PRELIMINARY DEFINITIONS OF OLD-GROWTH RED AND WHITE PINE FOREST IN CENTRAL ONTARIO

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EXECUTIVE SUMMARY

Few of the world's original old-growth white and red pine forests remain. In fact, throughout the majority of their natural ranges, these forests are threatened with extinction and in several states/provinces they are already extinct. Old-growth forests are valuable for a number of reasons: they maintain soil stability and water quality, retain large amounts of limiting nutrients, provide a reservoir of genetic diversity, provide unique wildlife habitat and they act as carbon sinks which can help to ameliorate global warming. Old-growth forests also provide the best opportunity to study natural forest ecosystems - the results of natural forest studies hold the key to developing better forestry practices. These old-growth forests also represent a valuable cultural heritage as exploitation of the original white and red pine forests sustained many of eastern North America's regional economies in their early years.

Throughout many portions of eastern North America, logging continues to destroy the few remaining old-growth white and red pine forests. This includes Ontario which has the greatest amount of unprotected forest of this type in the world. Although the Ontario Ministry of Natural Resources is aware of this, it contends that it cannot protect the old growth until it has been defined. Thus, the purpose of this study is to provide preliminary definitions of old-growth white pine and red pine forests in central Ontario so that these forests can be identified and conserved. Data from future surveys of old-growth stands can be used to further refine these old-growth definitions.

Because the Temagami Region is the centre of white pine and red pine abundance in Ontario, its white and red pine stands are most suitable for conducting initial studies to develop definitions of Ontario's old-growth white pine forests. For this study, 30 of Temagami's oldest and largest white and red pine stands were located and sampled in order to develop old-growth definitions. Old tree density was estimated by analyzing 1:15,840 aerial photographic diapositives with a magnifying dissecting microscope. Forest composition, both live and dead, was determined from field sampling.

A total of five old-growth pine forest types were identified including white pine-deciduous, white pine-mixed, white pine-conifer, white pine-red pine and red pine-conifer. The old-growth condition for each forest type was defined by quantifying old live tree density; snag density and size; and log biomass, density and size. Common tree associates and basic canopy structure were also determined for each forest type. General preliminary criteria for old-growth white and red pine forest are as follows:

(1) old pine tree density -
   a. old-growth white pine - at least 10 old pine/ha, 140 years+,
   b. old-growth red pine - at least 9 old pine/ha, 140 years+;
(2) snags (dead standing trees) - at least 30 snags/ha, minimum 10 cm dbh and 2 m tall;
(3) logs - at least 10 logs/ha, minimum 25 cm diameter at the large end, at least 8 m long; and
(4) minimal to no human disturbance.

Future studies to finalize old-growth definitions must recognize that forest ecosystems are variable and dynamic entities. Thus, both young and mature successional stages must be investigated in relation to old-growth development. However, because logging of old-growth white and red pine forest continues in Ontario, the longer we wait to finalize old-growth definitions, the more difficult and potentially fruitless this task will be.

INTRODUCTION

Before the turn of the century, "...in the country around Lakes Temagami and Lady Evelyn and to the north, an area of red and white pine of fine quality was explored and estimated to contain about 3,000,000,000 feet board measure" (Defebaugh 1906). These natural pine forests made Temagami "the best pinery in central Canada [containing] the largest body of white pine timber in the hands of the Crown in any one locality in the province" (Hodgins and Benidickson 1989). It was "...the harvest of eastern white pine [that] generated the capital and jobs needed to nourish the settlement of Ontario, and ultimately led to the confederation of the provinces" (Aird 1985).

Following clearcut logging of these forests, however, these once extensive stands of white pine declined to around 12% of the Temagami forest area by the mid-Twentieth Century (McAndrews 1978) and eventually to approximately 5% by 1978 (Day and Carter 1989). Currently, throughout all of Ontario, "only a few stands of the 'giant pine' remain" (Aird 1985). This is primarily due to a forest policy that continues to demand "...an accelerated depletion rate in order to harvest overmature timber with a minimum of further deterioration" (Ontario Ministry of Natural Resources 1987). Although this policy of old-growth forest liquidation facilitates efficient short-term fiber production, it is rapidly causing the extinction of an ancient ecosystem of great ecological, scientific and natural heritage value.

Old-growth forests maintain soil stability and water quality, retain large amounts of limiting nutrients, provide a reservoir of genetic diversity, provide unique wildlife habitat and act as carbon sinks which can help to ameliorate global warming (Franklin et al. 1981, Heinrichs 1983, Maser and Trappe 1984, Brown 1985, Whitney 1987, Maser 1988, Harmon et al. 1990). As well, "Old-growth forests have played a prominent role in the development of ecological thought and theory" (Whitney 1987). They provide the best opportunity to determine "the cummulative effect of the factors of site on vegetational development" (Lutz 1930). More recent workers have relied on the study of old-growth forests as the end-point of succession in order to construct theories of ecosystem development (Odum 1969, Vitousek and Reiners 1975, Bormann and Likens 1979). In addition, tree ring analysis of old trees in natural areas has aided in the understanding of hydrologic processes (Cook and Jacoby 1983), forest decline (Cook et al. 1987), trace metals in the environment (Brownbridge 1984) and historical climate conditions (Sheppard and Cook 1988).

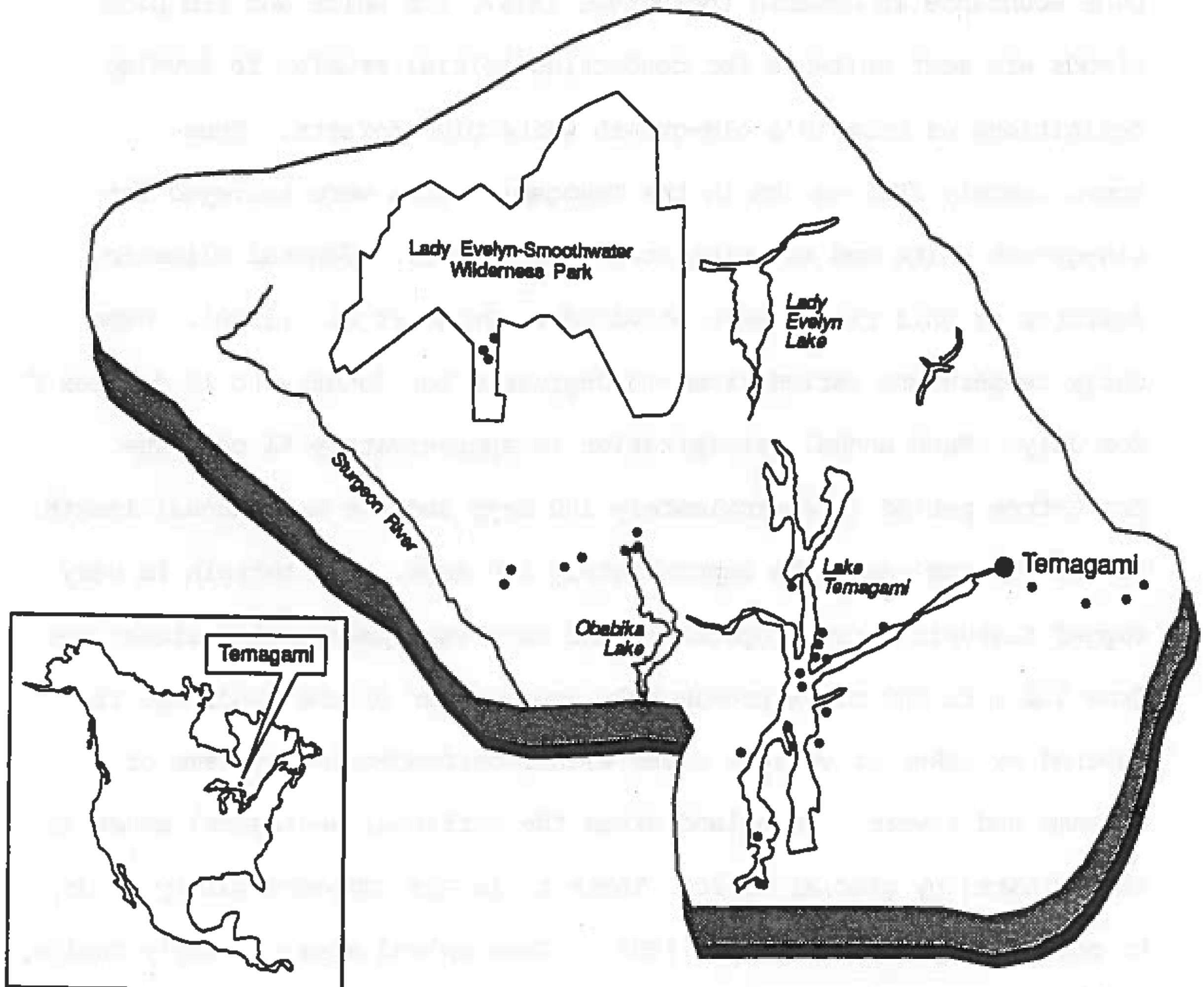
Little is known about the structure, function and development of these rare ancient pine ecosystems (Quinby in press), yet, logging continues to permanently alter the unique character of the few that remain. Thus, "working definitions are needed immediately...to guide current planning efforts, to restructure inventory procedures, and to clarify issues" (Old-Growth Definition Task Group 1986). In particular, until old-growth definitions are developed for Ontario, logging of old-growth white and red pine forest in this province will continue (Ontario Ministry of Natural Resources 1987, Ontario Ministry of Natural Resources 1990).

The purpose of this study is to provide preliminary definitions of old-growth white pine (<u>Pinus strobus</u> L.) and red pine (<u>Pinus resinosa</u> Ait.) forest in central Ontario as the necessary first step in conserving these rapidly diminishing ecosystems.

STUDY AREA

Because the Temagami Region is the centre of white pine and red pine abundance in Ontario (McAndrews 1978), its white and red pine stands are most suitable for conducting initial studies to develop definitions of Ontario's old-growth white pine forests. Thus, approximately 3800 sq. km in the Temagami Region were surveyed for old-growth white and red pine stands (Figure 1). General climatic features of this region were provided by Brown et al. (1980). Mean daily temperature varies from -13 degrees C for January to 19 degrees C for July. Mean annual precipitation is approximately 81 cm. The frost-free period is approximately 100 days and the mean annual length of the growing season is approximately 180 days. The terrain is very rugged featuring steep topography and many escarpments with elevations from 200 m to 700 m. Approximately one-quarter of the landscape is covered by lakes of various sizes with interconnecting systems of streams and rivers. In upland areas the surficial geological material is dominated by glacial tills. These tills are composed mainly of dry to moist silty loams (Johnson 1988). Some upland areas, usually knolls, are characterized by exposed bedrock and bedrock with very shallow loamy tills due to scouring during glacial advance. Valley bottoms are often dominated by medium to fine grained sands of glaciofluvial origin (Johnson 1988). A small percentage of the area is covered with organic soils where drainage is impaired.

FIGURE 1 - STUDY AREA AND LOCATION OF STANDS



The forest vegetation of the Temagami Region falls within the Temagami Section, Great Lakes-St. Lawrence Forest Region (Rowe 1972). These forests are typified by

> eastern white pine with scattered white birch and white spruce, although the spruce frequently rivals the pine in abundance. Another common though variable type is a mixture of the birch, pine and spruce, with balsam fir, trembling and largetooth aspens. Both red pine and jack pine are present, the former often prominent in bluffs along ridges and the latter generally restricted to the driest sandy or rocky sites. The tolerant hardwoods, yellow birch and sugar maple, have only a scattered occurrence. The prevalent forest cover on the uplands is clearly a reflection of periodic past fires, and the sandy soils have provided conditions especially favourable for the propagation of eastern white pine, red pine and jack pine. On the lowlands, in poorly-drained depressions and in swamps, black spruce with tamarack or eastern white cedar, form well-marked communities (Rowe 1972).

METHODS

Forest composition and structure within 30 stands of white and red pine forest were field sampled during the summers of 1988 and 1989, and old tree density was estimated using aerial photographs. These data were subsequently used to produce preliminary definitions of old-growth white and red pine forest.

Field Sampling

The following criteria were used to select stands for sampling: (1) those dominated by white and/or red pine, (2) those with the oldest trees within the local landscape as determined by forest stand maps, (3) those covering the greatest area and (4) those with minimal human disturbance. Based on both forest stand maps and field sampling, all stands were found to be older than 140 years ranging from 178 to 378 years. Evidence of minor selective logging was observed in only three of the stands sampled. Thus, the oldest, largest and least disturbed white and red pine stands in the Temagami Region were sampled. A minimum stand size was not applied as a stand criterion "...because of objections that minimum acreages will depend on management objectives and the nature of the surrounding areas" (Spies and Franklin 1988).

Within each stand at least one permanently marked 50 X 20 m plot was randomly located with the singular criterion that at least two white and/or red pine trees equal to or greater than 140 years of age be present within the plot. A minimum age of 140 years for both old-growth white and red pine forest was chosen because it is at that time or earlier, on average sites, that net stand growth reaches its upper limit (Ardenne 1950, Gilbert 1978, Ontario Ministry of Natural Resources 1989).

At the most basic level, old-growth forests are characterized by minimum amounts of old live trees, snags (dead standing trees) and logs (Old-Growth Definition Task Group 1986). Thus, in total, 41 plots were inventoried in the field for overstory trees, snags, and logs. Of the

30 stands studied, the 28 stands sampled in 1989 each had one plot, and the two stands sampled in 1988 together had 13 plots. The overstory was defined as all trees equal to or greater than 10 cm dbh and was sampled by recording species and dbh. All snags equal to or greater than 10 cm dbh and taller than 2 m within the plot were identified to species when possible and measured for dbh. For each individual tree and snag sampled, basal area was calculated from dbh values. Logs with a minimum diameter of 15 cm at the larger end and a minimum length of 1 m were also inventoried. Log diameter and length measurements were used to produce log biomass estimates. Three to five of the largest pines in each plot were sampled with an increment borer to obtain a tree age estimate.

Aerial Photographic Sampling

For each of the 30 pine stands, density estimates of old white and red pine trees were obtained using a Carl Zeiss dissecting microscope with a drawing tube at 17.5X magnification to view tree crowns on 1:15,840, 1977 black and white aerial photographic diapositives (Sayn-Wittgenstein 1978). Analysis of aerial photographs has also been used to estimate old tree density of Douglas-fir forests (Morrison 1988).

To evaluate the use of the 1:15,840 scale aerial photographic diapositives for estimating old tree density relative to using larger scale photos, seven different forested areas in the Chalk River, Ontario area were analyzed for old tree density using the 1:15,840 diapositives and 1:1500 color aerial photographs. It was assumed that use of the large-scale photographs would result in a better estimate of tree density which could subsequently be used as a baseline for comparison against the estimates obtained from analysis of the small-scale photographs. Only the inner two-thirds of the large-scale photographs, demarcated in the shape of a square, were used in the analysis due to major crown distortions near the edges of the photographs.

For the 30 stands studied in the Temagami Region, all white and red pine crowns were identified within 100 m wide transects inscribed on the diapositives running perpendicular to the long axis of each stand such that approximately 25% of the stand was systematically sampled. When viewed from above, the irregular, star-shaped crown of the white pine is the tree's most distinguishing characteristic. Red pine, when viewed from above, has a distinctly round or oval crown (Sayn-Wittgenstein 1978). As the white and red pine were identified, their crown boundaries were digitized with a Sigma Scan software package (Jandel Scientific 1989) that calculated tree crown areas. From the crown area value the average crown diameter was calculated using CD=(2)(square root of(Area/3.14)).

Because of correlations between stem diameter and crown diameter (Avery 1978), and correlations between stem diameter and age (see Results section), it was possible to use crown diameter as a rough index to tree age. A minimum of 38 cm dbh was chosen to represent old white pine trees because only one of 35 randomly chosen white pine was found to be younger than 140 years using this lower limit dbh value (Table 1). Correspondingly, a 29 cm dbh lower limit was chosen to represent old red pine trees because only one of 38 randomly chosen red pine was found to be younger than 140 years using this lower limit dbh value (Table 1). The 140 year lower age limit is conservative relative to that used by the Ontario Ministry of Natural Resources (1990) and the United States Forest Service (DeGraff et al. 1980), both of which use 120 years as the lower age limit for old-growth white pine forest.

Using regression models, 140 years was represented by a minimum crown diameter of 5.3 m for white pine and a minimum crown diameter of 4.5 m for red pine. Because crown diameter measurements from aerial photographs are generally lower than those taken on the ground (Avery 1978), those obtained in this study from the diapositives actually represented larger crown diameters in most cases. Because crown diameters provide only a rough index to tree age, it is necessary to follow up with more extensive and detailed tree age estimates from increment cores obtained in the field.

Forest Type Classification

The specific attributes of old-growth forest vary by forest type (United States Forest Service 1989, British Columbia Ministry of Forests 1990). Broad old-growth white and red pine forest types in the Temagami Region were distinguished as follows: those plots with white and red pine both greater than 25% basal area and less than 75% basal area were classified as white pine-red pine, those plots dominated by white pine with less than 25% red pine and more than 75% deciduous species were classified as white pine-deciduous forest, those plots dominated by white pine with less than 25% red pine and with both conifer and deciduous species comprising more than 25% but less than 75% of the total basal area were classified as white pine-mixed forest, those plots dominated by white pine with less than 25% red pine and with more than 75% conifer species were categorized as white pine-conifer forest, and those plots dominated by red pine with less than 25% white pine and with greater than 75% conifer species were classified as red pine-conifer. Detrended correspondence analysis (DCA) (Hill 1979, Hill and Gauch 1980) was also used to classify forest types by ordinating all 41 field sampled plots based on tree species basal areas.

Because old-growth forests are so complex in structure, multiple criteria are necessary for their definition (Old-Growth Definition Task Group 1986). Thus, for each forest type, means and ranges for old tree density, snag density, and log biomass and density were calculated. Four of the 41 plots were excluded from the definition analysis due to a forest type classification discrepancy between these four plots and their corresponding stands. This occurred due to the relatively small portion of the stand represented by a single randomly located plot and to the patchiness of forest composition within these stands. Finally, because "any old growth attribute exhibits a range of levels over a sample of stands...definitions are based on minimum criteria rather than average values" (Old-Growth Definition Task Group 1986).

RESULTS

The comparison of old tree density estimates derived from the large- and small-scale aerial photographs is presented in Table 1. For white pine, analysis of the large-scale photos provided a density estimate of 4.0/ha compared to the small-scale photo analysis which provided an estimate of 3.1/ha. The same comparison for red pine resulted in a larger diference between the two estimates, 4.1/ha for the large-scale photos versus 2.8/ha for the small-scale photos. Considering the density of the two species combined, analysis of the large-scale photos resulted in a density estimate of 8.1/ha versus 5.9/ha for the small-scale photos. Thus, use of 1:15,840 black and white aerial photographic diapositives to estimate the density of old pine trees in old-growth pine forests of Temagami may, on average, underestimate density by as much as 33%. However, due to the prohibitively high cost of obtaining large-scale aerial photos for all stands, the small-scale photos represented the only available alternative.

From measurements taken on the ground, significant correlations were found between stem diameter and age for white pine (r=.58; significant at .01 level) and for red pine (r=.53; significant at .01 level) (Table 2). Significant correlations were also found between stem diameter and crown diameter for white pine (r=.62; significant at .01 level) and red pine (r=.70; significant at .01 level) (Table 3). The indirect relationship between age and crown diameter, which was established through their correlation with stem diameter, served as the

TABLE 1 - RESULTS OF WHITE AND RED PINE DENSITY ESTIMATES FROM AERIAL PHOTOGRAPHS OF DIFFERING SCALES

Plot	Large Scale Photos							Small Scale Photos						
	No. Trees			Area	Density (trees/ha)			No. Trees			Area	Density (trees/ha)		
	Pw	Pr	Pw+Pr	(ha)	Pw	Pr	Pw+Pr	Pw	Pr	Pw+Pr	(ha)	Pw	Pr	Pw+Pr
1	25	36	61	7.1	3.5	5.1	8.6	27	14	41	9.0	3.0	1.6	4.6
2	33	30	63	7.1	4.7	4.2	8.9	29	19	48	9.3	3.1	2.0	5.1
3	28	14	42	7.1	3.9	2.0	5.9	38	23	61	8.8	4.3	2.6	6.9
4	77	48	125	14.5	5.3	3.3	8.6	54	28	82	16.0	3.4	1.7	5.1
5	47	68	115	13.3	3.5	5.1	8.6	43	75	118	14.9	2.9	5.0	7.9
6	30	22	52	8.8	3.4	2.5	5.9	21	8	29	9.3	2.3	.9	3.2
7	29	56	85	8.8	3.3	6.4	9.7	22	48	70	9.1	2.4	5.3	7.7
All	269	274	543	66.5	4.0	4.1	8.1	234	215	449	76.4	3.1	2.8	5.9

TABLE 2 - STEM DIAMETER AND AGE FOR WHITE AND RED PINE
(stem diameter (DBH) in cm)

White Pine

DBH	Age	DBH	Age	DBH	Age	DBH	Age
17.7	106	46.5	156	61.4	182	70.5	209
21.4	112	51.0	200	61.5	141	71.1	180
31.2	139	52.1	157	62.3	229	72.0	191
34.6	233	57.2	204	62.4	141	73.3	164
35.0	237	58.6	215	62.8	146	75.3	219
36.3	135	58.8	184	63.5	251	75.3	252
38.3	217	59.7	200	64.9	191	80.5	198
39.1	197	60.0	184	65.9	218	81.4	375
42.3	126	60.6	232	69.0	205	86.1	301
45.6	141	60.7	233	70.0	152	92.3	299

(r=.58; significant at .01 level)

Red Pine

DBH	Age	DBH	Age	DBH	Age	DBH	Age
21.1	92	45.3	224	49.5	216	59.3	229
28.9	124	45.5	242	51.3	269	60.1	246
29.5	192	46.5	211	52.1	202	60.7	204
30.0	193	47.2	229	52.3	219	61.0	204
30.0	274	47.6	186	52.7	199	62.3	217
31.6	182	48.0	180	54.5	218	63.2	321
33.9	110	48.0	224	54.7	229	63.3	216
34.4	194	48.2	244	55.2	243	67.0	223
38.5	190	49.3	248	56.5	225	67.5	221
44.5	216	49.5	231	56.5	251	69.8	202

(r=.53; significant at .01 level)

TABLE 3 - STEM DIAMETER AND CROWN DIAMETER FOR WHITE AND RED PINE
(stem diameter (DBH) in cm; crown diameter (CD) in m)

White Pine

DBH	CD	DBH	CD	DBH	CD
17.7	3.6	42.3	6.0	56.1	6.6
21.4	5.0	42.6	7.6	57.9	8.9
34.6	3.1	42.9	7.2	59.3	7.2
36.3	4.4	44.3	5.9	59.3	7.2
38.3	2.6	44.4	5.7	59.3	9.6
39.1	5.7	45.1	4.2	59.5	3.5
40.6	4.8	45.6	6.0	66.0	9.4
41.9	6.8	46.4	3.5	66.5	3.6
42.0	6.5	54.0	8.9	67.4	9.5
42.1	6.0	55.4	9.0	72.3	12.0

(r=.62; significant at .01 level)

Red Pine

DBH	CD	DBH	CD	DBH	CD
21.1	3.6	39.5	6.2	48.3	9.0
28.9	3.0	41.0	7.4	48.8	8.4
29.5	4.6	42.4	3.6	51.6	7.4
30.0	4.2	42.9	8.2	52.0	8.8
30.0	4.6	43.1	5.8	53.8	6.6
31.6	6.2	44.0	8.2	54.6	5.0
33.9	4.6	47.0	5.6	56.8	9.4
34.4	4.6	47.4	8.2	59.7	9.0
38.1	4.4	47.7	6.6	61.0	6.6
38.8	5.8	48.0	6.2	63.5	8.0

(r=.70; significant at .01 level)

basis for identifying old trees on aerial photographs. This was done by predicting a minimum crown diameter for old trees from the minimum stem diameter using regression models developed from ground measurements for white pine:

$$CD=(0.1098)(DBH)+1.0902; R^2=.38;$$

and for red pine:

$$CD=(0.1222)(DBH)+0.9932, R^2=.50.$$

A 38 cm dbh lower limit was chosen for white pine because only one of 35 randomly chosen white pine was found to be younger than 140 years above this 38 cm dbh limit. Similarily, because only one of 38 randomly chosen red pine was found to be younger than 140 years above 29 cm dbh, this dbh value was chosen as the lower limit for distinguishing old red pine trees. Substituting these lower dbh limits into the regression models, a minimum crown diameter of 5.3 +or-1.9 was predicted for white pine and for red pine, a minimum crown diameter of 4.5 +or-1.3 was predicted.

General stand and plot information is presented in Table 4. The old-growth stand area estimated in this study was often less than the area estimated on the forest stand maps. Stand areas according to this study ranged from 11 ha to 913 ha with a mean of 90 ha and a median of 42 ha. Age estimates of the oldest tree in the stand from this study were higher in every case except one compared to forest stand map age estimates. And, except for a few cases, there were no major differences between percentages of pine relative to each other as estimated in this study and as obtained from the forest stand maps. Analysis of aerial photographs indicated that 12 of the 30 stands sampled, or 40%, were

TABLE 4 - STAND AND PLOT SUMMARY DATA

Township	FRI Stand Number	TPP Stand Number	TPP Plot Number	Area (ha) FRI	Area (ha) TPP	Est. Age FRI	Est. Age TPP	% of Pines W. Pine FRI	% of Pines W. Pine TPP	% of Pines R. Pine FRI	% of Pines R. Pine TPP	Integrity
Delhi	42	40	14,15	184	157	183	--	0	16	100	84	natural
Delhi & Shelburne	34 & 123	41	11-17, 34-39	489 +319 808	913	186	362	67	66	33	34	natural
Vogt	88	42	42	193	111	201	247	100	99	0	1	fragmented
Vogt	45	43	43	139	78	179	167	100	100	0	0	natural
Joan & Phyllis	84 & 36	44	44	87 +168 255	220	203	207	86	79	14	21	natural
Phyllis	64 65	45	45	19 +108 127	62	173 156	192	20 43	48	80 57	52	fragmented
Phyllis	52	46	46	185	89	226	302	100	69	0	31	natural
Phyllis	72	47	47	66	42	196	378	80	68	20	32	natural
Briggs	82	48	48	79	56	171	266	100	81	0	19	fragmented
Briggs	78	49	49	31	27	166	178	67	75	33	25	fragmented
Joan	104	50	50	45	33	186	196	67	75	33	25	fragmented
Phyllis	45	51	51	47	40	153	199	37	34	63	66	natural
Phyllis	44	52	52	140	32	183	236	37	48	63	52	natural
Joan	90	53	53	147	21	171	259	80	83	20	17	natural
Joan	85	54	54	32	22	211	259	75	98	25	2	natural
Briggs	72	55	55	199	126	196	224	100	73	0	27	fragmented
Scholes	31	56	56	118	20	191	207	80	76	20	24	fragmented
Strathcona	6	57	57	116	78	197	337	75	73	25	27	natural
Riddell	10	58	58	96	88	172	269	0	36	100	64	natural
Parker	59	60 61	60 61	137	27 16	191	252 216	100	75 100	0	25 0	natural natural
Delhi	63	62	62	268	37	96	271	0	48	100	52	fragmented
Delhi	64	63	63	89	11	116	209	100	79	0	21	fragmented
Delhi	31	64	64	32	59	81	284	25	35	75	65	natural
Cynthia	211	65	65	63	71	168	227	56	63	44	37	fragmented
Seagram	112	67	67	52	60	218	212	75	60	25	40	fragmented
Clary	13	68	68	25	13	219	267	60	83	40	17	natural
Eldridge	121	69	69	23	21	172	261	57	85	43	15	natural
Eldridge	111	70	70	41	32	173	270	83	96	17	4	fragmented
Eldridge	97	71	71	90	141	183	259	40	38	60	62	natural

Abbreviations: FRI - forest resource inventory (forest stand maps produced by the Ontario Ministry of Natural Resources

TPP - Tall Pines Project, Temagami Wilderness Fund contiguous to areas where logging had occurred resulting in fragmentation of the local forested landscape.

Figure 2 shows the five old-growth forest types as identified by DCA which produced the following eigenvalues: axis 1-.439, axis 2-.107, axis 3-.045 and axis 4-.027. The large difference between the eigenvalues of the first and second axes indicates that the majority of variation in vegetation composition lies along the first axis. The only forest types that occupy unique ordination space are the white pine-red pine and the red pine-conifer forest types. Table 5 shows the basal areas for all 15 tree species according to forest type.

Characteristics of old-growth white and red pine forest types in Temagami are presented in Table 6. Because the white pine-deciduous, white pine-mixed and white pine-conifer forest types were not distinquished from each other in the aerial photographic analysis, density estimates were made for all three combined as one major forest type, hereafter referred to as the white pine-other forest type. On average, the density of old white pine trees in the white pine-other forest type was about four times greater than the density of old red pine trees. This compares with almost equal mean densities for old white and red pine in the white pine-red pine forest type, and with approximately twice the mean density of old red pine trees to old white pine trees in the red pine-conifer forest type. The mean old tree density of both pines combined was almost equal for both the white pine-other forest type (19.8/ha) and the white pine-red pine forest type (21.8/ha). This compares to a mean old tree density estimate for the red pine-conifer forest type of 14/ha which is approximately 25% lower

FIGURE 2 - FOREST TYPES AS IDENTIFIED BY DETRENDED CORRESPONDENCE ANALYSIS

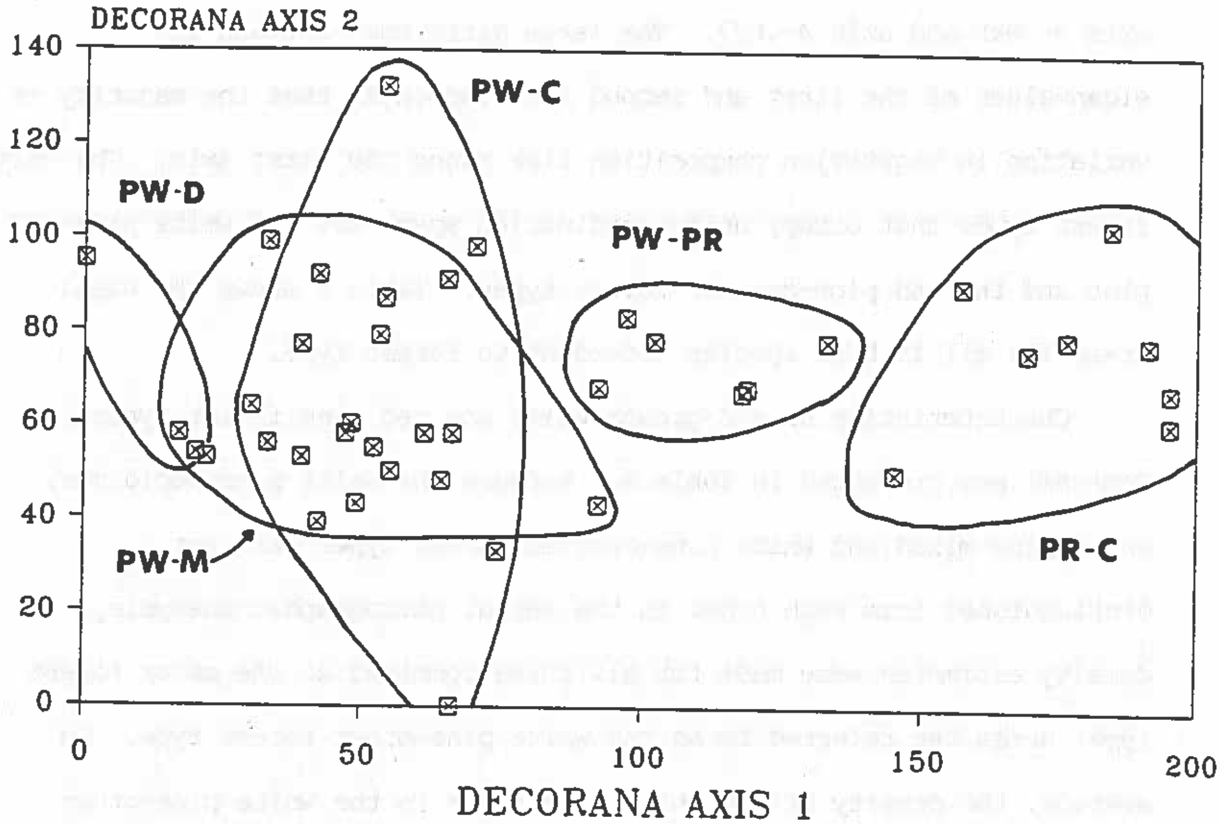


TABLE 5 - OVERSTORY SPECIES COMPOSITION OF OLD-GROWTH WHITE AND RED PINE FOREST PLOTS

Forest Type	Plot	DCA Axes 1 & 2	Species (basal area in m^2/ha)															
			By	Mh	Pg	A	Ms	Pw	B	Ce	Bw	Sb	Sw	Pr	Or	Po	Pj	All
PW-D	56	0,95	2.1	8.6			1.8	18.9	0.1	3.3	0.2							35.0
	44	20,54					4.9	33.3	0.6		1.3	1.0						41.1
	Mean		1.1	4.3			3.4	26.1	0.4	1.7	0.8	0.5						38.1
	43	17,50	1.1				1.4	27.8	2.1									32.4
	49	22,53					3.5	44.2	3.3			1.0						52.0
	61	33,56						34.3	0.6	1.0	3.9		0.8					40.6
	46	33,99	1.3			1.4	1.9	24.1	1.0	6.7	3.9					0.1		40.4
	48	42,92					1.8	17.4	4.6	3.8	2.9	0.1						30.6
PW-M	38	42,39						24.5	0.4		2.1	1.8	0.1	1.2				30.1
	60	47,50						27.6	0.1	1.3	7.4		2.0					38.4
	42	48,60	0.3				1.3	16.8	3.8		2.9	0.9		1.5				27.5
	69	53,79					2.9	13.9	0.7	1.5	0.1		0.4	3.7				23.2
	16	55,50					0.2	26.3	2.1		3.0	1.1	0.8	3.5				37.0
	47	61,50					2.6	22.0	1.0	0.2	1.1	1.1		6.4				34.4
	54	65,92					2.0	23.0	0.9	6.2	5.1	0.5		6.3				44.0
	37	92,43					.5	12.3	0.4		10.9	3.0	1.8	3.8				32.7
	Mean		0.2			0.1	1.5	24.2	1.6	1.6	3.3	0.7	0.5	2.0				35.7
	17	30,64			0.2			54.9	0.9	4.7	0.3	0.4		1.2				62.6
	65	39,53						31.9	0.3	0.3	0.5			3.3				36.3
	50	39,77					2.1	35.7	2.0	4.8		0.1	0.3	3.1				48.1
	39	49,43						27.7	1.4	0.7	2.1	2.6	0.1	2.4				37.0
	67	52,55					1.2	27.6	4.2		0.3		3.8	2.9				40.0
PW-C	68	54,132		0.2			0.6	16.6	1.0	11.7	1.2			1.4				32.7
	14	54,87						27.5	0.3	8.4	3.2	1.5	0.1	4.5				45.5
	12	64,40					0.3	29.3	0.2		2.0	1.3	1.0	6.7				40.8
	70	66,58					0.3	20.2	0.3	0.7	1.0	0.4	0.6	5.5				29.0
	36	66,0					0.3	15.1			0.8	6.0		1.8				24.0
	63	70,98					0.9	16.1		6.3	2.7	0.5	0.2	4.6				31.3
	13	74,33					0.4	22.9	0.3		1.3	4.1	0.2	6.9				36.1
	Mean						0.5	27.1	0.9	3.1	1.3	1.4	0.5	3.7				38.6
	34	92,68					0.2	22.4	3.3	1.5	2.0	1.0	0.1	13.2				43.7
	55	97,83					0.1	23.4	1.2	5.3	3.5	0.4	0.9	15.4				50.2
PW-PR	53	102,78					0.2	16.3	5.1	1.2	6.1			12.9				41.8
	35	118,67						17.8	0.2	1.0	5.9	0.9	0.5	18.3				44.6
	11	119,68						13.6	0.4	1.3	1.2	1.0		14.6				32.1
	71	133,78		0.2			0.7	12.8	3.5	1.4	1.7		2.3	22.4				45.0
	Mean						0.2	17.7	2.3	2.0	3.4	0.6	1.0	16.1				42.9
	57	145,50					1.4	7.9	0.4			3.6		18.5				31.8
	52	157,90					0.4	8.7	0.1	2.7	0.4		0.2	25.0	2.5			40.0
	45	169,76						8.2			0.5			27.4				36.1
PR-C	51	176,79		0.2			0.2	4.6	0.5		1.8			24.0				31.3
	58	184,103						0.3	1.8	5.1	1.7		2.0	30.5				41.4
	15	191,78						6.8	0.1		1.5	0.5		53.6				62.5
	64	195,68						0.4	0.1	1.7	1.7	2.8	3.8	35.8		0.9		47.2
	62	195,61						1.2		0.3	1.7	3.1		27.4			1.0	34.7
	Mean						0.3	4.8	0.4	1.2	1.2	1.3	0.8	30.3	0.3	0.1	0.1	40.6

Abreviations: PW-D - white pine-deciduous; PW-M - white pine-deciduous and coniferous; PW-C - white pine-coniferous; PW-PR - white pine-red pine; PR-C - red pine-coniferous; By - yellow birch (*Betula lutea* Michx. f.); Mh - sugar maple (*Acer saccharum* Marsh.); Pg - large-tooth aspen (*Populus grandidentata* Michx.); A - white ash (*Fraxinus americana* L.); Ms - red maple (*Acer rubrum* L.); Pw - white pine (*Pinus strobus* L.); B - balsam fir (*Abies balsamea* (L.) Mill.); Ce - eastern white cedar (*Thuja occidentalis* L.); Bw - white birch (*Betula papyrifera* Marsh.); Sb - black spruce (*Picea mariana* (Mill.) B.S.P.); Sw - white spruce (*Picea glauca* (Moench) Voss); Pr - red pine (*Pinus resinosa* Ait.); Or - red oak (*Quercus rubra* L.); Po - Poplar (*Populus* spp.); Pj - jack pine (*Pinus banksiana* Lamb.)

TABLE 6 - CHARACTERISTICS OF OLD-GROWTH WHITE AND RED PINE FOREST TYPE IN TEMAGAMI, ONTARIO

Stand Characteristics		White Pine-Deciduous	White Pine-Mixed	White Pine-Conifer	White Pine-Red Pine	Red Pine-Conifer
		Forest Type				
Number of Stands			22		4	4
Stand Size (ha)	mean		94.9		68.2	85.0
	range		16.3-913.2		26.0-141.4	39.6-156.0
Old Tree Density (no./ha)						
white pine	mean		16.1		10.3	4.5
	range		7-25		6-15	2-8
red pine	mean		3.7		11.5	9.1
	range		0-7		9-16	5-13
white & red pine	mean		19.8		21.0	13.8
	range		10-30		15-31	8-21
	maximum*		50		35	60
Snag Density (no./ha)						
number of plots		2	13	11	6	5
all species	mean	90	107	112	77	94
	range	70-110	30-190	60-190	50-120	30-140
Log Biomass & Density						
number of plots		2	13	11	6	5
biomass (Mg/ha)	mean	44.6	57.7	45.1	48.4	37.9
	range	23.2-66.1	15.6-131.4	16.5-83.6	32.4-80.2	5.9-43.4
number of large pieces/ha						
	mean	10.0	41.5	40.2	40.0	30.0
	range	10-10	10-130	10-80	20-70	10-70
		(51 cm dbh & 8 m long)	(37 cm dbh & 8 m long)	(20 cm dbh & 8 m long)	(35 cm dbh & 8 m long)	(25 cm dbh & 8 m long)

* Maximum Stand Density - greatest number of white and red pine combined found within one hectare within a single stand

Average density = 0.5 Mg/m^3 (from Harmon et al. 1986) than the mean old tree density estimates for the other two forest types. Maximum old tree density ranged from a low of 35/ha for the white pine-red pine forest type to a high of 60/ha for the red pine-conifer forest type.

The mean density of snags (all species) for each of the five forest types varied from a low of 77/ha for the white pine-red pine forest type to a high of 112/ha for the white pine-conifer forest type which is almost a 50% increase in density. However, within each forest type, snag density per plot varied considerably. For example, within the white pine-conifer forest type, snag density varied by as much as 130/ha. The greater variation in snag density within forest types compared to the smaller snag density variation between forest types may reflect the problems of too few samples, the variation in site productivity within each forest type, variations in species life history characteristics or combinations of these. In any case, these problems should be addressed in future studies.

Mean log biomass varied from a low of 37.9 Mg/ha for the red pine-conifer forest type to a high of 57.7 Mg/ha for the white pine-mixed forest type which is approximately a 50% increase in biomass. The mean density of large pieces of logs varies from a low of 10/ha in the white pine-deciduous forest type to a high of 48.2/ha in the white pine-conifer forest type which is almost a five-fold increase. It is interesting to note, however, that log pieces in the white pine-deciduous forest type are, on average, almost twice the diameter of those in the white pine-conifer forest type. Again, variation in both log biomass and density is greater within forest types than between forest types and must be investigated in the future.

Minimum values for old tree density, snags and logs presented in Table 7 are simply those values at the low end of the range presented in each category in Table 6. Common associates (mean basal area > 1 m^2/ha) were identified from the species composition matrix (Table 5) and canopy structure descriptions were derived from field observations.

Minimum old tree density varied from 9/ha for the red pine-conifer forest type to 10/ha for the white pine-other forest type to 15/ha for the white pine-red pine forest type. Sugar maple and yellow birch were found as common associates (>1 m^2/ha) only in the white pine-deciduous forest type and white spruce was found as a common associate only in the white pine-red pine forest type. All other common associates occurred in more than one forest type. The most frequently occurring common associates were white cedar, which was found in all five forest types, and white birch which was found in four forest types. A multilayered canopy was characteristic of the white pine-mixed, white pine-conifer and white pine-red pine forest types whereas the red pine-conifer forest type was characterized mainly by a single layered canopy. In the white pine-deciduous forest type, old white pine were often emergent above the deciduous canopy.

Minimum snag density varied from 30/ha for both the white pine-mixed forest type and the red pine-conifer forest type to 70/ha for the white pine-deciduous forest type. Minimum log biomass varied from 6 Mg/ha for the red pine-conifer forest type to 32 Mg/ha for the white pine-red pine forest type. The greatest density of large log pieces (20/ha) was found in the white pine-red pine forest type, however, the

TABLE 7 - PRELIMINARY MINIMUM STANDARDS FOR OLD-GROWTH WHITE AND RED PINE FORESTS IN CENTRAL ONTARIO

STAND CHARACTERISTICS	FOREST TYPE: White Pine-Deciduous	White Pine-Mixed	White Pine-Conifer	White Pine-Red Pine	Red Pine-Conifer
Old Live Trees					
Density	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>15 trees/ha >140 years old	>9 trees/ha >140 years old
Associates (>1 m^2/ha basal area)	sugar maple, red maple, yellow birch, white cedar	white birch, red pine, white cedar, balsam fir, red maple	red pine, white cedar, black spruce, white birch	white birch, balsam fir, white cedar, white spruce	white pine, black spruce, white cedar, white birch
Canopy	white pine emergent above deciduous	multilayered canopy	multilayered canopy	multilayered canopy	mainly a single layered canopy
Snags	all species >70/ha, >10 cm dbh and 2 m tall	all species >30/ha, >10 cm dbh and 2 m tall	all species >60/ha, >10 cm dbh and 2 m tall	all species >50/ha, >10 cm dbh and 2 m tall	all species >30/ha, >10 cm dbh and 2 m tall
Logs	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	16 metric tons/ha, 10 pieces/ha 37 cm diam and 8 m long	17 metric tons/ha, 10 pieces/ha 28 cm diam and 8 m long	32 metric tons/ha 20 pieces/ha 35 cm diam and 8 m long	6 metric tons/ha 10 pieces/ha 25 cm diam and 8 m long

largest pieces were found in the white pine-deciduous forest type.

PRELIMINARY DEFINITIONS

Five types of old-growth white and red pine forest were identified in the Temagami Region. Those plots dominated by white pine with greater amounts of deciduous than coniferous associates were classified as white pine-deciduous (WP-D), those dominated by white pine with nearly equal portions of coniferous and deciduous associates were classified as white pine-mixed (WP-M) and those dominated by white pine with greater portions of coniferous associates were classified as white pine-conifer (WP-C). Those plots with nearly equal portions of both dominant white and red pine were classified as white pine-red pine (WP-RP) and those plots dominated by red pine with a greater portion of coniferous associates were classified as red pine-conifer (RP-C). Because more data are required to develop final old-growth definitions for white and red pine, the following descriptions should be considered only as preliminary or interim.

Old-Growth White Pine-Mixed Forest

The old-growth WP-M forest type is one of the two most common old-growth white pine forest types in the Temagami Region. The minimum density of old white and red pine trees is 10 per ha. Species commonly associated with white pine in this old-growth forest type include white birch, red pine, white cedar, balsam fir and red maple. Together the white pine and its associates generally form a multilayered canopy. The minimum density for snags (all species) is 30 per ha. Minimum log biomass is 16 Mg per ha with at least 10 log pieces per ha, 37 cm in diameter and 8 m long. The surficial geology most commonly associated with the old-growth WP-M forest type includes outwash plains, dumped till over bedrock and dumped till over moulded till (Ontario Ministry of Natural Resources 1989). Also associated with this old-growth forest type are hot and normal microclimates with soil moisture conditions ranging from dry to mesic (Hills 1960).

Old-Growth White Pine-Conifer Forest

Also one of the two most common old-growth white pine forest types in the Temagami Region, the old-growth WP-C forest type has a minimum density of 10 old white and red pine trees per ha. Species commonly associated with the white pine include red pine, white cedar, black spruce and white birch. Generally, all woody vegetation combine to form a multilayered canopy. The minimum density for snags (all species) is 60 per ha and the minimum log volume is 17 Mg per ha including at least 10 pieces per ha, 28 cm diameter and 8 m long. Common surficial geology associated with this old-growth type includes outwash plains, dumped till over bedrock, and dumped till over moulded till (Ontario Ministry of Natural Resources 1989). It is also commonly associated with a hot to normal microclimate with dry to mesic soil moisture conditions (Hills 1960).

Old-Growth White Pine-Deciduous Forest

An uncommon old-growth white and red pine forest type in Temagami is the WP-D forest type. The minimum density of old white and red pine trees for this old-growth type is 10 per ha. Species commonly associated with the dominant white pine include sugar maple, red maple, yellow birch and white cedar. The white pine often penetrate and emerge above the deciduous canopy. The minimum density for snags (all species) is 70 per ha and the minimum log volume is 23 Mg per ha with a minimum of 10 pieces per ha, 51 cm diameter and 8 m long. The old-growth WP-D forest type is commonly found growing on sites with dumped till over moulded till and lacustrine deposits (Ontario Ministry of Natural Resources 1989). This old-growth forest type is also most common where a hot microclimate combines with mesic soil conditions and to a lesser extent where a normal microclimate combines with dry soil conditions (Hills 1960).

Old-Growth White Pine-Red Pine Forest

This old-growth pine forest type has similar amounts of both old white and old red pine trees. It typically has the highest density of old trees of all five old-growth forest types in Temagami. Common associates include white birch, balsam fir, white cedar and white spruce all of which combine with white pine to form a multilayered canopy. The minimum density for snags (all species) is 50 per ha and the minimum biomass for logs is 32 Mg per ha with a minimum of 20 log pieces per ha, 35 cm diameter and 8 m long. Common surficial deposits include outwash plains and dumped till (Ontario Ministry of Natural Resources 1989). The old-growth WP-RP forest type is commonly found where dry soil conditions combine with a hot microclimate, where dry soil conditions combine with a normal microclimate, and where mesic soil conditions combine with a normal microclimate (Hills 1960).

Old-Growth Red Pine-Conifer Forest

The minimum density for the old-growth RP-C forest type is 9 old red pine trees per ha or 9 old trees of both red and white pine per ha. This is the lowest minimum density of all five old-growth forest types. The common associates, which include white pine, black spruce, white cedar and white birch, combine with red pine to form, in most instances, a single layered canopy. In some stands, however, a lower or mid-level canopy of white pine is present. Minimum density of snags (all species) is 30 per ha and the minimum log volume is 6 Mg per ha with at least 10 log pieces per ha, 25 cm diameter and 8 m long. Common surficial deposits include outwash plains and dumped till over bedrock (Ontario Ministry of Natural Resources 1989). The old-growth RP-C forest type is also common where dry soil conditions combine with a hot or normal microclimate (Hills 1960).

General preliminary criteria for old-growth white and red pine forest in central Ontario include the following: (1) white pine - at least 10 old pine/ha, 140 years+, red pine - at least 9 old trees/ha, 140 years+, (2) at least 10 logs/ha, at least 25 cm diameter at large end and at least 8 m long; (3) at least 30 snags/ha, at least 10 cm dbh and 2 m tall; and (4) minimal to no human disturbance. Additional studies are required to identify minimum levels of human disturbance for old-growth white and red pine forest.

FUTURE OLD-GROWTH DEFINITIONS

Forests are highly variable and dynamic ecosystems. Thus, we must be careful not to develop a precise definition of old-growth forest that characterizes the structure and function of what may be a transitory phenomenon. "In effect, if today's definition of old growth is too exact, it cannot serve as a model for tomorrow's old growth" (Spies and Franklin 1988).

Perhaps the best way to avoid a restrictive definition of old-growth forest with limited application is to characterize both structural and functional features of forest ecosystem succession by including at least the young, mature and old-growth stages (Parker 1989). In addition to structural features such as old trees, snags and logs, other structural features such as heterogeneity of understory, species diversity, forest floor depth and live wood biomass should be considered (Spies and Franklin 1988). Barnes (1989) stressed that functional features such as regeneration, nutrient cycling, productivity, energy flow and gene pool dynamics should also be included in the context of the old-growth abiotic environment. Thus, we should expand the focus to the landscape ecosystem to include the interaction of factors such as climate, soil, landform and natural disturbance with the biotic community. Combinations of these factors determine site productivity which in turn determines the minimum age of old-growth forest. For example, on sites of low productivity, the old growth condition will occur at a younger age relative to sites of high productivity where the old growth condition will occur later. Initiation of the old growth stage needs to be determined for the variety of landscape ecosystem types associated with old-growth white and red pine forests.

Size may be the most critical factor determining the long-term viability of an ecosystem (Harris 1984). Once a forest is smaller than 10 ha it may be entirely edge habitat and may no longer have the properties of the original forest (Franklin and Forman 1987). The minimum viable size of an old-growth stand "...varies depending on species composition, management objectives, location of the stand in the landscape, and successional stages of neighboring stands" (Spies and Franklin 1988). It has also been determined that old growth is not necessarily "virgin" (Barnes 1989, United States Forest Service 1989). It remains, however, to identify acceptable levels of human disturbance for Temagami's old-growth forests.

Due to continuing pressure from logging and lack of provincial old-growth forest policies throughout eastern Canada, the few stands of old-growth white and red pine remaining throughout their natural ranges should be located, studied and conserved as quickly as possible.

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