DETERMINING AN APPROPRIATE FIRE FREQUENCY FOR RESTORATION AND MAINTENANCE OF OAK SAVANNAS IN PINERY PROVINCIAL PARK, ONTARIO.

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Abstract

Oak Savanna habitat is globally rare. Prescribed burning is currently a widely-adopted management approach for restoring and maintaining these communities. We examined patterns of habitat recovery in the largest existing remnant in Southern Ontario, Pinery Provincial Park, while setting up a long-term monitoring program aimed at evaluating the success of the long-term prescribed burn plan. Initial results suggest that there is a three year burn lag during which cover of typical oak savanna species increases over this time period following burning. Future studies will determine where the peak of maximum diversity of oak savanna species occurs with respect to time- since- burning.

Introduction

Oak Savanna habitat is now rare in North America (Anderson 1999). In the past, savanna cover has been estimated to have reached 77.5 million hectares in the USA (Nuzzo 1986). By 1985 only 0.02% of this area remained and the savanna was highly fragmented (Nuzzo 1986). The known southern Ontario remnants of prairie woodland and savanna total approximately 2100 hectares, which is less than 3 percent of its European pre-settlement extent (Bakowsky & Riley 1994).

In addition to habitat lost to development, fire suppression has been proposed as another leading cause of savanna loss (Peterson 2001, Arabas 2000). Reintroduction of fire disturbance regimes is key for the restoration and maintenance of the abiotic conditions that allow native species to persist in remaining savannas (Lorimer 2001, Batek 1999). The need to include appropriate prescribed fire regimes in the management of oak savanna communities has been acknowledged in recovery planning (Rodgers 1998). But, what is an appropriate burn regime? And, how does it vary among habitats and along environmental gradients? A relatively small number of papers have addressed the question of how the frequency of fire affects plant community composition (White 1983, Gibson 1988, Collins 1992). The major consensus is that more frequent burning results in increased cover and diversity of herbaceous native plant species, along with lower shrub and tree densities and canopy cover. This has lead to *The Most Frequent Fire Hypothesis*, which proposes that burning as frequently as fuels will allow is the best strategy for maintaining species richness and abundance (Glitzenstein 2003).

While burning as frequently as fuel load will allow, is one approach, an alternative approach which may not always yield similar results, is to base burning frequency on the fire history of an area (Olson 1998, Bravo 2001). However, reconstructing historical fire regimes is time-consuming, and may not be possible, since fire history is often influenced by human activities. Additionally, many of the oldest trees with fire scars may have been harvested.

Consequently, there may be no option other than to evaluate the current conditions of the site in question and to determine which fire frequency will best restore and maintain the desired community (McCarthy 1998). Since most ecosystems will support a range of plant communities depending on the disturbance regime, a set of goals and objectives for the desired status of the savanna must be developed. This kind of habitat management provides an excellent opportunity to work within an Adaptive Management Framework (Walters 1986).

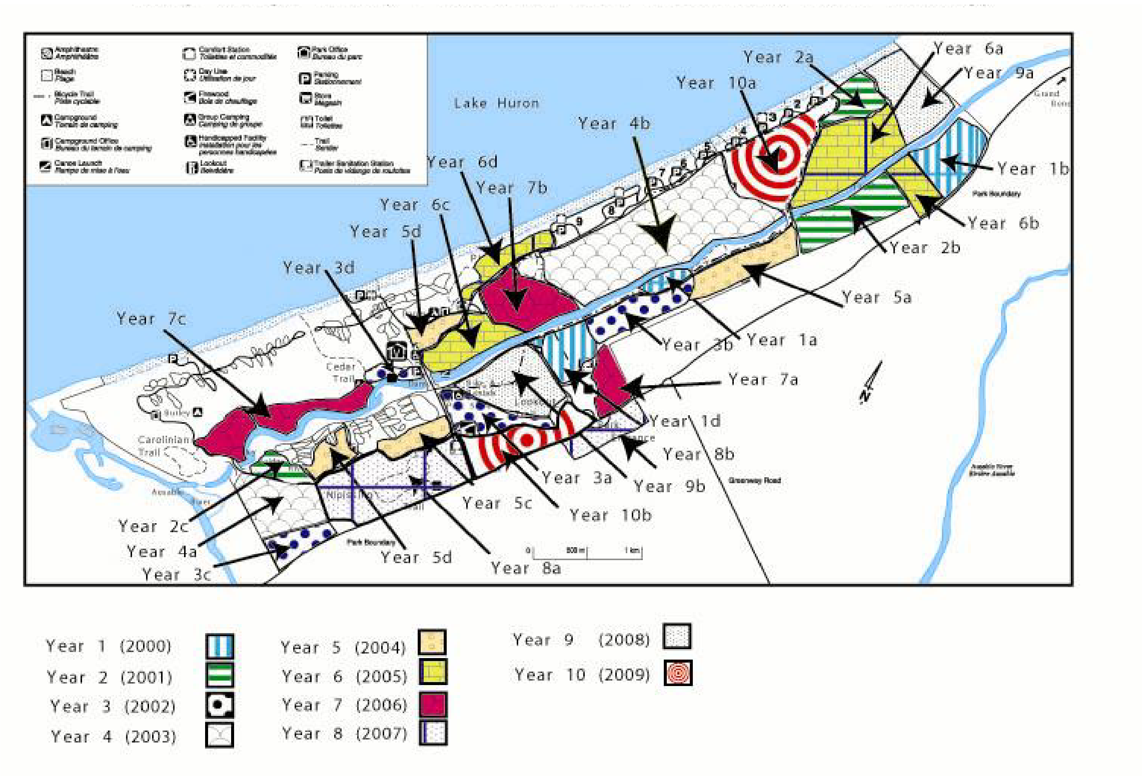

Figure 1: Pinery Provincial Park Long Term Burn Strategy (OMNR 2003).

Oak Savanna in Ontario

One of the largest remnants of oak savanna in Ontario, Canada, is located in Pinery Provincial Park, on the south shore of Lake Huron. The park has an extensive sand dune system, on which the savanna has developed (Yarranton and Morrison 1973).

Habitat managers at Ontario Parks have recognized that many ecosystems within their Parks and conservation reserves require disturbance by fire for renewal (OMNR 2003). The idea that thenatural heritage these areas were designed to protect will be lost unless they are exposed to fire in the coming decades, is clearly understood (Davis *et al*. 2003). Ontario Parks management efforts in recent years have lead to the development of detailed burn plans for Pinery Park that extend over a 10-year period. Since most of this park is oak savanna (Tagliavia 1992) the burn plan covers a large area (Figure 1). Each burn block will be burned at least once within a 20-year cycle for the entire park. As yet, specific objectives for the plant community composition have not been established for this program.

Is it Working? The Need for Long-Term Monitoring

In habitat restoration circles, the concept of long-term monitoring is respected, but despite best intentions, is rarely implemented by managers. The hurdles to implementing long-term monitoring that we have observed, include: lack of qualified personnel, lack of budgetary commitment, and shifting management priorities. However, given the cost of prescribed burning, it is essential to monitor plant community response to fire.

The overall goal of our research was to design and implement a long-term monitoring plan in which the oak savanna plant community of Pinery could be sampled every year, or less frequently, and to analyze these data using a multivariate approach. Permanent quadrats were randomly located throughout the different burn blocks in the park. Determination of the ecologically appropriate frequency for Pinery was approached through a comparison of species richness and abundance in different areas with different time-since-last-burning histories. *The Most Frequent Fire* Hypothesis generated the prediction that the most recently burned plots would have the highest diversity and abundance of native oak savanna species, and that this would rapidly decline to be no different from blocks that had not been burned in the last 50 years, as with increasing time-since-last-burning.

Methods

Plant Community Composition

In order to determine the impact of prescribed burns on the oak savanna community, sample plots were established throughout previously burned blocks (2000, 2001), scheduled burn blocks (2002, 2003) and in the blocks scheduled for burning in the near future (2004, 2005, post-study). This study incorporated exisiting long-term plots from research into the effects of deer herbivory (Koh 1995, Tagliavia 2002) into an expanded monitoring design. These plots were integrated with new plots in a master database. All plots were marked with metal rebar stakes in the field and their location co-ordinates were taken with a Garmin GPS unit.

Although planned prescribed burns did not take place in Pinery in the spring of either 2002 or 2003, due to early greening (and therefore, increased risk of critical plant injury due to fire) and weather conditions, one small area was burnt and used to determine the one-year burn effect (2003) (n=3).

Sample size was 1 x 1m. The plant species present in each plot were recorded along with cover and frequency. Graminoids were sampled for cover but not frequency due to the difficulty in identifying individuals. A total of 90 plots were sampled twice in 2003, in a spring (June 2-June 6, 2003) and summer sampling (July 18-24, 2003).

The abiotic variables of light and soil moisture were measured in each plot. Light levels were measured once the full canopy was established (Oct. 10-12, 2003), with a Li-Cor meter which recorded % PAR (Photosynthetically Active Radiation). One reading was taken for each plot between 10 a.m.- 2 p.m. on clear days (cloudless sky). However, due to poor weather conditions, light readings were not taken for each plot, and so could not be included in the statistical analyses. The light levels in the remaining plots will be sampled in 2004. Soil moisture was sampled at each plot as a point-in-time using a % moisture probe (Gro-Point) (sample dates given above).

Nominal variables, of plot burn history (burned in 2000 and/or 2001, and 2003) were included in the environmental data set. These three variables were coded as a zero or one for each plot. A one represented a plot burned in that year and a zero if the plot was not burned. Additionally, the number of typical oak savanna species present was summed for each plot (NHIC 2002). These four grouping variables were included in both the frequency and cover data sets.

Maximum cover and frequency were calculated for each plant species from the seasonal data. A full suite of multivariate analyses (Canoco v. 5.0) (ter Braak and Smilauer 1998) were performed on the plant community data, the environmental data (excluding light levels) and the grouping variables, to evaluate the trends in these changing plant communities. Analyses included Principal Components Analysis, Detrended Correspondence Analysis, Constrained Correspondence Analysis and Redundancy Analysis but only the results of the Redundancy Analysis, in which cover data were constrained with the nominal and environmental variables are reported here (Leps and Smilauer 2003).

Results

The frequency occurrence of 70 species in total was recorded from 90 plots. Plant cover data were recorded for a total of 82 species.

In the Redundancy Analysis, a three year post-burn time lag was evident (Figure 2). There was a strong gradient showing an increase in the number of savanna species in plots from left to right along the first-axis. Plots in blocks last burned in 2000 were closest to this, followed by plots last burned in 2001 and then 2003. This indicates that there is a lag effect of two to three years in terms of increasing cover of typical oak savanna species following prescribed burning in Pinery. However, though the plots burned in 2003 were positioned near to the 2001 plots, there were only three such plots, and thus, these results should be viewed with caution.

The first axis of the Redundancy Analysis explained 43.5% of the variation, while 19.2% variation was explained by the second axis. The Monte Carlo Test for repeatability of the resulting ordination was significant (p=0.001).

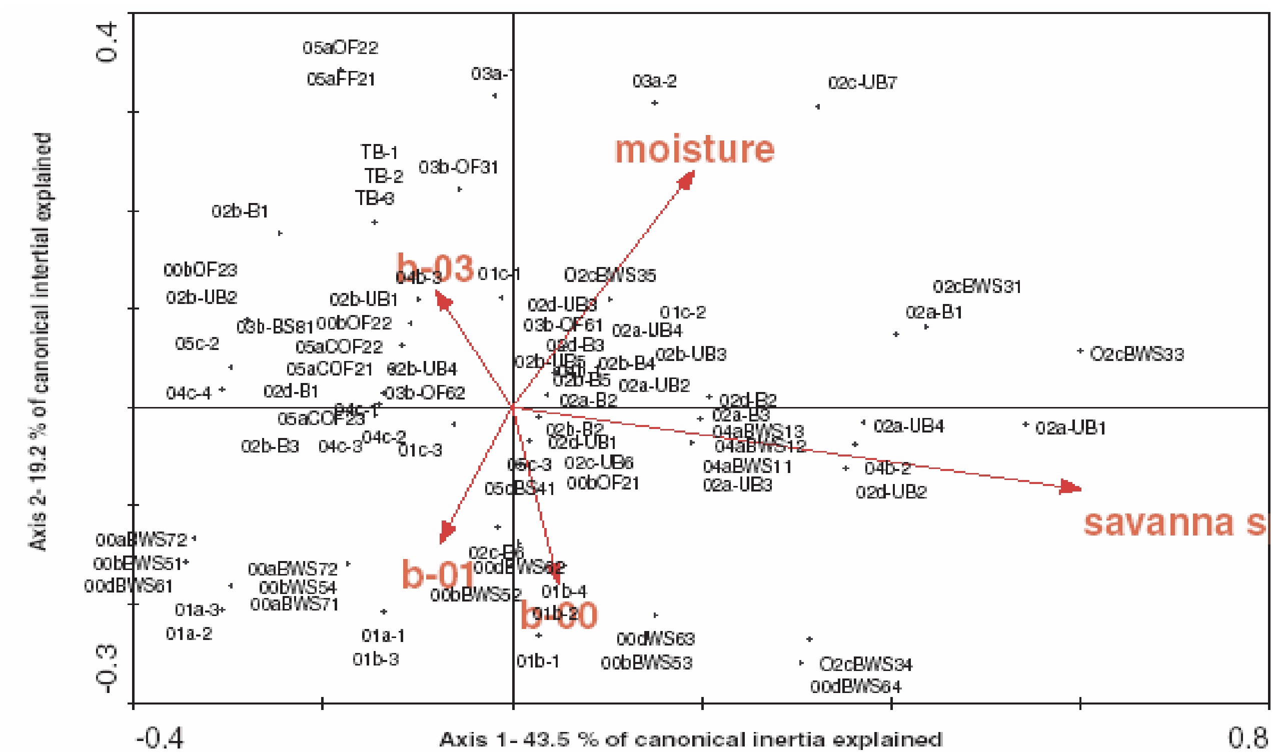

Figure 2: Sample plots and abiotic variables in Redundancy Analysis on burn block cover data, Pinery Provincial Park, sampled in 2003.

The strongest explanatory variable linked to change in plant community composition across the different burn blocks samples was the number of savanna species, which increased to the right of the graph. These plots were expected to be burned in 2002, and were located in what were considered to be “high quality” oak savanna sites. Some of these plots were burned in 2000 (and are designated as 2000c plots in Figure 2) but the majority of the others have not been burned since before the park was established in 1959. Plots 02cBWS3.2 and 02cBWS3.3, which are on the far right of the graph, have been burned. Also ordered in close proximity to the 2002 sites are a range of plots located in 2004 and 2000 burn sites, which are all located at the southern boundary of the park, at the farthest distance from the younger shoreline dunes.

When the distribution of the savanna species in plots was graphed (Figure 3), the gradient of increasing savanna species to the right of the graph towards the sites of 2002 became explicitly clear, and interestingly are in plots where the recent burn history is variable. Thus, even in the absence of burning in recent history, Pinery still has intact oak savanna plant communities in some places.

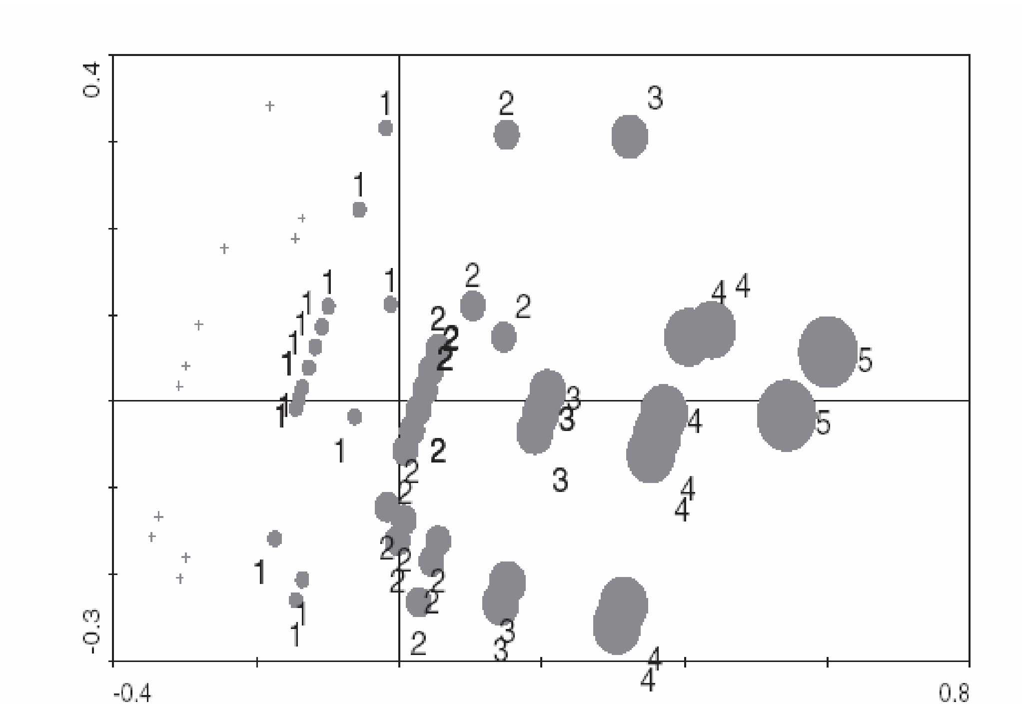

Figure 3: Gradient of number of savanna species in plots (cover data from Pinery Provincial Park, 2003).

When the mean number of oak savanna species per plot was plotted against the number of years since the last prescribed burn, there was a significant positive slope to the regression (Figure 4), indicating that burning is resulting in a directional change (increase) in oak savanna species over the short-term.

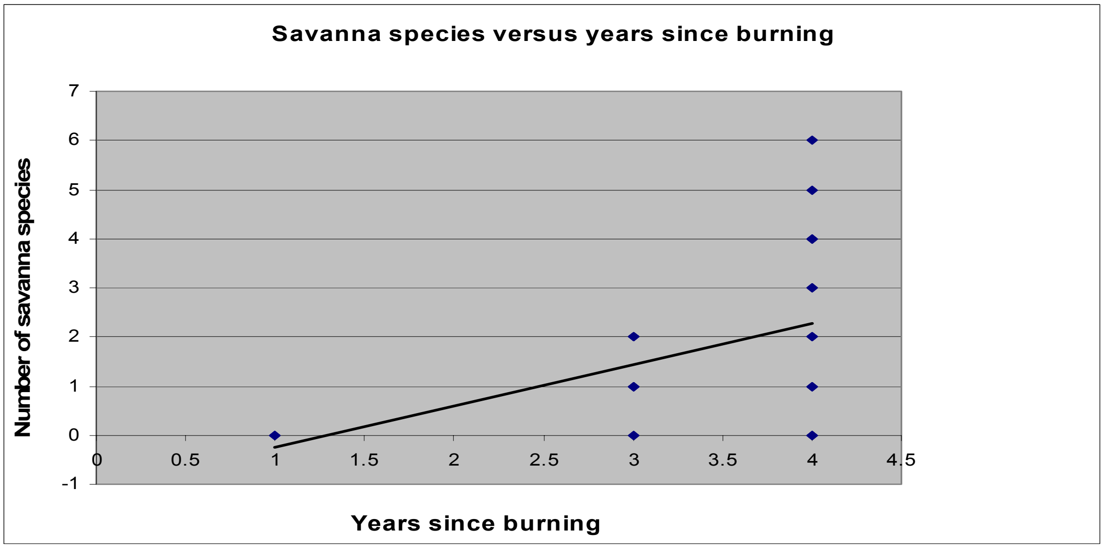

Figure 4: Number of savanna species per plot versus years since burning for Pinery Provincial Park quadrats. Regression line $y = 0.846x - 1.104$ ($F_{1,27} = 8.14$ $p < 0.01$).

Discussion

Overall, these results do not support the predictions of *The Most Frequent Fire Hypothesis*, since there is a time-lag of increasing cover of typical oak savanna species in the 3 years post-prescribed burn. This may be due to a number of reasons. First, the major management issue at Pinery during the 1990s was the need to reduce the high deer densities (Koh 1995, Tagliavia 2002). This was done prior to the implementation of the prescribed burn program. Since the late 1990s, the habitat has been recovering from being intensively grazed and browsed and the overall species richness has been steadily increasing. Thus, the oak savanna species that are increasing in presence and abundance in the 2-3 years following burns may be re-establishing following their removal by deer. The second reason for the lag effect is that in the last 4 years, many of the pine trees planted in the 1950 have been removed, which may have been shading out savanna species. The three-year lag could also be due to other aspects of the specific nature and conditions of this site. A companion seed bank study (Etwell unpubl. data) may be helpful in understanding this trend.

The nature of the relationship between number of savanna species per plot and time since burning, is expected to level off and decline – and to have a “humped” distribution, over a time period that is unknown. In future years the inclusion of additional data will define this pattern, which may be similar to that of the Intermediate Disturbance Hypothesis. However, it appears at this point, that the optimal fire frequency for this site is likely to be less than 10 years.

A recent reconstruction of the fire history of Pinery based on dendrochronology, found that burns in the last 150 years were generally low-intensity, patchy and occurred on average at 17-year intervals (Bravo 2004), which is a very close agreement with the timing of the prescribed burn plan.

Not only is Pinery a large tract of oak savanna, but the sand dunes are an outstanding example of a primary succession chronosequence. Some of the best-quality oak savanna sites are, sucessionally speaking, located in the oldest zone of this successional sequence (Yarranton and Morrison 1974). These sites appear to be candidates for becoming the most-species rich oak savanna communities in the park.

Conclusions and Management Implications

Our results strongly suggest that oak savanna sites in Pinery are responding positively to the prescribed burning. In future years, the directional change can be easily tracked, and whether the cause is due to fire or other factors, such as light levels, which are covariates of burning, can be determined.

The associated univariate approach gave supporting information about the number of savanna species based on time-since-last-burn year, but is of limited usefulness on its own, nevertheless, but the overall pattern of this relationship may be very useful in adjusting burn frequency to maximize the number of savanna species.

Although the high deer population of past years had a large impact on the herbaceous community, the browsing did in effect, arrest succession and prevent canopy closure, thereby maintaining light conditions conducive to savanna communities (Tagliavia 2002). The exclusion of the light data from our analysis is unfortunate as it was likely to have been as significant (see Taglivia 2002) as the number of savanna species per plot, with which it is likely to be a covariate.

To succeed in maintaining savanna species in light of the knowledge of the plant community response curve, management should incorporate the precautionary principle. Specifically, managers should probably plan to burn more frequently than their data suggest, as it is often hard to meet prescription targets, but is easy to cancel a burn in a given year if highly specific conditions are not met.

This study illustrates the relevance and value of an adaptive management approach, which is able to be reactive on a year-to-year basis. An effective long-term monitoring program is key to carrying out adaptive management.

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References

Anderson, R. C., J. S. Fralish, et al. (1999). Savannas, barrens, and rock outcrop plant communities of North America. Cambridge, USA, Cambridge University Press.

Arabas, K. B. (2000). "Spatial and temporal relationships among fire frequency, vegetation, and soil depth in an eastern North American serpentine barren." Journal of the Torrey Botanical Society 127(1): 51-65.

Bakowsky, W. and J. Riley (1994). A survey of the prairies and savannas of southern Ontario. Proceedings of the Thirteenth North American Prairie Conference: Spirit of the Land, a Prairie Legacy. P. Wickett, Dolan Lewis, A. Woodliffe and P. Pratt. Windsor, ON.

Batek, M. J., A. J. Rebertus, et al. (1999). "Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks." Journal of Biogeography 26(2): 397-412.

Bravo, D. (2004). Reconstructing the Fire History of an Oak Savanna in Pinery Provincial Park. Biology Undergraduate Thesis. Toronto, York University**:** 66 p.

Bravo, S., C. Kunst, et al. (2001). "Fire regime of a Elionorus muticus Spreng. savanna, western Chaco region, Argentina." International Journal of Wildland Fire 10(1): 65-72.

Collins, S., L (1992). "Fire Frequency and Community Heterogeneity in Tallgrass Prairie Vegetation." Ecology 73(6): 2001-2006.

Davis, R., J. Wilkinson, et al. (2003). Fire management efforts in Ontario's protected areas: A synopsis. Ontario Parks, Planning and Research. Peterborough, Ontario, Ontario Ministry of Natural Resources, Aviation and Forest Fire Management.

Gibson, D. J. (1988). "Regeneration and Fluctuation of Tallgrass Prairie Vegetation in Response to Burning Frequency." Bulletin of the Torrey Botanical Club 115(1): 1-12.

Glitzenstein, J. S. and D. R. Streng (2003). "Fire Frequency Effects on Longleaf Pine (Pinus palustris P.Miller) Vegetation in South Carolina and Northeast Florida, USA." Natural Areas Journal 23(1): 22-37.

Koh, S. (1995). The responses of four species of spring flowering perennial herbs to grazing by white-tailed deer in southern Ontario. Masters of Science Thesis,Biology. Toronto, York University.

Leps, J. and P. Smilauer (2003). Multivariate Analysis of Ecological Data Using CANOCO. New York, Cambridge University Press.

Lorimer, C. G. (2001). "Historical and ecological roles of disturbance in eastern North American forests: 9,000 Years of change." Wildlife Society Bulletin 29(2): 425-439.

McCarty, K. (1998). "Landscape-Scale Restoration in Missouri Savannas and Woodlands." Restoration and Management Notes 16(1): 22-32.

NHIC (2002). Natural Heritage Information Center website, Ministry of Natural Resources.Community Rankings. http://www.mnr.gov.on.ca/MNR/nhic/lists/commun.html#grank

Nuzzo, V. A. (1986). "Extent and status of midwest oak savannah: presettlement and 1985?" Natural Areas Journal 6(2): 6-36.

Olson, S. D. (1998). "The Historical Occurrence of Fire in the Central Hardwoods." Fire Managment Notes 58(3): 4-7.

OMNR (2003). Fire in Parks and Conservation Reserves, Background Report. Peterborough, Ontario Ministry of Natural Resources, Policy Guideline and Development Team: 20.

Peterson, D. W. and P. B. Reich (2001). "Prescribed fire in oak savanna: Fire frequency effects on stand structure and dynamics." Ecological Applications 11(3): 914-927.

Rodgers, L. (1998). Tallgrass Communities of Southern Ontario: A Recovery Plan, World Wildlife Fund and MNR.

Tagliavia, C. (2002). Characterization and Restoration of Degraded Oak Savanna Plant Communities in Southwestern Ontario. Biology. Toronto, York University**:** 200 p.

ter Braak, C. J. F. and P. Smilauer (1998). CANOCO Reference Manual and User's Guide to Canoco for Windows:Software for Canonical Community Ordination (version 4). Ithaca, NY, Microcomputer Power.

ter, J. R. (1996). "Effects of fire frequency on plant species in oak savanna in east-central Minnesota." Bulletin of the Torrey Botanical Club 123(4): 304-308.

Walters, C. (1986). Adaptive Management of Renewable Resources. New York, Macmillan Publishing Company.

White, A. S. (1983). "The Effects of Thirteen Years of Annual Prescribed Burning on A Quercus Ellipsoidalis Community in Minnesota." Ecology 64(5): 1081-1085.

Yarranton, G. A. and R. G. Morrison (1974). "Spatial Dynamics of a primary sand dune succession." Journal of Ecology 62:417-428.

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