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Tree Islands: Leave Patches as Refugia for Vascular Plants and Bryophytes in Harvest Blocks

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FINAL REPORT
for fiscal year: 2004 - 2005

Title of Project Tree islands: Leave patches as refugia for vascular plants and bryophytes in harvest blocks	
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EXECUTIVE SUMMARY

In the 2004-2005 project year, work progressed as planned. Monitoring of vegetation, environmental variables and blowdown was continued for the 8 existing tree islands. One reference island was established, and microclimate monitoring continued for tree islands and within a reference area, with a focused effort around one island immediately before and after snowfall.

1. Our sampling intensity captured 73% and 78% of the bryophyte and vascular species (respectively) in the area.
2. **Representivity.** The initial composition of experimental Islands is very similar to their surrounding block (high representivity), with a core of common species. Islands are variable in species content, especially in vascular flora; hence, individual islands are only locally representative. Inside areas of islands are dynamic in species richness and composition of both bryophytes and vascular plants; however, this must next be compared to reference areas to account for natural dynamics.
3. **Post-harvest Effectiveness.** Understory changes inside islands are much less marked than outside, with edges intermediate but perhaps more similar to outside. Microclimatic “edge effect” appears to penetrate less than 25 m into island, but differs considerably with cardinal direction. Major blowdown occurred in first year after harvest, but continues in second year.

Introduction and background

Leave patches or “tree islands” that are left in clearcuts and variable retention harvest blocks appear to function as refuges for some sensitive species of the herbaceous layer (i.e. non-woody plants of the forest floor) and the structural elements upon which they depend (e.g. Fenton and Frego 2004, Fenton et al. 2003, Ross-Davis and Frego 2002, Ramovs and Roberts 2003), but we do not know the critical characteristics of patches that would ensure preservation of these species. Other researchers have shown that microclimatic changes associated with clearing of the forest matrix penetrate forest edges on the order of tree-lengths (e.g. Chen 1992), indicating that only part of a leave patch is likely to escape "edge effects". However, the sensitivity of the understory species to the gradient of microclimatic edge effect is unknown.

Our preliminary work over three years showed that patches left as part of “standard operating procedure” are smaller than the expected 0.25ha, and are often lacking in species and critical elements of stand structure, such as snags, probably because the patches are delineated without these features or species in mind; in fact, they are often located in unique habitats, such as wet areas, within the harvest block. In addition, edge:volume ratios are not minimized (i.e. islands are not isodiametric) because they often follow drainage features such as ephemeral streams. To date it appears that post-harvest microclimatic and other changes on the periphery of the patches extend so deeply into these patches that they are too small to protect the habitats and species contained within. In addition, trees along the newly exposed forest edge are subject to higher winds and may experience a greater proportion of windthrow (‘blowdown’), extending edge effects even further into islands.

The overall goal of this project is therefore to assess the functionality of leave patches of various sizes as plant refugia (including prediction of edge effects), and sources of critical elements of stand structure. Recommendations to follow from this project will include minimum patch size based on thresholds of response of understory species to edge effects in the patches, and number and placement of patches within harvest blocks, based on comparison of species and structural features contained within the patches vs the surrounding areas.
This report focuses on the results of 2004-2005; *additional information from 2005-2006 has been added where available (italicized)*.

PROJECT OBJECTIVES:

1. Assess representivity of patches in harvest blocks in terms of understory species and habitat features.
2. Determine extent of edge effects in terms of (a) microclimatic change and (b) responses of understory species and guilds. Conversely, determine how much of the patch is “functional core” that escapes the immediate influence of the surrounding cutover (relative to natural change occurring in reference areas).
3. Determine patch dynamics, in terms of changes in patch size, and hence the functional core size, associated with blowdown. Do patches shrink symmetrically?

4. Provide recommendations with respect to the placement, minimum size and configuration of patches to insure that refugia for vascular plants and bryophytes and their habitats are maintained.

Workplan objectives for 2004-5:

1. Continue monitoring vegetation and blowdown in permanent plots established in and outside patches in 2002 and 2003.
2. Document microclimatic conditions and community dynamics in reference areas in unharvested areas. It is critical to compare community change in patch cores to that in reference areas to establish whether the centers are free of edge effect from anthropogenic disturbance.
3. Quantify new blowdown in existing islands.

METHODS

Five 1.0ha islands were delineated by Primary Investigators and graduate students, with approval from JDI personnel, as experimental patches in upland cut blocks. Two established in 2002 are within the Holmes Brook watershed (HB1, HB2), while two (Sanatorium Road SR, Babcock Brook BB; established in 2003) and one reference island (REF1; 2004) are located nearby (approx 10 km) in the Pollett River watershed. *A second reference island (REF2; 2005) is located in the Holmes Brook watershed.*

For each, transects on cardinal directions were established, each passing through the center, with belts of 5 1x1m quadrats set at 50 and 5 m from the island edge, in the area to be clearcut, and at 0, 25, 35 m inside the island (Fig. 1). A block of 10 quadrats was positioned at the center of the island.

All quadrats were marked with short wooden stakes driven to ground level, and mapped by GPS. All were sampled before harvest, recording abundance of vegetation (vascular and bryophyte species), environmental features (microtopography, canopy cover, etc.), stand structure (sizes and numbers of trees, snags, saplings and shrubs), and amount of coarse woody debris in four decay classes.

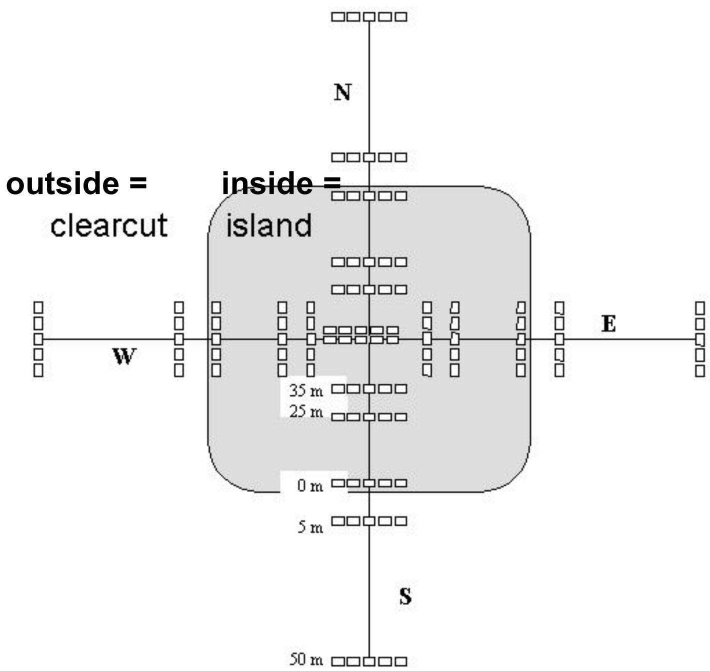

Figure 1. Schematic of sampling design for 1.0ha islands. 1x1m quadrats established in belts of 5, on 4 cardinal transects, at 50 and 5 m into future clearcut, and at 0, 25, and 35m inside island, with a block of 10 quadrats at island center, 50 m from island edge.

The forest block around the four experimental islands was harvested by JDI soon after pre-harvest sampling, according to their standard management prescriptions (e.g. clearcut, scarification, planting).

1: Post-harvest monitoring of existing permanent plots (2003, 2004, *2005*). Permanent quadrats in the reference island and experimental islands (relocated in the spring following harvest for the latter) were resampled for both vegetation and environmental features, including disturbance conditions (slash, machine tracks, exposed mineral soil, etc.). Microclimatic conditions (relative humidity, solar radiation and ground temperature) were monitored with dataloggers (2 each of models CR-10 and 21X; Campbell Scientific & 10 Hobo Pro Series; Onset Computer Corporation) throughout the summer on selected plots in a rotating design, representing the full gradient from the patch center to 50 m into the cutover.

2: Blowdown. Islands were surveyed annually (2002, 2003, 2004, *2005*) for newly broken or tipped up trees, recording species, diameter, height and location relative to edge and compass direction (Trimble GPS unit).

Analyses

Evaluation of sampling intensity
Because the spatial scale of variability for understory components (especially bryophytes) is poorly documented, species accumulation curves were created to determine the level of certainty associated with our sampling design.

Representivity of island flora:
Pre-harvest understories in islands and surrounding cutblock were compared in terms of richness, diversity and species composition to assess the ability of the interior of each island ($\geq$25m from edge) to capture the features of the impact area it was intended to represent.

Assessing early post-harvest changes within islands:
Pre- and post-harvest vegetation, structure and environmental characteristics in experimental and reference islands were compared (a) within islands (excluding edge quadrats) vs surrounding cutovers, (b) at various distances (25, 35, 50m) from the island edge, both overall and (c) among transects (N,S,E,W). Comparisons with the reference island (a) will allow us to quantify post-harvest changes accounting for natural dynamics in closed forest communities in an intact forest matrix. Comparison (b) will allow us to address edge effects in terms of both microclimatic changes and species responses, allowing determination of the extent of an island that is not equivalent to reference conditions; this will ultimately contribute to determination of minimum patch size. Comparison (c) will determine the role of aspect in the response of the forest plant community; it will ultimately contribute to recommendations for patch shape and orientation.

Blowdown and patterns of island shrinkage:
Blowdown was compared as total numbers and basal area of trees, as well as by species. Location (compass quadrant) of blowdown was assessed to identify portions of patches susceptible to loss, e.g. those exposed to prevailing winds.

PRELIMINARY RESULTS

Due to machinery breakdown and delays, scarification of islands established in 2003 was delayed beyond the sampling season. As a result, the cutover sampling of vegetation was delayed till 2004. The unexpected sampling of after harvest but before scarification provides a valuable opportunity to isolate effects of scarification from harvest per se.

Disturbance and environmental data were both sampled for all quadrats prior to scarification as scheduled (Table 1). Sampling in the first reference island (REF1) was completed in 2004; however, identification of bryophytes from it was completed too recently to be incorporated into analyses for this report. *(Establishment and sampling of REF2 was completed in 2005.)*

Table 1. Stages of sampling completed for each island, according to year. For island abbreviations, see text.

Island	Pre-harvest	Year 1	Year 2	Year 3
HB1	2002	2003	2004	*2005*
HB2	2002	2003	2004	*2005*
BB	2003	2004	*2005*	
SR	2003	2004	*2005*	
REF1	2004	*2005*		
REF2	*2005*			

Evaluation of sampling intensity

The species accumulation curve for vascular plants reaches a plateau more rapidly than that for bryophytes (Fig. 2); however, individual islands show considerable variability (Fig. 3). Based on these curves, our use of 110 quadrats should capture 79% and 73% of vascular plant and bryophyte species (respectively) known to occupy the areas sampled (Table 2). The 50 quadrats used to represent the inside of each island (i.e. not including those at the edge) can be expected to capture over 60% of those vascular plant and bryophyte species.

Table 2. Predicted species capture within islands (based on Fig. 2 with n>400 quadrats), relative to totals found in entire cutblock. 110 quadrats = total for each experimental island, island interior = 50; outside island = 40 outside.

# quadrats	vascular spp		bryophyte spp	
	#	%	#	%
110	57	79.2	78	72.8
50	48	66.1	66	62.2
40	45	62.0	62	57.9
Overall flora	**72**	**100**	**107**	**100**

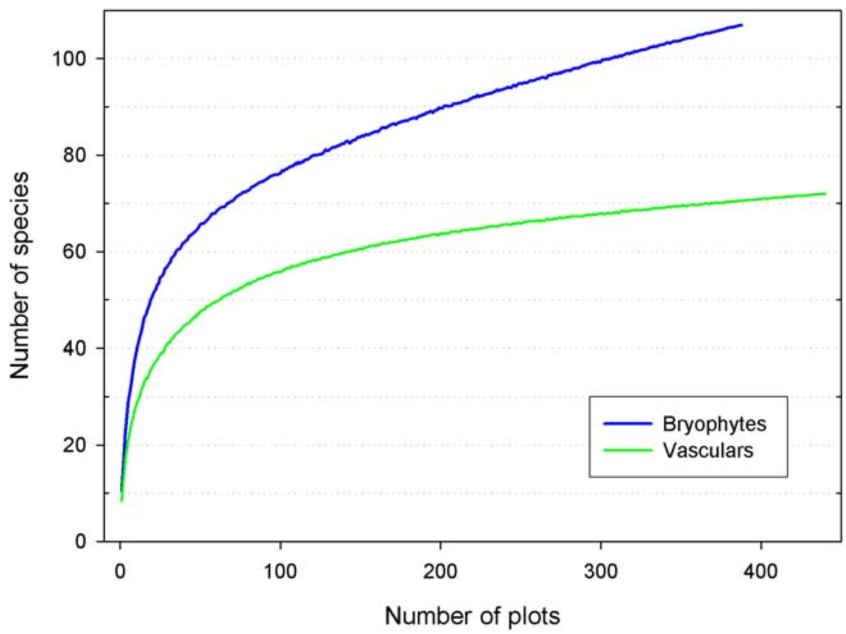

Fig. 2. Theoretical species accumulation curves for vascular (lower line) and bryophyte (upper line) species within tree island study area (all samples pooled). N>400 quadrats.

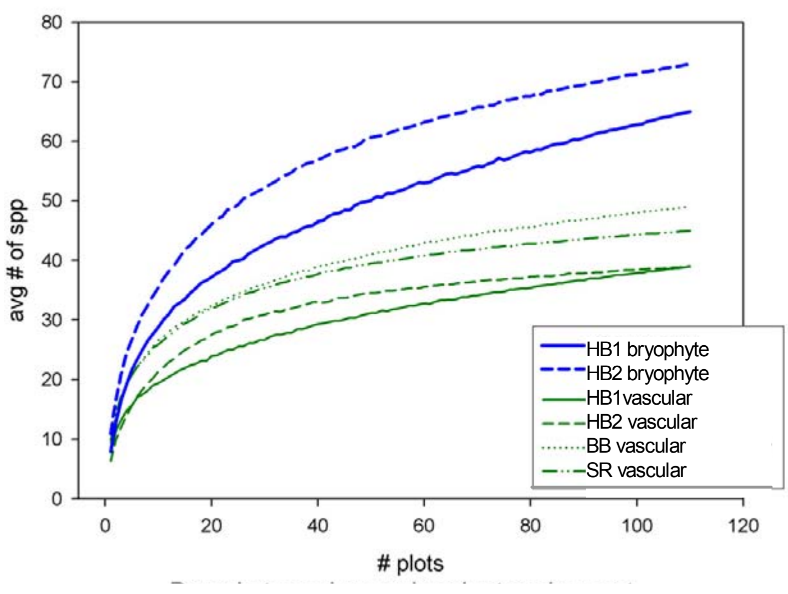

Fig. 3. Species accumulation curves for vascular and bryophytes, within individual islands. The upper two lines are bryophytes, the lower four are vascular species. N = 110 quadrats per island.

Representivity

Visual comparisons of the species found in 50 quadrats within the islands vs those found in the surrounding cutblock were made using Detrended Correspondence Analysis (DCA). Pooled, the four experimental islands captured high proportions of both vascular and bryophyte species (Fig. 3A,B). Variability among individual islands was evident (Fig. 4 A,B), with more pronounced differences for the vascular plant communities. For example, island SR contains more *Sphagnum girgensohnii,* a bryophyte indicative of slightly wetter forest conditions; spruces (*Picea* sp.) were more abundant in island HB1, while islands SR, BB, and HB2 each had greater proportions of balsam fir (*Abies balsamea*). Similarly, differences in island flora (outlined by "envelopes" on the figures) were influenced by different abundances of species found in them. Individual island compositions were most similar to their nearest neighbour islands: HB1-2, vs SR-BB.

The species and their presence inside vs outside the islands are documented in Appendix A. As a case study, using the pooled islands as "lifeboats" for the entire study area, 12 species of liverworts, 14 of moss and 7 of vascular plants would not be protected, i.e. they are present in the area but are not found within the four islands (Table 3).

Post-harvest response

Initial responses to harvest approximated our expectations. In the first year after harvest, plots outside the island showed high frequencies of bryophyte species loss with few additions, whereas plots inside islands showed a normal curve of losses and gains with most showing no change; edge plots were intermediate (Fig. 5).

Using pooled quadrats from the two islands for which two years of post-harvest data are available (HB1, HB2), DCA showed a distinct shift in vascular species composition from pre-harvest to one and two years post-harvest outside the islands, with far less change inside (Fig. 6). As expected, edges were intermediate but showed a notable increase in variability (as seen in spread of quadrats, or area of outlined areas). (Parallel analyses of bryophyte data will be completed soon.)

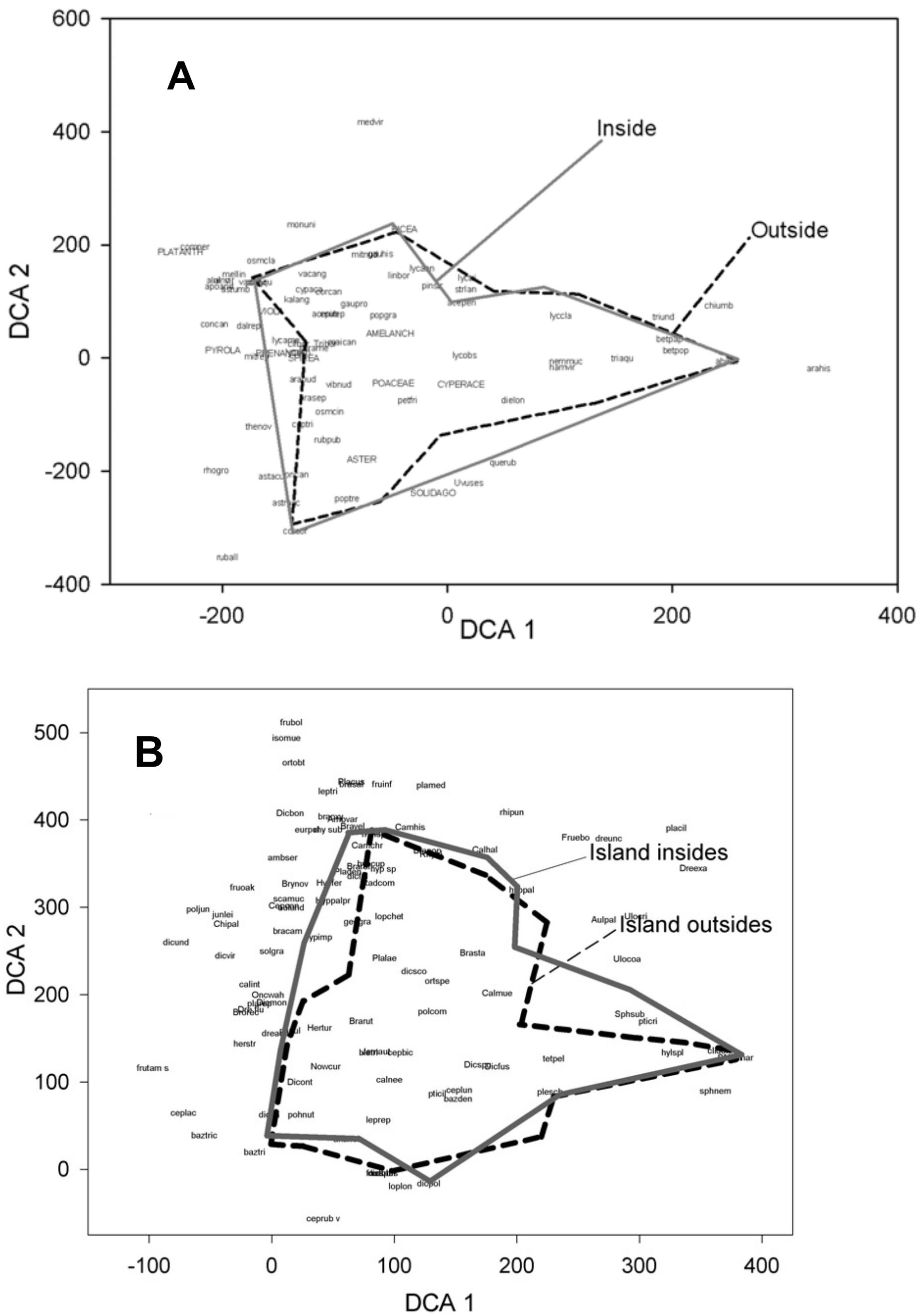

Fig. 3. Comparison of pooled pre-harvest species composition of (A) vascular plants, and (B) bryophytes, inside vs outside islands. Envelopes encase all quadrats of treatment, and degree of overlap is indicative of degree of representivity at this scale.

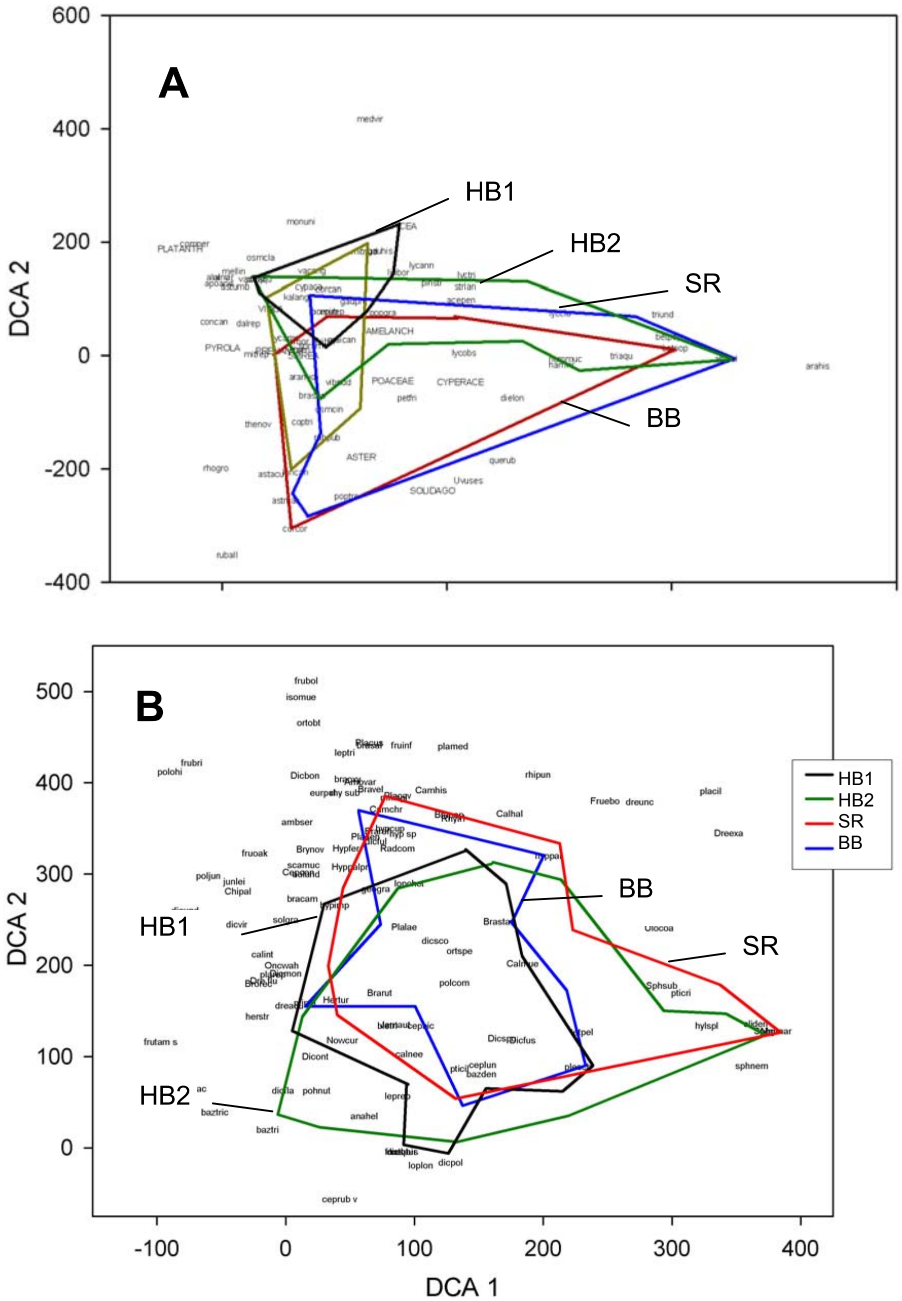

Fig. 4. Comparison of pre-harvest composition for (A) vascular, and (B) bryophyte species by individual island. Degree of overlap (envelopes encase all quadrats for each island) is indicative of similarity in species and abundance.

Table 3. List of species not protected within experimental islands.

Unprotected liverworts:	**Unprotected mosses:**
Bazzania tricrenata	*Aulocomnium androgynum*
Calypogeia muelleriana	*Brachythecium oxycladon*
Calypogeia neesiana	*Climacium dendroidies*
Cephalozia connivens	*Dicranum fulvum*
Chiloscyphus pallescens	*Dicranum spurium*
Frullania bolanderi	*Dicranum viride*
Frullania brittonae	*Drepanocladus aduncus*
Frullania eboracensis	*Drepanocladus fluitans*
Frullania tamarisci ssp. asagrayana	*Mnium spinulosum*
Lophozia longidens	*Orthotrichum ohioense*
Scapania mucronata	*Plagiomnium medium*
Solenostoma gracillimum	*Polytrichum juniperinum*
	Rhizomnium punctatum
	Sphagnum nemoreum

Unprotected vascular plants:	
Comptonia peregrina *Diphasiastrum tristachyum* *Rubus allegheniensis* *Solidago* sp.	Disturbance or open area spp.
Medeola virginianna *Monotropa uniflora* *Thelypteris noveboracensis*	Moist forest spp.

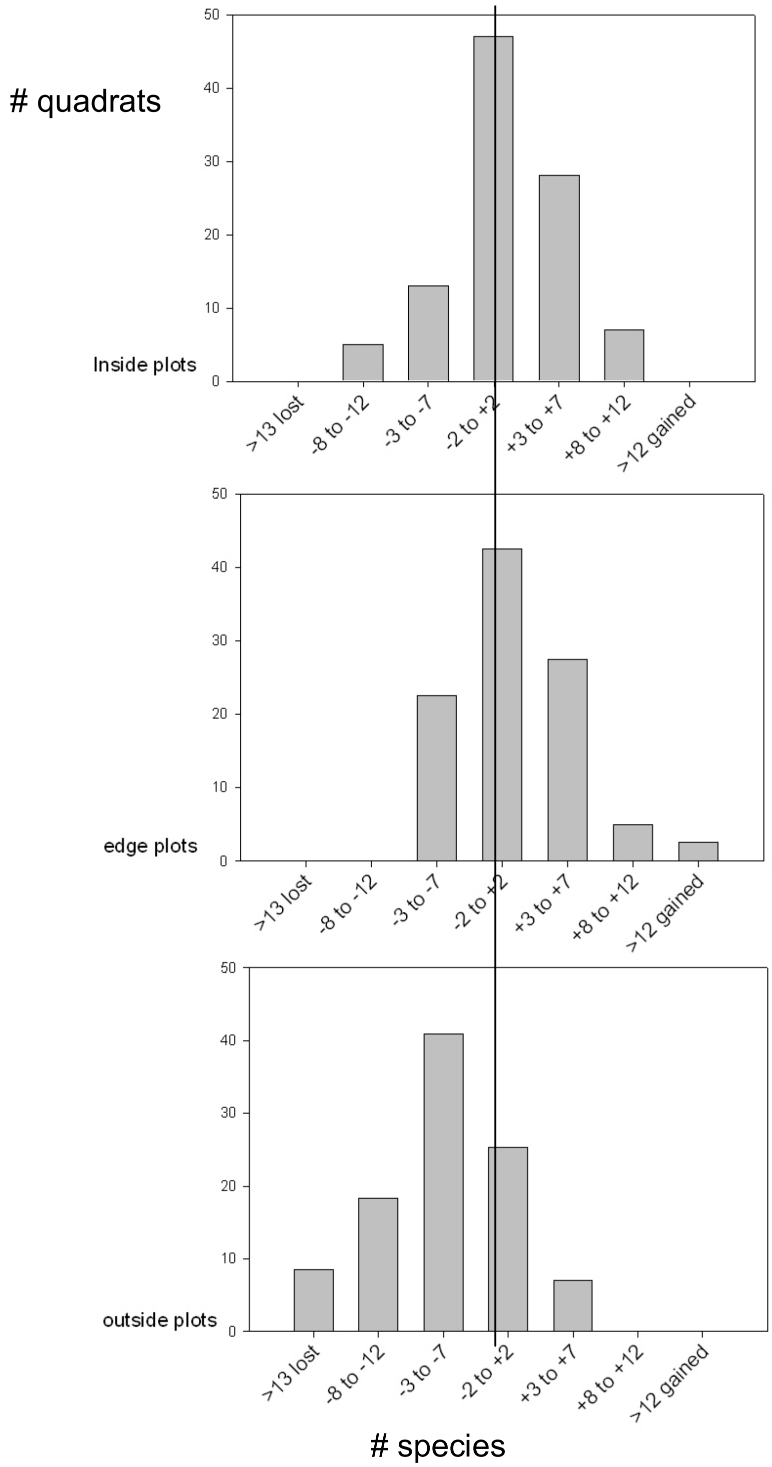

Fig. 5. Frequency distribution of bryophyte species change one year post-harvest, inside, on edge, and outside islands (pooled for 4 islands). Vertical line marks no change.

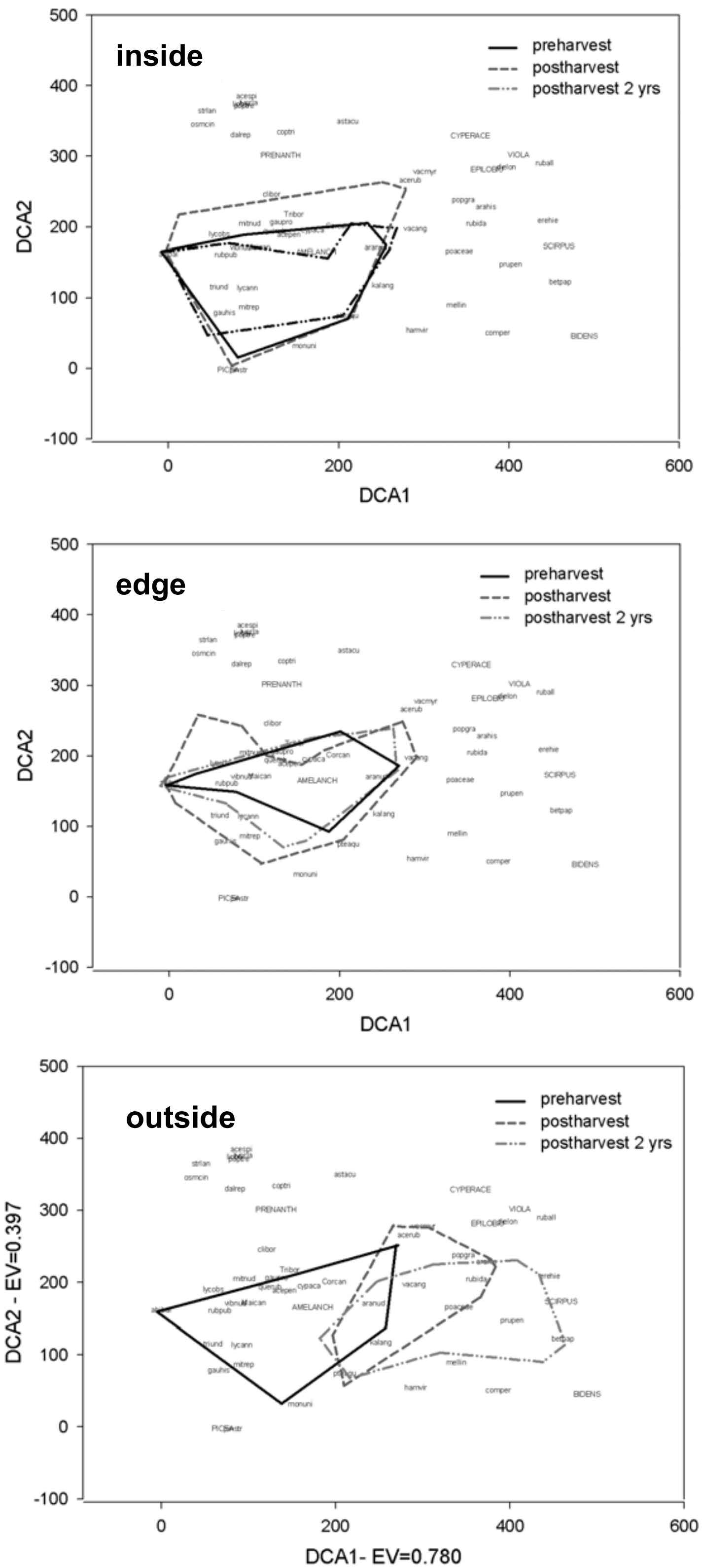

Fig. 6. Changes in vascular species composition inside, at edge, and outside 2 islands, before harvest, through years 1 and 2 after harvest. Total inertia = 6.6675.

Microclimate data require extensive manipulation and analysis which are only partially completed; however, preliminary assessment suggests that average microclimate changes related to the adjacent clearcut do not penetrate to the quadrats 25m from the edge (Fig. 7A). However, there are strong directional differences, with conditions on south and west transects much closer to those in the clearcut, and more extreme than those on north and east transects (Fig. 7B).

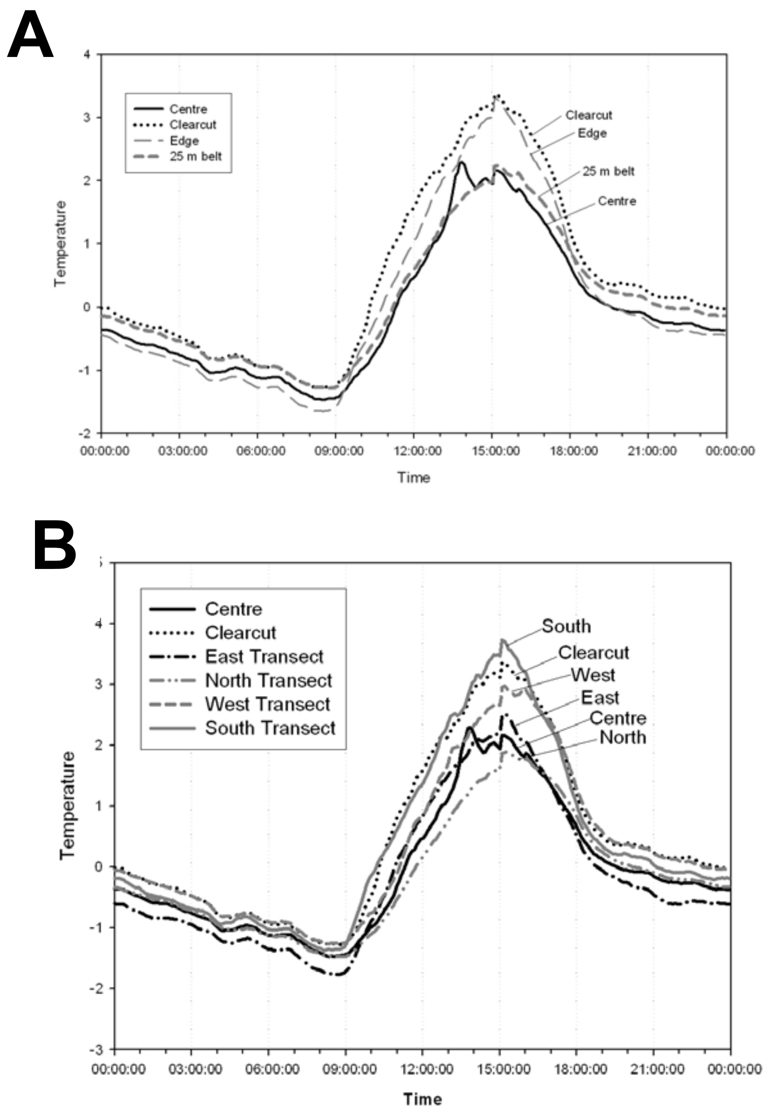

Fig. 7. Examples of daily temperature regimes for November 2004 at the Babcock Brook (BB) island. (A) Peaks for clearcut and edge are very similar, while those for centre and 25m from edge are similar and lower. (B) Average values for transects differ with direction, with peak temperatures ranked south>clearcut>west>east,centre>north.

Blowdown data have not yet been analyzed; however, preliminary assessment (Table 4) suggests that major blowdown occurred in the first year after harvest. Although the rate of blowdown has declined, it continues two years after harvest.

Table 4. Number and basal area (b.a.) of blowdown one year (2003) and two years (2004) after harvest for Holmes Brook tree islands, including data 4 additional smaller islands (I1, I2, I4, I5).

	Island	2003		2004	
Island	Size (ha)	# trees	b.a.	# trees	b.a.
I1	0.50	33	5130.9	8	194.3
I2	0.25	22	4778.1	3	44.38
HB1	1.00	174	28553.7	14	404.1
I4	0.50	49	7687.9	10	212.1
I5	0.25	16	2446.0	3	66.8
HB2	1.00	32	5839.2	8	292.4
Total		326	54435.8	46	1214.1

PRELIMINARY CONCLUSIONS

- With our sampling intensity, we estimate that we captured 73% and 78% of the bryophyte and vascular species (respectively) in the area.
- The initial composition of experimental Islands is very similar to their surrounding block (high representivity), with a core of common species.
  - Islands are variable in species content, especially in vascular flora; individual islands are only locally representative.
- Inside areas of islands are dynamic in species richness and composition of both bryophytes and vascular plants; however, this must next be compared to reference areas to account for natural dynamics.
  - Understory changes inside islands are much less marked than outside, with edges intermediate but perhaps more similar to outside.
- Microclimatic “edge effect” appears to penetrate less than 25 m into island, but differs considerably with cardinal direction.
- Major blowdown occurred in first year after harvest, but continues in second year.

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Appendix A. Species list for pooled islands and their cutblocks. N=4 1.0ha islands, each represented by 50-1m^2 quadrats; cutblocks represented by 40 quadrats.

(a) bryophytes

Species	Lifeform	inside	outside	at risk (only outside)
Amblystegium serpens	moss	●	●	
Amblystegium varium	moss	●	●	
Anastrophyllum hellerianum	liverwort	●	●	
Aulocomnium androgynum	moss		●	●
Aulacomnium palustre	moss	●	●	
Bazzania denudata	liverwort	●	●	
Bazzania trilobata	liverwort	●	●	
Bazzania tricrenata	liverwort		●	●
Blepharostoma trichophyllum	liverwort	●	●	
Brachythecium campestre	moss	●	●	
Brachythecium oxycladon	moss		●	●
Brachythecium populeum	moss	●	●	
Brachythecium reflexum	moss	●	●	
Brachythecium rutabulum	moss	●	●	
Brachythecium salebrosum	moss	●	●	
Brachythecium starkei	moss	●	●	
Brachythecium velutinum	moss	●	●	
Brotherella recurvans	moss	●	●	
Bryhnia novae-angliae	moss	●	●	
Callacladium haldanianum	moss	●	●	
Calypogeia integristipula	liverwort	●		
Calypogeia muelleriana	liverwort		●	●
Calypogeia neesiana	liverwort		●	●
Campylium chrysophyllum	moss	●	●	
Campylium hispidulum	moss	●	●	
Cephalozia bicuspidata	liverwort	●	●	
Cephalozia connivens	liverwort		●	●
Cephalozia lunulifolia	liverwort	●	●	
Chiloscyphus pallescens	liverwort		●	●
Climacium dendroidies	moss		●	●
Dicranum bonjeanii	moss	●	●	
Dicranum flagellare	moss	●	●	
Dicranum fulvum	moss		●	●
Dicranum fuscescens	moss	●	●	
Dicranum montanum	moss	●	●	
Dicranum ontariense	moss	●	●	
Dicranum polysetum	moss	●	●	
Dicranum scoparium	moss	●	●	
Dicranum spurium	moss		●	●
Dicranum undulatum	moss	●		
Dicranum viride	moss		●	●
Drepanocladus fluitans	moss			●
Drepanocladus aduncus	moss		●	●

Species	Lifeform	inside	outside	at risk (only outside)
Drepanocladus exannulatus	moss	●		
Drepanocladus uncinatus	moss	●	●	
Eurhynchium pulchellum	moss	●	●	
Frullania bolanderi	liverwort		●	●
Frullania brittonae	liverwort			●
Frullania eboracensis	liverwort	●	●	
Frullania eboracensis	liverwort		●	●
Frullania inflata	liverwort	●		
Frullania oakesiana	liverwort	●	●	
Frullania tamarisci ssp. asagrayana	liverwort		●	●
Geocalyx graveolens	liverwort	●	●	
Herzogiella striatella	moss	●	●	
Herzogiella turfacea	moss	●	●	
Hylocomium splendens	moss	●	●	
Hypnum cupressiforme	moss	●	●	
Hypnum fertile	moss	●		
Hypnum imponens	moss	●	●	
Hypnum pallescens	moss	●	●	
Hypnum pallescens var. protuberans	moss	●	●	
Isopterygium muellerianum	moss	●		
Jamesoniella autumnalis	liverwort	●	●	
Jungermannia leiantha	liverwort	●	●	
Lepidozia repens	liverwort	●	●	
Leptodictyum trichopodium	moss	●	●	
Lophocolea heterophylla	liverwort	●	●	
Lophozia longidens	liverwort		●	●
Mnium marginatum	moss	●		
Mnium spinulosum	moss		●	●
Nowellia curvifolia	liverwort	●	●	
Oncophorous wahlenbergii	moss	●	●	
Orthotrichum ohioense	moss		●	●
Orthotrichum speciosum	moss	●	●	
Plagiothecium cavifolium	moss	●	●	
Plagiomnium ciliare	moss	●	●	
Plagiomnium cuspidatum	moss	●	●	
Plagiothecium denticulatum	moss	●	●	
Plagiothecium laetum	moss	●	●	
Plagiomnium medium	moss		●	●
Platygyrium repens	moss	●	●	
Pleurozium schreberi	moss	●	●	
Pohlia nutans	moss	●	●	
Polytrichum commune	moss	●	●	
Polytrichum juniperinum	moss		●	●
Polytrichum ohioense	moss	●		
Ptilidium ciliare	liverwort	●	●	
Ptilium crista-castrensis	moss	●	●	
Ptilidium pulcherrimum	liverwort	●	●	

Species	Lifeform	inside	outside	at risk (only outside)
Radula complanata	liverwort	●	●	
Rhizomnium punctatum	moss		●	●
Rhytidiadelphus subpinnatus	moss	●		
Rhytidiadelphus triquetrus	moss	●	●	
Scapania mucronata	liverwort		●	●
Solenostoma gracillimum	liverwort		●	●
Sphaghum girgensohnii	moss	●	●	
Sphagnum nemoreum	moss		●	●
Sphagnum subtile	moss	●		
Tetraphis pellucida	moss	●	●	
Ulota coarctata	moss	●	●	
Ulota crispa	moss	●	●	

(b) vascular plants

Species	inside	outside	at risk (only outside)
Abies balsamea	●	●	
Acer pensylvanicum	●	●	
Acer rubrum	●	●	
Alnus incana	●	●	
Alnus viridis	●		
AMELANCHIER	●	●	
Apocynum androsaemifolium	●		
Aralia nudicaulis	●	●	
Aster acuminatus	●	●	
ASTER	●	●	
Aster macrophyllus	●	●	
Betula papyrifera	●		
Betula populifolia	●		
Brachyelytrum septentrionale	●	●	
Chimaphila umbellata	●		
Clintonia borealis	●	●	
Comptonia peregrina		●	●
Coptis trifolia	●	●	
Cornus canadensis	●	●	
Corylus cornuta	●	●	
Cypripedium acaule	●	●	
CYPERACEAE	●	●	
Dalibarda repens	●	●	
Diervilla lonicera	●	●	
Epigaea repens	●		
Gaultheria hipidula	●	●	
Gaultheria procumbens	●	●	
Hamamelis virginiana	●	●	
Kalmia angustifolia	●	●	
Linnaea borealis	●	●	
Lonicera canadensis	●	●	
Lycopodium annotinum	●	●	

Species	inside	outside	at risk (only outside)
Lycopodium clavatum	●	●	
Lycopodium dendroideum	●	●	
Lycopodium obscurum	●	●	
Diphasiastrum tristachyum		●	●
Maianthemum canadense	●	●	
Medeola virginianna		●	●
Melampyrum lineare	●		
Mitella nuda	●	●	
Mitchella repens	●	●	
Monotropa uniflora		●	●
Nemopanthus mucronatus	●	●	
Osmunda cinnamomea	●	●	
Osmunda claytoniana	●		
Petasites frigidus	●	●	
Picea glauca	●		
Picea marianna	●		
Picea rubens	●		
Pinus strobus	●	●	
PLATANTHERA	●		
POACEAE	●	●	
Populus grandidentata	●	●	
Populus tremuloides	●	●	
Prenanthes trifoliolata	●		
Pteridium aquilinum	●	●	
PYROLA	●		
Quercus rubra	●	●	
Rhododendron groenlandicum	●		
Rubus allegheniensis		●	●
Rubus pubescens	●	●	
SOLIDAGO		●	●
Sorbus americana	●	●	
SPIREA	●	●	
Streptopus lanceolatus	●	●	
Thelypteris noveboracensis		●	●
Trientalis borealis	●	●	
Trillium undulatum	●	●	
Uvularia sessilifolia	●	●	
Vaccinium angustifolium	●	●	
Vaccinium myrtilloides	●	●	
Viburnum nudum	●	●	
VIOLA	●	●	

Partners in Sustainability/Partenaires pour durabilité

Atlantic Society of Fish and Wildlife Biologists
Canadian Institute of Forestry
Canadian Forest Service
City of Moncton
Conservation Council of New Brunswick
Eel Ground First Nation
Elgin Eco Association
Environment Canada
Fawcett Lumber Company
Fisheries and Oceans Canada
Fundy Environmental Action Group
Fundy National Park
Greater Fundy Ecosystem Research Group
Indian and Northern Affairs Canada
INFOR Inc.
J.D. Irving, Limited
K.C. Irving Chair in Sustainable Development, Université de Moncton
Maritime College of Forest Technology
NB Department of Environment and Local Government
NB Department of Natural Resources and Energy
NB Federation of Naturalists
NB Federation of Woodlot Owners
NB Premier's Round Table on the Environment & Economy
NB School District 2
NB School District 6
Nova Forest Alliance
Petitcodiac Sportsman's Club
Red Bank First Nation
Remsoft Inc.
Southern New Brunswick Wood Cooperative Limited
Sussex & District Chamber of Commerce
Sussex Fish and Game Association
Town of Sussex
Université de Moncton
University of New Brunswick Fredericton Faculty of Forestry and Environmental Management
University of New Brunswick Saint John
Village of Petitcodiac
Washademoak Environmentalists