STTU REPORT: 1995-96

INTERACTIONS BETWEEN DEER AND VEGETATION IN SOUTHERN ONTARIO: MONITORING AND RESTORATION OF OVERGRAZED PLANT COMMUNITIES IN PINERY AND RONDEAU PROVINCIAL PARKS

REPORT 2: COVERING THE 1995 AND 1996 FIELD SEASONS

Dawn R. Bazely* [1], Laurie W. Carr [1], Saewan Koh [1],
John Carnie [1], Amy S. Greenberg [1],
Leigh Anne Isaac [1], Nancy Falkenberg [1],
Andrea M. Hunt [1], Catherine A. Sykes [1],
T. J. Carleton [2], Dennis R. Voigt [3] & Sarah M. Carleton [1]

Report to the Southern Region Science and Technology Transfer Unit (STTU), Ontario Ministry of Natural Resources, London, Ontario, Canada

[1]Department of Biology, York University, 4700 Keele Street, North York, Ontario, Canada, M3J 1P3.

[2]Department of Biology and Faculty of Forestry, University of Toronto, Toronto, Ontario.

[3]Ontario Ministry of Natural Resources, Peterborough.

*Author for correspondence: phone – (416) 736-2100 ext. 20109; fax – (416) 736-5698; e-mail – dbazely@yorku.ca.

Executive Summary

1. In 1994 the Science Technology Transfer Unit of the Ontario Ministry of Natural Resources initiated a 5-year project in collaboration with the Department of Biology, York University, Toronto, to monitor and assess southern Ontario forests affected by deer herbivory.

2. In 1995, we obtained the Cornell Ecology Detrended Correspondence Analysis (DECORANA) and Canonical Correspondence Analysis (CANOCO) computer programmes. These allowed multivariate analysis of changes in the herbaceous plant communities at Rondeau and Pinery Provincial Parks, as well as the relationship between these two parks and 8 other study locations. We have analysed Rondeau data for 1995 and compared 1992 to 1995. This period covered a 1993 herd reduction. Plant community composition changed significantly in grazed areas from 1992 to 1995, but did not change significantly over the same period in deer exclosures built in 1991. We concluded that we either missed a very rapid change that occurred in exclosures from 1991 to 1992 (we have the data to check this) or the overall composition of intensely grazed plant communities in Rondeau is very slow to change to pre-overgrazed conditions. In 1995, the plant community composition was significantly different between the Bennett and Gardiner exclosures, built in 1978, and the grazed areas and also the 1991 exclosures. We suggest that these differences may be due in part to the different shade conditions in these habitats. We also suggest that intense deer grazing has radically altered sub-canopy light conditions, and has subsequently affected the recovery of herbaceous communities. We will be testing this hypothesis in 1997. If it is valid then

herbaceous (understorey) plant communities may only recover when overstorey woody plant communities recover from the detrimental effects of deer grazing.

3. A range of species were found to be suitable indicators of grazing pressure and vegetation recovery at both Rondeau and Pinery Parks. Plants that survived deer grazing at Rondeau increased in height from 1994 to 1995. However, a 1996 study of *Arisaema triphyllum* by Dennis (1996) suggested that increasing deer numbers may again have started to have an adverse affect on this species. Plant heights need to be examined in 1997 in order to confirm these trends.

4. Exotic and invasive species are of concern in Rondeau and Pinery because of their ability to invade and dominate disturbed areas. *Alliaria petiolata,* Garlic Mustard, populations have expanded significantly in Rondeau from 1994 to 1996. The effectiveness of control programmes for Garlic Mustard, which were initiated in 1994, could not be evaluated due to the unusual population dynamics of Garlic Mustard in which plants go through alternate years of high and low flowering populations.

5. *Berberis thunbergii*, Japanese Barberry, is an exotic shrub common in Rondeau. If a removal policy for *B. thunbergii* is to be adopted, then the most effective method is cutting the bushes and then painting the stumps with herbicide.

6. The structure and composition of woody plant communities at Pinery and Rondeau Parks have been altered by intensive vertebrate grazing, resulting in lower shrub densities and the presence at both parks of unpalatable woody species. Intensively grazed sites such as Rondeau and Pinery had smaller trees (lower diameters at breast height - DBHs) than other forest locations. We suspect that there may be higher mortality rates of larger trees at Rondeau and in some Pinery habitats due to increased windthrow. This process could be initiated when intense deer grazing reduces the sub-canopy shrubs and saplings to the point where recruitment of saplings to the canopy does not occur. When recruitment declines, canopy gaps will increase in size, subsequently increasing the likelihood of windthrow of larger trees. In 1996, Catherine Sykes (M.Sc. student) revisited 1980 plots in Rondeau and found that in some of them over 50% of the large trees were gone and many of the smaller trees were also missing. These data, along with lower DBHs, suggest that regeneration rates at Rondeau are not high enough to fill existing canopy gaps. In addition, the relatively low shrub densities in Bennett and Gardiner exclosures indicate that recovery is proceeding slowly. Overall, these results are alarming because they suggest that the Rondeau forest will continue to decline as long as trees are no longer recruited to the overstorey.

We strongly recommend that the loss rates of large trees and rates of creation of canopy gaps be monitored at Rondeau (this is included as part of our 1997 research programme), and that the impact of altered understorey light conditions on plant communities be assessed. This will indicate whether some form of drastic management intervention might be justified to replace and/or protect large trees.

7. Available woody browse (current annual growth - CAG) was sampled in Rondeau and Pinery in the Fall of 1994 and 1995. In both parks the availability of woody browse was extremely low in 1995 (< 1 g dwt CAG m^{-2}), with the bulk of CAG from species traditionally considered to be less palatable to deer.

Acknowledgments

Once again we must thank very many people. First and foremost, we thank the Science Technology Transfer Unit and the Parks Zone Office at the Ontario Ministry of Natural Resources (London), for funding our research from 1994 to 1996. The Environmental Youth Corps Programme, OMNR, supported us financially during this same period, as did NSERC (Natural Sciences and Engineering Research Council of Canada). Rondeau and Pinery Provincial Parks provided logistic support.

On a more personal level we thank our many colleagues who pushed this project forward: Trev Kellar of STTU and Peter Sturdy the Parks Zone Manager at OMNR, London, Jack Sulston (ret.) and Rick Hornsby (Superintendents-Rondeau Provincial Park), Les Kobyashi (Superintendent-Pinery Provincial Park) and Terry Crabbe (Pinery). Your support and enthusiasm, during what has been a very tough period of cutbacks and restructuring, has been extraordinary, and it has been a pleasure to work with you. Our research also took us to other publicly and privately owned sites which provided the broader framework for the Pinery and Rondeau studies. In particular we thank Gary Mouland (Point Pelée National Park) and all those landowners who allowed us access to their lands. We believe that this project provides a working model for how partnerships between government, universities and private landowners can function effectively.

We also thank Pamela Burns (Rondeau), Paul Prevett (OMNR, London), Maxine Tang, Mika Timciska, Joanne Thorpe, Brian Campbell, Hannah Talbot and Phyllis Randall for comments or help with fieldwork. If we have left anyone out, we apologize.

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1. Introduction

In 1994, the Science and Technology Transfer Unit (STTU) of the Ontario Ministry of Natural Resources initiated a 5-year project in collaboration with the Department of Biology, York University, Toronto, to monitor and assess the impact of white-tailed deer on two Provincial Parks in southwestern Ontario: Rondeau and Pinery. This project was designed as a follow-up to the deer herd reduction carried out at Rondeau in the winter of 1993-94. A herd reduction was also planned for Pinery, but has not taken place yet.

In 1995, we completed the first STTU report, **Interactions between deer and vegetation in southern Ontario, Canada: Monitoring and restoration of overgrazed plant communities in Pinery and Rondeau Provincial Parks** (Pearl *et al.* 1995). One goal of this report was to lodge in one place, a brief description of research conducted from 1991 to 1993 by members of Dr. Dawn Bazely's laboratory at York University, in collaboration with OMNR staff at Maple, on deer-plant interactions in southern Ontario. During this period, not only Rondeau and Pinery were studied, but also several other southern Ontario sites (Fig 1.1). These have proven to be invaluable by providing a regional context. The 1995 report also presented methods and experimental protocols used in the 1994 research season at Rondeau and Pinery. These included a description of general approaches taken to the use of deer exclosures and the control methods tested on two non-native plant species, *Alliaria petiolata*, Garlic Mustard, and *Berberis thunbergii*, Japanese Barberry. Methods used to describe dispersal patterns of Garlic Mustard, and to survey

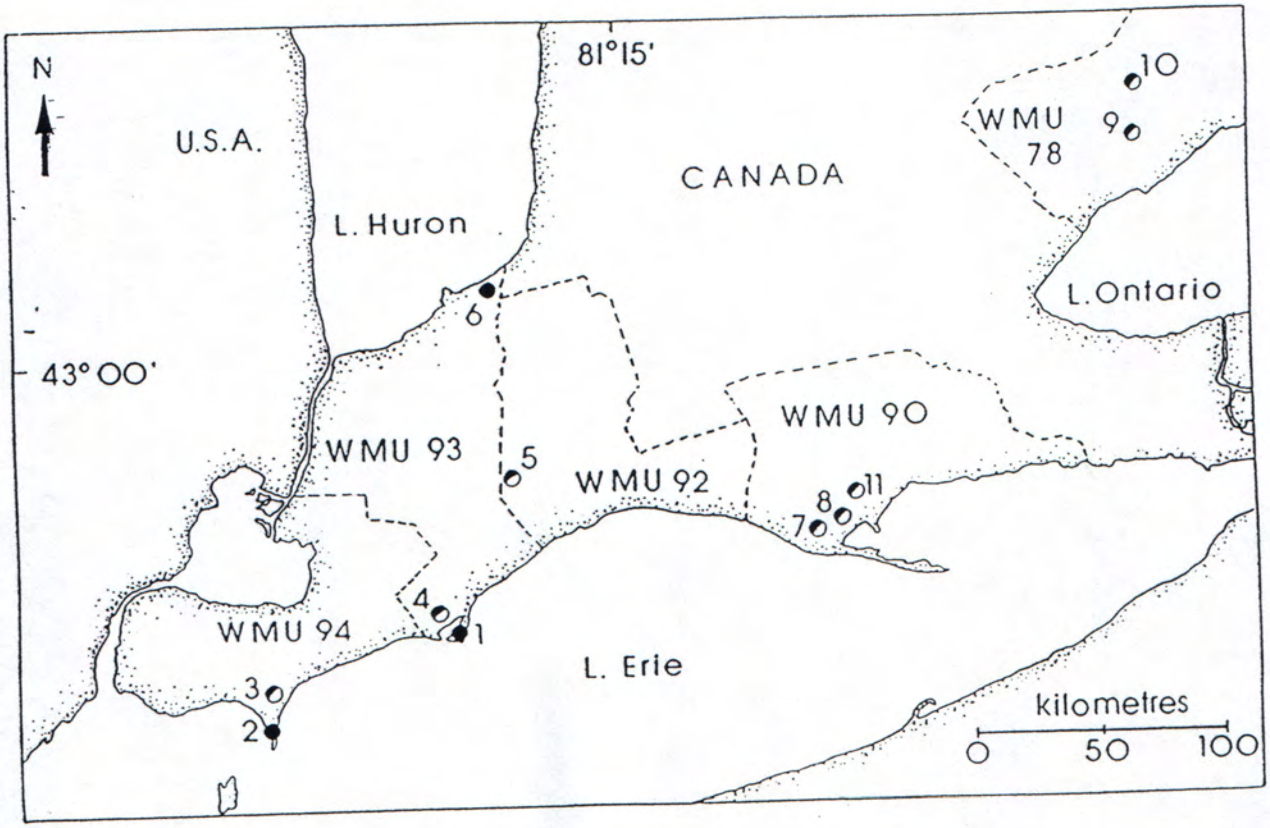


Figure 1.1. Location of study sites grazed by deer in southern Ontario, Canada. Wildlife Management Unit boundaries are shown. Sites with heavy deer grazing pressure (●). Sites with intermediate deer grazing pressure (◒).

1) Rondeau Provincial Park, 2) Point Pelée National Park, 3) Hillman Sandhills, 4) Sinclair's bush 5) Skunk's Misery, 6) Pinery Provincial Park, 7) Gartshore/Moulton Tract, 8) Backus Woods 9) Maple, 10) Joker's Hill, 11) Danijlevitch–Smith

woody plant communities (Rondeau 1993, Pinery 1994) and available woody browse (both parks 1994) were also described. Results were presented on the composition of herbaceous plant communities in Rondeau and Pinery Parks in 1992 and 1994 and in a number of other southern Ontario forests in 1992. Results of 1994 surveys of rare plant species and potential indicator species for the assessment of deer grazing in Rondeau were also presented.

The purpose of this report (STTU 1997) is to present the results of our 1995 research season at Rondeau and Pinery, as well as explain our ongoing analyses of the herbaceous and woody plant community databases covering the period 1991 to present. Specifically, this report includes the following:

(1) Changes in herbaceous plant communities between 1992 and 1995 following biomanipulations (exclosures and a herd reduction) of deer at Rondeau. The deer herd reduction took place during the winter of 1993/94. Data from an ongoing study at Rondeau which describes abiotic site conditions, specifically soil moisture data collected in 1996, were included in the analysis.

(2) Heights of plant species which may be useful indicators of deer grazing pressure at Rondeau and Pinery are presented for 1995.

(3) Test plot results from our experiment examining the effectiveness of different control methods for *Alliaria petiolata*, Garlic Mustard, and *Berberis thunbergii*, Japanese Barberry at Rondeau (study: 1994-95).

(4) The patterns of dispersal and establishment of populations of Garlic Mustard at Rondeau (study: 1994-96).

(6) Stand structure of woody vegetation at Rondeau, Pinery and seven other southern Ontario forests in 1993, and at Pinery in 1994.

(7) Composition and availability of woody browse in Rondeau and Pinery in Fall 1994 and 1995.

RATIONALE FOR STUDY

Why study the impact of deer herbivory in Ontario forests? Part of the rationale for this study is that, while we know that grazing by large vertebrate herbivores is frequently a major determinant of plant community composition, influencing both species richness and abundance (Crawley 1983, Bazely & Jefferies 1986, Gibson *et al.* 1987, Dolman & Sutherland 1992, Hill *et al.* 1992, Smith & Rushton 1994), we cannot predict exactly how habitats will respond to this type of disturbance. Herbivory delays succession towards woodland in grassland plant communities, and the introduction of herbivores to sites dominated by shrubs can result in reversion to herbaceous plant communities (Crawley 1983, Miles 1988). The relationship between grazing and plant species richness is not always predictable but tends to be non-linear (Crawley 1983, 1990, Bakker 1989). At low herbivore densities, plant species richness tends to be low because a few species become dominant (Harper 1977, Bakker 1989, Hill *et al.* 1992, Smith & Rushton 1994). At intermediate grazing pressures, species richness often increases, because herbivory modifies the outcome of inter-specific plant competition (Crawley 1983, 1990). Species richness often drops at extremely high grazing pressures, because few plant species can tolerate such intense defoliation (Bazely & Jefferies 1986). These observations are in accordance with predictions of the intermediate disturbance hypothesis, with herbivory acting as the disturbance in an ecosystem (Petraitis, Latham & Niesenbaum 1989).

A key question surrounds the issue of long-term recovery following intense and/or chronic disturbance of habitats. Recent studies of lesser snowgeese indicate that grazing may initiate positive feedbacks which in turn lead to the ultimate destabilization and destruction of the ecosystem (Bazely & Jefferies 1997). In the Carolinian Zone of southern Ontario's forests, herbivory by white - tailed deer (*Odocoileus virginianus*) has had a localized but major impact on the structure and composition of plant communities. This is of great concern since this forest zone contains 70% of the province's rare plant species (Varga & Allen 1990). In the last decade, high deer densities in some "premiere" Carolinian sites (e.g. Rondeau and Pinery Provincial Parks, Long Point National Wildlife Area, and Point Pelée National Park) have resulted in increased awareness of the potential loss of rare plant species. In some sites, reduction of deer populations has been undertaken to mitigate the problem (e.g. Rondeau, Long Point and Point Pelée). Our research is designed to assess the extent of deer overgrazing at Rondeau and Pinery, and, ultimately, to determine the level of grazing pressure which will allow the recovery of these habitats. We are also interested in the likelihood that forests will return to conditions prevailing prior to intense and chronic deer overgrazing.

2. Effects of Biomanipulations of Deer Density on Herbaceous Plant Communities at Rondeau Provincial Park

PURPOSE

To use ordination analysis to evaluate the effects of two biomanipulations, deer exclosures and reductions in deer numbers, on plant communities in Rondeau Provincial Park. The deer herd reduction took place in the winter of 1993/94.

DATES & LOCATIONS

We have amassed a large database on plant community composition at 10 locations in southern Ontario (see Pearl *et al.* 1995), but here we present only an analysis of data collected at Rondeau Provincial Park in 1992 and 1995 in grazed and ungrazed plots in Wet, Mesic and Dry habitats and at Bennett and Gardiner exclosures and their adjacent grazed areas.

METHODS

Detailed methods of field data collection, including establishment of deer exclosures and transects in different habitats, are given in Pearl *et al.* (1995).

Plant community composition data

The percent cover of individual plant species was scored in 1992 and 1995 in 1m x 1m plots in the following plot types at Rondeau:

a. grazed areas at all stations in Wet, Mesic and Dry habitats and near Gardiner and Bennett exclosures,

b. 2m x 2m exclosures erected in 1991 (short-term recovery) in Wet, Mesic and Dry habitats,

c. Bennett and Gardiner exclosures built in 1978 (long-term recovery),

In 1992 these plots were sampled five times during the spring and summer, while in 1995 they were sampled twice: in the third week of May and the second week of July. For both years the maximum cover of all species recorded at each plot was determined and entered into a database.

Additional environmental data

A. Soil moisture

In 1996, soil moisture levels were assessed at Rondeau by measuring fluctuations in the water table. At each station, and at Bennett and Gardiner, a single hole was drilled into the soil to a depth between 1 and 1.75 m. An ABS pipe, covered with screening and with holes drilled at the bottom, was inserted into the ground to create a well. The level of the water table was measured by lowering an electronic water detection device attached to the end of a tape measure into the well. These data were included in the multivariate analyses described below.

B. Canopy Cover at Rondeau

To date, the percentage of tree foliage directly over a plot has been estimated (1992 and 1995) and used as an indicator of shade in our multivariate analyses. In 1996, this method was refined by using a hemispherical fisheye camera lens to photograph the canopy above each plot in all habitats. Images will be digitized and analysed using a computer program (Hemiphot) to estimate the amount of PAR (photosynthetically active radiation) reaching each plot (see Conclusion and Recommendations, section 7).

Ordination Analysis

A key method used in this study to determine changes in plant community composition over time, in response to deer grazing, is that of multivariate analysis. In community ecology, data typically consist of species abundances in various sampling units. The data are arranged in a matrix with species in rows and the sample unit as a column (or with species and sample unit reversed). Data matrices can become large and complicated with much of the information contained within them being redundant. This results in the creation of a data matrix that is difficult to analyze when a researcher's interest lies mainly in how combinations of species or sample units occur. If such a matrix can be reduced to a more compact form with the loss of some very detailed resolution, an overall view of the changes occurring in sampling or species units can be elucidated. Employment of ordination techniques can approximate matrix data without the loss of the underlying structure and allow for the simultaneous determination of the occurrence of species and samples (ter Braak 1995).

Ordination analysis refers to a group of multivariate statistical techniques based on correspondence analysis (CA) algorithms, in which sites are represented in two dimensional space according to similarities in species composition (ter Braak 1995). Sites at which species are more similar are placed closer together, while sites at which species are less similar are placed farther apart. At times it is necessary to understand how abiotic or environmental forces can affect the relationships between site and species. Explicit environmental data can be collected and then direct gradient analysis such as Canonical Correspondence Analysis (CCA) can be used to relate the site and species ordinations to particular environmental variables (ter Braak 1995). CCA can "constrain" species data to environmental data in order to examine the direct relationship between environmental variables, sites and species. In ordination analysis, sites and species that are more affected by a particular environmental variable appear closer to the position of the variable in two dimensional space than sites and species that may be less influenced. In the case of Rondeau Provincial Park, grazing pressure, light, and soil moisture are of particular interest as environmental factors. Ordination analysis also allows for adjustments to account for differences in plant communities created by confounding variables such as light and soil moisture that may differ among plots. By the inclusion of "covariables" such as light and moisture we are able to examine the amount of influence grazing pressure may have on the data **independent** of other variables.

Ordination analysis is an increasingly popular tool for analyzing plant community data and has been used as a survey tool to characterize plant communities (Brown *et al.* 1993, Carleton & MacLellan 1994, ter Braak 1994, Fojt & Harding 1995, McIntyre & Lavorel 1995, O'Connor & Roux 1995) and as a method of analyzing the results of experiments involving the composition and abundance of plant communities (Gibson & Brown 1992, Leps *et al.* 1994). In the present study ordination analysis will be used to evaluate the effects of two biomanipulations, exclosures and reductions in deer numbers, on plant communities in southern Ontario.

Preliminary analysis of plant community data at Rondeau

Two types of analysis were performed with data on plant species cover, canopy cover and moisture:

a. Canonical correspondence analysis (CCA), and

b. Redundancy Analysis (RDA).

Two CCAs were carried out. The first analysis used 1992 and 1995 data from the short-term exclosures (2m x 2m exclosures established in 1991) and excluded the grazed plots and the long-term exclosures (Bennett and Gardiner - 0.4 ha exclosures established in 1978). The second analysis used 1992 and 1995 data from the grazed plots and excluded both long-term and short-term exclosures. These two analyses separately examined the effect on the plant community composition of:

a. building exclosures in 1991 (recovery in short-term exclosures), and

b. the 1993 deer herd reduction (grazed plots).

In order to better isolate the effect of recovery or grazing, soil moisture and shade (% canopy cover, estimated by observer) were used as covariables in both analyses. In subsequent analyses, digitized imagery will give a more quantitative estimate of light conditions in Rondeau. Both analyses were constrained to the first axis, which was sample year. If a species had greater cover in 1995 within an exclosure compared to its 1992 value, then it would have a higher score for the 1995 side of the axis. We would interpret this as an indication that the plant species was increasing in abundance after being protected from deer grazing. Similarly, in the analysis of grazed sites, a species with a greater score in 1995 could be interpreted as one that was increasing in abundance after the 1993 deer reduction. Higher scores for the 1992 side of the axis would indicate that these species had lower cover in 1995 compared to 1992.

The Redundancy Analysis (RDA) was carried out using 1995 data collected from all plots in all habitats. The RDA shows which species are most closely related to environmental variables, in this instance, exclosure type. Exclosure type defined whether or not a plot belonged to Bennett, Gardiner or 1991 exclosures, or their adjacent grazed areas. Diagramatically, both species and environmental variables are represented by arrows of different lengths emanating from the origin. The relationship between species and environmental variables is represented by the angle between arrows. If a species is highly influenced by a variable, then the angle between their arrows is narrow. If the angle between arrows representing two environmental variables is narrow, then these variables affect the data in a similar manner. This analysis provides a "snapshot" of what the plant community looked like in 1995 and unlike the two CCAs, does not show changes in the same plots over time. To better isolate site type as the main factor in the composition of the plant community, soil moisture and canopy cover were again used as covariables in the analysis.

RESULTS

Plant communities in the grazed sites and 1991 exclosures were dominated by summer flowering species typical of disturbed habitats while in Bennett and Gardiner exclosures, spring flowering species similar to those in sites with less grazing pressure were prominent (Pearl *et al.* 1995).

Effect of 1991 exclosures on plant community composition

The CCA analysis of plots in the 1991 exclosures did not show a significant change in plant species composition between 1992 and 1995 (Monte Carlo permutation test, $p = 0.11$). Most of the species occur near the origin of the first axis and so have low scores for both the 1992 and 1995 side of the axis (positive and negative on the horizontal axis respectively, Fig. 2.1). With light and soil moisture used as covariables, the first axis, which represents the exclosure effect, accounted for less than 2.08% of the variation in the data set. Regardless of any significance test at the community level, certain species (and groups) - *Aster* spp., *Carex* spp., *Polygonatum pubescens*, and *Viola* spp. - increased in abundance after being protected from deer grazing. Some species, most notably *Fraxinus* spp., had greater cover in 1992 than in 1995 (Fig. 2.1). While the percent cover of other species also increased or decreased, their weights were interpreted as being too low to have much influence on the analysis (Table 2.1).

Effect of 1993 deer reduction on plant community composition

The CCA analysis of the grazed plots showed that a significant change in plant community composition took place between 1992 and 1995 (Monte Carlo

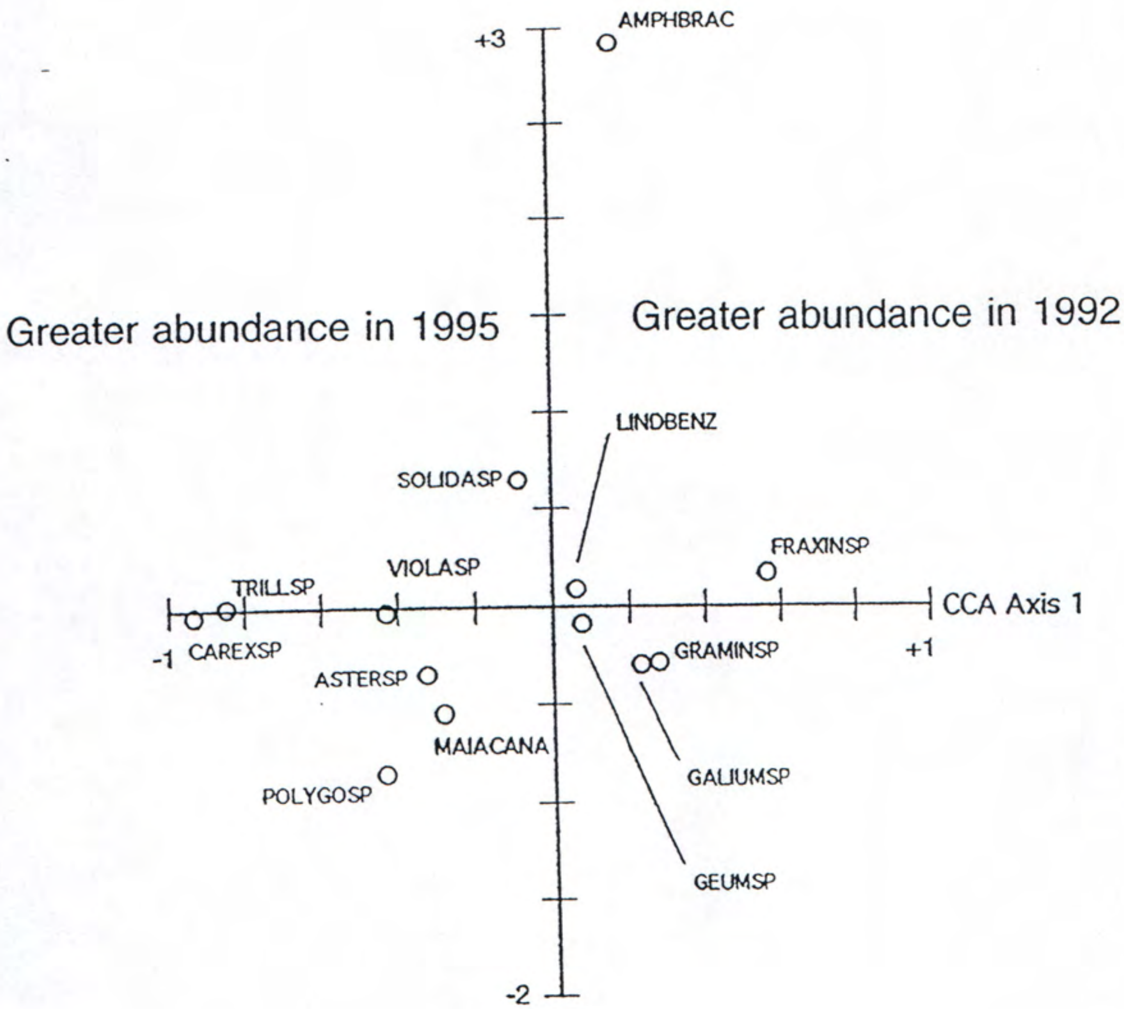


Figure 2.1. CCA ordination diagram of plant community composition in 2m x 2m deer exclosures in 1992 and 1995 at Rondeau. Exclosures were established in March 1991. Axis 1 represents sample year (1992 or 1995). Species that were greater in abundance in 1995 appear on the negative side of Axis 1. Species that were greater in abundance in 1992 appear on the positive side of Axis 1. Placement of a species point further from the origin indicates a relative change in abundance of greater magnitude. Abbreviations for the species are listed in Appendix 1. Other species present in these plots which are not shown in this figure are those for which abundance did not change greatly between 1992 and 1995.

Table 2.1. Species scores from CCA ordination of 1992 and 1995 plots within 2m x 2m exclosures at Rondeau Provincial Park. Scores are arranged from the highest to lowest values on the first axis.

N	NAME	AX1	AX2	AX3	AX4	WEIGHT
	EIG	0.1524	0.7267	0.5515	0.5255	
25	FRAG ARSP	1.1991	-0.5773	-0.9916	0.8998	1.5
21	EPIP HELL	1.1024	-0.6295	-0.1032	-0.4329	2.1
64	SMIL ROTU	1.0786	-0.2413	-0.3515	-0.3231	1.5
72	URTI SPPP	1.067	-0.0794	-0.2681	-0.4797	1
9	ASCL SYRI	1.0451	-0.9522	0.2744	-1.5454	8.1
54	QUER CUSP	1.0116	-0.4861	-0.4995	0.8473	1.2
51	POTE CANA	0.9892	0.1414	0.2742	-0.3114	0.2
11	BERB THUN	0.9736	-0.1407	-0.2956	-0.4517	14.2
28	GENT IASP	0.9699	-0.3726	-0.3964	0.9366	1
43	OXAL ISSP	0.9615	-0.334	-0.3427	0.6199	0.7
36	LAMI USPE	0.9551	-0.3051	-0.3024	0.3823	3
16	CIRS VULG	0.9439	-0.3117	-0.2864	0.4526	19.4
61	SASS ALBI	0.9101	-0.8934	1.0177	-0.7425	35
5	ANEM QUIN	0.8908	-0.2639	1.0023	-0.9364	3.2
47	PHRY LEPT	0.8761	0.034	-0.2071	-0.2312	19.7
53	PRUN SPPP	0.874	-0.6996	0.0985	-0.9136	9.5
3	ALLI OFFI	0.8731	-0.0658	-1.7484	-0.6184	13
63	SMIL HERB	0.8381	-0.4408	0.0372	-0.2656	11.6
45	PEDI CANA	0.8071	-0.2768	-0.2514	0.1473	2
68	TARA OFFI	0.7912	0.0017	-0.3285	-0.3888	11.4
58	RUBU IDAE	0.6512	0.3621	-0.1034	-0.499	31
26	FRAX INSP	0.5641	0.1671	0.4578	-0.4073	43.2
70	TOVA VIRG	0.5187	-0.1792	-0.1556	0.245	10.2
23	FAGU GRAN	0.4961	-0.2858	-0.0343	-0.0552	30.2
35	IMPA CAPE	0.4958	0.1076	0.4595	-1.3271	12
60	SANI TRIF	0.3816	1.1833	0.4672	-0.0848	19.4
24	FLOE PROS	0.3438	-0.2758	-0.3248	0.5686	103
67	STEL SPPP	0.2857	-0.1627	0.0512	-0.1197	1.5
44	PART QUIN	0.276	-0.2195	-0.2469	0.353	27.9
32	GRAM INSP	0.2747	-0.2906	-0.3853	0.6693	980.8
27	GALI UMSP	0.2273	-0.3002	-0.1382	-0.2137	176.8
56	RANU RECU	0.2268	0.0097	-0.0119	-0.1486	12.4
15	CIRC QUAD	0.2094	0.3912	0.1925	-0.0339	32.4
4	AMPH BRAC	0.1636	2.9187	0.9144	0.3581	242.1
49	PODO PELT	0.1429	-0.1319	0.0619	-0.0736	35
52	PREN ALBA	0.0992	-0.5562	0.0739	0.2212	10
38	LIRI TULI	0.0834	-0.2388	-0.2704	0.0108	2.5
31	GEUM SPPP	0.0739	-0.0912	-0.2006	0.144	36.4
37	LIND BENZ	0.0604	0.0916	0.5346	-1.0472	283.9
55	RANU ABOR	0.0484	0.0114	-0.8741	-0.8499	2.2
75	VITI AEST	0.0374	-0.611	-0.5618	-0.603	9.7
29	GERA MACU	0.0262	-0.2728	-0.0323	-0.2272	27.4
8	ARIS TRIP	-0.0171	-0.1993	-0.266	0.2517	19.5
22	EQUI ARVE	-0.0284	0.0691	0.7558	-1.5554	13.6
41	MITC REPE	-0.0656	-0.8991	0.4098	-2.3194	74.2
57	RHUS RADI	-0.0824	-0.1377	-0.2774	0.465	5.8
66	SOLI DASP	-0.0868	0.6454	-0.1215	-0.2948	341.1
7	AQUI CANA	-0.0969	-0.2752	-0.6576	0.4103	37.3
18	DENT LACI	-0.1277	-0.1241	-0.1356	-0.1538	7.7

Table 2.1 Continued

46	PHLO DIVA	-0.1892	-0.2846	-0.4619	0.7259	5.4
40	MAIA CANA	-0.2854	-0.5446	0.2929	-1.0124	76.8
10	ASTE SPPP	-0.3266	-0.3464	-0.2613	0.6553	285.9
42	OSMO CLAY	-0.3528	-0.0648	-0.6136	-0.4883	24.4
12	CARD DOUG	-0.4035	-0.1888	-0.3292	0.5523	7.4
74	VIOL ASPP	-0.43	-0.0288	-0.4837	-0.3013	490.8
50	POLY SPPP	-0.434	-0.8528	0.6366	-1.0904	145.6
39	LONI CESP	-0.5257	-0.8023	0.0396	-1.5887	12.6
1	ACER SPPP	-0.5336	-2.1567	4.5476	1.8263	69.2
14	CARP CARO	-0.6107	-0.4039	-0.041	-0.9303	3.5
33	HEPA ACTU	-0.6283	-0.1788	-0.1865	0.1475	15
69	THAL DIOI	-0.7925	-0.1757	-0.2993	0.2303	3.4
59	SANG CANA	-0.8091	0.1131	0.8049	-1.453	5
71	TRIL LISP	-0.849	0.0063	0.1383	-0.2371	36.1
30	GERA ROBE	-0.9019	1.0789	-0.0957	0.0578	0.8
13	CARE XSPP	-0.9352	-0.0362	-0.0322	0.5122	61.5
2	ACTA EASP	-0.9413	0.0057	-0.4102	-0.5313	16
62	SCUT SPPP	-0.9509	-0.1051	-0.2409	-0.5351	4.4
65	SMIL RACE	-0.9708	0.2643	-0.1326	0.224	7.2
19	DESM CUSP	-0.9974	-0.1468	-0.328	0.618	6.3
20	DRYO PTSP	-1.0271	-0.1398	0.011	0.08	0.4
17	CLAY CARO	-1.0403	-0.1715	-0.3824	0.7229	2
73	UVUL PERF	-1.0473	-0.057	0.2495	-0.2053	8.6
48	PILE PUMA	-1.0506	-0.1193	-0.3465	0.5843	8.4
6	ANTE NNSP	-1.0827	-0.1754	-0.7579	0.3242	5
34	HIER PRAT	-1.0827	-0.1754	-0.7579	0.3242	1.5

permutation test, p = 0.01). In general the cover of most species did not change a great deal on an individual basis between 1992 and 1995, as indicated by low scores in the positive and negative direction along the first axis (Table 2.2). However, those species which did change, experienced large changes. In grazed areas, *Amphicarpa bracteata*, *Aster* spp. and *Carex* spp. increased between 1992 and 1995 (Fig. 2.2). Plant species (and groups) that decreased in cover between 1992 and 1995 include *Alliaria petiolata*, *Fagus grandifolia* and *Solidago* spp. (Fig. 2.2). The outlying point representing *Alliaria petiolata* in Fig 2.2 may be related to the rather unusual population dynamics which we have documented for this species, in that 1992 would have been a naturally high year and 1995 a naturally low year for adult population density (see Section 6). Other species also changed in terms of cover, as indicated by higher positive and negative scores, but their weights were too low to be interpreted as having affected the overall analysis (Table 2.2).

Plant community structure at the exclosure level in 1995

Examination of the RDA ordination diagram showed that all three exclosure types and their grazed areas separated out completely, with each type being either negatively correlated or not correlated with the other types (right angled arrows indicate zero correlation, opposite directions indicate negative correlation) (Fig. 2.3). Although Bennett and Gardiner lie at right angles to each other they are both positioned on the positive side of the horizontal axis opposite to both the grazed plots and the 1991 Exclosures (Fig. 2.3). This indicates that the horizontal axis represents a disturbance gradient. Species most related to

Table 2.2. Species scores from CCA ordination of 1992 and 1995 plots within grazed site at Rondeau Provincial Park. Scores are arranged from the highest to lowest values on the first axis.

N	NAME	AX1	AX2	AX3	AX4	WEIGHT
	EIG	0.1646	0.4903	0.4312	0.4199	
17	EPIP HELL	1.1935	-1.1411	-0.0448	-0.4419	0.1
51	PYCN ANSP	1.1935	-1.1411	-0.0448	-0.4419	0.1
45	PINU STRO	1.152	-0.6054	0.0911	-0.3297	0.3
62	SMIL ROTU	1.1412	-0.2939	-0.0828	-0.2141	1
6	ANEM QUIN	1.1394	-0.1319	7.3661	-0.0858	0.2
48	POTE CANA	1.1385	-0.0436	14.398	-0.0781	3
25	GENT IASP	1.1321	-0.0379	-0.3375	-0.0687	1
37	MITC REPE	1.1307	-0.2463	0.1255	-0.1223	2.9
65	STEL SPPP	1.1239	0.0339	-0.1579	-0.0143	10
52	QUER CUSP	1.1156	-0.0709	-0.0811	-0.1114	0.5
10	BERB THUN	0.9958	-0.6439	-0.2503	-0.5375	1.2
4	ALLI OFFI	0.9856	4.9264	-0.3849	1.2578	30.1
61	SMIL HERB	0.8329	1.2701	0.0259	0.169	1.7
32	LAMI USPE	0.7333	-0.363	-0.1777	0.6092	0.5
59	SASS ALBI	0.599	-1.0433	0.3828	-0.718	0.7
72	VITI AEST	0.5734	-0.4342	-0.077	-0.4212	4.6
31	IMPA CAPE	0.5621	0.0059	0.4127	-0.1091	0.7
40	PART QUIN	0.525	0.0967	-0.0737	-0.129	5.9
18	EQUI ARVE	0.5225	-2.2341	-1.2328	-1.9935	9.1
44	PILE PUMA	0.5158	0.1212	-0.1785	-0.1095	5.9
68	TOVA VIRG	0.4764	0.2035	-0.1377	-0.15	6.5
67	THAL DIOI	0.4595	-0.3061	-0.2444	0.7759	4.5
28	GEUM SPPP	0.4306	-0.2098	-0.2038	0.1053	10
64	SOLI DASP	0.3757	-0.3772	-0.1581	-0.0775	49.4
20	FAGU GRAN	0.3611	-0.4073	0.1579	-0.3095	27.8
23	FRAX INSP	0.3595	-0.0357	0.0135	-0.1192	12.7
55	RHUS RADI	0.346	-0.0101	0.8365	-0.1018	4.3
39	OXAL ISSP	0.3168	0.3875	-0.3253	-0.2314	2.5
34	LIRI TULI	0.2191	-0.3517	-0.1005	-0.1484	3.7
42	PHLO DIVA	0.2184	0.367	-0.3582	-0.2316	4
29	GRAM INSP	0.1936	-0.0063	-0.0557	-0.0219	927
43	PHRY LEPT	0.1845	-0.2832	-0.005	-0.2537	12.7
58	SANI TRIF	0.1778	-1.0802	-0.2547	1.9292	3.3
63	SMIL RACE	0.1376	-0.1427	0.3379	-0.1873	0.4
71	VIOL ASPP	0.11	0.0699	-0.2153	-0.2088	164.5
47	POLY SPPP	0.1043	-0.3342	0.6271	-0.3307	13.9
21	FLOE PROS	0.1	0.2403	-0.3036	-0.1321	14.7
53	RANU ABOR	0.0407	-0.075	-0.2767	-0.1678	1.1
13	CIRC QUAD	-0.0081	-0.2976	0.0052	0.4005	21.4
8	ARIS TRIP	-0.017	0.158	0.0568	0.017	17.1
56	RUBU IDAE	-0.0476	-0.2144	-0.2748	-0.3084	10.8
49	PREN ALBA	-0.117	-0.2933	0.4054	-0.3811	4.3
26	GERA MACU	-0.1187	-0.712	0.1398	0.1246	13.2
33	LIND BENZ	-0.1579	0.124	1.2122	-0.0381	88.8
38	OSMO CLAY	-0.1923	0.602	-0.0509	0.3964	16.3
7	AQUI CANA	-0.2154	-0.6147	0.1184	-0.4554	26.8
50	PRUN SPPP	-0.2833	0.1067	0.7969	-0.42	9
24	GALI UMSP	-0.2923	-0.3095	-0.0371	-0.0701	82.6

Table 2.2 Continued

36	MAIA CANA	-0.3146	0.379	-0.0147	0.0398	23.9
22	FRAG ARSP	-0.3206	0.243	0.2173	-0.1642	0.7
66	TARA OFFI	-0.3624	-0.0869	-0.2379	-0.6052	10
16	DRYO PTSP	-0.3742	0.3013	-0.3871	0.0888	0.4
1	ACER SPPP	-0.401	0.0724	-0.0904	-0.2367	9.8
30	HEPA ACTU	-0.4744	-0.7336	-0.5865	-1.1685	6.9
41	PEDI CANA	-0.4784	0.5221	-0.2632	-0.2659	8.3
69	TRIL LISP	-0.5072	0.1568	-0.1163	0.0967	17.1
27	GERA ROBE	-0.5367	0.2492	-0.3932	0.0339	0.6
5	AMPH BRAC	-0.6185	-1.3952	-0.202	3.388	53.6
12	CARP CARO	-0.6418	-0.0787	0.5416	-0.3124	6.8
54	RANU RECU	-0.6568	0.2543	0.3344	-0.0041	7.2
46	PODO PELT	-0.6768	0.424	0.3967	0.39	19
14	CLAY CARO	-0.7371	0.7526	-0.4651	-0.4392	2.6
9	ASTE SPPP	-0.7864	0.3074	-0.0172	-0.3738	64.7
19	ERIC PULC	-0.8071	-1.5888	0.4517	-1.1687	0.9
60	SCUT SPPP	-0.8412	0.4371	-0.128	-0.0214	2.6
70	UVUL PERF	-0.8481	-0.1503	0.2152	0.7095	15.6
11	CARE XSPP	-0.8667	-0.2976	-0.4091	-0.7247	104.5
2	ADIA PEDA	-0.8763	0.4144	-0.4037	0.1414	3
35	LONI CESP	-0.8833	0.137	1.3389	-0.593	9.8
3	AGRI GRYP	-0.8939	0.9178	-0.5765	-0.557	0.8
15	DESM CUSP	-0.8939	0.9178	-0.5765	-0.557	8
57	SANG CANA	-0.9022	0.1787	-0.1391	0.8582	0.6

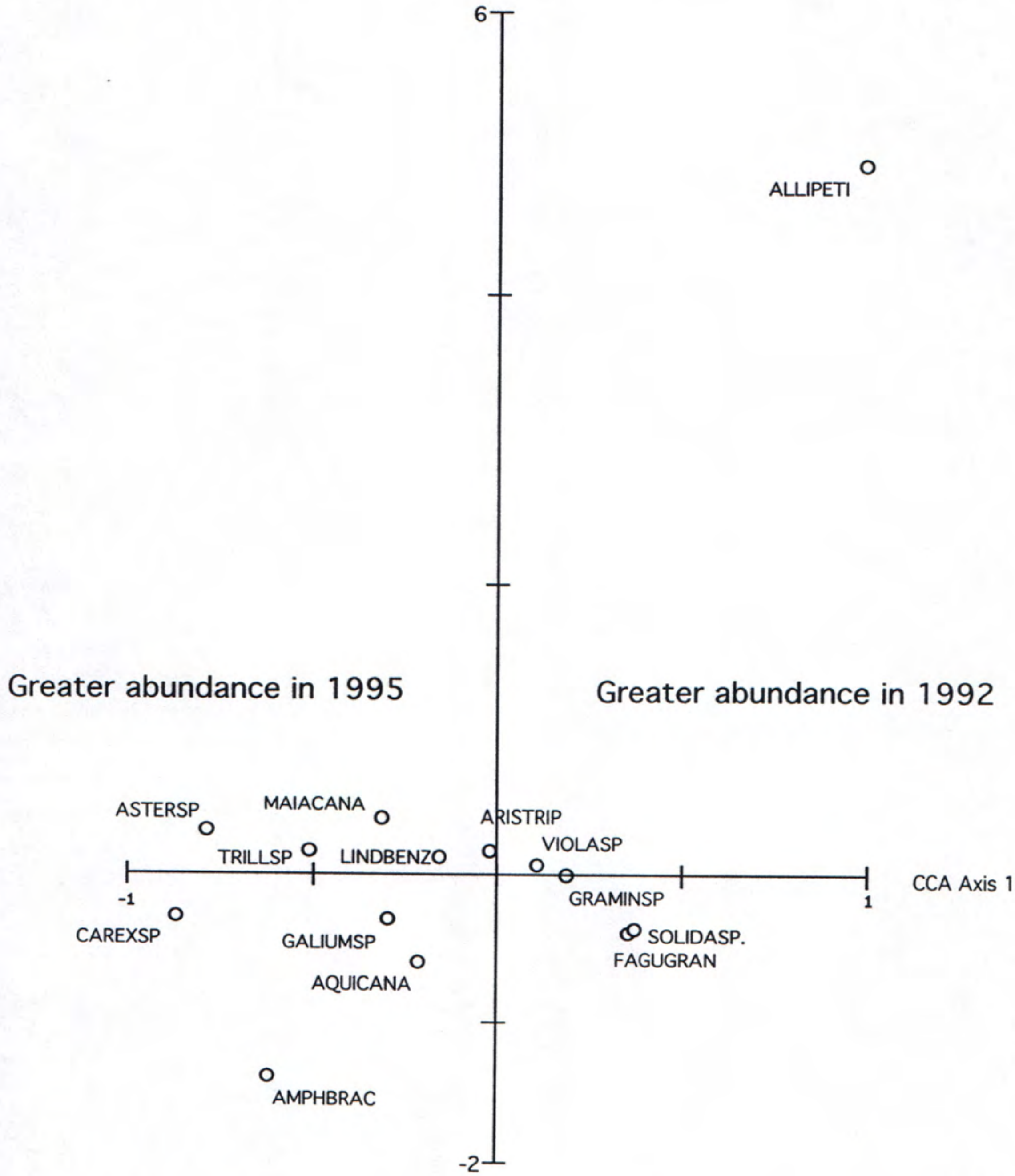


Figure 2.2. CCA ordination diagram of plant community composition in grazed plots in 1992 and 1995 at Rondeau. Axis 1 represents sample year (1992 or 1995). Species that were greater in abundance in 1995 appear on the negative side of Axis 1. Species that were greater in abundance in 1992 appear on the3 positive side of Axis 1. Placement of a species point further from the origin indicates a relative change in abundance of greater magnitude. Abbreviations for the species are listed in Appendix 1. Other species present in these plots which are not shown in this figure are those for which abundance did not change greatly between 1992 and 1995.

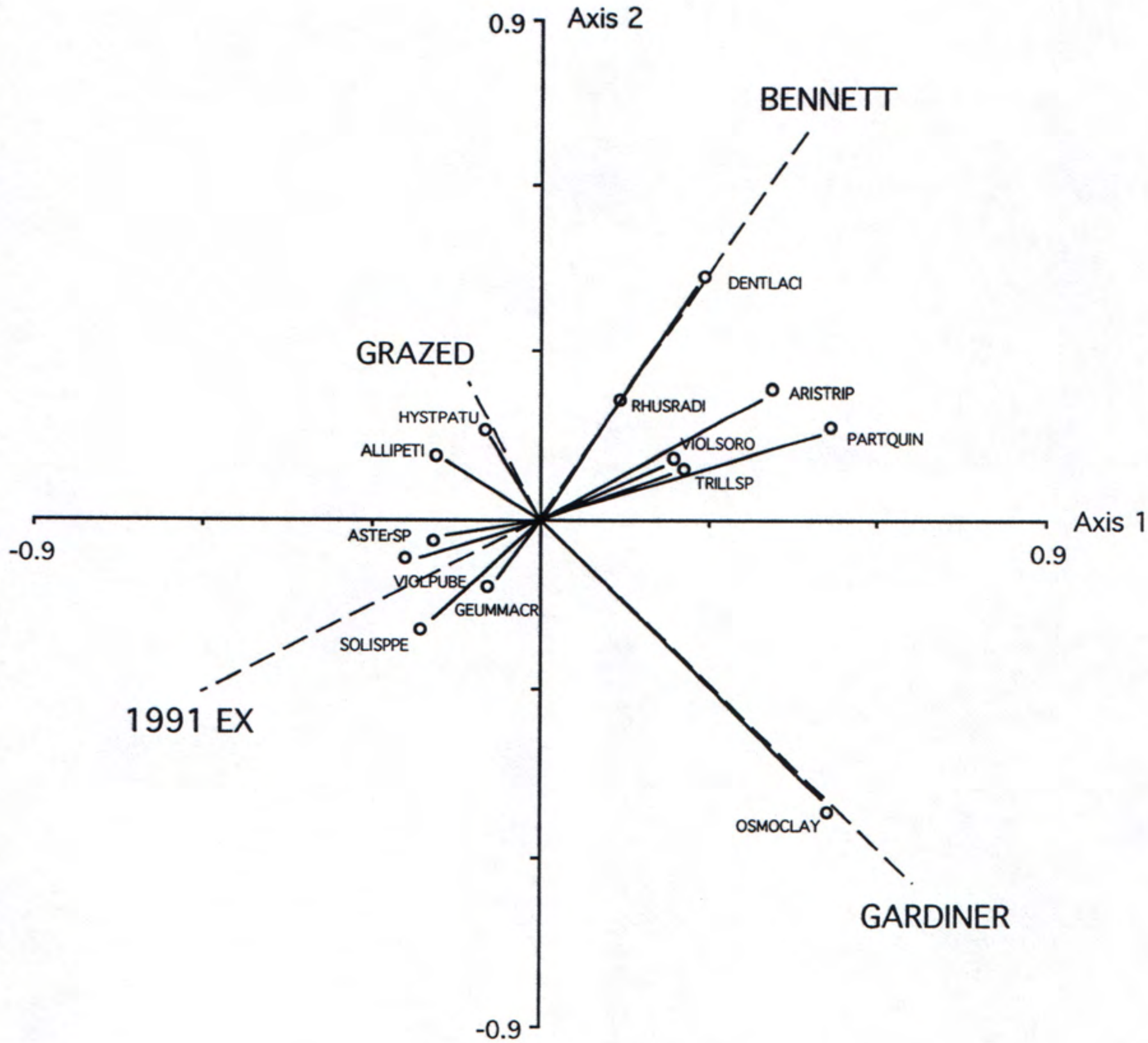


Figure 2.3. RDA biplots of exclosure types and grazed areas in 1995 at Rondeau. The location of the centroids are given by the labels for exclosure category or GRAZED plots on the diagram. Abbreviations for the species are listed in Appendix 1. Other species present in these plots which are not shown in this figure are those with low weights.

any exclosure type are shown in Fig. 2.3. *Dentaria laciniata* and *Arisaema triphyllum* are found mostly in Bennett Exclosure while *Osmorhiza claytonii* was associated mostly with Gardiner Exclosure. On the disturbance side of the axis, *Alliaria petiolata*, and *Hystrix patula* were mostly related to the grazed sites while *Polygonatum pubescens, Viola* spp., *Aster* spp., and *Solidago* spp. were associated with the 1991 exclosures. A Monte Carlo permutation test of the trace or sum of the environmental variables showed that the species in this data set were significantly related to the variables ($p = 0.01$).

DISCUSSION

In 1995, the plant communities in grazed areas at Rondeau, the 1991 exclosures and Bennett and Gardiner were significantly different from each other in their composition. In the RDA ordination, the 1991 exclosures and the grazed sites were opposite to Bennett and Gardiner, where plants have been protected from grazing since 1978. Eventually the community in the 1991 exclosures, which is characterized by *Aster* spp., *Viola* spp. and *Solidago* spp., may reach the same endpoint as Bennett and Gardiner, but due to the past effects of grazing, this may be delayed by a longer recovery period (Godwin 1929, Gibson & Brown 1992). The positioning of the 1991 exclosures away from Bennett and Gardiner may be what is referred to as a “seral stage” heading towards a “plagioclimax” if, indeed, these presently separate and distinct plant communities ever reach the same endpoint. Others, however, argue that disturbances such as the removal or reduction of species may result in an irreversible destabilization of a system or a trophic cascade (Bazely & Jefferies 1997).

Ecosystems, once established, become resistant to change (Bazely & Jefferies 1997), so protecting plant communities from deer with exclosures may not have a strong effect on their composition if overgrazing by deer has resulted in plant communities reaching an alternative stable state. Further evidence for a new state having been reached by the grazed Rondeau plant communities, comes from the CCA analysis of the 1991 exclosures between 1992 and 1995. This analysis showed that the plant community in these short-term exclosures did not change significantly over three years and appeared relatively stable, even though deer were excluded. In fact, plants that were more indicative of disturbed sites such as *Solidago* spp., *Aster* spp. and *Viola* spp. showed the greatest increase in cover over this time period. Similar increases in these species occurred in the grazed areas of Rondeau following the deer reduction of 1993/94. Here, the change in species composition was significant and also showed increases in *Aster* spp., *Carex* spp., *Amphicarpa bracteata* and *Galium* spp. The presence of these species is consistent with the structure of woody plant communities at Rondeau, in which shrub density is low and tree size is smaller compared with other Ontario forest locations (see Section 7). We have postulated that a more open canopy and a lack of replacement of upper canopy trees may be contributing to increased loss rates of larger trees via higher rates of windthrow. We suggest that this has created a more open canopy which has altered light conditions on the forest floor. Grazed herbaceous plant communities have changed in response to this, compared with those in the more shady Bennett and Gardiner exclosures. Interestingly, other species common in grazed habitats, *Alliaria petiolata*, *Solidago* spp. and graminoids, decreased after the herd reduction.

It should be noted that grazing intolerant spring perennials were not very influential in the RDA analysis. Spring perennials once reduced or removed from the communities in this study may take a long time to re-establish. Those spring perennials which are still present are slowly growing and increasing in size (see Section 3).

CONCLUSION & RECOMMENDATIONS

Neither short-term exclosures nor a reduction in deer numbers at Rondeau have resulted in a rapid shift in plant community composition towards spring species typical of stable undisturbed forest habitats in southwestern Ontario. This may indicate that understorey conditions at Rondeau have altered so as to allow domination by other plant species. This may be linked to changes in the structure of woody plant communities in which many of the larger canopy trees have been lost (see section 7). While the exact role of deer has not been identified yet in terms of whether they have truly initiated some kind of trophic cascade (Bazely & Jefferies 1997), the severe grazing pressure at Rondeau has clearly played a major role in altering the structure of both herbaceous and woody plant communities.

Our recommendations are as follows:

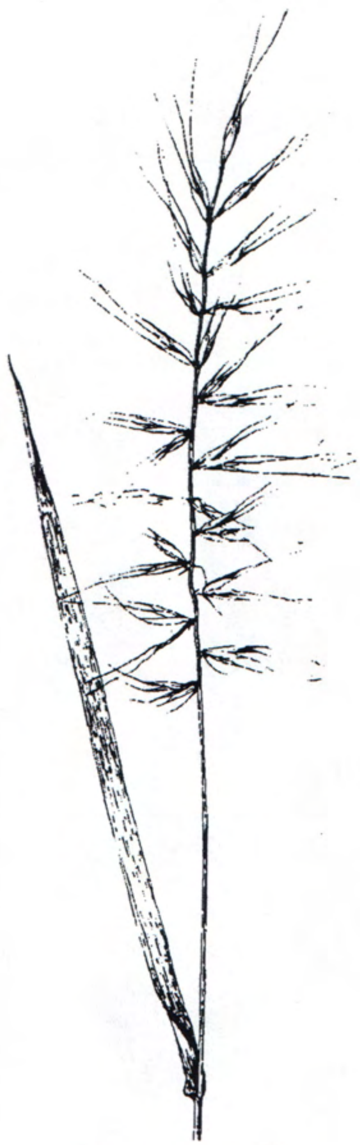
1. Evaluate seasonal trends in above-ground biomass

We are comparing 1992 data with 1996 data to test the prediction that due to ground level changes in light, summer productivity at Rondeau is increasing compared with other forest locations which have more closed canopies. We predict that these summer species are suppressing the growth and recovery of native spring species such as *Trillium*.

2. Experiments for 1996-1997

Multivariate analysis will continue with the 1992 and 1995 plant species composition data from Rondeau and other southern Ontario study sites. Plant species composition data from 1996 will be added to these analyses along with seedbank data from 1992 to determine the relationship between the seedbank and the herbaceous plant community. We predict that in Rondeau and Pinery, there will be a significant relationship between the seedbank and plant community composition compared with that in other less intensely grazed forests. If this prediction is confirmed, it will be further support for our conclusion that the plant community in Rondeau has fundamentally changed.

Analyses of digitized canopy photos will continue. Nitrogen, carbohydrate and fiber analyses of biomass collected in 1992 and 1995 was started in September 1996 and should be concluded by April 1997. Shading experiments will start at Rondeau and Pinery Provincial Parks in April 1997 to further examine the role of light, grazing and interspecific competition in structuring plant species composition. This experiment will also include the collection of biomass data in the spring and summer of 1997.



Hystrix patula

3. Plant Height as an Indicator of Grazing by White-tailed Deer

PURPOSE

To determine whether the height of particular plant species reflected the general level of deer grazing pressure on the herbaceous plant community in Rondeau and Pinery Parks.

DATES & LOCATIONS

Rondeau and Pinery Provincial Parks in spring and summer 1995. All habitat types were surveyed at both parks.

METHODS

Sampling methods generally followed those of Pearl *et al.* (1995). At Rondeau, height to leaf and, if the plant was flowering, height to flower measurements were collected for six species in 1995. Four of these species were sampled in both 1994 and 1995: *Circaea quadrisulcata*, Enchanter's Nightshade; *Arisaema triphyllum*, Jack-in-the pulpit; *Maianthemum canadense*, Canada Mayflower and *Polygonatum pubescens*, Hairy Solomon's Seal. *Polygonatum pubescens* was incorrectly identified as *P. biflorum* in 1994 (Pearl *et al.* 1995). *Rhus radicans*, Poison Ivy, was dropped from the study because factors other than deer grazing appeared to be more important in influencing its size (Pearl *et al.* 1995). In Rondeau, two species were added to the study, *Trillium grandiflorum*, White Trillium and *Viola pensylvanica* Michaux, Yellow Violet. These two species have been intensively studied at Rondeau (Koh 1995, Engel 1996). *V. pensylvanica* has been renamed as *V. pubescens* Aiton. (Voss 1985), but we have used the older name here for the sake of continuity between this and the previous STTU report (Pearl *et al.* 1995).

At Pinery, the heights of seven species were measured, when they occurred, in each of the six habitat types in which exclosures were built in 1994. The species were *Maianthemum canadense*, Canada Mayflower; *Viola pensylvanica*; Yellow Violet; *Rhus radicans*; Poison Ivy; *Fragaria virginiana*; Wild Strawberry; *Smilacina stellata*; False Solomon's Seal; *Arabis lyrata,* Lyre-leaved Rock-cress; and *Hamamelis virginiana*, Witch Hazel, a small tree.

RESULTS

Since there were few flowering plants at either park, only results for plant height to leaf are presented. With the exception of *Circaea*, the overall trend among all species measured at Rondeau was for populations protected from deer grazing over both the short-term and long-term, to have increased in height relative to those in grazed sites (Fig. 3.1). Similarly, all species measured at Pinery showed height increases after one year of exclosure (Fig. 3.2).

Nested ANOVAs were carried out to compare "among habitat" and "site within habitat" differences, for which results are presented in Table 3.1.

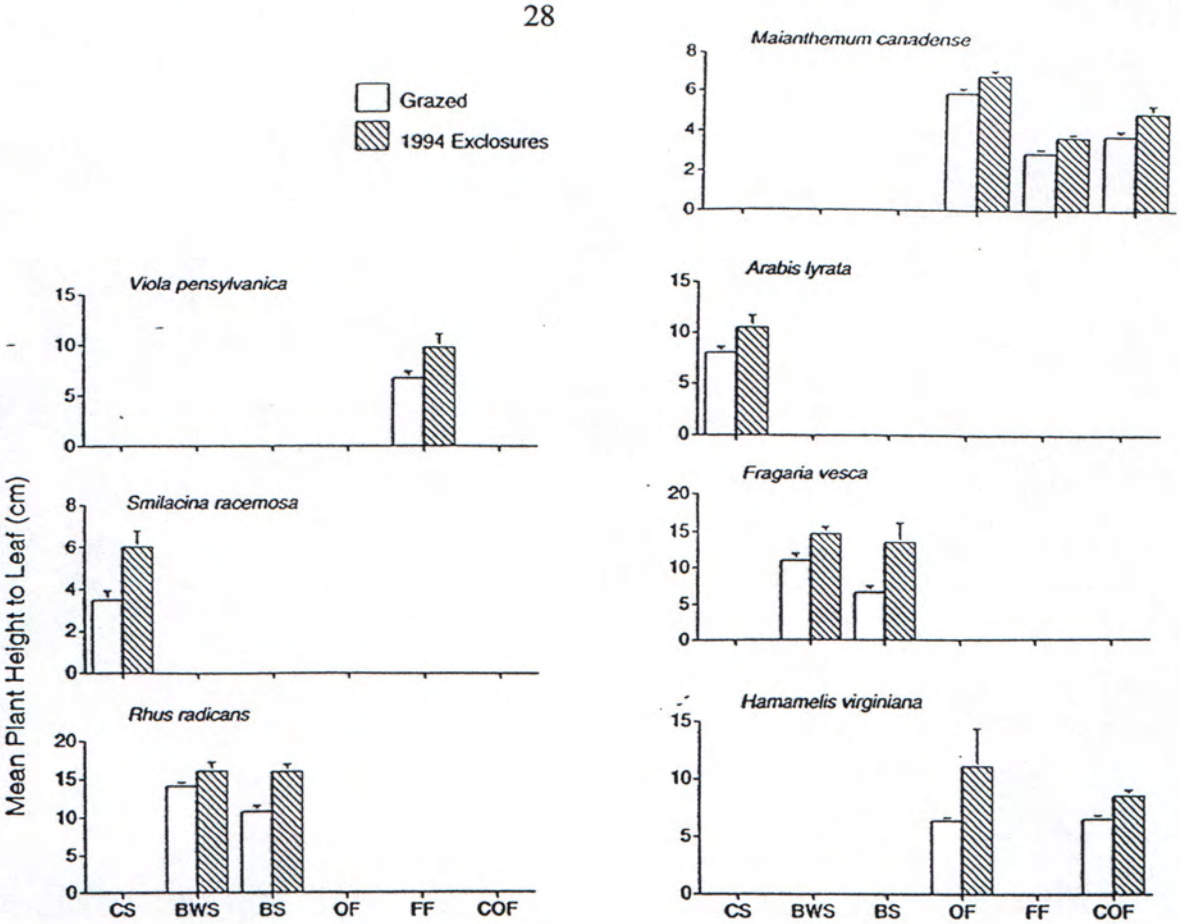


Figure 3.2. The mean plant height to leaf (cm) of indicator species measured at Pinery Provincial Park 1995. CS-cedar savanna; BWS-black/white oak savanna; BS-black oak savanna; OF-oak forest; FF-floodplain forest; COF-conifer/oak forest. Mean +/- S.E. n=3-49.

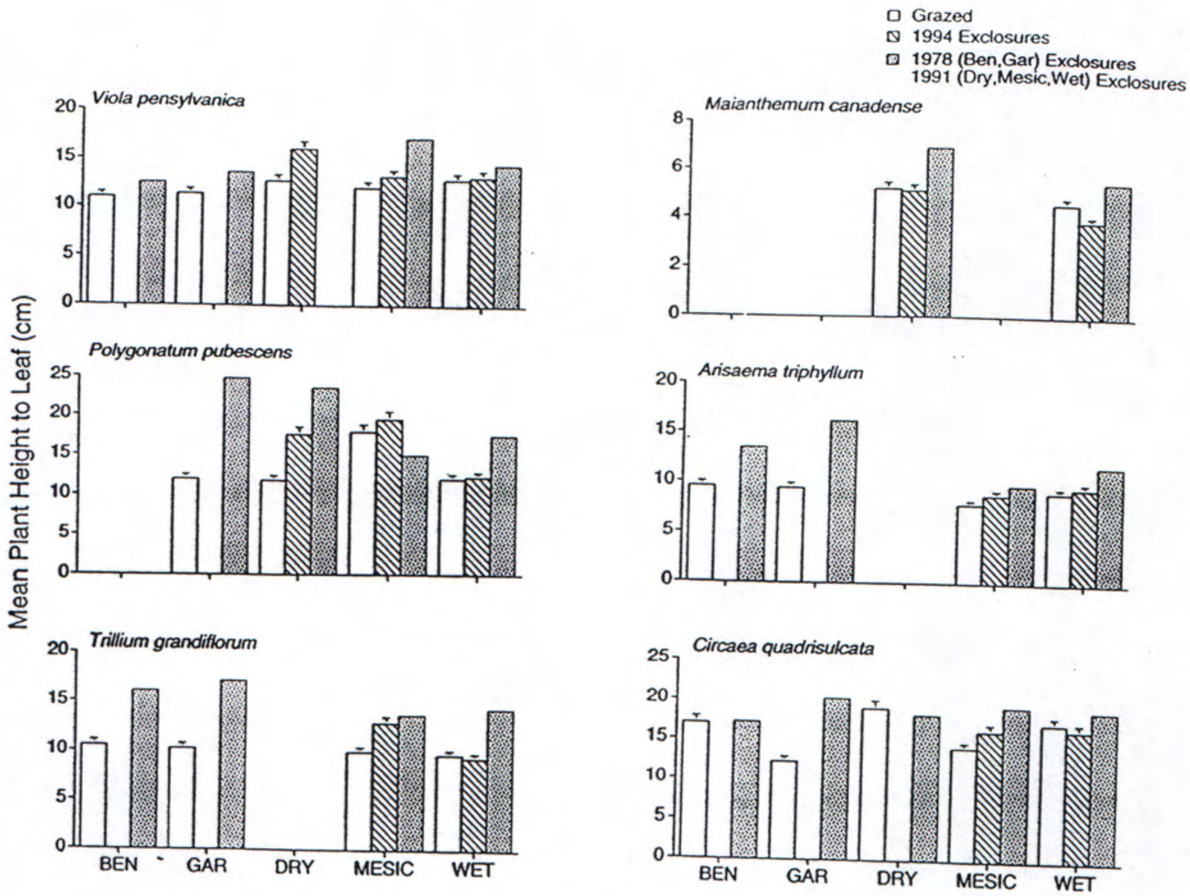


Figure 3.1. The mean plant height to leaf (cm) of indicator species measured at Rondeau Provincial Park 1995 in Bennett, Gardiner, Dry, Mesic, and Wet sites. Mean +/- S.E. n= 1-100.

Table 3.1. Results of Nested ANOVAs comparing plant heights.
(*p < 0.05, **p < 0.01, ***p < 0.001)

Species	Among habitat	Among sites within habitats
Rondeau		
Circaea quadrisulcata	$F_{4,8} = 0.10$ n.s.	$F_{8,378} = 5.2^{***}$
Arisaema triphyllum	$F_{3,6} = 1.22$ n.s.	$F_{6,491} = 16.9^{***}$
Maianthemum canadense	$F_{1,4} = 1.24$ n.s.	$F_{4,116} = 9.3^{***}$
Polygonatum pubescens	$F_{3,7} = 0.28$ n.s.	$F_{7,238} = 10.9^{***}$
Trillium grandiflorum	$F_{3,6} = 0.31$ n.s.	$F_{6,275} = 11.9^{***}$
Viola pensylvanica	$F_{4,7} = 0.56$ n.s.	$F_{7,362} = 8.1^{***}$
Pinery		
Viola pensylvanica		$F_{1,26} = 4.2$ n.s.
Smilacina stellata		$F_{1,38} = 9.2^{**}$
Rhus radicans	$F_{1,2} = 0.39$ n.s.	$F_{2.130} = 11.4^{***}$
Maianthemum canadense	$F_{2,3} = 10.9^{*}$	$F_{3,193} = 5.9^{**}$
Arabis lyrata		$F_{1,53} = 4.7^{*}$
Fragaria virginiana	$F_{1,2} = 0.49$ n.s.	$F_{2,35} = 6.8^{**}$
Hamamelis virginiana	$F_{1,2} = 0.02$ n.s.	$F_{2,92} = 6.9^{**}$

With the exception of *Maianthemum* in Pinery, plant height did not vary significantly among different habitats in either of the parks. Thus, when a plant species occurred in more than one habitat e.g. Bennett, Gardiner, Wet, Mesic etc. in Rondeau, it generally grew to a similar size in all of them. In the case of *Maianthemum*, the plants measured in the floodplain forest (FF) habitat were significantly smaller than those growing in open forest (OF) habitat. Similarly, with one exception, *Viola* in Pinery, exclosing plants from deer had a significant impact on their height in both parks. In the case of *Viola,* a significant height difference was approached ($F_{1,26} = 4.2$, $p = 0.051$). At Pinery, in contrast to Rondeau, no plant species occurred across all habitats studied. This reflects the greater diversity of habitat types found in Pinery compared with Rondeau.

While the Rondeau dataset yielded similar results to those found in 1994 (Pearl *et al.* 1995), there were some important differences. First, *Maianthemum* and *Polygonatum* were not measured in all the habitat types in which they were known to occur in 1994. This reflected a lack of intensive sampling and not the disappearance of these two species from some habitats. In contrast, the absence of *Trillium* and *Arisaema* from the dry habitat in 1995 reflected their true distribution. Second, the additional year of protection (between 1994 and 1995) resulted in *Maianthemum* plants in the 1991 exclosures growing significantly taller than plants in both the 1994 exclosures and grazed areas. Third, the differences observed in 1994 between *Circaea* plants in grazed sites and the short-term exclosures (built in 1991 and 1994) were not so uniformly clear cut in 1995. Although the underlying reason for the *Circaea* plant heights in grazed sites and exclosures being more similar in 1995 cannot be clearly stated without further analysis, there is one likely explanation. When these results are taken together with those for *Maianthemum*, *Polygonatum*, *Trillium* ,and *Arisaema,* in which plant heights in grazed areas showed an overall increase from 1994 to 1995, they strongly suggest that plants in grazed sites continued to experience some recovery from deer grazing in both 1994 and 1995, following the 1993-94 winter herd reduction at Rondeau.

CONCLUSION & RECOMMENDATION

Research in 1994 and 1995 has shown that a variety of plant species are suitable indicators of the effects of deer grazing pressures at both Rondeau and Pinery Parks. Deer grazing suppresses plant height, and following a release from grazing, some plants recover rapidly while others recover more slowly. In addition to the dataset presented here, research into *Trillium*, *Arisaema* and *Viola* spp. (Koh 1995, Dennis 1996, Engel 1996) over the period 1991 to 1996 also supports the hypothesis that understorey plant species are useful as indicators of the effects of deer herbivory. In addition, Dennis' (1996) analysis of long-term fluctuations in *Arisaema* heights from 1991 to 1996 suggest that up until 1995, grazed plants in Rondeau were recovering. However, in 1996 there were significant declines in the heights of plants in grazed sites, suggesting that deer grazing pressures were again increasing. Unfortunately, we cannot state with certainty that increasing deer numbers have reached the point where they are starting to have a negative effect on plant height, because in 1996 in both Bennett and Gardiner exclosures, there was also a significant decrease in plant height compared with 1995 which may have reflected the very late spring. However, these results were confounded by the absence of this decrease among plants in the mesic and wet exclosures (Dennis 1996). Clearly 1997 will be a crucial year for monitoring heights of indicator species in Rondeau, and an opportunity to clarify these contradictory results. We strongly recommend continuation of this study in 1997 with particular attention paid to *Circaea* and *Arisaema*.

4. Determining Methods for the Control of *Alliaria petiolata*, Garlic Mustard, at Rondeau Provincial Park

PURPOSE

To assess the effectiveness of different removal treatments in reducing Garlic Mustard populations at Rondeau Provincial Park.

DATES & LOCATIONS

Plants in three sites were subjected to a range of different removal methods in June-July 1994. The survival of plants in marked plots was determined in 1995.

METHODS

Detailed methods are given in Pearl *et al.* (1995). In late May and early June 1995, adult plants and non-flowering rosettes in 1994 plots were counted. In addition, the heights of ten randomly selected adult plants were measured and the number and percent cover of other species present in each plot was determined. One Lakeshore plot was excluded from the study in 1995, because a tree had fallen across it. Plot treatments in 1994 were: 1. cutting, 2. pulling, 3. spraying with the herbicide, Roundup, and 4. control (nothing was done).

RESULTS

None of the 1994 removal treatments had a significant effect on the density of Garlic Mustard plants when compared with the control plots (Fig. 4.1a, b). In 1995, neither the densities of adult plants nor the proportional change in

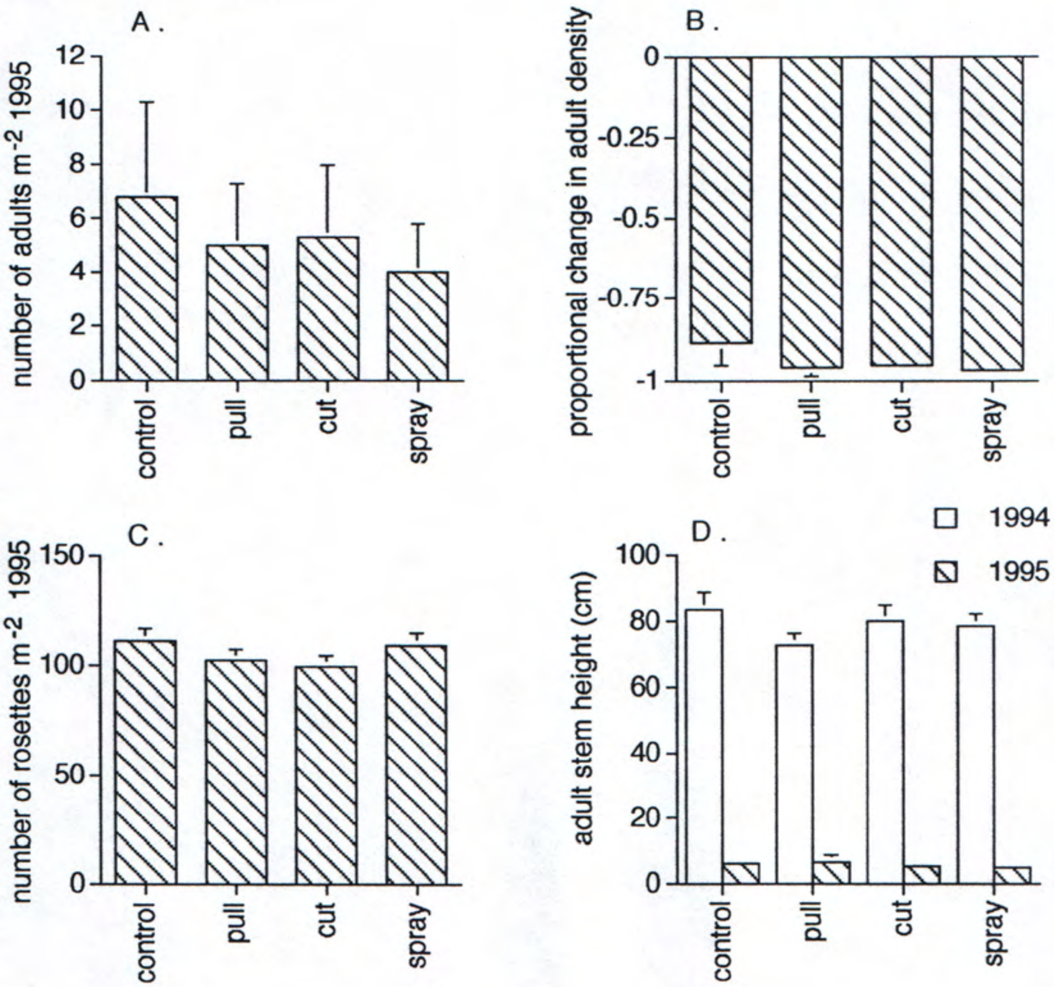


Figure 4.1. The results of the garlic mustard control experiment in which plots treated in 1994 were rescored in 1995.
a. density of adult plants in 1995.
b. change in adult density 1994-95.
c. density of rosettes in 1995.
d. stem height of adult plants in 1995.
Mean ± S. E., n = 9-10 plots (a-c) or plants (d).

adult density from 1994 to 1995, differed significantly between treated and control plots (randomized block ANOVA: adult density, treatment $F_{3,26} = 0.283$ n.s.; proportional change, treatment $F_{3,26} = 1.319$ n.s) (Fig. 4.1a, b). Rosette densities in control plots were not significantly different from densities in treated plots (randomized block ANOVA: treat $F_{3,26} = 0.046$ n.s.) (Fig. 4.1c). The stem heights of randomly-selected Garlic Mustard plants in the treated plots were not significantly different from those in the control plots in either 1994 or 1995 (randomized block ANOVA: 1994, treatment $F_{3,26} = 0.799$ n.s.; 1995, treatment $F_{3,26} = 0.400$ n.s) (Fig. 4.1d). The total number of other species present in the treated plots also did not differ significantly from those in the control plots (randomized block ANOVA: treatment $F_{3,26} = 0.860$ n.s.).

CONCLUSION & RECOMMENDATION

In this experiment none of the removal treatments effectively reduced Garlic Mustard population densities. However, the lack of an observed effect was probably due to the rather unique demography of the Garlic Mustard populations. These populations tend to have non-overlapping generations so that a high density adult (flowering plant) year is followed by a low density adult year in which rosette densities are high. This was the reason for adult density declining in all plots in 1995, irrespective of treatment. This demographic pattern is further described in section 6. We recommend that further tests of removal methods be carried out in parallel with population biology studies of this weedy species to ensure correct interpretation of results.

5. Determining Methods for the Eradication of *Berberis thunbergii*, Japanese Barberry, at Rondeau Provincial Park

PURPOSE

To assess the effectiveness of different removal methods for Japanese Barberry, an exotic shrub which is spreading westwards through the park. Plants probably escaped from cottage gardens on Lakeshore Road.

DATES & LOCATIONS

Bushes were subjected to a range of different removal methods in June-July 1994. The survival of these marked bushes was determined in the summer of 1995.

METHODS

Detailed methods are given in Pearl *et al.* (1995). Briefly, 14 groups of four bushes (n = 56 in total) were selected in 1994 and one bush in each group received one of four treatments: 1. pulling, 2. cutting, 3. cutting and painting the stump with the herbicide, Fencerow, and 4. control (nothing was done). There were seven groups of small bushes and seven groups of large bushes. In 1995 the marked bushes were visited twice to determine whether they were still alive.

RESULTS

There was no difference in mortality between bushes of different size (Fig. 5.1). All of the control bushes and about 75% of the cut bushes survived from 1994 to 1995 (Fig. 5.1). The most successful removal treatment was the cutting and

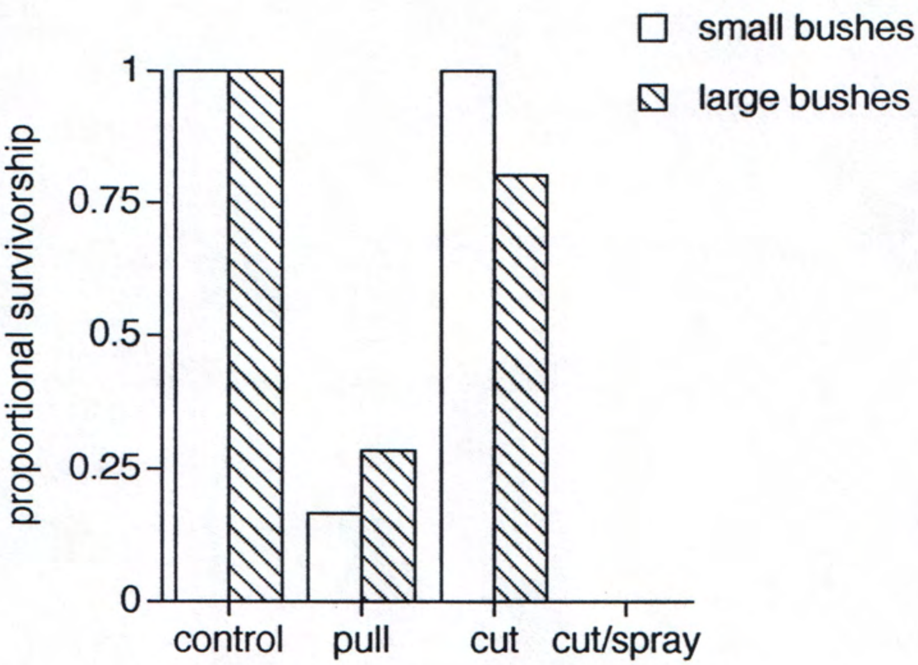


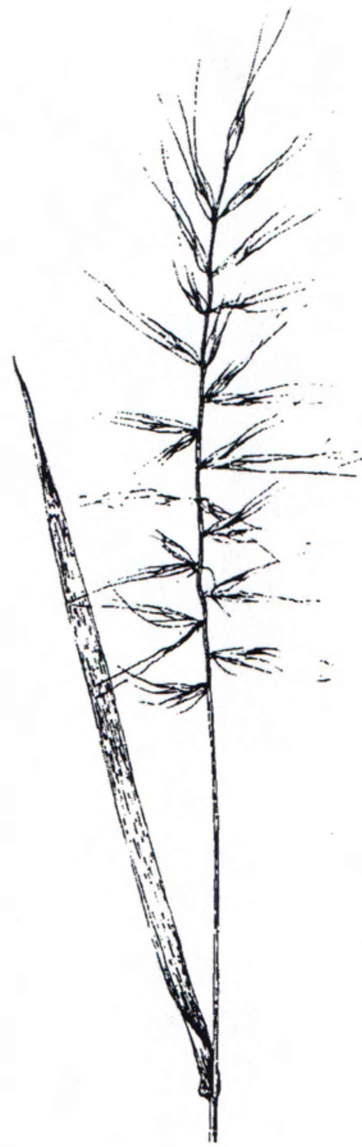
Figure 5.1. The proportional survival in 1995, of Japanese Barberry bushes subjected to different control treatments at Rondeau Provincial Park in 1994. n=5-7 bushes per treatment group.

painting of bush stumps with Fencerow herbicide which killed all marked bushes. Although the pulling out of *B. thunbergii* bushes was also an effective removal method, it was much more labour intensive than cutting and painting and was not 100% effective, as bushes regrew from rootstocks which remained in the soil. Pulling bushes out also disturbed the soil and surrounding vegetation.

We compared bush survival among experimental treatments with Fisher's Exact tests because many samples had zero mortality (100% survival) or zero survival (100% mortality). For small bushes, the pulling out treatment ($n = 6$) resulted in significantly lower survival than the control treatment ($n = 7$) ($p = 0.005$), while bush survival in the cutting treatment ($n = 7$) was significantly higher than in the cutting and painting treatment ($n = 7$) ($p = 0.001$). In the case of large bushes, there was significantly greater mortality in the pulling out treatment ($n = 7$) than in the control treatment ($n = 7$) ($p = 0.021$). Large bush survival in the cutting treatment ($n = 5$) was significantly higher than in the cutting and painting treatment ($n = 6$) ($p = 0.015$). A total of four marked bushes were not relocated in 1995. These reduced sample sizes would not have affected the results in the pulling out treatment for small bushes and the cutting/spraying treatment for large bushes. However, in the cutting treatment, there was a possibility that the two missing large bushes died. If so, cutting may have had a differential effect on mortality depending on bush size: large bushes may have been slightly although not significantly ($p = 0.192$) more likely to die in this treatment than smaller bushes.

CONCLUSION & RECOMMENDATION

If a removal policy for *B. thunbergii* is to be adopted, then the most effective method is cutting bushes and then painting stumps with herbicide.



Hystrix patula

6. Patterns of Dispersal and Establishment in *Alliaria petiolata,* Garlic Mustard, at Rondeau Provincial Park.

PURPOSE

To monitor changes in population density and range of the exotic plant species, Garlic Mustard, in Rondeau. To determine the effect of Garlic Mustard on native co-occurring species.

DATES & LOCATIONS

Rondeau Provincial Park spring and summer 1994-96.

METHODS

Dispersal patterns and density changes of Garlic Mustard

Eighteen circular plots were established at Rondeau in 1994 to determine if Garlic Mustard populations were expanding in any particular direction. These plots were also used to measure changes in population density with time. Detailed methods describing plot establishment, locations and sampling protocols were outlined in the 1995 STTU report (Pearl *et al.* 1995). There was a major protocol change from 1994 to 1995. In 1994 only flowering plants (adults or second year plants) were sampled in plots, but in 1995 and continuing, both flowering plants and rosettes (first year plants) were sampled in plots.

Population biology of Garlic Mustard

In May 1995, 15 permanent monitoring transects were established. Fifteen patches of Garlic Mustard were selected, which were distributed among three main sites in Rondeau: Southpoint (3 patches), Lakeshore Drive (6 patches), and Pony Barn (6 patches) (Fig. 6.1). A transect, 54m in length, was laid out through each patch. Quadrats (60 cm x 60 cm) were laid out and marked at 3m intervals along each transect, so that there were 19 permanent quadrats per transect and a total of 285 quadrats in the park. Numbers of flowering plants (adults or second year plants) and rosettes (first year plants) in each quadrat were counted in May-June 1995 and 1996. The non-flowering rosettes were also counted in July-August 1995, early May 1996 and July-August 1996 in order to determine within- and between-season mortality levels. In May 1996, rosette densities were extremely high, so transects were sub-sampled for these counts, with four randomly selected quadrats in each transect being measured.

Relationships between Garlic Mustard and other species

The other plant species present in quadrats along the permanent transects were identified during late May and July-August in 1995 and 1996. Numbers of individuals of each species were counted. A complete species list is given in Appendix 2. The Shannon Diversity Index was calculated for quadrats, using the following equation:

$$H' = - \Sigma \, p_i \ln p_i \qquad \text{(Magurran 1988)}$$

where p_i, the proportional abundance of the *i* th species, represents the abundance of each species/sum of all abundances.

RONDEAU PROVINCIAL PARK

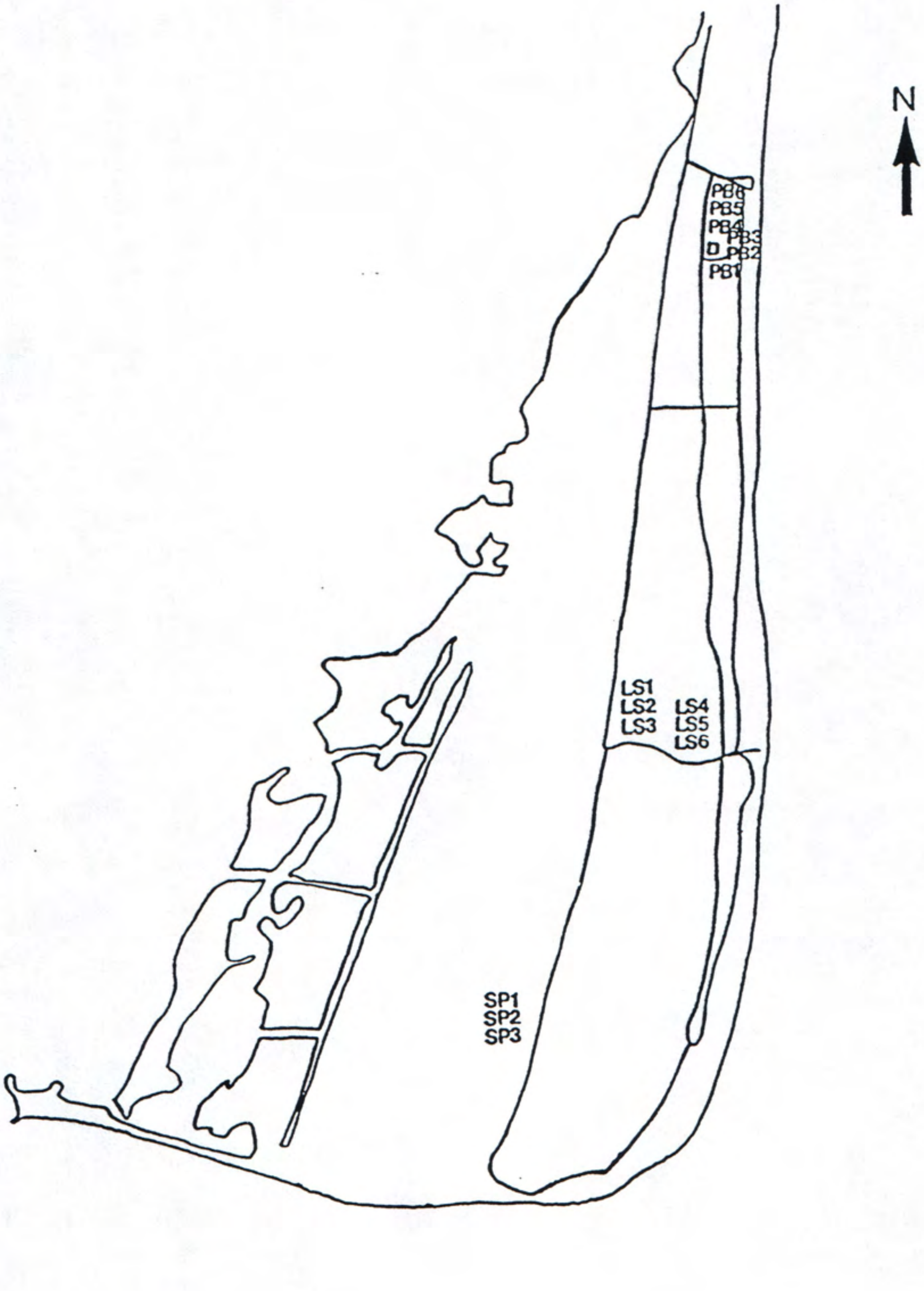


Figure 6.1. The location of Garlic Mustard monitoring transects in Rondeau Provincial Park. PB - Pony Barn, LS - Lakeshore Drive, SP - Southpoint Trail.

RESULTS & DISCUSSION

Dispersal patterns and density changes of Garlic Mustard

In both the circular plots established in 1994 and the permanent transect quadrats, the proportion of plots with Garlic Mustard plants increased from 1995 to 1996 (G-test: Circular plots, $G = 128.2910$ $p < 0.001$, Transect quadrats, $G = 78.7817$ $p < 0.001$), indicating that Garlic Mustard populations in Rondeau are expanding (Fig. 6.2a, b). However, while the overall story has a simple message, we uncovered a more complex situation underneath.

Initially, in 1994, we made the decision to sample only adult plants which are easier to count. In the circular plots, there was a significant increase from 1994 to 1995 in the percentage of quadrants containing adult Garlic Mustard plants (G-test: $G = 12.073$ $p < 0.01$). This percentage decreased significantly in 1996 (G-test: $G = 59.542$ $p < 0.001$), creating the perception of a year-to -year "wave effect" of Garlic Mustard presence (Fig. 6.2c). This wave effect is the result of the much more highly visible adult or flowering plants reaching high densities in alternate years. However, in between, the less visible rosettes, which will flower in their second year, are present and must be included in any study of Garlic Mustard.

Density estimates of Garlic Mustard also reflected this wave effect (Table 6.1). In the circular plots, density of flowering plants increased significantly between 1994 and 1995 from 0.8 to 2.2 plants m^{-2} (Wilcoxon $z = -4.82$ $p < 0.001$) (Table 6.1). This density then decreased between 1995 and 1996 from 2.2 to 0.1

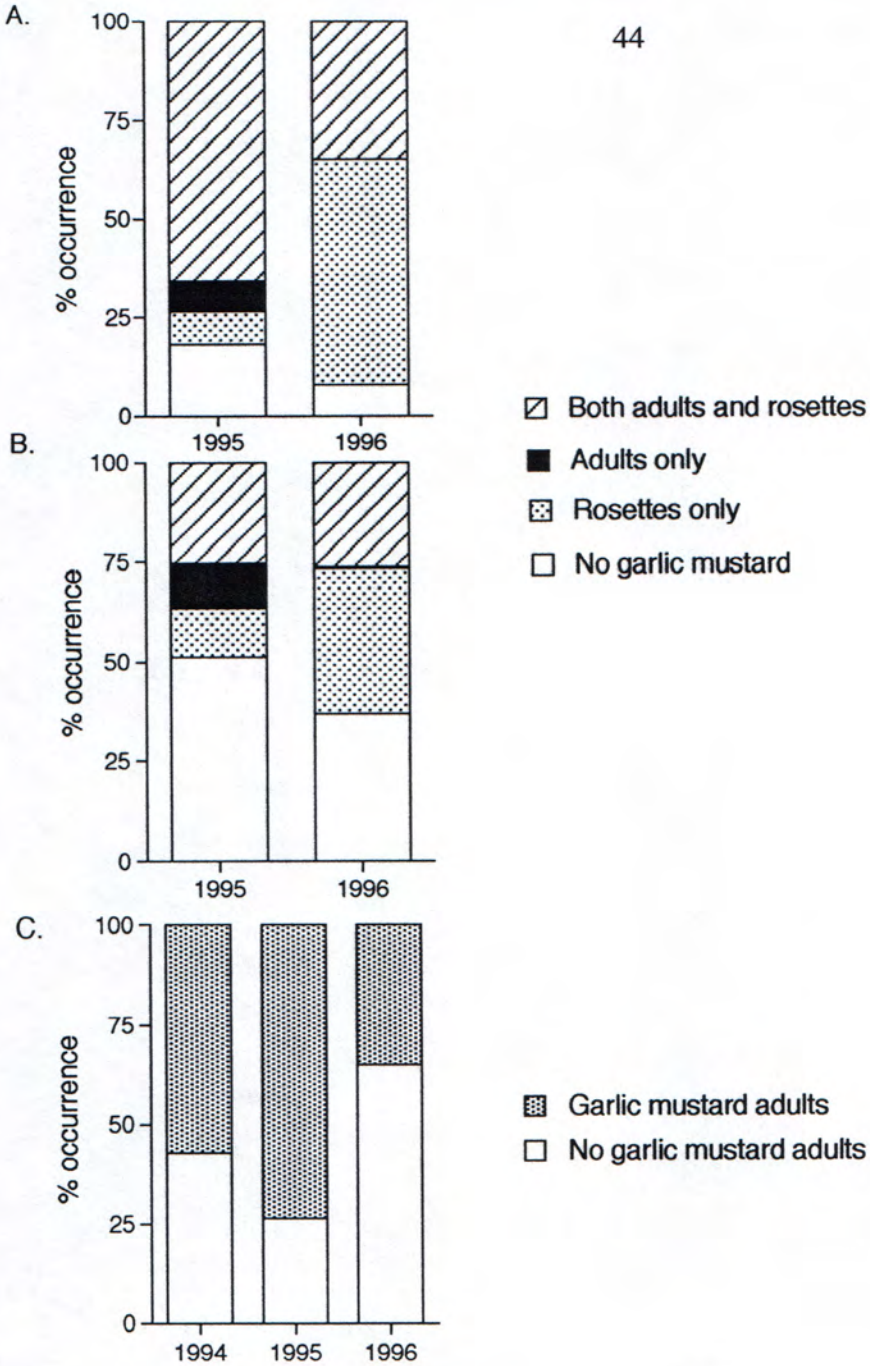


Figure 6.2. The composition of garlic mustard populations in circular plots and quadrats along permanent transects.
a. In circular plots, for years in which both life stages of garlic mustard were scored.
b. In permanent transect quadrats.
c. In circular plots, when only the adult life stage of garlic mustard is taken into account, allowing the inclusion of 1994 data.
Percent occurrrence refers to the proportion of quadrant plots or quadrats having a specific composition of garlic mustard life stages.

Table 6.1. Density of garlic mustard populations at Rondeau Provincial Park

Site	Flowering plants m^{-2}						Rosettes m^{-2}					
	1994		1995		1996		1994		1995		1996	
	mean[1]	n	mean	n	mean	n	mean	n	mean	n	mean	n
Circular plots[2]	0.8	58	2.2	59	0.1	44	--	--	4.5	59	7.9	58
Pony Barn[3]	--	--	24.3	49	9.6	37	--	--	46.1	50	66.7	74
Lakeshore[3]	--	--	22.6	37	11.5	24	--	--	18.2	28	44.7	52
Southpoint[3]	--	--	12.8	18	6.6	15	--	--	18.0	19	40.4	27
All transect plots (excludes circular plots)	--	--	21.2	104	9.4	76	--	--	24.5	97	54.6	153

[1] geometric mean reported in all years, thereby excluding plots with no garlic mustard (geometric mean = antilog (mean of ln density)).
[2] quadrants (n=4 per circular plot); all plants counted in spring, damaged and unrecoverable plots excluded.
[3] 1994: plants counted July-August. 1995: flowering plant densities for June, rosette densities for July. 1996: flowering plant densities for May, rosette densities for August.

plants m^{-2}, while rosette density increased from 4.5 to 7.9 plants m^{-2} (Table 6.1). The range of population change in quadrants varied from a four-fold decline in density to a 22-fold increase in density of flowering plants.

Analysis of variance indicated that the spread of Garlic Mustard had no particular direction from 1994 to 1995, although there was a significant variation among plots (randomized block ANOVA: plot $F_{16, 46} = 2.32$ $p < 0.05$; quadrant (direction) $F_{3, 46} = 0.226$ n.s.) (Fig. 6.3).

Population biology of Garlic Mustard

Frequency histograms of the ratio of rosettes to flowering plants in 1995 and 1996 indicated that in permanent quadrats there was a strong tendency for high densities of flowering plants to be associated with very low densities of rosettes and vice versa (Fig. 6.4). This pattern was associated with the "wave effect" in which either flowering plants or rosettes tended to dominate quadrats in a particular year. This could only happen if populations of Garlic Mustard in Rondeau tend to consist of discrete generations.

Annual plants complete their life cycle within one growing season, so that every summer we see a new generation. Garlic Mustard belongs to the group of plant species which complete their life cycle in two to five years, and which flower and reproduce only once before dying. This group of plants has traditionally been known as "biennials", and has been thought to require two years to complete their life cycle. Although we now know that many "biennials" may take up to five years to reach their flowering size, what little evidence exists for Garlic Mustard, suggests that it is a "true biennial" i.e. in the first year, seeds germinate

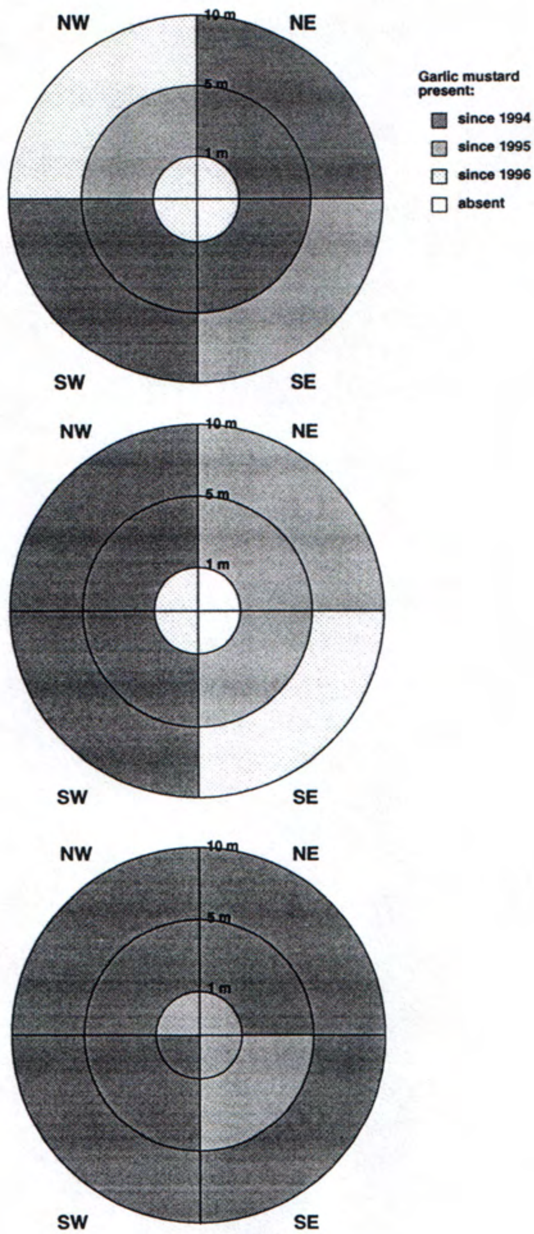


Figure 6.3. The spread of garlic mustard in the quadrants of three cirular plots at Rondeau from 1994- 1996. This spread occurred randomly with respect to direction.

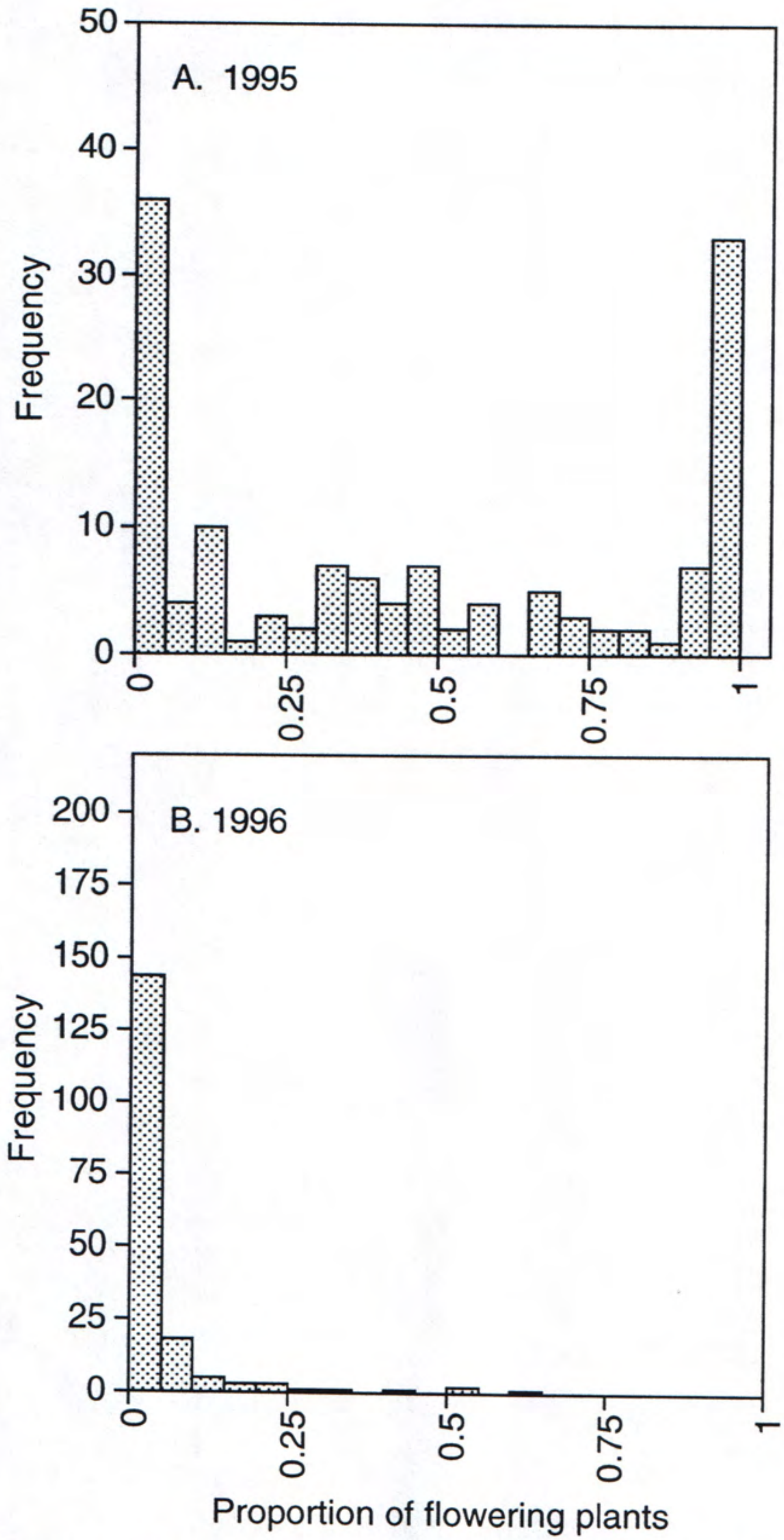


Figure 6.4. The frequency distribution of numbers of quadrats with different proportions of flowering plants (ratio of adult garlic mustard plants to rosettes) in 1995 and 1996. A low proportion of adults indicates that the quadrat was dominated by rosettes. All permanent quadrats were included in the sample.

and in the second year, the rosettes grow tall and flower. It is quite possible for a species having this kind of life cycle to produce many flowering plants every year, because each year there should be a constant supply of rosettes germinating from seeds in the seedbank, which will flower the next year. What is unusual about Rondeau is the wave effect of alternating high and low flowering years. This suggested that there may be strong suppression of first year rosettes by flowering plants in a high flowering plant year, while in a low flowering plant year, patterns of rosette mortality may be very different.

In 1995, there was no strong evidence of within-season density-dependent mortality occurring within the rosette population from spring to summer. Plots of logged proportional mortality data (log q_x, Silvertown 1987) against the log of spring plant density (flowering plants and rosettes) showed no clear linear relationships, and although the regression was significant, the slope was negative, indicating that higher spring rosette densities experienced lower mortality (Regression: $y = -0.22x + 0.25$, $F_{1,61} = 7.3$ $p < 0.01$). This observed lack of density-dependent mortality appeared to be related to high levels of within-season mortality in the rosette populations across a wide range of rosette densities, which was regulated by adult flowering plants.

In contrast, in 1996, a low flowering year, there was a significant positive relationship between spring rosette mortality (natural log of the proportional decrease in rosette density in quadrats from May to August) and rosette density, indicating density-dependent mortality over the spring (Regression: $y = 0.058x - 0.668$, $F_{1,162} = 5.63$ $p < 0.05$). The analysis of these data is ongoing.

Relationships between Garlic Mustard and other species

Given the possibility that one generation of Garlic Mustard could be suppressing the next generation, we were interested in whether co-occurring species were also being affected. Therefore, species richness (the number of other species present in a quadrat) and species diversity (Shannon Index - H') were regressed against density of Garlic Mustard plants. The data were plotted twice, once excluding quadrats without any Garlic Mustard, and once including them, to see if their presence significantly affected the result, which was sometimes the case.

A significant negative relationship was found between Garlic Mustard density and species richness in 1995 (high flowering year) when quadrats without Garlic Mustard were included (Fig. 6.5a). In 1996 this relationship was not significant (Fig. 6.5c). Significant negative relationships were found in 1995 when the Shannon Indices were regressed against Garlic Mustard density, when quadrats without Garlic Mustard were both included and excluded from analyses (data not included, but available upon request). In 1996, the absence of negative regressions was associated with overall lower species richness (Fig.6.5c, d). Thus, the impact of Garlic Mustard on other plant species may depend on whether it is a high or low adult year. Further tracking of *A. petiolata* cohorts is needed to determine whether this effect is consistent in all "adult years", and even to determine whether Garlic Mustard does in fact experience cycles of adult and rosette years.

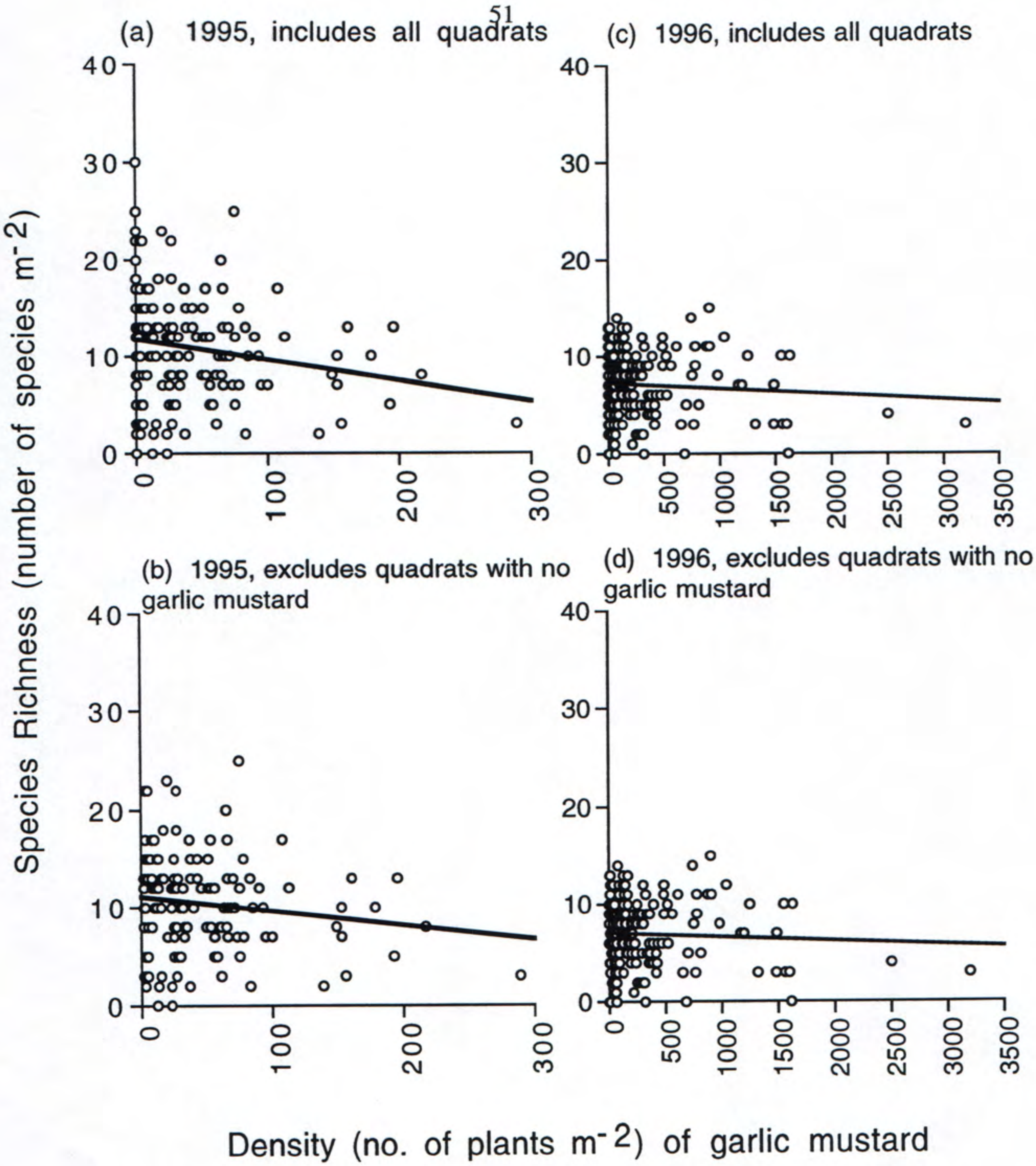


Figure 6.5 The relationship between species richness in a plot and all garlic mustard plants (rosettes and adults) in 1995 and 1996. Each point is one quadrat. Regressions are as follows.

(a) Signifcant negative regression. $y=-0.022x+11.805$, $F_{1,283}=8.403$ $p<0.005$

(b) Non-significant regression. $y=-0.014x+11.039$, $F_{1,137}=2.987$ $p=0.0867$

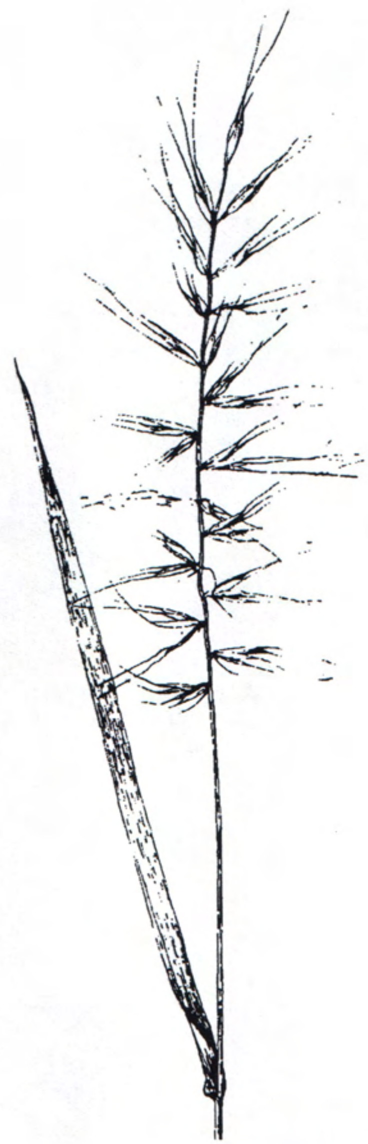
(c) Non-significant regression. $y=-0.001x+7.231$, $F_{1,282}=1.464$ $p=0.2274$

(d) Non-significant regression. $y=-0.000x+7.065$, $F_{1,178}=0.594$ $p=0.4417$

CONCLUSION & RECOMMENDATION

The range of Garlic Mustard populations at Rondeau has increased significantly following the deer cull. However, measuring changes in the density and occurrence of flowering plants (adults) is not an appropriate means of tracking the spread of Garlic Mustard. This is due to the population dynamics of this species at Rondeau. It appears that inter-generational competition results in the suppression of alternate-year cohorts, such that a high density of second year flowering plants suppresses the first year rosettes. This results in alternate high and low flowering years, which we have termed a "wave effect". Further population studies are recommended for 1997, to provide a third year of detailed data which will allow us to fully describe this process.

This wave effect has implications for co-occurring native species. We found negative effects of Garlic Mustard on species diversity in a high flowering year and no significant effect in the following low flowering year. One possibility is that the low flowering years provide an opportunity for native species to recover in the absence of dense, tall *A. petiolata* adults. We predict that in 1997, the third year of detailed data collection, which is expected to be a high flowering year, we will once again observe a negative relationship between Garlic Mustard density and plant species richness. What we are unable to predict, is whether there will be an overall drop in species richness compared with 1995.



Hystrix patula

7. Surveys of Woody Vegetation

PURPOSE

Surveys of the structure of woody plant communities were carried out in nine forest locations in southern Ontario, in order to provide a regional context for assessing the condition of the Rondeau and Pinery forests. The purpose of the surveys in Rondeau and Pinery was to determine the forest structure prior to deer herd reductions.

DATES & LOCATIONS

July-August 1993: Point Pelée National Park, Hillman Sandhills, Pinery Provincial Park, Skunk's Misery Tract, Rondeau Provincial Park, Gartshore Tract, Backus Woods, Maple Tract, and Joker's Hill Tract (Fig. 1.1).

July-September 1994: Pinery Provincial Park (characterized on a finer scale).

METHODS

Rondeau Provincial Park was subdivided into five habitat types: Rondeau-Dry, Rondeau-Mesic, Rondeau-Wet and Bennett and Gardiner exclosures. In 1994, Pinery Provincial Park was subdivided into six habitats: Black oak savanna (BS), Black/white oak savanna (BWS), Conifer/oak forest (COF), Cedar savanna (CS), Floodplain forest (FF), and Oak forest (OF). Ten plots in each habitat or location were measured except for: Point Pelée (13 plots), Maple (6 plots), Joker's Hill (7 plots), Bennett exclosure (9 plots) and Gardiner exclosure (9 plots). In 1993, Pinery

Provincial Park plots were unevenly spread across habitat types with plots in FF (7 plots), and BS and BWS (3 plots).

Each plot consisted of five stations, while Bennett and Gardiner plots had four stations. See Pearl *et al.* (1995) for detailed methods of data collection. Plants were identified to the species level where possible and varieties were pooled to species. The few trees and shrubs which could not be identified to species were excluded from the species composition calculations, but included in other calculations. We defined trees as live woody stems with diameters greater than 7.5 cm at 1.4 m above the ground or in the case of fallen live trees 1.4 m from where the ground would have been if the tree was still standing. We defined shrubs as woody stems that were taller than 0.4 m with a diameter of less than 7.5 cm at 0.4 m from ground level. We did not include dead trees and shrubs (Pearl *et al.* 1995)

Calculation of tree and shrub density

Rather than basal area being measured, diameter at breast height was taken. Only the nearest neighbour protocol was used to calculate mean distances between stems of trees and shrubs. The following density equation was used:

Absolute density (number of plants/ha) = $10{,}000\ m^2 / D^2$

D = *(Mean distance (m) between nearest neighbours in a habitat or location) * 1.67 correction factor* (Mueller-Dombois & Ellenberg 1974).

Calculation of diameter at breast height

The mean for diameter at breast height (DBH) was calculated as follows:

DBH (cm)= *Mean of A*

A = the average DBH (cm) of individual plots in a habitat or location

Calculation of species composition

Species composition was defined as the proportion of each species sampled in a habitat or location. The proportion was calculated as follows:

Species proportion (%) = *[(Total number of times species sampled) / (Total number of trees/shrubs sampled in a habitat or location)] * 100*

RESULTS & DISCUSSION

In all cases, further statistical analysis of data is required.

Density

Shrub density was greater than tree density in all habitats and locations (Fig. 7.1a). However, shrub density was considerably lower at Pinery, Rondeau, and Hillman, compared with other locations. This was probably the result of historically high vertebrate grazing pressures in these three locations. Pinery and Rondeau have experienced high deer densities, while Hillman has experienced both deer grazing and also cattle grazing during the 1950s and 60s. The Bennett and Gardiner exclosures at Rondeau, built in 1978, were expected to show the effect of removing deer on plant communities. When compared with the Dry, Mesic and Wet habitats, there was evidence of shrub recovery in Gardiner, but this recovery was not as great in Bennett. Even after 15 years of protection, Bennett and Gardiner still had relatively low shrub densities in comparison with other southern Ontario forests. Assuming that the endpoint recovery densities should approach those in other Ontario locations, this suggests that recovery has been slow. Alternatively, if intensive

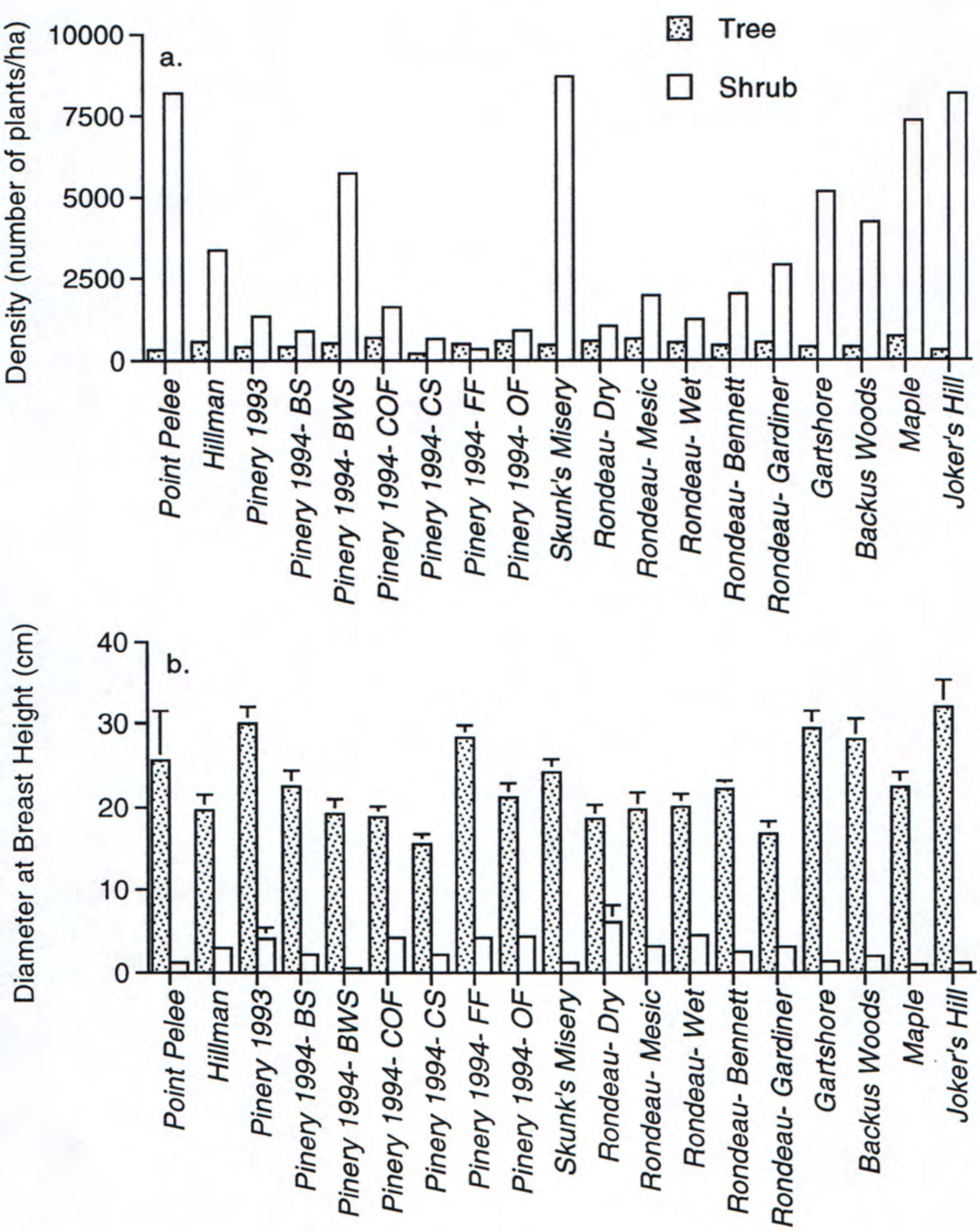


Figure 7.1. a. Density (number of plants/ha) and b. Diameter at Breast Height (DBH) (cm) of trees and shrubs in nine Ontario forest locations. BS-Black oak savanna, BWS-Black/white oak savanna, COF-Conifer oak forest, CS-Cedar savanna, FF-Floodplain forest, OF- Open forest. Mean DBH, for all habitats and locations was a mean of the plot means where plots=10, except for Point Pelee (n=13), Maple (n=6), Joker's Hill (n=7), Rondeau- Bennett (n=9) and Rondeau- Gardiner (n=9).

grazing has caused a shift in the plant community to an alternate state, then woody communities in these exclosures may never recover to pre-grazed shrub densities.

The densities of trees in Pinery and Rondeau (1993 and 1994) were similar to those in other Ontario locations.

Diameter at breast height (DBH)

The tree DBHs at Rondeau, Hillman and Maple tended to be lower than at other Ontario locations (Fig. 7.1b). In 1994 we found that DBHs at Pinery varied greatly among habitats. The Floodplain forest (FF) had the largest trees, while Cedar savanna (CS) had the smallest. Except for the Floodplain forest, in 1994, Pinery results were similar to those from Rondeau. The high proportion of Floodplain forest plots in the Pinery 1993 dataset explains the high tree DBH in this year. There was a general trend across locations towards a negative relationship between DBH and tree density: in locations where DBH was higher on average, trees tended to be present at lower densities (Fig. 7.1).

Shrubs at Hillman, Pinery and Rondeau had relatively high DBHs. Thus, at these locations, there were lower densities of bigger shrubs, indicating that smaller size classes were absent. This was in contrast to Point Pelée where the lower mean shrub DBH is a reflection of the prevalence of small shrubs following continued deer population control since 1989/90 (Koh & Bazely 1994).

Species composition

There was high variability in the composition of both tree (Fig. 7.2) and shrub (Fig. 7.3) communities among locations.

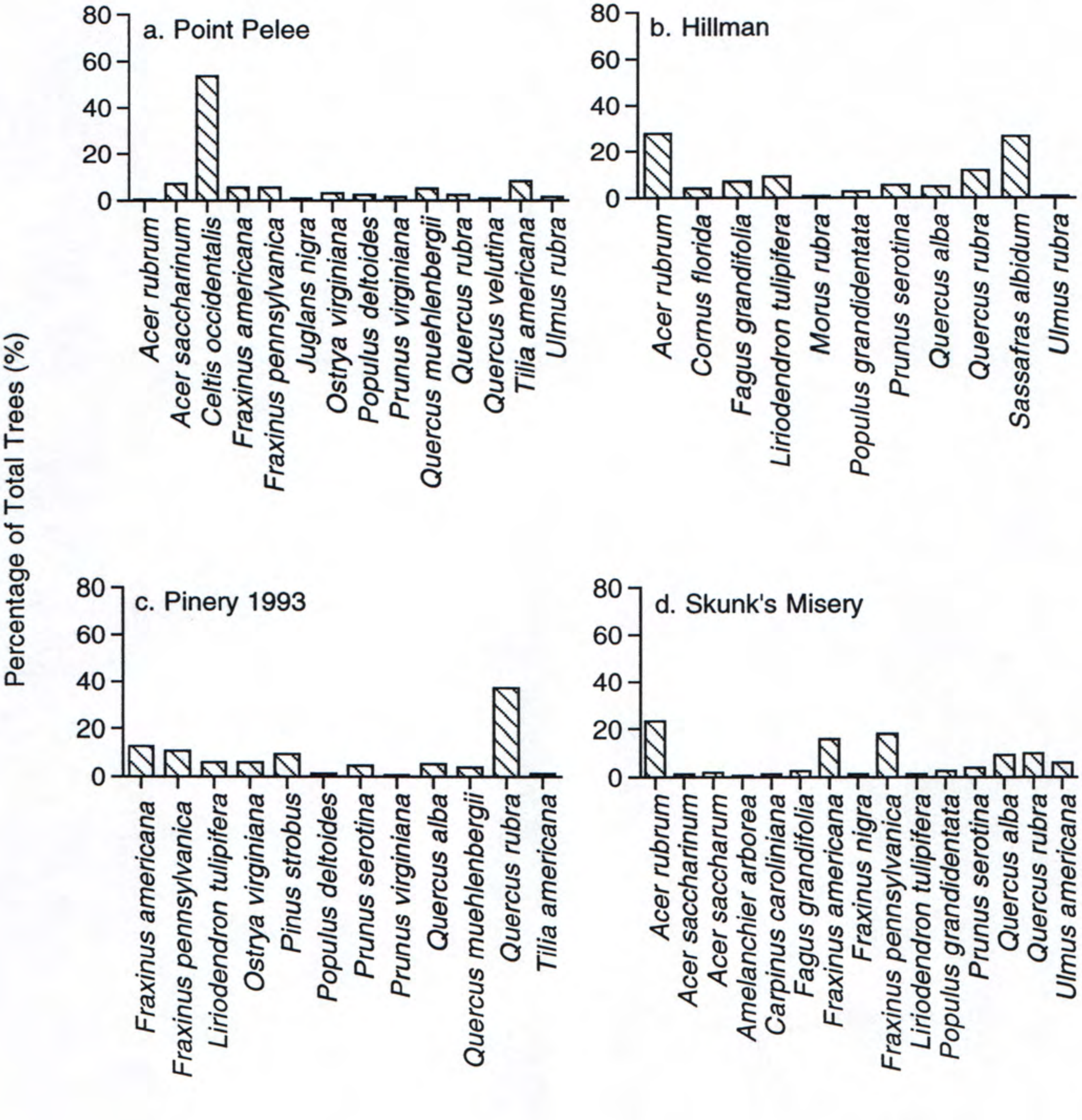
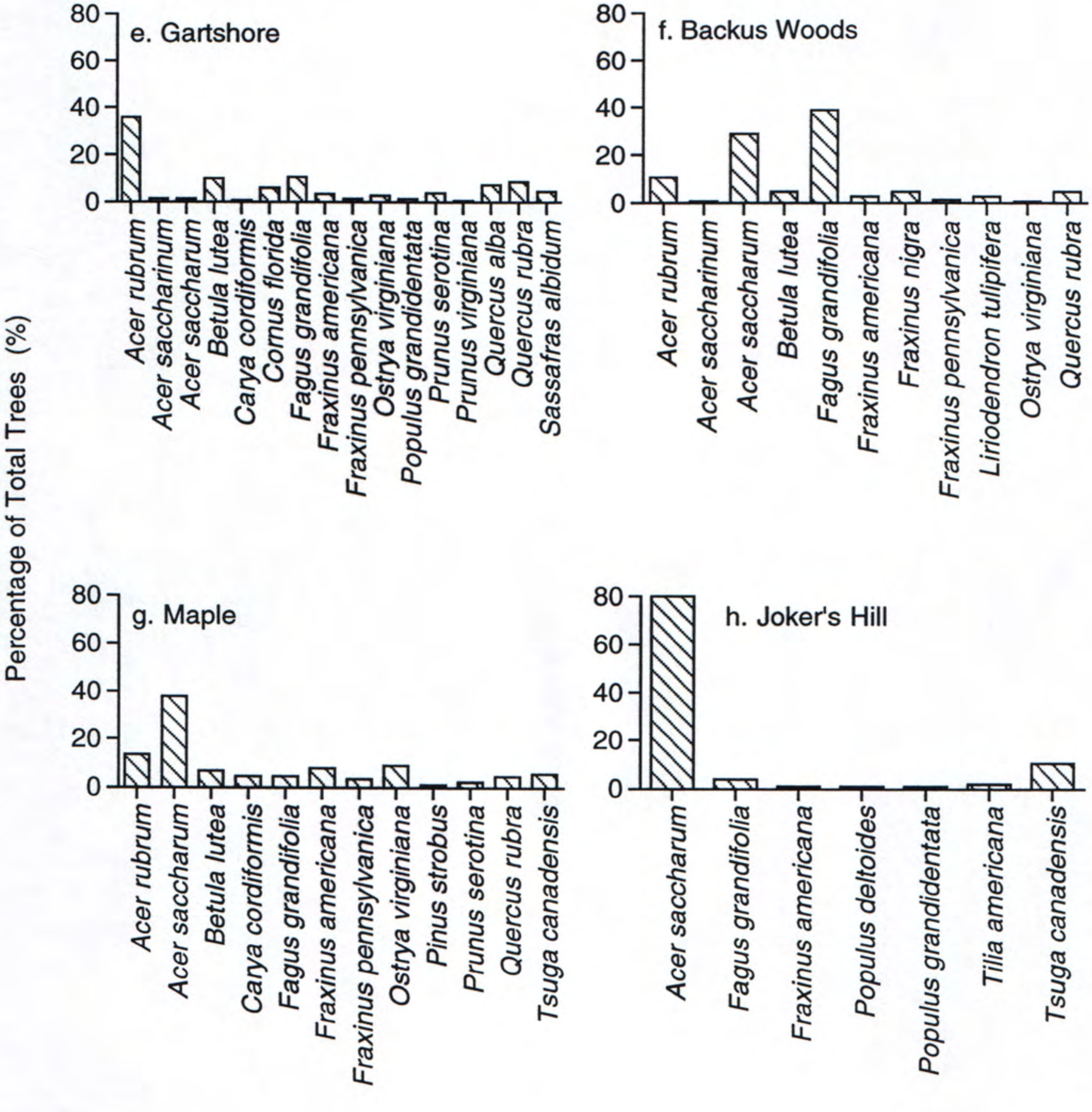


Figure 7.2. a.- s. The composition of tree communities in nine forest locations in Southern Ontario. Species occurrence is represented as the percentage of the total number of trees at a location.



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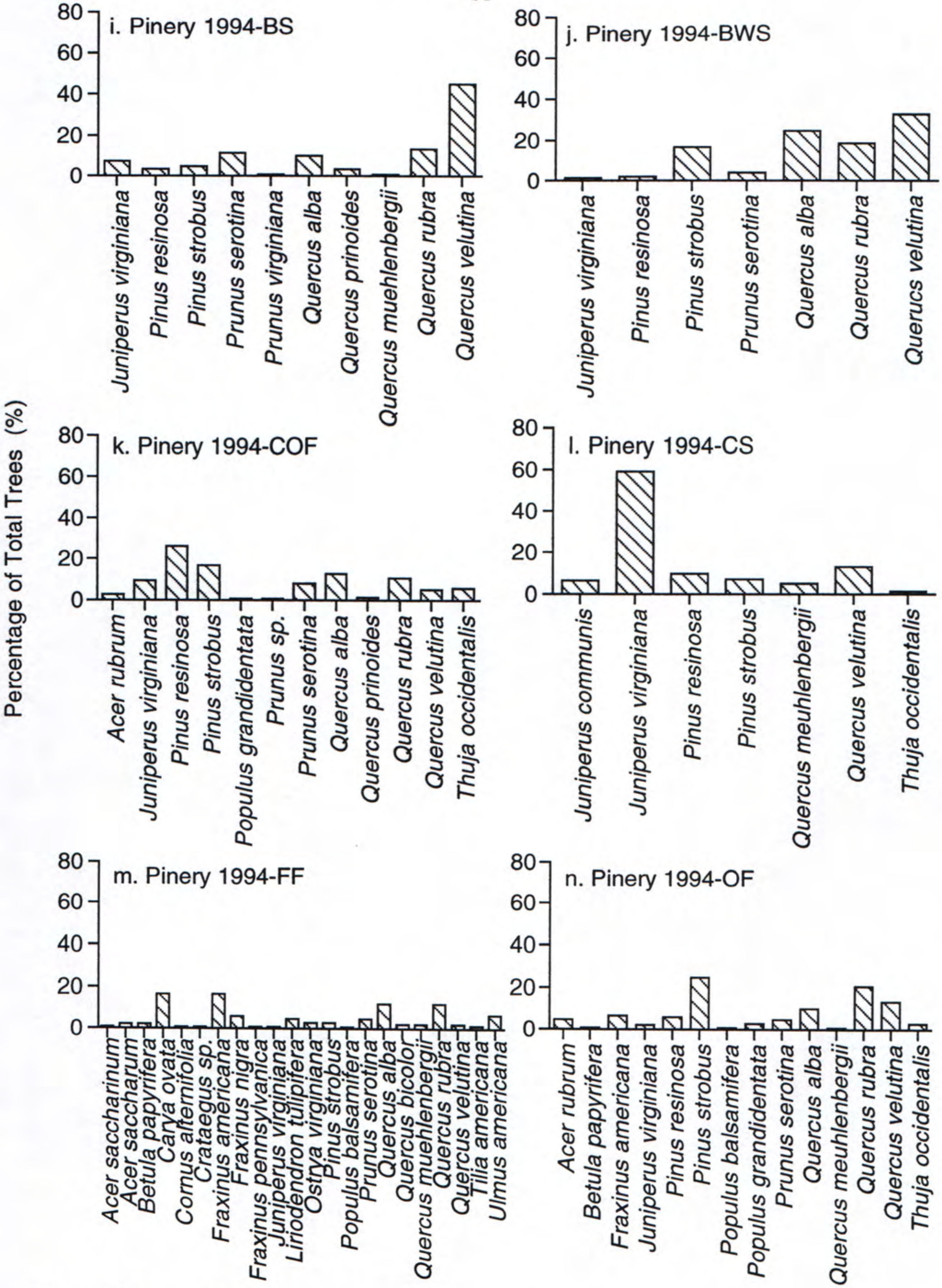

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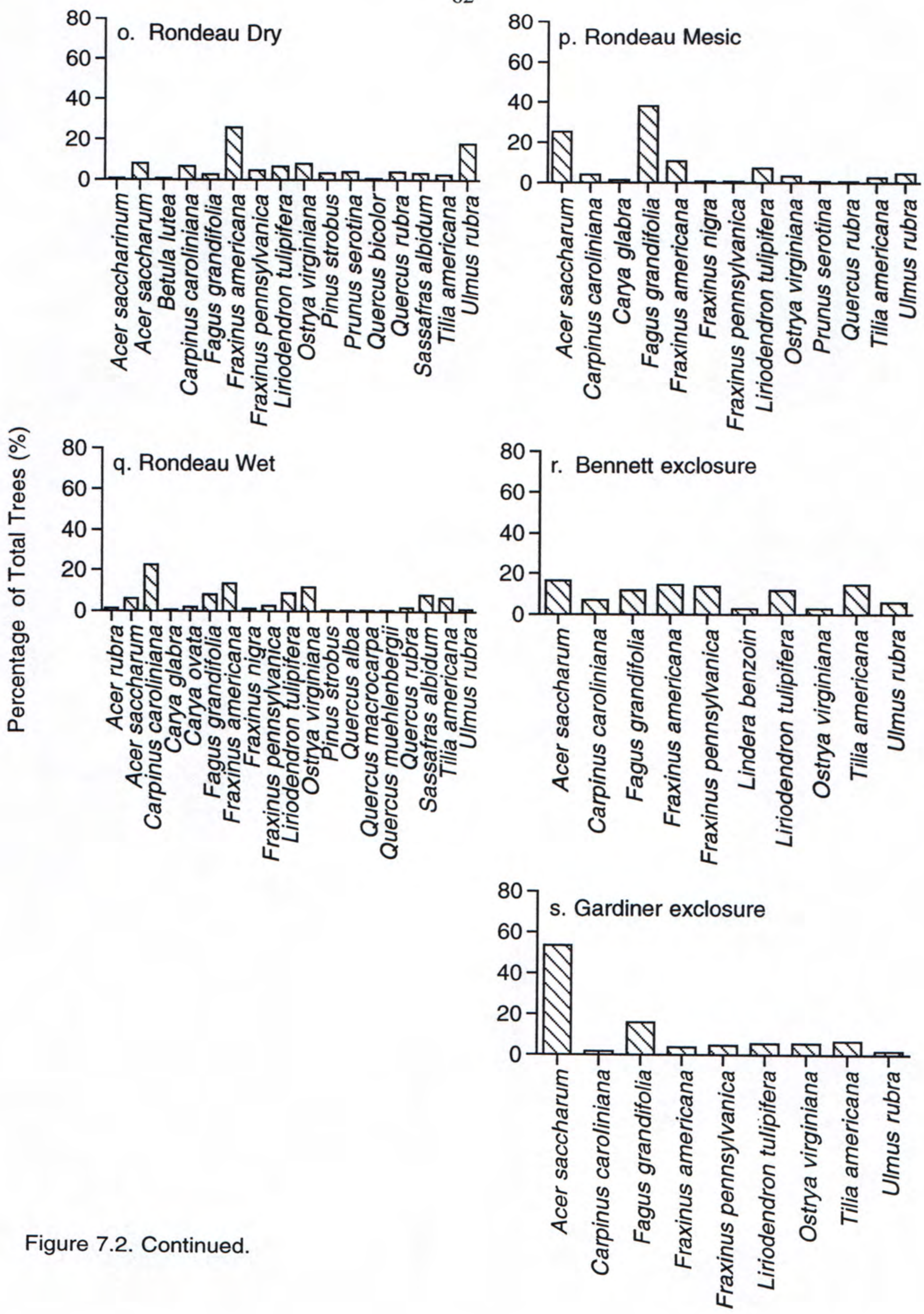

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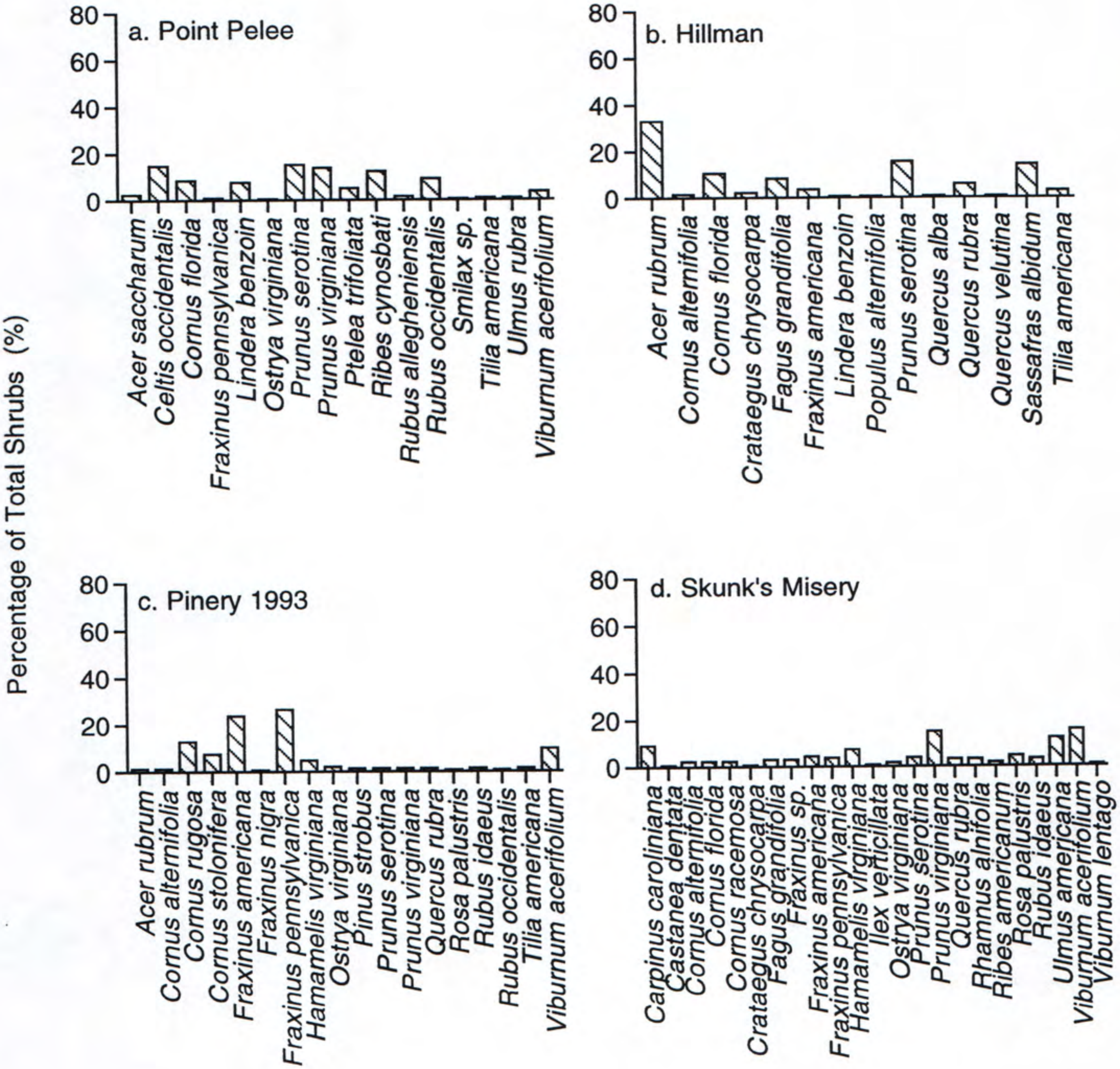
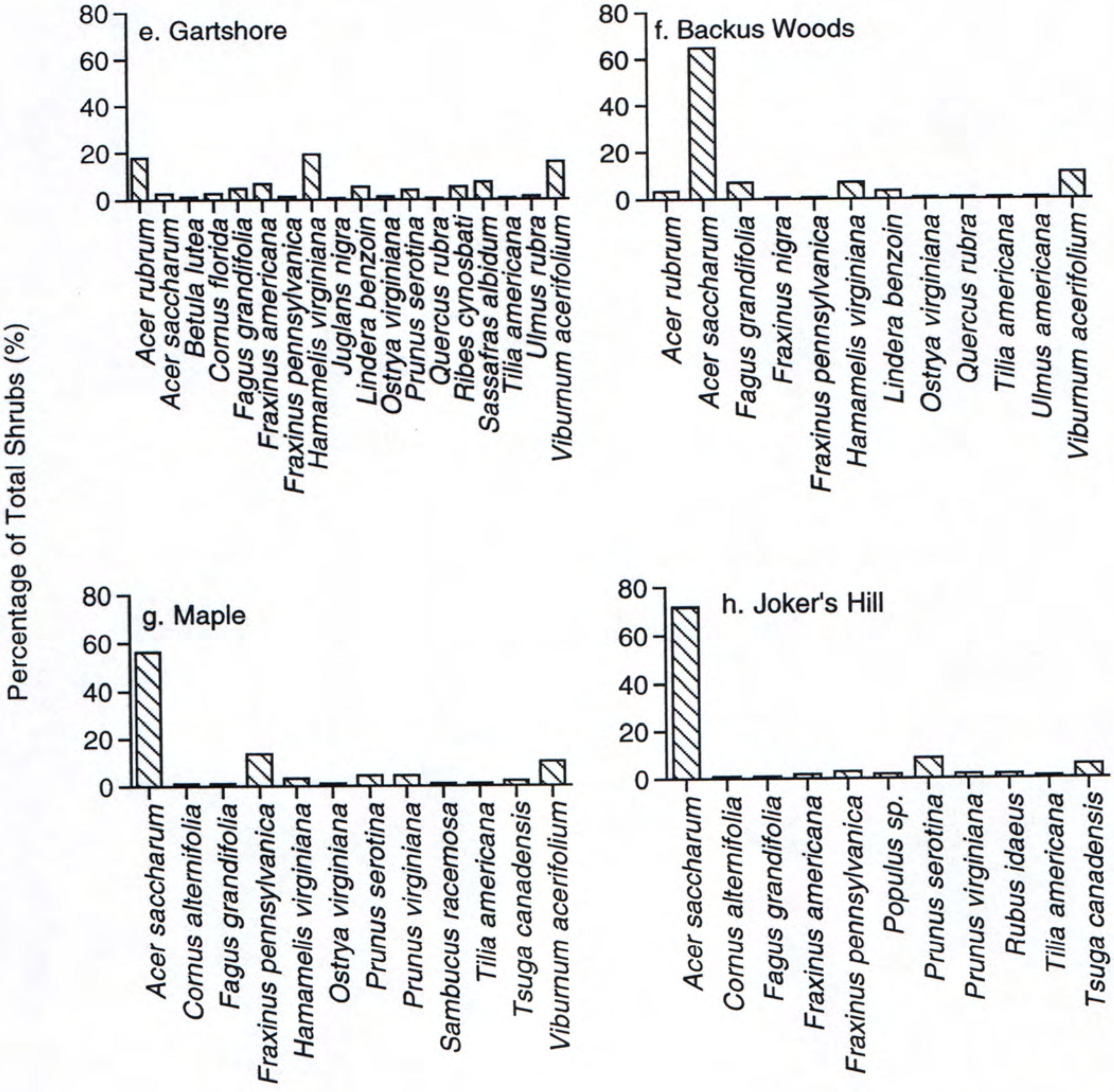


Figure 7.3. a.- s. The composition of shrub communities in nine forest locations in Southern Ontario. Species occurrence is represented as the percentage of the total number of shrubs at a location.



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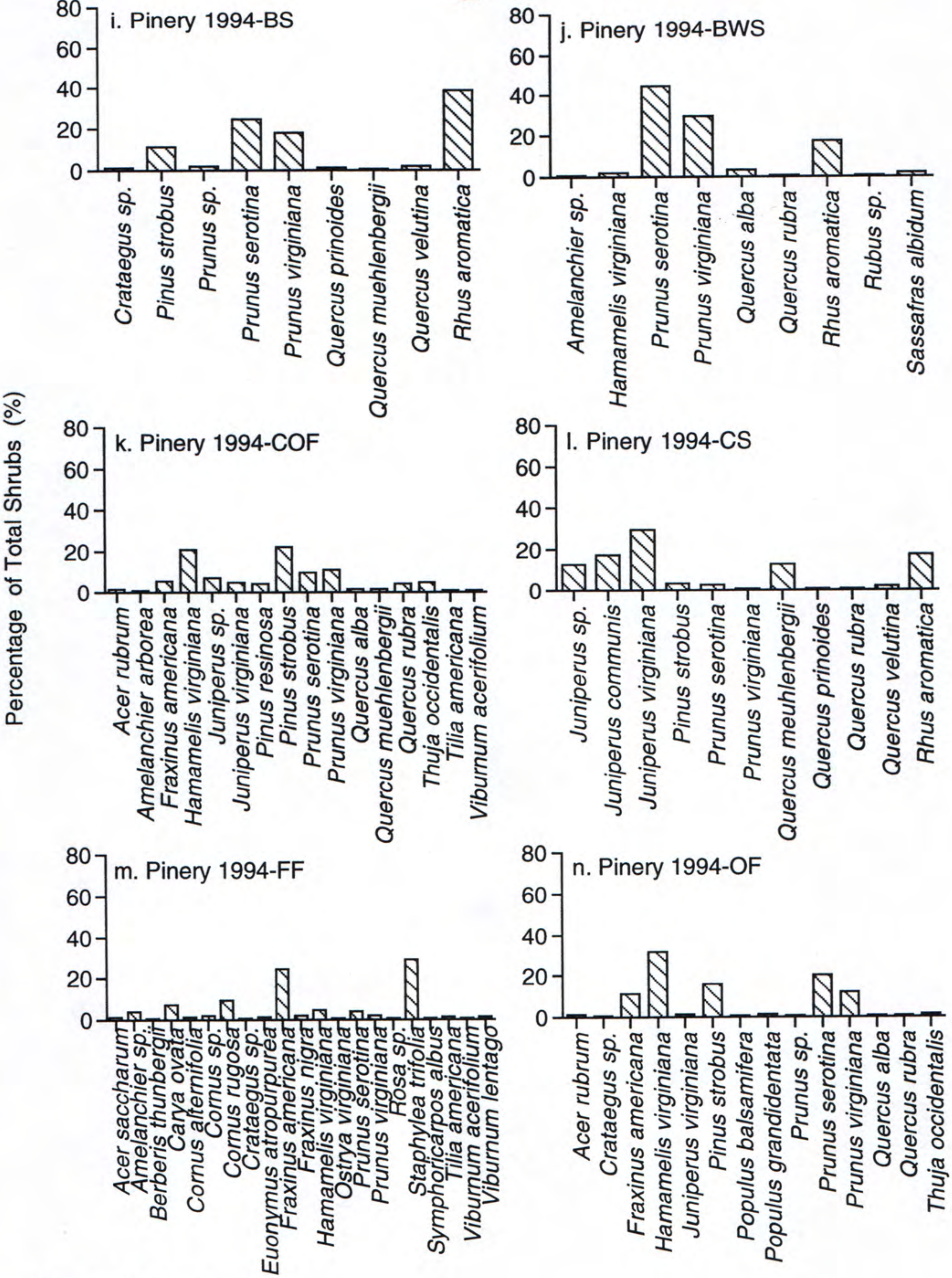

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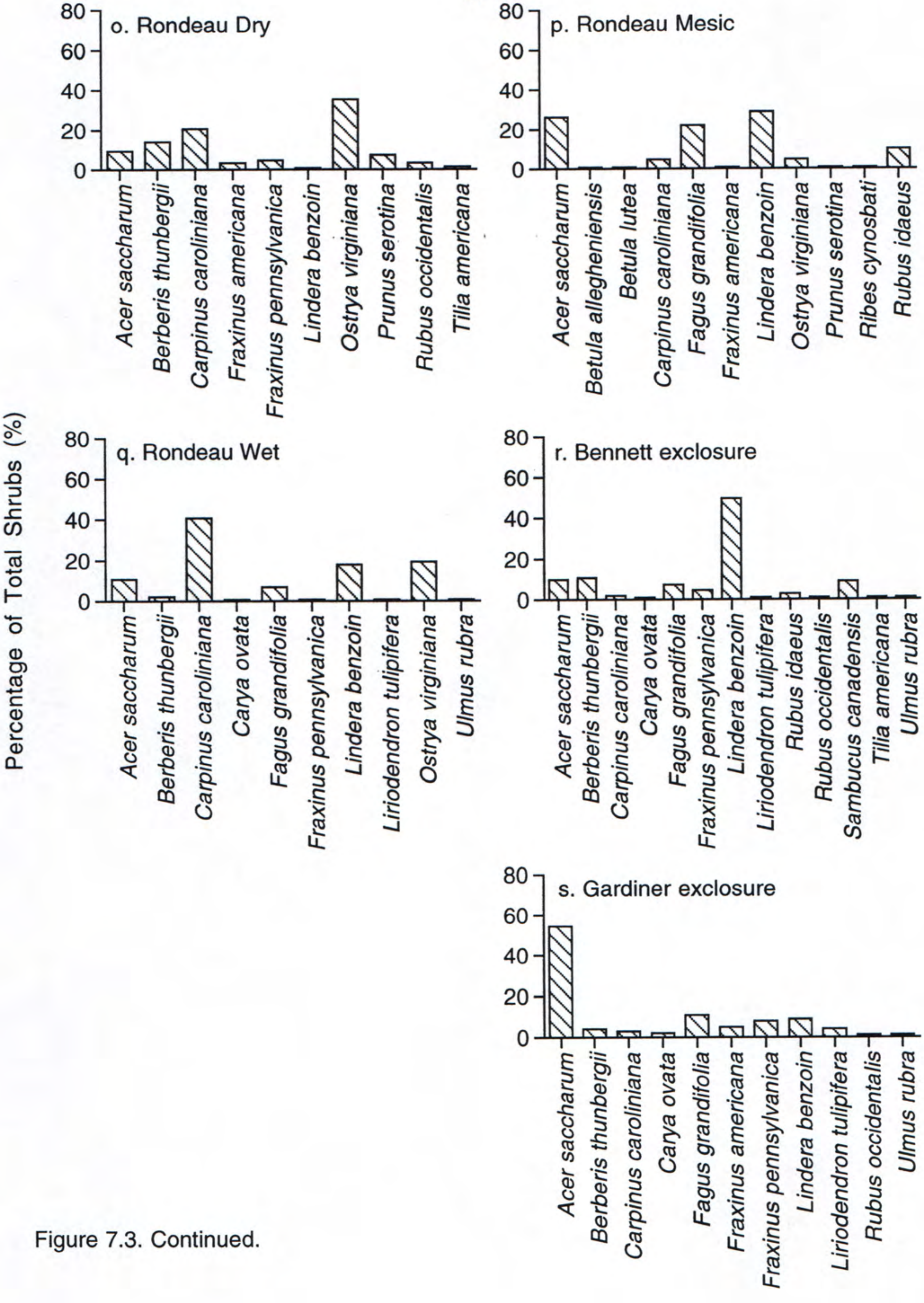

Figure 7.3. Continued.

Several unpalatable (to deer) shrub species were well established in Rondeau (Fig. 7.3). *Berberis thunbergii* , Japanese Barberry, which is invasive, was present in all habitats except Mesic, and was common in the Dry habitat. *Lindera benzoin,* Spicebush, was also present in all habitats, and comprised 49.5% of the shrub community in Bennett. *Fagus grandifolia* was present in all but one habitat, but its widespread distribution in Rondeau may be determined as much by seed input from canopy trees as by its unpalatability to deer.

CONCLUSION & RECOMMENDATIONS

The structure and composition of woody plant communities at Pinery, Rondeau and Hillman have been altered by intensive vertebrate grazing, resulting in lower shrub densities and the establishment at Rondeau of unpalatable woody species. While we can offer a number of explanations for differences in tree densities and tree DBHs among locations, further investigation is required. The presence of smaller trees (lower mean DBHs) at intensively grazed sites such as Rondeau and Pinery could be due to two factors. The first is that trees in these lake-edge habitats simply do not reach the maximum sizes attained by trees at more sheltered inland sites. However, this hypothesis is not supported by the Pinery 1993 and Point Pelée data. Alternately, there may be higher mortality rates of larger trees at Rondeau and some Pinery habitats sites due to increased windthrow. This process could be initiated by deer when intense grazing reduces the sub-canopy shrubs and saplings to the point where recruitment of saplings to the canopy does not occur. When recruitment is limited, canopy gaps will increase in size, subsequently increasing the possibility of windthrow of larger trees. In 1996 Catherine Sykes (M.Sc. student) revisited 1980 plots in Rondeau established by E. Haggith and found that in some plots, over 50% of the large trees were gone. These data, along with lower DBHs, suggest that regeneration rates at Rondeau are not high enough to fill existing canopy gaps. In addition, the abundance of unpalatable species within the Rondeau exclosures suggests that the plant community has been altered, and the low shrub DBHs indicate that recovery is either slow or not occurring. Overall, these results are alarming because they suggest that the Rondeau forest will continue to decline as trees are no longer recruited to the overstorey.

We strongly recommend that the loss rates of large trees and rates of creation of canopy gaps be monitored at Rondeau (this is included as part of our 1997 research programme), and that the impact of altered understorey light conditions on plant communities be assessed. This will indicate whether some form of drastic management intervention might be justified to replace and/or protect large trees.

Liriodendron tulipifera

8. Survey of Available Woody Browse at Pinery and Rondeau Provincial Parks

PURPOSE

To estimate the amount of woody browse available for deer in Pinery and Rondeau Provincial Parks. Baseline data were collected during the Fall of 1994 and 1995. Repeating this procedure in future years will allow us to examine changes in woody browse availability to the deer over time and to compare the parks. This will provide another indicator of habitat recovery following deer herd reductions.

DATES & LOCATIONS

October-December 1994: Pinery and Rondeau Provincial Parks.

October-December 1995: Pinery and Rondeau Provincial Parks.

METHODS

Detailed methods for collection of field data were described in Pearl *et al.* (1995). Rondeau was divided into three habitat types: Dry, Mesic and Wet and Pinery was subdivided into six habitat types: Black oak savanna (BS), Black/White oak savanna (BWS), Oak forest (OF), Conifer oak forest (COF), Cedar savanna (CS), and Floodplain forest (FF). Sample sizes were as follows: Rondeau 1994 - Dry (2 plots), Mesic (2 plots), Wet (2 plots); Rondeau 1995 - Dry (10 plots), Mesic (5 plots), Wet (9 plots); Pinery 1994 - BS (8 plots), BWS (7 plots), OF (0 plots), COF (10 plots), CS (12 plots), FF (11 plots); Pinery 1995 - BS (8 plots), BWS (7 plots), OF (7 plots), COF (7 plots), CS (2 plots), FF (6 plots).

Sampling was conducted in quadrats, with five quadrats per plot. In each quadrat the number of stems producing current annual growth (CAG) on woody plants between 0-50 cm and 50-200 cm in height were tallied (by species for the 50-200 cm height class) (Pearl *et al.* 1995). Current annual growth was sampled by clipping three stems. *Thuja occidentalis*, White Cedar, was not included in the calculations because it required a separate sampling procedure

Stem density

The mean stem density in a habitat was calculated as follows:

Mean stem density per habitat (no. stems m^{-2}) = *Mean of D*

Where D = *mean stem density* (stems/m^{-2})*per plot in a habitat*

D= *(Total number of stems summed for all quadrats in a plot) / [(Number of quadrats)* 10.24 m^2 (area of a quadrat)*

Available woody browse (Broadfoot & Voigt 1996)

The mean available woody browse was calculated as follows:

Mean available woody browse (g dwt m^{-2}) = *Mean of B*

Where B = *mean CAG biomass* (g dwt m^{-2}) *per plot in a habitat*

B= *[Stem density (no. stems m^{-2}) per plot] * [CAG (g dwt twigs $stem^{-1}$) per plot]*

CAG = [*Total mass of CAG (g dwt) per plot] / [Total number of stems clipped per plot].*

Species composition

Species composition was calculated as the percentage of each species comprising the total mass of CAG in a habitat. The following equation was used:

CAG per species (%) = *[(Total CAG weight for species) / (Total CAG weight of habitat)] * 100*

RESULTS & DISCUSSION

Stem density and the biomass of woody browse could not be calculated for 1994 datasets due to missing information. Only the species composition of woody browse in the 50-200 cm height range could be calculated. The evaluation of winter deer carrying capacity will be analysed and presented in the second 1997 report.

In both parks the density of stems and current annual growth (CAG) on shrubs and saplings was extremely low, although stem densities were higher in Rondeau, indicating some recovery following the deer herd reduction in 1993/94 (Fig. 8.1). The density of stems in the 0-50 cm height range exceeded the density of stems in the 50-200 cm height range in all habitats in both parks. In the latter height class, plants were virtually absent, indicating that both forests are without understorey shrub communities.

When CAG was calculated on a per stem basis, it was greater on stems in the 50-200 cm height class. This was because the height class consisted of older and larger plants which could produce more and fatter twigs (CAG). As a result, there was often more available woody browse in the 50-200 cm height class despite the lower overall stem densities (Fig. 8.1c, d).

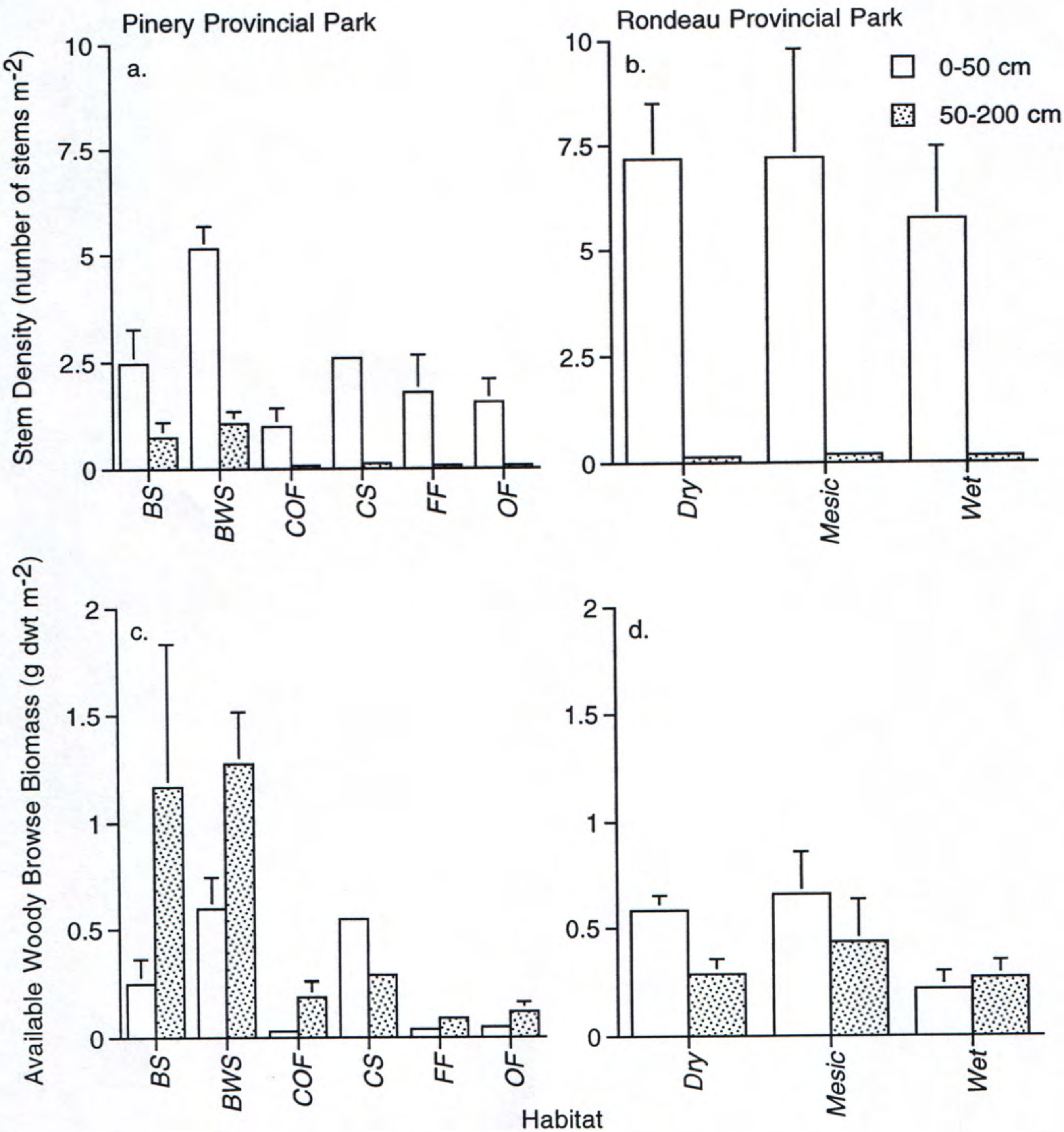

Figure 8.1. a.,b. Density of stems (number of stems m^{-2}) with current annual growth. c.,d. available woody browse (g dwt m^{-2}) in Pinery and Rondeau Provincial Parks 1995. Two height classes (0-50 and 50-200 cm) were measured. Habitat types in Pinery Provincial Park: BS- black oak savanna; BWS -black/white oak savanna; COF-conifer/oak forest; CS-cedar savanna; FF-floodplain forest, OF- oak forest. CS was based on two observations and has no S.E. error.

Toxic substances (e.g. in *Prunus serotina*) and mechanical defences (e.g. in *Berberis thunbergii*) make some plant species unpalatable to deer. The Black oak savanna (BS) and the Black/white oak savanna (BWS) habitats in Pinery had considerably more available woody browse in the 50-200 cm height class than any of the other habitats. This could be due to a higher proportion of unpalatable species present in these habitats. Species which are generally considered unpalatable to deer include *Prunus serotina, P. virginiana, Hamamelis virginiana*, *Rhus aromatica, Juniperus communis* and *Sassafras albidum* which comprised 92% and 91% of CAG biomass respectively in these habitats in 1995 (Fig. 8.2). Thus, grazing may contribute to the establishment of unpalatable species by reducing competition with palatable species. In 1995, the other Pinery habitats had between 20-68% of CAG biomass as unpalatable species.

In Rondeau, the proportion of available woody browse comprising unpalatable species was also very high, ranging from 39-86% of CAG biomass for the park (Fig. 8.3). Unpalatable species included *Carpinus caroliniana, Lindera benzoin*, *Berberis thunbergii*, *Rubus idaeus*, and *Fagus grandifolia*.

Finally, the high values of woody browse were in the range of 1 g dwt m^{-2} which is very, very low. In both parks, there is basically very little available woody browse, which begs the question - "what are the deer eating in the winter?"

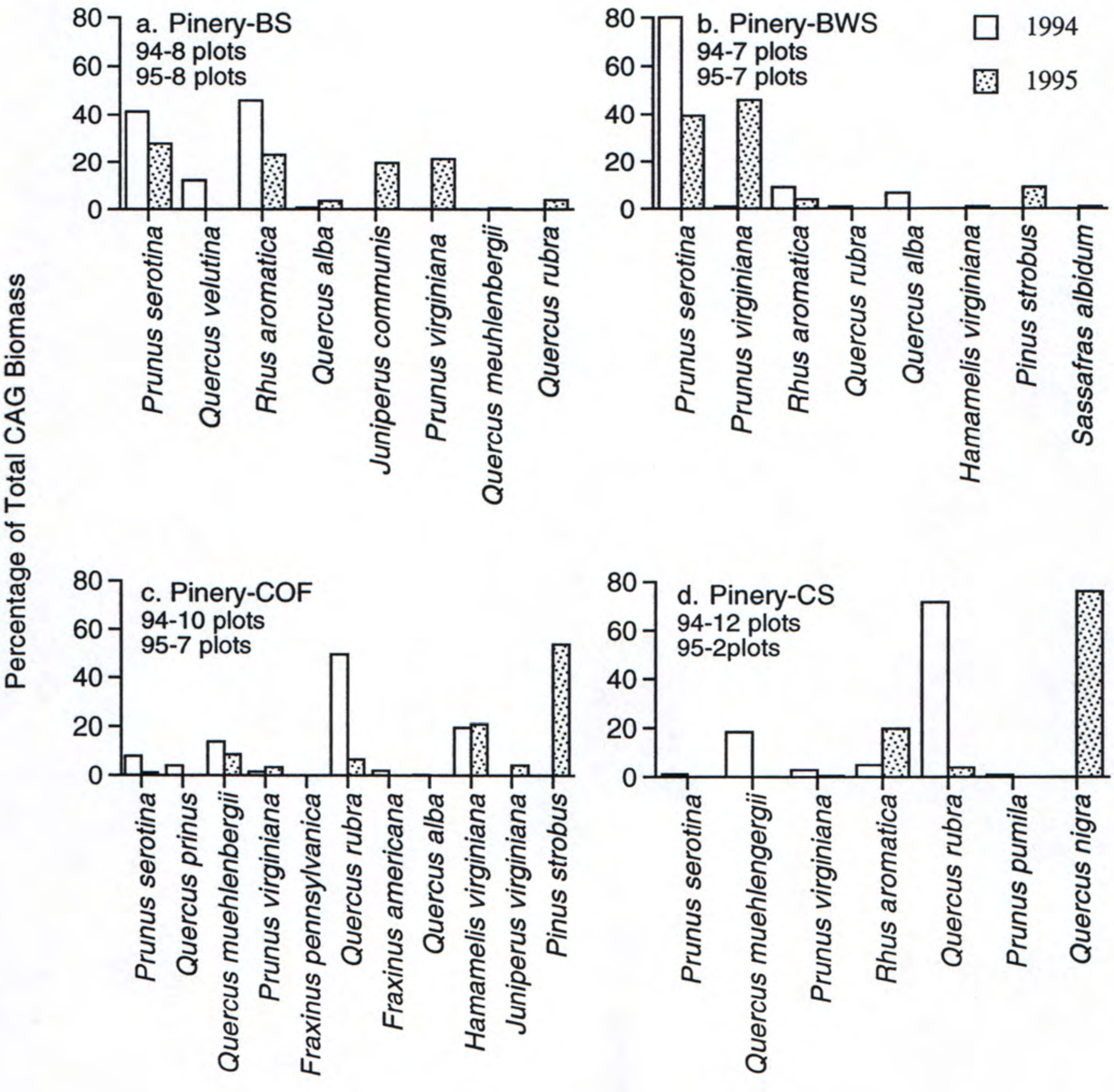

Figure 8.2. Composition of total current annual growth sampled (50-200 cm height class) in a.-f. Pinery Provincial Park and g.-i. Rondeau Provincial Park for 1994 and 1995. Pinery habitat types are: BS-Black oak savanna, BWS-Black/white oak savanna, COF-Conifer-oak forest, CS-Cedar savanna, FF-Flooplain forest, OF-Open forest.

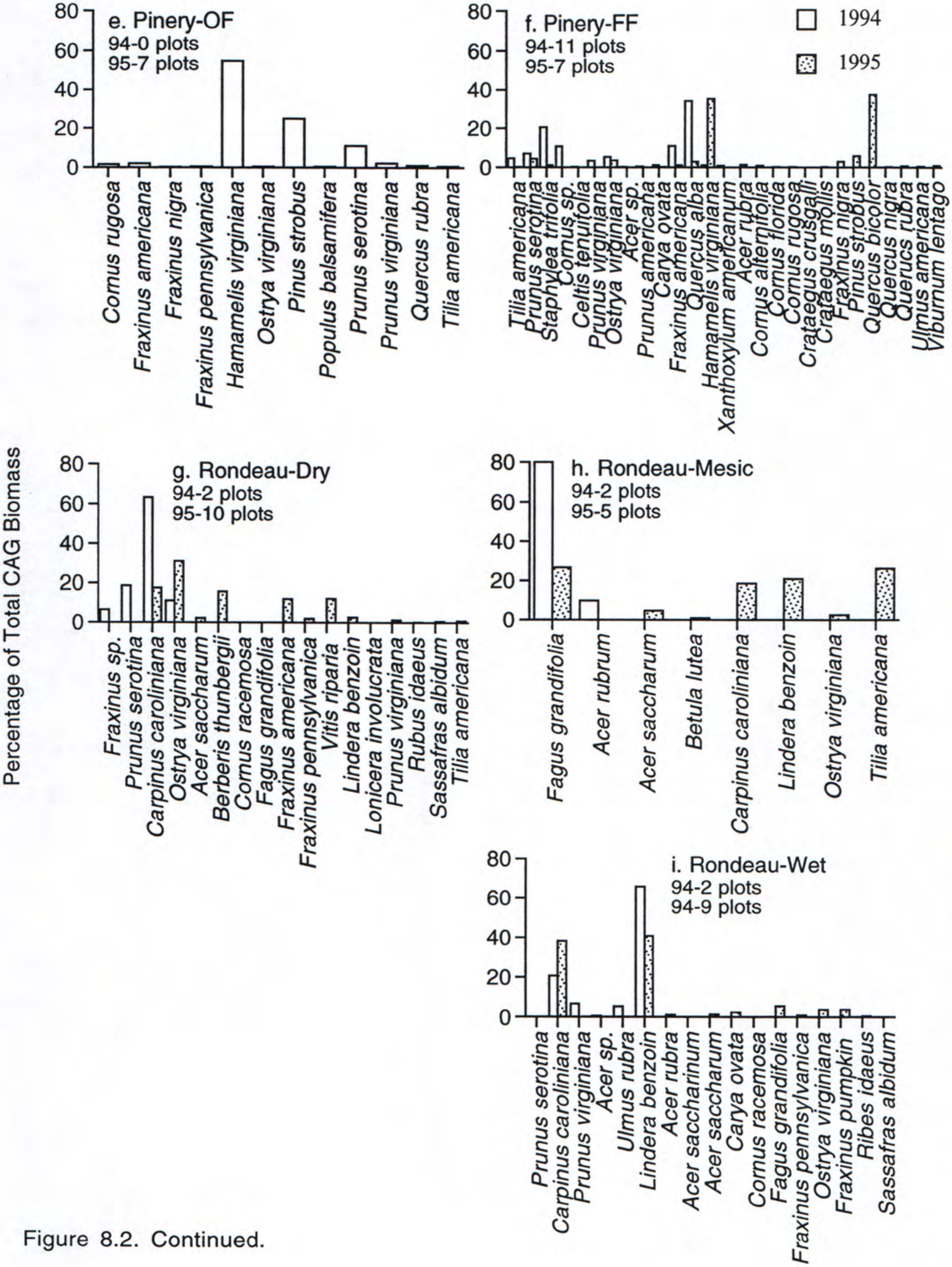

Figure 8.2. Continued.

CONCLUSION & RECOMMENDATION

Available woody browse in both Pinery and Rondeau Provincial Parks contained a high proportion of species considered unpalatable to deer and was at extremely low levels in 1995.

Nearly two years after the deer herd reduction in Rondeau there has been no obvious recovery in woody browse availability. This could be for two reasons. Either recovery has been slow and/or the deer population was not at a level low enough to allow regeneration. However, there was evidence of some recovery in woody plants in the 0-50 cm height class. Since this height class was not sampled by species, we do not know whether it had a greater representation of palatable species compared with the 50-200 cm height class.

Given the extremely low levels of woody browse availability in both parks, control of deer numbers is needed to allow recovery of this vegetation type.

Liriodendron tulipifera

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10. Related Research

Dennis, M. (1996) The response of *Arisaema triphyllum* to grazing by white-tailed deer in southern Ontario. B.Sc. (Hons) Thesis. York University.

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Appendix 1. Scientific names for abbreviations in Figures 2.1-2.3.

ALLIPETI	Alliaria petiolata
AMPHBRAC	Amphicarpa bracteata
AQUICANA	Aquilegia canadensis
ARISTRIP	Arisaema triphyllum
ASTERSP	Aster sp.
CAREXSP	Carex sp.
DENTLACI	Dentaria laciniata
FAGUGRAN	Fagus grandifolia
FRAXINSP	Fraxinus sp.
GALIUMSP	Galium sp.
GEUMMARCR	Geum macrophyllum
GEUMSP	Geum sp.
GRAMINSP	Graminoids
HYSTPATU	Hystrix patula
LINDBENZ	Lindera benzoin
MAIACANA	Maianthemum canadense
OSMOCLAY	Osmorhiza claytonii
PARTQUIN	Parthenocisuss quinquefolia
POLYGOSP	Polygonatum sp.
RHUSRADI	Rhus radicans
SOLIDASP	Solidago sp.
TRILLSP	Trillium sp.
VIOLAPUBE	Viola pubescens
VIOLASP	Viola sp.
VIOLSORO	Viola sororia

Appendix 2. List of all species found in all quadrats during the Garlic Mustard study at Rondeau Provincial Park.

Scientific Name	Common Name
Spring	
Adiantum pedatum*	maidenhair fern
Alliaria petiolata (adults and rosettes)	garlic mustard
Acer saccharum	sugar maple
Agrimonia rostellata*	beaked agromonia
Apios americana	groundnut
Aquilegia canadensis*	wild columbine
Arisaema triphyllum*	jack-in-the-pulpit
Fraxinus*	ash species
Aster macrophyllus*	large-leaved aster
Aster shortii*	shorts aster
Berberis thunbergii*	japanese barberry
Boehmeria cylindrica*	false nettle
Bromus inermis	smooth brome
Carex species*	sedge
Carpinus caroliniana*	blue-beech
Cerastium arvense	field chickweed
Cerastium vulgatum*	mouse-ear chickweed
Circaea quadrisulcata*	enchanter's nightshade
Cirsium arvense	Canada thistle
Cornus racemosa*	gray dogwood
Cryptotaenia canadensis*	honewort
Danthonia spicata*	poverty grass
Desmodium glutinosum*	pointed tick trefoil
Dicentra cucullaria	dutchman's breeches
Erigeron pulchellus*	robin's plantain
Equisetum arvense*	common horsetail
Galium aparine*	cleavers
Galium asprellum*	rough bedstraw
Galium circaezans*	wild licorice
Galium palustre*	marsh
Geranium robertiainum*	herb robert
Geum canadense*	white avens
Geum laciniatum*	rough avens
Glechoma hederacea*	gill-over-the-ground
Habenaria psycodes*	showy orchis
Hydrophyllum virginianum*	virgina waterleaf
Hystrix petula*	bottle-brush grass

Appendix 2. (continued). List of all species found in all quadrats during the Garlic Mustard study at Rondeau Provincial Park.

Scientific Name	Common Name
Leonurus cardiaca*	motherwort
Lindera benzoin*	spicebush
Liriodendron tulipifera*	tulip tree
Lonicera species*	honeysuckle
Lycopus uniflorus*	northern bugleweed
Maianthemum*	Canada mayflower
Nepeta cataria*	catnip
Monarda fistulosa*	wild bergamot
Onoclea sensibilis	sensitive fern
Osmorhiza claytoni*	hairy cicely
Osmorhiza longistylis*	aniseroot smooth
Osmunda claytoniana*	interrupted fern
Ostrya virginiana*	hop-hornbeam
Pteretis*	ostreich fern
Oxalis europaea*	yellow wood sorrel
Oxalis grandis*	great wood sorrel
Parthenocissus quinquefolia*	virginia creeper
Phalaris arundinacea*	craby grass
Plantago major*	common plantain
Poa compressa*	Canada bluegrass
Poa trivialis*	rough-stalked meadow grass
Podophyllum peltatum*	mayapple
Polygonatum canaliculatum	great soloman
Polygonatum pubescens*	hairy soloman
Polygonum scandens*	false buckwheat
Polymnia canadensis*	small-flowered leafcup
Pronanthes altimssima*	tall white lettuce
Prunus virginiana*	choke cherry
Rhus radicans*	poison ivy
Rhus typhina*	staghorn sumac
Rhus vernix	poison sumac
Ribes cynosbati*	prickly gooseberry
Rubus occidentalis*	black raspberry
Saponaria officinalis*	bouncing bet
Sassafras albidum*	sassafras
Scutellaria serrata*	showy skullcap
Smilacina racemosa*	false soloman
Smilacina stellata*	star-flowered solomon's seal
Smilax herbacea*	carrion flower

Appendix 2. (continued). List of all species found in all quadrats during the Garlic Mustard study at Rondeau Provincial Park.

Scientific Name	Common Name
Solanum dulcamara*	bittersweet nightshade
Solidago canadensis*	Canada goldenrod
Solidago flexicaulis*	zig zag goldenrod
Stellaria media*	common chickweed
Taraxacum officinale*	common dandelion
Tilia americana*	basswood
Tovara virginiana*	virginia knotweed
Urtica dioicia*	stinging nettle
Verbascum thapsus*	common mullein
Verbena urticifolia*	white vervain
Veronica peregrina*	purslane speedwell
Vinca minor*	periwinkle
Viola papilionacea*	common blue violet
Viola pubescenc*	downy yellow violet
Viola sororia*	woolly blue violet
Vitis aestivalis*	summer grape
Summer	
Alliaria petiolata (rosettes only)	garlic mustard
Amphicarpa bracteata	hog peanut
Fraxinus americana	white ash
Aster lateriflorus	starved aster
Aster sagittifolius	arrow-leaved aster
Cirsium vulgare	bull thistle
Cornus florida	eastern flowering dogwood
Fagus grandifolia	american beech
Fraxinus americana	white ash
Geranium maculatum	wild geranium
Hamamelis virginiana	witch-hazel
Impatiens	jewelweed
Lobelia cardinalis	cardinal flower
Phryma leptostachya	lopseed
Pilea pumila	clearweed
Prunus serotina	black cherry
Quercus alba	white oak
Ranunculus abortivus	kidneyleaf buttercup
Ranunculus recurvatus	hooked buttercup
Rubus flagellaris	dewberry

Appendix 2. (continued). List of all species found in all quadrats during the Garlic Mustard study at Rondeau Provincial Park.

Scientific Name	Common Name
Rubus idaeus	wild red raspberry
Sanicula gregaria	clustered snakeroot
Sanicula canadensis	short-styled snakeroot
Solidago caesia	blue-stemmed goldenrod
Stellaria media	common chickweed
Thalictrum polygamum	tall meadow rue
Viburnum alnifolium	hobblebush

*species found in both spring and summer counts