Fundy Model Forest

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Report Title: Effects of Forestry Practices on Plant Diversity: Selection Harvest

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FINAL REPORT

for fiscal year: 2001-2002

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Fundy Future Environment and Benefits Council
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INTRODUCTION

In earlier work in the Hayward Brook Watershed, we were able to assess effects of several common harvest practices, including clear cut, scarification and planting, herbicide, tree islands (as applied in 1995), and some aspects of riparian buffer management. These studies provided significant insight into the immediate and longer-term responses of the forest floor plants, including bryophytes. We have the opportunity to "fill in the blanks" in this work, by assessing the impact of specific applications of selection cuts using land owned by the Fundy Region Solid Waste Commission (FRSWC), near Grand Bay and adjacent to the Loch Alva protected area. Within their large land base, the FRSWC has planned a variety of management strategies for public education and recreation, including a demonstration woodlot. Jamie Floyd, of SNB, will be providing and implementing the management plan, and has agreed to accommodate the requirements of our sampling plan: pre-harvest establishment of permanent quadrats, spatially explicit application of harvest components, and control areas.

The Fundy Region Solid Waste Commission (FRSWC) sought input on several levels, including a thorough and spatially explicit vegetation inventory on which to base management of the land for multiple uses such as a working woodlot (to demonstrate sustainable management) and interpretive trails (for recreation and public education). In return, we were able to carry out biodiversity-related research on a variety of management applications, including assessment of impacts of human interventions. Even the first step, the initial vegetation inventory, was mutually advantageous because it allowed us to establish appropriate research locations, at both the stand and quadrat levels, which will allow us to continue the work initiated in the Hayward Brook Watershed. This collaborative effort also offered the FMF an opportunity to extend its sphere of influence to a new and different group of stakeholders and land managers.

Objectives

1. to document and map the vascular and non-vascular vegetation of the Crane Mountain landbase,

2. to relate distribution of understory species to habitat features, including stand types, and
3. to establish and thoroughly describe permanent quadrats in which will be subjected to selection harvest, or serve as controls.

METHODS:

Data collection. In order to provide thorough and spatial coverage of the whole FRSWC land base, it was sampled in a grid design. In total, 23 transects were established throughout the 227ha area, on which 144-100m^2 plots were positioned at 75 or 100m intervals (Figure 1).

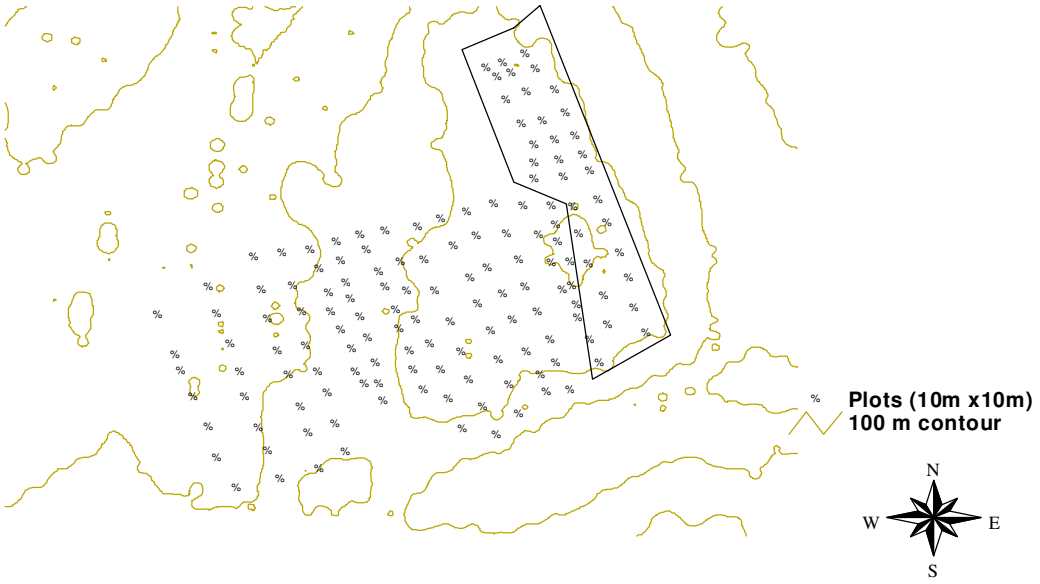

Figure 1. Distribution of sample 100m^2 plots throughout Crane Mountain land base. Plots containing permanent 1m^2 quadrats (33 plots containing 132 quadrats in total) are outlined.

Within each plot, presence of all tree and shrub species was recorded, as well as indications of disturbance including the abundance (percent cover) of slash, distinguishing between piles vs. scattered, garbage, exposed soil, and number of overturned trees and cut stumps. A global positioning system (GPS) unit (GeoExplorer™) was placed in the centre of

each plot to capture satellite signals, positioning the plot on the map and allowing for spatial analyses.

Abundance of all plants < 1m tall, including all bryophytes, was assessed in 4-1m^2 quadrats within each 100m^2 plot, each positioned 2m from the plot margins. Of the 576-1m^2 quadrats sampled, 132 were established as permanent quadrats by placing labeled plastic tent pegs into the ground at 2 diagonally opposite quadrat corners. These were established in an area slated for selection harvested by SNB in 2002.

Within each 1m^2 quadrat, percent covers of all clubmosses, ferns, herbaceous plants, small shrubs, and bryophytes were estimated and recorded, as were the percent covers of all unoccupied substrates, including coarse woody debris (CWD) and stumps categorized by decay class (Table 1), rocks, mineral soil, humus, needles, leaves, bark, cones, scat, exposed roots, and tree bole surfaces. Local tree canopy features were recorded as: (1) mean percent cover of coniferous and deciduous canopy using a spherical densiometer (n = 4 readings), and (2) local tree density and size (measured as trunk diameter at breast height, or dbh) using the point-centre quarter method.

Table 1. Coarse woody debris (CWD) decay classes, modified from Söderström (1987). Rotting wood provides an important substrate for many forest plants, animals and other organisms, which may utilize specific stages of decay.

Class	Definition
I	freshly fallen tree, branches still present
II	>50% bark remaining, wood hard
III	<50% bark remaining, wood hard
IV	no bark, decay beginning, no pieces missing
V	wood softening, a core of hard wood still remaining, pieces missing
VI	wood completely soft, outline still visible
VII	wood completely soft, outline indeterminable

Plant identification. Samples of each bryophyte species were collected from the field, brought to the laboratory and identified using Ireland (1982) and Crum and Anderson

(1981) for the mosses and Schuster (1966, 1969, 1974, 1980, 1992a, b) and Ireland and Bellolio-Trucco (1987) for the liverworts. Identification of most specimens of *Sphagnum* spp. has been contracted out to Bruce Bagnell, of B&B Botanical. Voucher specimens are deposited at the bryophyte herbarium, University of New Brunswick, Saint John campus. All vascular plants that could not be identified in the field were collected, pressed, identified in the laboratory using Hinds (2000) and verified using the New Brunswick Museum (NBM) herbarium collection.

Data analyses - Vegetation. As a general measure of ecological interest, species richness was calculated for the entire land base, and for all permanent quadrats, of vascular plants, non-vascular plants (i.e. bryophytes), and all plants combined. Mean abundance ± standard error and frequency of occurrence were calculated for each species present in the permanent quadrats. Affinity of each species to a particular vegetation community (see below) or combination of vegetation communities was determined by comparing the frequency distributions across vegetation communities (as percentages of the total frequency within the permanent quadrats). Species with an overall frequency of occurrence among the permanent quadrats ≥ 10, and having a percent frequency of occurrence within a particular vegetation community at least twice the percentage of the quadrats sampled within that vegetation community compared to the total number sampled, were considered to have an affinity for that particular vegetation community.

Data analyses - Environmental variables. Tree canopy characteristics were described as range and mean abundance ± standard error. Density (trees/ha) and basal area (m^2/ha) were calculated for 9 canopy species. Maximum and mean abundance ± standard error of all available substrates and disturbance variables were calculated. A disturbance index (DI) was created using 6 variables considered indicative of primarily anthropogenic disturbance: skidder trail, slash piles, scattered slash, cut stumps, overturned trees, and garbage. The index consisted of the average of the sum of these variables, each converted to a percent of its maximum. For example, a DI=0% showed no signs of disturbance, while DI=100% showed the maximum recorded values of all 6 variables.

Stand types were assigned by applying species composition criteria of vegetation communities set forth by the Department of Natural Resources and Energy (1999) to basal

area data for each plot. Species were ordered into one of the following classes: softwood (Red Spruce, Balsam Fir, and Eastern White Cedar), tolerant hardwood (Sugar Maple, Red Maple, Mountain Maple and Yellow Birch), and intolerant hardwood (White Birch and Speckled Alder). Basal area (m^2/ha) of each species was converted to a percentage of the total for each plot. These percentages were combined within each class (above) and plots were then categorized to vegetation community using the compositional criteria below (Table 2).

Table 2. Species composition criteria of vegetation communities (from DNRE 1999).

Vegetation community	Compositional criteria[1]
Tolerant Hardwood Pure (THP)	SW[2] < 50%; TH[3] ≥ 20%; TH+RM[4] ≥ 75%
Tolerant Hardwood - Softwood (THSW)	SW < 50%; TH ≥ 20%; TH+RM ≥ 35% and < 75%
Intolerant Hardwood - Softwood (IHSW)	SW < 50%; TH < 20% or TH+RM < 35
Pine (PI)	SW ≥ 50%; PI[5] ≥ 35%
Jack Pine (JP)	SW ≥ 50%; JP[6] ≥ 35%
Eastern White Cedar (CE)	SW ≥ 50%; EC[7] ≥ 35%
Black Spruce (BS)	SW ≥ 50%; BS[8] ≥ 35%
Spruce (SP)[11]	SW ≥ 50%; SP[9] ≥ 35%
Balsam Fir (BF) [12]	SW ≥ 50%; BF[10] ≥ 35%
Tolerant Hardwood - Softwood (THSW)	SW ≥ 50%; TH ≥ 20%; TH+RM ≥ 35% and < 75%

[1] Criteria are not mutually exclusive. Stands that meet more than one set of criteria are assigned based on the priority indicated by the order in the table; [2] All softwood species; [3] Tolerant hardwood; [4] Red maple; [5] Pine (White and Red); [6] Jack pine; [7] Eastern cedar; [8] Black spruce; [9] Spruce: white and red spruce; [10] Balsam fir; [11] Includes those stands with greater than 75% spruce + fir and greater than 35% spruce; [12] Includes those stands with greater than 75% spruce + fir and greater than 35% fir.

RESULTS AND DISCUSSION:

Environmental variables

While our focus is on the forest floor vegetation, its context is the larger scale environment, defined by tree components as well as by other types of variables.

Canopy characteristics. Although a total of 12 canopy species occurred throughout the land base as a whole, the canopy above the permanent quadrats consisted of 9 tree and shrub species, in order of decreasing basal area (m^2/ha): *Betula papyrifera* (Paper Birch; 4.88 ∀ 0.93m^2 per ha), *Betula alleghaniensis* (Yellow Birch; 4.42 ∀ 0.84m^2 per ha), *Abies balsamea* (Balsam Fir; 4.26 ∀ 0.63m^2 per ha), *Acer rubrum* (Red Maple; 2.64 ∀0.90m^2 per ha), *Picea rubens* (Red Spruce; 1.64 ∀ 0.42m^2 per ha), *Thuja occidentalis* (Eastern White Cedar; 0.79 ∀ 0.45m^2 per ha), *Alnus incana* (Speckled Alder; 0.03 ∀ 0.02m^2 per ha), *Acer saccharum* (Sugar Maple; 0.01 ∀ 0.01m^2 per ha), and *Acer spicatum* (Mountain Maple; < 0.01 ∀ 0.01). Red Maple, Speckled Alder, and Yellow Birch had higher mean densities and basal areas in the permanent quadrats than in the land base as a whole, indicating a concentration of these species in the northeastern arm of the land base, where the permanent quadrats have been established.

Forest stand types. The 132 permanent quadrats fell within 7 vegetation communities, which represented the full range found in the land base, with the exception of a boggy area adjacent to the lake. The majority of the plots fell within Tolerant hardwood/ softwood (THSW, 27%), followed by Intolerant hardwood/ softwood (IHSW, 24%), Balsam Fir (BF, 15%), Spruce (12%), Tolerant hardwood pure (12%), Eastern White Cedar (6%) and Softwood/ tolerant hardwood (3%). No cedar-dominated stands occurred in the Hayward Brook plots to which this study will be compared; given the low abundance of this stand type, permanent quadrats in this stand type may be reconsidered.

Substrates available for bryophyte colonization. The most abundant substrates available for bryophyte colonization were deciduous leaf litter (56.43 ± 2.61%), FWD with bark (10.63 ± 1.60%), tree trunks (6.66 ± 1.60%), coniferous needle litter (5.17 ± 0.96%) and CWD V (4.04 ± 0.84%). Least abundant substrates included CWD decay class 1 (not found), scat (0.06 ± 0.02%) and cones (0.15 ± 0.01%). A number of substrates had higher mean values in the permanent quadrats than in the land base as a whole, indicating a concentration

within the permanent quadrats. These include: CWD II-VI, FWD with bark, humus, leaves, rock, root, scat, and exposed soil. See Appendix Table B for distribution of these substrates among the 7 vegetation communities within which the permanent quadrats have been established.

Table 3. Comparison of percent permanent quadrats within each vegetation community to the total quadrats sampled throughout the Crane Mountain area.

Vegetation community	% of total permanent quadrats (n = 132)	% of total quadrats (n = 576)
Tolerant hardwood/ softwood	27	15
Intolerant hardwood/ softwood	24	20
Balsam Fir	15	17
Spruce	12	22
Tolerant hardwood pure	12	7
Eastern White Cedar	6	18
Softwood/ tolerant hardwood	3	1

Disturbance variables. Skidder trails passing through plots in which permanent quadrats were established had an average cover of 3.12 ± 1.44%. Mean slash pile abundance was 12.58 ± 1.90%. Mean scattered slash abundance was 8.00 ± 0.66%. Mean number of overturned trees per $100m^2$ was 1.52 ± 0.28 per $100m^2$. Mean number of stumps found in a $100m^2$ plot was 2.00 ± 0.33 per $100m^2$. Mean garbage cover was 0.05 ± 0.04% per $100m^2$. See Appendix Table B for distribution of these disturbance variables among the 7 vegetation communities within which permanent quadrats have been established. Permanent quadrats within THP will be reconsidered; it appears that some are truly dominated by tolerant hardwood, while others were previously THSW but the softwood component has been removed in earlier partial harvest (as indicated by coniferous stumps) hence not comparable.

The disturbance index, which summarized 6 measures of disturbance for each plot, ranged from 4.56 to 33.95%, with an average of 14.06%. Overall, 12% of the plots containing permanent quadrats were considered highly disturbed (DI > 20%), 61% were considered of intermediate disturbance severity (DI: 10-20%), and 24% of low disturbance severity (DI < 10%). Overall, the area in which the permanent plots have been established is more disturbed than the land base as a whole: mean values of all 6 disturbance variables were higher within the permanent quadrats than the entire land base sampled (Appendix Table B). This is unfortunate but unavoidable as this block is nearest road access and therefore appropriate for harvest; it emphasizes the need for control quadrats and for pre-harvest sampling.

Vegetation

Overall forest floor vegetation. In total, 147 plant taxa (mostly species) were found within the 132 permanent quadrats (compared to 225 in the FRSWC land base). Many were infrequent (i.e. 50 were found only once) or present in low abundance (56 taxa were found in patches # $1cm^2$). In addition, one species considered to be rare (Hinds 2000) was found in the permanent quadrats: *Pyrola americana* (Round-leaved Pyrola). Plot richness ranged from 5 to 36, with an average of 16.4 taxa per $1m^2$.

Vegetation - vascular plants

Species richness and diversity. In total, 64 vascular plant taxa were found in the permanent quadrats, compared to 118 throughout the land base. Permanent plot richness ranged from 1 to 17 taxa per $1m^2$, with an average of 7.2.

Frequency of occurrence. The most frequent vascular plant species found within the permanent quadrats were *Cornus canadensis* (Bunchberry; 103 occurrences), *Maianthemum canadense* (Wild Lily-of-the-valley; 65 occurrences), *Acer rubrum* (61 occurrences), *Abies balsamea* (55 occurrences), *Oxalis montana* (Wood-sorrel; 49 occurrences), *Betula alleghaniensis* (49 occurrences), *Trientalis borealis* (Starflower; 48 occurrences), *Coptis trifolia* (Goldthread; 45 occurrences), *Aralia nudicaulis* (Wild Sarsaparilla; 42 occurrences), and *Betula papyrifera* (39 occurrences). Many species were

very infrequent: 19 species were found only once. These species were also common at Hayward Brook, to which this study will be compared.

While most species were evenly distributed among the 7 vegetation communities (Appendix Table A), a number of species were found primarily in a particular vegetation community, or a combination thereof: *Aralia nudicaulis* (SWTH), *Betula papyrifera* (THP), *Carex trisperma* (EC), *Dennstaedtia punctilobula* (BF, EC, and SWTH), *Dryopteris carthusiana* (THSW and SWTH), *Dryopteris* spp. (SWTH), *Gaultheria hispidula* (SP, THP, and EC), *Linnaea borealis* (SP and EC), *Osmunda cinnamomea* (BF and EC), *Picea mariana* (IHSW), *Picea rubens* (SP and SWTH), *Picea* sp. (BF), *Rubus pubescens* (BF and EC), *Thuja occidentalis* (THSW and EC), and *Trientalis borealis* (BF and EC).

Species abundance. The most locally abundant vascular plant species of the understory (i.e. those with highest cover values) were *Cornus canadensis* (17.34 ± 1.77%), and *Abies balsamea* (8.05 ± 1.55%). Many vascular plants were present in very low abundance, i.e. 14 species had a mean percent cover value # 0.01%, i.e. # 1cm^2.

Vegetation - bryophytes

Species richness and diversity. In total, 83 bryophyte taxa were found within the 132 permanent quadrats, compared to 107 throughout the Cane Mountain area: 26 liverworts and 57 mosses. Plot richness ranged from 0 to 28 taxa per 1m^2, with an average of 9.2.

Frequency of occurrence. The most frequent bryophyte species found were *Dicranum scoparium* (Broom Moss; 112 occurrences), *Dicranum montanum* (84 occurrences), *Ptilidium pulcherrimum* (Naugehyde Liverwort; 82 occurrences), *Hypnum imponens* (79 occurrences), *Hypnum pallescens* (61 occurrences), *Bazzania trilobata* (59 occurrences), *Pleurozium schreberi* (Red-stemmed Moss, Schreber's Moss; 58 occurrences), and *Plagiothecium laetum* (55 occurrences). The majority of species were very infrequent: 31 species were found only once.

Again, most species were evenly distributed among the 7 vegetation communities (Appendix Table A), but a number of species were found primarily in a particular vegetation community, or a combination thereof: *Brachythecium starkei* (EC), *Cephalozia lunulifolia* (EC), *Dicranum flagellare* (SWTH), *Dicranum polysetum* (BF), *Hylocomium splendens*

(EC), *Lophocolea heterophylla* (SWTH), *Polytrichum commune* (THP), *Polytrichum ohioense* (BF), and *Sphagnum* spp. (BF and EC).

Species abundance. The most locally abundant bryophyte taxa (i.e. those with highest cover values) were *Sphagnum* spp. (Peat moss; 6.74 ± 1.44%), *Pleurozium schreberi* (1.70 ± 0.44%), *Dicranum scoparium* (1.26 ± 0.18%), *Bazzania trilobata* (1.16 ± 0.32%), *Hypnum imponens* (1.15 ± 0.21%), *Hylocomium splendens* (Stair-step Moss; 0.87 ± 0.27%), *Ptilidium pulcherrimum* (0.56 ± 0.08), and Hypnum pallescens (0.46 ± 0.09). Many bryophytes were present in very low abundance: 42 species had a mean percent cover value < 0.01%, i.e. < $1cm^2$.

New county records. A total of 16 new records (9 liverworts and 7 mosses) were documented for St. John County (NBM, unpublished data, and Bagnell 1995) based on permanent quadrat samples: *Blepharostoma trichophylla, Calypogeia integristipula, Cephalozia catenulata, Cephalozia macounii, Frullania oakesiana, Jamesoniella autumnalis, Lophozia longidens, Nowellia curvifolia, Riccardia latifrons, Brachythecium velutinum, Calliergon stramineum, Campylium hispidulum, Drepanocladus uncinatus, Isopterygium pulchellum, Platydictya subtile,* and *Sphagnum strictum.*

Bryophytes of special interest. Because an inventory of the bryophyte species of this land base has never been compiled, every species identified (102) is a new record for this area. Although not found in the permanent quadrats, 3 are considered to be rare; these should be considered in future monitoring of the land base.

(1) *Pohlia lescuriana* has only been reported to occur 6-20 times in all of Canada (Bélland 1998). Our data may provide sufficient evidence to downgrade its status from N2: in Crane Mountain alone, it occurred 8 times in 7 quadrats, most commonly with *Sphagnum* sp.*, Pleurozium schreberi, Dicranum scoparium, Dicranum montanum, Ptilidium pulcherrimum, Bazzania trilobata, Hypnum imponens, Tetraphis pellucida, Dicranum flagellare* and *Polytrichum ontariense*. It was typically found in low amounts, and was never the dominant species. The quadrats in which it was found were characterized by low canopy cover and low tree density, supporting Ireland's (1982) report that it prefers exposed habitats. Of the 8 occurrences, none were found on the substrate predicted from literature, i.e. mineral

soil. Rather, it was found on humus, a white birch sapling, CWD V, and CWD VII, therefore this species is less likely to be limited by substrate characteristics than by canopy coverage.

(2) *Calypogeia neesiana* occurred only once in the Crane Mountain quadrats, and was associated with *Dicranum scoparium, Dicranum montanum, Pleurozium schreberi, Bazzania trilobata, Hylocomium splendens, Jamsoniella autumnalis, Ptilidium pulcherrimum, Lepidozia reptans, Tetraphis pellucida* and *Dicranum flagellare*. The quadrat in which it was found had a high tree density and a strongly coniferous canopy with a minor deciduous component. Ireland and Bellolio-Trucco (1987) state that it prefers organic substrates in advanced stages of decay; it was found on humus at Crane Mountain. The quadrat had a high total bryophyte cover (51.2%), of which this species was only a small part (1%).

(3) *Calliergonella cuspidata* was found only once at Crane Mountain, in association with *Callicladium haldanianum, Nowellia curvifolia, Ptilidium pulcherrimum, Sphagnum* sp.*, Dicranum scoparium, Bazzania trilobata, Lepidozia repens* and *Plagiothecium laetum.* It was in a highly coniferous forested area on the margin of a small bog, which supports predictions from the literature (e.g. Ireland 1982) that it is specific to this habitat. It comprised nearly half the total bryophyte cover and was the dominant species in the quadrat.

FUTURE DIRECTIONS:

Based on our full report submitted to FRSWC, and its recommendations for trail placement, the Environmental Science Park steering committee will determine with which steps to proceed toward the goal of establishing a network of interpretive trails.

A proposal to establish a Construction and Demolition (C&D) site within the boundary of the land has been accepted. This development will directly affect the permanent quadrats established to date: 24 permanent quadrats will be destroyed. However, compensation has been provided to UNBSJ in the form of financial support for fieldwork in 2002 to establish replacement quadrats.

We are engaged in discussion with Jamie Floyd (SNB) to plan the selection harvest of the permanent plots for autumn 2002.

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Appendix Table A. Species found within 132 permanent 1m^2 quadrats established throughout the Crane Mountain area with mean abundance ∀ standard error, distribution among 7 vegetation communities (n = number of permanent quadrats), and frequencies of occurrence within 132 permanent plots and the land base as a whole (n = 576 quadrats). Rare species in bold; liverworts indicated by * and mosses by †.

Species	Mean % cover	Standard error	Frequency of occurrence		Distribution among 7 vegetation communities (% of total frequency in permanent quadrats within each class)						
			permanent (n=132)	whole (n=576)	THSW 27%	IHSW 24%	BF 15%	SP 12%	THP 12%	EC 6%	SWTH 3%
Abies balsamea (L.) Mill.	8.05	1.55	55	346	36	27	15	9	4	7	2
Acer pensylvanicum L.	0.41	0.18	13	20	46	23	8	0	23	0	0
Acer rubrum L.	3.43	0.62	61	242	34	28	10	8	15	5	0
Acer spicatum Lam.	1.92	0.51	23	24	39	13	9	22	4	9	4
Alnus incana (L.) Moench	0.05	0.05	1	23	0	0	0	0	0	100	0
Aralia nudicaulis L.	2.90	0.56	42	142	38	12	21	5	7	10	7
Aster acuminatus Michx.	1.62	0.63	18	46	50	11	22	0	11	6	0
Aster spp.	0.01	0.01	1	5	100	0	0	0	0	0	0
†*Bartramia pomiformis* Hedw.	t	t	1	4	0	0	100	0	0	0	0
**Bazzania denudata* (Torrey) Trev.	t	t	5	8	0	100	0	0	0	0	0
**Bazzania trilobata* (L.) S. Gray	1.16	0.32	59	287	25	31	17	17	5	5	0
Betula alleghaniensis Britt.	4.24	0.89	49	102	37	12	18	10	16	4	2
Betula papyrifera Marsh.	4.34	0.87	39	146	26	23	18	5	28	0	0
Betula spp.	t	t	2	5	0	0	0	0	50	50	0

**Blepharostoma trichophyllum* (L.) Dum	t	t	1	4	0	0	0	100	0	0	0
†*Brachythecium reflexum* (Starke ex Web. & Mohr) B.S.G.	t	t	3	3	0	0	0	33	67	0	0
†*Brachythecium rutabulum* (Hedw.) B.S.G.	t	t	1	2	100	0	0	0	0	0	0
†*Brachythecium starkei* (Brid.) B.S.G.	0.07	0.02	22	56	27	14	23	9	14	14	0
†*Brachythecium velutinum* (Hedw.) B.S.G.	0.07	0.03	22	106	18	23	27	14	9	9	0
†*Brotherella recurvans* (Michx.) Fleisch.	0.01	0.01	5	14	20	20	40	20	0	0	0
†*Callicladium haldanianum* (Grev.) Crum	0.02	0.01	8	23	38	13	13	0	38	0	0
**Calypogeia integristipula* Steph.	t	t	1	1	0	100	0	0	0	0	0
**Calypogeia muelleriana* (Schiffn.) K.Müll.	t	t	1	21	0	100	0	0	0	0	0
**Calypogeia* sp.	t	t	1	1	0	0	0	100	0	0	0
†*Calliergon stramineum* (Brid.) Kindb.	t	t	5	9	0	0	20	20	20	40	0
†*Campylium hispidulum* (Brid.) Mitt.	t	t	4	20	50	0	0	25	0	25	0

†*Campylium stellatum* (Hedw.) C. Jens.	t	t	1	2	100	0	0	0	0	0	0
Carex disperma Dewey	0.08	0.08	1	7	0	0	0	0	0	100	0
Carex intumescens Rudge	0.21	0.21	1	3	0	0	0	0	0	100	0
Carex trisperma Dewey	1.56	0.68	11	70	0	27	18	9	18	27	0
**Cephalozia bicuspidata* (L.) Dum	t	t	5	30	20	20	60	0	0	0	0
**Cephalozia catenulata* (Hüben.) Lindb.	t	t	2	4	50	0	50	0	0	0	0
**Cephalozia connivens* (Dicks.) Lindb.	t	t	4	7	25	25	0	0	0	50	0
**Cephalozia lunulifolia* (Dum.) Dum.	0.01	t	11	46	18	9	27	18	0	27	0
**Cephalozia macounii* (Aust.) Aust.	0.01	t	15	21	27	20	27	7	7	13	0
†*Ceratodon purpureus* (Hedw.) Brid.	0.01	t	7	12	29	0	43	0	14	0	14
Clintonia borealis (Ait.) Raf.	1.62	0.75	23	84	13	35	4	17	22	9	0
Coptis trifolia (L.) Salisb.	1.17	0.37	45	236	31	24	18	11	9	7	0
Cornus canadensis L.	17.34	1.77	103	371	24	26	14	11	15	8	3
†*Cynodontium alpestre* (Hüb.) Milde	t	t	1	1	0	0	0	100	0	0	0
Cypripedium acaule Ait.	0.01	0.01	1	5	0	100	0	0	0	0	0
Cyperaceae (vegetative specimens)	1.49	0.54	19	74	21	5	32	16	11	16	0

											18
Dennstaedtia punctilobula (Michx.) Moore	3.29	1.27	12	36	42	0	33	0	0	17	8
†*Dicranum flagellare* Hedw.	0.11	0.05	28	121	21	36	14	7	4	11	7
†*Dicranum fulvum* Hook.	t	t	1	1	0	100	0	0	0	0	0
†*Dicranum fuscescens* Turn.	t	t	1	1	0	100	0	0	0	0	0
†*Dicranum montanum* Hedw.	0.32	0.04	84	331	31	26	17	12	8	5	1
†*Dicranum ontariense* Peters.	0.01	0.01	6	14	0	17	33	50	0	0	0
†*Dicranum polysetum* Sw.	0.07	0.03	17	108	29	18	35	18	0	0	0
†*Dicranella rufescens* (With.) Schimp.	t	t	2	2	0	0	50	0	50	0	0
†*Dicranum scoparium* Hedw.	1.26	0.18	112	432	29	26	15	13	8	4	4
Diervilla lonicera P. Mill.	0.30	0.16	8	8	50	13	13	0	25	0	0
†*Drepanocladus uncinatus* (Hedw.) Warnst.	0.01	t	5	24	20	20	20	40	0	0	0
Dryopteris campyloptera (Kunze) Clarkson	1.64	0.62	15	7	53	13	7	7	13	7	0
Dryopteris campyloptera x intermedia	0.09	0.09	1	30	100	0	0	0	0	0	0

Dryopteris carthusiana (Vill.) H. P. Fuchs	1.58	0.49	14	2	64	7	14	0	0	7	7
Dryopteris intermedia (Muhl.) Gray	0.41	0.24	3	31	67	33	0	0	0	0	0
Dryopteris spp.	1.80	0.79	11	11	18	9	27	18	9	9	9
Equisetum sylvaticum L.	0.26	0.12	5	36	0	0	80	0	0	20	0
**Frullania eboreacensis* Gott.	t	t	1	20	0	0	0	0	0	100	0
**Frullania oakesiana* Aust.	t	t	3	3	33	0	67	0	0	0	0
**Frullania tamarisci* sbsp. *asagrayana* (Mont.) Hatt.	0.01	0.01	6	9	17	33	17	17	0	0	17
Gaultheria hispidula (L.) Muhl.	0.22	0.14	10	28	10	0	10	30	30	20	0
**Geocalyx graveolens* (Schrad.) Nees	t	t	1	64	0	100	0	0	0	0	0
Glyceria x laxa (Scribn.) Scribn.	0.04	0.04	1	6	0	0	0	0	0	100	0
†*Herzogiella striatella* (Brid.)Iwats.	0.01	0.01	4	1	50	0	25	25	0	0	0
†*Herzogiella turfacea* (Lindb.) Iwats.	0.08	0.02	37	8	38	14	19	14	5	5	5
Huperzia lucidula (Michx.) Trevisan	0.01	0.01	2	97	100	0	0	0	0	0	0
†*Hylocomium brevirostre* (Brid.) B.S.G.	t	t	1	5	0	100	0	0	0	0	0

											20
†*Hylocomium splendens* (Hedw.) B.S.G.	0.87	0.27	34	1	24	12	18	15	12	21	0
†*Hylocomium umbratum* (Hedw.) B.S.G.	0.01	0.01	2	159	0	0	50	0	50	0	0
†*Hypnum* spp.	t	t	1	3	0	0	0	100	0	0	0
†*Hypnum cupressiforme* Hedw.	t	t	1	2	0	0	0	100	0	0	0
†*Hypnum fertile* Sendtn.	t	t	1	2	0	0	0	100	0	0	0
†*Hypnum imponens* Hedw.	1.15	0.21	79	2	30	25	13	18	6	6	1
†*Hypnum pallescens* (Hedw.) P. Beauv.	0.46	0.09	61	236	26	30	13	20	5	5	2
†*Hypnum pallescens* var. *proturberans* (Brid.) Aust.	0.01	t	5	182	20	40	20	20	0	0	0
Ilex verticillata (L.) Gray	t	t	1	5	100	0	0	0	0	0	0
†*Isopterygium muellerianum* (Schimp.) Jaeg. & Sauerb.	t	t	1	4	0	0	0	100	0	0	0
†*Isopterygium pulchellum* (Hedw.) Jaeg. & Sauerb.	t	t	1	1	0	100	0	0	0	0	0
**Jamesoniella autumnalis* (DC.) Steph.	0.08	0.02	43	3	35	21	16	12	9	5	2
Kalmia angustifolia L.	0.02	0.02	1	194	0	0	0	100	0	0	0

Lepidozia reptans (L.) Dum	0.12	0.03	37	51	30	27	19	14	0	8	3
†*Leptodictyum riparium* (Hedw.) Warnst.	t	t	5	200	20	0	40	20	20	0	0
†*Leptodictyum trichopodium* (Schultz) Warnst.	t	t	1	13	100	0	0	0	0	0	0
†*Leucobryum glaucum* (Hedw.) Ångstr. ex Fries	t	t	1	1	0	0	100	0	0	0	0
Linnaea borealis L.	1.03	0.33	22	3	23	5	18	36	5	14	0
Lonicera canadensis Bartr. ex Marsh.	0.11	0.06	5	102	20	40	0	20	20	0	0
Lophocolea heterophylla (Schrad.) Dum.	0.03	0.01	24	8	46	4	25	8	8	0	8
Lophozia longidens (Lindb.) Mac.	t	t	1	113	0	0	0	100	0	0	0
Lophozia ventricosa (Dicks.) Dum.	t	t	1	1	100	0	0	0	0	0	0
Lycopodium dendroideum Michx.	0.01	0.01	1	1	100	0	0	0	0	0	0
Maianthemum canadense Desf.	1.89	0.45	65	5	28	34	6	12	15	2	3
Monotropa uniflora L.	t	t	3	1	33	67	0	0	0	0	0
Nemopanthus mucronatus (L.) Loes.	0.03	0.02	3	259	0	0	67	33	0	0	0
Nowellia curvifolia (Dicks.) Mitt.	0.21	0.09	29	6	28	17	28	17	0	10	0

Osmunda cinnamomea L.	2.30	0.83	10	83	0	0	30	20	20	30	0
Osmunda claytoniana L.	0.47	0.26	4	111	25	0	50	0	0	25	0
Phegopteris connectilis (Michx.) Watt	0.85	0.39	8	47	29	20	16	12	12	4	6
Picea hybrid	0.15	0.08	6	4	50	17	0	0	33	0	0
Picea mariana (Mill.) BSP	0.28	0.14	12	14	25	67	0	8	0	0	0
Picea rubens Sarg.	0.31	0.15	15	31	13	20	13	27	20	0	7
Picea spp.	0.80	0.29	20	77	20	30	30	0	15	5	0
Pinus strobus L.	0.01	0.01	1	41	100	0	0	0	0	0	0
†*Plagiothecium cavifolium* (Brid.) Iwats.	0.01	t	7	58	29	14	29	14	14	0	0
†*Plagiothecium laetum* B.S.G.	0.25	0.06	55	25	31	22	16	13	5	9	4
†*Platygyrium repens* (Brid.) B.S.G.	0.06	0.02	31	251	42	16	13	13	10	3	3
†*Platydictya subtile* (Hedw.) Crum	0.23	0.22	5	81	20	0	40	0	40	0	0
†*Pleurozium schreberi* (Brid.) Mitt.	1.70	0.44	58	5	16	29	14	17	14	10	0
Poaceae (unidentified grasses)	0.03	0.03	1	303	0	0	100	0	0	0	0
†*Pohlia nutans* (Hedw.) Lindb.	t	t	4	2	0	50	25	0	25	0	0
†*Polytrichum commune* Hedw.	0.25	0.12	14	16	21	14	21	7	36	0	0
†*Polytrichum juniperinum* Hedw.	t	t	1	46	0	0	100	0	0	0	0

†*Polytrichum ohioense* Ren. & Card.	0.09	0.05	10	8	10	30	30	10	20	0	0
†*Polytrichum strictum* Brid.	t	t	1	27	0	0	100	0	0	0	0
Prunus pensylvanica L.	0.14	0.14	1	1	0	100	0	0	0	0	0
**Ptilidium ciliare* (L.) Hampe	0.02	t	13	8	23	46	8	15	8	0	0
†*Ptilium crista-castrensis* (Hedw.) De Not.	0.06	0.03	8	75	0	13	25	25	0	38	0
**Ptilidium pulcherrimum* (G. Web.) Hampe	0.56	0.08	82	23	32	24	17	10	9	7	1
Pyrola americana Sweet	t	t	1	369	0	0	0	100	0	0	0
**Radula complanata* (L.) Dum.	t	t	1	1	100	0	0	0	0	0	0
Rhododendron canadense (L.) Torr.	0.01	0.01	1	1	0	0	0	100	0	0	0
†*Rhytidiadelphus subpinnatus* (Lindb.) Kop.	0.01	0.01	2	12	100	0	0	0	0	0	0
†*Rhytidiadelphus triquetrus* (Hedw.) Warnst.	t	t	2	2	0	0	50	0	0	50	0
**Riccardia latifrons* Lindb.	t	t	1	7	0	0	0	0	0	100	0
Rubus allegheniensis Porter	0.26	0.15	4	2	25	0	75	0	0	0	0
Rubus idaeus L.	3.08	0.95	23	7	43	9	22	17	9	0	0
Rubus pubescens Raf.	2.70	0.81	23	40	30	0	35	4	9	22	0
Rubus spp.	0.01	0.01	1	51	0	0	100	0	0	0	0

**Scapania nemorosa* (L.) Dum.	t	t	1	4	0	0	100	0	0	0	0
Solidago rugosa P. Mill.	0.06	0.05	2	1	50	0	50	0	0	0	0
Sorbus americana Marsh.	0.01	0.01	2	2	50	50	0	0	0	0	0
†*Sphagnum palustre* L.	0.02	0.02	1	24	0	0	0	0	0	100	0
†*Sphagnum* spp.	6.74	1.44	34	1	12	9	32	9	15	24	0
†*Sphagnum squarrosum* Crome	t	t	1	202	0	0	0	0	0	100	0
†*Sphagnum strictum* Sull.	t	t	1	1	0	0	100	0	0	0	0
Streptopus lanceolatus (Ait.) Reveal	0.06	0.04	2	1	0	0	50	50	0	0	0
†*Tetraphis geniculata* Girg ex Milde	t	t	1	3	0	100	0	0	0	0	0
†*Tetraphis pellucida* Hedw.	0.19	0.05	47	1	28	21	19	9	11	11	2
Thelypteris noveboracensis (L.) Nieuwl.	0.06	0.06	1	196	100	0	0	0	0	0	0
Thuja occidentalis L.	0.10	0.05	12	8	63	0	0	13	0	25	0
Trientalis borealis Raf.	0.48	0.12	48	73	17	8	33	0	0	42	0
Trillium undulatum Willd.	0.01	0.01	1	170	35	23	13	10	8	4	6
†*Ulota crispa* (Hedw.) Brid.	0.05	0.04	12	11	0	0	100	0	0	0	0
Vaccinium myrtilloides Michx.	t	t	1	31	33	50	8	8	0	0	0
Viburnum nudum L.	0.14	0.09	5	26	0	0	100	0	0	0	0
Viola spp.	0.05	0.03	4	57	0	60	0	20	20	0	0

Appendix Table B. Overall mean percent cover ∀ standard error (within 576-1m^2 quadrats), mean percent cover ∀ standard error within 132 permanent quadrats, and distribution among 7 vegetation classes of available substrates, canopy characteristics, elevation, and disturbance variables. CWD coarse woody debris, classes modified from Söderström (1987).

Variable	Overall mean ± standard error	Permanent quadrat mean ± standard error	Mean abundance within 7 vegetation communities						
			THSW 27%	IHSW 24%	BF 15%	SP 12%	THP 12%	EC 6%	SWTH 3%
bark	1.19 ± 0.27	0.82 ± 0.13	0.79	1.19	0.27	1.23	0.33	0.25	1.59
cones	1.18 ± 1.18	0.12 ± 0.01	0.09	0.13	0.04	0.23	0.05	0.34	0.07
CWD I	0.04 ± 0.04	_ ± _	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CWD II	1.01 ± 0.22	1.78 ± 0.55	3.56	2.34	0.00	0.00	0.88	0.00	0.00
CWD III	1.03 ± 0.22	2.08 ± 0.46	2.14	1.00	1.34	0.00	2.56	1.00	5.82
CWD IV	1.81 ± 0.24	2.73 ± 0.52	1.92	2.48	2.98	0.00	3.34	2.63	5.80
CWD V	2.10 ± 0.34	4.04 ± 0.84	7.39	4.66	1.56	3.00	2.00	1.44	0.60
CWD VI	0.87 ± 0.10	1.03 ± 0.22	1.27	1.10	1.50	3.82	0.00	0.05	0.57
CWD VII	0.21 ± 0.06	0.15 ± 0.07	0.09	0.36	0.04	0.46	0.09	0.00	0.09
FWD[1] with bark	5.98 ± 0.68	10.63 ± 1.60	7.92	10.62	12.31	1.56	19.26	3.68	4.49
FWD[1] without bark	2.50 ± 0.36	1.74 ± 0.24	0.85	2.44	1.89	0.60	3.15	0.93	0.11
humus	0.74 ± 0.12	1.08 ± 0.39	0.28	1.04	0.34	0.00	2.33	0.49	0.18
leaves[2]	42.19 ± 2.60	56.43 ± 2.61	68.81	61.24	41.65	75.20	52.19	31.06	70.00
live tree	8.43 ± 0.88	6.66 ± 1.60	9.00	4.78	4.60	11.36	0.38	9.13	3.94
needles[3]	7.35 ± 0.87	5.17 ± 0.96	1.76	5.48	4.20	16.20	1.42	9.70	2.69
other substrate[4]	0.14 ± 0.05	0.18 ± 0.14	0.17	0.02	0.88	0.00	0.00	0.00	0.00
rock	0.17 ± 0.04	0.18 ± 0.09	0.33	0.18	0.01	0.00	0.31	0.00	0.00
root	0.31 ± 0.07	0.36 ± 0.19	0.71	0.04	0.14	0.16	0.00	0.11	0.03
scat[5]	0.05 ± 0.01	0.06 ± 0.02	0.09	0.05	0.06	0.02	0.05	0.01	0.02
snag[6]	8.77 ± 1.63	2.16 ± 0.75	2.29	1.56	1.25	0.00	0.00	8.38	0.00
mineral soil	0.11 ± 0.05	0.20 ± 0.19	0.00	0.00	1.28	0.00	0.00	0.00	0.00
coniferous	43.55 ± 2.50	24.52 ± 2.88	26.48	8.24	30.12	66.30	3.96	59.73	35.84

canopy cover deciduous	29.13	± 2.06	47.13	± 2.97	61.11	55.60	37.06	8.44	43.21	25.72	44.70
canopy cover Balsam Fir ba[7]	7.03	± 0.71	4.26	± 0.63	4.76	4.44	5.90	5.63	6.99	7.89	2.80
Balsam Fir density[8]	999.60	± 132.61	459.57	± 68.27	482.28	168.06	821.05	562.40	152.75	1157.50	773.33
Eastern White Cedar ba	3.94	± 0.86	0.79	± 0.45	0.00	0.00	0.00	0.00	2.85	1.24	0.00
Eastern White Cedar density	78.59	± 22.09	7.92	± 4.47	0.00	0.00	0.00	0.00	2.38	126.00	0.00
Mountain Maple ba	0.03	± 0.03	t	± t	0.00	0.00	t	0.00	0.00	0.00	0.00
Mountain Maple density	8.12	± 7.50	0.45	± 0.45	0.00	0.00	3.00	0.00	0.00	0.00	0.00
Red Maple ba	2.01	± 0.49	2.64	± 0.90	4.93	1.56	0.01	0.00	2.95	0.00	0.01
Red Maple density	30.69	± 5.88	39.05	± 11.21	47.17	42.41	17.35	0.00	42.88	0.00	28.80
Red Spruce ba	5.43	± 1.14	1.64	± 0.42	0.66	0.67	0.76	6.59	1.19	2.23	4.42
Red Spruce density	147.11	± 41.34	51.42	± 15.71	13.97	26.88	62.80	35.00	20.31	38.75	64.60
Speckled Alder ba	0.01	± 0.01	0.03	± 0.02	0.00	0.00	0.00	0.00	0.00	0.35	0.00
Speckled Alder density	2.75	± 1.65	7.16	± 5.27	0.00	0.00	0.00	0.00	0.00	83.88	0.00
Sugar Maple	t	± t	0.01	± 0.01	0.00	0.00	0.06	0.00	0.00	0.00	0.00

ba											
Sugar Maple density	0.32	± 0.32	1.39	± 0.98	0.00	0.00	9.20	0.00	0.00	0.00	0.00
White Birch ba	5.75	± 0.62	4.88	± 0.93	4.48	12.84	1.16	37.17	0.40	1.25	0.36
White Birch density	545.2 2	± 65.68	273.55	± 48.40	337.72	581.78	109.80	149.00	52.44	80.63	26.48
Yellow Birch ba	1.99	± 0.41	4.42	± 0.84	7.78	10.60	0.28	0.00	13.20	2.94	4.23
Yellow Birch density	54.77	± 15.41	138.64	± 35.77	311.83	72.34	71.40	0.00	91.38	139.38	71.00
elevation[9]	87.52	± 0.73	88.01	± 0.66	87.58	88.68	88.15	86.95	86.97	86.225	93.4
skidder trail	3.01	± 0.77	3.12	± 1.44	0	1.88	12.4	1.75	4.75	0	0
slash (piles)	8.00	± 1.07	12.58	± 1.90	5.94	14.81	12.70	12.88	26.00	6.50	11
slash (scattered)	7.53	± 0.51	8.00	± 0.66	9.78	8.00	5.20	8.63	8.38	5.00	8
tip-ups[10]	1.05	± 0.12	1.52	± 0.28	1.44	0.88	2.60	1.50	1.50	2.00	1
stumps	1.31	± 0.20	2.00	± 0.33	1.33	2.34	1.80	2.75	2.25	1.50	3
garbage	0.01	± 0.01	0.05	± 0.04	t	t	0.30	0	2.25	0	0

[1] fine woody debris, i.e. < 5cm diameter; [2] deciduous leaf litter; [3] coniferous needle litter; [4] other substrate (e.g., lichen); [5] animal dung; [6] standing dead tree > 5cm diameter; [7] basal area (m^2/ha); [8] density (stems/ha); [9] metres above sea level; [10] toppled trees.