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Project No./Title: 5605 - Leave Patches as Refugia for Vascular Plants and Bryophytes in Harvest Blocks (Vascular Plant Component)

Project Proponent: Mark R. Roberts
Faculty of Forestry and Environmental Management
University of New Brunswick-Fredericton.

Executive Summary

Our work to date has focused on identifying herbaceous layer (vascular plants and bryophytes) species that are at risk to clearcut harvesting and plantation management practices in the Acadian Forest. The project described in this report was undertaken to provide information on the biodiversity conservation value of leave patches and provide recommendations on how leave patches can be best designed and managed to conserve species of the herbaceous layer and their habitats. Our design includes pre- and post-harvest sampling in permanent plots established before harvest in tree islands of varying sizes. Sampling in 2002 consisted of post-harvest remeasurements on three islands established in 2001 and pre-harvest measurements on six new islands that were delineated in 2002. Permanent 1m^2 plots are located on transects which extend through the islands into the surrounding cutover to allow us to assess the degree of edge effects in relation to island size and orientation. Species composition of the herbaceous layer (vascular plants and bryophytes), stand structure (tree sizes and densities, coarse woody debris and snags), and microclimatic characteristics (solar radiation, relative humidity and temperature) were measured along the transects. Based on comparisons between plots inside the islands and those in the adjacent areas outside, not all islands were representative of the species composition or stand structure variables (e.g., snag density) in the harvest blocks before harvest. Further work will be needed to determine how to make islands more representative of species composition throughout the cutblock. Large changes in microclimate and species abundances within 10 m of the inner island edge in the first year after harvest indicate that edge effects extend at least this far into the island, although additional monitoring will be needed to determine if the edge zone continues to expand over time. The results from this work will enhance managers' knowledge of the ecological role of leave patches, especially in maintaining habitats for sensitive species, and will provide guidelines for managing such patches.

Objectives

Assess effectiveness of leave patches of varying sizes and shapes in providing refugia for vascular plants and bryophytes and as a source of stand structure in harvest blocks.
Determine spatial extent of edge effect in leave patches as a function of patch size, shape, and orientation.
Quantify amount of blowdown and changes in size of leave patches over time.
Provide recommendations with respect to the minimum size and configuration of leave patches to insure that refugia for vascular plants and bryophytes and their habitats are

maintained.

Methods

New Islands

We delineated a total of six new leave patches (tree islands) before harvesting in June 2002. There were two islands in each of three size classes (0.25, 0.5 and 1.0 ha). These islands are located in two stands that were subsequently harvested in August 2002 in the Holmes Brook area near Petitcodiac, N.B. (45 ° 88' N, 65 ° 20' W). Our study design includes before and after monitoring of vegetation and environmental conditions within a network of permanent quadrats in these islands and the surrounding cutover.

Transects were laid in north, south, east, and west directions from the island center extending 25 m to 50 m into the adjacent cut block. In the 1.0 ha islands (Fig. 1), a belt of five 1m^2 quadrats were placed at each of six locations (50 m and 5 m from the edge into the cut block, at the edge, and 25 m and 35 m from the edge into the island) along the transect. The axis of the belt was perpendicular to the direction of the transect. Two belts, perpendicular to the north and south transects, were placed in the center of the island. Transects in the 0.25 ha and 0.5 ha islands (Fig. 2) contained single 1 m^2 quadrats at 5 m intervals (5, 10, 15, 20 and 25 m from the edge into the cut block, at the edge, and 5, 10, 15, and 20 m from the edge into the island). All species of vascular plants were recorded by percent cover in the quadrats. Bryophytes were sampled by percent cover by field assistants under the supervision of Kate Frego.

Environmental variables collected in each quadrat are shown in Table 1. Substrate data were collected as percent cover. Coarse woody debris was further broken down in four decay classes. Percent canopy cover was measured as the average of four measurements in each plot taken with a spherical densiometer and coniferous and deciduous cover were measured seperately. Microtopography was characterized as percent cover of pits, mounds, and level ground, along with depth of pits and height of mounds. The point centre quarter method was used to characterize tree density surrounding each quadrat. The four closest trees > 7 cm dbh, one for each of four quadrants extending from the plot center, were recorded by species, distance from the quadrat center, and dbh. These data will be used to calculate number of stems per hectare and basal area by species to characterize tree canopy conditions surrounding each quadrat.

5 m x 5 m stand structure plots were established at the 1.0 ha islands centered on the quadrats at 50 m into the cut and 5 m and 25 m inside the island on each transect. In the 0.25 ha and 0.5 ha islands, they were located at quadrats 1 and 6 on each transect (with an additional stand structure plot near the island center). Data collected were: 1) the dbh, height, species, and percent live crown for trees and snags >7 cm dbh; 2) saplings and shrubs (<7 cm dbh) by species and number of stems; and 3) coarse woody debris by length, dbh top and bottom, decay class, and species where possible (Table 1).

We used dataloggers placed adjacent to a subset of quadrats, in addition to two controls, before and after harvest to record temperature, relative humidity, photosynthetically active radiation (PAR), and rainfall. One CR21X (Campbell

Scientific) with one PAR and temperature-relative humidity probe was placed in an open area within a recent clearcut, in order to capture the ambient PAR, temperature, and relative humidity (RH) without any canopy influence (the open control). Another CR21X with the same probe configuration was placed in a contiguous forest to act as a reference compared to the microclimate of the islands (the forest control). These controls were in place from early June to mid-September. Two CR10's (Campbell Scientific) with PAR and temperature-RH probes attached and HOBO temperature/relative humidity dataloggers (Hoskin Scientific) were placed in the field in late June 2002 in the two 1.0 ha islands designated to be cut. These dataloggers were placed along a transect that passes from the centre of the future island to the southern edge and into the future clearcut. See Fig. 1 for probe placement. HOBOs were left in place while the CR10s were rotated between the two 1.0 ha islands on a bi-weekly basis. Dataloggers were removed during harvest in late July and reinstalled in late August in order to collect immediate post-harvest microclimatic data until mid-September. A CR10 was placed in each 1.0 ha island with PAR and RH probes and HOBOs at 25 m and 35 m into the interior. An additional HOBO was placed at the edge. Because of the continued presence of heavy harvesting equipment, dataloggers were not returned to the cut immediately following harvest but were restricted to the edge and the island interior. These data will be collected in the summer of 2003. Rain gauges were placed in association with each datalogger sensor pair in the controls and the 1.0 ha islands throughout the sampling.

In order to relocate quadrats in the cut after harvesting, witness tree data were recorded. Compass bearings and distances from selected trees to the corner stake of the permanent quadrat were measured. Species and diameter were recorded and the base of each tree was blazed with spray paint.

Existing Islands

Three islands established in 2001 in the Hayward Brook area near Petitcodiac were resampled in 2002, the first year after harvest. In addition to resampling of vegetation and environmental conditions (preharvest sampling was done in 2001), disturbance conditions were characterized (see Table 2). Disturbance data collected were quadrat location relative to the island edge, slash variables, and percent cover of substrate covered by organic and inorganic debris. We also catagorized the substrate according to percent invisible, undisturbed, disturbed, and with exposed mineral soil along with the percent of the plot surface that was invisible. Skidder tracks were recorded by percent cover, type (litter, mixed litter and soil, soil, crushed wood, litter and crushed wood, and soil and crushed wood), and depth.

Data Analysis

For each of the six new islands (established in 2002), mean values for each environmental variable and mean cover for each species were calculated by: 1) plot location (in island, on edge, or out of island), and 2) distance from island edge (minus values indicate plots within island, plus values indicate plots outside island). Values were compared for plots in the island to those outside the island to determine how representative the islands are of species and environments within the harvest block. Values were graphed as a function of distance from island edge to determine extent of edge effect. Microclimate data (temperature and relative humidity) were examined as daily maximum and minimum temperature and relative humidity over the measurement period (July-August, 2002). Separate graphs were generated for each plot that was monitored in one island.

For each of the three existing islands (established in 2001), we compared mean cover of each species by plot location and distance from island edge (as above); in addition, we compared the change in cover from 2001 to 2002 for each species as a function of plot location (inside vs. outside island) and distance from the island edge. Results are displayed graphically. Because the results are preliminary (only one year of response data to date), we have not made statistical comparisons.

Objective 1: Effectiveness of leave patches as refugia for vascular plants and stand structure.

There are two components of effective refugia: 1) representivity, measured as the degree to which species composition in the patches corresponds to composition in the area immediately surrounding the patch, and 2) response following harvest in terms of survival of species and changes in stand structure and environments. Our approach to assessing each of these two components is described separately below.

Representivity

With the preharvest data collected in the 2001 and 2002 islands, we can determine whether the species composition, stand structure and environments in the islands are representative of conditions in the harvest block by comparing the plots within the islands to those outside of the islands.

Preharvest vegetation data from the 2001 islands indicate that most species have low abundance (< 1% average cover) and that there are some large differences in the abundance of individual species between plots inside and outside of the islands. In island 2, for example, both the "in" and the "out" plots are dominated by *Abies balsamea* and *Osmunda cinnamomea*, although the cover of these two species in the "out" plots is twice that of the "in" plots (Fig. 3). Also, cover of *Pteridium aquilinum*, *Aralia nudicaulis*, *Acer rubrum*, *Cornus canadensis*, and *Thelypteris phegopteris* is greater in the "out" plots, whereas cover of *Rubus pubescens*, *Trientalis borealis* and *Prenanthes* spp. is greater in the "in" plots. The other two 2001 islands show similar patterns of in versus out differences, although for different individual species. Sörensens index, a measure of overall compositional similarity, was calculated for each island separately, comparing the in versus out plots. The values are 65%, 54%, and 65%, for islands 1, 2 and 3, respectively.

Some of the 2002 islands showed differences in species composition between the in and out plots and some did not. Three of the six islands are shown in Fig. 4 as examples. In island 1, *Aster acuminatus, Coptis trifolia, Lycopodium annotinum, Osmunda cinnamonea* and *Viola* spp. were all more abundant inside the island. Several of these species grow in wet sites, suggesting that the island location was wetter than the surrounding area. Species composition was similar between in and out locations in islands 2 and 3, although the ferns *Dennstaedtia punctilobula* and *Osmunda cinnamonea* were more abundant inside than outside island 2. Islands 4 and 5 also showed obvious differences in individual species inside versus outside the island, whereas island 6 did not (not shown).

The environments in the 2002 islands were quite similar among in and out locations (islands 1-3 shown as examples in Fig. 5). One notable difference was higher leaf cover (and lower needle cover) in the out plots than the in plots in island 2.

Stand structure was also assessed for the plots inside and outside the islands for each 2002 island. A number of variables were measured but only total tree density (stems > 7cm dbh), snag density (> 7 cm dbh) and density of saplings and shrubs (woody stems < 7 cm dbh) for one island are presented for simplicity. For island 2 (Fig. 6), *Acer rubrum* and *Tsuga canadensis* were more abundant outside the island whereas *Abies balsamea* and *Picea rubens* were more abundant inside. No snags were encountered inside island 2 compared to a total of 16 snags outside. The sapling/shrub layer was more well developed inside the island than outside, with 5 times the density of *Abies balsamea* saplings. The other islands showed variable patterns, but in 4 of 6 islands, there was lower snag density inside the island than outside.

When delineating islands in proposed cut blocks, islands should be located to represent the typical species composition, stand structure and environments in the harvest block. In addition, some islands may need to be established to represent local unique patches such as wet areas.

Initial response after harvest

Results from the first year after harvest in the existing (2001) islands indicate several different types of trends among individual species, as illustrated for Island 1 in Figure 7, which shows cover change by species from 2001 to 2002. In plots outside the island, several early successional species (*Carex* spp., *Populus tremuloides* and *Rubus idaeus*) invaded and two forest species (*Coptis trifolia* and *Lycopodium lucidulum*) declined in abundance. Inside the island, *Populus tremuloides* and *Pteridium aquilinum* increased in abundance. Most species present before harvest in the islands are still present after the first year. Sampling this coming summer will help clarify whether a pattern develops in terms of losses of forest species or gains of early successional species.

Data from the new islands so far are limited to the preharvest species composition and initial changes in microclimate in the first month after harvest. We hope to continue sampling this summer (the first full year after harvest) to establish initial changes in species composition and environments. In addition, we propose to establish additional new islands this summer and conduct preharvest sampling. This will increase replication and confidence in results.

Objective 2: Spatial extent of edge effect in leave patches.

The full extent of the edge effect in islands will not likely be apparent until several years following harvest. Nonetheless, we expect that several microclimate and vegetation variables will be useful indicators in the first year after harvest of the potential long-term edge effects. These variables include increases in number and cover of early successional species, decreases in relative humidity and increases in ground surface temperature within the interior portion of the edge. Other variables, such as decreases in forest interior species, are likely to develop over a longer time period and will require monitoring over several years. In addition, we expect to observe a gradient in these changes, large near the edge of the island and decreasing toward the center of the island. It is critical to identify the maximum extent of this edge effect because in order to function as refugia for herbaceous plants and bryophytes, and probably other organisms, the island has to be large enough to provide a functional core, free from the influence of edge effects. Our sampling design, which includes plots at varying distances along transects across the edge, will allow us to identify the extent of edge effects both into the island and into the cut from the island edge.

Microclimate

Daily maximum temperature was similar between the island edge (0 m) and the island interior (25 m) in July and early August before harvest (Fig. 8). There is a gap in the data in mid-August during harvest. Temperatures were roughly 5 degrees lower in the island after harvest. Daily minimum temperatures were similar between the two locations, both before and after harvest.

Daily maximum relative humidity was similar between the two locations before and after harvest. Minimum RH was roughly 20% greater at 25 m in the island after harvest. These results confirm our general expectations with respect to temperature and humidity changes following canopy removal as found in other studies. Additional microclimate monitoring over a full growing season will be required to quantify the degree of difference between island and cutover locations and to characterize peak occurrences which are likely to be correlated with plant mortality patterns.

Vegetation

The pre-harvest vegetation data collected in the 2002 islands indicate that there was considerable variability among islands in terms of total cover and species composition. In particular, Island 1 contained little cover in the herbaceous layer compared to the other 5 islands. Islands 1, 2 and 6 were dominated by *Abies balsamea* (ABIBA) in the ground layer, whereas islands 3, 4, and 5 were domianted by spruce (*Picea*) cover.

Changes in species abundance (average cover) after harvest, relative to preharvest cover, are being examined on a species by species basis in the 2001 islands. Response in the first year after harvest revealed the following patterns (Fig. 9): 1) Cover of *Abies balsamea* (stems < 1 m tall) declined dramatically in plots outside the island but much less so in plots inside the island; 2) *Carex* invaded plots outside the island within 25 m of the edge; 3) *Populus tremuloides* showed the greatest increases from within 5 m outside the edge to 10 m inside the edge. Based on these early results, obvious vegetation changes occur inside the edge within 10 m. Additional sampling over a longer time period will be required to determine if the maximum extent of this edge effect changes over time.

Objective 3: Amount of blowdown and changes in size of leave patches over time.

Blowdown was assessed in 26 previously existing islands (approx. 1-2 years-old) in summer 2001 and results were presented in the 2002 FMF Year-End Report. In brief, we found that most blowdown was spread across the entire range of dbh classes (5-25 cm) and trees > 5 m height appeared most likely to blow down. In addition, the northeast quadrant of islands consistently experienced the least blowdown, reflecting the direction of prevailing winds from the southwest. Future work is needed to establish rate of island shrinkage which is necessary to determine minimum island size.

Objective 4: Recommendations on minimum size and configuration of leave patches.

Recommendations will be developed over the next year after another year of response data has been collected. These recommendations will be based on the spatial extent of edge effects (which determine area of the functional core in islands), the amount of blowdown that occurs within the first 2 years after harvest and the resulting change in island size (which again affects the functional core) and the response of vascular plants in terms of survival and changes in abundance in islands. Our preliminary findings this year suggest the following:

- Species composition in islands can be quite variable; thus, islands may not be representative of species composition throughout the cutblock unless islands are delineated with species representivity in mind
- Islands may not always contain important structural features, e.g., snags, large trees, coarse woody debris, unless these features are considered in laying out the islands
- Increases in early successional species extend at least 10 m into the islands from the edge

Expenditures

Expenses

Graduate student salary (Ms. Jolan Sulinski)	$ 18,900
Student summer salaries (Mr. Maurice LeBlanc)	4,839
Student Academic year salaries (Mr. M. LeBlanc, C. Gruenwald)	1,776
Field accommodations and meal subsidy	1,500
Transportation (vehicle rental, gas, insurance)	5,400
Presentation materials (e.g. photographs, poster)	500
Equipment and supplies (temp./humidity sensors)	1,000
Total	$ 33,915

Collaborative Funding

Agency	Cash	In-kind
Summer Career Placement	$ 1,283	
UNB Work-Study	$ 1,376	
UNB Faculty of Forestry & EM (salary of PI)		$ 17,000
UNB Fac. Forestry & EM (lab, computer, printer)		$ 14,000
UNB Graduate Teaching/Research Assistantships	$ 6,000	
Mountain Equipment Co-op	$ 3,000	
Atlantic Land Improvement Contractors	$ 3,900	
UNB Fac. Forestry & EM (dataloggers, sensors)		$ 10,000
UNB Fac. Forestry & EM	$ 6,356	
Fundy Model Forest	$12,000	
Total	$33,915	

Deliverables

Assessment of changes in vascular plants, bryophytes (companion study by Kate Frego) and stand structure features in leave patches as a function of distance from the edge.
Quantification of the amount of blowdown in tree islands over time.
Assessment of size distribution of tree islands established in past years.
Recommendations for minimum size and optimum arrangement of leave patches.

Table 1: Data collected on new and existing islands in 2002.

ironmental variables and vegetation data were collected in all 1 m x 1 m quadrats. These data were measured as percent cover except where noted. Microclimate data were collected in selected quadrats.
nd structure data were collected in 5 m x 5 m stand structure plots.

Environmental variables	Stand structure	Microclimate	Vegetation
Substrate	**Trees and snags**	nperature (°C)	cular plants by
iduous leaves	**(>7cm DBH)**	ative humidity (%)	cies
dles	cies	R (μms-1m-2)	
t	H (cm)	nfall (cm)	ophytes (data
es	ght (m)		ected by field
eral soil	crown (%)		stants under
nus			supervision of
k	**Saplings and shr**		e Frego)
e woody debris with bark	**(<7cm DBH)**		
e woody debris without bark	cies		
rse woody debris by decay class	H (cm)		
d trunk	nber of stems		
trunk			
np	**Coarse woody de**		
root	cies		
k	H (cm) top and bottom		
	gth (m)		
Canopy cover	ay class		
n			
iduous			
iferous			
Microtopography			
el			
nd			
neight (cm)			
nd depth (cm)			
Tree density			
r trees >7cm dbh closest to quadrat recor			
by:			
cies			
H (cm)			
ance from quadrat center (m)			

Table 2: Disturbance variables collected in 1 x 1 m quadrats after harvest.

Variable	Description
Site Designation	
Plot #	Plot number on stake
Location	C (plot in cut), I (plot in tree island), T (plot in transition between cut and tree island)
Slash	
<0.5 cm HW	Percent cover of hardwood twigs < 0.5 cm diameter and attached foliage
<0.5 cm SW	Percent cover of softwood twigs < 0.5 cm diameter and attached foliage
>0.5 cm	Percent cover of hardwood and softwood twigs > 0.5 cm diameter and attached foliage
Cones	Percent cover of cones on slash
Height (cm)	Height under which 90% of slash cover occurs
Living slash: Dying trees ≤ 45 degree angle from horizontal with some green foliage present	
HW	Percent cover of hardwood living slash
SW	Percent cover of softwood living slash
Height (cm)	Height under which 90% of living slash occurs
Sustrate: Material on which a sedentary organism lives or grows. Provides nutrients or support.	
Invisible substrate	Percent cover of substrate completely covered by slash
Rocks	Percent cover of rocks > 7.5 cm diameter
Stumps	Percent cover of fresh stumps
Undisturbed litter	Percent cover of disturbed litter
Exp. min. soil	Percent cover of exposed mineral soil
WD <7 cm	Percent cover of woody debris < 7 cm diameter which touches the ground, including twigs, branches, chips, sawdust, fragmented wood, etc.
WD >7 cm: DC 1-4	Percent cover of woody debris > 7 cm diameter which touches ground, separated into the following decay classes:
	1: Freshly fallen, bark intact, no large branches
	2: No/little bark, solid wood, including chips and fresh wood fragments
	3: Decay started on grain or advanced, loose wood
	4: Indefinite outline, scattered fragments, decay advanced, fragments crumble
Bark	Percent cover of tree bark not attached to wood

Scat	Percent cover of animal scat
Cones	Percent cover of cones which touch ground
Trunks	Percent cover of stems of living trees

Tracks

Cover	Percent cover of skidder tracks
Type	L (litter), M (mixed litter and soil), S (soil), W (crushed wood), LW (litter and crushed wood), and WS (soil and crushed wood)
Depth	Depth (cm) of the track