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A PREDICTIVE MODEL FOR UPLAND FOREST COMMUNITY COMPOSITION IN ALGONQUIN PARK, ONTARIO

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Introduction

Forest management in Algonquin Park is considered by many to be the most progressive in all of Ontario (Clugston 1993). Yet it continues to operate in the absence of a scientific, ecosystem-based adaptive approach (Wildlands League 1993), the need for which has been recognized by the Ministry of Natural Resources (1992a, 1992b). The purpose of this study was to develop an ecological model for Algonquin's common upland forests that will provide a better understanding of the structure and function of these forests, serve as a quantitative basis for formulating hypotheses that can be tested in the field, and provide the foundation for an adaptive, scientific approach to conserving biodiversity in Algonquin Park, which will facilitate the evaluation of various management options for the Park's upland landscapes. All data used in this study are based on Quinby (1988).

Methods

The typical upland forest communities of Algonquin Park were sampled for overstory vegetation and habitat influences in 100 mature and old-growth stands within a transect that was two townships wide extending across the approximate 72 km width of the Park. Nine tree species were identified as typical upland forest dominants from a survey of Forest Resource Inventory (FRI) Maps (Ontario Ministry of Natural Resources 1978). Selection of stands for sampling was based on the following criteria: stands were (1) dominated by one of the nine typical upland tree species - the number of stands sampled for each forest community type reflected the approximate proportion of each dominant species as determined by the FRI survey, (2) restricted to upland sites on which surface runoff waters never accumulate, (3) at least six ha in size, and (4) not recently disturbed by natural or human agency. During the 1983 and 1984 field seasons, the overstory, defined as all trees 2 cm dbh (diameter at breast height) and greater, was sampled by recording tree diameter at dbh within three randomly placed 10 x 30 m plots per stand. Dbh measurements were converted to basal area values per ha for each species within each stand for analysis. Nomenclature follows Fernald (1950).

Complete soil profile descriptions and homogenized soil samples from the 0 to 10 cm portion of the mineral soil were obtained from each of the three excavated soil pits (1 m depth) within each stand. Soil samples were analyzed in the laboratory for %sand, %silt, %clay, organic matter, total nitrogen, calcium, magnesium, potassium, phosphorus and pH. Latitude, longitude and elevation for each stand were determined from topographic maps. Mean annual precipitation (mm) and mean daily temperature for July were estimated for each stand by interpolating between precipitation and temperature isolines provided by Brown et al. (1980). An index to fire incidence (Quinby 1987) was used to quantify fire. Detrended correspondence analysis (DCA) (Hill 1979, Hill and Gauch 1980) was used to ordinate overstory vegetation samples using basal area of each species within each stand. Samples were then edited from the data set until the maximum number of homogeneous forest stand classes were obtained using DCA axis 1 scores as classification criteria (van der Maarel 1982). This editing operation was performed so that interpolation along DCA axis 1 could be used to interpret predicted DCA axis 1 scores in terms of stand composition. Once the data editing operation was complete, the multiple regression analysis was carried out using the fire and habitat variables as the independent variables and DCA axis 1 as the dependent variable (Chang and Gauch 1986, Fralish 1988). In order to minimize interaction between independent variables and to minimize model complexity, one soil variable, one climate variable and one disturbance variable were used as predictors in the model. The ability of the model to predict the correct forest community type was evaluated by determining whether the predicted DCA axis 1 score fell within the original DCA axis 1 score range for each forest community type.

Results

The eigenvalue of the first DCA axis was .875 meaning that close to 90% of the variation in the overstory stand data (23 tree species) is represented by DCA axis 1 scores. The eigenvalue for the second DCA axis was more than four times less (.217) indicating that the vast majority of the variation in the overstory data is explained by the first DCA axis. As a result of the editing process, the white birch (*Betula papyrifera* Marsh.) and red oak (*Quercus rubra* L.) stand types were eliminated from the data set leaving seven forest community types (described by their dominant species) and 81 samples (Table 1).

TABLE 1 - Classification of Forest Community Types based on DCA Axis 1 Scores

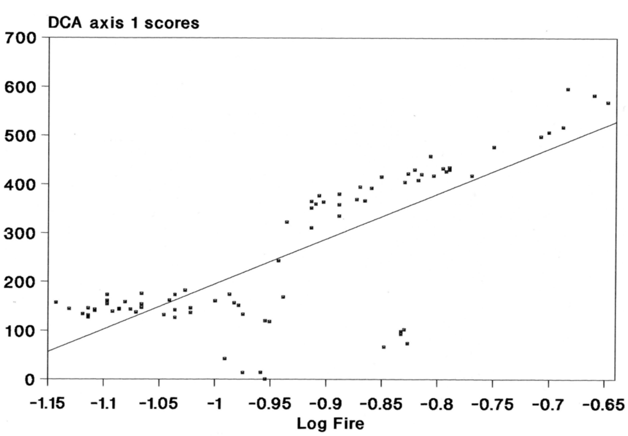
Community Type	Classification (DCA axis 1 scores)	% Predicted Correctly
hemlock (*Tsuga canadensis* (L.) Carr.)	0 to 54 (4 stands)	100
yellow birch (*Betula lutea* Michx. f.)	55 to 110 (5 stands)	80
sugar maple (*Acer saccharum* Marsh.)	111 to 276 (37 stands)	89
poplar (*Populus grandidentata* Michx. and *P. tremuloides* Michx.)	277 to 399 (14 stands)	100
white pine (*Pinus strobus* L.)	400 to 466 (14 stands)	57
red pine (*Pinus resinosa* Ait.)	467 to 575 (5 stands)	80
jack pine (*Pinus banksiana* Lamb.)	576 to 596 (2 stands)	0
ALL		83

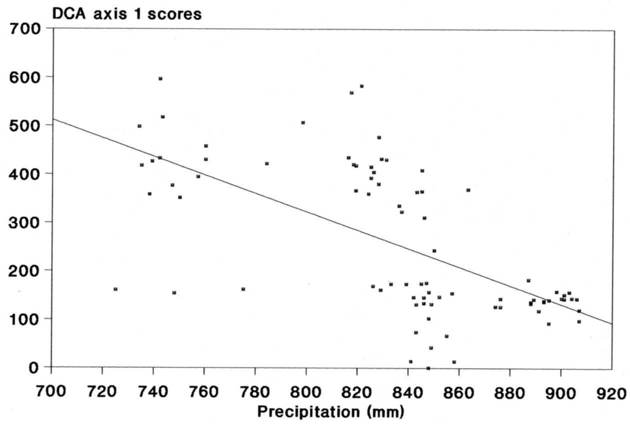
The final multiple regression model included $\log_{10}$ of the fire index, precipitation, %sand, and a dummy variable (0 for hemlock and yellow birch stands and 1 for all others) as independent variables (R^2=.92; F=215; p<.001).

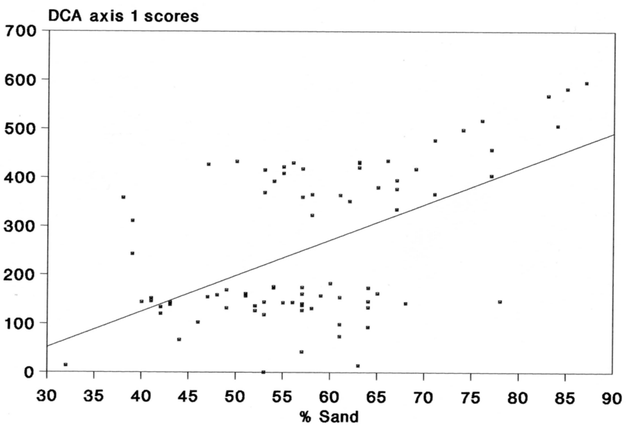
$$\textbf{DCA axis 1 score} = (1049.0915) + (884.6215 \cdot \log_{10} \text{fire}) - (.2948 \cdot \text{precip.}) + (.9666 \cdot \%\text{sand}) + (251.4495 \cdot \text{dum})$$

The scattergrams for the three independent variables versus DCA axis 1 scores are shown in Figures 1 to 3. DCA axis 1 was most highly correlated with $\log_{10}$ of the fire index (.780) followed by precipitation (-.623), %sand (.552) and the dummy variable (.461). The model was most effective for predicting hemlock and poplar communities, least effective at predicting jack pine and white pine communities and moderately effective at predicting yellow birch, red pine and sugar maple communities. Overall, the model predicted the correct community type 83% of the time.

FIGURES 1,2 & 3 - Scattergrams of the Relationships between the Three Independent Variables and DCA axis 1 Scores







Discussion

Quinby (1988) found that the major influence on forest overstory composition in Algonquin Park's upland landscape is a fire-soil moisture complex gradient in which the two variables are inversely related and fire has the greatest impact. The tolerant hardwood communities, dominated by sugar maple, yellow birch and hemlock, occur mainly at the low fire-high moisture end of the gradient. The white, red and jack pine dominated communities occur mainly at the high fire-low moisture end of the gradient, and the intolerant hardwoods, dominated primarily by poplar, occur at an intermediate position along the gradient.

Fire is particularly important in perpetuating the pine communities in Algonquin Park (Cwynar 1977, 1978). On the east side of the Park, where these communities dominate, the subdued relief, fewer lakes and streams and fewer moist slopes historically facilitated the spread of wildfires. Both live and dead foliage of the pine species are more flammable than the other forest community dominants (van Wagner 1977). As a result, the more flammable pines have evolved anatomical features, such as thick bark, and reproductive strategies that favour their regeneration following natural wildfire (Mutch 1970, van Wagner 1971, Methven 1973, Ahlgren 1976).

On the west side of Algonquin Park, where the tolerant hardwood forest dominates, the common presence of firebreaks and the low flammability of the vegetation has resulted in a low fire frequency. In contrast to the strong influence of fire on the east side, the creation of relatively small canopy gaps by wind, insects and tree senescence is the major form of natural disturbance facilitating forest regeneration (Bormann and Likens 1979, Fahey and Reiners 1981). Also, the more productive growing conditions on the west side (eg. greater soil moisture and nutrient availability) in combination with gap-based regeneration has resulted in dense upper canopies and low light levels at the forest floor. Dominance of the tolerant hardwoods on these productive sites is enhanced by their greater photosynthetic efficiency (Logan and Krotkov 1969, Logan 1970) and their ability to maintain lower rates of respiration under shaded conditions (Grime 1965, Loach 1967) compared to pine and poplar.

The model developed in this study incorporates the complex fire-soil moisture (combination of precipitation and %sand) gradient as the major influence on upland forest composition in Algonquin Park. Prior to application of this model, however, the variation in prediction accuracy among the seven community types must be addressed. Some applications of immediate concern include evaluation of fire suppression and timber management activities in the Park.

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