Progress Report on the Long-term Ecosystem Monitoring Project (LEMP):

2008-2011 Sampling Seasons

Green Mountain National Forest, Vermont
United States Forest Service

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1) Introduction

1.1) *Abstract*

The Long-term Ecosystem Monitoring Project (LEMP) is a 50-year monitoring effort that examines the long-term effects of broad-scale environmental changes--particularly changes in climate, air quality, soil health, and vegetation. Plots are located on the Green Mountain National Forest (GMNF) in areas with minimal evidence of past anthropogenic disturbance. Monitoring plots are designed to cover a minimum 50-year period, with monitoring data collected during the field season of years zero (2008, 2009, 2010, and 2011), 10, 20, 30, 40, and 50. Monitoring of vegetation, trees and saplings, soil, lichens, and down woody material occurs during each sampling session. This monitoring will help us to understand change in forest ecosystems over time, in response to environmental factors such as acid deposition, climate change, and non-native invasive species. During 2008, 2009, 2010 and 2011, a total of 20 LEMP plots were established—5 per sampling season. These plots ranged throughout the GMNF and throughout various forest and soil types.

1.2) *Purpose and Need*

Forest managers recognize that a number of broad-scale factors such as atmospheric deposition, climate change, and invasion of non-native plant species have the potential to introduce long-term changes into forested environments. Baseline and long-term monitoring data is needed to track these changes so that land managers can respond by adapting their forest management decisions and strategies.

1.3) *Background*

To address these monitoring and information needs, the Green Mountain National Forest and the Forest Service Northern Research Station joined forces to co-lead the LEMP. Led by Nancy Burt, GMNF Soil Scientist, and Brian Keel, GMNF Monitoring and Research Coordinator, a committee of partners convened in 2007 to assist designing the project. This committee was made up of representatives from the Forest Service, Natural Resource Conservation Service, State of Vermont, and the Vermont Monitoring Cooperative (see list of project participants below). The committee helped the FS to:

- Clarify the scope and objectives of the project
- Identify plot citing criteria
- Decide what resource data would be collected and how frequently
- Establish data collection protocols

The committee was careful to select data collection protocols that would produce data comparable to similar long-term monitoring efforts in New England and New York. The project was also designed so that plots would accommodate ancillary studies, both long and short term. These ancillary projects could provide more detailed information about specific or additional parameters.

1.4) *Partnerships*

Partnerships have been valuable in this project throughout the design, sampling, and analysis phases. The Northern Research Station co-leads the LEMP, providing guidance on project design and analysis of the soil samples. The Vermont Youth Conservation Corps dug soil pits during the 2009-2011 seasons. In addition, the Natural Resources Conservation Service supplied a soil scientist to describe the soil pits and collect soil samples for each plot. Several other partners served as consultants during project design and planning.

A full list of project participants follows in **Table A:**

Entity	Project Participant and Title	Role	Contact Information as of 2011

Green Mountain National Forest (GMNF)	Brian Keel, Ph.D., Research and Monitoring Coordinator	GMNF Co-leader	2538 Depot Street Manchester Center, VT 05255 (802)362-2307 bkeel@fs.fed.us
	Nancy Burt, Soil Scientist	GMNF Co-leader	231 North Main Street Rutland, VT 05701 (802)747-6742 nburt@fs.fed.us
	Diane Burbank, Ecologist	Technical guidance, vegetation sampling	1007 Route 7 South Middlebury, VT 05753 (802) 388-4362 x116 dburbank@fs.fed.us
	Dayle Ann Stratton, Volunteer	Project planning	Not available
	Mary Beth Dewey, Biological Technician	Project implementation 2009-2011; report writing	231 North Main Street Rutland, VT 05701 (802)287-6741 marybethdewey@fs.fed.us
Northern Research Station (NRS)	Chris Eagar, Research Ecologist	NRS Co-leader	Louis C. Wyman Forestry Sciences Laboratory, 271 Mast Road Durham, N.H., 03824-0640 (603)868-7636 ceagar@fs.fed.us
	Scott W. Bailey, Research Geologist and Adjunct Professor	Technical guidance	USDA Forest Service, Northern Research Station Center for the Environment, Plymouth State University MSC 63, 213 Boyd Science Center Plymouth, NH 03264-1595 (603) 535-3262 swbailey@fs.fed.us
	Paul Schaberg, Research Plant Physiologist	Technical guidance	George D. Aiken Forestry Sciences Laboratory, 705 Spear Street, South Burlington, VT, 05403-6102 (802)951-6771 pschaberg@fs.fed.us
Natural Resource Conservation Service (NRCS)	Thom Villars, Soil Scientist and Soil Survey Project Leader	Technical guidance, soil descriptions and sampling	28 Farmvu Drive, White River Junction, VT 05001 (802) 295-7942, Ext. 24 thomas.villars@vt.usda.gov
State of Vermont, Agency of Natural Resources, Dept. of Forests, Parks and Recreation	Sandra Wilmot, Forest Health Specialist	Technical guidance	29 Sunset Drive, Suite 1 Morrisville, VT 05661-8331 (802)888-5733 sandy.wilmot@state.vt.us
Vermont Monitoring Cooperative	Sean Lawson Monitoring Coordinator	Technical guidance	Department of Forests, Parks, and Rec. 111 West St. Essex Junction, VT 05452-4695 (802)879-5683 sean.lawson@state.vt.us

Table A. *LEMP Participants*

1.5) *Companion Projects*

LEMP project objectives and protocols were designed to produce data comparable to similar soil and vegetative community monitoring projects in eastern New York and New England. These "companion" projects are listed in **Table B**. Companion projects used FIA protocols (with minor modifications) for collection of vegetation and tree condition data and NRCS protocols for soil pit descriptions. All projects included soil sampling by horizon and/or sampling at predetermined depths in the A, B and C horizons. With the exception of the monitoring project led by the University of Vermont, all project plots were located in areas with minimal anthropogenic disturbance.

Companion Monitoring Projects

Project Location	**Lead(s)**	**Contact Person(s)**	**Brief Description**
White Mountain National Forest (WMNF) in New Hampshire	USDA-Forest Service, White Mountain National Forest (WMNF) and the Northern Research Station	**Scott W. Bailey,** Research Geologist and Adjunct Professor, USDA Forest Service, Northern Research Station Center for the Environment, Plymouth State University; **Robert Colter**, Soil Scientist and Ecologist, White Mountain National Forest	Forty plots were established on the WMNF between *2004 and 2006.*
Lye Brook Wilderness and Mount Mansfield in Vermont	Vermont Monitoring Cooperative	**Sean Larson,** Monitoring Coordinator, Vermont Monitoring Cooperative; **Nancy Burt,** GMNF Soil Scientist; **Thom Villars,** Soil Scientist, NRCS.	Five plots designed for periodic data collection over a period of 200 years.
Throughout Vermont	University of Vermont	**Don Ross,** Research Associate Professor, University of Vermont	Approximately 24 plots scattered through Vermont, located on lands with planned harvests. Established in 2008-2009.
Adirondacks of New York	Northern Research Station	**Scott W. Bailey,** USFS Research Geologist and Adjunct Professor, Plymouth State University	

Table B. *Projects similar to the LEMP in objectives and protocols*.

2) Methods

2.1) *Study Areas*

The fifteen plots currently established are located throughout the Green Mountain National Forest. Eight plots are in federally designated Wilderness areas, three are in a National Recreation Area, three are in Ecological Special Areas, and one is in National Forest at the edge of a Wilderness Area. Plots are located in management areas where anthropogenic vegetative manipulation is not expected. In this way, forest conditions reflect, as close as possible, "reference" or undisturbed conditions. All plots are located where visitors are unlikely to traverse. There is nothing to attract visitors to the vicinity of the plots. Any visual impacts have been and will continue to be short term.

Please refer to **Table C** for more detailed plot location information.

Locations of Plots Established 2008-2011

Plot Name	Town	Area Type	Area Name
1) Hancock Branch	Hancock	Forest (Wilderness edge)	Breadloaf (Wilderness Area)
2) Little Rock Pond	Wallingford	National Recreation Area	Robert T. Stafford White Rocks
3) Forest Road 60	Danby	National Recreation Area	Robert T. Stafford White Rocks
4) Sunderland	Sunderland	Wilderness	Lye Brook
5) French Hollow	Winhall	Ecological Special Area (ESA)	French Hollow
6) Lake Brook	Mount Tabor	Wilderness	Peru Peak
7) Three Shanties Knoll	Mount Tabor	Wilderness	Peru Peak
8) Mad Tom	Peru	Wilderness	Peru Peak
9) Maple Hill	Woodford	Wilderness	Glastenbury
10) Camp Meadows	Woodford	Wilderness	George D. Aiken
11) Leicester Oak	Leicester	National Recreation Area	Moosalamoo
12) Bingo Brook	Rochester	Wilderness	Joseph Battell
13) Bryant Mountain Hollow	Salisbury	ESA & Escarpment	Bryant Mtn. Hollow (ESA)
14) Gilmore Pond	Lincoln	Wilderness	Bristol Cliffs
15) Mount Abraham	Lincoln	Alpine/Subalpine Special Area	N/A
16) Greenwall Shelter	Wallingford	National Recreation Area	Robert T. Stafford White Rocks
17) Wallingford Pond	Wallingford	National Recreation Area	Robert T. Stafford White Rocks
18) Griffith Lake	Peru	Wilderness	Big Branch
19) Castle Brook	Glastenbury	Wilderness	Glastenbury
20) Yaw Pond	Woodford	Wilderness	George D. Aiken

Table C. *Locations of Established Plots*.

Plots were located based on a combination of remote and field analysis. Several criteria were used to determine appropriate plot locations. The LEMP focuses on monitoring the natural progression of locally undisturbed areas faced with global and regional impacts such as climate change and acid deposition. Therefore, the plots must not have been disturbed in the recent past and must not be disturbed in the future. Attention was focused on forests located in Wilderness Areas because they would not be harvested by humans in the foreseeable future. Other criteria considered during plot selection were accessibility and sampling ease. Areas with a shorter hiking distance and those accessible by trail were favored. Therefore, some areas with long hiking distances, steep terrain or standing water were disqualified.

2.1.1) Plot Location Parameters

Prior to locating plots in the field, project leaders and cooperators agreed to a list of parameters to be met on all plots. These parameters were designed to ensure that plots represent the dominant soil and vegetation conditions on the GMNF and that establishment and sampling are logistically feasible. Some parameters were modified slightly because they proved to be too restrictive in the field. The parameters specify that plots should be located on lands with the following attributes:

1) Minimal evidence of past anthropogenic disturbance
2) Representative of the five dominant Ecological Landtype Groups on the GMNF (spruce-fir, northern hardwoods-spruce, northern hardwoods, oak-northern hardwoods, and hemlock-northern hardwoods)
3) At least ¼ mile from a road but less than a one hour hike from a gravel or forest road
4) Representative of the range of most common soils on the GMNF
5) On slopes of less than 35% grade
6) In areas of relatively uniform topography, soils and vegetation

Not every parameter was or will be adhered to for every plot. For instance, an otherwise suitable site may be selected despite old skid roads found nearby. In the state of Vermont, as in the rest of the northeast, nearly every forest has been impacted by logging, human-caused fires, and/or agriculture at some point in recent history. These parameters are guidelines to aid selection of the most suitable plots for the purposes of this project. More detailed parameters are provided in **Appendix A2**.

2.1.2) Plot Selection: Pre-Field Analysis and Field Identification

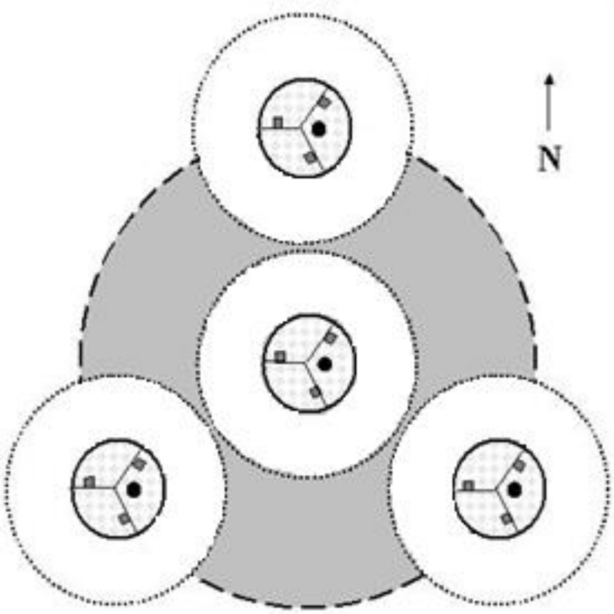
Promising areas were located remotely using GIS layers, topographic maps, and aerial photographs. Those areas were then investigated by traverses through the forest and specific plot locations were identified. Soil profiles were examined at each prospective plot and hydrology and vegetation types were noted. After the plot locations were determined, resource specialists confirmed that no adverse effects on resources would occur if these areas were included in the LEMP.

2.2) *Field Methods*

The LEMP plot design and protocols are based largely on the USDA Forest Service, Forest Inventory & Analysis (FIA) National Core Field Guide, Version 4.0, October, 2007, Volume 1: Field Data Collection Procedures for Phase 2 Plots and Phase 3 Field Guide. These FIA protocols are located on the web at: http://fia.fs.fed.us. The plot layout is circular and the plot center forms the vertex of the circle. Four subplot centers are incorporated into the plot. The plot center doubles as the center of subplot 1 and the centers of subplots 2-4 are arranged at specific angles from the plot center. Vegetation, down woody debris, trees and saplings, lichens, and soil are collected in specified areas of the plot (more information in **Figure A** and **Appendices C2-C4**).

The following diagram (**Figure A**) shows the plot layout as specified in the FIA Protocols with modifications.

LEMP Plot Layout



◯	Subplot (Vegetation, Trees)	24.0 ft (7.32m) radius
●	Microplot (Saplings)	6.8 ft (2.07m) radius
◌	Annular Plot (Lichens)	58.9 ft (17.95m) radius
⬤	Soil Sampling	Details in **Appendix C3**
■	Vegetation Plot	1.0 m² area
–	Down Woody Material	24.0 ft (7.32m) transects

Figure A. *Long-term Ecosystem Monitoring Project Plot Layout. Modified FIA Phase 2 and 3 plot design.*

Two significant departures were made from the FIA protocols. For soil sampling, the 2007 Vermont Monitoring Cooperative Long-term Soil Monitoring Project protocols were followed. In addition, the layout specified by the FIA lichen sampling protocols was modified to accommodate the soil sampling. These changes are reflected in **Figure A** above.

2.2.1) Plot Establishment

Short-term (within sampling period) plot markings consisted of a plastic flag inserted into the ground marking the plot center and each subplot center. These flags served as temporary markers until permanent monuments were installed. Flagging tied to tree trunks and branches near subplot centers aided samplers in locating the plots. Temporary markings were also used for locating the soil pits. Each soil pit center was marked with a plastic flag inserted into the ground. In addition, the north wall of the pit was marked with two stakes connected with rope to assist pit diggers.

The procedure for long-term plot marking was the same for all three years. Throughout each field season, one-inch-diameter permanent steel survey markers with brass caps were placed at the center of each subplot. These permanent markers feature anchors that will hinder their removal by human and natural forces. When the terrain allowed and plots were located in Wilderness areas, brass caps were placed 1-2 inches below the leaf litter to minimize discovery of the plot by passers-by. When bedrock, rocks, or other obstructions were encountered in Wilderness areas, caps were left 1-5 inches above the ground and covered with rocks and other natural debris to disguise the monuments to possible passers-by. Monuments were left exposed in non-Wilderness areas. Please refer to **Appendix C1** for further details.

Three healthy, mature trees growing close to subplot centers were scribed to aid in locating plots. Three scribes were made through the outer layer of bark of each tree—two at DBH (diameter at breast height, 4.5 feet) and one at the base of the trunk. In the future, these monuments will be located using plot location descriptions, a GPS device, a metal detector, and descriptions of the scribed trees and their positions. **Appendix B4** contains bearing tree data for the established plots.

2.2.2) Sampling

Vegetation, lichen, tree, down woody debris, and soil data were collected in the plots. During this time temporary plot disturbances were limited to:

- Marking plots temporarily with flagging tape, stakes, flags, and some rope.
- Some trampled vegetation. Travel routes were planned and followed to concentrate trampling outside of sampling area.
- Small samples collected of each lichen species and some plant species for identification and archiving.

2.2.2.1) Soil

Three pits were dug for soil sampling within each plot. While pits were being dug and described, some flagging and stakes were used to identify the pit locations. Pits were approximately 2 feet long by 3 feet wide by 3 feet deep. Several soil samples were gathered from each pit. One 4-ounce soil sample of each described soil horizon was collected in a plastic bag. In addition, four gallon-sized plastic bags were filled to collect the “bulk” samples. Bulk samples were taken in the following soil layers:

- The Oi plus Oe horizons
- The A plus Oa horizons

- The top 10 inches of the B horizon
- At 60-70 centimeters below the ground surface

In all pits, dug out soil material was placed on a plastic tarp to minimize disturbance of the adjacent area. When pits were filled in, the topsoil was placed at the ground surface. Care was taken to camouflage the pit areas by randomly spreading leaves and dead wood over each pit after it was filled.

Photo: Thomas Villars 2009

Figure B. *Completed soil pit ready for description and sampling*.

2.2.2.2) Vegetation

Vegetation was monitored in 24-foot diameter circular subplots surrounding each subplot center. First, all plant species within the circle were identified and each species' abundance was estimated. Next, vegetation was divided into height classes and relative abundances of species were estimated. A small (1 m^2) vegetation plot was placed along each of three transects radiating at set degrees from the subplot center. All vegetation growing within these 1 m^2 vegetation plots was inventoried.

2.2.2.3) Trees, Saplings, and Down Woody Material

Trees, saplings, and down woody material were inventoried in each subplot. Samplers measured diameters and estimated heights of each tree within the 24-foot radius subplots, measured diameters and heights of all saplings within a 6.8-foot radius microplot, and measured sizes and described decay classes of coarse woody material along a transect. Fine woody material was not measured.

2.2.2.4) Lichens

Lichen specimens were collected to determine species diversity. Lichens were collected throughout each 58.9-foot radius annular plot. Each specimen was placed in its own brown paper bag and labeled with plot number, collection number, date, abundance, and occasional microhabitat notes. These specimens will later be identified in the laboratory. As specimens were collected in the field, the sampler estimated the abundance of each species in the plot.

Please refer to **Appendices C2-C5** for sampling protocols.

2.3) *Laboratory Methods*

Soil samples were dried at the Mount Tabor Work Station of the GMNF at the end of each field season. During the drying process, the soil samples were laid out to air dry on clean plastic tarps in the fall. Samples took 2-3 months to dry. Samples were then bagged and delivered to the laboratory at the Hubbard Brook Experimental Forest for analysis. At Hubbard Brook, soil samples are analyzed for a full complement of chemical parameters. Soil samples collected in 2009-2010 are currently undergoing lab analysis. Samples collected in 2011 will be analyzed in 2012. Archived soil samples will be stored at Hubbard Brook.

Lichens were dried and stored in brown paper bags at the Rutland Supervisory Office of the GMNF. These bags are permeable, allowing for moisture to escape, and opaque, shielding the lichen specimens from the light. Lichens can be preserved in excellent condition for decades, provided they are protected from light and moisture. Each bag is labeled with the plot number, collection number, abundance, and habitat notes of the specimen it holds. The paper bags are stored in cardboard boxes. Lichens will be identified and this data will be entered into a spreadsheet. In the future we plan to find a secure location for long-term storage; the lichen samples will ideally be stored near the soil samples.

If additional funding is obtained for more expensive laboratory analyses, some lichen species may be selected for tissue analysis. This analysis would examine the levels of certain elements contained in the foliar tissues of the lichen. Later, the results could be compared to analyses of lichens collected in future sampling periods.

2.4) *Data Storage*

From 2008-2011, data sheets were stored with the resource managers that sampled the plots. Copies of these sheets are held by project leaders at the Rutland Supervisory Office. Long-term data storage is discussed in Section 5, Plan for Future Efforts, below.

3) Results

A summary of data collected follows. Information is current as of October 27, 2011. Any data missing from the following tables will be collected during the 2012 field season.

LEMP Data Collection 2008

Sampled	Sampler	When Sampled	Plots Complete
Soil	Thom Villars	August 2008	1-5
Vegetation	Diane Burbank	Aug. 2008 & Aug. 2009	1-5
Tree/Sapling/DWM	Brian Keel/Bill Garrison	Aug 2008	2,3 and 4
Lichens	Mary Beth Dewey	Aug. 2008-Nov. 2008	1-5

Table D. *What, Who, When, and Where of Data Collection for 2008 Plots*.

LEMP Data Collection 2009

Sampled	Sampler	When Sampled	Plots Complete
Soil	Thom Villars	August 2009	6-10
Vegetation	Diane Burbank	August 2009	6-10
Tree/Sapling/DWM			Part of 6
Lichens	Mary Beth Dewey	Sept-Oct. 2009	8, 10

Table E. *Data Collection Details for 2009 Plots.*

LEMP Data Collection 2010

Sampled	Sampler	When Sampled	Plots Complete
Soil	Thom Villars	August 2010	11-15
Vegetation	Diane Burbank	August 2010	11-15
Tree/Sapling/DWM	M. B. Dewey/Frank Thompson	August 2010	5, 8, 11, 12, 13, part of 15
Lichens	Mary Beth Dewey	Sept-Oct. 2010	12, 15

Table F. *Data Collection Details for 2010 Plots.*

LEMP Data Collection 2011

Sampled	Sampler	When Sampled	Plots Complete
Soil	Thom Villars	August 2011	16-20
Vegetation	Diane Burbank	August 2011	16-20
Tree/Sapling/DWM	Mary Beth Dewey, FrankThompson	Summer 2011	part of 19
Lichens	Mary Beth Dewey	Sept-Oct. 2010	19

Table G. *Data Collection Details for 2011 Plots.*

As not all sampling had been completed for trees, saplings, and DWM during the four sampling years, additional data collection was completed in 2012 for these resources.

LEMP Data Collection 2012

Sampled	Sampler	When Sampled	Plots Complete
Tree/Sapling/DWM	Mary Beth Dewey, FrankThompson	Summer 2012	17, 19

Table H. *Data Collection Details for 2012.*

To date, the following sites have tree/sapling/dwd data on one or more subplots, but not all of them: 6) Lake Brook, 15) Mount Abe

3.1) *Soil Field Results*

Thomas Villars of the Natural Resources Conservation Service (NRCS) described the soil pits and collected soil samples for laboratory analysis. The horizons of three pits (each approximately 2 feet wide by 3 feet long by 3 feet deep) were described per plot, totaling 15 pits per year. A summary of each pit description for the 2008 and 2009 field seasons follows.

Soil pits in plot 1 were most similar to either Buckland (Aquic Dystric Eutrudepts) or Peru (Aquic Haplorthod). Buckland-like soils had a cambic (Bw) horizon, and a horizon sequence of Oi-Oe-A-Bw1-Bw2-C or Cd. The Peru-like soil had a spodic horizon (Bhs), and the horizon sequence was Oi-Oe-Oa-E-Bhs-Bs-Bc-Cd. Site vegetation indicated the potential for a lime influence on the Buckland soils.

Plot 2 had two pits that most closely fit the Peru series (Aquic Haplorthod) and one pit that best fit the Marlow (Oxyaquic Haplorthod) series. All pits had a horizon sequence of Oi-Oe-Oa E Bhs-Bs-Bw, and were underlain by dense basal till.

Plot 3 had Mundal soils (Oxyaquic Haplorthod) at all three pits. The typical horizon sequence was O1-Oe-A-Bhs1-Bhs2. This was underlain by Bw, BC, and/or Cd horizons. Dense basal till (Cd) was observed at only one pit, but was suspected in the substratum of all pits.

High rock fragment contents and thick E horizons were major features of the soils in Plot 4. The soils did not fit existing soil series. The typical horizon sequence was Oi-Oe-Oa-E1-E2, underlain by Bs or Bw horizons. Soil textures typically ranged from very gravelly loamy sand to very gravelly fine sandy loam.

Only one pit at plot 5 was assigned a soil series in the field – the well drained Berkshire series (Typic Haplorthod). The other two pits most closely resemble the Peru or Marlow series (Aquic Haplorthod and Oxyaquic Haplorthod, respectively. The typical horizon sequence was Oi-Oe-Oa-E-Bhs1-Bhs2, underlain by Bs, BC, and/or Cd horizons.

Plot 6 contained soils of the Worden series (Aquic Haplorthods) and Rawsonville series (Typic Haplohumods). The soils had no E horizon (albic, leached) and redoximorphic features indicated seasonal saturation of the lower horizons. The typical horizon sequence was Oi-Oe-Oa-A-Bhs-Bs-Bw-Cd, underlain at one pit by potential bedrock.

The Hogback (Lithic Haplohumods) and Worden series (Aquic Haplorthods) were found in plot 7. Soils had varying depths to bedrock, and sporadic E horizons. Redoximorphic features were only witnessed in deeper soil. The typical horizon sequence was Oi-Oe-Oa /A-Bhs-Bs or Bw, underlain by Cd or R.

Plot 8 contained soils of the Hogback series (Lithic Haplohumods) and Rawsonville series (Typic Haplohumods), moderately well drained variant. All soils were shallow to bedrock and displayed redoximorphic features. The typical horizon sequence was Oi-Oe-Oa-E-Bhs1-Bhs2, underlain by Bhs3-R, or Bw-Cd-R, or Cd-R.

Soils in plot 9 soil belong to the Hogback (Lithic Haplohumods) and Worden series (Aquic Haplorthods). Depth to bedrock varied between pits, but all pits were underlain with dense basal till. The most typical horizon sequence was Oi-Oe-Oa-A-Bhs1-Bhs2-Bw-Cd. Soil textures were fine or very fine sandy loam. Redoximorphic features were displayed in lower horizons of all pits.

Plot 10 had soils that appeared to be underlain with dense basal till at a depth of greater than 70 cm. Two pits best fit the Mundal series (Oxyaquic Haplorthods) and one best fit the Worden series (Aquic Haplorthods). The typical horizon sequence was Oi-Oe-Oa-Bhs1-Bhs2, underlain by Bw and/or Bs. General observations of the area (i.e. stone walls, wolf trees) and an apparent old Ap (plowed) horizon indicate this plot was cultivated at some time over 90 years ago.

Villars' comprehensive reports of the 2009-2011 field analyses are located in **Appendix D1**. No comprehensive report was completed for the 2008 field season (plots 1-5). A summary table of soil sampling data is located in **Appendix D2,** and a summary of the lab analysis of this data is located in Appendix **D3.**

3.2) *Vegetation Diversity and Structure* – Data analysis has not yet been completed.

3.3) *Trees and Saplings*

Brian Keel led inventories of the 2008 and 2009 plots for trees, saplings, and down woody material. Inventory of three 2008 plots was completed and only part of one 2009 plot was completed. Only the results of the completed plots (2008) will be discussed here. Sugar maple dominated the canopy in plots 2 and 3 and red spruce in plot 4. Meanwhile, beech and striped maple dominated the understory in plot 2 and beech in plots 3 and 4.

In the canopy of plot 2, sugar maple dominated (8 trees), beech and red maple co-dominated (4 of each), and yellow birch was present (1 tree). The understory of plot 2 was dominated by beech and striped maple (11 each) while mountain maple and sugar maple were also present (1 each). Striped maple and mountain maple have shrub growth forms, which should be taken into consideration when predicting future forest composition using saplings.

The canopy of plot 3 was dominated by sugar maple (15 trees) with beech and yellow birch present (1 each). Beech dominated the understory of plot 3 (19 saplings) while yellow birch (3 saplings), sugar maple (2 saplings), and red spruce (1 sapling) also occurred.

Red maple dominated in the canopy of plot 4 (6 trees) and sweet birch and beech (3 trees each) co-dominated. Yellow birch (2 trees) and eastern hemlock (1 tree) were also present in the canopy. The understory of plot 4 was dominated by beech (10 saplings) while eastern hemlock (4 saplings) was common and yellow birch (1 sapling) was present. Please refer to **Appendix D4** for all available tree and sapling results.

3.4) *Down Woody Material*

Down woody material (DWM) was monitored at the same plots in which tree and sapling data were collected. In plot 2, no DWM was found in subplots 1 and 3, subplot 2 contained 1 piece of coarse woody material (CWM), and subplot 4 contained 3 pieces of fine woody material (FWM). In plot 3, subplot 1 contained no DWM, subplot 2 contained 2 pieces of CWM and 1 piece of FWM, subplot 3 contained 1 piece of CWM, and subplot 4 contained 1 piece of FWM. In plot 4, no DWM was found in subplots 1 and 4, 1 piece of CWM was found in subplot 2, and 1 piece of CWM was found in subplot 3. In plot 8, only subplot 1 was monitored; there, 1 piece of CWM was found and FWM was not recorded due to the large number of FWM in the subplot and the limited time available for monitoring. Please refer to **Appendix D5** for all available down woody material results.

3.5) *Lichens*

Lichens were monitored at all five 2008 plots and three of the 2009 plots. Two species found in LEMP plots, *Lobaria pulmonaria* (symbol LOPU60) *and Hypogymnia physodes* (symbol HYPH60), are of particular importance to the project. Both species were found in Lye Brook Wilderness and were included in the 1995 USFS-sponsored study, “Lichens and Air Quality in Lye Brook Wilderness of the Green Mountain National Forest” by Clifford Wetmore (Wetmore 1995). As part of the study, lichen species were inventoried throughout Lye Brook Wilderness and common species were selected for foliar elemental analysis.

As part of the lichen inventory conducted for Wetmore’s 1995 study, the pollution sensitivity of various lichens was noted. Several sensitive species were found, including *Lobaria pulmonaria*. This species is uncommon (but not rare) throughout its range and two specimens were found at Lye Brook Wilderness in 1995 (Wetmore 1995). This species was found at Plot 5, French Hollow, but not at Plot 4, Sunderland—the only LEMP plot located within the Lye Brook Wilderness. In order to determine whether *Lobaria pulmonaria* exists in Lye Brook Wilderness now, more than 15 years later, a more extensive inventory would need to be done in that area.

Hypogymnia physodes is one of the most common species in forests throughout the Northern Forest Bioregion (northern New England and New York and adjacent Canada). This species was found in all LEMP plots sampled and it has an intermediate pollution sensitivity rating. *Hypogymnia physodes* was one of the four common species selected for elemental analysis in Wetmore’s 1995 study; therefore, it will be selected for foliar elemental analysis if such funding is obtained for the LEMP.

Please refer to **Figure C** for photographs of both species.

Hypogymnia physodes. Photo by Ralph Pope.

Lobaria pulmonaria. Photo by Ralph Pope.

Figure C. *Two important lichen species found in LEMP plots during sampling:* Lobaria pulmonaria *(LOPU60; left photograph) and* Hypogymnia physodes *(HYPH60; right photograph). Source: http://www.fs.fed.us/wildflowers/interesting/lichens/glossary.shtml*

Lichen specimens are currently stored as described in sections 2.3 and 2.4.

4) Discussion

4.1) *Relevance of Current Results*

At this point in time (October 2011), the data collected in 2008-2011 is valuable as an inventory of current resources. The substantial value of the data collected during this establishment phase of the LEMP (2008-2011) will start to be realized after the next suite of sampling (beginning 2018). At that point, changes in forest ecosystems will be recorded and analyzed.

4.2) *Data Gaps to be Addressed*

During the 2008-2011 sampling periods, some data collection was not completed in some of the plots. As of October 2011, all of the monument installation and vegetation and soil sampling are complete. Tree, sapling, and down woody material sampling needs to be finished in plots 1, 6, 7, 9, 10, 14, 15, and 16-20. Plots 6, 15, and 19 are partially completed. In addition, lichen sampling has not been completed in plots 6, 7, 9, 12, 14, 16-18, and 20. We intend to complete this sampling in all 2008-2011 plots by the end of the 2012 field season.

5) Plan for Future Efforts

5.1) *Establishment and Initial Sampling of Plots*

Our long-term goal is to establish, measure, and periodically re-measure 20 plots on the GMNF. All 20 plots have been established, yet some areas have not yet been sampled (lichen, tree, sapling, and down woody material in several plots). We plan to finish the initial stage of data collection during the 2012 field season.

There are four additional data collection and/or analysis efforts we would like to initiate in the future if we have adequate resources:

- Leaf and lichen tissue analysis for common trees and lichens on selected LEMP plots to quantify the impact of acid deposition.
- Tree core analysis for age and growth rates.
- Tree health data collection (for example, twig dieback and crown transparency)

5.2) *Re-sampling of Established Plots*

Plots are scheduled for re-sampling every ten years following establishment. The next re-sampling period should begin in 2018.

5.3) *Ensuring Long-term Project Viability*

There is a risk of the LEMP not being continued in the future due to problems such as lack of funding for re-sampling, lost data or documents, or lack of awareness that the project exists. Several actions are planned or are already taking place to encourage continuation of this project into the long term future and make the data accessible and useable to scientists. These actions include:

- Several intra- and inter-agency partners have been identified and briefed on the project, its goals, and its importance.
- The project will be further publicized so that the value of its continuation becomes widely recognized.
- Selected younger employees of the Northern Research Station and the GMNF working in forest ecosystem research and management will be encouraged to be involved in the project.
- When all plots are established, a final report should be compiled and distributed to key present and future cooperators.
- We will investigate if the Vermont Monitoring Cooperative is interested in playing a long-term role in the project. For example, they could help us make data more easily accessible to the public.

- The NRS and GMNF will investigate other ways to ensure that data and the overall project is not lost or forgotten.

5.4) *Long-term Data Storage*

Data collected so far will be entered into Microsoft Excel files during the summer and fall of 2010, and in NRIS in 2012. Digital and hard copies of the data will be stored long-term both at Hubbard Brook Experimental Forest and in the offices of the Forest Service resource managers involved in the project. As previously stated, we will also investigate if the Vermont Monitoring Cooperative is interested in playing a long-term role in the project, including data storage.

5.5) *Future Use of Data*

Our long-term hope is that LEMP field data and analyses will be used by scientists to study trends in acid deposition, climate change, invasive or rare plants, or any number of ecosystem issues. We anticipate our dataset will be compared and combined with other similar datasets in the northeastern U.S. to discern regional trends. We expect our long-term monitoring data to be transferred into larger databases to be used by any interested parties locally, regionally and nationally. We plan to make our data easily available to scientists in both digital and hard-copy formats.

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7) Abbreviations

AT – Appalachian National Scenic Trail

CWM – Coarse Woody Material

DBH – Diameter at Breast Height

DWD – Down Woody Material

ELT – Ecological Land Type

FIA – Forest Inventory and Analysis

FR – Forest Road

FS – Forest Service

FWM – Fine Woody Material

FY – Fiscal Year

GIS – Geographic Information Systems

GMFL – Green Mountain and Finger Lakes National Forest

GMNF – Green Mountain National Forest

GPS – Global Positioning System

LEM – Long-term Ecosystem Monitoring

LEMP – Long-term Ecosystem Monitoring Project

LT – Long Trail

LTA – Land Type Association

MA – Management Area

NNIS – Non-native Invasive Species

NRA – National Recreation Area

NRCS – Natural Resources Conservation Service

NRS – Northern Research Station

RD – Ranger District

RNA – Research Natural Area

USDA – United States Department of Agriculture

USFS – United States Forest Service

VMC – Vermont Monitoring Cooperative

VYCC – Vermont Youth Conservation Corps

WMNF – White Mountain National Forest

8) Glossary

AGE CLASS – An age grouping of trees according to an interval of years, usually 20 years. A single age class would have trees that are within 20 years of the same age, such as 1-20 years or 21-40 years (USDA 2006).

AIRSHED – A geographic area that shares the same air (USDA 2006).

AQUIC – moist soil.

ASPECT – The direction a slope faces. A hillside facing east has an eastern aspect (USDA 2006).

BIOLOGICAL DIVERSITY – the variety of life forms and processes within an area. Included in the consideration of diversity are genetic variation, number and distribution of species, and the ways in which the variety of biologic communities interact and function (USDA 2006).

BIOLOGICAL EVALUATION – The use of a variety of tools, including review of existing literature and data, field survey, and data gathering and analysis, to determine the presence of, and effects of activities on, threatened, endangered, proposed, and sensitive species (FSM 2670; USDA 2006).

BUFFER – A land area that is designated to block or absorb unwanted impacts to the area beyond the buffer. Buffer strips along a trail could block views that may be undesirable. Buffers may be set aside next to wildlife habitat to reduce abrupt change to the habitat (USDA 2006).

CANOPY – The part of any stand of trees represented by the tree crowns. It usually refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried forest (USDA 2006).

COMMUNITY (Natural Community) – An interacting assemblage of organisms, their physical environment, and the natural processes that affect them (Thompson and Sorenson; USDA 2006).

COMPOSITION – The types of organisms and environmental features present in a particular area (USDA 2006).

CONIFER – A tree that produces cones, such as a pine, spruce, or fir tree (USDA 2006).

CROWN HEIGHT – The distance from the ground to the base of the crown of a tree (USDA 2006).

DIAMETER AT BREAST HEIGHT (DBH) – The diameter of a tree 4 and ½ feet above the ground on the uphill side of the tree (USDA 2006).

DISTURBANCE – Any relatively discrete event in space and time that disrupts ecosystem, community, or population structure and changes resources, substrate, or the physical environment (White and Pickett 1985; USDA 2006).

DIVERSITY – The distribution and abundance of different plant and animal communities and species within the area covered by a land and resource management plan (USDA 2006).

ECOLOGY – The interrelationships of living things to one another and to their environment, or the study of these interrelationships (USDA 2006).

ECOSYSTEM – A dynamic arrangement of living organisms interacting with each other and their non-living environment. Living organisms include plants and animals. The non-living environment includes soils, landforms, weather, and disturbances (USDA 2006).

ENDANGERED SPECIES – A plant or animal that is in danger of extinction throughout all, or a significant portion, of its range. Endangered species are identified by the Secretary of the Interior in accordance with the Endangered Species Act of 1973 (USDA 2006).

EROSION – The wearing away of the land surface by wind, water, ice or other geological agents (USDA 2006).

FOREST HEALTH – A measure of the robustness of forest ecosystems. Aspects of forest health include biological diversity; soil, air and water productivity; natural disturbances; and the capacity of the forest to provide a sustainable flow of goods and services for people (USDA 2006).

FOREST ROADS AND TRAILS – Roads and trails under the jurisdiction of the Forest Service (USDA 2006).

FUNCTION – All the processes within an ecosystem through which the elements interact, such as succession, the food chain, fire, weather, and the hydrologic cycle (USDA 2006).

GEOGRAPHIC INFORMATION SYSTEMS (GIS) – GIS is both a database designed to handle geographic data as well as a set of computer operations that can be used to analyze data (USDA 2006).

GLOBAL POSITIONING SYSTEM (GPS) – a navigational system using satellite signals to fix the location of a receiver on or above the earth's surface (USDA 2006).

HABITAT – The area where a plant or animal lives and grows under natural conditions (USDA 2006).

HERITAGE RESOURCE – Historic landscapes, archeological sites, buildings, structures, features, artifacts, Native American Traditional Cultural properties, and/or related clusters of these (referred to as "districts"). They are deemed "significant" if they meet, or may meet, the criteria for eligibility to the National State Registers of Historic Places (NR). Any Heritage Resource that is considered significant (NR-eligible) may be referred to as a "historic property" (USDA 2006).

INDICATOR SPECIES – A plant or animal species related to a particular kind of environment. Its presence indicates that specific habitat conditions are also present (USDA 2006).

INDIGENOUS (species) – Any plant or animal species native to a given land or water area by natural occurrence (USDA 2006).

LATE SUCCESSIONAL FOREST – A forest beyond the age of economic maturity, generally beyond 100 years of age. These forests are older, have larger trees, and have more structural complexity than mature forest, and they are either in the process of or have developed old growth characteristics. They may exhibit evidence of past human or natural disturbances. These forests may exist as entire stands or as smaller patches within younger stands (see SUCCESSION) (USDA 2006).

LITTER (forest litter) – The freshly fallen, or only slightly decomposed, plant material on the forest floor. This layer includes foliage, bark fragments, twigs, flowers, and fruit (USDA 2006).

MANAGEMENT AREAS – Areas of the National Forest designated in the Forest Plan as having similar management objectives. Similar to city planning zones (USDA 2006).

MESIC – moderately moist (USDA 2006).

MINERAL SOIL – Soil that consists mainly of inorganic material, such as weathered rock, rather than organic matter (USDA 2006).

NATIONAL RECREATION AREA (NRA) – Congressionally-designated areas that have outstanding combinations of outdoor recreation, aesthetic attractions, and proximity to potential users. They may also have cultural, historical, archaeological, pastoral, wilderness, scientific, wildlife, and other values contributing to public enjoyment (USDA 2006).

NON-NATIVE INVASIVE SPECIES (NNIS) – An organism that has been purposefully or accidentally introduced outside its original geographic range, and that is able to proliferate and aggressively alter its new environment, causing harm to the economy, environment, or human health (Executive Order 13112; USDA 2006).

NORTHERN HARDWOODS – Primarily sugar maple, yellow birch, and beech. May include red maple, white ash, black cherry, red spruce, and hemlock (USDA 2006).

OLD GROWTH FOREST – A patch of relatively old forest of at least 5-10 acres that has escaped catastrophic or stand-replacing disturbance associated with the prevailing natural disturbance regimes of the Forest. Such old growth stands exhibit a long history of continuity and a demonstrated future via replacement dynamics (USDA 2006).

ORGANIC SOIL – Soil at least partly derived from living matter, such as decayed plant material (USDA 2006).

OVERSTORY – The upper canopy layer; the plants below comprise the under-story (USDA 2006).

PARENT MATERIAL – The mineral or organic matter from which the upper layers of soil are formed (USDA 2006).

SAPLING – A general term for a young tree more than a few feet tall and an inch or so in diameter that is typically growing vigorously (USDA 2006).

SECOND-GROWTH FOREST – An area of forest that has established after some kind of human intervention that has removed some or all of the previous forested area (USDA 2006).

SKID ROADS (a.k.a. tractor roads) – Roads constructed for the purpose of transporting cut trees to a landing. They are ordinarily constructed by ground clearing or excavation (FSH 2409.15; USDA 2006).

SKID TRAILS – Trails constructed for the purpose of transporting cut trees to a skid road or landing. The resultant ground disturbance created by skidding logs on the ground by all skidding and yarding methods. Skid trail construction normally does not include ground excavation or clearing (FSH 2409; USDA 2006).

STAND -- A group of trees that occupies a specific area and is similar in species, age, and condition (USDA 2006).

STRUCTURE – How the parts of an ecosystem are arranged, both horizontally and vertically. Structure might reveal a pattern, mosaic, or total randomness of vegetation (USDA 2006).

SUCCESSION – The sequence of changes in plant and animal communities on a site over time (USDA 2006).

THREATENED SPECIES – Those plant or animal species likely to become endangered throughout all or a specific portion of their range within the foreseeable future as designated by the U.S. Fish and Wildlife Service under the Endangered Species Act of 1973 (USDA 2006).

UNDERSTORY – The trees and woody shrubs growing beneath the overstory in a stand of trees (USDA 2006).

WETLAND – Those areas that under normal circumstances are inundated by surface or ground water with a frequency sufficient to support a prevalence of vegetation or aquatic life that requires saturated or seasonally-saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar areas such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds (FSM 2527.05; USDA 2006).

WILDERNESS – The Wilderness Act of 1964 defined a wilderness as an area of undeveloped federal land designated by Congress that has the following characteristics: (1) It generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) It has outstanding opportunities for solitude or a primitive and unconfirmed type of recreation; (3) It has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) It may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value (Wilderness Act, Sec. 2(c); USDA 2006).

XERIC – dry.

9) Bibliography

USDA Forest Service. 2006. Green Mountain National Forest Land and Resource Management Plan. USDA Forest Service, Rutland, VT.

Wetmore, Clifford M. 1995. Lichens and Air Quality in Lye Brook Wilderness of the Green Mountain National Forest. USDA Forest Service and Northeastern Area State and Private Forestry, Rutland, VT.

10) Appendix

A. Planning Documents
  1. *Project Proposal (Letter to the File)*
  2. *Criteria for Plot Selection*

B. Plot Locations
  1. *Plot Location Descriptions*
  2. *Maps of Plot Locations (with coordinates)*
  3. *General Plot Information*
  4. *Bearing Tree Data*

C. Protocols
  1. *Plot Establishment and Marking*
  2. *FIA Sampling Protocols*
  3. *Soil Sampling Protocols*
  4. *Vegetation Diversity and Structure Sampling Protocols*
  5. *Alterations to Protocols for Other Sampling Areas*

D. Results
  1. *Soil Scientist Report*
  2. *Soil Pit Summary Data*
  3. *Soil Lab Data Summary*
  4. *Tree and Sapling Data*
  5. *Down Woody Material Data*
  6. *Vegetation Data (tbd)*
  7. *Lichen Data (tbd)*