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INFLUENCE OF LOGGING, STAND SIZE AND STAND SHAPE ON THE REGENERATION OF WHITE PINE IN OLD-GROWTH FORESTS

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Introduction

In order to have an economically viable society that depends on goods and services derived from the forest, we must have biologically viable forest ecosystems (Maser 1994). And, according to Ontario's new Comprehensive Forest Policy Framework (Ontario Forest Policy Panel 1993), this can only happen when "the use of renewable resources is sustainable [meaning the use] is within the resource's capacity for regeneration." Recent evidence of severely reduced white pine (*Pinus strobus* L.) regeneration in fragmented old-growth forests dominated by white pine in Temagami, Ontario (Quinby 1993a) suggests that the influence of adjacent logging activities is impairing the sustainability of old-growth white pine stands. Currently, there are less than 350 known stands of the endangered old-growth white pine forest remaining in the world (Quinby 1993b, Quinby and Giroux 1993), the vast majority of which have been fragmented by logging, agriculture or other forms of human activity. There is a high probability that those fragmented old-growth white pine stands beyond Temagami also do not have a sustainable level of white pine regeneration. The status of and requirements for white pine regeneration must be determined if these old growth forests are to be maintained.

Few studies of natural landscape fragmentation have focussed on the response of tree populations. Most have addressed effects on mammals, birds, insects and species diversity (Burgess and Sharpe 1981, Harris 1984, Hunter 1990, Shafer 1990, Noss and Cooperrider 1994). Those that have considered the influence of fragmentation on tree populations have focussed on insect pollinators (Aizen and Feinsinger 1994a); pollination, fruit set and seed set (Aizen and Feinsinger 1994b); seed production and dispersal (Johnson et al. 1981) and mature tree mortality (Lovejoy et al. 1986). No studies have yet investigated the influence of fragmentation on actual populations of regenerating trees. The purpose of this study is to examine the influence of forest fragmentation on white pine regeneration within old-growth forest stands dominated by white pine.

Methods

During the 1991 and 1992 field seasons, 14 old-growth white pine stands in Temagami, Ontario were sampled for white pine regeneration. Half of the stands are fragmented, although their interior remains unlogged, and the other half are surrounded by a natural, unlogged landscape. All individual white pine seedlings and saplings (1 to 65 yrs.) encountered in 1 x 1 m quadrats spaced at 6 m intervals along transects were aged by counting branch whorles. In each stand, 21 meters of transect were sampled for each ha of forest and transects were distributed according to the relative amount of slope, hill and flat topography present within the stand. In total, over 6,500 quadrats located along 40 km of transect were assessed for regeneration of white pine in this study. In order to eliminate the influence of seed production on the density of regeneration, white pine regeneration was expressed relative to the density

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of seed-producing trees (140 yrs.+; obtained from Quinby 1991) and was called regeneration production. The rank sum test (two-tailed) was used to test for differences between the means of the white pine regeneration production for the natural versus the fragmented stands (Analytical Software 1994). Also, for each stand the size, shape (edge to interior ratio or E:I) and percent of the stand boundary adjacent to the logged area were determined. Multiple linear regression was used to explore relationships between white pine regeneration production and the biogeographical variables (Analytical Software 1994). A $\log_{10}$ transformation for stand size provided a better linear relationship with regeneration production than did the untransformed stand size values.

Results

The means for white pine regeneration production for the natural (371) and fragmented (137) stands were significantly different (p=.02). Regeneration production in the natural stands was almost three times greater than in the fragmented stands (see Table 1 for stand variable values).

TABLE 1 - Biogeographical and Tree Density Values for the 14 Old-Growth White Pine Stands (7 natural, 7 fragmented) in Temagami, Ontario (E-I - edge to interior; Pw140+ - white pine over 139 years of age; Pwreg. - white pine regeneration; Pwreg. Production - no. white pine <66 yrs./Pw140+ Density)

Stand No.	Size (ha)	Size $\log_{10}$	% Boundary Logged	E-I Ratio	Pw140+ Density (no./ha)	Pwreg. Density (no./ha)	Pwreg. Production
69	21	1.32	0	103	18	3600	200
47	41	1.61	0	79	10	3860	386
43	79	1.90	0	58	11	2981	271
58	90	1.95	0	66	8	3456	432
71	137	2.14	0	31	6	3348	558
44	179	2.25	0	54	14	3780	270
41	900	2.95	0	35	6	2880	480
56	21	1.32	68	142	22	2266	103
49	27	1.43	43	109	18	2214	123
70	29	1.46	34	171	22	2200	100
48	56	1.75	40	95	16	720	45
45	63	1.80	16	97	11	5192	472
42	110	2.04	45	112	23	1380	60
55	136	2.13	47	93	11	616	56

When stratified by regeneration production, most of the fragmented stands fall below the 201 to 300 class, whereas most of the natural stands fall above the 201 to 300 class (Figure 1).

The regression analysis showed that only the "% boundary logged" and the "E-I ratio" variables contributed significantly to the resulting regression equation (F<.003; R^2=.64):

white pine regeneration production = 468 - (4.13 %boundlog) - (1.43 E-Iratio).

White pine regeneraton production was most highly correlated with the % boundary logged variable (r=-.7731; p<.01) and was slightly less correlated with the E-I ratio variable (r=-.7069; p<.01) (Figures 2a and 2b).

FIGURE 1 - Frequency Distribution of Regeneration Production in Fragmented and Natural Old-Growth White Pine Stands in Temagami, Ontario

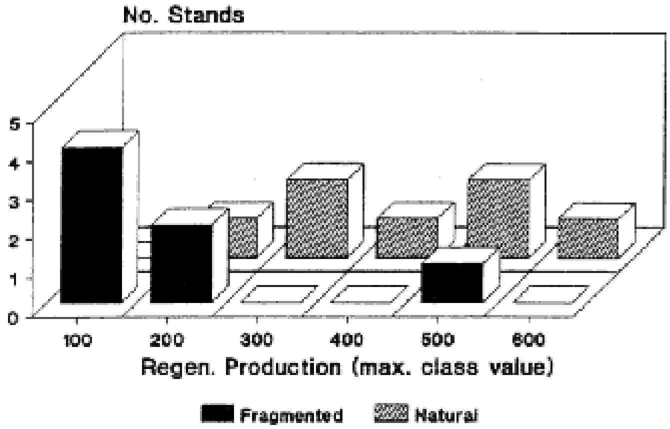


FIGURE 2 - (a) Scatterplot of the Relationship Between Regeneration Production and the % Boundary Logged Variable; (b) Scatterplot of the Relationship Between Regeneration Production and the Edge to Interior Ratio Variable (Old-Growth Stands in Temagami, Ontario)

Figure 2a

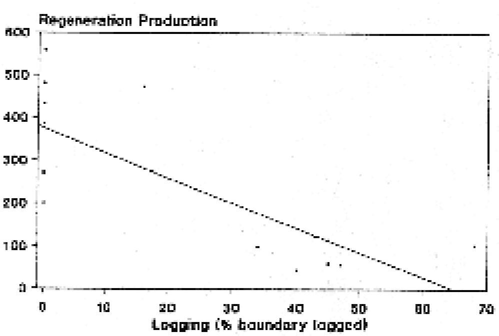
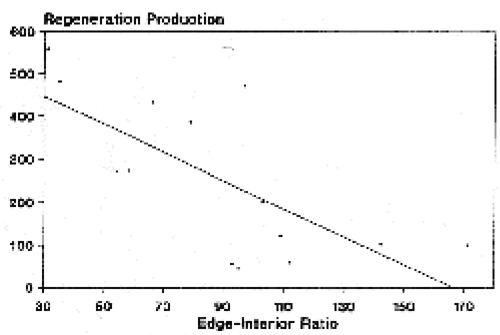


Figure 2b



Discussion

Regeneration production of white pine was almost three times higher in the natural old-growth white pine stands compared to the fragmented stands and the level of regeneration production is most highly correlated with the amount of adjacent logging. Generally, as the amount of logging contiguous to the stand (fragmentation) increases, regeneration production in the stand decreases. The shape of the stand is also significantly correlated with regeneration production - as the ratio of edge to interior increases, the regeneration production of white pine decreases. Although size has often been identified as the most important reserve viability variable (Noss and Cooperrider 1994), its correlation with regeneration production in this study was insignificant probably because of the extensive connectivity of the fragmented stands to the surrounding forested landscape which provides an external source of seed. On average, 58% of the boundaries of the fragmented stands are contiguous with either ancient or second-growth forest.

Both the logging and E:I variables represent the effects of fragmentation on old-growth white pine stands. Fragmentation tends to (1) create more stand boundary (2) change the physical environment along the modified edge of the stand and (3) reduce the amount of white pine seed germinating in the old-growth stands (Lovejoy et al. 1986, Saunders et al. 1991). It is likely that many white pine seeds are blown out of fragmented stands due to greater wind exposure along the edge which also penetrates into the stand, and for those seeds that do land within the old-growth stand, the germination rate is likely reduced due to higher temperatures and drier conditions at the forest floor.

The regression equation developed in this study can predict regeneration production using biogeographical variables (the percent of the boundary adjacent to logging and the edge to interior ratio) that can be easily measured on aerial photographs. To evaluate the accuracy of the equation's predictions, field tests should be conducted to compare predicted to actual white pine regeneration production. Assuming an acceptable level of accuracy, the fragmented old-growth white pine stands most in need of regeneration management can be identified by using aerial photographs and the regeneration production regression equation which is cheaper and faster than using field methods.

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