Fundy Model Forest

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Report Title: Effects of Forestry Practices on Plant Diversity: Monitoring Vascular Plants and Bryophytes in Permanent Quadrats

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Title of Project Effects of Forestry Practices on Plant Diversity: Monitoring vascular plants and bryophytes in permanent quadrats	
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EXECUTIVE SUMMARY

This is the ninth year of this long-term project monitoring the responses of understory plant communities in 175 permanent plots (quadrats) in the Hayward Brook Watershed from 1995 (pre-harvest) to 2003/2004.

While bryophyte diversity has been affected by both management regimes, (a) fine-scale compositional changes in the clearcut-only treatment (CUT) are not evident at the block scale; (b) the community in the clearcut-and-scarified treatment (C&S) continues to diverge from its preharvest composition 9 yrs after harvest; and (c) liverworts that were lost are recovering in neither treatment.

Vascular plant diversity and richness also initially increased after harvest, but remain well above preharvest levels. Response trajectories of species of concern have not yet stabilized. Unexpectedly high changes in the UNCUT plots require further investigation.

INTRODUCTION AND BACKGROUND

Our results at 4 years after harvest documented:
1. immediate changes in the community in response to (a) canopy removal, (b) slash deposition, and (c) substrate disturbance (scarification), including loss of many species (Peterson 1999, Zhu 1998);
2. gradual changes in subsequent years, including decline of some species (e.g., some 20 species of vascular plants), invasion of some new species, and spread of some survivors (Fenton et al. 2003, Roberts and Zhu 2002);
3. bryophyte species, especially liverworts, that appear to be at risk (#1 and 2) persist for at least 4 years in small, remnant tree islands, in relation to height of residual canopy and degree of substrate disturbance (Fenton and Frego 2005);
4. the riparian buffer does not act as a refugium for bryophyte and vascular species likely to be impacted by harvesting in upland stands, because it does not contain the same suite of species as in those communities.

The coincidence of species that declined in the clearcut, their continued absence from plantations, and even from naturally regenerated stands of a range of ages (Ross-Davis and Frego 2002, Ramovs 2001, Ramovs and Roberts 2003) and their absence or infrequency in the bryophyte diaspore rain and propagule bank (Ross-Davis and Frego 2004), suggest that at least some of the forest floor species are at risk.

In 2002 we noted that regeneration of seedlings and saplings on these sites had sufficiently advanced (prior to thinning) to form a closed canopy for the forest floor, hence many of the pre-harvest microhabitat conditions (such as temperature, humidity and light regimes) at the forest floor are likely to have changed dramatically. As the thinning was patchy in nature, some areas with closed canopy still exist. This is likely to be a critical stage in community (re)assembly.

Aside from providing insight into the earliest stages of disturbance response (0-12 years), this project is unique in that (a) spatially specific pre-disturbance data allow us to document with certainty the <u>changes</u> in community composition (unlike dependence on the assumptions associated with chronosequence approach); and (b) the intensive sampling procedure and fine-filter approach allows us to document extremely sensitive species (such as the liverworts) that are overlooked in most other studies.

Currently, identification of bryophyte specimens from the buffer and uncut plots in 2003 and 2004 awaits completion. **This document reports results for the 2004-05 project year for vascular plants in harvested and uncut plots, and for bryophytes in harvested areas only.**

PROJECT OBJECTIVES

The goal of this project is to fill knowledge gaps concerning the dynamics of the earliest stages of disturbance response (0-12 years). Results of our other studies indicate that, in order to document changes in the rare and potentially most sensitive species (about which the least is known, globally, such as liverworts) this must be done (a) using repeated sampling, and (b) at a fine scale.

The objective, therefore, is to assess changes in the permanent quadrats relative to (a) their preharvest condition, (b) management treatment at the fine scale, and (c) through time since disturbance. More specifically, the objectives are to:

1. improve the quantitative understanding of the forest floor (including bryophyte, vascular plant and tree regeneration) component of forest ecosystem structure and function, by contributing to understanding of:
(a) native biodiversity of these species (Year 1), and
(b) ecological processes involved in re-establishment of forest floor communities after various levels of disturbance (following years).

2. relate changes in vascular plant and bryophyte diversity to operational forest management procedures: clear-cut, clear-cut plus scarification, herbicide application, residual tree canopy, riparian buffer strips.

3. fill information gaps in terms of ecological data on ecologically important but poorly understood plant species

PROGRESS TO DATE

The quadrats were relocated and remarked in 2002 to prevent loss, and resampled from 2003 (70 quadrats) to 2004 (122 quadrats). To date, the bryophytes of all of the harvested areas and some buffer and uncut areas (n=160 quadrats) have been identified; those from the remaining 32 quadrats will be finished by November 2005.

Data analysis for vascular plants during the 2004-05 funding period included entering data from the permanent quadrats sampled in 2004 and meshing with the 2003 data; creating a master vegetation data set which includes percent cover values across all measurement years (1995, 1996, 1997, 1999, 2003-04) for each species in each plot; updating species names to keep abreast of recent changes in nomenclature; analysis of changes in total species richness; and analysis of changes in cover for selected species of concern over the 9-year measurement period. Annual and master data sets were converted from Excel spreadsheets into Microsoft Access format to facilitate analysis of past trends and incorporation of new data in future remeasurements. A Work-Study student (Norm Robichaud) and the Technical Coordinator in the Faculty of Forestry and

Environmental Management at UNB-F (Marie-Paule McNutt) assisted with the analysis.

METHODS

Field sampling

In 1995, we established and sampled all vegetation in 168 quadrats (each 1.25m^2 for bryophytes and 5m^2 for vascular plants) throughout several blocks of the Hayward Brook watershed that were slated for clearcut. Two different harvesting methods were used in the research site. Some quadrats were in areas that were clearcut (CUT), whereas others were in areas that were clearcut and then scarified (C&S) (i.e. the lower soil levels were uplifted). The remaining plots remained unharvested (UNCUT). In 1996, we established an additional 26 quadrats in the adjacent riparian buffer, resampled those in the harvested areas to describe the disturbance effects of the harvest operation, and have since resampled in 1997, 1999 and 2003-4 to monitor the changes/recovery of the forest floor community.

Analyses

For bryophytes, average richness of quadrats in CUT and C&S harvest blocks were calculated for each sampled year (mosses, liverworts, and pooled). Percent similarity of quadrats between years was calculated and compared. Biodiversity indices such as evenness, Simpson's and Shannon's indices were also averaged for quadrats in CUT and C&S blocks. Ordinations were used to assess block scale changes.

Comparisons of community composition, individual species abundances, etc. will be assessed to continue the trajectory of change following harvest. (However, final analyses await identification of the remaining samples.)

Total species richness of vascular plant species was calculated in CUT, C&S and UNCUT control treatments in each year. Average percent cover in each treatment and year was calculated for each of nine individual species that are considered to be at risk based on previous work. Percent cover data for all species for 1995-97 have been published elsewhere (Roberts and Zhu 2002). These analyses will be updated through 2003-04 by December 2005. Additional analyses, including species diversity indices and ordinations will be completed as time permits.

PRELIMINARY RESULTS

Bryophytes

Richness

Mean bryophyte richness per quadrat did not differ significantly among any of the post-harvest sampling years (1995, 1999 or 2003/4) in the CUT quadrats. In the C&S quadrats, however, richness significantly decreased from 1999 to 2003/4 (Figure 1).

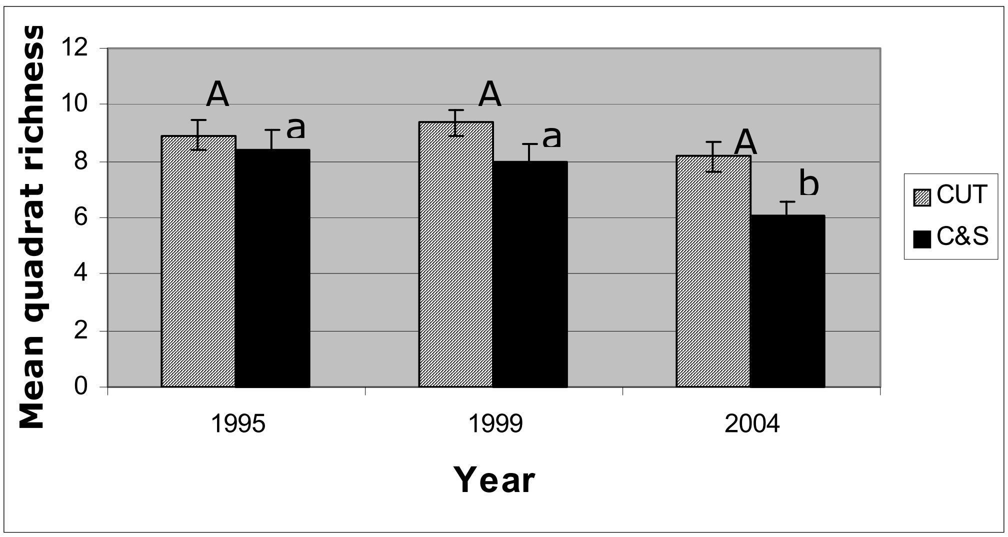

Figure 1. Mean bryophyte quadrat richness of CUT and C&S quadrats in 1995, 1999 and 2004. Different letters above bars indicate significant differences within a treatment.

As the average richness did not show any strong trends, we analysed mosses and liverworts separately. As is common in most forest bryophyte communities in NB, there were more moss species than liverworts (total for CUT and C&S quadrats, moss = 56, liverworts = 15).

Mosses and liverworts displayed different response patterns. In the CUT quadrats (Figure 2), at 4 years post harvest, there was a significant increase in moss species while there was a significant decline in liverwort species. By 9 years post harvest, moss richness had returned to pre-harvest levels; however, liverwort richness did not recover.

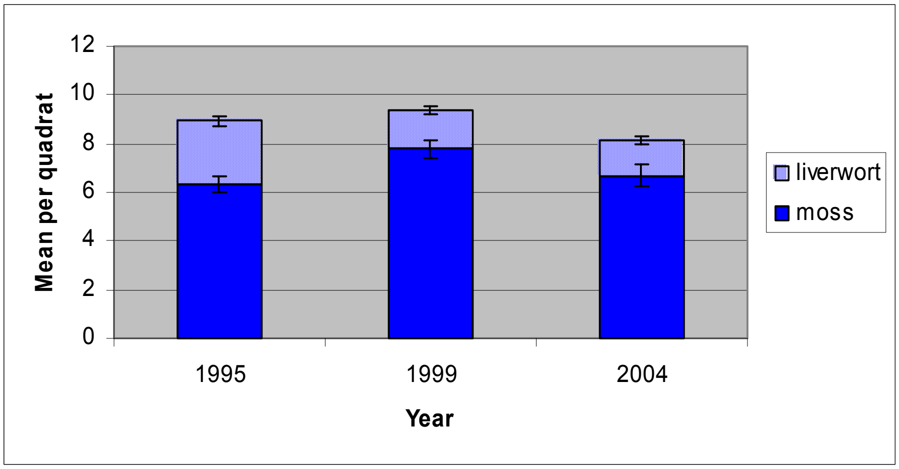

Figure 2. Responses of mosses and liverworts in CUT quadrats in 1995, 1999 and 2004.

A similar pattern was seen in the C&S quadrats (Figure 3). From 1995 to 1999, there was a trend towards increase in moss species richness, with a similar decrease to preharvest levels by 2004. Liverwort richness declined even more severely, with no recovery in 2004.

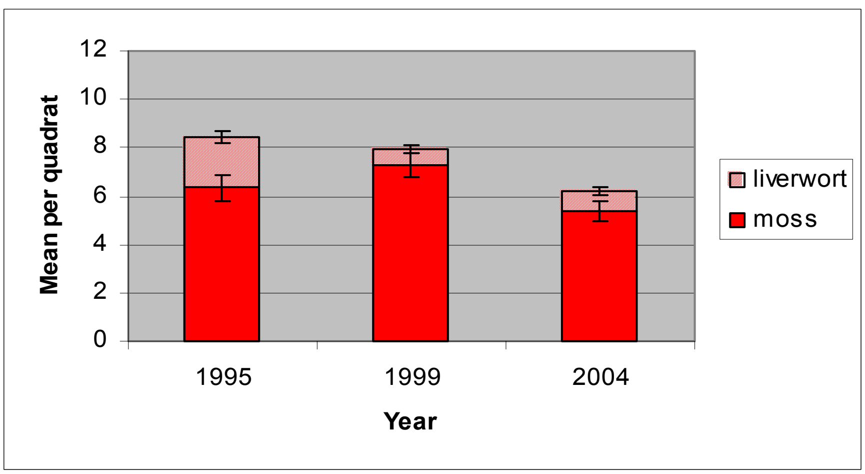

Figure 3. Responses of mosses and liverworts in CUT quadrats in 1995, 1999 and 2004.

Similarity

Similarity in species composition within quadrats over time was low in both treatments for all sampled years (Table 1). At 4 year intervals, quadrats in the CUT treatment showed only ~36% similarity, which is not significantly different from values previously determined for uncut areas (Fenton et al. 2003). However, the C&S quadrats showed lower similarity (greater change) over time than the CUT quadrats. The change between 1995 and 2004 was greater than any other year comparison, indicating that the C&S quadrats are continue to change, diverging from their pre-harvest state over time.

Table 1. Mean % similarity between quadrats in CUT and C&S block. Different letters indicate significant differences within a treatment; ns = not significant.

	CUT		C&S	
	1995	1999	1995	1999
1999	36.8[ns]		19.1[a]	
2004	33.1[ns]	36.4[ns]	14.8[b]	21.8[a]

Biodiversity indices

Other biodiversity indices, including evenness, Shannon's and Simpson's indices supported the patterns seen in the % similarity, particularly in the C&S quadrats. Diversity in CUT quadrats initially increased at 4 years post-harvest, but decreased to pre-harvest levels at 9 years post harvest (Figure 4). The C&S quadrats showed significant declines at both 4 and 9 years post-harvest (Figure 5).

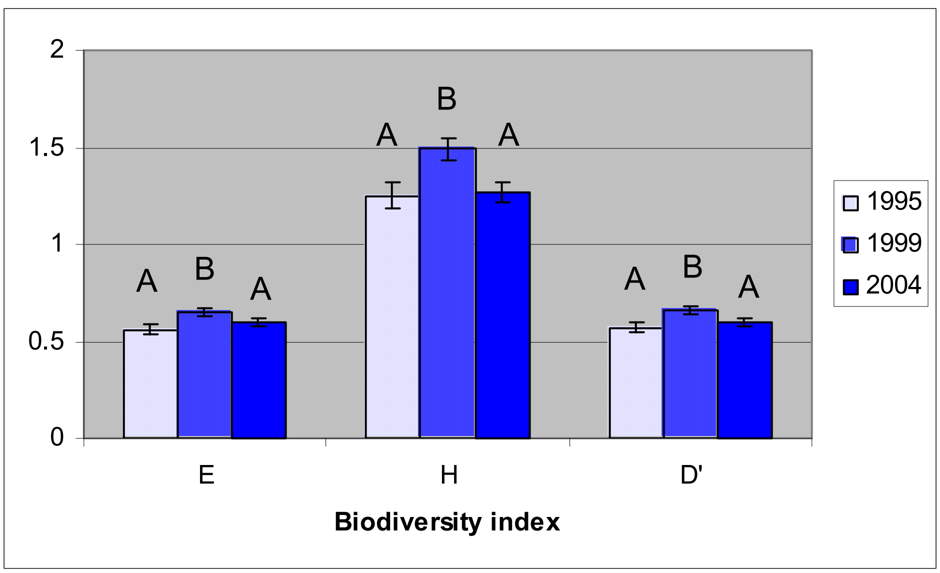

Figure 4. Average biodiversity values of evenness (E), Shannon's (H), and Simpson's (D') indices for CUT quadrats in 1995, 1999 and 2004. Letters above bars indicate significant differences within one index.

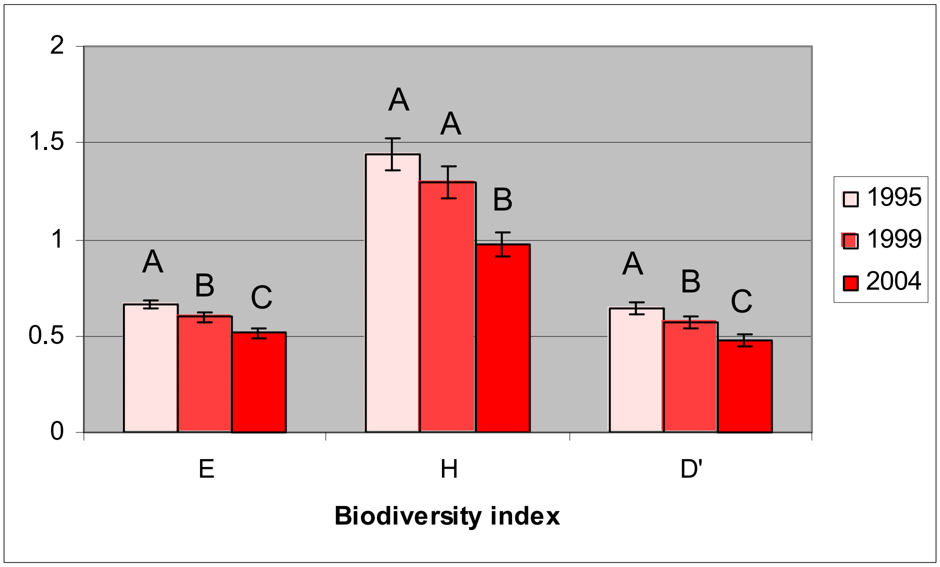

Figure 5. Average biodiversity values of evenness (E), Shannon's (H), and Simpson's (D') indices for C&S quadrats in 1995, 1999 and 2004. Letters above bars indicate significant differences within one index.

Multivariate analyses (Ordination)

Detrended correspondence analysis (DCA) was performed to determine what changes were occurring at the harvest block scale. In the CUT harvest block, the spread of quadrats between 1995 and 1999 can be attributed to an increase or invasion of colonizing species such as *Ceratodon purpureus*, *Pohlia nutans* and *Pohlia lescuriana* (Figure 6). These same species either decreased in abundance or were lost in 2004, shown in the decreasing spread of quadrats in ordination space. Other forest species such as *Ptilium crista-castrensis* and *Jamesoniella autumnalis* either declined or were lost in 1999, and did not recover in 2004.

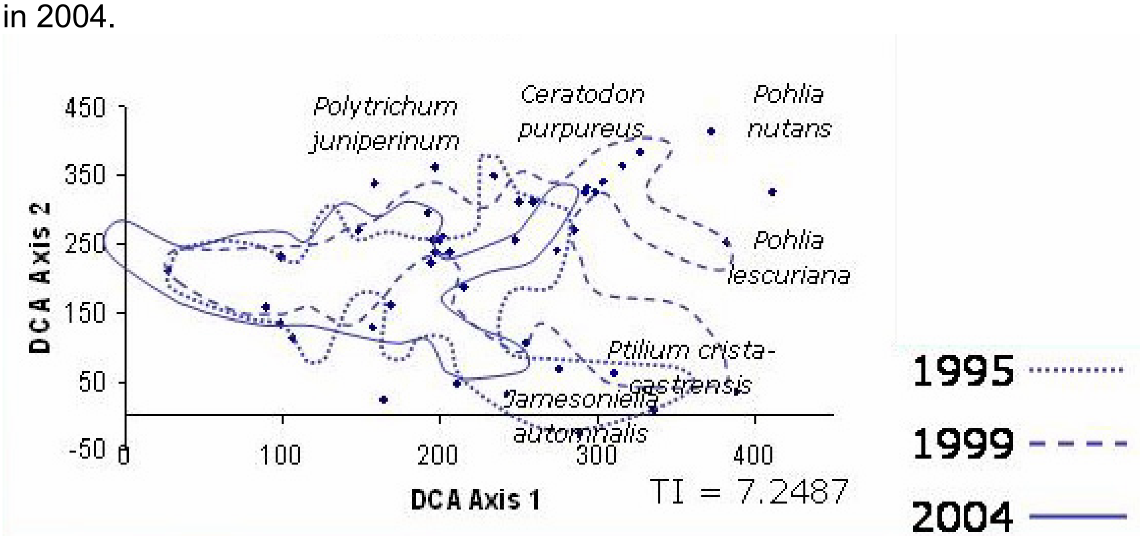

Figure 6. Detrended correspondence analysis (DCA) of CUT data; dots = species, quadrat spread outlined for each sampling date.

A similar trend from 1995 to 1999 (increase in spread of quadrats due to invasion or increase of colonizers) was seen in the C&S quadrats, as well as the loss or decrease of forest bryophytes (Figure 7). However, the colonizers have not declined in 2004 as they did in the CUT quadrats.

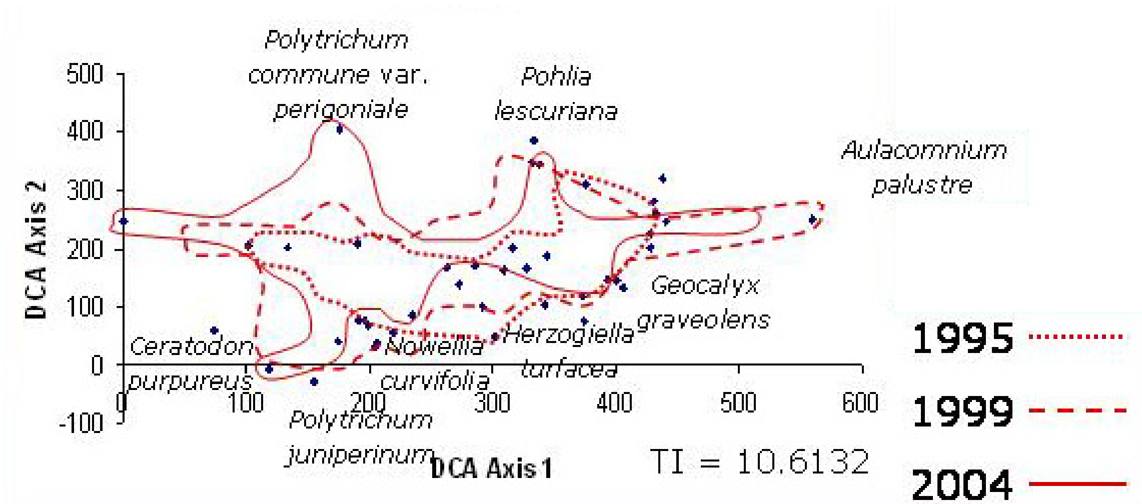

Figure 7. Detrended correspondence analysis (DCA) of C&S treatment showing changes in composition (outlines) by sampling year. Dots = species; selected species are labelled to illustrate compositional changes.

Vascular Plants

Changes in composition

The greatest changes occurred on the C&S treatment, in terms of the number of species that were gained, lost or increased in percent cover (Table 2). More species decreased in abundance on the CUT than the C&S treatment. A relatively large number of species changed on the UNCUT treatment. The two harvest treatments exceeded the UNCUT treatment only in the number of species that decreased in abundance.

Table 2. The number of species that changed in presence or abundance by category of change from 1995 to 2004.

	Treatment		
	Uncut	Cut	C&S
Species lost	10	5	13
Colonists added	23	26	29
Abundance increased	17	12	18
Abundance decreased	9	28	24

Species richness

Total vascular species richness decreased gradually over the entire period on the UNCUT controls (Figure 8). After initially decreasing in the first year after harvest in the CUT and C&S treatments, richness increased to a maximum in 1999 then decreased somewhat in 2003-04.

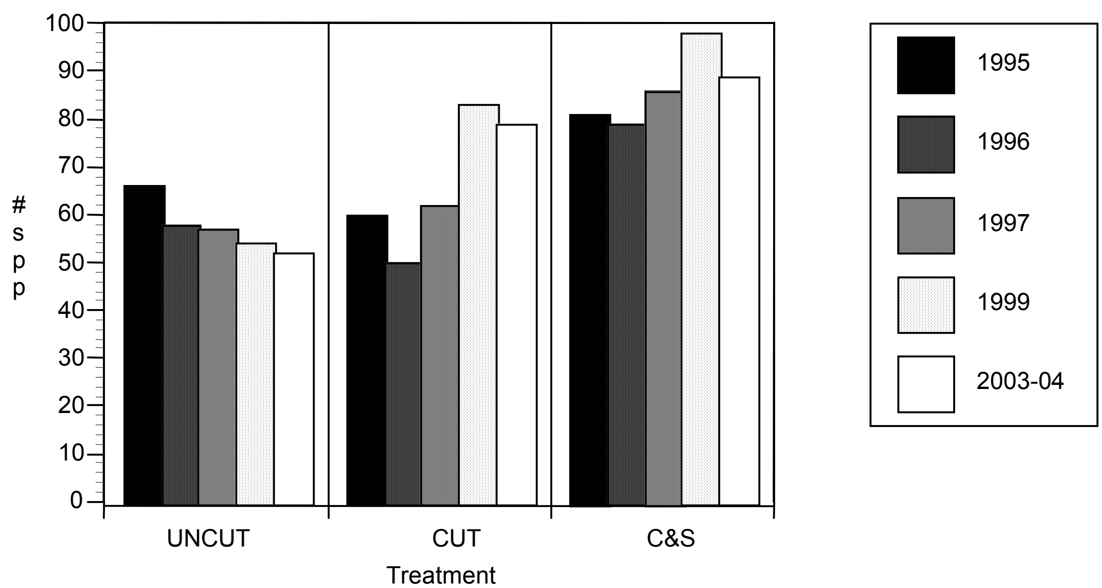

Figure 8. Total richness of vascular plant species in UNCUT, CUT and C&S treatments in all measurement years.

Total species richness decreased gradually over the entire period on the UNCUT controls. After initially decreasing in the first year after harvest in the CUT and C&S treatments, richness increased to a maximum in 1999 then decreased somewhat in 2003-04.

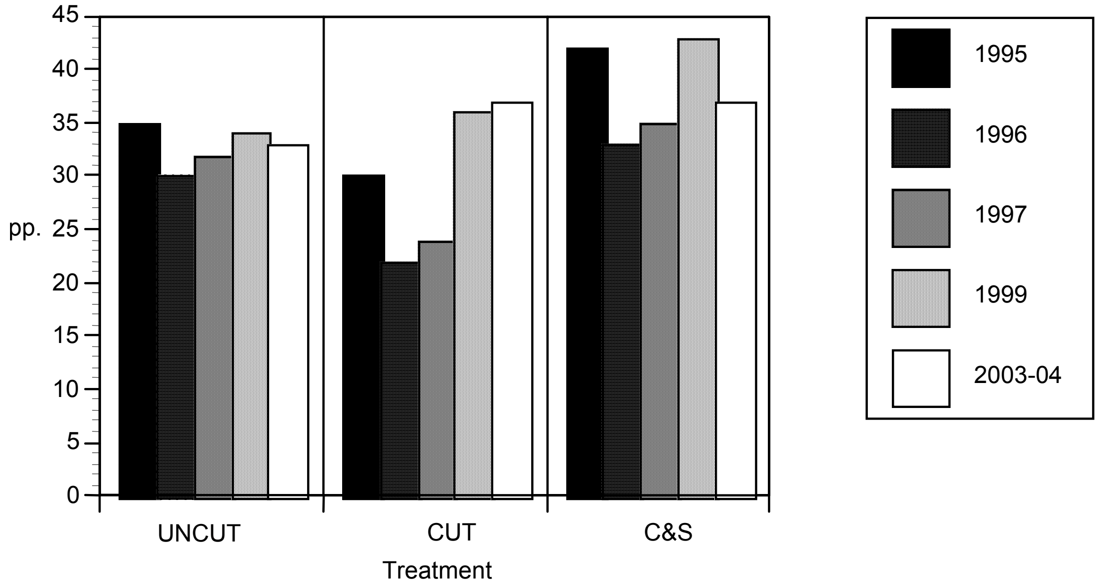

Figure 9. Richness of forest species in UNCUT, CUT, and C&S treatments in all measurement years.

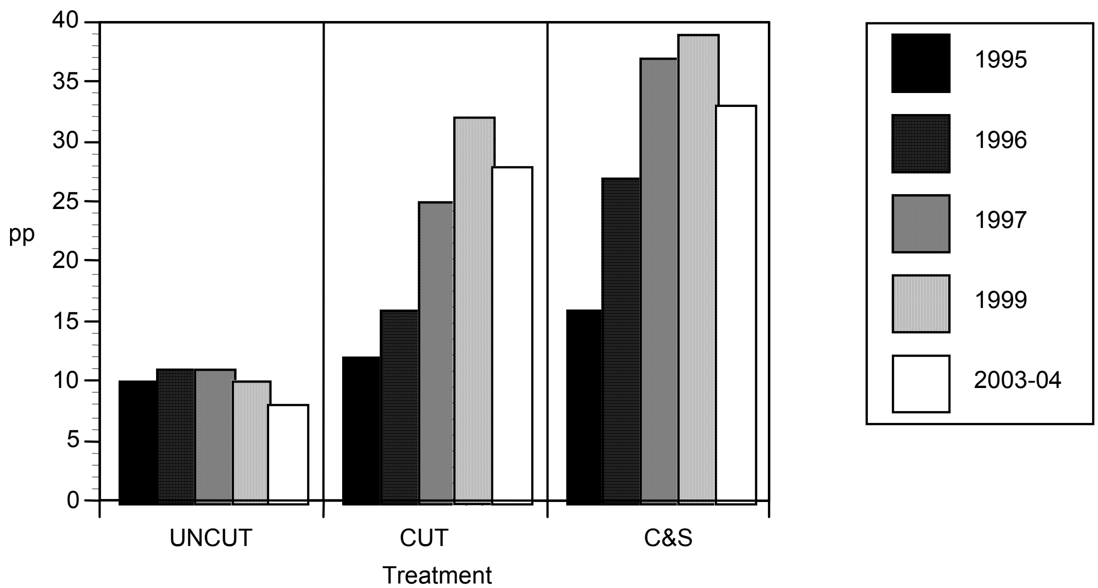

Figure 10. Richness of disturbance species in UNCUT, CUT, and C&S treatments in all measurement years.

Other than the loss of five forest species in 1996, there were few changes in forest and disturbance species on the UNCUT treatment over time (Figures 9-10). Both forest and disturbance species reached a plateau (forest species, CUT treatment), or peaked in 1999 and then declined by 2003-04 (forest species, C&S; disturbance species, CUT and C&S).

Species at risk

Several species at risk have increased in 1999 and 2003-04 to approach preharvest abundance levels (*Chimaphila umbellata, Coptis trifolia, Osmunda* spp., *Trientalis borealis, Trillium undulatum)* in the two harvesting treatments. Other species (i.e. *Dryopteris* spp., *Lycopodium dendroideum, Oxalis montana*) continued to decline in abundance from the first year after harvest (1996) to 2004. *Mitella nuda* showed no consistent pattern.

PRELIMINARY CONCLUSIONS

Bryophytes

Moss richness tended to increase after harvest, and has returned to preharvest levels in both C and C&S, but liverwort richness continues to decline, especially in C&S.

Diversity in CUT quadrats rose slightly after harvest, then returned to pre-harvest levels, while diversity after C&S continues to decline.

In terms of fine-scale dynamics, communities in CUT quadrats showed consistent change (approx 65%) over each four-yr interval, but C&S quadrats showed much greater change, especially in the first 4 yrs after harvest. In each case, the change was attributable to both invasion by colonizer species and loss of forest species, with few of the latter returning. In C&S the colonizers are persisting longer than in CUT.

In summary, while bryophyte diversity has been affected by both management regimes, (a) fine-scale changes in CUT are not evident at the block scale; (b) the community in C&S continues to diverge from its preharvest composition 9 yrs post harvest; and (c) liverworts that were lost are recovering in neither treatment.

Vascular plants

Total species richness of vascular plants reached a plateau in 1999 in the two harvest treatments and appears to be declining. The recent decrease in the C&S treatment reflects losses of both forest and disturbance species, whereas on the C treatment there was a gain of one forest species and loss of four disturbance species. The loss of disturbance species in 2003-04 in the harvest treatments is likely related to closing of the canopy.

The consistent loss of species in the UNCUT control plots is surprising. We will investigate possible causes as the analyses continue. At present, we hypothesize that species losses are occurring in edge plots (UNCUT plots bordering the harvested areas).

All species at risk (based on declines in abundance in 1996-97) were low in abundance throughout the entire study (average percent cover <3% in all years and treatments). Continued remeasurements will be required to determine if *Dryopteris* spp., *Lycopodium dendroideum,* and *Oxalis montana* eventually recover to preharvest abundance levels.

The patterns for all other species beyond 1997 are not yet known. As the analyses continue, we may identify other species that have declined more recently.

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