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RESEARCH ARTICLE

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Scale of Ecological Representation: A Case Study of Old-Growth Forest Conservation in Temagami, Ontario, Canada

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ABSTRACT: According to Ontario's first forest ecosystem conservation strategy, stands of old-growth red pine (*Pinus resinosa* Ait.) and eastern white pine (*P. strobus* L.) forest that are ecologically representative of their forest type are to be protected from logging. In a recent case in the Temagami region of Ontario, the Ministry of Natural Resources used an ecological assessment based on maps of landform and forest composition to determine that the Owain Lake Old-Growth Pine Area occurs on the same landform type and has the same vegetation composition as a previously protected old-growth pine area. Based on this cursory analysis, the Ministry suggested that the ecological features in the Owain Area were already represented elsewhere and, therefore, need not be protected. Shortly after that assessment was completed, a major portion of the Owain Lake Area was logged. I used existing forest classification schemes, Forest Resource Inventory data, field data collected by the Ministry of Natural Resources, and my own field data to compare the Owain Area with the reference protected area. Despite location on the same landform type and some similarities in overstory tree species composition, I found numerous differences between the two old-growth areas in terms of presence/absence of individual plant taxa and rare forest communities, abundance of common plant taxa and of logs, plant community composition, and stand age and size. Design criteria for protected areas including ecological representation, replication, and conservation status are addressed in the context of Ontario's Conservation Strategy for Old-Growth Red and White Pine Forest Ecosystems.

Escala de Representación Ecológica: Un Caso de Estudio de Bosque Desarrollado en Temagami, Ontario, Canada

RESUMEN: De acuerdo con la primer estrategia de conservación de ecosistema de bosque de Ontario, los bosques desarrollados de pinos rojo y blanco del este que sean ecológicamente representativos de su tipo de bosque deben ser protegidos de la tala. En un caso reciente en la región de Temagami en Ontario, el Ministerio de Recursos Naturales usó una imposición ecológica basada en mapas de la tierra y de composición de bosques para determinar que el área de Pinos de edad del lago Owain tiene la misma composición de suelo y la misma composición de vegetación que un área de pinos de edad previamente protegido. Basado en ese análisis precipitado, el ministerio sugirió que las características en el área de Owain ya estaban preservadas en otro lugar y por lo tanto, no necesitabas estar protegidas. Al poco tiempo que la imposición estuvo completa, una gran parte del área del lago Owain fue talada. Usé esquemas de clasificación de bosques existentes, datos del Inventario de Recursos del Bosque, datos de campo colectados por el Ministerio de Recursos Naturales, y mis propios datos para comparar el área de Owain con el área protegida de referencia. Además de la localización en la misma formación de suelo, y algunas similitudes en composición de especies de árboles del dosel, encontré numerosas diferencias entre las dos áreas en términos de presencia/ausencia de taxones de plantas y raras comunidades de bosques, abundancia de platas comunes y de valor maderero composición de comunidades de plantas y edad y tamaño de los ejemplares. El criterio de diseño para áreas protegidas incluyendo representación ecológica, réplicas y estados de conservación es considerado en el contexto de la Estrategia de Conservación de Ontario para Ecosistemas de Bosques desarrollados de pinos Rojo y Blanco.

Index terms: conservation; ecological representation; landscape scale; old-growth forest; Temagami, Ontario

INTRODUCTION

In 1994 the Ontario Ministry of Environment and Energy presented the Ontario Ministry of Natural Resources (OMNR) with numerous "terms and conditions" that it should meet in order to continue with forest management activities in the province (Ontario Environmental Assessment Board 1994). One of these requirements was to produce a conservation strategy for old-growth red pine (*Pinus resinosa* Aiton) and eastern white pine (*Pinus strobus* L.) forests. Accordingly, by 1995 the OMNR had produced the document, "A Conservation Strategy for Old-Growth Red and White Pine Forest Ecosystems for Ontario" (hereafter, Conservation Strategy; OMNR 1995a). A primary objective of this strategy is "to protect representative ecosystems of old-growth red and white pine in each site district in Ontario within the natural range of pine." Missing from the Conservation Strategy, however, are any criteria for evaluating ecological representation, for defining these forests, and for considering stand size and shape, despite the fact that substantial discussion of these concerns occurred prior to the development of the Conservation Strategy (Geomatics International 1992; OMNR 1992, 1994; Iacobelli et al. 1994).

For example, a comprehensive consideration of ecological representation was provided by the Canadian Council on Ecological Areas (Gauthier 1992): "Full representation will be judged relative to all climatic, edaphic and biological site conditions characteristic of the ecoregion. There will, therefore, need to be a hierarchy of classification schemes below the level of landforms . . . that include biological factors such as plant communities . . . [creating] increasingly finer levels of physiographic and ecological characterization. Replication will help to maximize representation, act as insurance against catastrophe and help to increase management options. Representation should be assessed on the basis of regional surveys coupled with more intensive follow-up site-specific surveys."

In the past, typical ecological assessments of candidate reserves carried out by the OMNR have included site-specific field surveys as well as coarse-level analysis of landscape features such as landform (e.g., Walshe 1969; Crins and Darbyshire 1977; Brunton 1990, 1992; White 1990a,1990b). Recently, however, the OMNR conducted an ecological assessment of the Owain Lake Old Growth Pine Area (OMNR 1995b) using (1) a coarse resolution assessment of regional landforms demarcated on 1:250,000-scale maps and (2) qualitative comparison of forest overstory composition obtained from Forest Resource Inventory (FRI) maps at 1:20,000 scale (OMNR 1995c). The crux of this analysis involved the finding that the currently protected Obabika Lake Old Growth Pine Area and the Owain Area, where logging was proposed, both occurred on the same "moderately broken shallow sandy till uplands ground moraine" landform type and did not differ substantially in overstory composition. Based on these coarse-level analyses, the OMNR determined that the natural heritage values of the Owain Area were currently represented by the Obabika Area and, therefore, rejected the option of protecting the Owain Area (OMNR 1995c, Crins 1996). Shortly thereafter, in late 1996, approximately 320 ha of the Owain Area were logged and the remainder is available for logging in the future.

By excluding a definition of ecological representation including scale criteria from the Conservation Strategy, the OMNR created a framework that can justify the use of a spatial scale of analysis that minimizes the detection of ecological differences between sites. For example, ecological assessments at map scales such as 1:250,000 are much less likely to identify ecological differences than are assessments using larger map scales (e.g., finer resolution). When few, if any, ecological differences are found between the reference reserve and the candidate site, it can be argued that the candidate site is "ecologically redundant"—meaning that it has no additional natural heritage value and can be logged.

Ultimately the most effective conservation strategies are those based on ecological assessments at multiple spatial scales (Murphy 1989, Norton and Ulanowicz 1992, Noss 1992, Porritt 1994, Turner et al. 1995), which include at least some field assessment (Gauthier 1992, Raven and Wilson 1992). The purpose of my study was to (1) compare the ecological features of the Owain Area and the Obabika Area using field data and data derived from aerial photos, and (2) consider the differences between the two stands in the context of biodiversity conservation. Although an explanation for any ecological differences between sites is desirable and useful, as the first step, this study focused only on identifying and describing differences.

STUDY AREAS

Both the Owain Area (47° 0' N, 79° 24' W) and the Obabika Area (47° 9' N, 80° 15' W) are located in the Temagami Site District (4E4) of Ontario, Canada, which is approximately 1,656,300 ha in size (Figure 1). Elevation ranges from 310 to 685 m throughout the district, which is entirely underlain by the Canadian Shield (Wickware and Rubec 1989). Both areas are located on the "moderately broken shallow sandy till uplands ground moraine" landform, which occupies 1,127,000 ha and is the most common landform, constituting 68% of the district's area (Figure 2). This landform primarily consists of bedrock-controlled uplands with thin deposits (usually less than 1 m thick) of stony, bouldery, sandy till. Exposed bedrock, lakes, and rivers are common on this landform (Noble 1983). Whereas this landform type comprises 100% of the Owain Area, it comprises approximately 60% of the Obabika Area. The other 40% of the Obabika Area is made up of the "weakly broken deep outwash plain" (Va-1; Figure 2) landform type. The Superior, Southern, and Grenville Provinces make up most of the district's exposed bedrock, which is composed primarily of Early Proterozoic sedimentary rocks of the Cobalt Group and to a lesser extent of Archean metavolcanic rocks and Archean granitic rocks (Ontario Geological Survey 1991). Humo-Ferric Podzols and Eluviated Brunisols are the dominant mineral soils in upland areas, whereas mineral soils in lowland areas are dominated by Humic or Rego Gleysols (Clayton et al. 1977).

Mean January temperatures are below −10° C, mean summer temperature is at or above 10° C, and the frost-free period lasts from May to mid-September. Precipitation varies from 50 to 100 mm per month with maximum precipitation in middle to late summer (Ecoregions Working Group 1989). The research area is located within the Upper Great Lakes–St. Lawrence Forest Region of Canada (Hoise 1979). There are seven forest types that make up the majority of the landscape in the Temagami Site District. These forest types, from most to least abundant, include those dominated by white birch (*Betula papyrifera* Marshall), white and black spruce (*Picea glauca* [Moench] and *P. mariana* [Miller] BSP), trembling and largetooth aspen (*Populus tremuloides* Michx. and *P. grandidentata* Michx.), jack pine (*Pinus banksiana* Lambert), balsam fir (*Abies balsamea* [L.] Miller), eastern white pine, and red pine (OMNR 1991a).

The Owain Area (Figure 1) is located in the southeastern portion of the Temagami Site District and straddles the southern part of Hebert Township and the northern part of Burnaby Township along the western bank of the upper Ottawa River. Prior

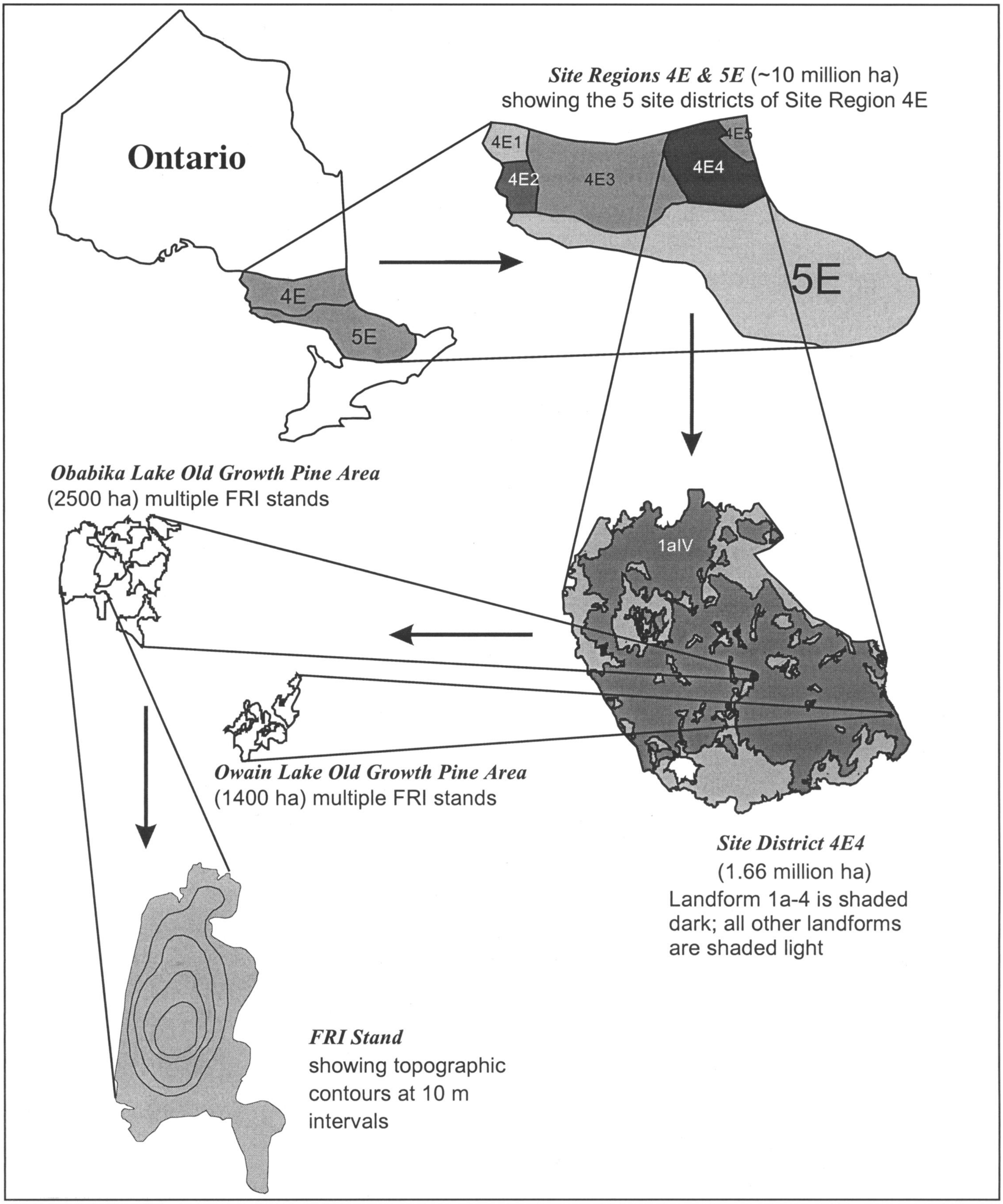

Figure 1. Study area and relative spatial scale of the ecological units relevant to the conservation of the Owain Lake and Obabika Lake Old-Growth Pine Areas, Ontario, Canada.

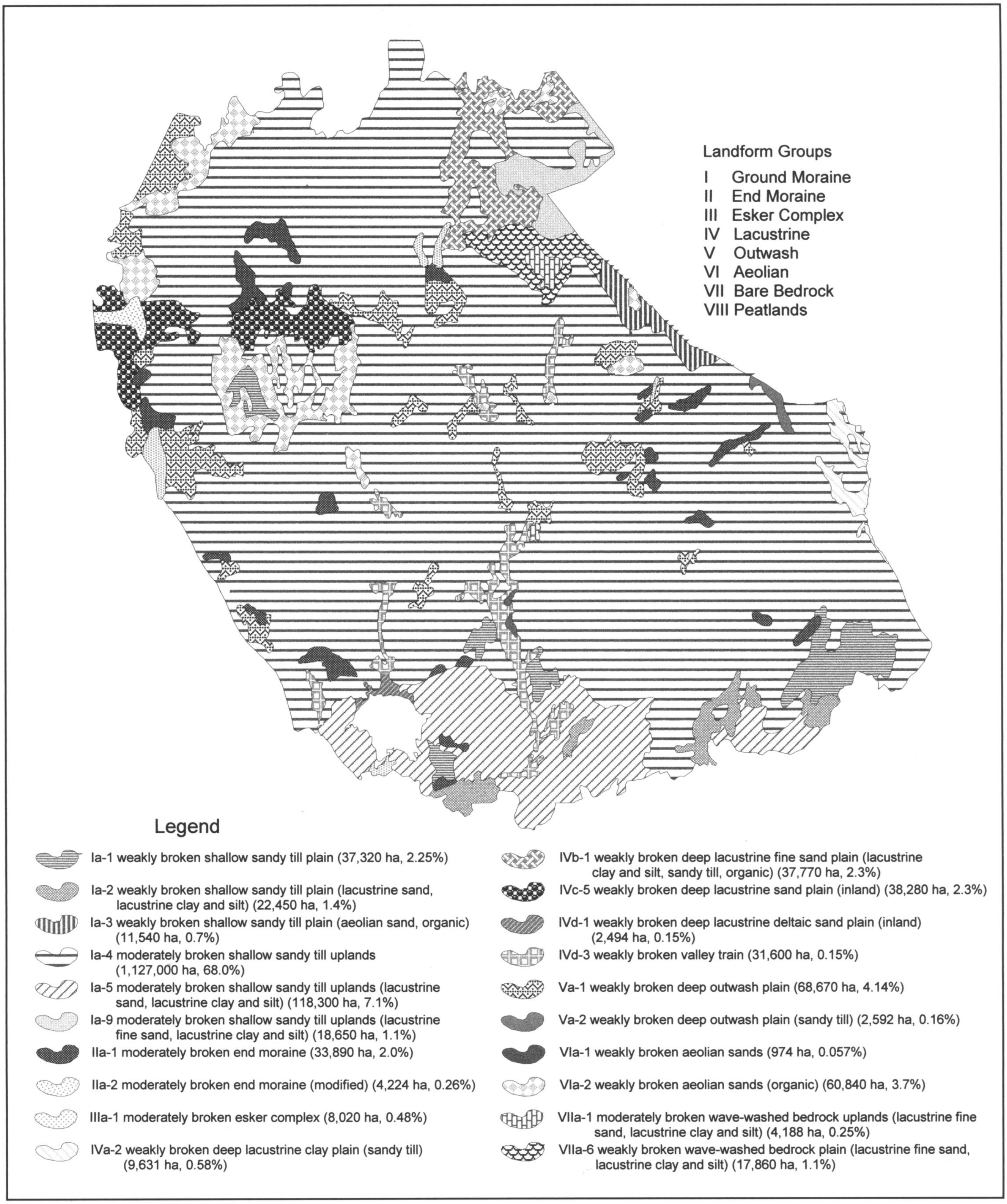

Figure 2. Landform types in the Temagami Site District (4E4), Ontario, Canada.

to logging, the Owain Area consisted of approximately 1400 ha of red and eastern white pine-dominated forest ranging in age from 75 to 150 years (mean =105 years), as determined from FRI maps (OMNR 1991b). Based on analysis of government logging records (Quinby et al. 1995) and a cursory ground survey, it appears that the vast majority of the Owain Area had not been logged prior to 1996.

The Obabika Area (Figure 1), approximately 2500 ha in size (White 1990b), consists primarily of red and eastern white pine-dominated forest with some trees well over 300 years old. It is located in the northeastern portion of Delhi Township and the southeastern part of Shelburne Township, which are both located in the central portion of the Temagami Site District. It was recently added to Obabika River Provincial Park (OMNR 1997) and thus has been protected. Because of its pristine nature (Sharpe 1989) and size, the Obabika Area has natural heritage significance at both provincial (White 1990b) and global (Quinby 1993) levels. The two study areas are about 60 km apart.

METHODS

In order to conduct a more detailed study than the OMNR's comparison of the two old-growth areas, I analyzed remotely sensed data and field data describing additional ecological features and representing a variety of spatial scales. These ecological features, their total and mean areas, the associated variables used in analysis, the sources of the data, and their application in the conservation decision are displayed in Table 1. These ecological features (Table 1) are ordered from most coarse to finest spatial resolution according to the mean size of the ecological feature (column 3 in Table 1). At the most coarse spatial resolution, 54 common forest ecosystem types have been identified by Chambers et al. (1997) within the roughly 10 million ha area of Site Regions 4E and 5E located in central Ontario (Figure 1). For analysis at this most coarse level, I used the field guide produced by Chambers et al. (1997) to classify the 20 red and

Table 1. The spatial hierarchy of ecological features, their area, and the variables sampled for the Owain Lake and Obabika Lake Old-Growth Pine Areas, Ontario, Canada.

Ecological Features and their Quantity	Area Covered	Mean Size of the Ecological Feature (ha)	Variables Studied	Data Source	Applied to Decision?	Reference
Forest Ecosystems (54)	Site Regions 4E and 5E (~ 10,000,000 ha)	~185,000	mature forest types	field data	no	Chambers et al. 1997
Landforms (20)[a]	Site District 4E4 (1,656,293 ha)	83,000	old-growth forest types	soils maps, aerial photos	yes	Noble 1983
Plant Communities (223)	Site District 4E4 (1,656,293 ha)	4484	community types	aerial photos, field data	no	Maycock 1979
Landscapes (2) (flora)	Obabika (2500 ha) and Owain (300 ha) Areas surveyed (total 2,800 ha)	1400	presence of vascular plant species (floral list)	field data	no	White 1990b, this study
Landscapes (2) (plot data)	Core portions of the Obabika (700 ha) and Owain (300 ha) Areas (total 1,000 ha)	500	understory spp. abundance overstory spp. density snag density log density	field data	no	this study
Forest Stands: Red- and Eastern White Pine-Dominated (35)	Obabika (741 ha[b]) and Owain (1331 ha) Areas (total 2072 ha)	59	stand size stand age overstory tree density overstory spp. abundance	aerial photos	yes (qualitative only)	OMNR 1991b, 1991c; this study

[a] Only ecological feature that was not focused on for analysis in this study.

[b] Roughly 1500 ha of the Obabika Area occurs on the Ia-4 landform type; of this area, approximately 741 ha are dominated by red or eastern white pine, and the remaining 759 ha contains significant amounts of co-dominant red and eastern white pine.

eastern white pine-dominated stands located in the Owain Area in order to identify stands in the Owain Area that are rare within Site Regions 4E and 5E.

At the level of resolution below the regional forest types, a qualitative comparison of landforms and FRI stands at each old-growth area was carried out by the OMNR. Although a landform-based analysis was not included in the present study, a map of the 20 different landforms in the Temagami Site District is provided (Figure 2), and landform as a hierarchical ecological feature is included in Table 1. At the next level of spatial resolution, I used Maycock's (1979) classification of plant communities based on dominants and co-dominants to classify the 20 red and eastern white pine-dominated FRI stands in the Owain Area in order to identify forest stands that are rare within the Temagami Site District (see also Geomatics International 1992). Progressing to the next finer level of spatial resolution, I compared field data from White's (1990a, 1990b) rare plant studies in the Temagami Site District (4E4; Figure 1) and his plant species list for the Obabika Area (White 1990b) with my field data from the Owain Area to produce a list of plant species present in the Owain Area but absent from the Obabika Area. The entire 2500 ha of the Obabika Area were surveyed by White (1990b) to derive his species list for that area, whereas only the 300-ha core of the 1400-ha Owain Area were surveyed (including areas outside of plots) to derive the species list for that area. Although a survey of the entire 1400-ha Owain Area would have been ideal, a comparison of species found at the Owain Area and not at the Obabika Area depends only on a complete inventory at the Obabika Area, which was produced by White (1990b). Thus, this list of floral differences is a conservative one; additional inventory work at Owain would probably turn up more plant species that are not present at the Obabika Area.

At an even finer level of spatial resolution, I used data collected in the core portions of both the Obabika Area and the Owain Area to compare vegetative (live and dead) features of the overstory and understory in the two old-growth areas (Table 1, Figure 1). The data for both areas were originally collected for two separate studies (in 1990 for Quinby 1991, and in 1996 for Quinby 1997); thus the sampling design for the two old-growth areas is different. At the time of sampling, the estimated maximum stand age for the Obabika Area (from FRI maps) was 300 years and for the Owain Area it was 145 years. In the core of the Obabika Area (700 ha) in 1990, 20-m x 50-m plots were used to sample for overstory trees (> 10 cm dbh), snags (dead trees > 10 cm dbh), and logs (>1 m long; >15 cm at the large end), although for the present study only a randomly selected 20-m x 20-m portion of the larger plot was used to characterize these three features. Also in 1990, understory vegetation in the Obabika Area was sampled for species abundance (percent cover) by systematically placing eighteen 1-m x 2-m quadrats along three 50-m lines such that six quadrats were located 10 m apart along each 50-m side and along a 50-m line bisecting the plot. The nine 1-m x 2-m quadrats located closest to the selected 20-m x 20-m subsection of the overstory plot (total of 18 m^2) were used in the present study.

For the Owain Area, a total of 20 plots of 20 m x 20 m (from Quinby 1997) were used to characterize overstory trees (> 10 cm dbh), snags (dead trees > 10 cm dbh), and logs (>1 m long, >15 cm at the large end). Understory vascular plants (<0.5 m tall) in the Owain Area were sampled for abundance (percent cover) using fifteen 1-m x 1-m quadrats systematically placed within each plot totaling 15 m^2 of sampled area (also from Quinby 1997). The lower number of understory quadrats per plot in the Obabika Area (9 vs. 15 quadrats) was counteracted to some extent by the higher total understory area sampled per plot in that area (18 m^2 vs. 15 m^2). A range of slope positions was sampled in each old-growth area. Plant nomenclature follows Gleason and Cronquist (1991) and Chambers et al. (1996). All field work in the Owain Area was completed prior to logging.

Only the most common herbaceous understory plant species occurring in both old-growth areas were compared for differences in abundance (percent cover). Similarly, only tree species that were common in at least one old-growth area were analyzed for differences in abundance (density). Log and snag densities were also compared between the two old-growth areas. Mean abundances for these common species in each area were compared using the nonparametric rank sum test (significant at $P \leq 0.05$) (Analytical Software 1994).

I used DCA (Detrended Correspondence Analysis; Hill [1979], Hill and Gauch [1980]) to ordinate the density of trees, snags, and logs as one group, and the percent cover of the understory plants as another group. Ordination diagrams were used to evaluate the community similarity of the two old-growth areas by calculating a community similarity index (CSI). This index was derived by determining the area of the DCA ordination space shared by both forest communities and dividing it by the total area of DCA ordination space occupied by the two communities. For determining the total ordination space, shared ordination space was enumerated only once, and the index is expressed as a percentage. For example, a CSI of 10% indicates a very low degree of similarity between the plant communities being compared. This approach to evaluating similarity among ordination classifications was suggested by Manly (1986) and applied by Halpern (1988).

Finally, at the finest level of spatial resolution, features of the FRI stands occurring on the moderately broken shallow sandy till uplands for each old-growth area (Ontario Ministry of Natural Resources 1991b, 1991c) were compared; these features were overstory tree composition (relative abundance of 12 species), stand age, stand size, and overstory tree density (percent cover) (Table 1, Figure 1). Only those stands dominated by pine (20 stands at Owain and 15 stands at Obabika; total of 2072 ha) were included in this analysis. Stand means for each of these features were compared for significant differences using the rank sum test (significant at $P \leq 0.05$) (Analytical Software 1994). The 35 stands were also ordinated based on overstory tree species composition (percent cover from FRI maps) using DCA to examine the CSI between the two old-growth areas (Manly 1986, Halpern 1988).

RESULTS

Representation of Forest Types in Site Regions 4E and 5E

Chambers et al. (1997) identified a total of 54 "forested ecosites," or mature forest types, in Ontario's Site Regions 4E and 5E (~10 million ha; Figure 1). Eight of these are classified as red and eastern white pine types. The classification was derived using forest types that have been mapped at scales up to 1:50,000, and the classification is considered by the authors to be suitable for a variety of applications including silvicultural and wildlife habitat planning. In total, and based on their FRI overstory composition (determined by OMNR photo interpreters), 15 of the 20 stands in the Owain Area cannot be classified into any of the eight red and eastern white pine forest types described by Chambers et al. (1997). The Owain Area FRI stands do not fit this classification due to their content of (1) red maple (*Acer rubrum* L.), which is present in all six stands at a relative abundance of 10%; (2) black spruce (*Picea mariana*), which is present in six stands ranging in abundance from 10% to 20%; (3) sugar maple (*Acer saccharum* Marshall), which is present in six stands and ranges in abundance from 10% to 20%; and (4) yellow birch (*Betula alleghaniensis* Britton), which is present in one stand with 10% abundance. These 15 stands, representing 12 different FRI stand types, amount to 802 ha (57.3%) of the Owain Area (1400 ha). Chambers et al. (1997) pointed out that their mature forest ecosites are based on "average or modal conditions," implying that the less common, or rare, mature forest types are not described in their field guide.

Representation of Plant Communities in the Temagami Site District (4E4)

The OMNR has identified 223 plant community types in Ontario's Temagami Site District (4E4) (Maycock 1979). Of these, 22 community types are dominated by eastern white pine, red pine, or both. Using Maycock's (1979) classification, I found that 13 of the 20 FRI pine stands in the Owain Area cannot be classified, accounting for 742 ha (53.0%) of the Owain Area (1400 ha). According to the FRI stand composition, the unique nature of these 13 stands, representing 11 rare overstory types, is based on the presence of six overstory tree species including (1) black spruce, which is present in one stand with an abundance of 20%; (2) poplar (trembling and large-tooth aspen), which is present in five stands and ranges in abundance from 10% to 20%; (3) red maple, which is present in three stands with an abundance of 10%; (4) white spruce, which is present in three stands with an abundance of 10%; (5) sugar maple, which is present in six stands and ranges in abundance from 10% to 20%; and (6) yellow birch, which is present in one stand with an abundance of 10%.

Comparing Flora in the Landscapes of the Owain and Obabika Areas

A comparison of White's (1990b) plant species list for the Obabika Area with my plant species list for the Owain Area showed that 10 vascular plant species present in the Owain Area were absent in the Obabika Area (Table 2). According to White (1990a, 1990b), four of these plant species—Indian cucumber root (*Medeola virginiana* L.), marginal wood fern (*Dryopteris marginalis* [L.] A. Gray), partridgeberry (*Mitchella repens* L.), and striped maple (*Acer pensylvanicum* L.)—are regionally rare, or rare within the 5 million-ha Lake Temagami Site Region (4E), and three of these plant species—dwarf rattlesnake plantain (*Goodyera repens* [L.] R.Br.), ostrich fern (*Matteuccia struthiopteris* [L.] Todaro), and round-leaved dogwood (*Cornus rugosa* Lam.)—are locally rare, or rare within the Temagami Site District (4E4). Three plant species that are not known to be rare—dewdrop (*Dalibarda repens* L.), naked mitrewort (*Mitella nuda* L.), and one-sided wintergreen (*Orthilia secunda* [L.] House)—were present in the Owain Area but absent from the Obabika Area. None of the rare plant species present in the Owain Area were found by White (1990b) in the Obabika Area. It is likely that additional rare plant species occur in the Owain Area, considering that the plant species inventory included less than half of the entire Owain Area due to time constraints.

Comparing Plot Data in the Core Portions of the Owain and Obabika Areas

Although plot data describing the two core areas are more precise than data obtained from aerial photographs, which are used to describe stand features, the mean size of a core area (500 ha) is greater than the mean size of an FRI stand (50 ha). Thus, the core plot data are ranked higher in the hierarchy of ecological features (Table 1). A comparison of the abundance of live vegetation between the Owain Area and the Obabika Area showed that the abundance (percent cover) of seven of the eight common understory herbaceous species is significantly different ($P < 0.05$; rank sum test) (Table 3). Large-leaved aster (*Aster*

Table 2. Vascular plant species present at the Owain Lake Old Growth Pine Area that are absent from the Obabika Lake Old Growth Pine Area.

Scientific Name	Common Name	Plant Type	Significance
Acer pensylvanicum	striped maple	shrub	regionally rare
Cornus rugosa	round-leaved dogwood	shrub	locally rare
Dalibarda repens	dewdrop	herb	common
Dryopteris marginalis	marginal wood fern	fern	regionally rare
Goodyera repens	dwarf rattlesnake plantain	herb	locally rare
Matteuccia struthiopteris	ostrich fern	fern	locally rare
Medeola virginiana	Indian cucumber root	herb	regionally rare
Mitchella repens	partridgeberry	shrub	regionally rare
Mitella nuda	naked mitrewort	herb	common
Orthilia secunda	one-sided wintergreen	herb	common

macrophyllus L.) is approximately 3.6 times more abundant in the core portion of the Owain Area compared to the core of the Obabika Area. However, the following understory taxa are significantly more abundant in the Obabika Area: blue bead lily (*Clintonia borealis* [Aiton] Raf.) (6.8 times greater), bracken fern (*Pteridium aquilinum* [L.] Kuhn) (4 times greater), bryophyte (moss) species (4 times greater), bunchberry (*Cornus canadensis* L.) (5 times greater), Canada mayflower (*Maianthemum canadense* Desf.) (2.2 times greater), and starflower (*Trientalis borealis* Raf.) (6.4 times greater).

Three of the nine common overstory tree species are also significantly more abundant in one old-growth area than in the other (Table 3). Northern white cedar (*Thuja occidentalis* L.) is approximately 27 times more abundant in the Obabika Area compared to the Owain Area, whereas both red maple (3 times greater) and white spruce (8.5 times greater) are significantly more abundant in the Owain Area. For the dead wood (snags and logs) comparison, only the density of logs showed a significant difference between the two stands with an abundance 2.2 times greater in the Obabika Area (Table 3).

Table 3. Comparison of mean abundance of some common plant species and some dead wood components between the core portions of the Owain Lake and Obabika Lake Old-Growth Pine Areas (boldface indicates statistical significance based on the Mann-Whitney U statistic).

Vegetation	Mean Abundance: Owain Lake Area (n=20)	Mean Abundance: Obabika Lake Area (n=20)	Critical Values and Statistical Significance
Understory (percent cover)			
Aralia nudicaulis (wild sarsaparilla)	3.2	4.6	0.00; *P*=1.00
Aster macrophyllus (large-leaved aster)	**4.3**	**1.2**	3.38; *p*<0.01
Bryophyte spp. (moss species)	**5.4**	**24.3**	4.65; *P*<0.01
Clintonia borealis (blue bead lily)	**1.7**	**11.5**	4.45; *P*<0.01
Cornus canadensis (bunchberry)	**.7**	**3.6**	2.07; *P*<0.04
Maianthemum canadense (Canada mayflower)	**5.3**	**11.7**	3.15; *P*<0.01
Pteridium aquilinum (bracken fern)	**2.8**	**10.8**	2.66; *P*<0.01
Trientalis borealis (starflower)	**.5**	**3.2**	4.57; *P*<0.01
Overstory (number/ha)			
Abies balsamea (balsam fir)	33	58	1.68; *P*=0.09
Acer rubrum (red maple)	**55**	**18**	2.34; *P*<0.02
Betula papyrifera (white birch)	45	73	1.23; *P*=0.22
Picea glauca (white spruce)	**85**	**10**	4.46; *P*<0.01
Picea mariana (black spruce)	75	65	0.42; *P*=0.68
Pinus resinosa (red pine)	150	128	1.00; *P*=0.32
Pinus strobus (white pine)	113	115	0.50; *P*=0.62
Populus spp. (poplar spp.)	23	8	1.47; *P*=0.14
Thuja occidentalis (white cedar)	**4**	**103**	2.44; *P*<0.02
Dead Wood (number/ha)			
snags (all species)	86	106	1.30; *P*=0.19
logs (all species)	**98**	**213**	3.94; *P*<0.01

The first two axes of the DCA ordination of tree, snag, and log densities combined explained 43.6% of the variance within the data (40 plots) with a CSI of 12.2% (Figure 3). The DCA ordination for the understory plot data resulted in 28.6% variance explained for the first two axes, and a CSI of 0.9%. Only two understory samples from the Owain Area overlapped into the ordination space of the Obabika Lake Area (Figure 4).

Comparing Forest Stands in the Owain and Obabika Areas

Forest stand features from both old-growth areas, which were determined from FRI maps, were analyzed both qualitatively and quantitatively. Using a qualitative comparison of overstory tree species composition, I found that 13 FRI stands representing 11 different stand types in the Owain Area had a species composition that is not present in the Obabika Area. The unique composition of these stands in the Owain Area relative to the Obabika Area is due in large part to the presence of three overstory tree species: sugar maple (six stands), red maple (six stands), and yellow birch (one stand). These 13 stands include 760 ha (54.3%) of the Owain Area. In addition, two stand types that are found in the Obabika Area are not present in the Owain Area. One stand type is dominated by white and red pine with balsam fir, white birch, white cedar, and black spruce as subdominants; the other stand type is dominated by red pine, white cedar, and white pine with white birch and white spruce as subdominants. This result is due primarily to the presence of white cedar in the Obabika Area and its absence at the Owain Area.

Quantitative comparison of stand features assessed from FRI maps for the two old-growth areas showed that abundance of seven overstory tree species differed significantly (Table 4). Abundance of overstory jack pine and poplar were both more than 9 times greater in the Owain Area (9.0% and 6.5% cover respectively) compared to the Obabika Area (both 0.7% cover) ($P = 0.02$, critical value = 2.25 and $P = 0.05$, critical value = 1.93, respectively). Overstory red maple, sugar maple, and yellow birch were all present in the

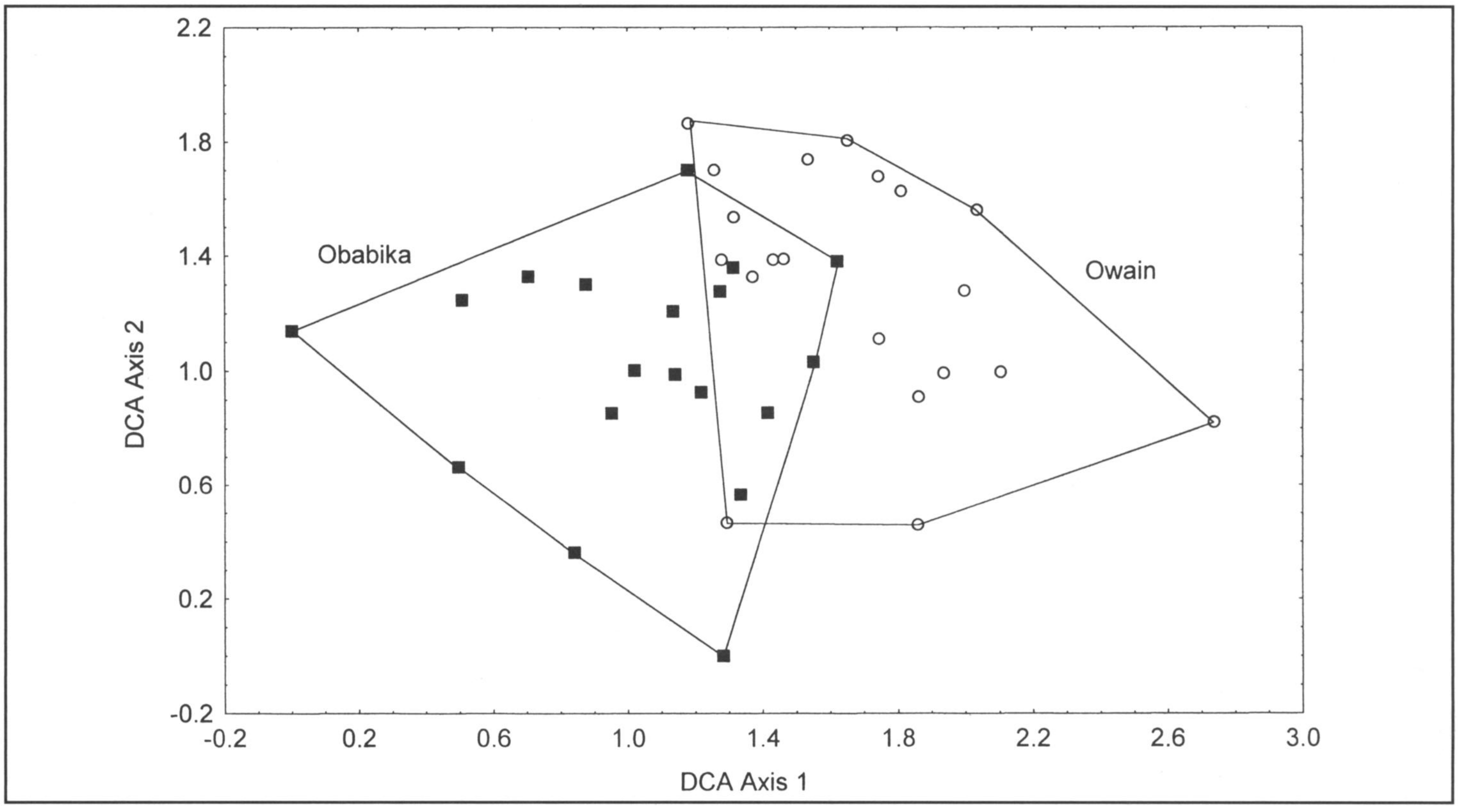

Figure 3. Ordination of field sample plots based on tree, snag, and log densities combined in the core portions of the Owain Lake and Obabika Lake Old-Growth Pine Areas, Ontario, Canada, using Detrended Correspondence Analysis.

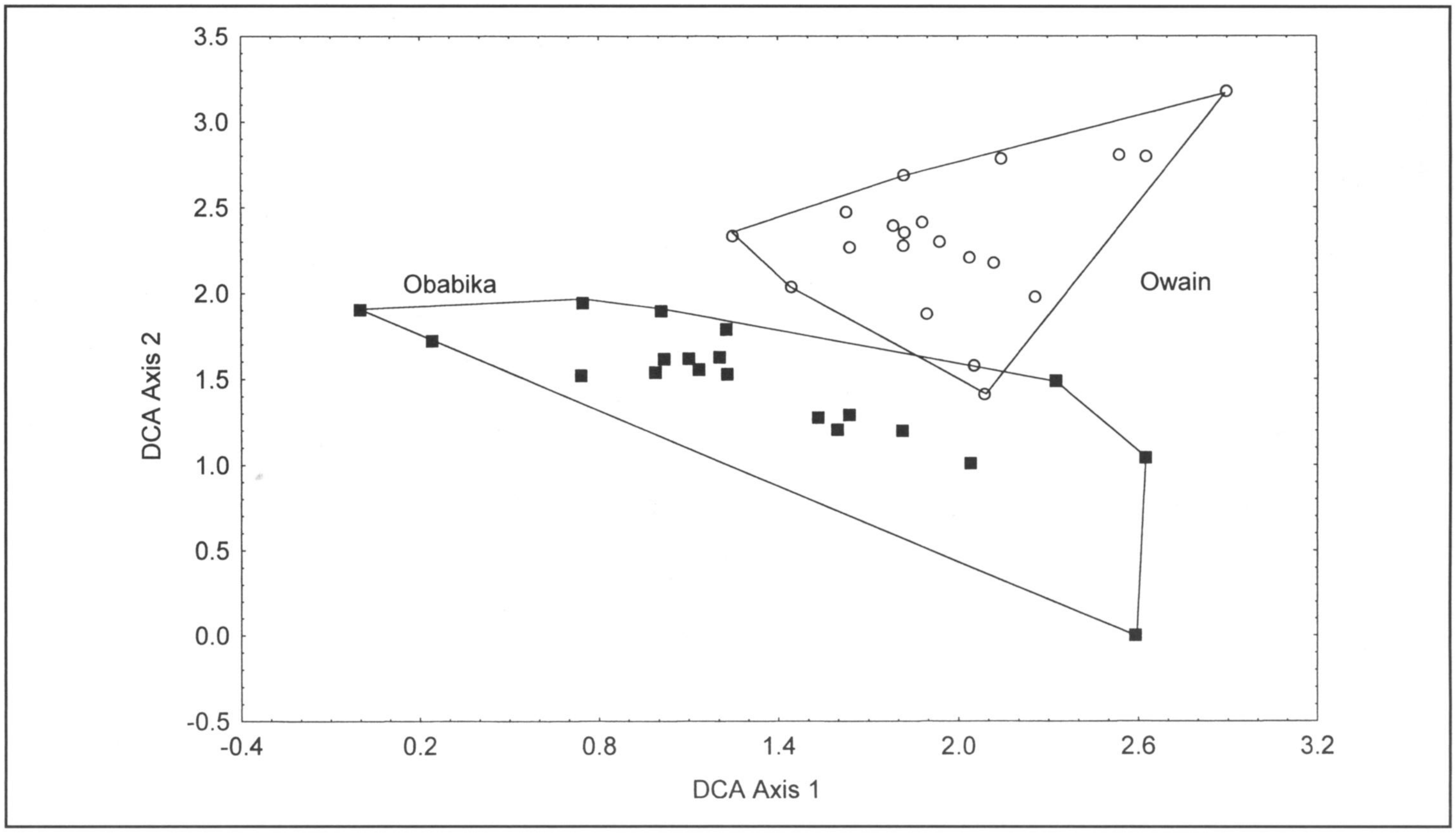

Figure 4. Ordination of field sample plots based on understory plant species composition (percent cover) in the core portions of the Owain Lake and Obabika Lake Old-Growth Pine Areas, Ontario, Canada, using Detrended Correspondence Analysis.

Owain Area but absent from the Obabika Area. Abundance of overstory white spruce was almost 3 times greater in the Obabika Area (9.3% cover) compared to the Owain Area (3.5% cover) ($P < 0.01$, critical value = 2.68), and overstory white cedar was present in the Obabika Area but not in the Owain Area. In addition, mean stand age was 1.7 times higher in the Obabika Area (177.4 years.; maximum age of 206 years) compared to the Owain Area (105.5 years.; maximum age of 140 years) ($P = 0.00$, critical value = 4.98). Finally, tree density in the Owain Area (90.5) was 2.3 times higher than it was for the Obabika Area (40.0) ($P = 0.00$, critical value = 4.98). The first two axes of the DCA ordination of FRI tree species composition explained 51% of the variance within the species data with a CSI of 22.5% (Figure 5). In other words, according to the DCA analysis, the overstory in the two old-growth areas differs by 77.5%.

DISCUSSION

Although the Owain and Obabika old-growth areas occur on the same landform type (Ia-4 in Figure 2), use of existing forest classification schemes, analysis of FRI stand features, and analysis of existing and original field data at multiple spatial scales has identified numerous differences between them. These include differences in the presence/absence of individual plant taxa, differences in the abundance of common plant taxa and logs, differences in plant community composition including rare forest community types, and differences in stand age and tree density. Although the plot data were obtained from the core portions of each old-growth area, they are probably representative of each area because the soils, climate, and topography in the core areas are typical of areas adjacent to the core. The extensive differences documented in this study between the two old-growth areas strongly suggest that they each represent a different community within the old-growth red and eastern white pine forest type.

On the other hand, because the FRI stands in the Owain Area are, on average, 72 years younger than those in the Obabika Area, the differences between the two old-growth areas might be interpreted as simply a feature of successional development. This is unlikely for a few reasons. In the context of forest succession in the northern temperate forests of Ontario, sugar maple and yellow birch typify the oldest stages of forest succession (Hills 1959, Martin 1959, Rowe 1972), yet the Owain Area, which supports both sugar maple and yellow birch (according to FRI maps), is actually younger than the Obabika Area. In addition, for the Owain Area to undergo a successional transition to match the current tree species composition of the overstory in the Obabika Area (based on FRI maps), the abundance of three tree species (red maple, sugar maple, and yellow birch) would have to decrease to zero and the abundance of two species (white cedar and white spruce) would have to at least triple in abundance, all in a time period of only 72 years. This successional trajectory is highly unlikely; thus, the presence of these tolerant hardwood species in the Owain Area is more likely due to population and/or habitat influences. These multiple ecological differences between the two old-growth areas support the notion that the Owain Area has ecological features that set it apart from the Obabika Area, meriting protection according to current government policy (OMNR 1995a).

Furthermore, when two candidate areas do represent the same community type, but are at different stages of their successional development, it may be wise to protect both "so that the full spectrum of age classes is maintained across the landscape" (OMNR 1995a). Ecological redundancy within a reserve system protects the long-term integrity of ecologically representative communities from the destructive effects of random and unpredictable natural disturbances (Gauthier 1992, Noss and Cooperrider 1994, Meffe and Carroll 1997). Wind storms, wildfire, insects, and

Table 4. A comparison of stand features from Forest Resource Inventory maps between the Owain Lake and Obabika Lake Old-Growth Pine Areas (boldface indicates statistical significance based on the Mann-Whitney U statistic).

Stand Features	Mean Abundance (% cover) Owain Lake Area (n=20)	Obabika Lake Area (n=20)	Critical Values and Statistical Significance
Overstory Tree Species			
Abies balsamea (balsam fir)	0.5	2.0	0.73; *P*=0.46
Acer rubrum (red maple)	**3.0**	**0.0**	N/A
Acer saccharum (sugar maple)	**4.0**	**0.0**	N/A
Betula alleghaniensis (yellow birch)	**0.7**	**0.0**	N/A
Betula papyrifera (white birch)	13.0	9.3	1.63; *P*=0.10
Picea glauca (white spruce)	**3.5**	**9.3**	2.68; *P*<0.01
Picea mariana (black spruce)	5.0	2.7	0.42; *P*=0.68
Pinus banksiana (jack pine)	**9.0**	**0.7**	2.25; *P*=0.02
Pinus resinosa (red pine)	32.0	29.3	0.17; *P*=0.87
Pinus strobus (white pine)	23.5	22.7	0.15; *P*=0.88
Populus grandidentata and *P. tremuloides* (poplar)	**6.5**	**0.7**	1.93; *P*=0.05
Thuja occidentalis (white cedar)	**0.0**	**23.3**	N/A
Other Features			
stand age (years)	**105.5**	**177.4**	4.98; *P*=0.00
stand size (ha)	66.5	49.4	1.65; *P*=0.10
tree density (% cover)	**90.5**	**40.0**	4.98; *P*=0.00

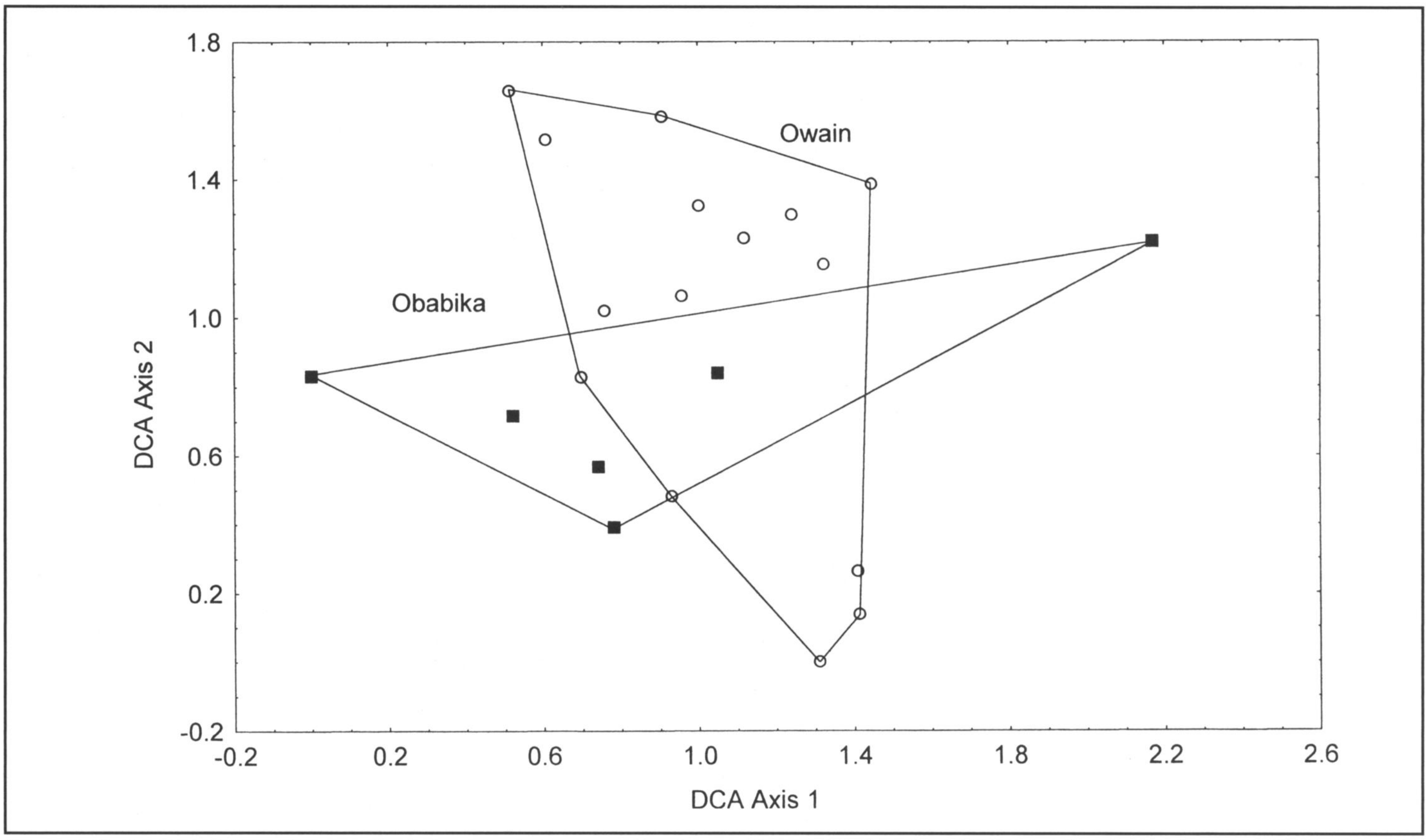

Figure 5. Ordination of Forest Resource Inventory stands based on overstory species composition (from FRI maps) for the Owain Lake and Obabika Lake Old-Growth Pine Areas, Ontario, Canada, using Detrended Correspondence Analysis.

disease can severely modify areas much larger than any single Area of Natural and Scientific Interest, Nature Reserve, or Conservation Reserve that currently exists anywhere in Ontario. In fact, in direct contradiction to this principle, the Conservation Strategy for Old-Growth Red and White Pine Forest Ecosystems in Ontario states that a minimum of only "one old growth red and white pine ecosystem . . . in each site district" must be protected (OMNR 1995a).

The mean size of the five site districts in the Lake Temagami Site Region (4E) is approximately 1 million ha. Protecting one old-growth red and eastern white pine forest stand for every 1 million ha is almost ecologically meaningless as even the smallest of site districts in central Ontario have numerous old-growth red and eastern white pine community types as yet inadequately described and classified (Clark and Perera 1995). For example, Maycock's (1979) 22 red and eastern white pine forest types in the Temagami Site District (4E4) are based entirely on forest overstory species. If these overstory forest types were combined with most of the 91 common vascular plants found in the understory of red and eastern white pine forests throughout central Ontario (Carleton et al. 1996), dozens of additional overstory-understory community types would result for red and eastern white pine forests just in the Temagami Site District alone. This would substantially increase the number of additional stands required for protection in order to achieve adequate representation. In fact, The Nature Conservancy (Maybury 1999) has identified the forest overstory-understory combination (or "association") as the critical focus for biodiversity conservation because it is "fine enough to be useful for identifying specific, ecologically meaningful sites for conservation, but broad enough to be connected to landscape-scale processes and patterns."

Ultimately, both the "ecological representation" and "multiple examples" criteria for the design of a protected areas system lose their relevance in the context of an ecosystem type that is in danger of being lost. Since 1992 it has been known that old-growth white pine forest is an endangered ecosystem (Quinby 1992, 1993). During its review of forest management in Ontario, the Ontario Environmental Assessment Board (1994) supported this conservation status assessment for old-growth white pine forest, stating that "less than 1% of Ontario's original white pine [dominated] forest remains. We do not quarrel with this estimate; it is clear that not much original white pine forest is left. We are persuaded that steps need to be taken to protect it." Both old-growth red pine and old-growth white pine ecosystems are classified as endangered ecosystems in the United States (Noss et al. 1995), and there is little doubt that old-growth red pine–dominated forest in Canada is also endangered from severe over-exploitation (Quinby 1996).

Just as endangered species are protected from the impacts of human activities, so too should endangered ecosystems such as old-growth red and eastern white pine forests be protected from any further human exploitation (Wilson 1992, Orians 1993, Noss et al. 1995). A conservation strategy for old-growth red and eastern white pine forest ecosystems that does not recognize their endangered status "while permitting their sustainable harvest" (OMNR 1995a) will only continue to perpetuate the rapid decline of these unique forest ecosystems.

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