, DOC, color, major ions, and pH.

Work in 1996 was completed to identify a suitable device with which to collect soil water for the 1997 field season. Although there are numerous methods for sampling soil water, only the methods that are believed to sample water moving through the soil horizons were considered. For example, the technique of extracting water from bulk soil samples or soil cores was not used because these methods yield water samples that represent the solute concentration in micropores and macropores (Boll et al., 1992) but not necessarily the concentrations in bulk flow. Many methods that use bulk soil samples require air-drying and re-wetting soil, and this method alters the chemistry of the collected solution sample (Lawrence and David, 1996). Tension lysimeters also extract tightly-bound water contained in small soil pores (Swistock et al., 1990), and so tend to collect higher concentrations of soil constituents. In addition, strict requirements of ultra-clean laboratory methods for analyzing trace levels of Hg limited the possible materials usable for sampling to those known to be non-contaminating. For this study, two different soil water sampling devices were tested for use, and these devices are described in the following paragraphs.

Zero-tension Lysimeter (ZTL). ZTLs collect solution that moves downward through the soil by force of gravity, often through macropores. This method is therefore believed to be representative of soil water that is actually moving through the soil. ZTLs require that the soil above the samplers be saturated during collection (Boll et al., 1992). One drawback of lysimeters is that their installation can disturb the overlying soil and root structures, but the soil eventually (within several months) recovers to pre-installation conditions.

Fiberglass Wick Sampler. A new technique to sample water and solutes moving through the unsaturated layers in soil uses fiberglass wicks to collect water by capillary action (Holder et al., 1991; Poletika et al., 1992; Boll et al., 1992; Knutson and Selker, 1996; Brandi-Dohrn et al., 1996). The wick is self-priming and acts as a hanging water column, making it possible to draw samples from unsaturated soil without external application of suction (Boll et al., 1992). Based on a study by Brandi-Dohrn et al. (1996), there is evidence that the wick method collects solute concentrations representative of water in motion through the soil profile, whereas suction cup samplers collect concentrations of water adhering to soil particles.

METHODS

Two different tests were completed to identify which soil water collector would be more suitable for use in the field study. The tests were designed to answer the following two questions:

1. Does either device release or adsorb Hg or other heavy metals?
2. Which soil water collector collects more water?

Zero-tension lysimeters were constructed of 14.7 cm-diameter Pyrex funnels containing silica sand (170 cm^2 sampling area). Silica sand is assumed to be the least reactive media to use in the funnel but it has been demonstrated to adsorb metals. McGuire et al. (1992) tested the adsorption of cadmium, cobalt, chromium, and zinc at three different pH levels (4, 6, and 8) on silica sand that is typically packed around tension lysimeters to achieve good contact with the soil. At a pH of 4, up to 6% of these metals were lost from solution via adsorption, and adsorption increased at higher pH levels.

Fiberglass wick samplers consist of a length of 1.5-inch diameter wick encased in Pyrex glass tubing (30 cm x 4 cm) placed vertically within the soil. At the top end, the glass tubing is flared out to form a flat plate where the top portion of the wick is unraveled and pressed flat on the plate. This part of the wick is in contact with the soil, and the area of the plate is the sampling area. Our wick samplers were constructed with a plate diameter of 14.7 cm (170 cm^2 sampling area). Water flowing through the soil is intercepted by the sampler plate, drawn into the wick, and conducted down the glass column. The water ultimately drains into a sample bottle via Teflon tubing (based on Holder et al., 1991). Adsorbance of Hg by the wick fibers had not yet been reported in the literature, but was cause for concern because of the large number of possible exchange sites created by the fibers.

Laboratory Tests

In the laboratory, initial performance of the collectors was quantified using rain water to simulate field conditions. Rain water (250 ml) was slowly poured through three ZTLs and two fiberglass wick samplers. These samples were analyzed for Hg and compared against control samples of rain water.

It was hypothesized that ion exchange sites in the collectors (which might adsorb or desorb Hg) would become saturated with time in the field. A ZTL and fiberglass wick sampler were placed in the field for a period of one month (27 September 1996 to 27 October 1996). The sampling devices were removed from the field and tested again as above using rain water. These samples were analyzed for Hg and other trace metals.

Water Volume Tests

Soil water collectors were installed in the field by digging soil pits (approximately 3'x2' and 2½' deep) and tunneling laterally so that the soil water collectors could be placed under a given depth of undisturbed soil. After installation of the samplers, access holes were back-filled with moistened soil. Solutions drain from a Teflon tube into a large container where sample bottles are placed.

Two shallow (4-7 cm below ground surface) and two deep (22-28 cm below ground surface) collectors were installed of both the ZTL and fiberglass wick collectors (a total of 8 collectors) at the lower elevation site along Nettle Brook.

Soil water was collected after three substantial rain events in September and October, 1996 to determine the volume collection efficiency. Rainfall amount was crudely estimated using a single rain gauge placed under the tree canopy. Rainfall amounts were 2.7, 7.4, and 7.2 cm for storms before the dates of October 12, October 23, and November 10, 1996.

RESULTS

In the first laboratory experiment, both the ZTL and wick collector adsorbed approximately 20% of Hg compared to control samples (Figure 1). Although this adsorbance rate seems high, it was better than expected and was considered acceptable for use with trace mercury analysis.

After one month in the field, laboratory rinses (using rainwater, as above) from both the ZTL and wick collectors initially contained more Hg than control samples (Figure 2). Out of three rinses, only the third rinse showed a slight adsorption of Hg. Because there were some unremovable soil particles on both collectors following extraction from the field, some of the Hg in the first two rinses may be attributable to Hg that was flushed through the wick or sand. Therefore, this experiment was not conclusive regarding saturation of ion adsorption sites.

Trace metal concentrations were also analyzed in these samples (Figure 3). Because of small sample sizes, only qualitative comparisons can be made. Similar to the Hg results, concentrations were highest in rinse 1 and declined during rinses 2 and 3. Mg was leached by the ZTL, and Pb was adsorbed by both devices. These data also suggest that Cr, Mn, and Ni may be leached by the ZTL, and Cu, Cd, and Zn may be adsorbed by both the ZTL and the wick. Samples were also analyzed for Ce, La, Nd, Rb, Sr, and Ti, however the results are not summarized here.

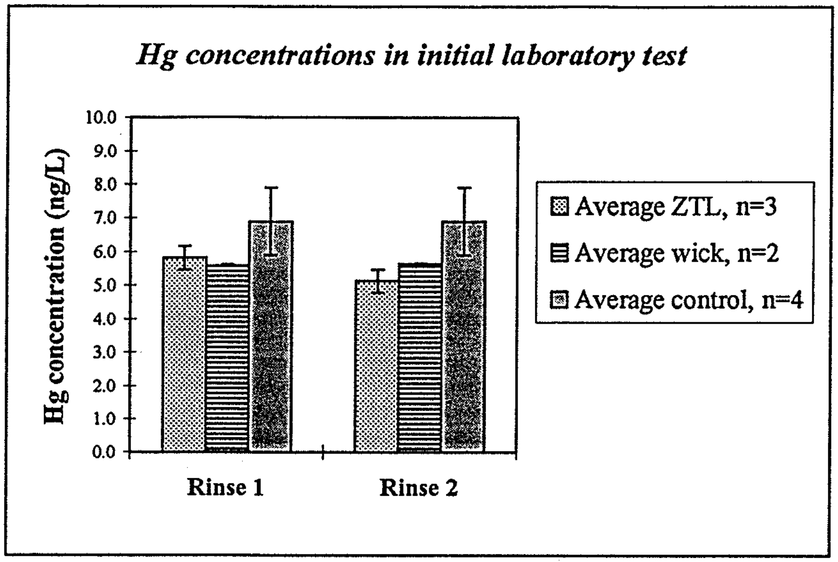


Figure 1. Results from the first laboratory test comparing Hg concentrations in rain water (control) vs. water poured through ZTL and wick devices. Error bars represent one standard error of the mean (not visible for wick because of small sample size and consistent results).

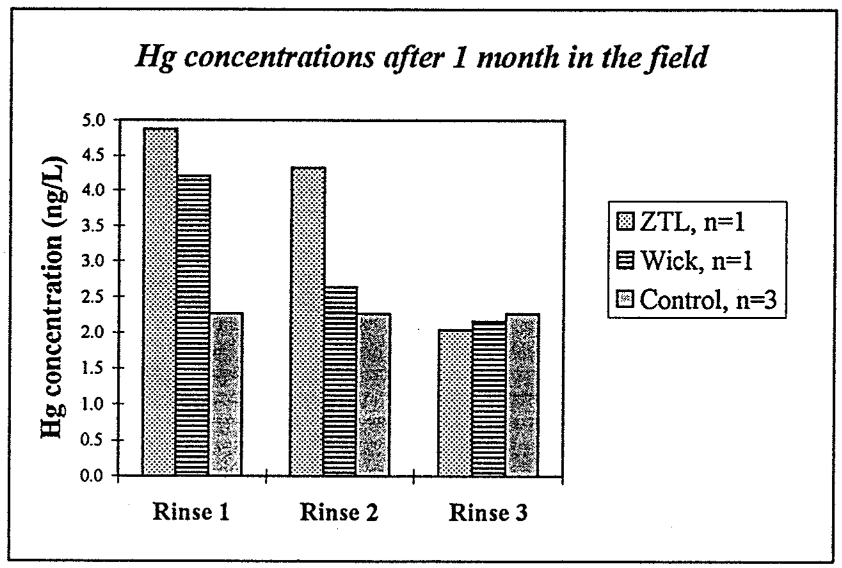
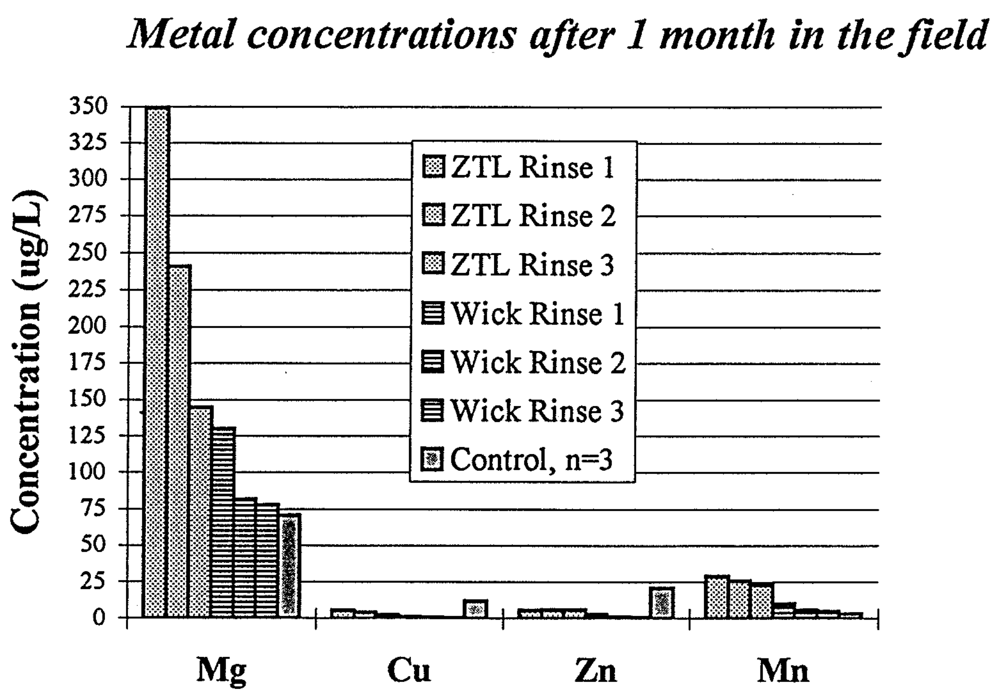


Figure 2: Results from the second laboratory test (after field installation) comparing Hg concentrations in rain water (control) vs. water poured through ZTL and wick devices.

Volumes of water collected by both devices in the field varied by amount of antecedent rainfall and by depth. The rain gauge measured 2.7 cm, 7.4 cm, and 7.2 cm for the three storms after which collection occurred. Generally, the shallow devices collected more water than deep ones, and the wick collected greater volumes than the ZTL. Our hope was to collect at least 50 ml in a sample to be able to analyze for Hg. After the first storm, no collectors in one of the pits collected enough water, but otherwise sample volumes exceeded 50 ml and commonly reached the bottle capacity of 500 ml.



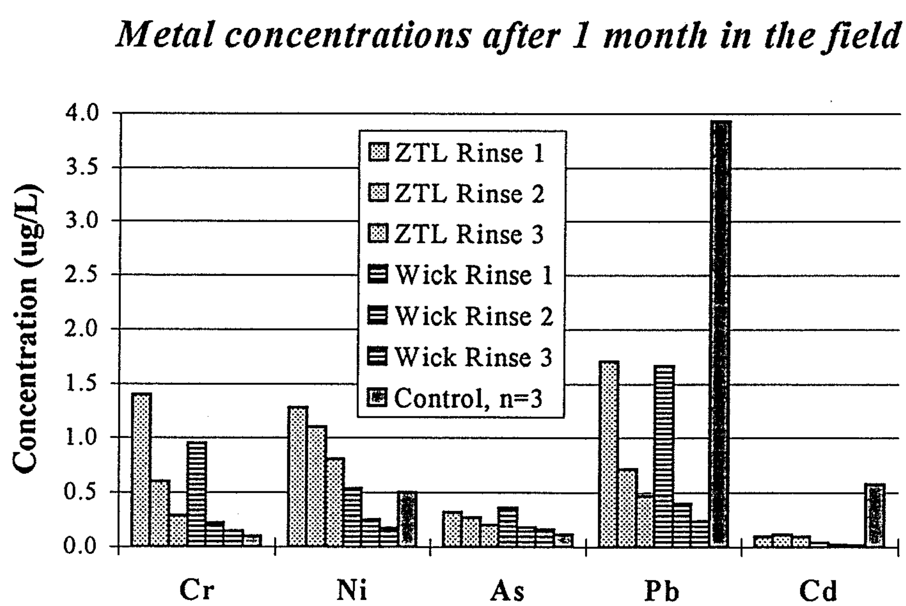


Figure 3. Results from the second laboratory test comparing trace metal concentrations. Rinses 1, 2, and 3 are shown left to right on graph (n=1 for each rinse).

Because the fiberglass wick sampler tended to collect more water and also had less effect on metal concentrations, the wick was chosen for use in the field study. At each of the three sampling sites, two sets of paired wick soil water collectors have been installed (four collectors at each site, two shallow and two deep). Soil water will be collected from these sites during snowmelt and precipitation events beginning in 1997. These samples and streamwater samples collected during events will be analyzed for Hg, dissolved organic carbon (DOC), major ions, and other characteristics. The good of this research will be to clarify relationships between soil water and stream water, and to understand mechanisms involved in Hg transport from forested watersheds to streams.

ACKNOWLEDGEMENTS

Financial support for this work is from a cooperative grant from U.S. EPA OAQPS Great Waters Program and NOAA via the Cooperative Institute for Limnology and Ecosystems Research (CILER). We also wish to acknowledge the assistance and support of James Shanley of U.S.G.S., and Joanne Cummings and Carl Waite of UVM. This study was undertaken in cooperation with VForEM.

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Nettle Brook Streamflow in 1996

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U.S. Geological Survey

Year 3. Nettle Brook is a small mountain stream draining a steep 11-hectare catchment. It lies between the two main branches of Stevensville Brook on the west slope of Mt. Mansfield. In 1996 we completed the third full water year of streamflow monitoring at Nettle Brook. The hydrologic water year runs from October through the following September; here we report on Water Year 1996 which ended on September 30, 1996.

Water Year 1995 was a tough act to follow, an unusual year with the big January thaw, minimal spring runoff, summer drought, and August flood. But 1996 had its share of extreme and unusual conditions. Just like the weather, to which hydrology is so intimately tied, it is preferable to compare conditions to "average" rather than "normal;" variability *is* the norm.

The water year in review. Streamflow for the Water Year is plotted in Fig. 1. Note the logarithmic scale; flow rates range over 4 orders of magnitude. (It can be misleading to speak of orders of magnitude of flow on very small streams. If the stream were to dry up - and it has come close - it would pass through an infinite number of them!) Despite its small size and steep slopes, Nettle Brook appears to have sufficient groundwater storage capacity to sustain permanent flow. By comparison, streams draining catchments 2 and 3 times larger at the Hubbard Brook watershed in New Hampshire frequently go dry in the summer months.

Special features of the water year are depicted with numbers in Fig. 1: (1) Heavy fall rains follow on the August 1995 flood, causing some high peak flows and thorough recharge to the groundwater aquifer. (2) An early snowpack and consistent cold temperatures in late fall and early winter cause a steady depletion of groundwater storage and low base flow levels. (3) An unusually strong January thaw - temperatures in the 60's and heavy rain. This is the same event that caused devastating flooding in the mid-Atlantic states, where record snowpacks melted very quickly. Note that the main thaw was followed by 2 smaller thaws. (4) A significant February thaw. (5) Heavy snows in March and April replenished the snowpack, leading to a snowmelt that was heavier and later than average. Peak flow did not occur until April 21. (6) A very rainy June and July kept streamflow higher than average; a drier August finally led to the typical low summer base flow.

Snowmelt. The 1996 snowmelt was somewhat less than 1994 snowmelt in terms of total volume of runoff, but its peak flow was about the same (Fig. 2). Regionwide, the 1994 and 1996 spring melts were well above average, while the 1995 melt was well below average. The 1996 snowmelt was notable for its late peak (April 21); a series of late-season storms kept augmenting the snowpack.

Flow duration. One way to compare water years is flow duration curves (Fig. 3). Flow duration curves indicate the percentage of time flow exceeds a given amount. The size, physical characteristics, and climatic conditions in a catchment determine the shape of the flow duration curve. For example, the curve for a flashy watershed (thin soils, steep topography) would have a steep exponential decline in the low percentiles, indicating that high flows rapidly dissipate. The curve for a less flashy system, such as a large river basin or the Lake Champlain outlet, would be more horizontal (high flows - e.g., flooding on Lake Champlain - last for days and dissipate gradually).

Because of the strong control that basin size and physical characteristics have on the shape of the flow duration curves, the 3 annual curves in fig. 3 are close together. However, it is clear from the figure that 1996 is the wettest year; its curve plots higher than the other 2 years for much of the range. For example, at the 20^{th} percentile, the 1996 flow is approximately double that of 1994.

All in all, it was another normal year - lots of departures from average!

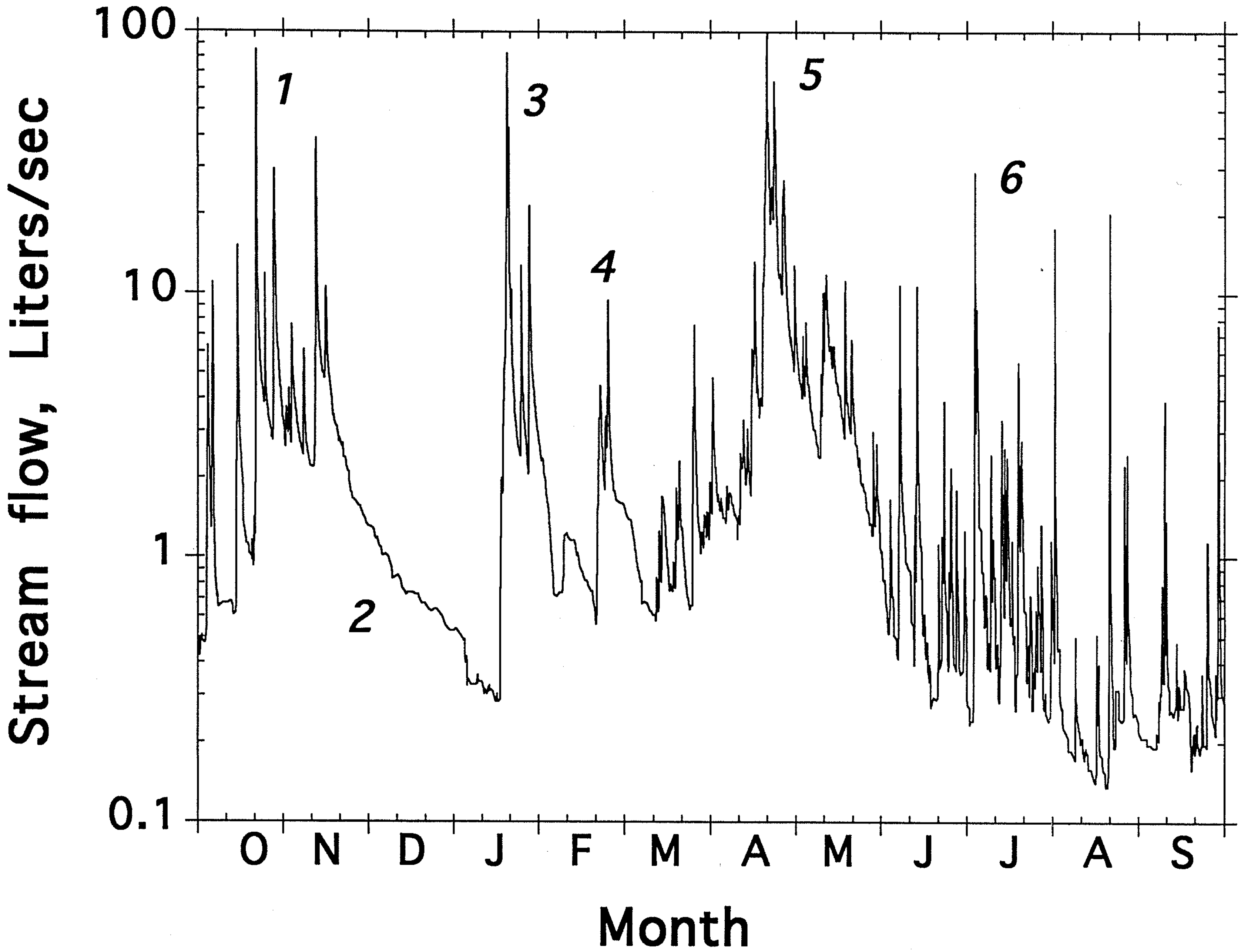

Fig. 1. Nettle Brook hydrograph, Water Year 1996 (October 1, 1995 through September 30, 1996). See text for explanation of numbers.

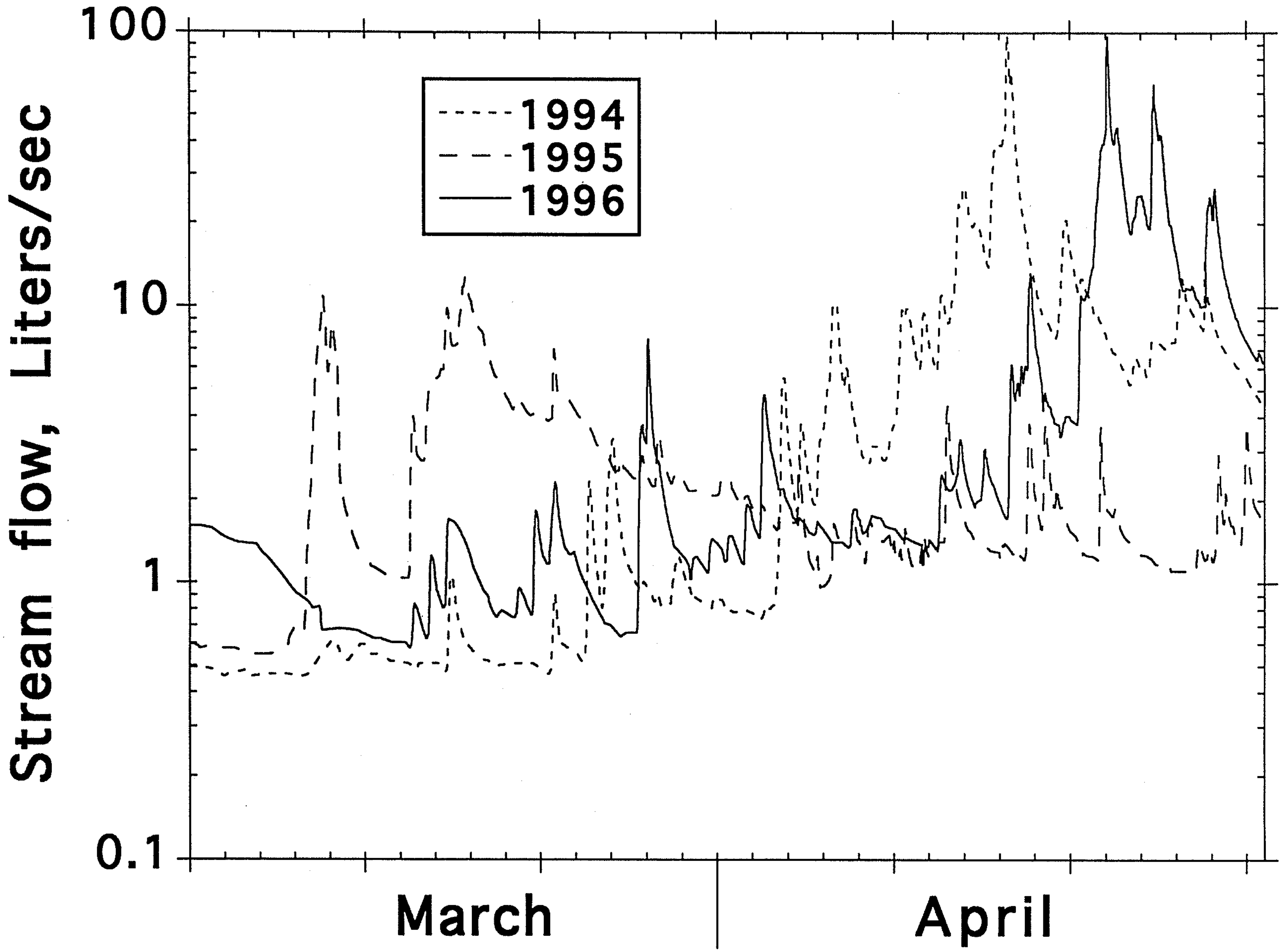

Fig. 2. Comparison of snowmelt hydrographs for water years 1994, 1995, and 1996 at Nettle Brook.

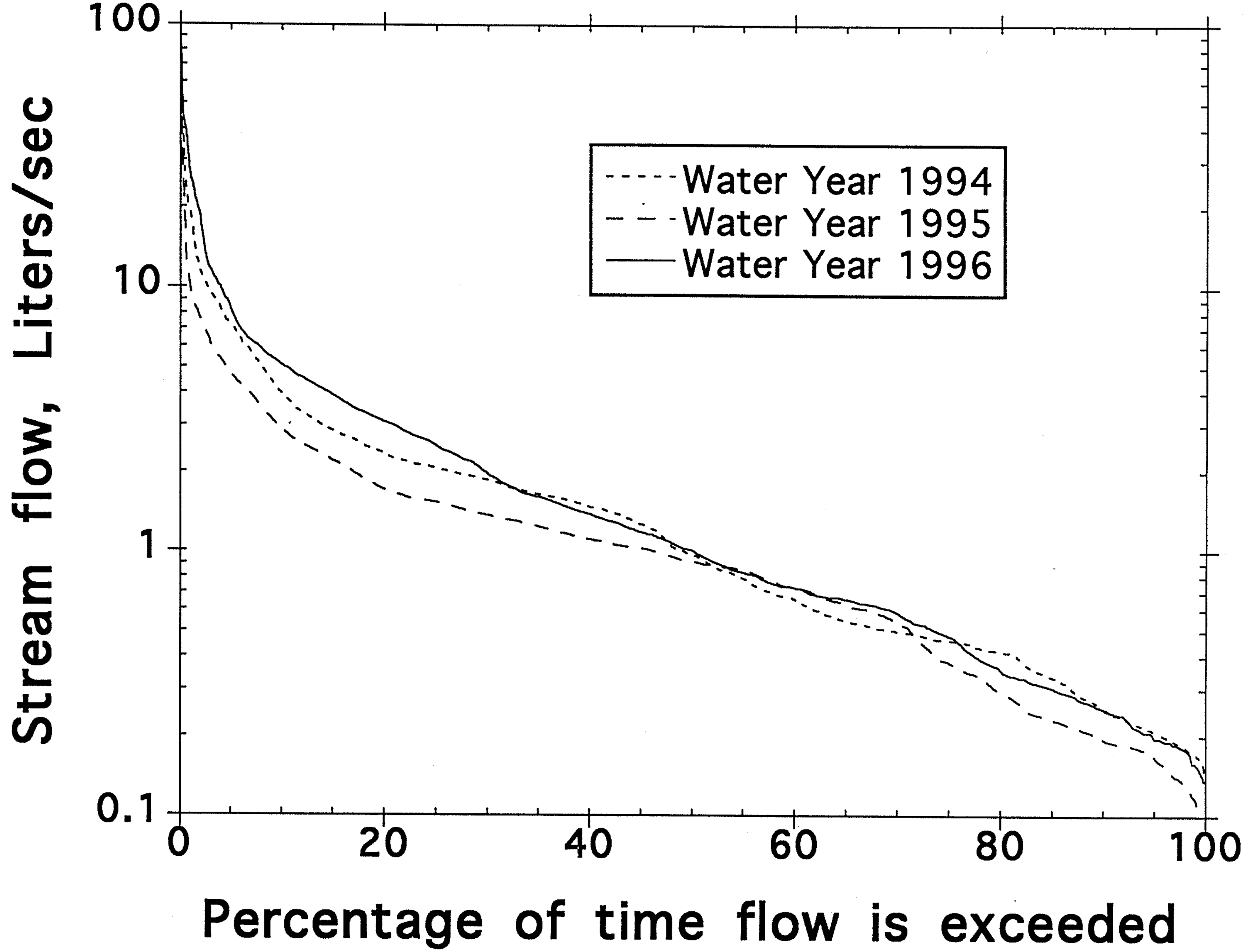

Fig. 3. Flow duration curves for water years 1994, 1995, and 1996 at Nettle Brook.

Using Streamwater Chemistry to Assess the Impacts of Acid Deposition at the Lye Brook Wilderness, Vermont

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Abstract

Streamwater chemistry was monitored in the Lye Brook Wilderness from May through October of 1996 as part of a surface water chemistry study that was initiated in 1994. Stream samples were collected once every three weeks at four sampling locations within the wilderness boundary. Samples were analyzed for pH, major cations and anions and total organic carbon (TOC). The low pH values of streams sampled indicates that many of the streams in this region are acidic. Sulfate appeared to be the dominant acid in stream water. However NO_3^- also contributed to the acidity of streams, particularly during the spring before vegetative uptake began. Wetland areas in the headwaters of some sampled streams were a source of TOC and associated organic acids. The presence of these organic compounds decreased the concentration of inorganic aluminum through the process of chelation. Therefore, although the pH of these waters may be low enough to cause mortality of some biota, Al toxicity does not appear to be a major threat.

Introduction

Much of northeastern United States is vulnerable to acid inputs because the region receives relatively large amounts of acid deposition and the streams generally have a low acid neutralizing capacity (Adams et al. 1991). Therefore, acid deposition caused by atmospheric pollution is a major threat to aquatic systems in the Lye Brook Wilderness. This research focuses on streamwater chemistry because there is very little existing data for streams and the effects of air pollution on streamwater chemistry have not been thoroughly established for this region of New England. The objectives of this study were to: 1) Investigate spatial and seasonal variability in stream chemistry as a function of site characteristics; 2) Determine factors that contribute to the acidity of streams in this region.

Methods

In 1994, nine streamwater sampling sites were established throughout the wilderness area by determining the major site dynamics of interest, such as geology, wetlands and elevation (Figure 1). Samples were collected from these sites once every two weeks until 1996. In 1996, the number of sampling sites was reduced to four (sites 2, 3, 8 and 9) and the sampling interval was changed to three weeks. These four sites were chosen because they had the lowest pH and acid neutralizing capacity values of the nine sites. Streamwater grab samples were collected at these locations from May 1996 through October 1996.

Determination of pH was made using a portable pH meter on the day the samples were collected. Cation values were obtained using direct current plasma spectroscopy. Anions, NH_4^+ and SiO_2 were measured on a continuous flow system (Autoanalyzer II). Speciated Al was also determined with an Autoanalyzer using pyrochatechol violet colorimetry (McAvoy et al. 1992). Total Al concentrations were calculated in µeq/L using a charge of 3 if the pH $\leq$ 4.5, 2.5 if the pH was 4.6 to 5.5 and 2 if the pH $\geq$ 5.5. A Schimadzu 5000 organic carbon analyzer was used to measure TOC. The value of TOC in µeq/L was calculated using a constant charge density approach similar to the one developed by Oliver et al. (1983).

Results and Discussion

Measurements of pH were used to determine the acidity of streams and to assess whether the streams in this region are susceptible to the affects of acid deposition. Sites 2, 3, 8 and 9 were sampled in 1996 because these sites were the most acidic of the nine original sites. Table 1 lists the streamwater chemistry for these four sites in mg/L and table 2 lists the streamwater chemistry in µeq/L. Streamwater ion values were converted from mg/L to µeq/L for the purpose of making comparisons of ionic strength.

Based on the values in table 2, SO_4^{2-} was the dominant strong acid anion at all sites followed by Cl^- and NO_3^-. In addition, weak organic acids associated with TOC contributed substantially to the acidity of streamwater and was greater than Cl^- and NO_3^- acidity. The concentrations of base cations followed a general trend of $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ with the exception of site 2 which had slightly higher Mg^{2+} than Na^+.

There are several factors that may affect the concentration of cations and anions and which consequently affect the acid-base status of streams. In the Lye Brook Wilderness watershed geology may influence the concentration of some ions in streamwater.
The geologic substrates underlying the sampled streams consist of rock that is resistant to chemical weathering. Therefore weathering rates are generally not fast enough to completely buffer incoming acids. These rocks contain low concentrations of Ca^{2+}, Mg^{2+}

and K^+ and higher concentrations of Fe and Al resulting in leachates that are low in base cations and high in metals.

In addition, the soils in this area generally have a low cation exchange capacity. This causes a subsequent reduction of base cations in soil leachates and ultimately results in low concentrations of base cations in streamwater. Soils that are highly affected by acid deposition are characterized by the movement of NO_3^- and SO_4^{2-} in soil water. As these mobile anions are exported to streams they are balanced by mobile cations. Unless these cations are replaced by atmospheric deposition or weathering inputs, the base saturation of the soil will decrease and the soil will become acidified. In areas where base saturation is severely reduced, Al concentrations in soil water and streamwater increase.

In addition to factors associated with geology and soils, biological reactions can also increase or decrease acidity in surface waters. For example, factors such as uptake by vegetation and microbial decomposition can have a strong impact on inorganic elements, particularly NO_3^- which is biologically important. In Lye Brook streams NO_3^- concentrations were highest during May and early June. Concentrations of NO_3^- generally peak during spring because soil temperatures increase and mineralization and subsequent nitrification of N begins before vegetation initiates nutrient uptake (Likens et al. 1970; Galloway et al. 1987, Rascher et al. 1987). In the study streams, concentrations of NO_3^- were highest during spring which caused a subsequent reduction in pH. Despite this increase, SO_4^{2-} remained the dominant strong acid, unlike some other areas where NO_3^- acidity exceeds SO_4^{2-} (Stoddard and Murdoch 1991).

The presence of wetlands at the source of streams sampled resulted in high concentrations of TOC and organic acids. These naturally occurring, organic acids may partially explain the low pH of streamwater draining wetlands (McKnight et al. 1985). Site 8 is an exception because it does not have headwater wetlands and it had relatively high TOC concentrations compared to the nine original sample sites. The most likely reason for high TOC at this site is related to soil depth. Site 8 is located on an exposed ridge at a high elevation where soils are thin. Mineral soils absorb organic C; therefore streams draining thick soils generally have lower organic C concentrations (Lawrence et al. 1988; Cronan 1985). Factors regulating organic C concentrations are important because organic C may influence mineral weathering, cation leaching and trace metal speciation. Streams with high concentrations of TOC typically exhibit low pH values because of the contribution of organic acids associated with TOC.

In addition to contributing to stream acidity, organic acids can also increase weathering rates through chelation (Huang 1988). In this process, organic acids form complexes with Fe and Al, which subsequently affects the form and concentration of these elements in solution. When chelation occurs it causes a reduction in the concentration of inorganic Fe and Al because these metals are bound in non-labile, organic forms. In general, waters dominated by naturally occurring acids are less likely to cause damage to acid-sensitive biota because of the tendency of these waters to form Al complexes (Driscoll et al. 1980).

Therefore, the four sites that were sampled in 1996 had low inorganic Al concentrations despite low pH values.

Conclusion

This research indicates that the streams sampled in the Lye Brook Wilderness are acidic and have a low buffering capacity. Sulfate was the most abundant ion contributing to the acidity of streams, however NO_3^- was seasonally important, particularly during the spring. Increases in air pollution may increase streamwater concentrations of SO_4^{2-} and NO_3^- causing further reductions in pH. Although organic acidity contributed greatly to the low pH of sampled streams, it reduced concentrations of inorganic Al which is the form of Al that is most toxic to aquatic biota. Therefore although the pH of streams sampled was low enough to cause damage to acid-sensitive species, Al toxicity does not appear to be a major threat because of the complexation of inorganic Al with organic C compounds.

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Table 1. 1996 chemistry of 4 study streams in the Lye Brook Wilderness.

DATE (yymmdd)	Site	pH	Cond. µeq/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	T-Al mg/L	O-Al mg/L	I-Al mg/L	Fe mg/L	NH4 mg/L	SO4 mg/L	NO3 mg/L	Cl mg/L	SiO2 mg/L	TOC mg/L
960515	2	4.1	26.8	0.65	0.22	0.30	0.13	0.33	0.27	0.06	0.19	0.28	4.97	0.09	0.70	1.71	12.11
960606	2	4.2	27.9	0.72	0.27	0.62	0.27	0.30	0.26	0.04	0.30	0.52	5.08	0.09	0.98	3.10	15.83
960627	2	4.2	31.0	0.81	0.27	0.59	0.29	0.32	0.28	0.04	0.65	0.67	7.14	0.00	0.88	4.14	17.40
960717	2	4.1	34.9	1.09	0.35	0.57	0.52	0.52	0.48	0.04	1.05	0.91	7.74	0.00	1.22	3.42	27.28
960809	2	4.3	28.0	0.98	0.36	0.65	1.03	0.59	0.59	0.00	2.48	1.94	7.29	0.00	1.45	3.80	25.36
960925	2	4.4	36.0	1.07	0.47	0.95	1.18	0.39	0.36	0.03	0.95	1.08	6.09	0.00	2.23	5.24	22.13
961018	2	4.6	27.3	0.94	0.40	0.72	0.84	0.41	0.35	0.06	0.72	0.79	6.02	0.00	1.34	5.78	19.81
960515	3	4.3	30.8	0.49	0.14	0.25	0.13	0.28	0.25	0.03	0.19	0.31	5.17	0.13	0.81	2.64	13.49
960606	3	4.1	32.5	0.77	0.23	0.59	0.29	0.34	0.31	0.04	0.26	0.49	6.29	0.13	1.25	4.92	19.50
960627	3	4.2	35.8	0.92	0.25	0.62	0.21	0.39	0.35	0.04	0.54	0.58	9.62	0.00	1.10	4.93	24.03
960717	3	4.1	37.1	0.82	0.21	0.51	0.19	0.46	0.46	0.00	0.54	0.73	9.24	0.00	1.48	4.45	27.36
960809	3	4.3	33.8	0.87	0.27	0.77	0.45	0.44	0.43	0.01	0.62	0.84	7.40	0.00	1.34	7.08	22.67
960925	3	4.0	62.4	1.20	0.35	0.67	0.19	0.50	0.43	0.07	0.52	0.52	8.88	0.00	1.51	5.63	24.66
961018	3	4.2	44.7	0.88	0.27	0.63	0.43	0.47	0.37	0.10	0.37	0.45	7.68	0.00	1.25	6.73	19.79
960515	8	4.2	37.9	0.31	0.10	0.14	0.32	0.32	0.27	0.04	0.66	0.41	6.49	0.09	1.21	2.41	18.23
960605	8	4.0	40.9	0.47	0.16	0.42	0.50	0.32	0.27	0.06	0.94	0.37	7.71	0.09	1.24	5.54	18.20
960627	8	4.1	44.8	0.60	0.20	0.53	0.50	0.35	0.29	0.06	1.34	0.35	10.21	0.00	1.11	6.71	19.96
960717	8	3.9	50.8	0.54	0.15	0.47	0.35	0.56	0.54	0.02	1.66	0.61	5.37	0.00	1.14	4.88	32.16
960809	8	4.2	40.1	0.56	0.23	0.87	0.78	0.33	0.30	0.03	1.31	0.24	4.90	0.22	1.68	10.31	12.77
960925	8	4.1	65.8	0.65	0.23	0.60	0.49	0.41	0.32	0.09	1.22	0.28	8.51	0.00	0.99	8.86	16.70
961018	8	4.0	57.7	0.58	0.21	0.50	0.50	0.46	0.33	0.13	1.06	0.27	8.02	0.00	0.91	8.22	19.55
960515	9	5.4	26.4	0.56	0.19	0.27	0.18	0.25	0.21	0.03	0.17	0.30	4.33	0.09	0.63	1.61	10.89
960605	9	4.2	20.9	0.66	0.24	0.61	0.35	0.25	0.23	0.03	0.25	0.62	4.88	0.13	0.85	2.48	12.63
960627	9	4.5	21.1	0.82	0.28	0.70	0.34	0.29	0.25	0.03	0.45	0.62	7.68	0.04	0.74	3.77	13.70
960717	9	4.2	25.2	0.90	0.26	0.50	0.12	0.37	0.35	0.02	0.54	0.73	9.73	0.00	0.83	3.02	19.31
960809	9	4.6	20.6	0.85	0.27	0.78	0.36	0.32	0.31	0.01	0.68	1.03	5.94	0.40	0.93	4.39	13.49
960925	9	4.4	36.9	1.17	0.43	0.87	0.45	0.31	0.25	0.06	0.40	0.48	6.14	0.00	0.94	5.03	14.85
961018	9	4.4	29.8	0.97	0.35	0.76	0.46	0.32	0.23	0.09	0.27	0.28	5.90	0.00	0.87	5.29	13.51

Table 2. Concentrations of major anions and cations in μeq/L in 4 study streams in the Lye Brook Wilderness.

DATE (yymmdd)	Site	Ca μeq/L	Mg μeq/L	Na μeq/L	K μeq/L	T-Al μeq/L	NH4 μeq/L	SO4 μeq/L	NO3 μeq/L	Cl μeq/L	TOC μeq/L
960515	2	32.53	18.26	12.96	3.30	36.76	15.71	103.53	1.43	19.75	55.71
960606	2	35.78	22.54	26.84	6.88	33.47	28.56	105.82	1.43	27.65	72.82
960627	2	40.17	22.46	25.75	7.39	35.45	37.13	148.73	0.00	24.82	80.04
960717	2	54.39	28.54	24.75	13.22	57.82	50.69	161.22	0.00	34.42	125.49
960809	2	48.65	29.86	28.36	26.34	65.60	107.81	151.85	0.00	40.90	116.66
960925	2	53.39	38.66	41.37	30.17	43.36	59.97	126.85	0.00	62.91	101.80
961018	2	47.01	32.82	31.15	21.45	37.99	43.55	125.40	0.00	37.80	91.13
960515	3	24.40	11.76	10.79	3.27	31.41	17.14	107.69	2.14	22.85	62.05
960606	3	38.47	18.59	25.75	7.34	38.35	27.13	131.02	2.14	35.26	89.70
960627	3	45.86	20.89	27.06	5.42	43.64	32.13	200.38	0.00	31.03	110.54
960717	3	40.87	17.19	22.19	4.86	51.15	40.70	192.47	0.00	41.75	125.86
960809	3	43.61	21.80	33.58	11.58	48.92	46.41	154.14	0.00	37.80	104.28
960925	3	59.88	28.79	29.15	4.73	55.60	28.56	184.97	0.00	42.60	113.44
961018	3	44.11	22.21	27.19	11.02	52.26	24.99	159.97	0.00	35.26	91.03
960515	8	15.37	7.98	6.26	8.16	35.31	22.85	135.19	1.43	34.13	83.86
960605	8	23.65	13.08	18.44	12.79	35.94	20.71	160.60	1.43	34.98	83.72
960627	8	29.69	16.37	23.23	12.71	39.44	19.28	212.67	0.00	31.31	91.82
960717	8	26.70	12.42	20.62	9.03	62.27	33.56	111.86	0.00	32.16	147.94
960809	8	28.04	19.08	37.80	19.84	36.69	13.57	102.07	3.57	47.39	58.74
960925	8	32.24	19.17	26.14	12.61	45.59	15.71	177.26	0.00	27.93	76.82
961018	8	29.09	17.44	21.58	12.84	51.15	14.99	167.06	0.00	25.67	89.93
960515	9	27.99	15.38	11.66	4.53	22.72	16.42	90.19	1.43	17.77	50.09
960605	9	33.08	19.74	26.71	8.85	28.34	34.27	101.65	2.14	23.98	58.10
960627	9	41.02	23.12	30.32	8.67	31.84	34.27	159.97	0.71	20.88	63.02
960717	9	44.81	21.55	21.53	3.12	41.14	40.70	202.68	0.00	23.41	88.83
960809	9	42.42	22.46	33.97	9.21	29.65	57.12	123.73	6.43	26.24	62.05
960925	9	58.38	35.04	37.67	11.58	34.47	26.42	127.90	0.00	26.52	68.31
961018	9	48.35	29.04	33.06	11.79	35.58	15.71	122.90	0.00	24.54	62.15

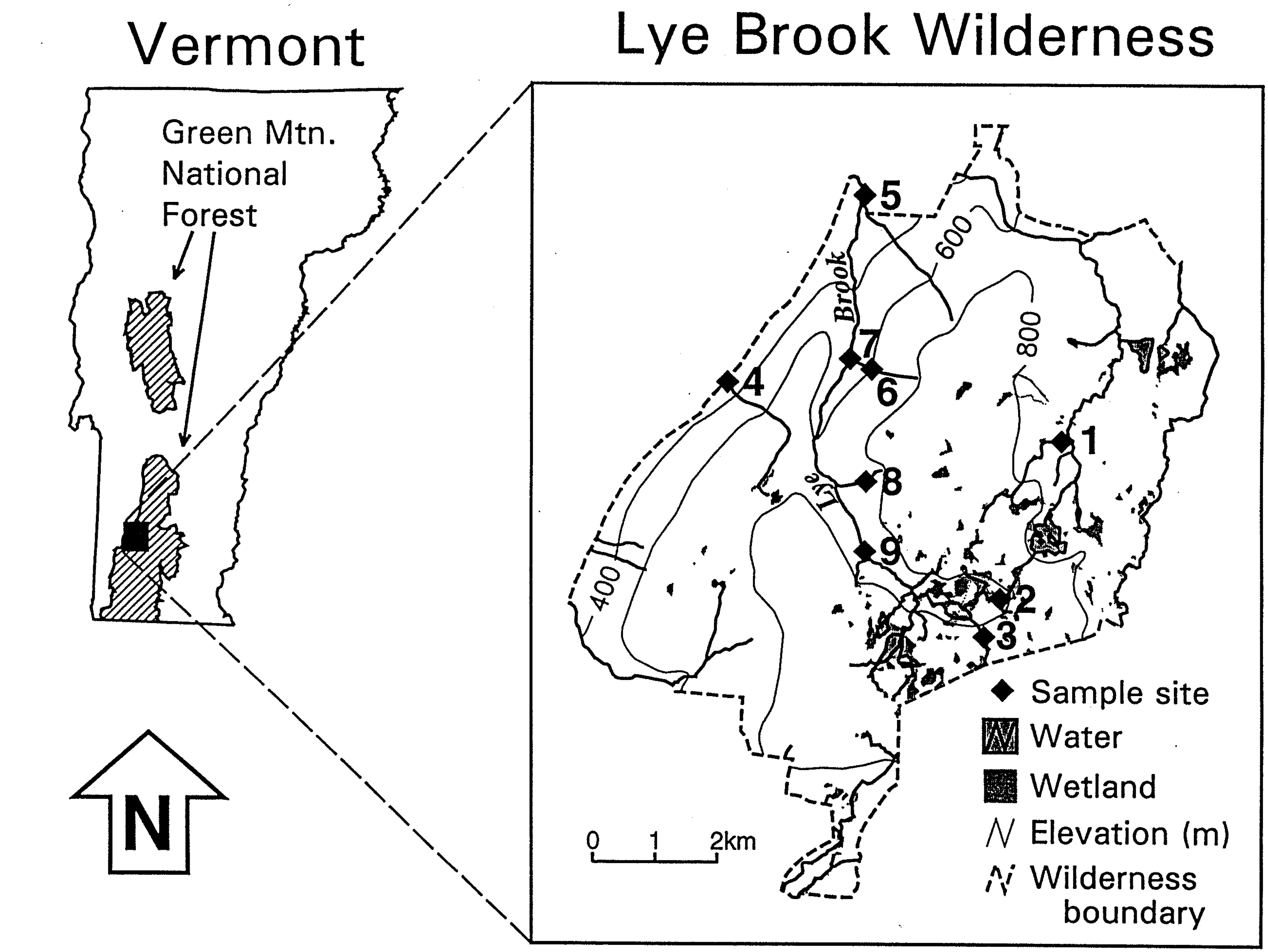

Figure 1. Study site and sample locations.

Terrestrial Fauna

Amphibian Monitoring in the Lye Brook Wilderness Region of the Green Mountain National Forest
April - October 1996

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Abstract

An inventory of amphibians in the Lye Brook Region of the Green Mountain National Forest in Bennington County was begun in 1993 and completed in 1995. Monitoring of selected amphibian species began in 1994. The minimum goals of this monitoring effort are to establish a five-year baseline of population indices against which future comparisons can be made. If monitoring can be sustained, the long-term goals are to determine if any population trends can be seen at this site, to compare population changes between this site and other monitoring locations in the Green Mountains, to monitor the occurrence of obvious external deformities, and to look for correlations between amphibian populations and other data gathered at this site. Five species of salamander (Eastern newt, Northern two-lined salamander, Redback salamander, Spotted salamander, Spring salamander) and five species of frog (American toad, Green frog, Pickerel frog, Spring peeper, Wood frog) are monitored using drift-fences, egg-mass counts, and stream surveys. Three years of monitoring data have been gathered using egg-mass counts and stream surveys. Although it is early to look for trends, the stream surveys suggest both decreasing pH and decreasing numbers of Spring and Two-lined salamanders. The egg-mass counts show no clear trends in populations of Wood frogs, Spotted salamanders or the pH of their breeding ponds. Two years of monitoring data have been gathered at the upper drift-fences. Numbers of each species varied considerably between the two years but the relative abundances of each species were the same from year to year. Eastern newt continues to be the most frequently caught salamander, followed in order both years by Spotted salamander, Redback salamander and Northern two-lined salamander. Eastern newts had a very successful breeding year: 314 of the 432 newts caught at the upper fences were young of the year. Wood frogs continue to be the most frequently caught frog followed in the same order as last year by Green frog, American toad, and Spring peeper. The lower drift-fence is located farther away from water and in higher pH soils. At this fence, the Redback salamander was the most frequently caught salamander and the Pickerel frog the most frequently caught frog. Their were no Pickerel frogs caught at this fence two years ago. No deformities were seen in any of the amphibians caught at any fence, although newts in nearby ponds have shown signs of disease as reported in the 1995 report.

Amphibian Monitoring on Mt. Mansfield, Vermont
April - October, 1996

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Abstract

Populations of amphibian species are monitored annually on Mount Mansfield using drift-fences. The goals of the monitoring are to (1) establish a baseline data set of abundance indices for the amphibian species caught in the fences, (2) monitor year-to-year changes in their abundance, (3) monitor changes in the number or type of obvious external deformities. Amphibians are targeted for this kind of study because their unique life-history characteristics, involving multiple habitat useage, as well as permeable skin, make them especially well suited as an indicator taxa of changes in environmental conditions in forest environments. Although more years of data will be necessary to determine long-term population trends, four years of solid monitoring data can be examined for short-term population trends for the first time. Of the eight species abundant enough to monitor, none have shown steady declines or increases. The species monitored fall into two groups whose populations have oscillated synchronously. Eastern newt, Spring peeper, Green frog, and Pickerel frog populations have all increased or decreased in the same years. Populations of Spotted salamanders and Wood frogs (both early spring breeders) are synchronized only with each other. Populations of Redback salamanders have varied in direct opposition to the Eastern newt group. Of the over 1,000 amphibians caught at these drift-fences in the last four years, none have ever had an obvious external deformity. Of all amphibians caught using all methods at this site since 1991, only one frog showed obvious external deformities. A Wood frog metamorph caught in 1994 was missing one eye and a portion of its rear leg.

FOREST BIRD SURVEYS ON MT. MANSFIELD AND UNDERHILL STATE PARK

1996 REPORT TO THE VERMONT FOREST ECOSYSTEM MONITORING

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In 1996, breeding bird censuses were conducted for the sixth consecutive year at two permanent study sites on Mt. Mansfield. One site, in Underhill State Park at an elevation of 2200 feet, consisted of mature northern hardwoods, while the second site on the Mt. Mansfield ridgeline at 3800 feet consisted of subalpine spruce-fir. These two study sites are part of a long-term Forest Bird Monitoring Program (FBMP) conducted by the Vermont Institute of Natural Science (VINS). This program was initiated in 1989 with the primary goals of conducting habitat-specific monitoring of forest interior breeding bird populations in Vermont and tracking long-term changes. As of 1996, VINS has established 27 monitoring sites in 9 different forested habitats in Vermont.

On the Mt. Mansfield ridgeline plot in 1996, both overall numerical abundance and species diversity increased to their highest levels since 1992 (Table 1). One hundred and sixty individuals of 15 species were detected, up from 134 individuals of 13 species in 1995. Of the 8 species recorded in each year since 1991, 5 showed increases over 1995 totals, and 6 were above the five-year average (Table 2). Yellow-rumped Warbler numbers reached their highest level in 1996 (n=28), as did Blackpoll Warbler (n=30), which had shown a steady decline since 1991. On the other hand, Winter Wren numbers bottomed out at an all time low of 4 individuals after rebounding slightly last year from a downward trend recorded between 1991-1994.

At Underhill State Park, overall numerical abundance dropped slightly from 1995's record high, while species diversity equaled last year's five-year high (Table 3). Twenty species were recorded, with a maximum count of 135 individuals (151 in 1995). Five of the seven most common species, Red-eyed Vireo, Black-throated Blue Warbler, Black-throated Green Warbler, Canada Warbler, and Ovenbird, were recorded above their 1991-1995 average (Table 4). Two of these species, Canada Warbler and Black-throated Green Warbler, were observed at or above their maximum counts. Both Hermit Thrush and Winter Wren however, dropped below their five-year average after increasing in 1995 from a downward trend.

The population fluctuations detected at both Mt. Mansfield and Underhill State Park, underscore the need for continued monitoring and development of a long-term database. With only 6 years of data at these two sites, detection of meaningful population trends is not yet possible. Changes in population trends may simply reflect natural fluctuations, variable detection rates, and/or a variety of dynamic factors, such as prey abundance, overwinter survival, and habitat change. Several years of additional data collection, their correlation with other VFEM data, and comparison with census data from other ecologically similar sites will be necessary to elucidate population trends of various species at these two sites. This winter,VINS will be pooling data from the 17 original FBMP sites and calculating population trends for each breeding species using a route regression program. This analysis will reveal broad scale trends from an 8-year data set which includes the Mansfield and Underhill State Park sites.

Table 1. Maximum counts of individual birds recorded on Mt. Mansfield site, 1991-1996.

Species	Mansfield 91	92	93	94	95	96
Northern Flicker			1			
Hairy Woodpecker				1		
Yellow-bellied Flycatcher			2		1	3
Blue Jay		1				
Common Raven			1			1
Red-breasted Nuthatch		2	3	1	3	1
Winter Wren	20	18	14	8	10	4
Ruby-crowned Kinglet		4			2	
Bicknell's Thrush	10	23	15	9	15	20
Swainson's Thrush	6	16	2	2	5	13
American Robin	2	7	2	4	4	4
Cedar Waxwing		1	4			
Nashville Warbler	4					4
Magnolia Warbler	2	4				8
Yellow-rumped Warbler	22	21	16	18	16	28
Blackpoll Warbler	20	18	18	14	14	30
Ovenbird				2		
Lincoln's Sparrow	4					2
White-throated Sparrow	14	28	26	21	24	28
Dark-eyed Junco	8	17	10	4	10	10
Purple Finch	2	8	2	4		4
White-winged Crossbill					8	
Pine Siskin		1			22	
Evening Grosbeak		2				
Number of individuals	114	171	118	86	134	160
Number of species	12	16	15	11	13	15

Table 2. Maximum counts of the 8 most common species on Mt. Mansfield site, 1991-1996.

SPECIES	YEAR 1991	1992	1993	1994	1995	1996	91-95 avg.
Winter Wren	20	18	14	8	10	4	14.0
Bicknell's Thrush	10	23	15	9	15	20	20.0
Swainson's Thrush	6	16	2	2	5	13	6.2
American Robin	2	7	2	4	4	4	3.8
Yellow-rumped Warbler	22	21	16	18	16	28	18.6
Blackpoll Warbler	20	18	18	14	14	30	16.8
White-throated Sparrow	14	28	26	21	24	28	22.6
Dark-eyed Junco	8	17	10	4	10	10	9.8

Table 3. Maximum counts of individual birds recorded at Underhill State Park, 1991-1996.

Species	Underhill 91	92	93	94	95	96
Northern Flicker			2			
Yellow-bellied Sapsucker		2		2	2	
Hairy Woodpecker				1		
Pileated woodpecker						2
Blue Jay				1		4
Common Raven				4	1	
Brown Creeper				1		
Black-capped Chickadee		2	1		4	5
Winter Wren		12	4	2	10	6
American Robin					5	4
Veery	2	2				
Swainson's Thrush		2		4	8	8
Hermit Thrush		7	2	11	14	5
Wood Thrush	1	2				
Solitary Vireo	1	4				2
Red-eyed Vireo	5	8	8	12	18	16
Black-throated Blue Warbler	11	17	10	12	14	16
Yellow-rumped Warbler			4	4		4
Magnolia Warbler					2	
Black-throated Green Warbler	9	14	12	14	14	15
Blackpoll Warbler						2
Black-and-white Warbler		6	4	4	8	4
American Redstart		6			2	2
Ovenbird	7	20	22	22	26	20
Canada Warbler	5	8	8	10	4	10
Rose-breasted Grosbeak	7	3		2	6	2
White-throated Sparrow	2		2	2	2	
Dark-eyed Junco		6	2	6	8	6
Pine Siskin					1	
Scarlet Tanager					2	
Purple Finch						2
Number of individuals	52	112	83	114	151	135
Number of species	11	18	14	18	20	20

Table 4. Maximum counts of the 7 most common species at Underhill State Park, 1991-1996.

SPECIES	YEAR 1991	1992	1993	1994	1995	1996	91-95 avg.
Winter Wren	0	12	4	2	10	6	5.6
Hermit Thrush	0	7	2	11	14	5	6.8
Red-eyed Vireo	5	8	8	12	18	16	10.2
Black-throated Blue Warbler	11	17	10	12	14	16	12.8
Black-thr. Green Warbler	9	14	12	14	14	15	12.6
Ovenbird	7	20	22	22	26	20	19.4
Canada Warbler	5	8	8	10	4	10	7.0

Investigations of Bicknell's Thrush (*Catharus bicknelli*) in the Northeastern United States

PROGRESS REPORT
1996

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The Bicknell's Thrush, recognized as a subspecies of the Gray-cheeked Thrush since its discovery in 1881 on Slide Mountain in the Catskills of New York, has recently been given full species status (AOU 1995). Significant differences between the two taxa in morphology, vocalizations, genetics, and breeding and wintering distributions contributed to this designation (Ouellet 1993). With this classification Bicknell's Thrush has become recognized as one of the most at-risk passerine species in the eastern United States. Rosenberg and Wells (1995) ranked Bicknell's Thrush as number one on a conservation priority list of Neotropical migrant birds in the Northeast. The species has been proposed for "threatened" status in Canada (Nixon 1995).

The breeding range of Bicknell's Thrush in the United States is limited to subalpine spruce-fir forests of New England and New York (Atwood et al. 1996). In Canada it is found in highland spruce-fir forests in Quebec, Nova Scotia and New Brunswick (Erskine 1992, Ouellet 1993, Gauthier and Aubry 1995). It has also been found in mixed second-growth forest following clear cutting or burning in Quebec (Ouellet 1993) and New Brunswick (Nixon 1996). As the only breeding songbird endemic to high altitude and maritime spruce-fir forests of the northeastern United States and adjacent Canada, Bicknell's Thrush qualifies as a potentially valuable indicator of the health of subalpine avian populations and their associated forest habitat. Surveys aimed at clarifying the distribution and population status of Bicknell's Thrush in the Northeast were conducted from 1992-95 (Atwood et al. 1996, Rimmer et al. 1996) and are in progress in New Brunswick, Canada (Nixon 1996).

Many important questions about the ecology and stability of Bicknell's Thrush breeding populations require intensive monitoring of discrete habitat units and studies of known-identity individuals. Baseline data on population densities, territory size, movements, productivity, site fidelity, survivorship, and habitat use are needed to evaluate the conservation status of the species across its fragmented, high elevation breeding range. Studies conducted since 1992 on Vermont's Mt. Mansfield, the site of a large, dense breeding population, have established a solid foundation for future long and short-term research.

In 1996 research was expanded on Mt. Mansfield and on other peaks in the Northeast, using a variety of methods (Table 1). Primary research objectives in 1996 were: 1) to uniquely color-band all known breeding pairs of Bicknell's Thrushes on 5 Mt. Mansfield study plots for demographic investigations ; 2) to obtain estimates of population density on 4 Mt. Mansfield study plots, and single plots on Belvidere Mtn. in n. Vermont, Equinox Mtn. s. Vermont, and Plateau Mtn. in the Catskills by spot-mapping and tracking movements of known identity individuals; 3) to examine site fidelity, territorial turnover, survivorship, and population stability on 3 established plots by searching for previously color-banded thrushes; 4) to obtain productivity data by locating and monitoring nests on Mt. Mansfield study plots, and through combined mist-netting and observations of banded family groups; and 5) to establish point count stations on additional peaks and to complete censuses on as many of these sites as possible.

Research on the population ecology of Bicknell's Thrush *(Catharus bicknelli)* was continued on Mt. Mansfield and several other northeastern U.S. peaks in 1996. Our methods included the following (Table 1):

Table 1. Locations and summary descriptions of Bicknell's Thrush study areas in the northeastern United States.

Location	USGS 7.5 Quad	Study Plot ID	Elevation (m)	Plot Size (Ha)	Impacts [a] on/near Study Plot	Study [b] Methods	Study Years
Mt. Mansfield, VT	Mansfield	MANS	1,160 - 1,190	8.8	1,3,4	1,2,3,4,5,6	91-96
Mt. Mansfield, VT	Mansfield	RABR	914 - 1,070	20	3	1,2,3,4,5,6	95-96
Mt. Mansfield, VT	Mansfield	NDPO	885 - 1,070	20	2,3	2,3,4,5,6	95-96
Mt. Mansfield, VT	Mansfield	OCTA	1,070 - 1,130	6	1,2,3,4	3,4	92-96
Belvidere Mtn., VT	Hazens Notch	BELV	960 - 1,000	16.5	3	1,2,3,4,5,6	94-96
Mt. Equinox, VT	Manchester	EQUI	1,100 - 1,160	13.5	3,4	1,2,3,4,5,6	95-96
Plateau Mtn., NY	Hunter	PLAT	1,130 - 1,175	12.2	3	1,2,3,4,5,6	95-96
Burke, VT	Burke	BURK	915 - 985		1,2,3,4	1,4,6	94-96
Okemo Mtn., VT	Mt. Holly	OKEM	945 - 1,020		1,2,3,4	1,4,6	94-95
Haystack, VT	Wilmington	HAYS	930 - 1,040		3	1,4,6	94-96
Mt. Hunger, VT	Stowe	HUNG	1,005 - 1,080		3	1,6	95
Camel's Hump, VT	Huntington	CAME	1,130 - 1,230		3	1,6	91-96
Mt. Kearsarge, NH	Warner	KEAR	825 - 895		3,4	1,6	94-95
Whiteface, Mtn., NY	Lake Placid	WHIT	1,250 - 1,330		1,3	1,6	95

[a] 1-road(s), 2-ski area, 3-foot trails, 4-communications equipment/buildings.

[b] 1-point counts, 2-spot mapping, 3-nest monitoring, 4-color banding, 5-constant effort mist netting, 6-habitat monitoring. Not all methods used during all years of study on each site.

Spot mapping. Mapping was conducted from 1992-96 on the MANS plot, from 1995-96 on the RABR and NDPO plots and in 1996 on FORE, EQUI, PLAT and BELV plots (Table 1). For each bird seen or heard a compass bearing and distance estimate were recorded from marked vantage points (MANS) or following a 25m grid system marked with blue survey flagging and metal tree tags (all others). Data were plotted on a base map of each study area. Simultaneous registration of two or more vocalizing birds was used as the primary means of discriminating between adjacent territories (Robbins 1970). Sightings and captures of color banded birds were mapped in an attempt to match each territory with a known identity bird.

Surveys were conducted on at least 8 different dates on each plot every year (Table 1). We calculated the number of territories on each study plot using the international spot mapping standards (Robbins 1970), where each territory that is at least 50% within the plot boundaries is counted as a full territory on the plot.

Color Banding. On 6 study plots (Table 1) we used strategically placed mist nets in combination with tape recorded playbacks of Bicknell's Thrush vocalizations and a life-like wooden decoy to attempt to capture and color band all known Bicknell's Thrushes. 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, tarsus, culmen) and body condition (e.g., subcutaneous fat, molt, feather wear) data were recorded for all captured birds. Age and sex were determined using skull ossification, presence of terminal buffy shaft streak or spot on any greater coverts, outer retrice shape, cloacal protuburance and brood patch (Pyle et al. 1987, Collier and Wallace 1989). Capture locations were marked on study plot base maps. On plots where spot mapping was conducted we attempted to identify the color banded adults on each known territory. Concerted efforts were made to locate color banded birds throughout the season.

Nest Monitoring. From early June through mid-July in 1992-1996, 5 Mt. Mansfield study plots were searched to locate active and recently used nests. Nest were located through systematic searches, parental behavior and spot mapping data patterns. Each nest location was marked on a study plot base map. The chronology and success of all active nests were monitored every 2 to 4 days. Nestlings were banded at approximately seven days age. Nest monitoring was conducted according to guidelines established by the Breeding Biology Research and Monitoring Database Program (BBIRD) (Martin and Geupel 1993, Martin and Conway 1994). Nests that fledged at least one young were considered successful.

After termination of nesting activity, data on nest-site characteristics were collected in accordance with BBIRD protocols (Martin and Conway 1994). Nest height and nest tree height were measured with meter tape or clinometer. Nest distance from main stem and outer foliage were measured with centimeter tape from outer edge of nest. Orientation of nest in relation to main stem was recorded in 90° quadrants. Nest concealment was indexed by estimating percent foliage cover in a 25 cm circle centered on the nest from a distance of 1m from above and from the side in each cardinal directions.

Habitat characteristics were measured within a 5m radius circle around each nest, Bicknell's Thrush non-use sites (BTNU), and other species non-use sites (OSNU). BTNU and OSNU sites were selected by measuring at least 35m away from nest on same elevation and selecting a site that appears to most represent the nest site. OSNU sites represent a more complete coverage of the range of habitat sites available because other species choose different micro-habitat types. Shrub stem densities were counted for each species. Shrubs were defined as woody plants > 0.5 m high with a diameter at 10 cm high < 8 cm and placed into two classes, < 2.5cm diameter and > 2.5cm diameter for each species. Ocular estimates for ground coverage included: total green cover, moss, leaf litter, bare ground, water, grasses and sedges, shrubs (woody stems under 50cm height), ferns, all forbs, and downed logs > 12 cm diameter. Canopy density > 5m high and total was determined using a convex densiometer held waist high. Readings are taken at the center of the plot in four cardinal directions. An average of the four readings was used for analysis. Litter depth was measured at six sites east to west and six sites north to south across the plot with a centimeter ruler. Average depth was used for analysis.

Within an 11.3m radius circle tree densities were counted. Trees were defined as woody stems $>$ 8cm DBH and were placed in three classes: >8-23, >23-38, and >38 cm. Snags were defined as standing dead trees and were placed into two DBH classes: >12 cm - 23 cm and > 23 cm. Average tree canopy height was measured by choosing an average tree and calculating height with a clinometer.

Univariate comparisons were made between Bicknell's Thrush nest sites (n=21) and non-use sites (similar habitat $\pm$ 35 m from nest site), nest sites and random non-use sites (non-use sites of all other species) and Bicknell's nest sites and Swainson's nest sites using SYSTAT 5.0 (Wilkinson 1993). Ocular estimate variables (i.e., ground cover parameters) were placed in 5 classes (Table 5) (Barbour et al. 1987). These indices were compared with a Mann-Whitney test. All other comparisons were made with two-sample t-tests. When data failed to meet the equal variances assumption separate variances t test was used to adjust the degrees of freedom to account for unequal variances (Wilkinson 1993). We pooled data from all Bicknell's Thrush nests found on Mt. Mansfield from 1992-96 due to small sample sizes (n=21). Sample sizes were small because of the difficulty in locating nests in the extremely dense habitat. We were unable to compare successful nest sites and unsuccessful sites due to this small sample size. At least 20 nests are needed to give a reliable estimate of nest success (Hensler and Nichols 1981). Nearly all nests were found after the onset of incubation, so nest success and mortality were calculated using the Mayfield method (Mayfield 1961, 1975) as modified by Johnson (1979) and Hensler and Nichols (1981). Half the number of days between the final visit and the depredation event or assumed fledging was added to the number of previous days the nest survived to arrive at the total number of days the nest survived while under observation. Initiation date is the day on which the first egg was laid. To calculate this date we assumed laying intervals of one day for each egg, an incubation period of 13 days and nestling periods of 11 days (Wallace 1939, Rimmer and McFarland, unpub. data). The small sample size should be kept in perspective when reviewing results.

The following results and discussion are presented in a preliminary fashion. Data collection and analysis are continuing. A full progress report will be available in Fall 1997 and will include 1997 breeding season data.

On Mt. Mansfield, spot mapping of territorial males on MANS and FORE ridgeline study plots yielded density estimates of 45.5 pairs/40 ha and 20 pairs/40 ha respectively, while estimates of 22 and 10 pairs /40 ha were obtained from two plots at lower elevations (Ranch Brook and Nose Dive Pod respectively). Other peaks generally had lower densities (EQUI = 6 pairs/40 ha, BELV = 14.5 pairs/40 ha, PLAT = 19.7 pairs/40 ha). Differences in densities could be related to habitat suitability and availability. However, this requires further habitat data analysis. Since 1992 several point count stations have been completed each year throughout the Northeast and more have been added each year. This monitoring methodology requires many years of data and will be analyzed in the future. Spot mapping data and point count data are being analyzed with statistical power analysis software to determine the number of years necessary to detected significant levels of change in population trends.

Efforts to capture and band thrushes on Mt. Mansfield resulted in a total of 231 birds being uniquely color-banded in 1992-96 (Table 2). Band returns of adults indicated high survivorship and site fidelity on most plots. Two juveniles banded on Mt. Mansfield in 1992-95 were recaptured in 1996. One originally banded in 1994 was recaptured on the OCTA plot and the other banded in 1995 was recaptured near the same site. Survivorship estimates based on capture-recapture data is being analyzed using SURGE software (Cooch et al. 1996).

Despite many hours of observations and systematic searches we found only 21 active or recently active nests in 1992-96 (9 MANS, 4 OCTA, 5 RABR, 1 NDPO, 2 FORE). Of these 21 nests: 9 were successful (fledging at least one), 4 were depredated, 3 failed due to nest abandonment, 1 failed due to unknown circumstances, 2 failed due to severe weather, and 2 were of unknown status because they were never occupied during observation. It remains unclear why three MANS nests were abandoned. Of the 18 active (status known) nests that we monitored, 8 fledged young (44.4%). We calculated the Mayfield predicted nest success as 26% (Table 3). Wallace (1939) reported that only 4 of 15 nests (26.7%) monitored during his study on Mt. Mansfield fledged young. One nest with eggs was abandoned and the remaining 10 were depredated.

Table 2. Number of individual Bicknell's Thrush captured each year (presented by age[a] and sex[b]).

LOC	YEAR	AGE: 1			1 Total	2	2 Total	4	4 Total	5			5 Total	6			6 Total	Grand Total
	SEX:	0	4	5		0		0		0	4	5		0	4	5		
FORE	1996	0	1	1	2	1	1	4	4	0	0	0	0	0	5	2	7	14
	Total	0	1	1	2	1	1	4	4	0	0	0	0	0	5	2	7	14
MANS	1992	0	3	2	5	0	0	2	2	0	0	1	1	0	0	0	0	8
	1993	0	11	4	15	2	2	0	0	0	1	0	1	0	2	1	3	21
	1994	1	4	2	7	11	11	0	0	0	0	0	0	0	7	3	10	28
	1995	2	4	3	9	8	8	2	2	1	3	3	7	0	8	2	10	36
	1996	1	0	0	1	24	24	0	0	2	4	0	6	1	5	6	12	43
	Total	4	22	11	37	45	45	4	4	3	8	4	15	1	22	12	35	136
NDPO	1995	0	1	0	1	0	0	0	0	0	1	1	2	0	0	0	0	3
	1996	0	0	0	0	0	0	4	4	0	2	0	2	0	2	1	3	9
	Total	0	1	0	1	0	0	4	4	0	3	1	4	0	2	1	3	12
OCTA	1992	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
	1993	0	3	2	5	0	0	0	0	0	0	0	0	0	0	0	0	5
	1994	0	2	0	2	1	1	0	0	0	1	0	1	0	1	1	2	6
	1995	0	1	2	3	0	0	0	0	0	0	0	0	0	2	0	2	5
	1996	1	1	1	3	1	1	4	4	0	1	0	1	1	2	1	4	13
	Total	1	10	5	16	2	2	4	4	0	2	0	2	1	5	2	8	32
RABR	1995	0	0	0	0	0	0	3	3	1	3	0	4	0	4	2	6	13
	1996	0	0	2	2	2	2	5	5	0	6	3	9	0	4	2	6	24
	Total	0	0	2	2	2	2	8	8	1	9	3	13	0	8	4	12	37
Grand Total		5	34	19	58	50	50	24	24	4	22	8	34	2	42	21	65	231

[a] Age codes: 1-after hatch year, 2-hatch year, 4- nestling, 5- second year adult, 6- older than second year.
[b] Sex codes: 0- unknown, 4- male, 5- female.

Table 3. Numbers of successful and unsuccessful nests and nesting success based on numbers of Bicknell's Thrush nests monitored on Mt. Mansfield, Vermont, 1992-96. Number of days those nests were observed to survive, daily mortalities (Standard Error) and predicted nest success calculated from the Mayfield method.

No. successful/ unsuccessful [a]	% Nests successful	Days observed	Daily mortality (SE)[b]	Predicted nest success (%) [c]
8/10	44.4	164.5	0.049 (0.017)	26.0

a Nests in following groups not included: 1- status unknown/occupied but fate unknown (n=1), 2- status unknown/nest not occupied but built in current year (n=2).
b Standard error as calculated under the methods of Hensler and Nichols (1981).
c Based on a 27 day average exposure period for each nest (Wallace 1938, Rimmer and McFarland, unpub. data).

Clutch sizes ranged from 3-4 eggs (n = 18 nests, x = 3.6, SD = 0.5). Wallace (1939) recorded the same clutch size range (n = 13 nests, x = 3.46, SD = 0.56). Initiation dates ranged from 7 June to 12 July (n = 18 nests, x = 17 June, SD = 9.4 days). The latest date represents a probable second attempt by a pair that failed during the egg laying period. Wallace (1939) reported clutch initiation dates from 9 June to 10

July (n = 11 nests, x = 18 June, SD = 8.9 days). His latest nest also represented a second attempt. It is unclear how he calculated these initiation dates.

Twelve of 18 nest trees were balsam fir (*Abies balsamea*), 2 nests were located in a red spruce (*Picea rubens*), and one was situated in the junction of a balsam fir leaning on a white birch (*Betula papyrifera* var. *cordifolia*). Wallace (1939) found 7 nests in balsam fir, 5 in red spruce and 1 in a white birch. Nests were invariably found in a live portion of the tree and in healthy trees, except in one case where a nest tree's top quarter was gnarled and dead. Nest trees were small (1.8-7.2 m tall and 1 - 19.1 cm DBH), and nests were located between 1 and 4.3 m above ground (Table 4). Wallace (1939) found nests to be 0.9 - 3.7 m above the ground (Table 4). Nests were most often on the east to south quadrant of the nest tree ($n = 21, x^2 = 11.105, P < 0.025$).

Table 4. Bicknell's Thrush nest placement and concealment (n = 21) on Mt. Mansfield, Vermont. Nest heights for this study and Wallace (1939) compared. Wallace did not record other pertinent measurements for comparison.

Parameter	Range	Mean	± SD
Nest height (m)	1 - 4.3	1.79	0.82
Nest height (Wallace 1939)	0.9 - 3.7	2.1	0.87
Nest plant height (m)	1.5 - 7.2	3.08	1.54
Nest plant DBH (cm)	1 - 19.1	5.32	4.25
Concealment:			
west side	0 - 100	68.2	27
east side	5-100	68.1	25.5
south side	10 - 100	71.4	27.8
north side	5 - 100	59.8	29.3
above	50 - 100	85.3	16.9
No. of nest support branches	1 - 5	2.8	1.0
Diameter. of nest support branches (cm)	0.3 - 2.5	1	0.5
Nest distance from main stem (cm)	0 - 190	19.1	48.5
Nest distance from outer foliage of plant (cm)	0 - 110	49.6	29.6

Despite our small sample size (n = 21) of nests, we conducted a preliminary analysis of vegetation at nest sites versus non-use sites to examine possible selection features by Bicknell's Thrush. We suspected a priori that nest site selection was based primarily on woody stem density, as nest sites seemed to be characterized by high densities of balsam fir trees. We compared vegetation surrounding Bicknell's Thrush (BITH) nest sites (n = 21) with non-use sites (BTNU) (n = 21), Bicknell's Thrush nest sites with other species non-use sites (OSNU) (n=65), and Bicknell's Thrush nest sites with Swainson's Thrush (SWTH) nest sites (n=9). We found no statistical differences between BITH nest sites and BTNU sites.

Bicknell's Thrush nest sites were distinctly different than OSNU sites (Table 5). BITH nest sites had significantly higher densities of shrub stems, (particularly balsam fir, white birch and dead stems), small white birch tree stems as well as lower densities of medium class (DBH >23-38 cm) trees (particularly balsam fir and white birch). Nest sites had higher shrub and downed log cover while OSNU sites had higher fern and grass/sedge cover. The average top canopy height and high (>5m) canopy cover was considerably lower around thrush nests. Bicknell's Thrush and Swainson's Thrush nest sites were located in different microhabitats (Table 6). BITH nest sites contained significantly higher densities of small shrub stems (especially balsam fir and white birch), large shrub stems (especially balsam fir), and standing dead trees. SWTH nest sites had higher fern and grass/sedge cover. Average top canopy height and high (>5m) canopy cover were significantly lower over BITH nest sites.

Possible nest predators of adults or nests observed from 1992-1996 on Mt. Mansfield included: Blue Jay, Northern Raven, *Accipiter* species, red squirrel *(Tamiasciurus hudsonicus)*, eastern chipmunk (*Tamias striatus*; observed only on RABR and NDPO), raccoon *(Procyon lotor)*, and long-tailed weasel *(Mustela frenata)*. Wallace (1939) reported that red squirrels and a Blue Jay preyed on Bicknell's Thrush nests on Mt. Mansfield. We strongly suspect red squirrels to be the major nest predator. We began to map red squirrel territories in 1995 to obtain yearly population indices and found 10 squirrel territories on RABR and 5 territories on NDPO. In 1996 we found none on RABR and 3 territories on NDPO. We believe that extremely high cone production in 1994 may have resulted in high numbers of red squirrels on Mt. Mansfield in 1995. Lower numbers of Red Squirrels in 1996 may reflect the poor cone crop noted in 1995. Future indices of red squirrel populations and their correlation with annual nest predation rates may reveal the influence of this species on Bicknell's Thrush and other bird species productivity.

Table 5. Comparison of microhabitat variables at Bicknell's Thrush nest sites with other species non-use sites on Mt. Mansfield Vermont, 1992-96. Coverage indices were compared with a Mann-Whitney U-test; all other comparisons made with a two-sample *t*-test.

Parameter	Nest Site				Random Site				P
	n	mean	SD	range	n	mean	SD	range	
5m radius woody stem density < 2.5 cm diameter at 10 cm height:									
Dead	21	4.76	6.07	0-23	65	1.12	2.69	0-19	0.01
Balsam Fir	21	44.81	39.08	0-140	65	28.86	32.08	1-137	
Red Spruce	21	0.14	0.48	0-2	65	1.09	2.67	0-18	0.008
White Birch	21	11.33	11.99	0-39	65	4.92	7.3	0-36	0.03
Mt. Ash	21	0.71	1.01	0-4	65	3.14	6.19	0-34	0.003
Mt. Shadbush	21	0.67	2.42	0-11	65	0.19	0.93	0-7	
Mt. Maple	21	0.29	1.31	0-6	65	0.62	2.83	0-14	
Mt. Holly	21	9.81	22.42	0-89	65	1.05	5.42	0-34	
Hobblebush	21	0	0	0	65	0.63	4.26	0.34	
Pin Cherry	21	0	0	0	65	0.15	1.24	0-10	
Total Small Stems	21	80.05	49.94	11-187	65	38.29	22.24	9-108	0.001
5m radius woody stem density >2.5 cm diameter at 10 cm height:									
Dead	21	5.24	6.34	0-29	65	1.98	2.58	0-10	0.03
Balsam Fir	21	52.33	33.23	6-154	65	25.39	17.44	2-99	0.002
Red Spruce	21	0.38	0.86	0-3	65	1.63	2.91	0-12	0.003
White Birch	21	11.33	11.99	0-39	65	3.46	5.58	0-23	0.004
Mt. Ash	21	1.38	2.09	0-7	65	2.32	4.66	0-25	
Mt. Shadbush	21	0.67	3.06	0-14	65	0.03	0.25	0-2	
Mt. Maple	21	0.33	1.53	0-7	65	0.17	0.12	0-6	
Mt. Holly	21	0.86	3.28	0-15	65	0.14	0.63	0-3	
Pin Cherry	21	0	0	0	65	0.12	0.76	0-6	
Elderberry	21	0.1	0.44	0-2	65	0	0	0	
Black Spruce	21	0	0	0	65	0.02	0.12	0-1	
Total Large Stems	21	64.62	46.06	6-159	65	38.74	32.74	3-142	0.02
Total Stems (small + large)	21	144.67	91.43	28-290	65	77.03	44.1	14-199	0.003
11.3m radius tree density >8-23 cm DBH:									
Balsam Fir	21	28	22.22	2-89	65	21.3	13.3	0-75	
Red Spruce	21	0.57	1.21	0-5	65	0.9	1.7	0-11	
White Birch	21	1.29	2.08	0-6	65	4.94	6.69	0-36	<0.001
Mt. Ash	21	0.48	1.12	0-4	65	0.4	0.8	0-4	
Yellow Birch	21	0	0	0	65	0.03	0.17	0-1	
Total Small Trees	21	30.33	22.46	7-89	65	27.54	14.05	0-75	
Dead (>12-23 cm DBH)	21	10.48	6.71	1-26	65	7.6	6.5	0-24	
11.3m radius tree density >23-38 cm DBH:									
Balsam Fir	21	1.14	1.42	0-4	65	2	2	0-8	0.04
Red Spruce	21	0.05	0.22	0-1	65	0.1	0.4	0-2	
White Birch	21	0.14	0.48	0-2	65	0.8	1.3	0-6	0.001
Mt. Ash	21	0	0	0	65	0.02	0.12	0-1	
Total Medium Trees	21	1.33	1.59	0-5	65	2.92	2.42	0-11	0.001
Dead (> 23 cm DBH)	21	1.81	1.75	0-6	65	2.1	2.1	0-9	

Table 5. Continued.

Parameter	Nest Site				Random Site				P
	n	mean	SD	range	n	mean	SD	range	
11.3m radius tree density > 38 cm DBH:									
Balsam Fir	21	0	0	0	65	0.14	0.4	0-2	
White Birch	21	0	0	0	65	0.14	0.4	0-2	
Total Large Trees	21	0	0	0	65	0.28	0.63	0-3	
Total Live Trees (all 3 size classes)	21	31.67	22.31	7-90	65	30.74	14.37	0-81	
Total Snags (both size classes)	21	12.29	6.75	3-27	65	9.65	7.4	0-33	
Total Tree Stems	21	43.95	22.38	15-93	65	40.39	17.2	7-96	
5m radius ground cover[a] (%):									
Total Green	21	4.76	1.09	3-6	63	4.94	0.82	2-6	
Shrubs	21	2.33	1.2	1-5	64	1.75	0.64	1-3	0.045
Forbs	21	2.14	0.65	1-4	64	2.44	0.89	1-5	
Ferns	21	1.76	0.83	1-4	64	2.61	1.15	1-5	0.003
Grass/sedge	21	1	0		64	1.42	0.75	1-4	0.007
Leaf litter	21	2.9	1.17	1-5	64	2.59	0.89	1-5	
Downed Logs (>12cm dia)	21	1.57	0.6	1-3	65	1.31	0.47	1-2	0.058
Water	21	1	0		65	1.03	0.17	1-2	
Moss	21	3.19	1.12	2-5	65	2.71	0.46	1-3	
Bare ground	21	1.29	0.56	1-3	65	1.23	1.11	1-6	
Litter depth (cm)	21	3.97	1.36	1.8-6.5	64	4.17	1.58	0.2-7.4	
Aspect (degrees)	21	144.7	75.6	40-315	64	152.84	59.05	0-340	
Slope (degrees)	15	20.93	12.83	8-46	64	18.92	9.04	0-39	
Average Top Canopy Height (m)	21	4.26	2.13	2-9.8	64	8.17	3.95	1.5-20	< 0.001
Canopy Cover >5m (%)	15	16.84	25.44	0-86	64	47.12	34.77	0-97.24	0.001
Total Canopy Cover (%)	15	76.46	24.4	13.26-99.84	64	74.56	24.89	17.94-99.84	

[a] Index of percent coverage: 1=0-4, 2=5-24, 3=25-49, 4=50-74, 5=75-94, 6=95-100.

Table 6. Comparison of habitat variables at Bicknell's Thrush nest sites with Swainson's Thrush nest sites on Mt. Mansfield, Vermont, 1992-96. Coverage indices were compared with a Mann-Whitney U-test; all other comparisons made with a two-sample *t*-test.

Parameter	Nest Site				Random Site				P
	n	mean	SD	range	n	mean	SD	range	
5m radius woody stem density < 2.5 cm diameter at 10 cm height:									
Dead	21	4.76	6.07	0-23	9	1.78	3.03	0-9	
Balsam Fir	21	44.81	39.08	0-140	9	19	10.68	6-35	0.01
Red Spruce	21	0.14	0.48	0-2	9	1.11	1.54	0-4	
White Birch	21	11.33	11.99	0-39	9	2.22	3.23	0-10	0.003
Mt. Ash	21	0.71	1.01	0-4	9	2.56	3.94	0-11	
Mt. Shadbush	21	0.67	2.42	0-11	9	1.89	5.67	0-17	
Mt. Maple	21	0.29	1.31	0-6	9	0.44	1.33	0-4	
Mt. Holly	21	9.81	22.42	0-89	9	0	0	0	
Wild Raisin	21	0	0	0	9	1.33	4	0-12	
Total Small Stems	21	80.05	49.94	11-187	9	37.22	13.94	18-58	0.001
5m radius woody stem density >2.5 cm diameter at 10 cm height:									
Dead	21	5.24	6.34	0-29	9	2.33	2.78	0-9	
Balsam Fir	21	52.33	33.23	6-154	9	25.89	10.76	12-44	0.003
Red Spruce	21	0.38	0.86	0-3	9	1.67	1.66	0-4	0.053
White Birch	21	11.33	11.99	0-39	9	6.22	9.11	0-25	
Mt. Ash	21	1.38	2.09	0-7	9	1.11	1.76	0-5	
Mt. Shadbush	21	0.67	3.06	0-14	9	0.11	0.33	0-1	
Mt. Maple	21	0.33	1.53	0-7	9	0.56	1.67	0-5	
Mt. Holly	21	0.86	3.28	0-15	9	0	0	0	
Pin Cherry	21	0	0	0	9	0.11	0.33	0-1	
Elderberry	21	0.1	0.44	0-2	9	0	0	0	
Wild Raisin	21	0	0	0	9	1.11	3.33	0-10	
Total Large Stems	21	64.62	46.06	6-159	9	32.22	13.01	9-51	0.007
Total Stems (small + large)	21	144.67	91.43	28-290	9	72	24.06	30-102	0.002
11.3m radius tree density >8-23 cm DBH:									
Balsam Fir	21	28	22.22	2-89	9	23.67	15.12	8-57	
Red Spruce	21	0.57	1.21	0-5	9	1.11	1.54	0-5	
White Birch	21	1.29	2.08	0-6	9	5.78	6.32	0-21	
Mt. Ash	21	0.48	1.12	0-4	9	0.44	0.73	0-2	
Total Small Trees	21	30.33	22.46	7-89	9	31	16.21	11-59	
Dead (>12-23 cm DBH)	21	10.48	6.71	1-26	9	4.44	2.13	0-7	0.001
11.3m radius tree density >23-38 cm DBH:									
Balsam Fir	21	1.14	1.42	0-4	9	1.67	1.22	0-4	
Red Spruce	21	0.05	0.22	0-1	9	0	0	0	
White Birch	21	0.14	0.48	0-2	9	1	0.71	0-2	0.007
Mt. Ash	21	0	0	0	9	0.11	0.33	0-1	
Total Medium Trees	21	1.33	1.59	0-5	9	2.78	1.39	2-6	0.023
Dead (> 23 cm DBH)	21	1.81	1.75	0-6	9	2.67	1.8	0-5	

Table 6. Continued.

Parameter	Nest Site				Random Site				P
	n	mean	SD	range	n	mean	SD	range	
11.3m radius tree density > 38 cm DBH:									
Balsam Fir	21	0	0	0	9	0.22	0.44	0-1	
Red Spruce	21	0	0	0	9	0.22	0.44	0-1	
White Birch	21	0	0	0	9	0.33	0.5	0-1	
Total Large Trees	21	0	0	0	9	0.78	0.83	0-2	
Total Live Trees (all 3 size classes)	21	31.67	22.31	7-90	9	34.56	16.43	15-62	
Total Snags (both size classes)	21	12.29	6.75	3-27	9	7.11	2.76	2-11	0.006
Total Tree Stems	21	43.95	22.38	15-93	9	41.67	16.16	25-71	
5m radius ground cover[a] (%):									
Total Green	21	4.76	1.09	3-6	8	4.75	0.71	4-6	
Shrubs	21	2.33	1.2	1-5	9	1.67	0.5	1-2	
Forbs	21	2.14	0.65	1-4	9	2.33	0.87	1-4	
Ferns	21	1.76	0.83	1-4	9	2.44	0.53	2-3	0.017
Grass/sedge	21	1	0		9	1.22	0.44	1-2	0.028
Leaf litter	21	2.9	1.17	1-5	9	3	1.12	2-5	
Downed Logs (>12cm dia)	21	1.57	0.6	1-3	9	1.44	0.53	1-2	
Water	21	1	0		9	1.11	0.33	1-2	
Moss	21	3.19	1.12	2-5	9	2.44	0.88	1-4	
Bare ground	21	1.29	0.56	1-3	9	1.33	0.71	1-3	
Litter depth (cm)	21	3.97	1.36	1.8-6.5	9	4.12	1.63	2-6.6	
Aspect (degrees)	21	144.7	75.6	40-315	9	150.11	49.54	89-220	
Slope (degrees)	15	20.93	12.83	8-46	9	19.11	5.78	13-31	
Average Top Canopy Height (m)	21	4.26	2.13	2-9.8	9	8.72	2.73	3.15-12.5	0.001
Canopy Cover >5m (%)	15	16.84	25.44	0-86	9	58.43	34.48	6.76-95.68	0.012
Total Canopy Cover (%)	15	76.46	24.4	13.26-99.84	9	87.68	12.42	65.76-99.84	

[a] Index of percent coverage: 1=0-4, 2=5-24, 3=25-49, 4=50-74, 5=75-94, 6=95-100.

Table 6. Continued.

Parameter	Nest Site n	mean	SD	range	Random Site n	mean	SD	range	P
11.3m radius tree density > 38 cm DBH:									
Balsam Fir	21	0	0	0	9	0.22	0.44	0-1	
Red Spruce	21	0	0	0	9	0.22	0.44	0-1	
White Birch	21	0	0	0	9	0.33	0.5	0-1	
Total Large Trees	21	0	0	0	9	0.78	0.83	0-2	
Total Live Trees (all 3 size classes)	21	31.67	22.31	7-90	9	34.56	16.43	15-62	
Total Snags (both size classes)	21	12.29	6.75	3-27	9	7.11	2.76	2-11	0.006
Total Tree Stems	21	43.95	22.38	15-93	9	41.67	16.16	25-71	
5m radius ground cover[a] (%):									
Total Green	21	4.76	1.09	3-6	8	4.75	0.71	4-6	
Shrubs	21	2.33	1.2	1-5	9	1.67	0.5	1-2	
Forbs	21	2.14	0.65	1-4	9	2.33	0.87	1-4	
Ferns	21	1.76	0.83	1-4	9	2.44	0.53	2-3	0.017
Grass/sedge	21	1	0		9	1.22	0.44	1-2	0.028
Leaf litter	21	2.9	1.17	1-5	9	3	1.12	2-5	
Downed Logs (>12cm dia)	21	1.57	0.6	1-3	9	1.44	0.53	1-2	
Water	21	1	0		9	1.11	0.33	1-2	
Moss	21	3.19	1.12	2-5	9	2.44	0.88	1-4	
Bare ground	21	1.29	0.56	1-3	9	1.33	0.71	1-3	
Litter depth (cm)	21	3.97	1.36	1.8-6.5	9	4.12	1.63	2-6.6	
Aspect (degrees)	21	144.7	75.6	40-315	9	150.11	49.54	89-220	
Slope (degrees)	15	20.93	12.83	8-46	9	19.11	5.78	13-31	
Average Top Canopy Height (m)	21	4.26	2.13	2-9.8	9	8.72	2.73	3.15-12.5	0.001
Canopy Cover >5m (%)	15	16.84	25.44	0-86	9	58.43	34.48	6.76-95.68	0.012
Total Canopy Cover (%)	15	76.46	24.4	13.26-99.84	9	87.68	12.42	65.76-99.84	

[a] Index of percent coverage: 1=0-4, 2=5-24, 3=25-49, 4=50-74, 5=75-94, 6=95-100.

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Report of Collecting Activities

Walter G. Ellison

I am studying molecular geographic variation in Bicknell's and Gray-cheeked thrushes to determine whether genetic interchange is interrupted among distant populations of these highly migratory birds. In particular the subdivided distribution of Bicknell's Thrush, a bird limited to the upper elevations of mountains over much of its range, suggests the possibility of isolation of populations and the fixation of genetic differences among them via drift. However migration provides an avenue for sufficient gene flow to genetically homogenize populations. I intend to provide evidence that gene flow has been aided by migration or is of such recent vintage that Bicknell's Thrush populations represent a single management unit. To answer this question I am using molecular techniques including the polymerase chain reaction (PCR) and DNA cycle sequencing to identify mitochondrial DNA (mtDNA) haplotypes, and characterize their distribution among populations. Because my sample of Gray-cheeked Thrushes is small (n=5) I use these birds as an outgroup to allow ingroup comparison of Bicknell's Thrush sequences.

I capture birds lured to mist nets by playback of aggressive male vocalizations. I then remove 100 µl of blood from the medial wing vein, and release the bird essentially unharmed. I extract DNA from each sample with a protocol employing LiCl and chloroform:isoamyl alcohol. I amplify targeted regions of mtDNA with PCR and sequence the resulting products with an Applied Biosystems automated sequencer. I analyze the resulting sequences with a sequence alignment program, the phylogenetic inference program PAUP, and the population genetic program AMOVA (analysis of molecular variance).

I worked in Mount Mansfield State Forest from 2 to 6 June 1993, 26 July 1993, and from 1 to 3 June 1994. On these occasions I worked closely with fellow Bicknell's Thrush researcher Christopher C. Rimmer of the Vermont Institute of Natural Science, Woodstock, Vermont. I have samples from 11 birds on Mount Mansfield, four from 1993 and seven from 1994. I collected samples on Shrewsbury Peak, Mendon on 17 and 19 June 1993, and on 10 June 1994 capturing four birds in 1993 and one in 1994. I have several encounters with sampled birds in subsequent years indicating that birds suffer no ill effects from my sampling. I also possess samples from 14 birds in the Adirondacks, 11 from the White Mountains (10 from the Presidential Range), and 18 birds from the Catskills.

I have obtained 430 base pairs of sequence in the mtDNA control region (a.k.a. the D-loop) from 15 Bicknell's Thrushes and three Gray-cheeked Thrushes. I have identified nine haplotypes in Bicknell's Thrush, and two in Gray-cheeked Thrush. The shared haplotype in Gray-cheeked Thrush was found in a bird from central Labrador and another from the Northern Peninsula of Newfoundland. My data suggest no mtDNA basis for the current subspecific distinction between Newfoundland and eastern continental Gray-cheeked Thrushes. In Bicknell's Thrush there are two poorly differentiated groupings with broad geographic affinities. One group represents a series of haplotypes from the White Mountains (New Hampshire), the southern Green Mountains (Vermont), and the Catskill Mountains (southeastern New York). The second group consists of haplotypes from Mount Mansfield (Vermont) and the Adirondacks (northern New York). Gene flow appears to be high within these geographic groups, but I need to subject these preliminary data to population genetic analysis before I could make a more conclusive statement about putative gene flow.

Bicknell's Thrushes Sampled on Mt. Mansfield and Shrewsbury Peak
June 1993 and June 1994

Walter G. Ellison - Principal Investigator

<u>1993</u>

Location	USFWS Band Number	Collection Date
Mt. Mansfield	1471-4917	2 June
" "	1161-17715	3 June
" "	1161-17716	4 June
" "	1161-17717	5 June
Shrewsbury Peak	1161-17722	17 June
" "	1161-17723	17 June
" "	1161-17724	19 June
" "	1161-17725	19 June

<u>1994</u>

Mt. Mansfield	1471-7932	1 June
" "	1471-7921	1 June
" "	1471-7901	2 June
" "	1471-7916	2 June
" "	1471-7937	2 June
" "	1471-7904	3 June
" "	1471-7938	3 June
" "	1161-17742	10 June

Terrestrial Flora

Annual Assessment of Forest Health in the Lye Brook Wilderness Area 1996

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

Cooperators

Brent Teillon, Barbara Burns, Jay Lackey, Brad Greenough, Ron Wells, Department of Forests, Parks & Recreation; Susan Cox, USDA Forest Service-Forest Health Protection.

Abstract

Most indicators of forest health measured in 1996 showed an improvement in tree condition from the previous year. At the 1400 foot elevation plots, overstory tree dieback remains low (6.1%), crown density has varied little (50.3%) and foliage was more abundant than in 1995, with average foliage transparency improving from 23% to 18%. At the 2200 foot elevation plots, overstory tree dieback remains very low (5.1%), crown density and foliage transparency both improved substantially from 1995.

Black cherry at the 1400 foot elevation plots continues to show high average dieback (12.5%), high foliage transparency (26.5%), and reduced crown density (38%). Other overstory tree species rebounded from dry conditions of 1995 and show improvements in most tree health indicators.

Damages to trees from insects, diseases, weather and other factors are a natural part of forests. Detecting and recording those damages that are significant to tree health and survival provides a information that can explain unexpected declines in tree health. Injury and damages present on tree boles, exposed roots, crownstem, branches and foliage are recorded when above a threshold established as "significant to tree health".

In 1996, nearly 40% of overstory red maple and black cherry trees on plots had visible damage symptoms. Fewer damages were detected on paper birch (20%), balsam fir (8%) and red spruce (5%). The most common type of damage was indicators of internal decay on tree boles.

Introduction

Annual assessments of crown condition, mortality, and damage are conducted on permanent plots located at two elevations, 1400 and 2300 feet. The purpose of these plots is to document changes in tree health over time and to 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) (Tallent-Halsell, N.G. 1994)are used to represent forest health in the Lye Brook Wilderness Area. Data collected to assess forest health includes mensuration, crown condition and tree damages. 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. An additional high elevation plot was added in 1995 to improve the hardwood sample size. These elevations were chosen for comparison with plots on Mt. Mansfield, the northern Vermont VForEM study site.

Results and Discussion

Most indicators of forest health measured in 1996 showed an improvement in tree condition from the previous year. At the 1400 foot elevation plots, overstory tree dieback remains low (6.1%)[Table 1], crown density has varied little (50.3%)[Table 2], foliage was more abundant than in 1995, with average foliage transparency improving from 23% to 18% (Table 3), and the percentage of trees in a healthy condition increased to 94%.. At the 2200 foot elevation plots, overstory tree dieback remains very low (5.1%) [Table 1], crown density and foliage transparency both improved substantially from 1995 (Table 2 & 3), but there was a slight decrease in the percentage of trees in a healthy condition, from 97.6 to 92.7%, 1995 and 1996, respectively.

Black cherry at the 1400 foot elevation plots continues to show high average dieback (12.5%), high foliage transparency (26.5%), and reduced crown density (38%). Only 80% of the trees are in a healthy condition. Other overstory tree species rebounded from dry conditions of 1995 and show improvements in most tree health indicators.

Damages to trees from insects, diseases, weather and other factors are a natural part of forests. Detecting and recording those damages that are significant to tree health and survival provides a information that can explain unexpected declines in tree health. Injury and damages present on tree boles, exposed roots, crownstem, branches and foliage are recorded when above a threshold established as "significant to tree health".

In 1996, nearly 40% of overstory red maple and black cherry trees on plots had visible damage symptoms (Table 5). Fewer damages were detected on paper birch (20%), balsam fir (8%) and red spruce (5%). The most common type of damage was indicators of internal decay on tree boles.

Table 1. Trend in average crown dieback measurements for overstory trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area, 1994 - 1996.

Species	Elevation	1994	1995	1996
Balsam Fir	2200	1.0	1.8	2.9
Black Cherry	1400	6.5	12.5	12.5
Paper Birch	1400	*	*	4.5
Red Maple	1400	3.8	5.4	5.4
	2200	6.0	6.4	6.9
Red Spruce	2200	1.0	2.6	4.3
All Species	1400	5.2	7.1	6.7
	2200	3.4	4.2	5.1

* Sample size <10 trees.

Table 2. Trend in average crown density measurements for overstory trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area, 1994 - 1996.

Species	Elevation	1994	1995	1996
Balsam Fir	2200	48.3	44.2	50.6
Black Cherry	1400	45.5	42.5	38
Paper Birch	1400	*	*	54
Red Maple	1400	55.2	52.3	51.5
	2200	46.7	50.2	56.4
Red Spruce	2200	51.0	51.4	58.6
All Species	1400	53.0	52.4	50.3
	2200	48.3	48.7	55.2

Table 3. Trend in average foliage transparency measurements for overstory trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area, 1994 - 1996. *indicates < 10 trees

Species	Elevation	1994	1995	1996
Balsam Fir	2200	18.3	24.4	16.7
Black Cherry	1400	25	*	26.5
Paper Birch	1400	*	*	20.5
Red Maple	1400	14.2	19.6	15
	2200	20.9	24.8	16.0
Red Spruce	2200	16.6	22.1	12.9
All Species	1400	17.0	23.1	18.2
	2200	18.9	24.1	15.3

Table 4. Trend in percent of trees healthy for overstory trees growing on monitoring plots at different elevations in the Lye Brook Wilderness Area, 1994 - 1996. *indicates < 10 trees

Species	Elevation	1994	1995	1996
Balsam Fir	2200	100	100	91.7
Black Cherry	1400	100	*	80
Paper Birch	1400	*	*	100
Red Maple	1400	100	100	100
	2200	93.1	96.8	90
Red Spruce	2200	100	100	100
All Species	1400	98.1	92.2	94.0
	2200	98.6	97.6	92.7

Table 5. Percent of overstory trees affected by different types of tree damages in 1996.

Species	Elevation	Percent of trees and type of damage
Balsam Fir	2200	4 % with resinosis from bark beetles 4 % with broken or dead crownstem
Black Cherry	1400	10% with cankers 30% with indicators of decay
Paper Birch	1400	10% with indicators of decay 10% with open wounds (size > 20% of circumference)
Red Maple	1400	30% with indicators of decay 4% with open wounds 4% with xxx foliage
	2200	6% with cankers 2% with indicators of decay 6% with open wounds 9% with xxx foliage
Red Spruce	2200	5% with open wounds

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ANNUAL ASSESSMENT OF FOREST HEALTH ON MOUNT MANSFIELD 1996

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

Cooperators

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

Abstract

Forest health monitoring plots on Mount Mansfield show denser than usual foliage, especially on sugar maple and other hardwoods. This reflects good growing conditions this year.

Past stress events produced increases in dieback on trees measured at 2200 and 3800 foot elevations. Here, yellow birch (2200 ft.) and balsam fir (3800 ft.) showed trends towards increasing dieback. No new mortality was recorded. Trees at 3800 ft. continue in generally poor condition, exhibiting mechanical injuries typical of ice and wind damage: broken tops, broken branches and boles, and uprooted trees. Yellow birch trees at 2200 ft. continue to be affected by light defoliation by an unknown shot-hole defoliator affecting 74% of trees.

Changes in tree condition over a 5 year period are discussed. A range of changes have occurred, from 13% of healthy trees declining, to 50% of severely declining trees showing signs of improvment.

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 trees examined as part of the North American Maple Project continue to maintain a generally healthy condition. Over 95% of overstory sugar maples were considered healthy in 1996. Other indicators of health likewise showed signs of good condition: average dieback was 6.9% and average foliage transparency was 9.5. There was no new mortality in 1996.

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.

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
1995	7.3	11.3	0	95.8
1996	6.9	9.5	0	95.7

Forest Health Plot Methods

Eight permanent plots are used to monitor the health of forests on the west slope of Mount Mansfield, annually. 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, paired plots are located in each of the two watersheds: Browns River and Stevensville Brook. In the Stevensville Brook watershed, no canopy trees are present at the 3800 foot elevation, so the paired plots at this elevation are in the Browns River watershed. English units are used for data collection and analysis.

In 1996, annual averages for dieback and healthy trees were reanalyzed. In previous years, subplot averages were used to then calculate elevational averages. This years analysis was conducted strictly on an elevational basis.

Forest Health Plot Results and Discussion

A trend towards increasing dieback was observed on trees surveyed at 2200 and 3800 foot elevations (Table 2a). Yellow birch at 2200 feet and balsam fir at 3800 feet increased average dieback from 1995 to 1996. But when compared to the 4 year baseline, there was no significant difference between dieback in 1996 and the baseline (Figure 1). Other indicators of crown condition, foliage transparency and crown density (Figure 2-3) show good foliage density, reflecting this year's favorable growing conditions. Despite current year growing conditions, trees at 3800 feet remain in poor condition. Percentage of healthy trees is low (57.1%), and average dieback is high (21.7%). The types of damage symptoms include dead terminals (42% of trees), broken branches (16%), indicators of decay (19%) and broken bole or roots (9%), all evidence of harsh winter conditions that feature ice, snow and high winds (Table 3). There was no new mortality on any of the plots in 1996.

An examination of the fate of trees after five years (1992-1996) shows a combination of recovery and decline (Figure 4). In 1992, the condition of overstory trees in different dieback categories showed 77.3% had 0-10% dieback (healthy), 21.6% had 15-50% dieback (moderate decline) and 1.1% had >50% dieback (severe decline). Of the healthy trees in 1992, 87% were still healthy in 1996, 12% were moderately declining and 1% had died. Conversely, 26% of the moderately declining trees in 1992 had recovered to a healthy condition after 5 years, while 12% were severely declining or dead. Of the 2 trees considered severely declining in 1992, one remained in this category, while the other improved slightly.

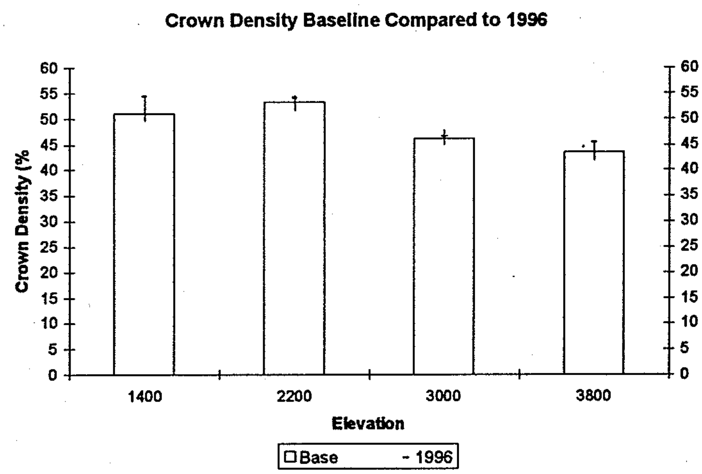
Table 2a. Average dieback for overstory trees of species growing on monitoring plots at different elevations on Mt. Mansfield from 1992 through 1996.

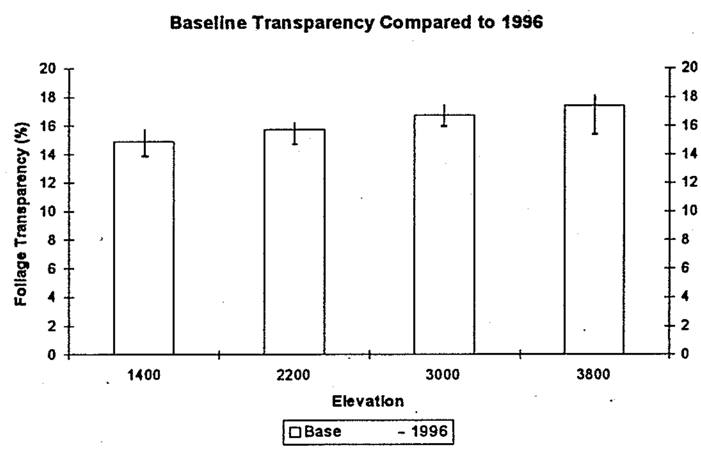
SPECIES	ELEVATION	1992 DIEBACK (%)	1993 DIEBACK (%)	1994 DIEBACK (%)	1995 DIEBACK (%)	1996 DIEBACK (%)
BALSAM FIR	3000	5.6	7.3	10.4	10	10
	3800	18.8	20.5	20.9	16.9	21.9
SUGAR MAPLE	1400	3.9	5.6	5.9	5.0	5.3
YELLOW BIRCH	2200	6.4	6.8	6.4	6.4	7.5
PAPER BIRCH	3000	9.8	8.8	8	7.6	8.2
ALL SPECIES	1400	5.3	6.0	5.4	5.3	5.6
	2200	8.6	9.2	8.2	9.0	10.2
	3000	9.0	8.5	9.3	9.1	9.3
	3800	18.8	20.2	20.7	16.7	21.7

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 5 year period, 1992 through 1996.

SPECIES	ELEVATION	1992 HEALTHY (%)	1993 HEALTHY (%)	1994 HEALTHY (%)	1995 HEALTHY (%)	1996 HEALTHY (%)
BALSAM FIR	3000	100	91.3	88	88	95.6
	3800	54.0	60.6	56.5	64.2	56.7
SUGAR MAPLE	1400	100	100	100	100	100
YELLOW BIRCH	2200	94.7	94.7	100	100	100
PAPER BIRCH	3000	88	91.7	96	92	96
ALL SPECIES	1400	97.0	100	100	100	100
	2200	90.6	90.6	96.9	93.8	87.5
	3000	89.8	88.1	91.7	90	94.8
	3800	54.0	61.6	57.7	64.7	57.1

Figures 1-3. Overstory tree health in 1996 compared to 4 year averages (baseline) for survey plots at 4 elevations on Mount Mansfield. Tree health indicators used are crown dieback, foliage transparency and crown density.





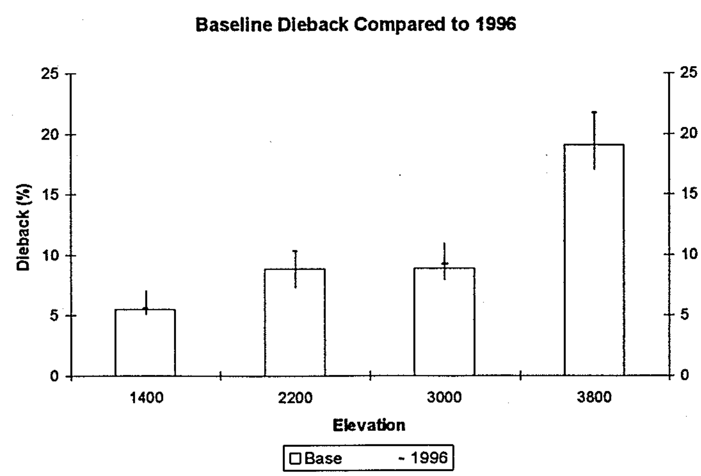


Figure 4. Condition of live overstory trees on Mount Mansfield after five years (1992 to 1996. Trees are grouped into 3 condition classes: healthy trees (0-10% dieback), moderately declining trees (15-50% dieback) and severely declining trees (>50% dieback).

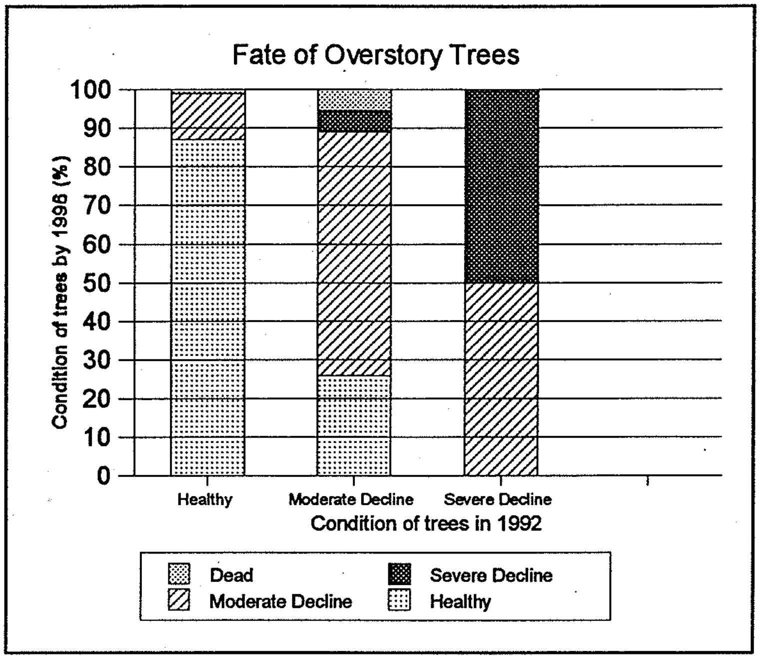


Table 3. Percent of trees affected by significant damages. Minimum thresholds for each type of damage are those considered significant for tree growth and vigor. Protocols follow those of the National Forest Health Monitoring Program.

Species (elevation)	Percent of trees and type of damage
Balsam Fir (3000 ft.)	5 % with dead terminal 5 % with discolored foliage (30% of foliage)
Balsam Fir (3800 ft.)	19 % with indicator of decay 42 % with dead terminal 16 % with broken branches 9 % with broken bole or roots
Sugar Maple (1400 ft.)	15 % with indicator of decay
Yellow Birch (2200 ft.)	42 % with indicator of decay 5 % with open wound (size > 20% of circumference) 74 % with light defoliation by unknown shot hole defoliator (<30% defoliation)
Paper Birch (3000 ft.)	43 % with indicator of decay 22 % with cankers

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Forest damage assessment at Mt. Mansfield and the Lye Brook Wilderness Area

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Abstract

Annual monitoring of pest population trends and tree damage is conducted on a statewide basis to understand trends in stress agent occurrence in relation to forest health. More recently, concerns about the role of air pollutants in forest health have prompted monitoring of plants sensitive to ground level ozone.

Monitoring efforts on Mount Mansfield include conducting aerial surveys to detect areas of defoliation or decline, ground plot evaluations of tree damages, and monitoring of forest pest population trends. At the Lye Brook Wilderness Area (LBW) aerial surveys and ground plot evaluations are used to detect defoliation and declines.

The objective of this monitoring effort is to detect trends in the populations of major insect pests, and to document the occurrence, location and severity of damage to the forests on Mount Mansfield and the LBW.

At Mount Mansfield, populations of most major forest insect pests remained low. Pear thrips adult populations increased, and light defoliation was observed on scattered regeneration and trees. Spruce budworm populations at the high elevation site remain high, exceeding other sites statewide, but no detectable defoliation has resulted. Aerial survey results revealed persistent birch leaf miner and birch decline on the northwest part of the study area, and birch defoliation in areas in Ranch Valley on the east slope of the mountain. Hardwood decline was mapped in Ranch Valley adjacent to the toll road at high and low elevations.

In the LBW, large areas of birch leaf miner damage and spruce winter injury were mapped from aerial surveys. A small area of hardwood breakage was also recorded, probably associated with heavy winds in July of 1995.

Surveys of ozone sensitive bioindicator plants continue to detect plants with symptoms of ozone injury. Despite lower than usual ozone exposures, especially at Underhill, abundant precipitation favored ozone uptake by plants, resulting in injury symptoms.

Introduction

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

Monitoring efforts on Mount Mansfield include conducting aerial surveys to detect areas of defoliation or decline, ground plot evaluations of tree damages, and monitoring of forest pest population trends. At the Lye Brook Wilderness Area (LBW) aerial surveys and ground plot evaluations are used to detect defoliation and declines.

The objective of this monitoring effort is to detect trends in the populations of major insect pests, and to document the occurrence, location, and severity of damage to the forests on Mount Mansfield and the LBW from detectable stress agents.

Mount Mansfield Monitoring 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), 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 aerial survey.

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 accordance with that of other statewide surveys for these pests (Teillon et al, 1996).

Each trap type is deployed during the adult moth flight period. FTC traps are active between June 10 and August 16. SHL traps are placed out between May 19 and July 29. FHL catches are made from July 10 to October 31. SBW traps are deployed between June 18 and August 16. Trap catches were returned to the Vermont Department of Forests, Parks & Recreation (FPR) Forest Biology Laboratory in Waterbury for identification and counting of target and non-target species.

PEAR THRIPS

Pear thrips 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 Proctor Maple Research Center [1360 ft. (415 m) elevation]. Additional soil sample plots were established in 1995 at 3 elevations in the Stevensville Brook watershed as part of the planned Forest Management Study. Here, the sampling transects are located at 1500, 2000 and 2500' elevations off the Butler Lodge Trail.

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 at each sampling site are used as reference points for soil sampling, using a bulb planter collecting tool, and in the following spring are assessed for defoliation.

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 conducted at the VT FPR Forest Biology Laboratory.

Mount Mansfield and Lye Brook Wilderness Area Methods

AERIAL SURVEY OF FOREST DAMAGE

Aerial surveys conducted by trained FPR staff during the summer months are used 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, severity and possible cause of injury. Procedures are standardized statewide and remeasurement is conducted on 10% of the area evaluated (Teillon et al, 1996). Information is later digitized into a Geographic Information System.

OZONE BIOINDICATOR PLANTS

Plants sensitive to ground level ozone are surveyed as part of the National Forest Health Monitoring Program (NFHM)(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, blackberry, white ash and dogbane. Symptoms are verified by a regional expert in ozone injury identification as part of the NFHM. For Mount Mansfield, plant evaluations are conducted at the Proctor Maple Research Center in the open field where the state ozone monitor is located. The availability of large (>3 acres) opening containing plants sensitive to ozone have not been possible at LBW. A location in Rupert (Bennington County) is used to represent exposure and injury for the southern Vermont site. Ozone exposure data is provided by the Vermont Air Pollution Control Division for the two Vermont sites: Bennington and Underhill.

Mount Mansfield
Results And Discussion

Insect populations of forest tent caterpillar and spring hemlock looper remained below detection limits, as has been the case in the past 4-5 years (Table 1). Fall hemlock looper populations continue to thrive at the two lower elevation sites, but no noticeable defoliation has been observed. Spruce budworm populations at the 3800' elevation were the highest of all the statewide monitoring sites, but was not associated with noticeable defoliation. Pear thrips populations remained very low in the soil assessment (Table 2), but the adult traps showed an increasing population (Table 1). Light defoliation was observed on scattered regeneration and trees.

Mount Mansfield and Lye Brook Wilderness Area
Results And Discussion

Aerial surveys over Mount Mansfield detected persistent areas of birch leaf miner, also associated with birch decline, on the west slope of the mountain (Figure 1). On the east slope in Ranch Valley, hardwood decline areas and patches of birch leaf miner were mapped.

The Lye Brook Wilderness Area aerial survey detected large areas of birch leaf miner defoliation, especially on the west slopes (Figure 2). Spruce winter injury was mapped in areas towards the southwest corner of the site, and one patch of breakage on hardwoods was mapped in the northwest corner, probably associated with localized heavy winds during July 1995.

Plants sensitive to ozone showed symptoms of injury at both the Underhill and Bennington County (Rupert) sites, despite a large difference in ozone exposure, as expressed as the cumulative dose of all hourly ozone greater than 60 ppb over a 24 hour period (Figure 3). The severity of plant injury at the Underhill site averaged 3 (26-50% of leaf area affected) on a scale of 0-5. The Bennington County site bioindicator plant injury was only slightly less severe. Abundant precipitation this year may have favored ozone uptake, despite relatively low exposure levels at Underhill.

Acknowledgments

Aerial survey and ground plot data collection was conducted by dedicated Forest Resource Protection staff. GIS maps of aerial survey information was provided by Tom Luther of the USDA Forest Service, Northeastern Area State & Private Forestry in Durham, NH. Ozone data has been generously provided by the Vermont Air Pollution Control Division.

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Table 1. Survey results on five forest pests monitored on Mount Mansfield from 1991 to 1996. Results are in average population counted unless otherwise indicated.

Target Pest	Survey Type	Elevation	1991	1992	1993	1994	1995	1996
Forest Tent Caterpillar	Pheromone traps	1400'	0	0	0	0	0	0
		2200'		0	0	0	0	0
		3800'		0	0	0	0	0
Spring Hemlock Looper	Pheromone traps	1400'		0	0	0	0	0
		2200'		0	0	0	0	0
		3800'		-	0	0	0	0
Fall Hemlock Looper	Pheromone traps	1400'		325	80	123	111	49
		2200'		521	-	133	28	232
		3800'		41	0	0	0	1
Spruce Budworm	Pheromone traps	1400'	19.7	29.0	16.0	53.0	11.7	30.3
		2200'		5.0	6.3	16.0	5.0	9.7
		3800'		2.3	1.7	18.7	25.7	49.0
Pear Thrips	Adult sticky traps	1400'	8	313	1472	4	37	111

Table 2. Pear thrips soil populations and resulting damage to sugar maple foliage at the Proctor Maple Research Center at 1400' on Mount Mansfield from 1989 through 1996. 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
1995	.1	NONE	6.0	11.0	NONE	NONE
1996	.1	LIGHT	10.0	11.25	LIGHT	LIGHT

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

Figure 1. Forest damage mapped on Mt. Mansfield, 1996.

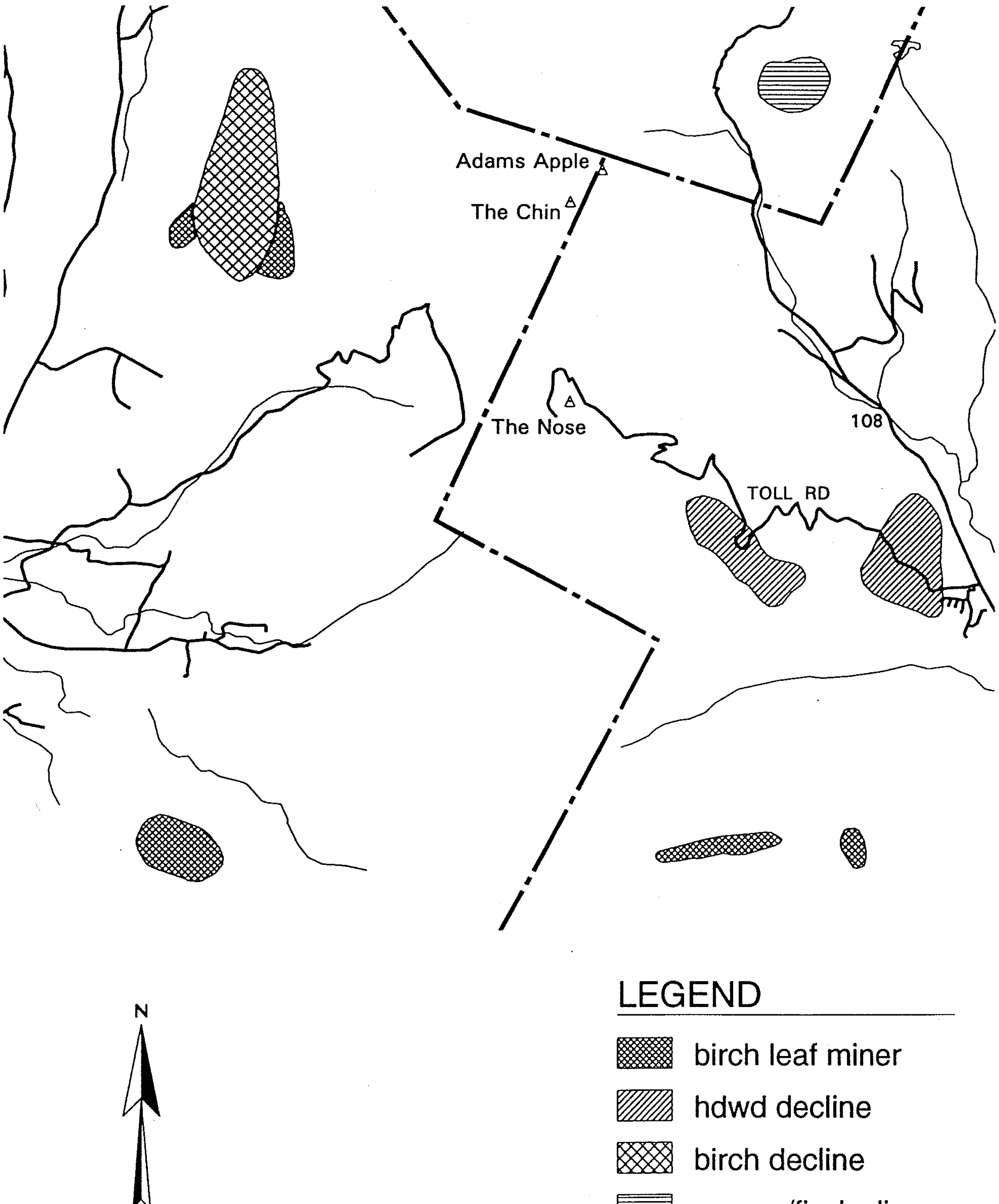

Figure 2. Forest damage mapped in Lye Brook Wilderness Area, 1996.

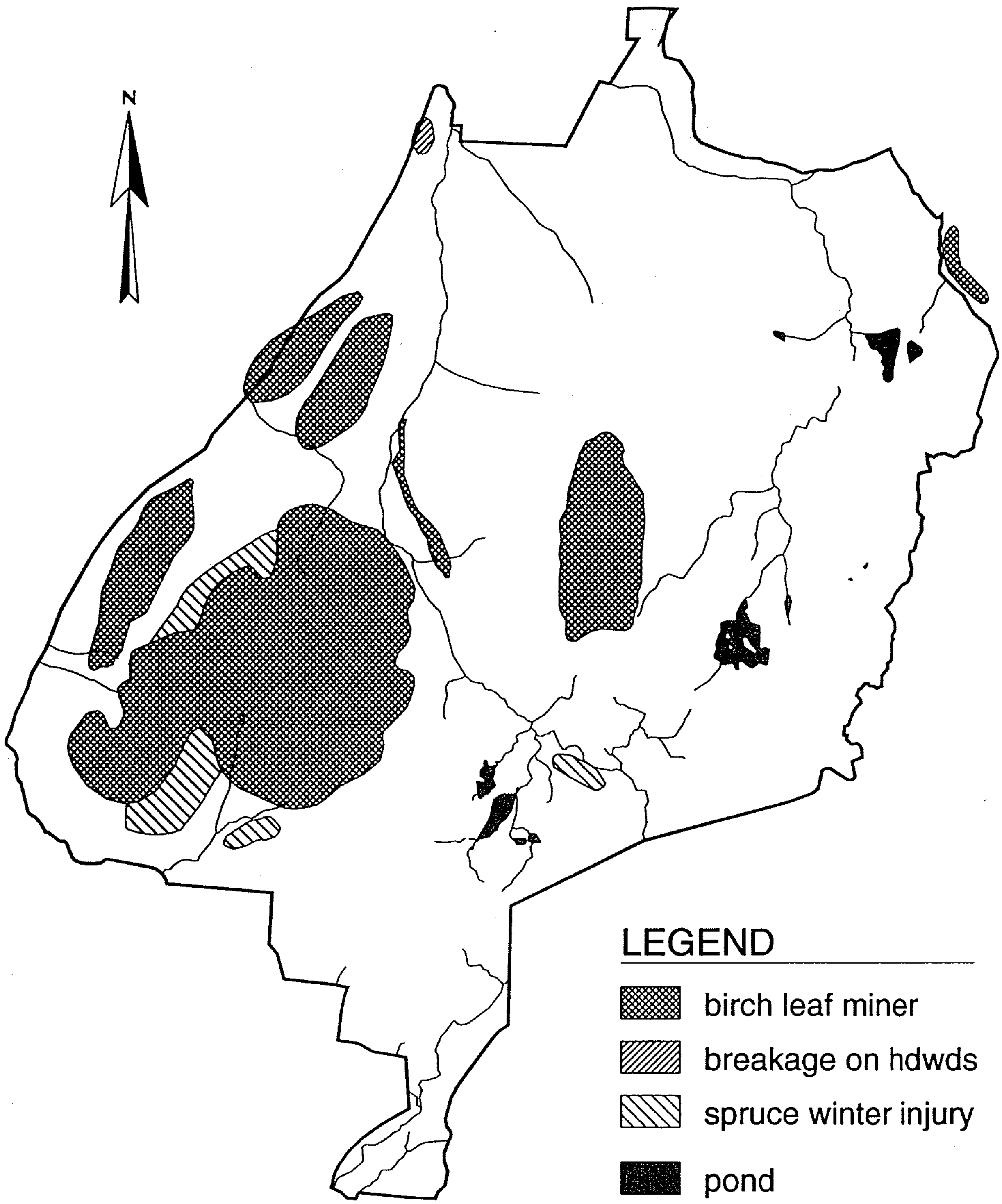

Figure 3. Weekly cumulative ozone exposures (expressed as cumulative sum60 ozone based on 24 hour period) representing the Underhill (Mount Mansfield) and Bennington (Lye Brook) study sites compared with injury to ozone sensitive bioindicator plants surveyed at Underhill and Rupert (Bennington County). Plant injury severity is based on a 0 - 5 rating system where 0=no injury, 1=1-6% of leaf area affected ,2=7-25%, 3=26-50%, 4=51-75%, and 5=>75%. Despite lower exposures at Underhill, both sites show moderate plant injury.