Implications of Spruce Budworm (Lepidoptera: Tortricidae: *Choristoneura fumiferana* Clem.) Management for the Species Diversity of Moths (Lepidoptera) and Carabid Beetles (Coleoptera: Carabidae) in the Manitoba Boreal Forest

By

Carla M. Wytrykush

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
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Master of Science

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Abstract

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Implications of spruce budworm (Lepidoptera: Tortricidae: *Choristoneura fumiferana* Clem.) management for the species diversity of moths (Lepidoptera) and carabid beetles (Coleoptera: Carabidae) in the Manitoba boreal forest.

Major professor: N. J. Holliday

The purpose of this study was to determine the implications of foliage protection measures as a spruce budworm management technique on the species diversity of moths and carabid beetles in the Manitoba boreal forest. This objective was addressed by comparing control sites not infested with spruce budworm, infested sprayed sites and infested unsprayed sites. A paired design of sprayed and unsprayed sites was used. Each pair of sites had a similar history of budworm infestation. An unpaired set of three control sites outside the area of infestation was also used. Treatment effects on the vegetation were assessed by quadrat sampling of the trees, shrubs and ground vegetation in each site. Light traps were used to collect moths, and pitfall traps for carabid beetles.

Summary diversity and abundance statistics did not show strong effects of treatment. There was higher tree diversity in most unsprayed sites presumably because of the presence of deciduous tree species. Shrub diversity was higher in sprayed sites. There were more moths in most sprayed sites in 1996. Two carabid beetle species, *Agonum retractum* LeConte, and *Sphaeroderus nitidicollis brevoorti* LeConte, were more abundant in unsprayed sites, and this tended to lower carabid diversity in the unsprayed sites.

Species composition, as reflected in ordination analysis, was more sensitive to treatments. The ordination of the vegetation data showed strong influences of treatment. The moth assemblage also showed responses to treatment and a close linkage to the vegetation patterns. The carabid beetle assemblage was not distinctly affected by the treatment imposed. It is concluded that the vegetation changes were the mechanism by which treatments influenced the insect assemblages, and that phytophagous insects were most influenced, because of their direct response to the vegetation assemblage.

Introduction

Spruce budworm, *Choristoneura fumiferana* Clem. is an important pest throughout the North American boreal forest. The larvae of this tortricid moth consume the needles of both white spruce (*Picea glauca* (Moench) Voss) and balsam fir (*Abies balsamea* (L.) Mill.). In Manitoba, a spruce budworm outbreak has been in progress since the early 1980's. In outbreak situations, with prolonged periods of severe defoliation, entire stands of trees can be killed. In Manitoba, foliage protection measures are a response to protect the trees from budworm attack. In reaction to budworm outbreaks, lepidopterous specific insecticide is applied in order to protect the foliage and prevent tree death. If insecticide is not applied, the budworm continue to defoliate, and death of the host trees is a likely outcome. This results in a type of secondary forest succession, that is unique from the succession produced following forest fire. This study compares this secondary succession with that resulting from spraying budworm infested sites.

The major objective of this research was to determine the implications of foliage protection measures as a form of spruce budworm management for the community ecology of insects in white spruce stands. A second goal was to assess whether spraying results in insect assemblages that are similar or different from uninfested forest. The primary focus of this thesis is on the species diversity and community assemblages of moths and carabid beetles approximately 5 years following severe budworm infestation and spray treatments. Because treatments induced changes in the vegetation, these were documented to provide insight into the insect responses.

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LITERATURE REVIEW

Disturbance and succession

Succession is the change of species composition and community structure in a site over time. Succession represents the development towards an equilibrium between organisms and the environment (Clements 1916). These changes occur following a disturbance that opens up a space in any ecological community (Connell and Slatyer 1977). Disturbance can be defined as a discrete event that alters ecosystem, community, or population structure, thereby changing resources, substrate availability, or the physical environment (White and Pickett 1985). This disruption either directly or indirectly creates opportunities for individuals of new species to establish (Sousa 1984). Succession may follow a predictable sequence beginning with a pioneer stage, continuing through consolidation and subclimax stages, to the final climax stage (Dansereau 1957). The temporal pattern of the changes in the floral and faunal assemblages following the disturbance is the successional pathway (Pickett *et al.* 1987).

During succession, the major events are that species colonize sites and species become extinct, and their abundance changes. This is a complex process and so special techniques are used to examine the major patterns of this process. These techniques include measurement of diversity, and elucidation of major patterns using ordination analysis.

Ecological Diversity

As communities progress through the successional pathway, there are temporal changes in community attributes, including changes in diversity. Measurement of diversity may therefore provide information about successional processes.

Diversity is an important concept in ecology. However, despite the vast array of literature on the subject, diversity is somewhat difficult to define. Most simply, ecological diversity refers to the richness and variety within a community (Pielou 1975). Magurran (1988) describes ecological diversity as a measure of community content expressed in terms of the number and relative abundance of the species within an area. Most ecologists study diversity at one of two levels related to community scale: species diversity, or ecosystem diversity. Species diversity is an indicator of the number and relative abundance of species within a single habitat. This is also called alpha (α) diversity. Ecosystem diversity relates to changes in species composition between two or more habitats. Ecosystem diversity is also called beta (β) diversity (Pielou 1975, Magurran 1988).

Diversity measurements can provide information on mechanisms of community assembly, as well as insight into the effects of environmental change on an ecosystem (Pielou 1975). It is important to examine ecological diversity following disturbances to determine how ecosystems respond to various disturbances. There may be benefits to managing human-induced disturbances so that the ecosystem responds to them in the same way as to natural disturbances (Dennis and Patil 1979, Frambs 1990). Species diversity can be used as an indicator of ecosystem health (Pielou 1975). An understanding of how diversity has changed as a result of any type of disturbance is necessary in understanding the effects of a disturbance on the ecosystem.

There are many different indices used to measure species, or alpha diversity. Magurran (1988) summarized the more commonly used alpha diversity measures. She evaluated the indices based on their theoretical properties, dependency on sample size, ability of the index to discriminate between sites, and whether or not the index is easily understood and widely used. Two of the most commonly used indices are the Shannon Wiener index, and the log series alpha index.

The Shannon Wiener index is easily calculated, and is widely used. It assumes that individuals are sampled from an infinitely large population. Although it is easy to calculate, the index has only moderate discriminating abilities, is highly influenced by the most abundant species, and is quite sensitive to sample size (Magurran 1988). The Shannon Wiener index is useful when calculating diversity from proportional values rather than abundance data (Causton 1988).

The log series alpha index describes the log series distribution of species abundance, which is widely applicable (Fisher *et al.* 1943). The index is calculated from the relationship between the number of individuals, and the number of species in the habitat (Fisher *et al.* 1943). It is less influenced than the Shannon Wiener by the most abundant species, and has good discriminatory ability (Magurran 1988). It is also less affected by sample size (Magurran 1988). The log series alpha has been used by researchers studying insect diversity (Taylor *et al.* 1976, Holliday 1992, Lafrenière 1994, Thomas and Thomas 1994, Elliott 1997).

Ordination

Ordination analysis is a term for the multivariate techniques used to analyse multidimensional data sets that arrange sites along axes on the basis of species composition data (Jongman *et al.* 1995). Ordination results in a diagram in which sites are represented by points in two dimensional space (Jongman *et al.* 1995). The goal of ordination analysis is to arrange these points in two dimensional space so that points that are close together are similar in species composition, and points that are far apart are dissimilar (Jongman *et al.* 1995). The eigenvalue of each ordination axis is a measure of the importance of that axis (ter Braak and Šmilauer 1998). The first axis (axis 1) has the largest eigenvalue and represents the largest portion of the variance; axis 2 has the second largest eigenvalue, and represents the second largest portion of the variance (Green and Carroll 1976). The ordination axes can be often be interpreted as related to environmental variables, and inferences drawn based upon what is known about the species and the environment (Jongman *et al.* 1995).

Boreal forest characteristics

The boreal forest is the largest ecological zone in Canada. It occupies more than 30% of the mainland, over 2.6 x 10^6 km^2 (Danks and Foottit 1989). The forest is primarily coniferous, and is characterized by white spruce (*Picea glauca* (Moench)Voss), and black spruce (*P. mariana* Lamb.) (Rowe 1956). Balsam fir (*Abies balsamea* (L.)Mill.) and jackpine (*Pinus banksiana* Lamb.) are also important along with some deciduous species including: birch (*Betula papyrifera* Marsh.), mountain maple (*Acer spicatum* Lam.), hazelnut (*Corylus cornuta* Marsh.), and aspen (*Populus tremuloides*

Michx.) (Rowe 1956).

Disturbance is a natural, recurring phenomenon in the boreal forest and is important in ensuring the long-term development of the ecosystem (Danks and Foottit 1989). Disturbances in the boreal forest lead to secondary succession (Rowe 1983). Such disturbances are important sources of spatial and temporal heterogeneity in the boreal forest, as well as agents for natural selection (Sousa 1984). Disturbance maintains a mix of successional stages in the "vegetative mosaic", leading to variation within the boreal forest ecosystem (Wright and Heinselman 1973, Danks and Foottit 1989). Major disturbances such as fire, or insect outbreak are natural disturbances that create large gaps in the forest that are subsequently colonized by plant species (Danks and Foottit 1989, Fleming and Candau 1998). These colonizations are the starting points for successional processes. As forest succession proceeds, there are changes in structure and composition of vegetation over time. Tied to these floral changes, are the changes in the faunal assemblages as succession proceeds (Danks and Foottit 1989).

Insect outbreaks are an important disturbance throughout the boreal forest. Throughout history there have been severe outbreaks of insect defoliators that have caused damage and mortality of trees over large tracts of forest (Bonan and Shugart 1989). When trees are defoliated by insects, photosynthetic capacity is reduced, and primary productivity declines. When an outbreak occurs, the feeding by a large number of insects causes reductions in photosynthesis, and interference with translocation and transpiration. Defoliation of coniferous trees can affect photosynthesis for 3-4 years (Kulman 1971, Larsen 1980). Insect attack can cause tree mortality directly, or it can decrease growth, or increase susceptibility to further insect attack, which may lead to tree mortality (Kulman 1971). Mortality of trees caused by insect outbreaks is an important disturbance in the boreal forest. Defoliation by insects and subsequent tree death releases the understory vegetation and permits succession to proceed.

Boreal forest vegetation does not tend to progress toward a single climax community type (Johnson and Rowe 1975, Black and Bliss 1978, Carleton and Maycock 1978). The replacement of canopy trees by an understory of the same species does not usually occur in the boreal forest (Rowe 1961, Dix and Swan 1971, Black and Bliss 1978, Carleton and Maycock 1978, Johnson 1981, Bergeron and Dubuc 1989, Johnson 1992). As the boreal forest regenerates following a disturbance, there will be portions of the forest in which different floral associations dominate, and each location has a regeneration cycle influenced by site and environmental conditions, both before and after disturbance (Larsen 1980, Bergeron and Dansereau 1993, Youngblood 1995). Even with constant abiotic conditions, there are numerous successional patterns following a fire in the boreal forest (Bergeron and Dubuc 1989). In Canada, forest conditions and vegetation species composition varies from east to west and north to south creating regional differences in successional patterns (Larsen 1980).

Following disturbance caused by an insect outbreak there is vegetational succession. Morin (1994) found even-aged, and unimodal stands of balsam fir regenerating from a single spruce budworm outbreak. Areas that had been affected by two separate budworm outbreaks were characterized by bimodal, uneven-aged stands of balsam fir (Morin 1994). Bergeron and Dansereau (1993) observed a general trend from deciduous to coniferous forest following fire in the Québec boreal forest. However, this trend is interrupted in the presence of spruce budworm outbreaks. In severe outbreaks, the budworm causes mortality of balsam fir, which leads to a mixed deciduous forest (Bergeron and Dansereau 1993).

The vegetation changes following disturbance in the boreal forest have important implications for the floral and faunal communities present. There are many factors influencing these vegetation changes including: the type of disturbance, pre- and post-disturbance stand characteristics, climatic factors, moisture regimes, and vegetation characteristics. All of these factors interact making successional changes in the boreal forest difficult to study, understand, and predict.

These successional processes have implications for boreal forest diversity. For both the floral and faunal assemblages, species richness is usually low immediately following a disturbance event and also at the climax. In these two successional stages there are limitations on the types of species that can occupy the sites (McLeod 1980, Petraitis *et al.* 1989). The ability to colonize a disturbed site, or to inhabit a late-successional site, is related to the life history strategies and competitive abilities of the organism. As the forest regenerates following a disturbance such as fire or insect attack, there is an increase in species diversity of certain plant groups (Ahlgren 1960, Shafi and Yaranton 1973, Abrams and Dickmann 1982, Abrams 1989). The increased diversity is not permanent, and usually lasts only a few years. Several studies have shown that species richness increases after fire; burning promotes the establishment of plant species not typical of unburned areas (Ahlgren 1960, Abrams and Dickmann 1982).

Evergreen coniferous forests generally have lower vegetational diversity than broadleaf deciduous forests (Whittaker 1965, La Roi 1967). La Roi (1967) suggests that many boreal plant species are physiologically unable to colonize coniferous forests. Leaf litter from evergreen trees decomposes more slowly than deciduous leaf litter (Whittaker 1965). The evergreen condition creates less seasonal variation in light conditions, which may reduce the diversity of herbaceous vegetation (Whittaker 1965).

The spruce budworm

Spruce budworm (*Choristoneura fumiferana* Clem.) is a naturally occurring boreal forest defoliator in North America. This insect feeds on balsam fir (*Abies balsamea* (L.) Mill.), and the spruces, but generally favouring white spruce over black spruce. When population levels of this insect are high, and the forest is unprotected, budworm causes severe defoliation. This results in reduced volume and height, stem deformities, increased susceptibility to disease and other insects, and tree mortality (MacLean 1985). Tree mortality caused by outbreaks of spruce budworm is a natural phase in the dynamics of the boreal forest (Blais 1954). Trees usually begin to die after 4-5 years of severe defoliation by spruce budworm. After 10-15 years of defoliation, mortality can claim 70-100% of the trees in a stand, and the outbreak then collapses (MacLean 1980).

The susceptibility of a region to spruce budworm outbreaks, as well as the duration and severity of attack, and the rate of spread of the outbreak are affected by a number of factors. The structure and composition of the forest stand is an important factor (Bonan and Shugart 1989): Spruce budworm prefers mature balsam fir over spruce

(*Picea* spp.) (MacLean 1980). Epicentres of spruce budworm outbreaks are forest types characterized by ecological conditions that promote balsam fir, and white spruce (Hardy *et al.* 1983). Vulnerability to spruce budworm is related to ecological characteristics other than tree species composition. These factors include: moisture regime, climate, tree density, tree age, tree phenology and tree vigour (MacLean 1980, Dupont *et al.* 1991, Morin *et al.* 1993).

In eastern Manitoba, the most recent spruce budworm outbreak began in 1975. Balsam fir mortality has been significant throughout the infestation area (Anon. 1986, 1987, 1988, 1989, Knowles 1991a,b, 1992, 1993, Knowles and Matwee 1994). This mortality has had significant economic implications. In 1991, 15% of the spruce/fir forest within Abitibi-Price Inc. Forest Management Licence in Manitoba was dead timber as a result of spruce budworm infestation. This timber potentially could have contributed $30 million to the province's gross domestic product (Knowles *et al.* 1992).

Because of the economic effects resulting from the spruce budworm outbreak, foliage protection measures are undertaken to protect trees from defoliation. Aerial applications of insecticide are used to protect the trees from budworm defoliation. From 1986 to 1990 aerial applications of the insecticide *Bacillus thuringiensis* (*Bt*) were used to protect trees in various areas of the Manitoba spruce budworm outbreak region (Anon. 1986, 1987, 1988, 1989, Knowles 1991a,b, 1992, 1993, Knowles and Matwee 1994).

Insects and forest succession

There is little information in the scientific literature that discusses the patterns of moth succession in forest systems following disturbance. Moths are generally phytophagous as larvae and therefore are linked strongly to their habitat. It is thought that as species richness of plants changes through succession, so does the species richness of Lepidoptera (Hammond and Miller 1998). Most adult moths are nocturnal, and therefore are not strongly affected by light levels in the forest, but are sensitive to changes in temperature and humidity (Muirhead-Thomson 1991).

Hammond and Miller (1998) compared species richness and abundance of moths in three different vegetation types. Hardwood trees and shrubs supported the greatest species richness and numbers of moths, followed by herbs and grasses. The lowest species richness and abundance was supported by conifer trees. Their study began following a multi-year outbreak of the western spruce budworm, *Choristoneura occidentalis* Freeman. These authors hypothesize that the outbreak of a conifer-feeding caterpillar may decrease the abundance of other conifer-feeding moths, and increase the abundance of hardwood and herb-grass-feeding moths (Hammond and Miller 1998). If an outbreak of conifer-feeding larvae creates a gap in the forest through canopy decline through defoliation or tree death, woody deciduous vegetation can flourish. Consequently, hardwood and herb-grass-feeding insects may occur as their host plants become more abundant.

Following disturbance, a typical pattern of carabid succession is evident. There is a clear difference in the carabid species and assemblage composition from the early, open successional stages, to the older, closed canopy stages (Niemelä *et al.* 1996). In early regeneration following disturbance, the carabid fauna is dominated by macropterous, open habitat species (Holliday 1991, Lafrenière 1994). As the forest matures, the fauna becomes dominated by large, brachypterous species (Holliday 1991, Lafrenière 1994). The trend toward increasing brachyptery continues until the forest is dominated by conifers, but the trend toward increasing body size is restricted to the early stages of regeneration (Holliday 1991).

Survival of forest fires may not be an important strategy for carabid beetles (Holliday 1991). Beetle species may become locally extinct as they are killed by the fire. It is probably not beneficial for carabid beetles to survive a fire on site. The extreme changes in habitat following a fire may force beetles to emigrate, or die (Holliday 1991). Immediately following logging of an old-growth site, a high proportion of carabid species characteristic of old-growth forest remain. This proportion declines rapidly, probably because the old-growth specialists are not able to survive on the logged site (Niemelä *et al.* 1996). Species occurring in the mature coniferous forest make up >60% of the carabid assemblage in all successional stages following logging (Niemelä *et al.* 1996). Canopy dieback is another type of disturbance that may affect carabid beetles. Dieback does not alter the dominance structure of the carabid community, but reduces the abundance of all carabids except the most dominant species (Martel *et al.* 1991).

In forest successions, the species richness of the carabid fauna is strongly influenced by microclimatic conditions and plant ecology of the habitat (Lafrenière 1994). Niemelä *et al.* (1996) argue that because carabid beetles are predators, they are more dependant on habitat characteristics that determine the availability and abundance of prey, and which aid in successful hunting, than on particular plant species. Low carabid abundance is associated with low prey abundance in the soil, which implies that carabid abundance may be controlled by the numbers of prey in the soil (Guillemain *et al.* 1997). Holliday (1991) suggests that the distinct environment of early successional stages might lack suitable prey for large carabids, and this could be why larger species do not arrive until later regeneration stages. Habitat heterogeneity affects carabid species richness (Niemelä *et al.* 1992). In a black spruce succession during the11 years following fire, the rate of species turnover is influenced by habitat structure. Habitat heterogeneity probably represents the availability of niche space in the forest site (Holliday 1992).

Summary

Spruce budworm defoliation is a disturbance that permits floral and faunal succession to proceed. These successional processes are important to forest regeneration and have implications for the diversity of organisms that inhabit it. Because the forest is an important economic resource, budworm suppression measures are necessary to protect the foliage. There is little research that determines how suppression of spruce budworm defoliation affects the longer term dynamics of the forest. The implications of spruce budworm management for forest succession and diversity can be studied through investigations of the floral changes and accompanying responses of the insect fauna.

MATERIALS AND METHODS

General study area description

This study was conducted in 1996 and 1997 in the boreal forest region of Manitoba, east of Lake Winnipeg, and between latitudes 49° and 52°N. The study areas were located in Nopiming Provincial Park and Whiteshell Provincial Park, within the Subhumid Transitional Low Boreal ecozone of Southeastern Manitoba (Zoladeski *et al.* 1998)

Experimental design

The study was intended to compare the long term effects of spruce budworm management on arthropod assemblages. Comparisons were made between sites that had applications of Lepidoptera-specific insecticides (*Bt*) with sites that had received no insecticides. Because of the heterogeneity of budworm infestations in the region, insecticide-treated and control sites were paired by geographic location. In addition, uninfested control sites were selected, just outside the region affected by the budworm outbreak.

Site selection and description

Spruce budworm infestation and spray location maps provided by Manitoba Conservation were used to select white spruce-balsam fir forest stands in which potential sites could be placed. Many potential stands were visited, and 13 stands were selected. One study site was set up in each stand. This resulted in five sprayed-unsprayed site pairs and three uninfested control sites as detailed in Fig. 1 and Table 1. Table 1 also summarizes the spray dates for the infested sprayed sites. In total, 14 sites were used. During the winter of 1996, parts of the Long Lake area were logged. In 1997, site 3-S-96 was unsuitable for sampling, and site 3-S-97 was used as a replacement site for comparison with site 3-NS.

Most sites were 100 m x 100 m square plots, and located 20 m away from major discontinuities such as a roadways or lakes (Fig. 2). To maintain this 20 m buffer, sites in one pair, 2-NS and 2-S, had to be rectangular, measuring 166 m x 60 m (Fig. 3). Following the 1996 winter logging, the shape of site 4-S had to be modified so that the 20 m buffer zone could be maintained (Fig. 4).

Vegetation sampling

Vegetation sampling occurred in 1996 and 1997. A stratified random design was used in square sites. Each square site was divided into four quadrants (Fig. 2). Random quadrats were chosen so that there was at least one tree sample, two shrub samples, and two ground vegetation samples in each quadrant. In sites that were not square, the same total numbers of each type of quadrat were taken in a completely randomized manner.

To assess tree vegetation, five randomly selected 10 m x 10 m quadrat samples were taken in each site. Trees were considered to be any woody vegetation greater than 2 m in height. Each tree was identified to species. The circumference at breast height (CBH) was also measured for any tree with CBH >10 cm.

Ten randomly selected 2 m x 2 m quadrats were used to assess shrub vegetation. Shrubs were considered to be any woody vegetation >50 cm, but <2 m in height. To assess ground vegetation, ten 1 m x 1 m quadrats were randomly selected

(Fig. 5). Ground vegetation consisted of any herbaceous vegetation, and any woody vegetation <50 cm in height. In each quadrat sample of ground and shrub vegetation, the number of stems and percent cover were recorded for each species.

Insect sampling

Moths

Adult moths were collected using one Luminoc® battery operated light trap (Fig. 6) placed in the centre of each site (Figs. 2-4). An ultraviolet light source was used at the low light intensity level. Each trap was powered by a 6V battery. A trichlorvos impregnated strip of resin (Vapona®) was placed in each trap to kill the adult moths. Each night at dusk, the light was turned on by a photocell, and operated for 4 hours. The traps were hung in trees, approximately 2 m from ground level (Fig. 7). Traps were operated from 23 May to 27 October 1996 and from 21 May to 02 October 1997, and emptied at two week intervals. The sampling dates for each site are shown in Table 1. Specimens were returned to the laboratory for identification.

Carabid beetles

Adult carabid beetles were collected using 9 cm diameter pitfall traps with the rims level to the ground surface. Each trap consisted of either two 445 ml, or two 240 ml plastic cups nested together. The shallower cups were used where rocks prevented the deeper cups being sunk into the ground. Traps were filled ⅔ full with a 50:50 mixture of propylene glycol and water to act as killing agent and preservative (Fig. 8). Each trap was covered by a 15 cm x 15 cm square plywood rain cover suspended about 2 cm above the ground on legs of nails (Fig. 8).

Each site contained 16 pitfall traps arranged in a grid, as shown in Figs. 2-4. Traps were set 20 m away from the site edge, with 20 m between each trap. Traps were emptied every two weeks from 04 June to 10 November 1996 and from 21 May to 02 October 1997. The sampling dates for each site are summarized in Table 1. Trap contents were returned to the laboratory where adult carabid beetles were separated from other specimens and identified to species.

Data analysis

The percent cover and the number of species were used to indicate species occurrence and species richness for the shrub and ground vegetation. The Shannon Wiener diversity index (H′) was used as an index of alpha diversity of the shrub and ground vegetation for each site using the equation:

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

Where s is the total number of species found in the site, and p_i is the average percent cover of the i^{th} species divided by the total percent cover of all species found in the site (Krebs 1989).

Percent cover values used to calculate p_i were the average for the quadrats taken in the site.

The number of stems and the number species of were used to indicate species occurrence and species richness for the tree vegetation. The number of individuals collected and the number of species were used to indicate species occurrence and species richness for both the carabid beetles and moths. Alpha diversity of the tree vegetation, carabid beetles, and moths for each site was indicated by the log series alpha of the equation:

$$S = \alpha \ \ln\left(1 + \frac{N}{\alpha}\right)$$

The log series alpha was calculated for each site using a two step process. In the first step, the logarithmic series parameter, *x*, was estimated using least squares minimization in the NONLIN module of SYSTAT, (Wilkinson 1997) for the equation:

$$\frac{S}{N} = \frac{1-x}{x}\left[-\ln(1-x)\right]$$

> Where *S* is the total number of species in the sample and *N* is the total number of individuals in the sample. The value of *x* ranges between 0 and 1 (Williams 1964).

The log series alpha was derived from *N* and the estimate of *x* using the equation:

$$\alpha = \frac{N(1-x)}{x}$$

Analysis of variance was used to determine the significance of the effect of treatment (control, spray, no spray) on the number of individuals or percent cover, the number of species, and the index of alpha diversity for all sites. In the ANOVA analysis for vegetation, all 14 sites were analyzed together including sites 3-S-96 and

3-S-97. Paired t-tests were used to determine the significance of differences between sprayed and unsprayed site pairs. For the paired t-tests, the analysis was performed on the sites sampled for each year separately. In order to render the mean and variance independent, these statistical analyses were performed on log transformed data. The level considered significant for all statistical analyses was $p \leq 0.05$.

Ordination analysis by correspondence analysis, and canonical correspondence analysis were conducted using the default settings of the CANOCO version 4 software (ter Braak and Šmilauer 1998), except that all data were transformed logarithmically before ordination analysis. In canonical correspondence analysis, unrestricted Monte Carlo permutation tests were used to determine the significance of the relationship between the environmental variables and the species data. For each Monte Carlo test, 199 iterations were used (ter Braak and Šmilauer 1998).

Because preliminary analyses showed that the Whiteshell sites (5-S, 5-NS, and C-3) were often outliers in the results, all analyses were performed with and without the Whiteshell sites. Statistical test results are always provided for tests of the complete data set. Where exclusion of the Whiteshell sites does not affect the significance of hypotheses tests, the detailed test results for the reduced data set are not given.

RESULTS

Trees

The results of the tree vegetation sampling are summarized in Appendix I. For each site, the most common tree species, the percentage of coniferous trees, and the mean circumferences at breast height (CBH) of trees with CBH >10 cm are summarized in Table 2.

In uninfested control sites, the three most common tree species were *Alnus* sp., *Abies balsamea*, and *Picea glauca.* Ten different tree species were in samples from control sites, and *Larix laricina* (DuRoi) K. Koch was unique to control sites. In infested unsprayed sites, the three most common tree species were *Acer spicatum*, *Corylus cornuta*, and *Abies balsamea.* Thirteen different tree species were in samples from the unsprayed sites. No species were unique to unsprayed sites. In the infested sprayed sites, the three most common species were: *Acer spicatum*, *Abies balsamea*, and *Corylus cornuta.* Fifteen different species were in samples from sprayed sites. Two of these, *Prunus virginiana* L., and *Quercus macrocarpa* Michx. were trees unique to the 5-S site located in the Whiteshell Provincial Park.

There was no significant effect of site type on the number of tree stems (F=0.58, df=2,11) (Fig. 9). Paired t-tests showed no significant difference between sprayed and unsprayed site pairs in the number of tree stems in sites sampled during both years (1996:t=1.53, df=4; 1997:t=0.83, df=4) (Fig. 10).

There was no significant effect of site type on the number of tree species (F=0.20, df=2,11) (Fig. 11). When the Whiteshell sites (5-S, 5-NS, and C-3) were removed from the analysis, there is a non-significant trend for there to be more species in unsprayed sites than sprayed sites (F=3.7, df=1,8) (Fig. 12). Paired t-tests showed no significant difference between sprayed and unsprayed site pairs in the number of tree species in either 1996 or 1997 sites (1996:t=0.69, df=4; 1997:t=0.31, df=4) (Fig. 13).

Log series alpha diversity of the tree vegetation was not significantly affected by site type (F= 0.10, df=2,11, p=0.90) (Fig. 14). When the Whiteshell sites were removed, a contrast of sprayed and unsprayed sites suggests that diversity tended to be higher in unsprayed sites (F=3.9, df=1,8, p=0.085) (Fig. 15). Paired t-tests showed no significant difference between sprayed and unsprayed site pairs in the log series alpha for sites sampled during either year (1996:t=0.35, df=4; 1997:t=0.04, df=4) (Fig. 16). However, when the Whiteshell sites were omitted from the analysis, alpha diversity was significantly higher in unsprayed sites for the 1997 sites, and almost significantly higher for the 1996 sites (1996:t=2.84, df=3, p=0.07; 1997:t=5.72, df=3, p=0.01).

Correspondence analysis of tree vegetation

Correspondence analysis (CA) of the tree species and all 14 sites produced an ordination diagram in which 50.9% of the variation in species data is explained by the combined eigenvalues of the first two axes (Fig. 17). The first axis separates the sites based on budworm infestation. All of the sites that have no recent history of budworm infestation (Control sites) were separated from most of the other sites and placed at the positive end of axis 1. In general, the budworm infested sites (S, NS) were negatively correlated with the first axis. The second correlation axis does not provide significant separation of sites. However, site 5-S has a strong positive correlation with the second axis and is separated from all other sites in ordination space. Two species, *Prunus virginiana* and *Quercus macrocarpa*, are placed near site 5-S. These two species were present as trees only in the 5-S site and as a result, this site was separated from the others in ordination space. The O'Hanly River control sites (C-1, C-2) and *Larix laricina* have a negative correlation with the second axis. Several of the tree species are located near the origin of the ordination diagram. These species are associated with most sites. Some of these species include: *Populus tremuloides, Betula papyrifera,* and *Picea glauca.*

Because site 5-S has such a strong influence on the ordination, the analysis was performed excluding the Whiteshell sites. When the Whiteshell sites (5-S, 5-NS, C-3) were removed from the CA, the combined eigenvalues of the first two ordination axes explain 56.9% of the variation in species data. As before, the first ordination axis separates the sites based upon budworm infestation (Fig. 18). The uninfested control sites are located on the positive side of the first axis. However, the second ordination axis now separates the infested sites based upon their treatment. The sprayed sites are positively correlated with the second axis, and the unsprayed sites are located toward the negative end of axis 2. The 3-S-97 site is placed near the negative end of the second axis with the unsprayed sites. This appears to be because *Corylus cornuta* is a dominant tree in this site, and this species is more typical of unsprayed sites.

Canonical correspondence analysis of the tree vegetation

Canonical correspondence analysis (CCA) of the tree vegetation produced an ordination diagram in which there was collinearity among the environmental variables. Forward selection was used to determine which environmental variables were most important in describing the variation. Two environmental variables were significant: Infestation and control. To allow comparisons of sites based upon treatment, unsprayed, and sprayed were included as environmental variables.

The sum of the eigenvalues of the first two axes is 0.280, and these axes explain 34.2% of the variation in the species data, and 75.9% of the species-environment relationship (Fig. 19). A Monte-Carlo test shows that the canonical axes are significant (F=1.84, p=0.01).

The first axis separates the uninfested control sites from the budworm infested sites. *Larix laricina* is important in placing the control sites near the positive end of axis 1. If the three control sites are ignored, the second axis separates the other sites into three groups based upon treatment. Sites 4-S, 1-S, and 2-S are placed together near the positive end of the second axis, all of the unsprayed sites are placed near the origin of the axis, and sites 5-S, 3-S-96 and 3-S-97 are placed together toward the negative end of the second axis.

When the Whiteshell sites are excluded from the CCA, an ordination diagram is produced in which 49.2 % of the variation in the tree species data, and 81.2 % of the species-environment relation is explained by the first two ordination axes (Fig. 20). The groupings that were evident with all sites included have broken down. The first axis separates the two control sites from all of the others, but the second ordination axis does not provide adequate separation of the sites based upon treatment.

Shrubs

The results of the shrub vegetation sampling are summarized in Appendix II. The most common shrub species are summarized in Table 2.

The most common shrub species in control sites were *Cornus stolonifera* Michx., *Ledum groenlandicum* Oeder, *Alnus* sp., and *Amelanchier alnifolia* Nutt.. Two species were unique to control sites *Rhamnus alnifolia* L'Hér and *Kalmia polifolia* Wang. Some shrub species common in the budworm infested sites were absent in the control sites. These species were *Acer spicatum, Betula papyrifera, Populus tremuloides,* and *Lonicera dioica* L.

In unsprayed sites the most common shrub species were *Corylus cornuta, Rubus idaeus* L. [var. *strigosus*] (Michx.) Maxim., *Acer spicatum*, and *Abies balsamea. Diervilla lonicera* Mill., *Ribes americanum* Mill., and *Rubus pubescens* Raf. were unique to unsprayed sites. Species found in the other site types but absent from unsprayed sites include *Fraxinus pensylvanicus* Marsh., *Ledum. groenlandicum, Vaccinium myrtilloides* Michx., and *Viburnum edule* (Michx.) Raf.

The most common shrub species in sprayed sites were: *A. spicatum, C. cornuta, Abies balsamea,* and *Rubus idaeus*. Several species were unique to sprayed sites. These species were: *Apocynum androsaemifolium* L., *Ribes* sp., *Cornus alternifolia* L. f., and *Prunus virginiana*. *Apocynum androsaemifolium,* and *Ribes* sp. were found only in the 5-S site in the Whiteshell Provincial Park. *Cornus alternifolia* was only found in site 3-S-97. *Prunus virginiana* was found in site 5-S and site 3-S-97, however only one stem was sampled in the 3-S-97 site. Both *Ribes* *oxycanthoides* L., and *Salix* sp. were absent from sprayed sites.

The percent cover of the shrub vegetation was not affected by site type (F=2.108, df=2,11, p=0.17) (Fig. 21). A contrast of the unsprayed sites versus the sprayed sites showed a higher percent cover in unsprayed sites that was almost significant (F=4.206, df=1,11, p=0.065). Paired t-tests revealed no significant difference in the total average percent cover for sprayed and unsprayed site pairs (1996: t=-1.93, df=4, p=0.16; 1997:t=1.26, df=4, p=0.27) (Fig. 22).

Site type did not significantly affect the number of shrub species for sites (F=0.43, df=2,11, p=0.67) (Fig. 23). Paired t-tests showed no significant difference between sprayed and unsprayed site pairs in the number of shrub species present for either 1996 or 1997 sites (1996:t=-0.2, df=4, p=0.85; 1997:t=-0.44, df=4, p=0.68) (Fig. 24).

There was no significant effect of site type on the Shannon Wiener index of diversity for the shrub vegetation (F=2.94, df=2,11, p=0.095) (Fig. 25). A contrast of the unsprayed sites versus the sprayed sites showed significantly higher diversity in sprayed sites (F=4.91, df=1,11,p=0.05). A paired t-test between sprayed and unsprayed sites in 1996 showed no significant difference in Shannon Wiener diversity (t=-2.34, df=4, p=0.08) (Fig. 26). However, in 1997, Shannon Wiener diversity was higher in sprayed sites compared to unsprayed sites(t=-2.69, df= 4, p=0.05) (Fig. 26).

Correspondence analysis of shrub vegetation

Correspondence analysis of the shrub species produced an ordination diagram where 43.6% of the variation in species data is explained by the first two ordination axes (Fig. 27). The first axis separates the Whiteshell site 5-S from all other sites and places it at the positive end of the axis with species including *Prunus* sp., *Apocynum androsaemifolium*, and *Fraxinus pensylvanicus*. *Apocynum androsaemifolium* is a species unique to this site.

The second axis separates the sites based upon budworm infestation. All of the sites with no recent history of budworm infestation (C-1, C-2, C-3) are separated from the budworm infested sites, and placed at the positive end of the second axis. These sites are associated with species such as *Ledum groenlandicum* and *Rhamnus alnifolia*. Species common in moist areas are more positively correlated with the second ordination axis. All the budworm infested sites have a negative correlation with the second ordination axis. There is not adequate separation of the sprayed and unsprayed sites; they are all located close together in the ordination space. The ordination is strongly influenced by site 5-S. This site is separated from all of the others, and as a result the remaining sites are not well separated by the ordination.

When the Whiteshell sites are removed, the ordination produces a diagram in which the combined eigenvalue of the first two ordination axes is 0.698 and this explains 47.9% of the variation in species data (Fig. 28). The first axis separates the sites based upon budworm infestation. The two control sites (C-1, C-2) are placed at the positive end of the first axis with *Ledum groenlandicum*, and *Rhamnus alnifolia*. The second ordination axis places some sprayed sites at the positive end of the axis, and the unsprayed sites near the origin. The site pair 3 sites (3-NS, 3-S-96, and

3-S-97) are located together and placed at the negative end of the second axis. Within each site pair, the unsprayed site is always more negative in axis score than its corresponding sprayed sites.

Canonical correspondence analysis of the shrub vegetation

Canonical correspondence analysis (CCA) was performed on the shrub vegetation with the environmental variables. There was collinearity among the environmental variables. Forward selection was used to determine which environmental variables were significant in explaining the trends in the shrub data. Monte Carlo testing of the environmental variables indicated that control, spray and percent deciduous were all significant.

The CCA of the shrub vegetation and the environmental variables produced an ordination diagram in which 32% of the variation in the species data is explained by the first two ordination axes, which have a combined eigenvalue of 0.625 (Fig. 29). The first two axes also explain 79.5% of the variation in the species-environment relation. A Monte-Carlo test shows that the canonical axes are significant (F=2.24, p=0.005).

The placement of sites on the CCA diagram is quite different from the arrangement of sites using CA. Site 5-S does not have a strong influence on the CCA ordination. The three control sites have a strong correlation with the first axis and are placed near the positive end of axis 1. The first axis does not provide adequate separation of the infested sprayed and unsprayed sites. The second axis separates the infested sites into three distinct groups: i) 4-S, 1-S, and 2-S at the positive end of axis

2, ii) all of the unsprayed sites near the origin of axis 2, and iii) 3-S-96, 3-S-97, and 5-S located near the negative end of axis 2. These groupings appear to be correlated with the percentage of deciduous tree vegetation in each site (Fig. 29). When the Whiteshell sites are excluded from the ordination there are no significant differences in the ordination diagram (Fig. 30).

Ground vegetation

The results of the ground vegetation sampling are summarized in Appendix III. The most common species are summarized in Table 2.

Feather moss and *Ptilium crista-castrensis* (Hedw.) De Not. were the most common species of ground vegetation in all site types. Only *P. crista-castrensis* is listed in the most common species table (Table 2), because it is a type of feather moss. The most common species in control sites are *Sphagnum* sp., *Lycopodium clavatum* L., *Pteridium aquilinum* (L.) Kuhn, and *Circaea alpina* L. Some species unique to control sites include *Calamagrostis inexpansa* A.Gray, *Danthonia spicata* (L.) Beauv., *Dryopteris austriaca* (Jacq.) Woynar, *Petasites frigidus* (L.) Fr., *Polypodium vulgare* var. *virginianum* (L.) D.C.Eaton, and *Ribes glandulosum* Grauer.

The most common species in unsprayed sites are *P. aquilinum, Mitella nuda* L., *Cornus canadensis* L., and *Calamagrostis canadensis* (Michx.) Beauv. Species unique to unsprayed sites include: *Goodyera repens* (L.) Br., *Mertensia paniculatum* (Ait.) G. Don, *Calamagrostis canadensis, Aster umbellatus* Mill., and *Bidens cernua* L.

In sprayed sites, the most common species of ground vegetation were

Sphagnum sp., *Cornus canadensis*, *Cladina rangifera* (L.) Harm., and *Maianthemum canadense* Desf. Species of ground vegetation unique to sprayed sites include *Anemone canadensis* L., *Cirsium arvense* (L.) Scop., *Melampyrum lineare* Desr., and *Taraxacum officinale* Weber.

There was no significant effect of site type on the percent cover of ground vegetation (F=0.30, df=2,11, p=0.75) (Fig. 31). Paired t-tests revealed no significant difference in the total average percent cover for sprayed and unsprayed site pairs (1996: t=-0.67, df=4, p=0.54; 1997:t=-0.43, df=4, p=0.69) (Fig. 32).

There was also no significant effect of site type on the number of species of ground vegetation (F=1.17, df=2,11, p=0.35) (Fig. 33). Paired t-tests showed no significant difference between sprayed and unsprayed site pairs in the number of species present in sites from either year (1996:t=1.28, df=4, p=0.27; 1997:t=0.79, df=4, p=0.47) (Fig. 34).

The Shannon Wiener index of diversity calculated for the ground vegetation was not significantly affected by site type (F=0.31, df=2,11, p=0.74) (Fig. 35). There was also no significant difference in Shannon Wiener diversity between sprayed and unsprayed site pairs (1996:t=1.02, df=4, p=0.37; 1997:t=1.07, df= 4, p=0.34) (Fig. 36).

Correspondence analysis of ground vegetation

Correspondence analysis of the ground vegetation produces an ordination diagram in which the combined eigenvalue of the first two ordination axes is 0.575, and the axes account for 32.5% of the variation (Fig. 37). The first ordination axis separates the C-3 site from all of the other sites. This site is placed at the positive end of the first axis and is associated with species unique to that site including: *Danthonia spicata*, *Kalmia polifolia*, *Oenothera biennis* L., and *Lysmachia thyrsiflora* L. Axis 1 does not provide adequate separation of the other sites. The second axis separates 5-S from all of the other sites and places it at the positive end of axis 2. A group of sprayed sites (3-S-96, 3-S-97, and 2-S) is placed at the negative end of axis 2.

Because both 5-S and C-3 were influencing the ordination strongly, and both of these sites are located in the Whiteshell, the CA was performed again, excluding the Whiteshell sites. The combined eigenvalue of the first two axes of the ordination diagram produced by excluding the Whiteshell sites equals 0.486, and the axes explain 34.1% of the variation in the ground vegetation (Fig. 38). Again, two sites seem to be influencing the ordination diagram: C-2, and 2-NS. Site C-2 is strongly correlated with the first axis, and is placed at the positive end of axis 1. Axis 1 does not provide separation of the other sites. Site 2-NS is correlated with the second axis and is placed at the positive end of axis 2. Once again, a group of sprayed sites (3-S-96, 3-S-97 and 4-S) are placed together near the negative end of axis 2. Correspondence analysis of the ground vegetation does not appear useful in explaining differences between sites.

Canonical correspondence analysis of the ground vegetation

Canonical correspondence analysis (CCA) was performed on the ground vegetation with the environmental variables. There was collinearity among the environmental variables. Forward selection was used to determine which environmental variables were significant in explaining trends in the ground vegetation data. Monte Carlo tests of the environmental variables indicated that control and percentage of deciduous trees were the only significant environmental variables. In order to allow comparisons of sites based upon treatment, unsprayed, sprayed and infested were included as environmental variables.

The CCA of the ground vegetation and the environmental variables produced an ordination diagram in which the combined eigenvalue of the first two ordination axes equals 0.413, and this explains 23.4% of the variation in the species data (Fig. 39). The first two axes also explain 80.2% of the variation in the species-environment relation. A Monte-Carlo test shows that the canonical axes are significant (F=1.37, p=0.05).

The control sites are positively correlated with axis 1. This axis separates the uninfested control sites from the infested sprayed and unsprayed sites. There are three distinct groupings of infested sites along axis 2. Near the positive end of axis 2 is a group of sprayed sites (4-S, 1-S, and 2-S). A second group of sprayed sites (3-S-96, 3-S-97, and 5-S) is located on the negative side of axis 2 near the origin. The third group consists of all the unsprayed sites and is placed near the negative end of axis 2. Once again, these groupings appear to be correlated with the percentage of deciduous tree vegetation in each site (Fig. 39). The unsprayed sites appear to be associated with increasing percentages of deciduous tree vegetation.

When the Whiteshell sites are excluded from the CCA, the first ordination axis in the diagram separates the uninfested sites from all of the other sites and places them at the positive end of the first axis (Fig.40). There are several species of ground vegetation that are also placed at the positive end of the first axis including *Ribes oxyacanthoides, Anenome quinquefolia,* and *Symphoricarpos alba.* The second axis separates the sprayed and unsprayed sites. The unsprayed sites are located on the positive side of the second axis, and the sprayed sites are placed on the negative side. All sprayed sites are placed very close together, as are the unsprayed sites. When the Whiteshell sites are excluded, the CCA provides very good separation of sprayed from unsprayed sites based upon the ground vegetation species data, and the environmental variables.

Moths

Number of moths and most common species

A total of 4214 moths representing 201 different species was collected during this study. In 1996, 2309 individuals representing 175 species were collected, and in 1997, 1905 individuals representing 111 species were collected (Appendix IV).

The 10 most common species made up 47.8% of the total catch (Table 3). Species 7 is a geometrid moth that possibly belongs to the genus *Anacamptodes.* Because it was impossible to determine the species of this moth with any certainty, it is simply referred to as Species 7. The three most common species were Species 7, *Enargia decolor* (Walker), and *Nematocampa limbata* (Haw.). These three species were found in all three site types in both 1996 and 1997. Some species were unique to certain site types. Unsprayed sites had 44 unique species, control sites had 31 unique species and 20 species were unique to sprayed sites.

There was no significant effect of site type on the numbers of moths collected in both years (1996: F=3.08, df=2,10; 1997: F=1.82, df=2,10) (Fig. 41). When the Whiteshell sites were removed from the analysis, there was a significant effect of site type on the number of moths for 1996 (F=4.77, df=2,7, p<0.05) but not in 1997 (F=2.79, df=2,7). A contrast of sprayed and unsprayed sites in 1996 with the Whiteshell sites removed indicates more moths were collected in unsprayed sites (F=9.19, df=1,7, p<0.05). For both years, paired t-tests showed no significant difference between sprayed and unsprayed sites with respect to the number of moths collected (1996: t=2.18, df=4; 1997: t=2.10, df=4) (Fig. 42). Paired t-tests with the Whiteshell sites removed showed significantly more moths were collected in unsprayed sites in 1996 (t=6.00, df=3, p<0.01), but there was no difference between sprayed and unsprayed sites in 1997 (t=2.88, df=3).

Moth species richness

There was no significant effect of site type on the number of moth species collected in either year (1996: F=1.09, df=2,10; 1997: F=1.72, df=2,10) (Fig. 43). This was also the case when the Whiteshell sites were excluded (1996: F=0.87, df=2,7; 1997: F=5.67, df=2,7). Paired t-tests also revealed no significant difference in the number of moth species between sprayed and unsprayed sites (1996: t=1.28, df=4; 1997: t=2.11, df=4) (Fig.44). When the Whiteshell sites were removed there was again no significant difference between sprayed and unsprayed sites with respect to the number of moth species (1996: t=1.63, df=3; 1997: t=2.22, df=3).

Moth alpha diversity

There was no significant effect of site type on the log series alpha for either year (1996: F=0.33, df=2,10; 1997: F=0.57, df=2,10) (Fig. 45). There was also no significant effect of site type when the Whiteshell sites were excluded (1996: F=1.15, df=2,7; 1997: F=1.01, df=2,7). Paired t-tests also revealed no significant difference in log series alpha diversity for either year, both with (1996: t=-0.72, df=4; 1997: t=1.07, df=4) and without (1996: t=-1.00, df=3; 1997: t=1.30, df=3) the Whiteshell sites included in the analysis (Fig. 46).

Correspondence analysis of moth species

1996

In 1996, correspondence analysis of the moth species produced an ordination diagram where 24.4% of the variation in the species data is explained by the combined eigenvalue of the first two ordination axes (Fig. 47). These axes have similar eigenvalues. Axis 1 has an eigenvalue of 0.294, and axis 2 has an eigenvalue of 0.274. The first ordination axis separates the sites based upon budworm infestation. The uninfested control sites are placed together toward the negative end of axis 1. This first ordination axis also separates site 2-S from all of the other sites and places it at the positive end of the axis with species unique to this site in 1996 including *Eurois occulta* L. , *Lithophane pexata* Grote, *Nephelodes minians* (Gueneé), and *Xanthorhoe ferrugata* (Clerck). The second ordination axis generally separates the unsprayed sites from the other sites and places them at the negative end of the axis. The second axis also separates site 2-S from all of the other sites. This site is located at the positive end of the second ordination axis. In general, the ordination diagram of the first and second axes places the sites into groups based upon their treatment. The exception to this is the Whiteshell site pair, sites 5-S, and 5-NS. These two sites are placed close together and are located near to the control sites.

The combined eigenvalues of the second and third ordination axes explain 22.2% of the variation in the species data (Fig. 48). The third ordination axis separates the Whiteshell site pair (5-S, 5-NS) from all other sites and places them toward the positive end of the axis with species that are unique to each site in 1996. Some of these species include *Anacamptodes humaria* (Gn.), *Lithophane fasciola* , *Xanthorhoe lacustrata* (Gn.) (all from 5-NS), *Clostera inclusa* (Hübner), *Dysstroma hersiliata* (Gn.), *Eulithis testata* (L.), *Orthosia revicta* (Morr.), and *Palpita magniferalis* (Walker) (all from 5-S).

When the three Whiteshell sites were excluded from the analysis, an ordination diagram was produced in which 31.0% of the variation in the moth species data was explained by the combined eigenvalues of the first two ordination axes (Fig. 49). The first axis separates the uninfested control sites from the budworm infested sites and places them at the positive end of the axis. The second ordination axis separates site 2-S from all of the others and places it at the positive end of the axis. The second ordination axis provides some separation of sprayed and unsprayed sites. The sprayed sites are located closer to the positive end of axis 2, than the other sites.

1997

Correspondence analysis of the 1997 moth species produced an ordination diagram in which 26.1% of the variation is explained by the combined eigenvalues of the first two ordination axes (Fig. 50). The ordination diagram provides good separation of the sites, but there is no separation of sites based upon treatment for either axis 1 or 2. The second ordination axis separates site 3-S-97 from the other sites and places it at the positive end of the axis. There are several moth species that are unique to this site in 1997 including: *Anacamptodes ephyraria* (Wlk.), *Catocala relicta* Walker, *Laothoe juglandis* (J.E. Smith), *Oreta rosea* (Wlk.), and *Sicya macularia* (Harr.). The other ordination axes also provide good separation of the sites, but there is no separation of sites based upon treatment.

When the Whiteshell sites were excluded from the CA, an ordination diagram was produced in which 30.9% of the variation is explained by the combined eigenvalues of ordination axes 1 and 2 (Fig. 51). The ordination diagram provides good separation of the sites, but there is no separation of sites based upon treatment for either axis 1 or 2. The combined eigenvalues of the second and third ordination axes account for 28.7% of the variation in the moth species data (Fig. 52). Axis 3 separates the sprayed sites from the control and unsprayed, and places them at the negative end of the axis. The unsprayed and control sites are located together at the positive end of axis 3.

Canonical correspondence analysis of the moth species

Canonical correspondence analysis (CCA) was performed on the moth species data with the environmental variables for both 1996 and 1997. There was collinearity among the environmental variables. Forward selection was used to determine which environmental variables were significant in explaining the trends in the moth species data. Monte Carlo tests of the environmental variables indicated which variables were significant. In order to allow comparisons of sites based upon treatment, unsprayed, sprayed and infested were always included as environmental variables, even when they were not significant. The percentage of deciduous tree vegetation was also included as an environmental variable in the ordination diagrams.

1996

The CCA of the 1996 moth species data and the environmental variables produced an ordination diagram in which the first two ordination axes explain 21.2% of the variation in the species data, and 56.2% of the variation in the species-environment relation (Fig. 53). Monte Carlo tests of the environmental variables indicate that control and spray are the only significant environmental variables, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant ($F=1.21$, $p<0.01$).

The first ordination axis separates the sites based upon treatment (Fig. 53). The control sites are located together near the positive end of axis 1. The sprayed sites are located near the origin of the first axis, and at the negative end of the first axis are the unsprayed sites. The unsprayed sites appear to be correlated with increasing percentages of deciduous tree vegetation. The second ordination axis separates the sprayed sites from all other sites. The sprayed sites are located toward the positive end of the second axis. The second axis does not separate control sites from unsprayed sites. The control and unsprayed sites are located on the negative side of the second ordination axis.

Canonical correspondence analysis was again performed on the 1996 moth species data and the environmental variables but with the Whiteshell sites excluded. The CCA of the 1996 moth species data and the environmental variables excluding the Whiteshell sites produced an ordination diagram in which the combined eigenvalues of the first two ordination axes explain 29.5% of the variation in the species data, and 60.0% of the variation in the species-environment relation (Fig. 54). Monte Carlo tests of the environmental variables indicate that again, control and spray are the only significant environmental variables, however all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant ($F=1.21$, $p<0.01$).

The ordination diagram does not change significantly when the Whiteshell sites are excluded from analysis. Once again, the first ordination axis separates the sites based upon treatment. The control sites are located at the positive end of the first axis, sprayed sites near the origin, and unsprayed sites toward the negative end of ordination axis 1. Again, the second ordination axis separates the sprayed sites from all other sites and places them near the positive end of the axis. Removal of the Whiteshell sites places sites from the same area, and of the same treatment closer together in ordination space than when the Whiteshell sites were included. For example, sites 2-S and 1-S, both located in the Bird Lake area are placed closer together in ordination space when the Whiteshell sites are removed.

1997

The CCA of the 1997 moth species data and the environmental variables produced an ordination diagram in which the first two ordination axes explain 22.6 % of the variation in the species data, and 57.8% of the variation in the species-environment relation (Fig. 55). Monte Carlo tests of the environmental variables indicate that no spray and percentage of deciduous tree vegetation are the only significant environmental variables, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant ($F=1.29$, $p<0.01$).

The first ordination axis separates the unsprayed sites from the control and sprayed sites. The unsprayed sites are located at the negative end of the first ordination axis. The control and sprayed sites are placed together toward the positive end of the first ordination axis. Axis 2 does not provide adequate separation of sites based upon treatment. Unsprayed sites again seem to be associated with increasing percentages of deciduous tree vegetation. The ordination diagram displays two groupings of sprayed sites. One group of sprayed sites (1-S, 2-S, 4-S) is placed near the positive end of axis 2. These three sprayed sites are close to the control sites in ordination space, and are associated with decreasing percentages of deciduous tree vegetation. The second group of sprayed sites (3-S-97 and 5-S) is located toward the negative end of the second ordination axis. These two sites are associated with increased percentages of deciduous tree vegetation, and are therefore located away from the other sprayed sites in ordination space.

Canonical correspondence analysis was again performed on the 1997 moth species data and the environmental variables, but with the Whiteshell sites excluded. The CCA of the 1997 moth species data and the environmental variables excluding the Whiteshell sites produced an ordination diagram in which the combined eigenvalues of the first two ordination axes explain 28.4% of the variation in the species data, and 56.9% of the variation in the species-environment relation (Fig. 56). Monte Carlo tests of the environmental variables indicate that control and percentage of deciduous tree vegetation are the only significant environmental variables, however all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant ($F=1.25$, $p<0.01$).

The ordination diagram changes when the Whiteshell sites are excluded from analysis. The first ordination axis is less effective in separating the sites based upon treatment, but there are some general trends. The control and sprayed sites are located at the positive end of the first axis, and unsprayed sites toward the negative end of ordination axis 1. The second ordination axis is also less effective at separating the sprayed sites from all other sites. In general however, the sprayed sites are located toward the positive end of the second ordination axis. Removal of the Whiteshell sites from the ordination places sites from the same area, and of the same treatment closer together in ordination space than when the Whiteshell sites were included. For example, sites 2-S and 1-S, both located in the Bird Lake area are placed closer together in ordination space when the Whiteshell sites are removed. The combined eigenvalues of the second and third ordination axes account for 26.6% of the variation in the moth species data, and 53.3% of the variation in the species-environment relation (Fig. 57). Axis 3 separates all the sprayed sites except for 3-S-97 from the control and unsprayed sites, and places them at the positive end of the axis. Site 3-S-97 has separated from the other sprayed sites because it is associated with increasing percentages of deciduous tree vegetation.

Carabid beetles

Number of carabid beetles and most common species

A total of 11134 beetles representing 38 species was collected during this study. In 1996, 2575 individuals representing 30 species were collected, and in 1997, 8559 individuals representing 33 species were collected (Appendix V). The seven most common species represented more than 93% of the total catch (Table 4). The most common species were *Agonum retractum* LeConte, *Pterostichus pensylvanicus* LeConte, *Synuchus impunctatus* (Say), *Sphaeroderus nitidicollis brevoorti* LeConte, *Calathus ingratus* Dejean, *Pterostichus adstrictus* Eschscholtz, and *Sphaeroderus stenosmus lecontei* Dejean. Most of the species that were collected were present in all three site types. Some species were unique to certain site types. Species unique to control sites were *Bembidion* sp., *Cymindis neglectus* Haldeman, *Notiophilus intermedius* Lindroth, *Pterostichus mutus* (Say), and *Syntomus americanus* (Dejean). Species that were unique to unsprayed sites included *Chlaenius niger* Randall, and *Harpalus pleuriticus* Kirby. Sprayed sites had no unique species.

There was no significant effect of site type on the number of carabid beetles collected in 1996 (F=3.31,df=2,10) (Fig. 58). However, in 1997, there was an effect of site type on the number of carabids collected (F=6.294, df=2,10, p<0.05) (Fig. 58). Contrasts of the sprayed and unsprayed sites in both years showed significantly more individuals in unsprayed sites (1996:F=5.07, df=1,10, p<0.05; 1997: F=12.52, df=1,10, p<0.01).

When the Whiteshell sites were excluded from the analysis, there was a significant effect of site type on the number of carabid beetles collected in 1996 (F=4.75, df=2,7, p=0.05), and an almost significant effect in 1997 (F=4.30, df=2,10, p=0.06) (Fig. 59). A contrast of the sprayed and unsprayed sites indicated significantly more carabid beetles in unsprayed sites for both years (1996:F=8.39, df=1,7, p<0.05: 1997: F=8.35, df=1,7, p<0.05)

For both years, t-tests showed significantly more individuals in unsprayed sites compared to sprayed sites (1996: t=3.55, df=4, p<0.05; 1997: t=6.81, df=4, p<0.01) (Fig. 60). However, when the Whiteshell sites were excluded from the analysis, there was no significant difference between sprayed an unsprayed site pairs with respect to the number of carabid beetles in 1996 (t=2.59, df=3), but significantly more carabids were collected in unsprayed sites in 1997 (t=3.69, df=3, p<0.05).

For both sampling years, *Agonum retractum* (1996: p=0.004; 1997:p=0.02), and *Sphaeroderus nitidicollis brevoorti* (1996: p=0.035; 1997: p=0.05) were more commonly collected in unsprayed sites compared to sprayed sites (Fig. 61).

Carabid beetle species richness

There was no significant effect of site type on the number of species collected in 1996 and 1997, both with (1996:F=1.802, df=2,10; 1997: F=1.17, df=2,10) (Fig.

62), and without the Whiteshell sites included (1996:F=1.27, df=2,7; 1997: F=2.09, df=1,7).

There was no significant difference between sprayed/unsprayed site pairs with respect to the number of species present for 1996 (t=0.52, df=4), although there was a tendency for there to be more species in unsprayed sites (Fig. 63). In 1997 there were significantly more carabid species in unsprayed sites (t=3.77, df=4, p<0.05) (Fig. 63). When the Whiteshell sites were excluded from the analysis, there was no significant difference between sprayed/unsprayed site pairs with respect to the number of species present for 1996, but again, significantly more species were present in unsprayed sites in 1997 (1996: t=0.51, df=3; 1997: t=3.69, df=3, p<0.05).

Carabid beetle alpha diversity

There was no significant effect of site type on the log series alpha for the carabids in both years (1996: F=3.33, df=2,10; 1997: F=0.005, df=2,10) (Fig. 64).

There was a significant difference between sprayed/unsprayed site pairs with respect to log series alpha for 1996, but no difference in 1997 (1996: t=-4.97, df=4, p<0.01; 1997: t=-0.23, df=4) (Fig. 65). This was also true when the Whiteshell sites were excluded from the analysis (1996: t=-4.16, df=3, p<0.05; 1997: t=0.09, df=3).

Correspondence analysis of carabid species

1996

Correspondence analysis of the 1996 carabid beetle species data produces an ordination diagram in which the combined eigenvalues of the first two ordination axes explain 39.8% of the variation (Fig. 66). The first ordination axis does not provide adequate separation of the sites based upon treatment. The first axis separates C-3 from all of the other sites and places it at the positive end of the axis. This site is associated with several species that were unique to it in 1996 including *Badister obtusus* LeConte, *Cymindis neglectus*, *Pterostichus mutus*, and *Syntomus americanus*. The second ordination axis does not provide adequate separation of the sites based upon treatment. The second ordination axis separates sites 5-S and 5-NS from all of the other sites and places them at the positive end of the axis. These two sites are associated with species unique to each including: *Harpalus pleuriticus* (5-NS), and *Harpalus* sp., and *Agonum* spp. (5-S). This site pair also differed from the other sites because *Pterostichus melanarius* (Illiger) occurred only in this pair of sites. The three sites that are separated from the others in ordination space are the Whiteshell sites, which also differed on the basis of other indicators. So, the CA was performed a second time, but excluding the Whiteshell sites from the analysis.

When the Whiteshell sites were excluded from the analysis, an ordination diagram was produced in which 41.2% of the variation in the carabid species data was explained by the combined eigenvalues of the first two ordination axes (Fig. 67). The first and second ordination axes do not provide significant separation of the sites based upon treatment. The second ordination axis separates site 1-NS from all of the other sites and places it at the positive end of the axis. This site is associated with *Carabus taedatus agassii* LeConte, which is unique to site 1-NS in 1996 when the Whiteshell sites are removed. All of the other sites are located near the origin of axis 2, and are not separated based upon treatment.

1997

Correspondence analysis of the 1997 carabid beetle species data produces an ordination diagram in which the combined eigenvalues of the first two ordination axes explain 39.6 % of the variation in the species data (Fig. 68). The first ordination axis separates the three Whiteshell sites from all other sites. All three Whiteshell sites are placed on the positive side of the first ordination axis. The Whiteshell control site C-3 is separated from all of the other sites and is placed at the positive end of axis 1, with species that are unique to this site in 1997 including *Bembidion* sp., *Notiophilus intermedius*, and *Pterostichus mutus*. There are several carabid species that are also placed towards the positive end of the first axis including *Platynus mannerheimii*, *Sphaeroderus stenosmus lecontei*, and *Pterostichus femoralis*. The second ordination axis separates site 2-NS from the others, and places it at the positive end of the axis. This site is associated with species unique to this site in 1997, including *Chlaenius niger*, *Patrobus* sp., and *Badister obtusus*. The second ordination axis does not provide significant separation of the other non-Whiteshell sites based upon treatment. Once again, because the Whiteshell sites are separated in ordination space, the CA was performed a second time without these sites.

When the Whiteshell sites were excluded from the analysis, an ordination diagram was produced in which 49.4 % of the variation in the carabid species data was explained by the combined eigenvalues of the first two ordination axes (Fig. 69). The first and second ordination axes do not provide significant separation of the sites based upon treatment. The Bird Lake unsprayed sites 1-NS and 2-NS, are placed together near the positive end of the first axis. They are associated with carabid species including *Carabus taedatus agassii*, *Syntomus americanus*, and *Harpalus fulvilabris*. These two sites are widely separated by axis 2. Site 1-NS is placed at the positive end of axis 2, and site 2-NS is placed at the negative end. These sites are separated on axis 2, because 2-NS has several species unique to it, including *Chlaenius niger*, *Patrobus* sp., and *Badister obtusus*, and it is associated with other species that have a negative association with axis 2 including *Agonum placidum*. Site 3–S-97 and 3-NS have been placed together near the negative end of both axis 1 and 2. All of the other sites are placed together on the positive side of axis 2, and the negative side of axis 1. Many of the carabid species are found near the origin of the ordination diagram and this is because they are common in most sites.

Canonical correspondence analysis of carabid species

Canonical correspondence analysis (CCA) was performed on the carabid beetle data with the environmental variables for both 1996 and 1997. There was collinearity among the environmental variables. Forward selection was used to determine which environmental variables were significant in explaining the trends in the carabid species data. Monte Carlo tests of the environmental variables indicated which variables were significant. In order to allow comparisons of sites based upon treatment, unsprayed, sprayed and infested were always included as environmental variables, even when they were not significant. The latitude and percentage of deciduous tree vegetation were also included as environmental variables in the ordination diagrams.

1996

The CCA of the 1996 carabid species data and the environmental variables produced an ordination diagram in which the first two ordination axes explain 32.1% of the variation in the species data, and 68.0% of the variation in the species-environment relation (Fig. 70). Monte Carlo tests of the environmental variables indicate that latitude and percentage of deciduous tree vegetation are the only significant environmental variables, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant (F=1.79, p=0.005).

The first ordination axis does not provide adequate separation of sites based upon treatment (Fig.70). Site C-3 is separated from the other sites and place near the positive end of the first ordination axis. This is again because there were several species unique to this site in 1996 (*Badister obtusus*, *Cymindis neglecta*, *Pterostichus mutus*, and *Syntomus americanum)*. Site C-3, and its unique species are negatively associated with latitude; this site is located further south than all of the other sites. The second ordination axis appears to be negatively associated with the percentage of deciduous tree vegetation. A group of sprayed and control sites (1-S, 2-S, 3-S and C-1, C-2) is located near the positive end of the second ordination axis. These sites are associated with less deciduous tree vegetation than all of the other sites. A second group of sprayed sites (3-S-96 and 5-S) is located at the negative end of the second ordination axis. These two sites are different from the other sprayed sites because they are associated with higher percentages of deciduous tree vegetation. The unsprayed sites are located together on the negative side of the second ordination axis.

The combined eigenvalues of the second and third ordination axes explain 20.0% of the variation in the carabid species data, and 42.3% of the variation in the species-environment relation (Fig. 71). The third ordination axis separates the sprayed sites from the control and unsprayed sites. The sprayed sites are located near the positive end of the third ordination axis. The unsprayed and control sites are located toward the negative end of the third ordination axis.

When the Whiteshell sites were excluded from the CCA of the 1996 carabid species data and the environmental variables an ordination diagram was produced in which the first two ordination axes explain 35.3% of the variation in the species data, and 68.2% of the variation in the species-environment relation (Fig. 72). Monte Carlo tests of the environmental variables indicate that the percentage of deciduous tree vegetation was the only significant environmental variable, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are marginally significant ($F=1.34$, $p=0.055$).

The first ordination axis does not provide adequate separation of sites based upon treatment. Site 3-S-96 is separated from the other sites and placed at the positive end of the first ordination axis. Site 3-S-96 is also associated with two species that become unique to it in 1996 when the Whiteshell sites are removed: *Platynus mannerheimii*, and *Pterostichus* sp. The second ordination axis separates the unsprayed sites from the control and sprayed sites. The unsprayed sites are located at the negative end of the second axis, and are all associated with higher levels of deciduous tree vegetation. The control and sprayed sites are located toward the positive end of the second ordination axis. These sites are associated with low percentages of deciduous tree vegetation, except for site 3-S-96. This sprayed site is different from other sprayed sites because it is associated with high percentages of deciduous tree vegetation. In this respect, it is more like an unsprayed site.

The second and third ordination axes explain 26.4% of the variation in the carabid species data, and 51.0% of the variation in the species-environment relation (Fig. 73). The third ordination axis separates the sites based upon treatment. The control sites are located at the negative end of ordination axis 3. The unsprayed sites are located near the origin of the third ordination axis, and the sprayed sites are located near the positive end of the axis. Once again, site 3-S-96 is located near to the unsprayed sites, and remote from the other sprayed sites.

1997

The CCA of the 1997 carabid species data and the environmental variables produced an ordination diagram in which the first two ordination axes explain 31.5 % of the variation in the species data, and 74.8% of the variation in the species-environment relation (Fig. 74). Monte Carlo tests of the environmental variables indicate that latitude and no spray are the only significant environmental variables, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are significant ($F=1.45$, $p<0.05$).

The first ordination axis explains 49.6 % of the variation in the species-environment relationship, but does not provide adequate separation of sites based upon treatment (Fig. 74). Latitude is negatively associated with axis 1, and the percentage of deciduous tree vegetation is positively associated with axis 1, and negatively with axis 2. Once again, the Whiteshell sites are separated from the other sites and placed on the positive side of axis 1. Once again, site C-3 is separated from the other sites and placed at the positive end of the first axis. This is because there were several unique species to this site in 1997 (*Bembidion* sp., *Notiophilus intermedius*, and *Pterostichus mutus*). Site C-3, and its unique species are negatively associated with latitude; this site is located further south than all of the other sites. The second ordination axis appears to be negatively associated with deciduous tree vegetation, and also separates the sites based upon treatment. All of the unsprayed sites are placed toward the negative end of the second axis, and are associated with higher percentages of deciduous tree vegetation. The sprayed and control sites are all located towards the positive end of the second axis. Most of these sites are associated with lower percentages of deciduous tree vegetation, except for the sites 5-S, and C-3. These two sites are located in the Whiteshell, and appear to be associated with a higher proportion of deciduous vegetation. This makes these sites different from the other sprayed and control sites. Most of the carabids are placed near the origin of the ordination diagram, however, there are some species that seem to be associated with increased levels of deciduous vegetation including *Trechus apicalis*, *Syntomus americanus*, and *Carabus taedatus agassii*.

When the Whiteshell sites were excluded from the CCA of the 1997 carabid species data and the environmental variables, an ordination diagram was produced in which the first two ordination axes explain 36.3 % of the variation in the species data, and 81.4 % of the variation in the species-environment relation (Fig. 75). Monte Carlo tests of the environmental variables indicate that latitude and no spray were the significant environmental variables, however, all environmental variables were included in the ordination. A Monte Carlo test shows that the canonical axes are not significant (F=1.00, p=0.51).

The first ordination axis does not provide significant separation of the sites based upon treatment, but does separate the sites based upon geographical location. The most northerly sites (4-NS, 4-S, 3-NS, 3-S-97) are all located towards the positive end of the first axis. The more southerly sites (2-NS, 2-S, 1-NS, 1-S) are all placed toward the negative end of the first axis. Latitude is positively associated with axis 1, and percentage of deciduous vegetation is positively associated with axis 2. The second axis separates sprayed and unsprayed sites within site pairs. Every sprayed site is always placed more toward the negative end of the second axis than its corresponding unsprayed site. Each sprayed site is also associated with a lower percentage of deciduous vegetation than its corresponding unsprayed site.

The second and third ordination axes explain 18.4 % of the variation in the carabid species data, and 51.3 % of the variation in the species-environment relation (Fig. 76). The third ordination axis separates the sites based upon treatment. The control sites are located at the positive end of the third ordination axis. The unsprayed sites are located near the origin of axis 3, and the sprayed sites are placed near the negative end of the axis. The third axis does not provide effective separation of the carabid species, and most species are located near the origin of the third ordination axis.

Table 1: Site labels, treatments, dates of spray application, locations, arrangement of site pairings, and sampling dates for carabid beetles and moths in 1996 and 1997.

						1996		1997		1996		1997	
Site pair	Site	Site type	Dates of insecticide application	Latitude	Longitude	Light trap erected	Light trap removed	Light trap erected	Light trap removed	Pitfall traps installed	Pitfall traps removed	Pitfall traps installed	Pitfall traps removed
1	1-NS	No spray		50° 27' 06" N	95° 19' 33" W	29 May	20 Oct	23 May	27 Sep	14 June	2 Nov	23 May	27 Sep
	2-S	Spray	1986, 1987	50° 28' 07" N	95° 15' 55" W	24 May	20 Oct	23 May	27 Sep	15 June	2 Nov	23 May	27 Sep
2	2-NS	No spray		50° 27' 36" N	95° 19' 35" W	14 June	20 Oct	23 May	27 Sep	14 June	2 Nov	23 May	27 Sep
	2-S	Spray	1986, 1989, 1990	50° 27' 58" N	95° 19' 28" W	24 May	20 Oct	23 May	27 Sep	15 June	2 Nov	23 May	27 Sep
3	3-NS	No spray		50° 51' 13" N	95° 22' 23" W	6 June	6 Oct	30 May	2 Oct	12 July	19 Oct	30 May	2 Oct
	3-S-96	Spray	1989, 1990	50° 51' 16" N	95° 23' 48" W	6 June	6 Oct			12 July	19 Oct		
	3-S-97	Spray	1989, 1990	50° 52' 16" N	95° 29' 06" W			9 June	2 Oct			9 June	2 Oct
4	4-NS	No spray		50° 52' 05" N	95° 27' 25" W	6 June	6 Oct	30 May	2 Oct	12 July	19 Oct	30 May	2 Oct
	4-S	Spray	1989, 1990	50° 51' 42" N	95° 26' 10" W	6 June	6 Oct	9 June	2 Oct	12 July	19 Oct	30 May	2 Oct
5	5-NS	No spray		50° 07' 45" N	95° 44' 55" W	23 May	27 Oct	21 May	29 Sep	20 June	10 Nov	21 May	29 Sep
	5-S	Spray	1987, 1988, 1990	50° 10' 21" N	95° 43' 43" W	23 May	27 Oct	21 May	29 Sep	21 June	10 Nov	21 May	29 Sep
	C-1	Control		50° 42' 50" N	96° 07' 36" W	29 June	28 Sep	25 May	28 Sep	29 June	3 Nov	25 May	28 Sep
	C-2	Control		50° 48' 45" N	96° 14' 05" W	30 June	28 Sep	25 May	28 Sep	30 June	3 Nov	25 May	28 Sep
	C-3	Control		49° 48' 36" N	95° 16' 35" W	23 May	27 Oct	21 May	29 Sep	4 June	10 Nov	21 May	29 Sep

Table 2: Dominant species of ground, shrub and tree vegetation, tree size and percent of coniferous trees in each site.

Site pair	Site	Site type	Ground	Shrub	Tree	CBH (cm)·	Percentage coniferous tree stems
			DOMINANT VEGETATION				
1	1-NS	Non Spray	*Ptilium crista-castrensis* *Aralia nudicaulis* *Comus canadensis* *Lycopodium clavatum* *Clintonia borealis*	*Corylus comuta* *Rubus idaeus* *Abies balsamea*	*Corylus comuta* *Abies balsamea*	 29.4 ± 18.5	21.9
	1-S	Spray	*Ptilium crista-castrensis* *Vaccinium myrtilloides* *Sphagnum* sp. *Clintonia borealis*	*Acer spicatum* *Rubus idaeus*	*Abies balsamea* *Acer spicatum*	26.8 ± 12.0 11.5 ± 0.0	61.7
2	2-NS	Non Spray	*Malanthemum canadense* *Viola* sp. *Carex* sp.	*Acer spicatum Corylus comuta* *Rubus idaeus*	*Abies balsamea* *Corylus comuta* *Populus tremuloides* *Betula papyrifera*	26.0 ± 11.5 22.8 ± 9.0 19.0 ± 8.2	18.5
	2-S	Spray	*Comus canadensis* *Ptilium crista-castrensis* *Lycopodium clavatum*	*Rubus idaeus* *Betula papyrifera* *Ribes glandulosum*	*Abies balsamea* *Acer spicatum*	36.1 ± 18.3	54.2
3	3-NS	Non Spray	*Mitella nuda* *Ptilium crista-castrensis* *Comus canadensis*	*Acer spicatum* *Abies balsamea* *Corylus comuta* *Comus stolonifera* *Rosa* sp.	*Acer spicatum* *Betula papyrifera*	11.8 ± 1.5 18.7 ± 9.6	16.2
	3-S-96	Spray	*Ptilium crista-castrensis*	*Abies balsamea* *Acer spicatum* *Rosa* sp. *Corylus comuta*	*Acer spicatum*	14.6 ± 4.6	14.5

Table 2: Continued

Site pair	Site	Site type	DOMINANT VEGETATION Ground	Shrub	Tree	CBH (cm)*	Percentage coniferous tree stems
	3-S-97	Spray	*Sphagnum* sp.	*Corylus comuta*	*Acer spicatum*	10.0 ± 0.0	8.2
				Abies balsamea	*Corylus comuta*		
				Acer spicatum			
				Abies balsamea			
4	4-NS	Non Spray	*Ptilium crista-castrensis*	*Acer spicatum*	*Acer spicatum*	12.6 ± 2.9	10.5
			Mitella nuda	*Rubus idaeus*			
			Rubus pubescens	*Abies balsamea*			
			Comus canadensis				
	4-S	Spray	*Sphagnum* sp.	*Abies balsamea*	*Abies balsamea*	12.4 ± 2.2	75.5
			Comus canadensis	*Rubus idaeus*	*Picea glauca*	34.3 ± 24.2	
			Maianthemum canadense	*Picea glauca*	*Betula papyrifera*	14.0 ± 5.0	
			Cladina rangifera				
5	5-NS	Non Spray	*Pteridium aquilinum*	*Abies balsamea*	*Corylus comuta*		23.4
			Comus canadensis	*Corylus comuta*	*Acer spicatum*	11.5 ± 2.2	
				Acer spicatum	*Abies balsamea*	30.6 ± 17.8	
	5-S	Spray	*Diervilla lonicera*	*Fraxinus pensylvanicus*	*Fraxinus pensylvanicus*	18.1 ± 10.8	8.4
				Prunus virginiana	*Populus tremuloides*	20.7 ± 10.9	
				Comus stolonifera			
				Vibumum rafinesquianum			
				Amelanchier alnifolia			

Table 2: Continued

			DOMINANT VEGETATION				
Site pair	Site	Site type	Ground	Shrub	Tree	CBH (cm)*	Percentage coniferous tree stems
	C-1	Control	*Lycopodium clavatum* *Circaea alpina* *Carex* sp.	*Alnus* sp. *Ledum groenlandicum* *Abies balsamea* *Corylus cornuta*	*Abies balsamea* *Alnus* sp.	23.6 ± 12.7 10.7 ± 0.4	50.8
	C-2	Control	*Ptilium crista-castrensis* *Other mosses*	*Ledum groenlandicum*	*Abies balsamea*	26.0 ± 13.5	70.3
	C-3	Control	*Sphagnum* sp. *Lycopodium clavatum* *Ledum groenlandicum* *Pteridium aquilinum* *Maianthemum canadense* *Cornus canadensis* *Equisetum sylvaticum* *Vaccinium angustifolium*	*Cornus stolonifera* *Amelanchier alnifolia* *Alnus* sp. *Ledum groenlandicum*	*Alnus* sp.		11.3

* CBH is circumference at breast height for trees with CBH >10 cm..

Table 3: Total catches in each site in each year of the 10 most commonly caught moth species.

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Species 7	1996	50	7	87	5	33	14	29	1	17	29	16	43	37	368
	1997	41	0	65	56	18	75	39	1	28	17	0	27	26	393
Cabera erythemaria Gn.	1996	2	1	5	3	2	2	3	0	1	2	3	11	5	40
	1997	2	0	7	3	10	7	7	0	0	6	1	0	0	43
Campaea perlata (Gn.)	1996	17	0	15	1	7	4	1	0	0	0	5	3	6	59
	1997	6	0	18	0	5	4	7	0	4	2	1	1	3	51
Caripeta divisata Wlk.	1996	1	2	9	0	1	0	0	0	3	2	14	17	8	57
	1997	0	0	1	0	1	0	0	0	0	3	11	1	0	17
Eilema bicolor (Grote)	1996	0	2	2	1	2	6	1	1	0	0	3	1	4	23
	1997	2	3	4	1	23	11	6	0	2	1	0	5	5	63
Enargia decolor (Walker)	1996	33	1	39	11	66	13	21	0	2	27	35	24	35	307
	1997	1	0	1	7	25	18	11	0	0	22	13	20	20	138
Holomelina aurantiaca (Hbn.)	1996	3	14	4	8	6	1	0	2	0	4	2	9	4	57
	1997	5	1	7	1	2	3	2	0	2	2	0	0	0	25
Lambdina fiscellaria (Gn.)	1996	3	1	10	1	25	1	4	0	0	0	0	0	0	45
	1997	2	1	0	1	23	0	7	0	0	0	4	2	2	42
Nematocampa limbata (Haw.)	1996	2	0	19	0	5	2	1	0	1	2	0	4	5	41
	1997	12	1	80	9	15	7	20	0	5	3	0	13	3	168
Procherodes transversata (Dru.)	1996	10	0	15	1	11	1	0	1	0	0	1	4	4	48
	1997	4	0	0	6	5	1	2	0	0	3	0	4	6	31

Table 4: Total catches in each site in each year of the most commonly collected carabid species.

		1		2		3		4		5		CONTROL			
CARABID SPECIES	**YEAR**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**1**	**2**	**3**	**SUM**
Agonum gratiosum (Mannerheim)	1996	0	0	6	1	7	8	9	0	0	4	18	0	2	55
	1997	0	0	16	3	3	7	8	2	0	7	10	7	14	77
A. retractum LeConte	1996	154	10	97	12	64	41	34	9	131	29	84	11	16	692
	1997	400	6	281	75	83	97	122	30	348	79	143	88	98	1850
Calathus ingratus Dejean	1996	17	0	15	5	0	1	3	6	56	6	25	34	46	214
	1997	120	4	52	47	14	11	7	7	93	8	57	75	31	526
Carabus taedatus agassii Leconte	1996	9	0	0	0	0	0	0	0	8	0	0	0	9	26
	1997	14	0	1	0	0	0	0	0	3	0	0	0	1	19
Platynus decentis (Say)	1996	0	0	0	0	1	1	2	0	55	3	6	2	1	71
	1997	52	11	32	38	293	51	170	2	181	44	99	153	7	1133
Pterostichus adstrictus Eschscholtz	1996	7	1	12	4	1	2	4	1	90	2	9	28	1	162
	1997	232	117	113	147	55	36	66	19	128	4	23	56	5	1001
P. pensylvanicus LeConte	1996	4	0	66	2	1	6	0	4	52	66	15	2	169	387
	1997	266	8	675	16	41	18	5	7	172	133	75	191	188	1795
P. punctatissima (Randall)	1996	0	0	0	3	0	0	0	1	0	0	1	4	14	23
	1997	1	2	1	23	4	4	1	3	0	0	3	15	1	58

Table 4: Continued

CARABID SPECIES	YEAR	1		2		3		4		5		CONTROL			
		NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Scaphinotus bilobus (Say)	1996	6	1	9	10	4	0	1	0	6	5	5	3	4	54
	1997	1	2	4	1	4	5	4	0	0	2	0	5	1	29
Sphaeroderus nitidicollis brevoorti LeConte	1996	0	7	59	20	21	19	17	6	61	22	12	2	22	268
	1997	35	3	36	23	14	19	18	3	13	6	7	3	1	181
S. stenosmus lecontei Dejean	1996	35	0	0	0	0	0	0	0	6	15	0	0	34	90
	1997	0	0	0	0	0	0	0	0	0	6	0	0	5	11
Synuchus impunctatus (Say)	1996	7	10	42	10	5	9	4	5	95	38	12	12	216	465
	1997	192	53	687	134	32	17	18	24	199	79	73	113	77	1698

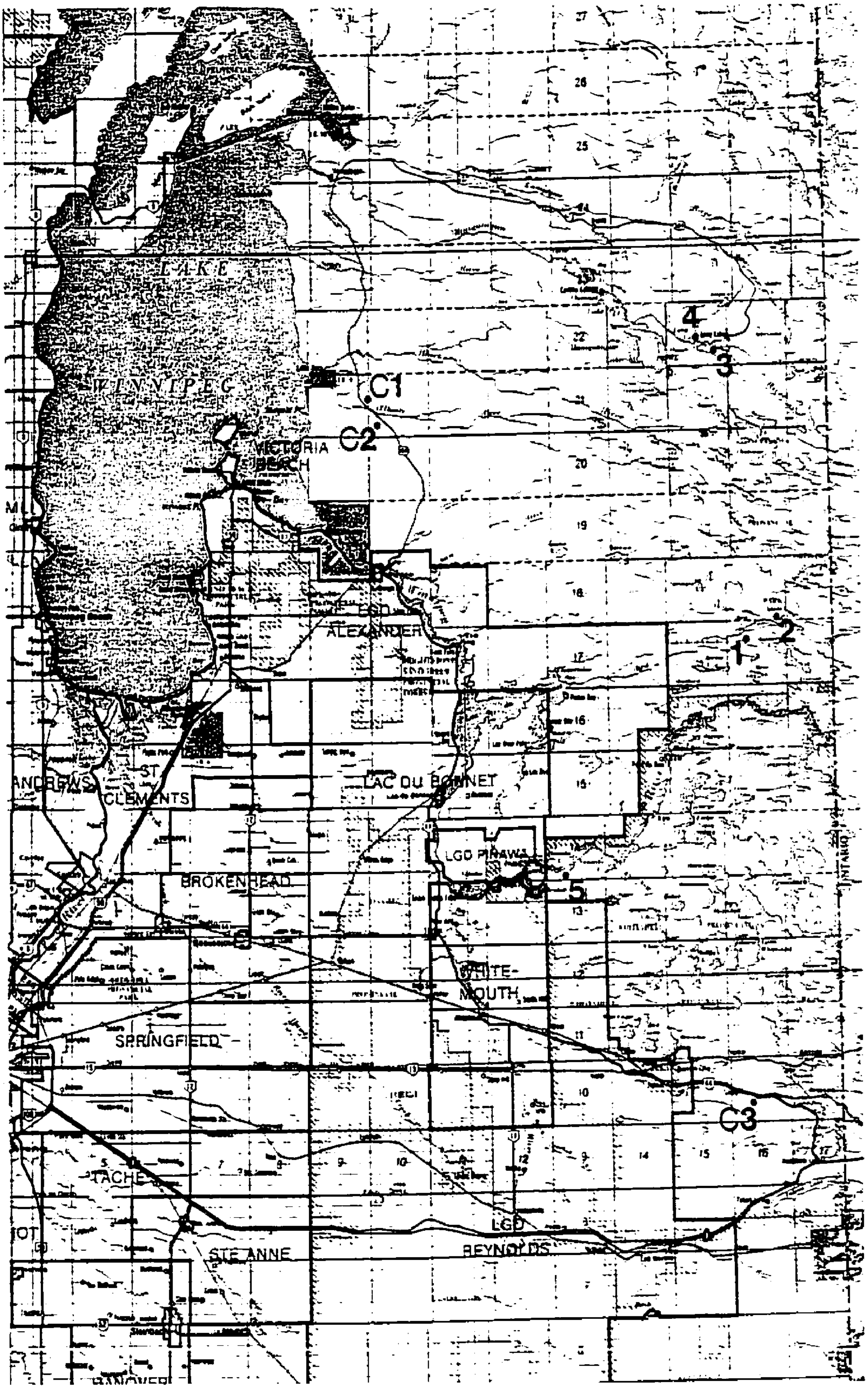
Table 5: Summary of significant effects of site differences on each taxon. Trends that are not quite significant are shown in brackets. Test results with the Whiteshell sites removed are indicated with †. Only the most significant of tests are reported here. Diversity measures for % cover data were Shannon Wiener indices. For all other data, log series alpha was used.

Taxon	Overall site type			Sprayed vs. unsprayed sites		
	Number of individuals	Number of species	Diversity	Number of individuals	Number of species	Diversity
Trees (Number of stems)	-	-	-	-	(More in unsprayed)†	Higher in unsprayed †
Shrubs (% cover)	-	-	-	(More in sprayed)	-	Higher in sprayed
Ground vegetation (% cover)	-	-	-	-	-	-
Moths 1996	Significant effect†	-	-	More in sprayed†	-	-
Moths 1997	-	-	-	-	-	-
Carabid beetles 1996	-	-	-	More in unsprayed	-	Higher in sprayed
Carabid beetles 1997	Significant effect	-	-	More in unsprayed	More in unsprayed	-

Table 6: Summary of influences on ordinations of each taxon with the Whiteshell sites excluded. Only the most significant trends are reported here. Trends that are not clearly defined are shown with (?).

Taxon	**CA**		**CCA**	
	Axis 1	**Axis 2**	**Axis 1**	**Axis 2**
Trees	Infested vs. control	Sprayed vs. unsprayed	Infested vs. control	?
Shrubs	Infested vs. control	Sprayed vs. unsprayed	Infested vs. control	% Deciduous trees
Ground vegetation	?	?	Infested vs. control	Sprayed vs. unsprayed
Moths 1996	Infested vs. control	Sprayed vs. unsprayed	Infested vs. control	Sprayed vs. unsprayed
Moths 1997	?	? (Axis 3 sprayed vs. unsprayed)	Unsprayed vs. sprayed & control	Sprayed vs. unsprayed
Carabid beetles 1996	?	?	?	Unsprayed vs. sprayed & control
Carabid beetles 1997	?	?	Geographical location	Sprayed vs. unsprayed within site pairs

Figure 1: Map showing general study region and locations of sites with site pairs and control sites.



LAKE
WINNIPEG
VICTORIA BEACH
C1
C2
4
3
2
1
5
C3
LGD ALEXANDER
LAC DU BONNET
LGD PINAWA
ST CLEMENTS
ANDREWS
BROKENHEAD
WHITEMOUTH
SPRINGFIELD
TACHE
STE ANNE
LGD REYNOLDS
HANOVER
ONTARIO

Figure 2: General layout of a typical 100 m x 100 m sampling site divided into four quadrants for vegetation sampling. The pitfall traps and light trap were in fixed locations during the study. The vegetation quadrats were randomly selected for each study site.
●= pitfall trap
X= light trap

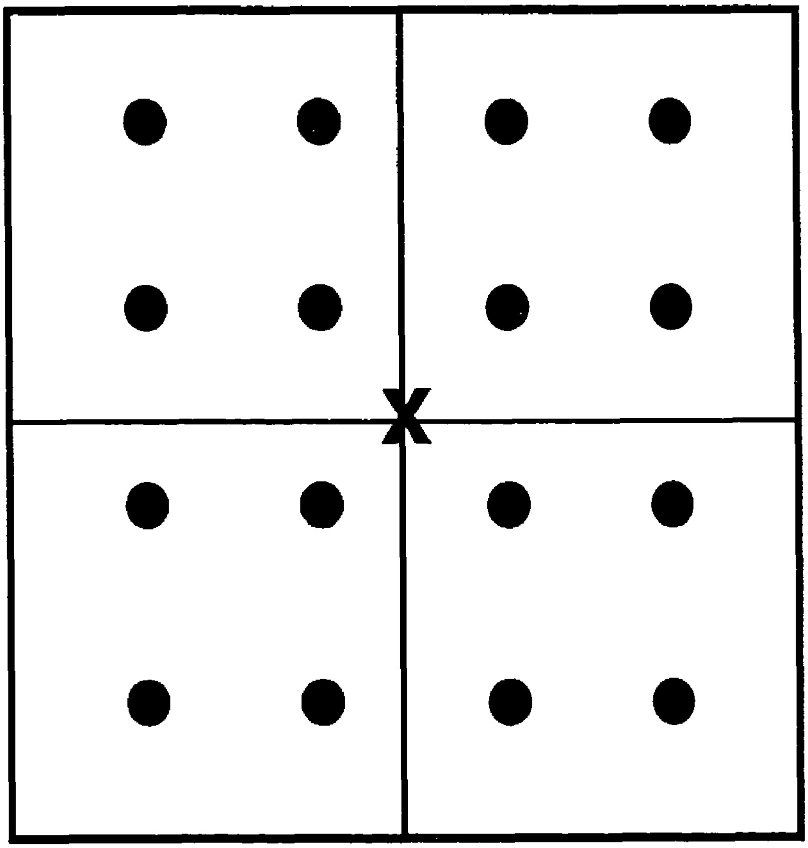

X

Figure 3: Arrangement of 166 m x 60 m rectangular site with pitfall traps (●) and light trap (X).

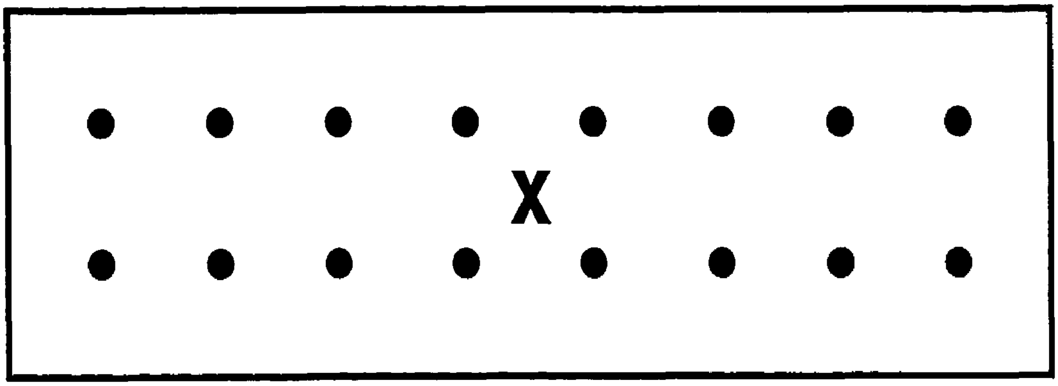

X

Figure 4: Modified layout of site 4-S following logging

● = pitfall trap
× = light trap
○ =1997 pitfall trap

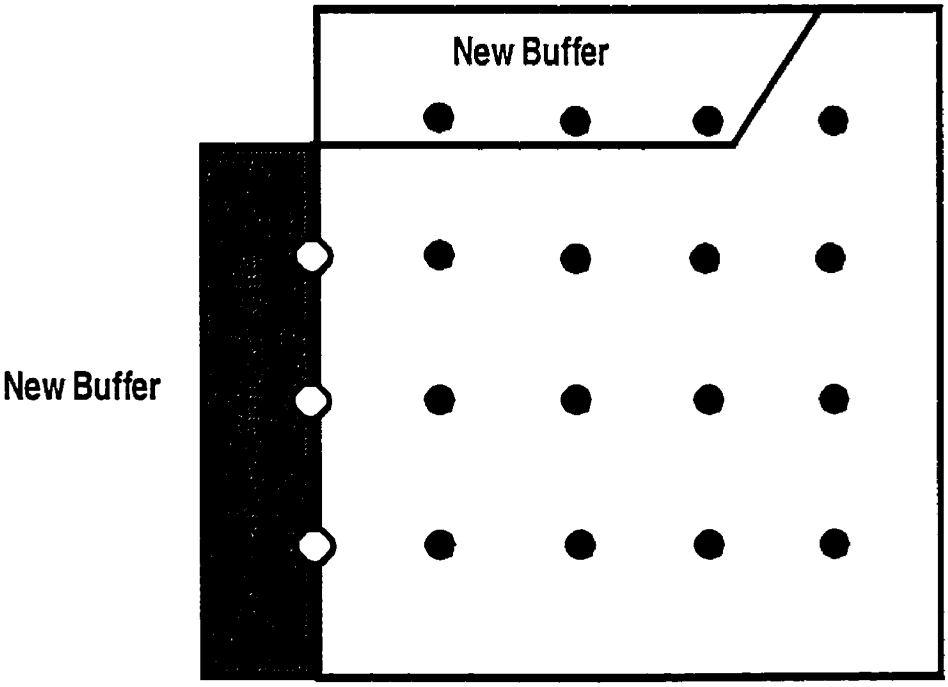

New Buffer
New Buffer

Figure 5: Photograph of a typical 1 m^2 quadrat used to sample ground vegetation.

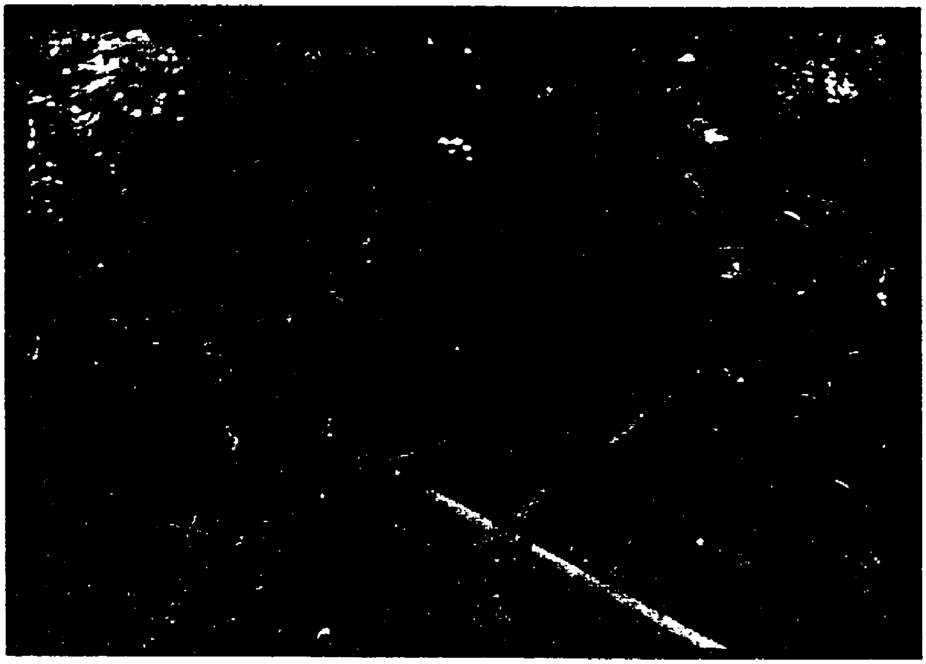


Figure 6: A schematic diagram of the Luminoc® light trap used for sampling moths.

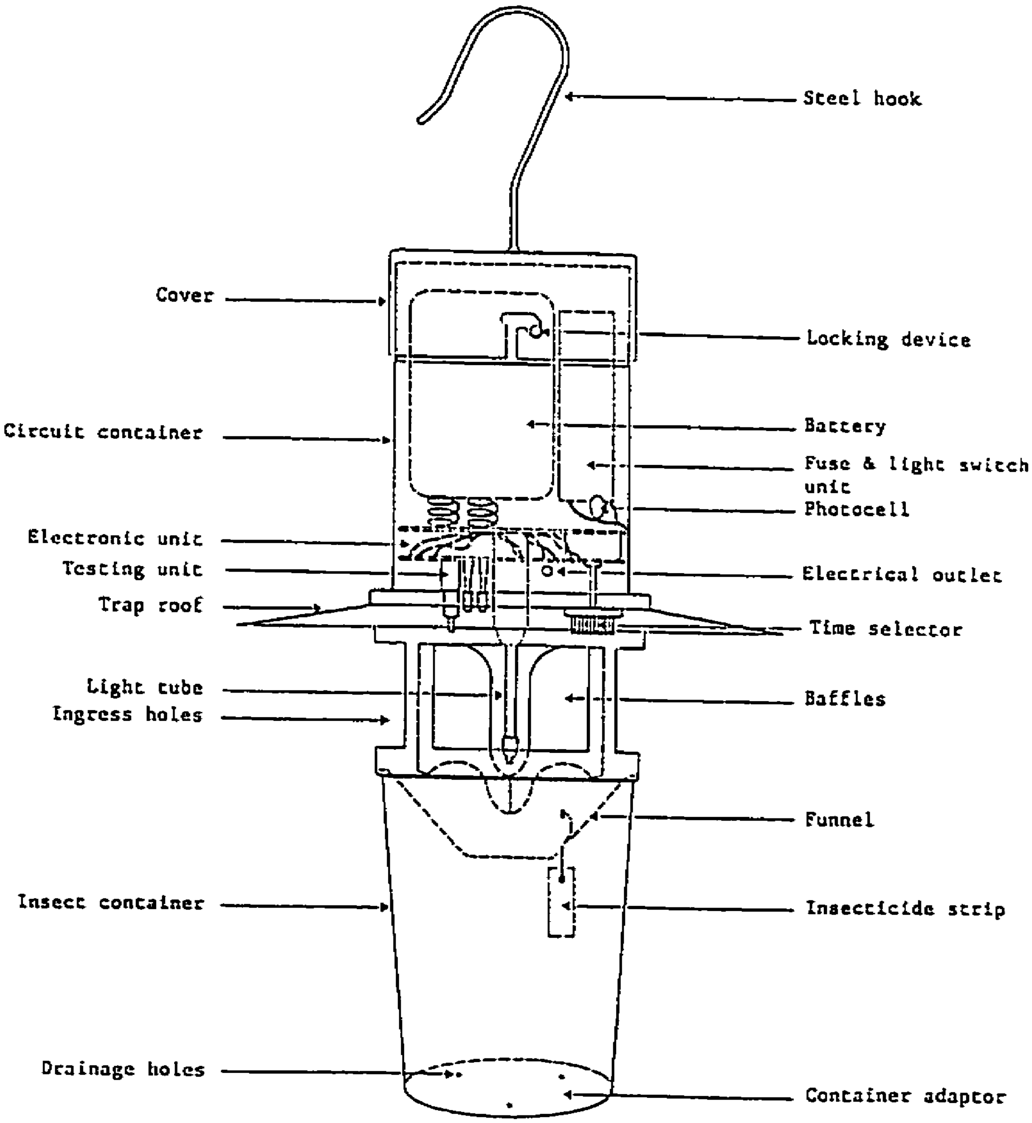

Steel hook
Cover
Locking device
Circuit container
Battery
Fuse & light switch unit
Photocell
Electronic unit
Testing unit
Electrical outlet
Trap roof
Time selector
Light tube
Ingress holes
Baffles
Funnel
Insect container
Insecticide strip
Drainage holes
Container adaptor

Figure 7: A photograph of the Luminoc® light trap approximately 2 m above ground in a tree.

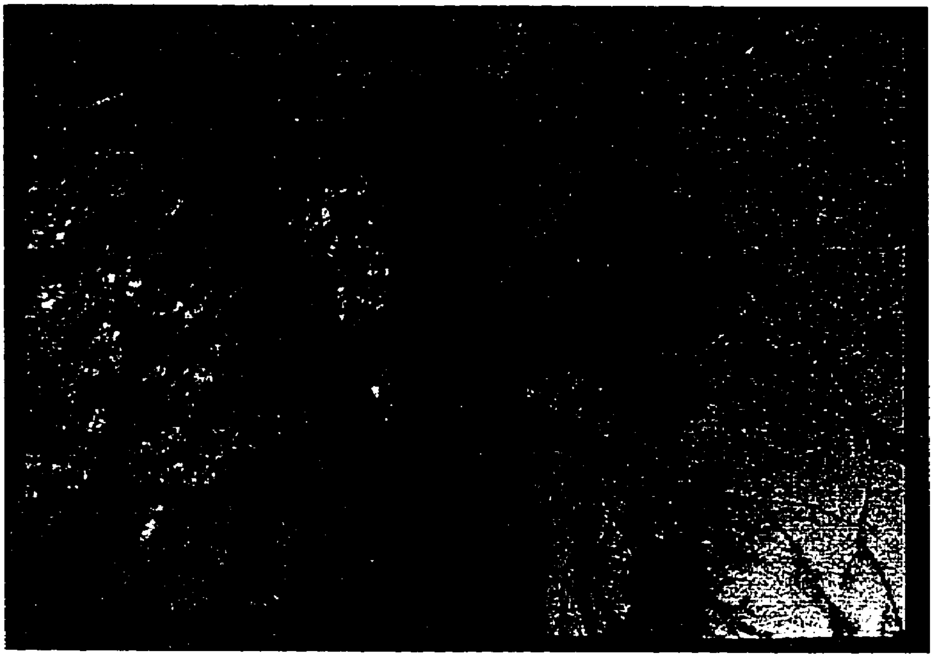


Figure 8: A pitfall trap for sampling carabid beetles. The trap was filled ⅔ full with a 50:50 mixture of propylene glycol and water. The square plywood rain cover is removed, and placed beside the trap.

Figure 9: Number (Mean± SEM) of tree stems in 500 m^2 for each site type.

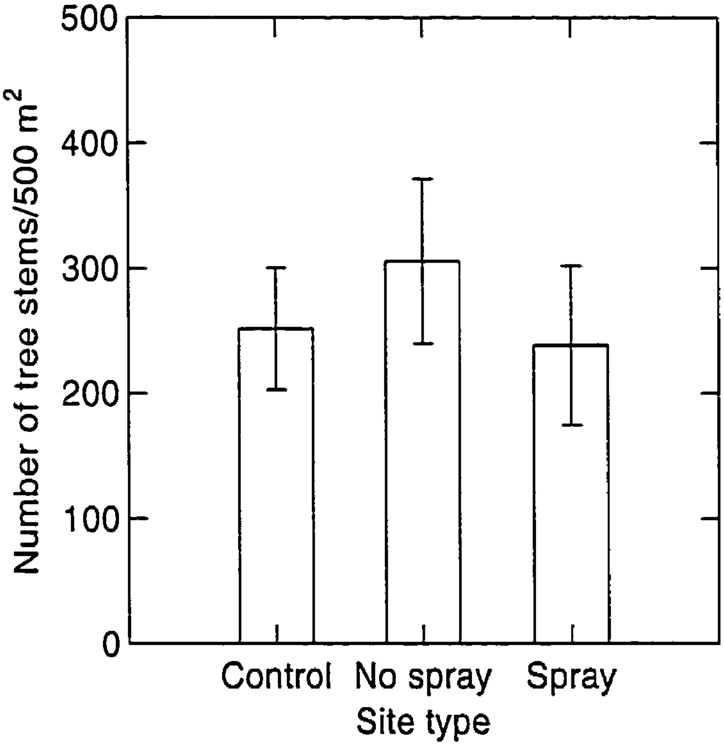

Number of tree stems/500 m^2
500
400
300
200
100
0
Control
No spray
Spray
Site type

Figure 10: The number of tree stems in 500 m^2 in sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

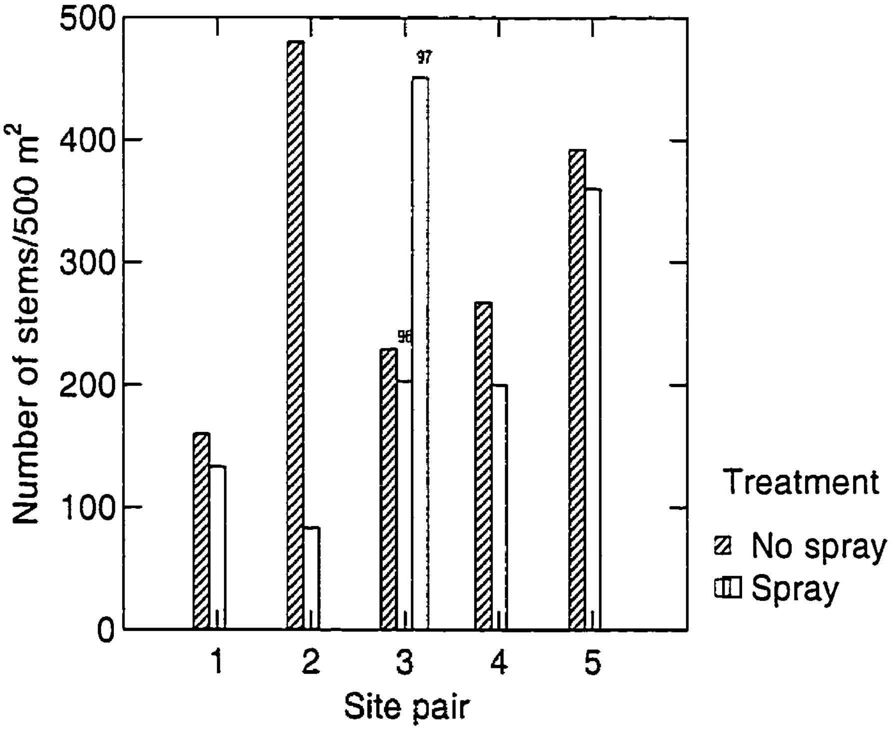

500
400
300
200
100
0
Number of stems/500 m^2
97
96
1
2
3
4
5
Site pair
Treatment
▨ No spray
□ Spray

Figure 11: Number (Mean ± SEM) of tree species in quadrat samples from each site type.

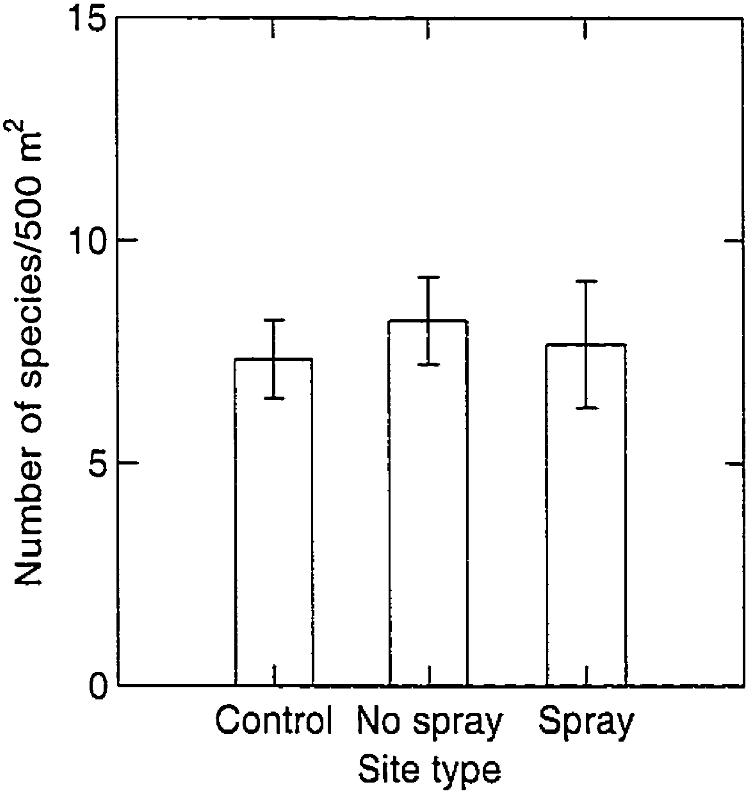

15
10
5
0
Number of species/500 m^2
Control
No spray
Spray
Site type

Figure 12: Number (Mean ± SEM) of tree species in quadrat samples from each site type with the Whiteshell sites excluded from analysis.

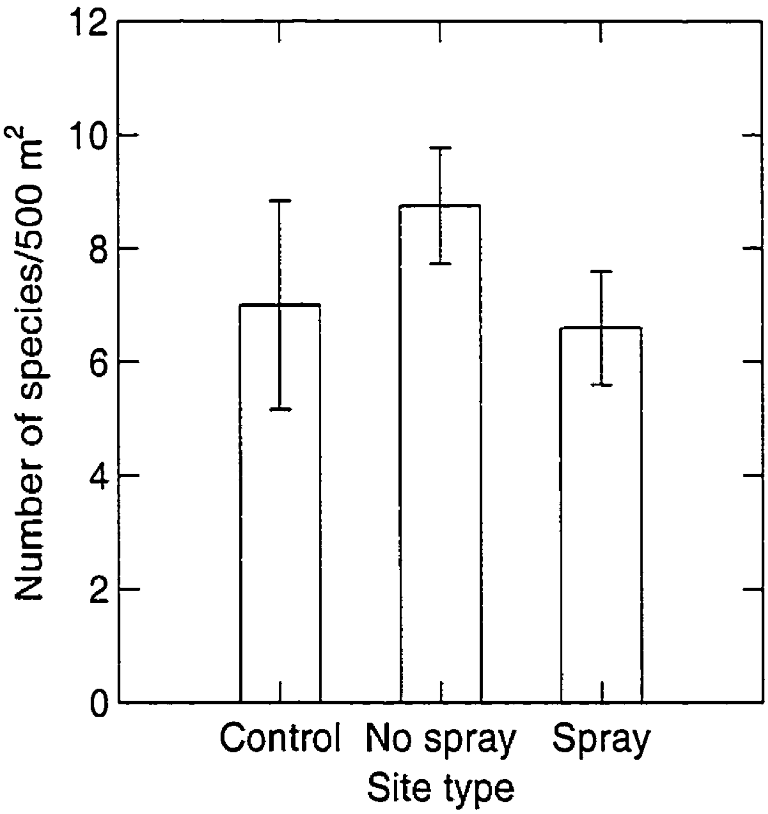

Number of species/500 m²
12
10
8
6
4
2
0
Control
No spray
Spray
Site type

Figure 13: The number of tree species in quadrat samples from sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

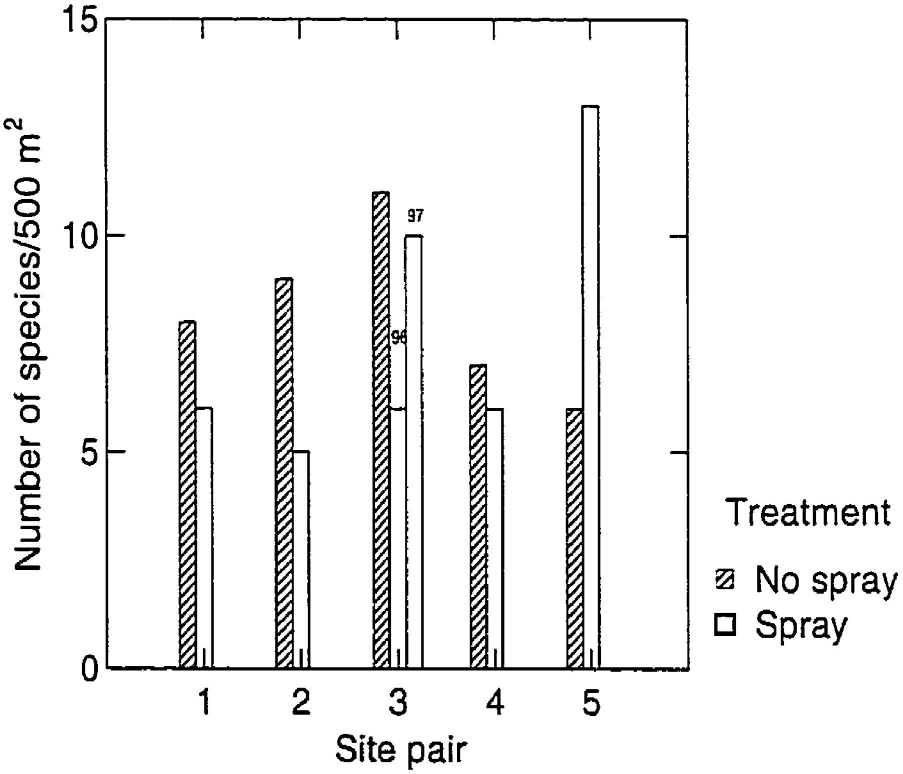

15
10
5
0
Number of species/500 m²
1
2
3
4
5
Site pair
97
96
Treatment
▨ No spray
☐ Spray

Figure 14: Log series alpha diversity (Mean ± SEM) of tree vegetation for each site type.

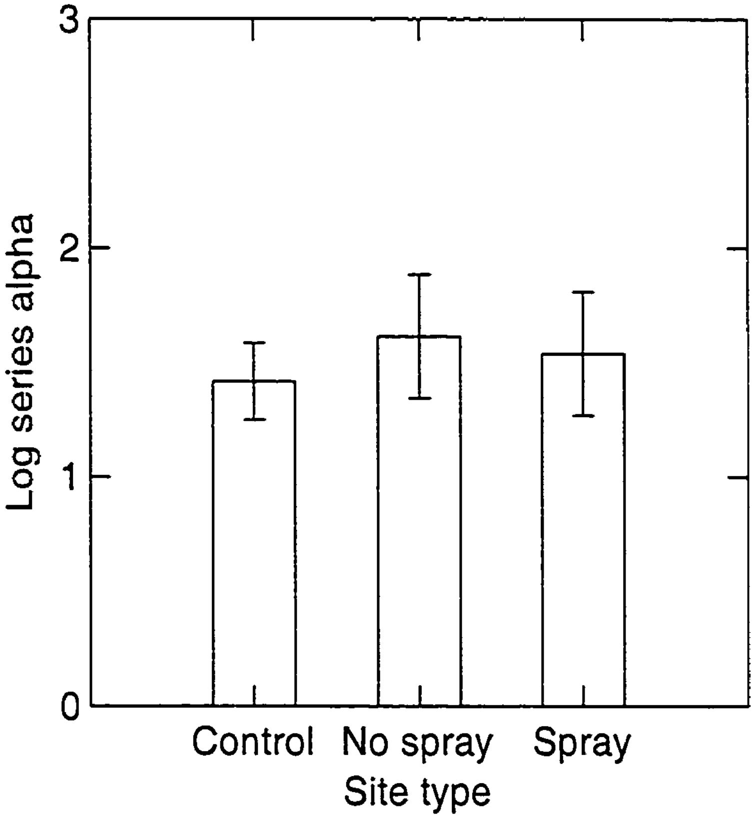

3
2
1
0
Log series alpha
Control
No spray
Spray
Site type

Figure 15: Log series alpha diversity (Mean ± SEM) of tree vegetation for each site type with the Whiteshell sites excluded from the analysis.

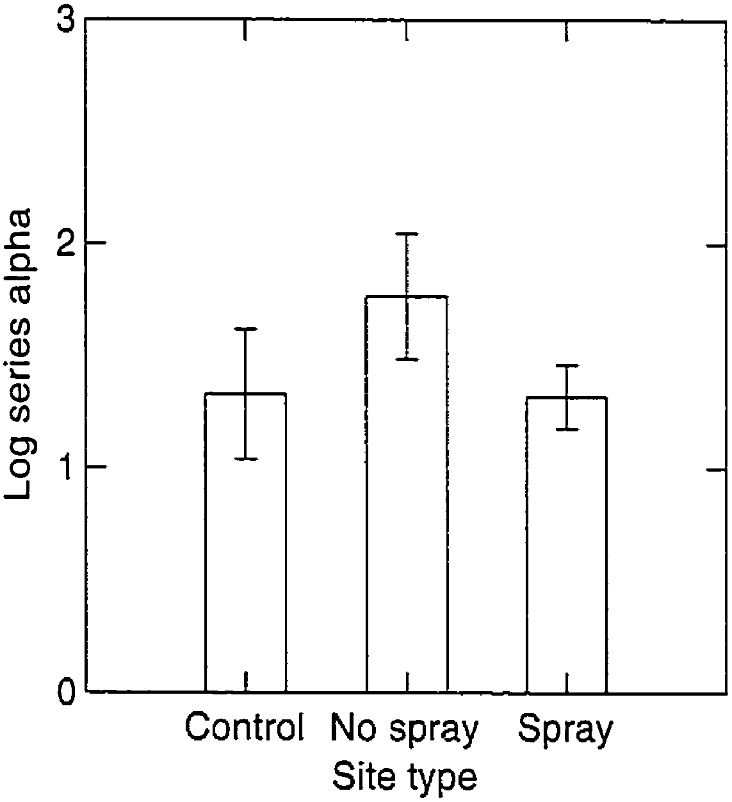

3
2
1
0
Log series alpha
Control
No spray
Spray
Site type

Figure 16: Log series alpha diversity of trees in sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

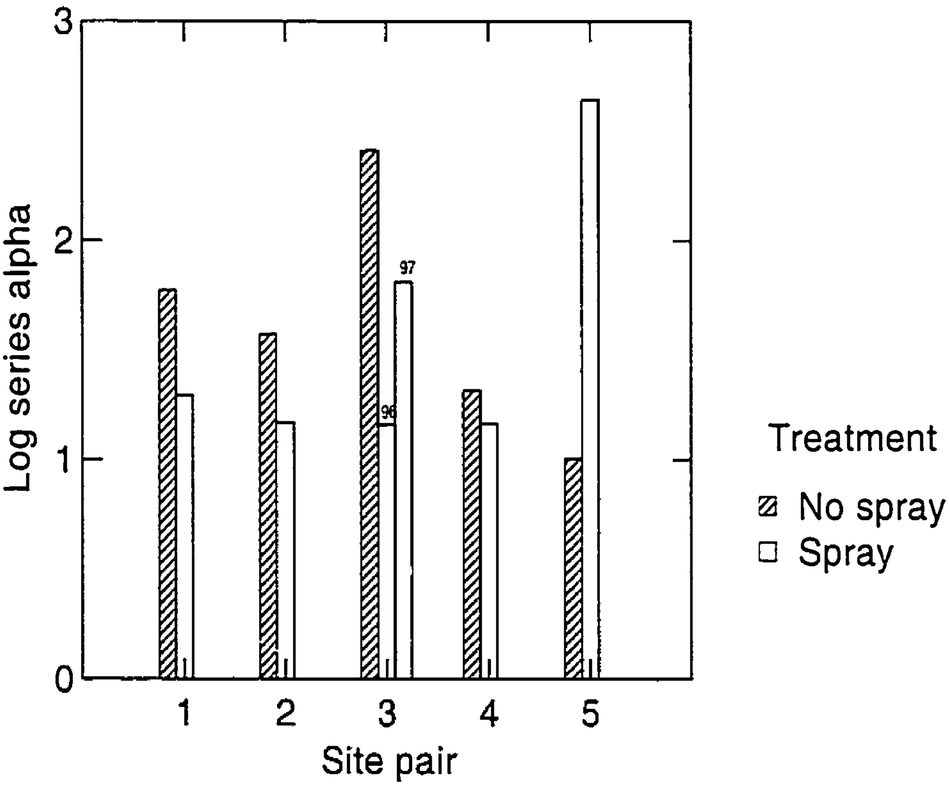

3
2
1
0
Log series alpha
96
97
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 17: Tree vegetation data. Correspondence analysis (CA) ordination diagram with site scores (◇) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.284=32.4%, and the second axis (vertical) has an eigenvalue of 0.162=18.5%.

Key to species:

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
BETPAP= *Betula papyrifera*
CORCOR= *Corylus cornuta*
CORSTO= *Cornus stolonifera*
FRAPEN= *Fraxinus pensylvanicus*
LARLAR= *Larix laricina*
PINBAN= *Pinus banksiana*
POPTRE= *Populus tremuloides*
PRUVIR= *Prunus virginiana*
QUEMAC= *Quercus macrocarpa*
SALIX= *Salix* sp.
VIBRAF= *Viburnum rafinesquianum*

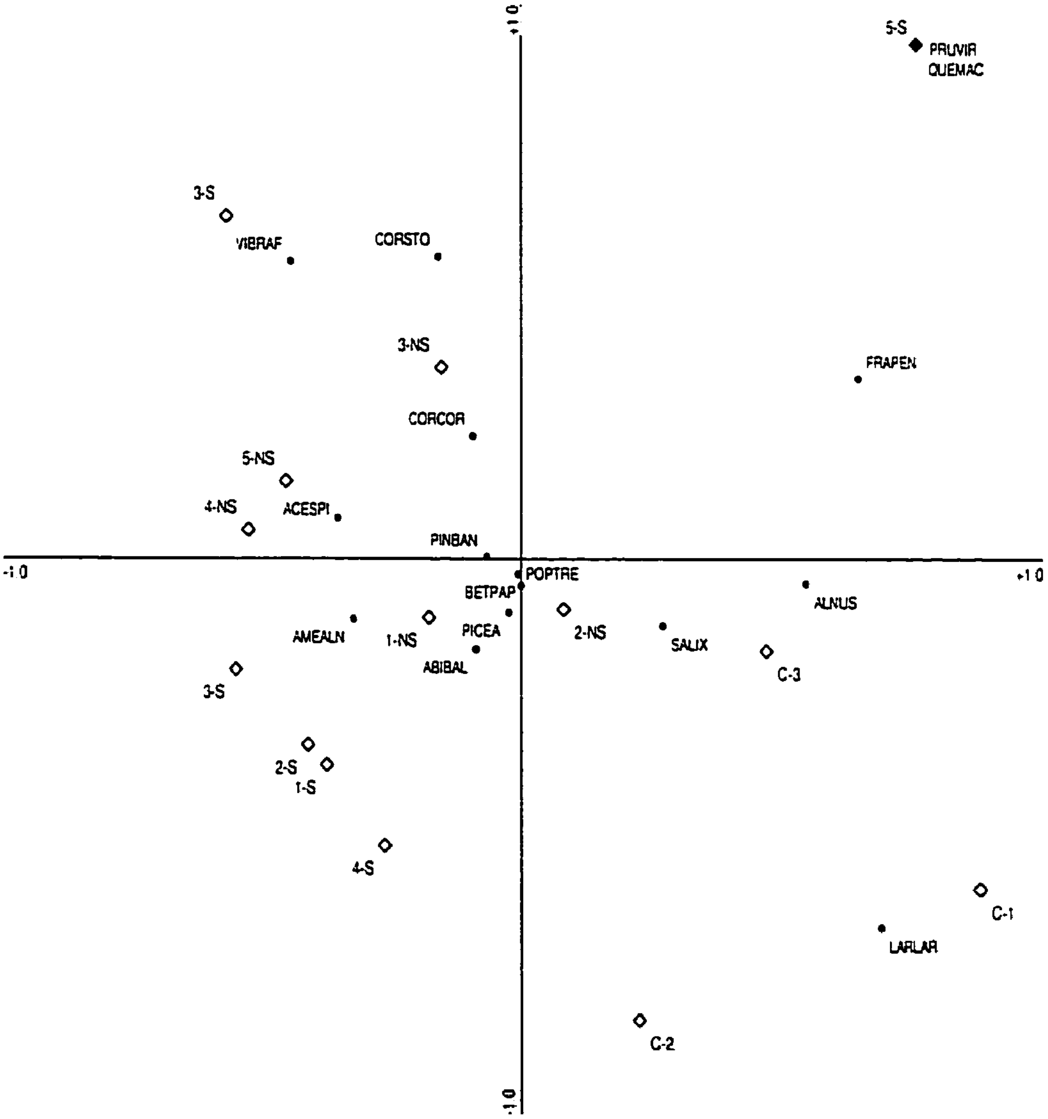

+1.0
5-S
PRUVIR
QUEMAC
3-S
VIBRAF
CORSTO
3-NS
FRAPEN
CORCOR
5-NS
4-NS
ACESPI
PINBAN
-1.0
POPTRE
+1.0
BETPAP
ALNUS
AMEALN
1-NS
PICEA
2-NS
SALIX
ABIBAL
C-3
3-S
2-S
1-S
4-S
C-1
LARLAR
C-2
-1.0

Figure 18: Tree vegetation data excluding the Whiteshell sites. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.289=37.5%, and the second axis (vertical) has an eigenvalue of 0.150=19.4%.

Key to species:
ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
BETPAP= *Betula papyrifera*
CORCOR= *Corylus cornuta*
CORSTO= *Cornus stolonifera*
FRAPEN= *Fraxinus pensylvanicus*
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PINBAN= *Pinus banksiana*
POPTRE= *Populus tremuloides*
PRUVIR= *Prunus virginiana*
QUEMAC= *Quercus macrocarpa*
SALIX= *Salix* sp.
VIBRAF= *Viburnum rafinesquianum*

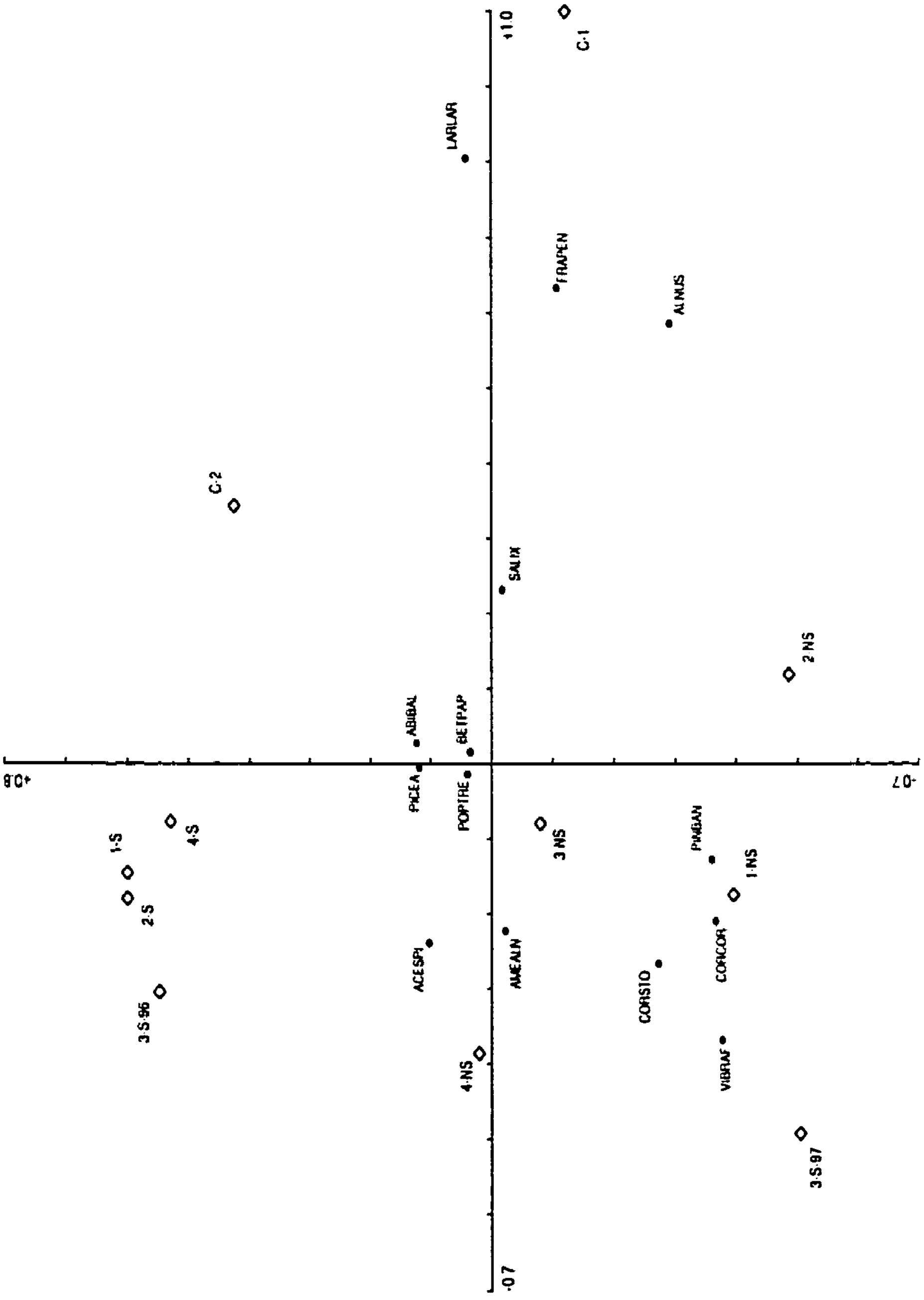
+1.0
-0.7
+0.8
-0.7
C-1
C-2
LARLAR
FRAPEN
ALNUS
SALIX
2-NS
ABIBAL
BETPAP
PICEA
POPTRE
3-NS
4-S
1-S
2-S
PINBAN
1-NS
CORCOR
ACESPI
AMEALN
CORSTO
3-S-96
VIBRAF
4-NS
3-S-97

Figure 19: Tree vegetation data. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.171=19.5%, and the second axis (vertical) has an eigenvalue of 0.109=12.5%.

Key to species:
ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
BETPAP= *Betula papyrifera*
CORCOR= *Corylus cornuta*
CORSTO= *Cornus stolonifera*
FRAPEN= *Fraxinus pensylvanicus*
LARLAR= *Larix laricina*
PINBAN= *Pinus banksiana*
POPTRE= *Populus tremuloides*
PRUVIR= *Prunus virginiana*
QUEMAC= *Quercus macrocarpa*
SALIX= *Salix* sp.
VIBRAF= *Viburnum rafinesquianum*

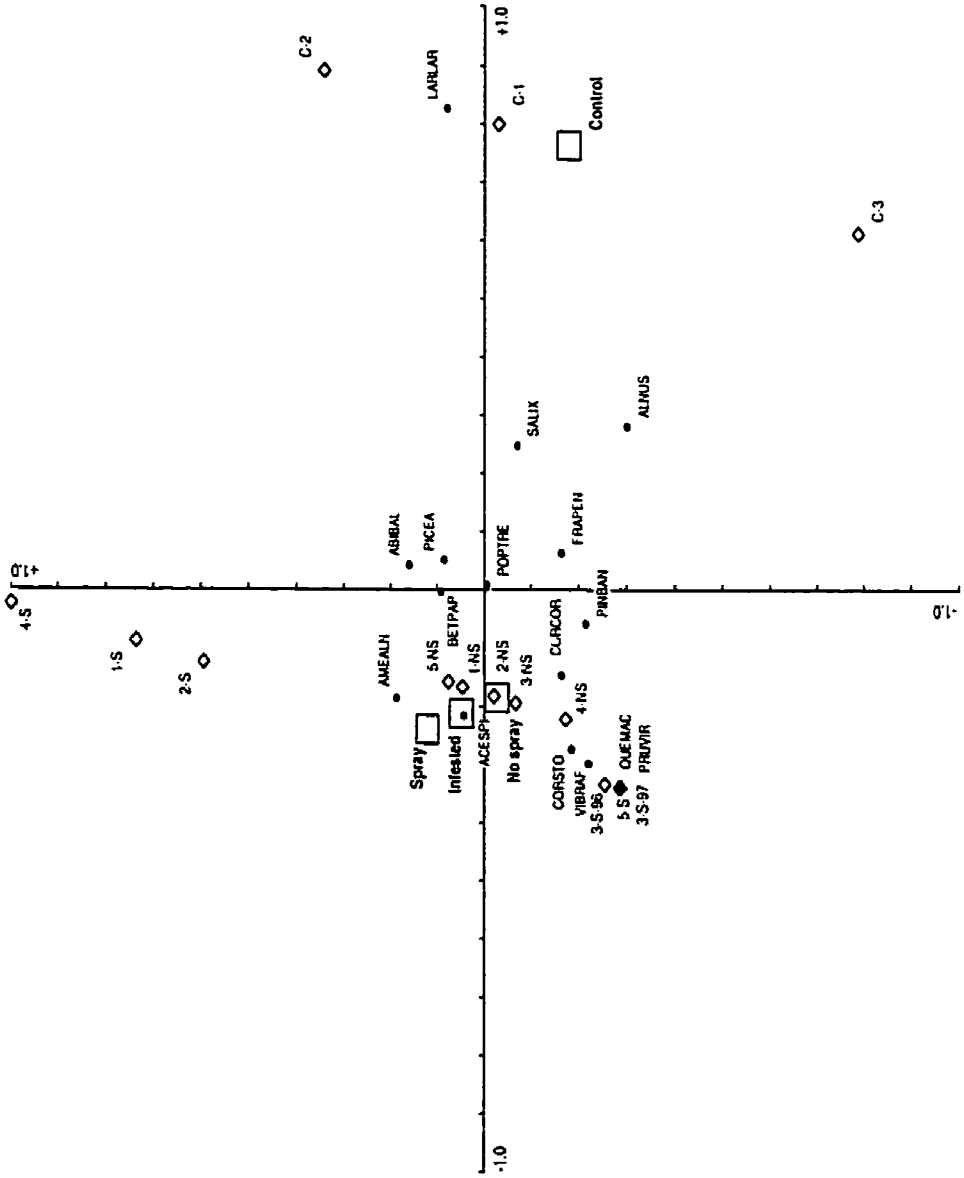
+1.0
-1.0
+1.0
-1.0
C-2
LARLAR
C-1
Control
C-3
ALNUS
SALIX
FRAPEN
ABIBAL
PICEA
POPTRE
PINBAN
4-S
1-S
2-S
AMEALN
5-NS
BETPAP
1-NS
2-NS
3-NS
CLRCOR
4-NS
Spray
Infested
ACESPI
No spray
CORSTO
VIBRAF
3-S-96
5-S
3-S-97
QUEMAC
PRUVIR

Figure 20: Tree vegetation data excluding the Whiteshell sites. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.171=19.5%, and the second axis (vertical) has an eigenvalue of 0.109=12.5%.

Key to species:

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
BETPAP= *Betula papyrifera*
CORCOR= *Corylus cornuta*
CORSTO= *Cornus stolonifera*
FRAPEN= *Fraxinus pensylvanicus*
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PINBAN= *Pinus banksiana*
POPTRE= *Populus tremuloides*
PRUVIR= *Prunus virginiana*
QUEMAC= *Quercus macrocarpa*
SALIX= *Salix* sp.
VIBRAF= *Viburnum rafinesquianum*

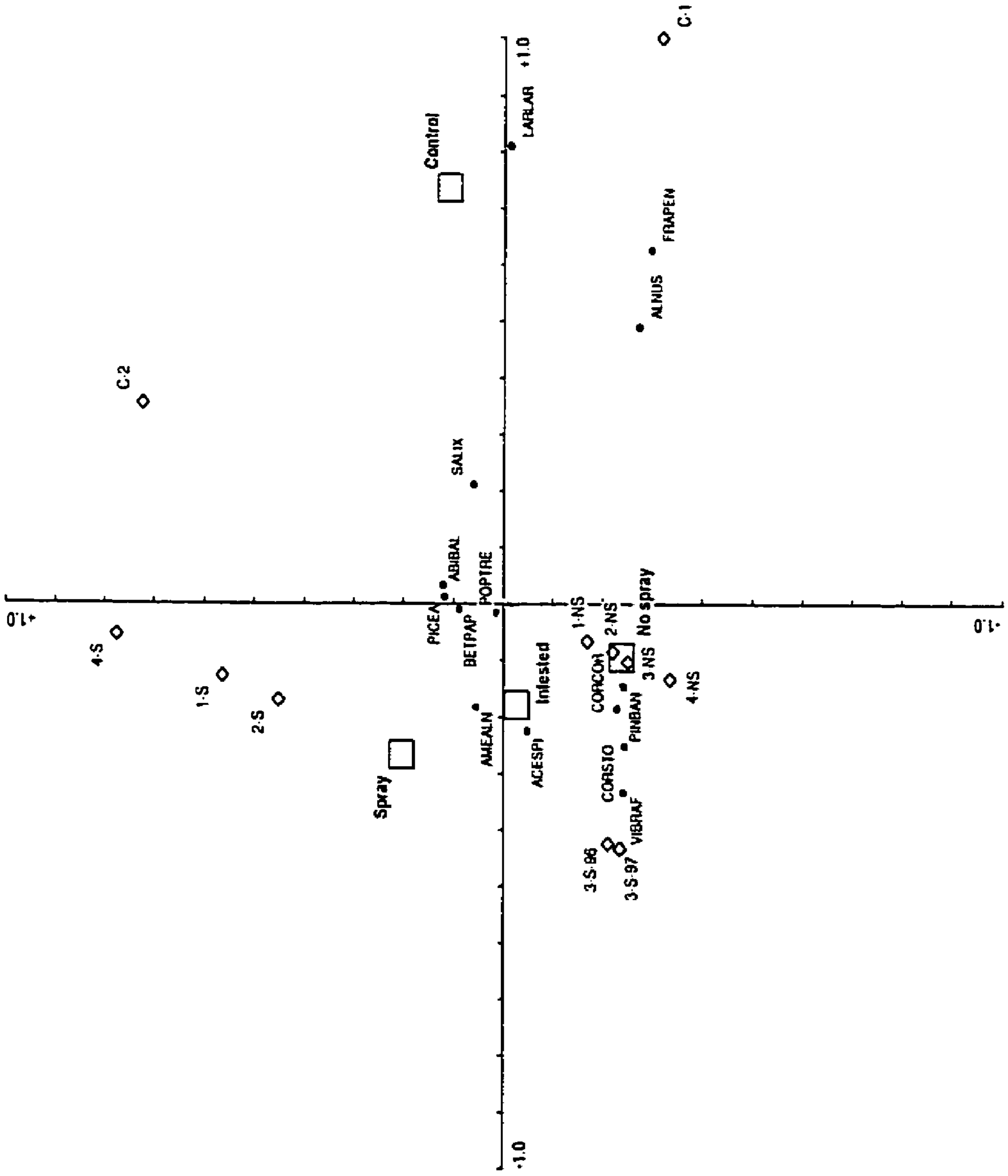

+1.0
-1.0
+1.0
-1.0
Control
Spray
Infested
No spray
C-1
C-2
1-S
2-S
4-S
3-S-96
3-S-97
1-NS
2-NS
3-NS
4-NS
LARLAR
FRAPEN
ALNUS
SALIX
ABIBAL
PICEA
BETPAP
POPTRE
AMEALN
ACESPI
CORCOR
PINBAN
CORSTO
VIBRAF

Figure 21: Percent cover (Mean ± SEM) of shrub vegetation in 4 m^2 for each site type.

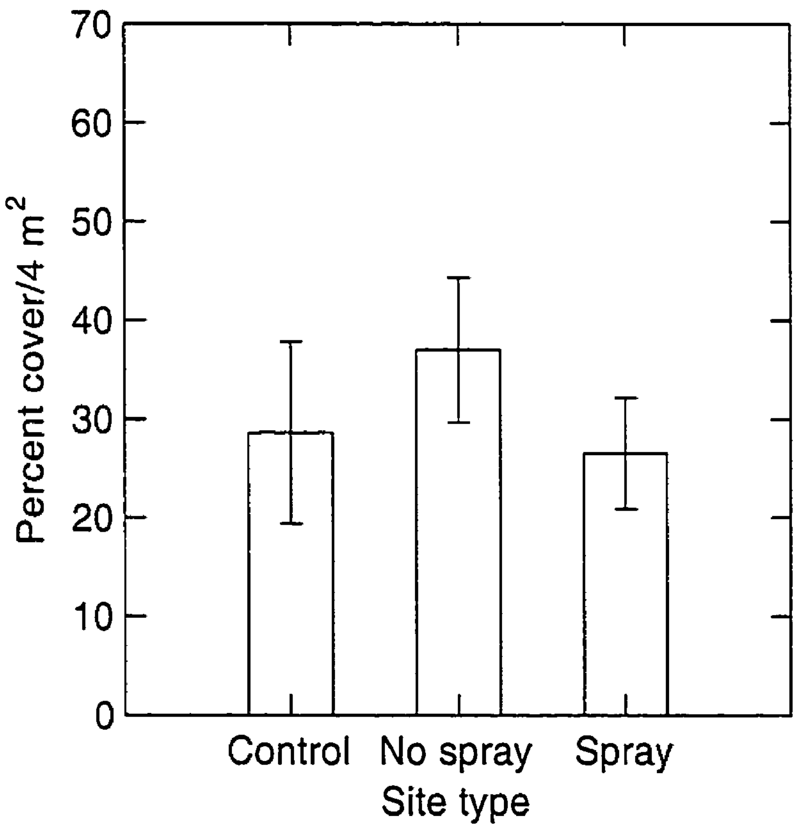

Percent cover/4 m^2
70
60
50
40
30
20
10
0
Control
No spray
Spray
Site type

Figure 22: The percent cover of shrub vegetation in quadrat samples from sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

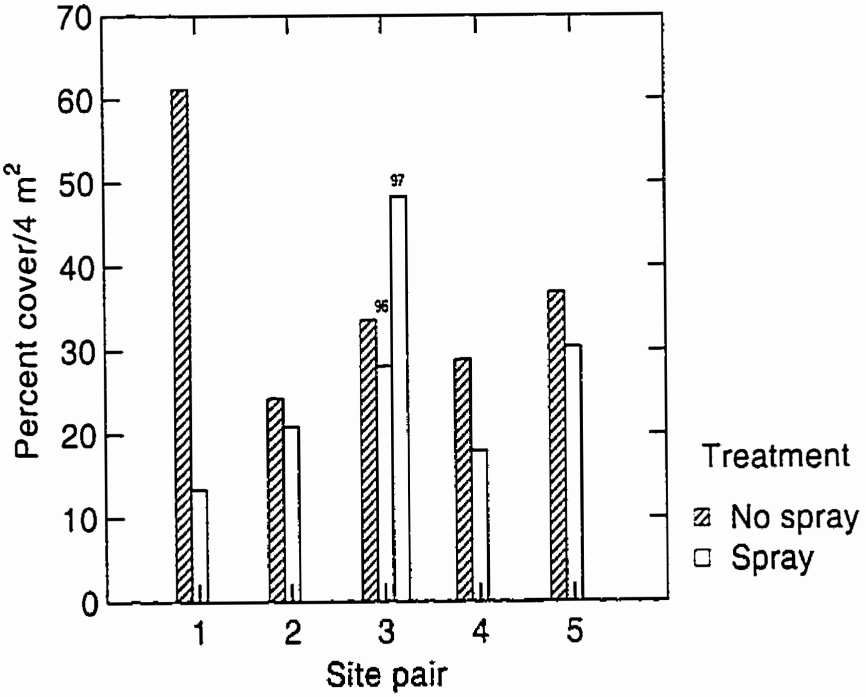

70
60
50
40
30
20
10
0
Percent cover/4 m2
97
96
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 23: Number (Mean ± SEM) of shrub species in quadrat samples from each site type.

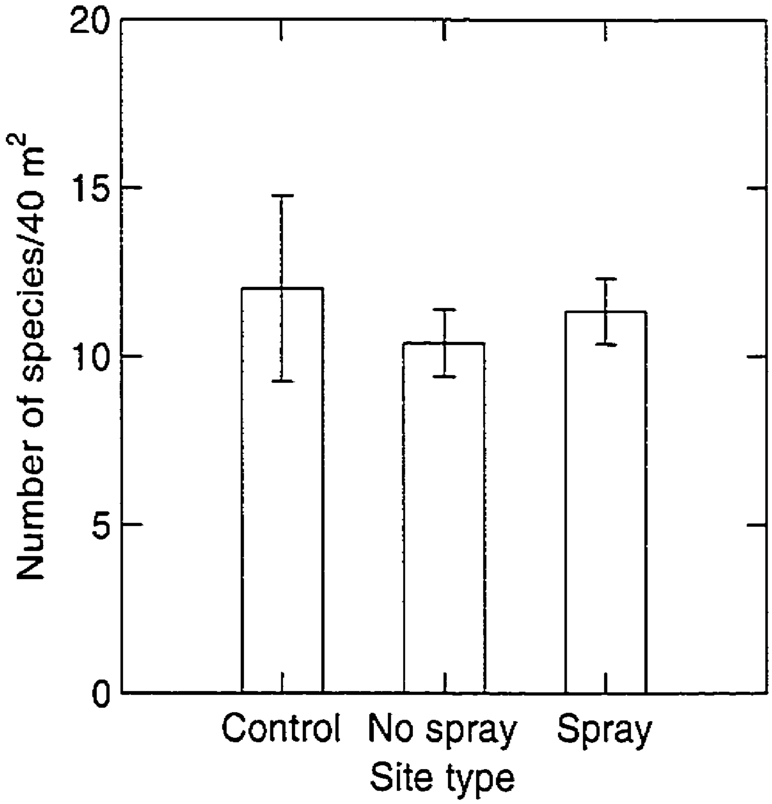

20
15
10
5
0
Number of species/40 m^2
Control
No spray
Spray
Site type

Figure 24: The number of shrub species in quadrat samples from sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

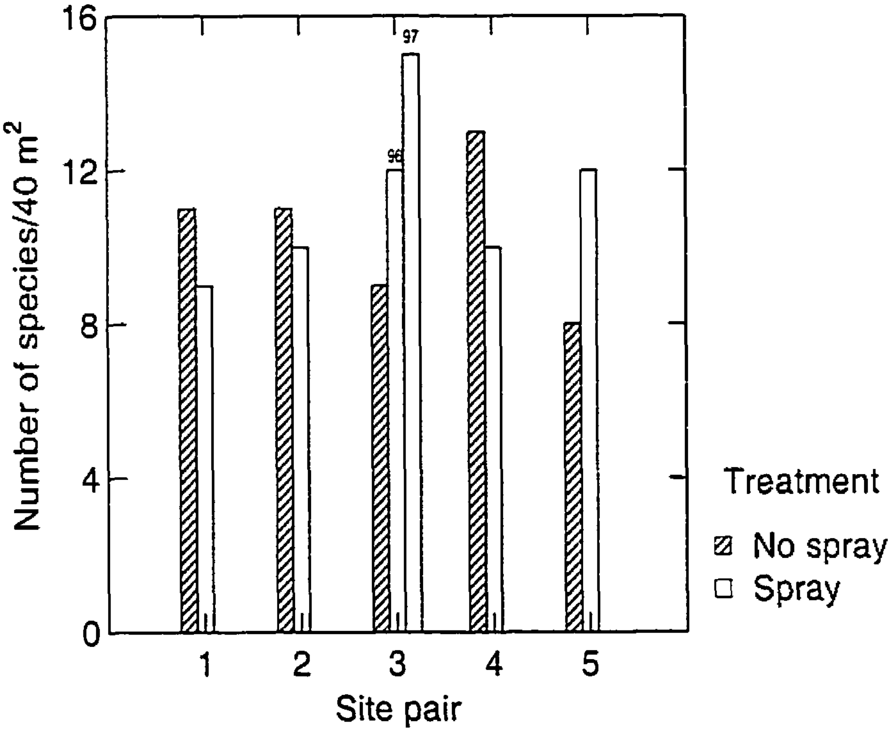

Number of species/40 m²
16
12
8
4
0
1
2
3
4
5
Site pair
97
96
Treatment
▨ No spray
☐ Spray

Figure 25: Shannon Wiener index of diversity (Mean ± SEM) of shrub vegetation for each site type.

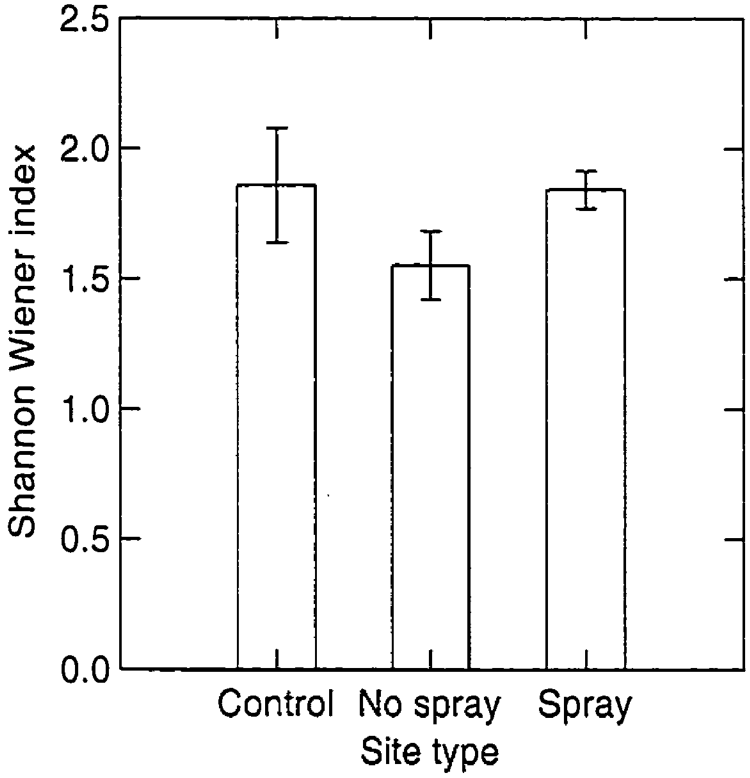

2.5
2.0
1.5
1.0
0.5
0.0
Shannon Wiener index
Control
No spray
Spray
Site type

Figure 26: Shannon Wiener diversity of shrub vegetation in sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

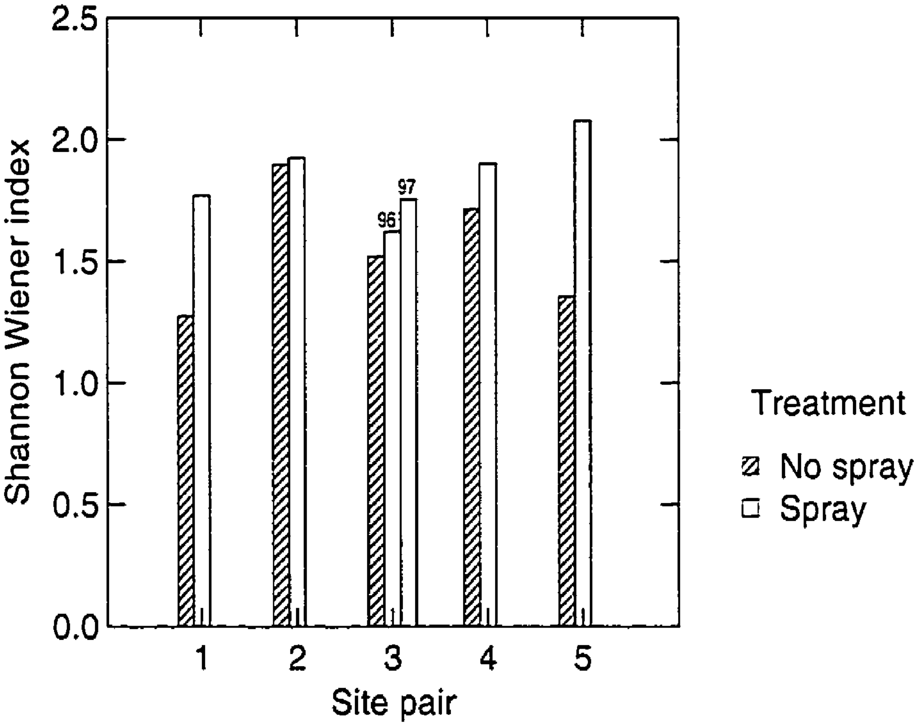

2.5
2.0
1.5
1.0
0.5
0.0
Shannon Wiener index
96
97
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 27: Shrub vegetation data. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.481=24.6%, and the second axis (vertical) has an eigenvalue of 0.372=19.0%.

Key to species:

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
APOAND= *Apocynum androsaemifolium*
BETPAP= *Betula papyrifera*
CORALT= *Cornus alternifolia*
CORCOR= *Cornus cornuta*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
KALPOL= *Kalmia polifolia*
FRAPEN= *Fraxinus pensylvanicus*
LEDGRO= *Ledum groenlandicum*
LONDIO= *Lonicera dioca*
PICEA=*Picea glauca*
POPTRE= *Populus tremuloides*
PRUNUS= *Prunus* sp.
RHAALN= *Rhamnus alnifolia*
RIBAME= *Ribes americanum*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
RIBTRI= *Ribes triste*
RUBIDA= *Rubus idaeus*
ROSA= *Rosa* sp.
SALIX= *Salix* sp.
SYMPHO= *Symphoricarpos alba*
VACMYR= *Vaccinium myrtilloides*
VIBEDU= *Viburnum edule*
VIBRAF= *Viburnum rafinesquianum*

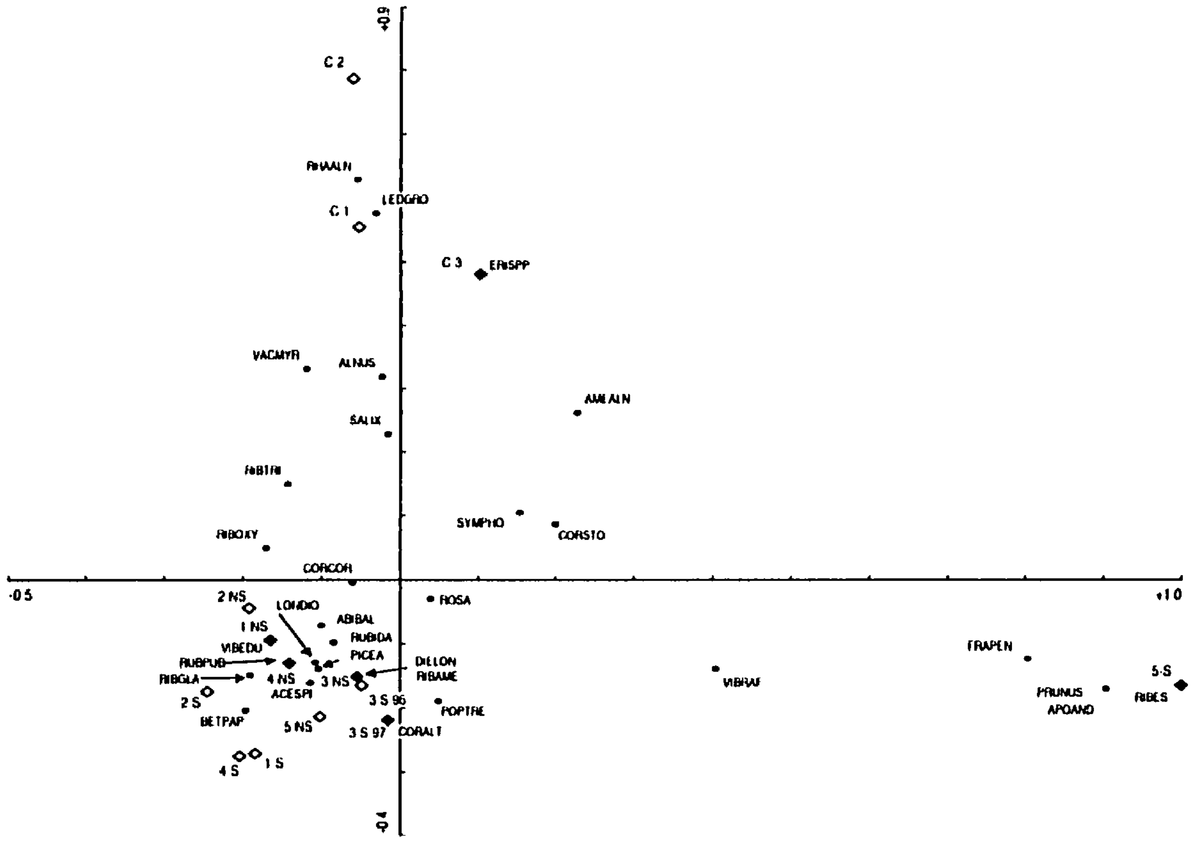

+0.9
-0.4
-0.5
+1.0
C 2
RHAALN
LEDGRO
C 1
C 3
ERISPP
VACMYR
ALNUS
AMEALN
SALIX
RIBTRI
SYMPHO
CORSTO
RIBOXY
CORCOR
2 NS
LONDIO
ROSA
ABIBAL
1 NS
RUBIDA
VIBEDU
PICEA
DIELON
RIBAME
RUBPUB
RIBGLA
4 NS
3 NS
ACESPI
2 S
3 S 96
POPTRE
BETPAP
5 NS
3 S 97
CORALT
4 S
1 S
VIBRAF
FRAPEN
5 S
PRUNUS
APOAND
RIBES

Figure 28: Shrub vegetation data excluding the Whiteshell sites. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.395=27.1%, and the second axis (vertical) has an eigenvalue of 0.303=20.8%.

Key to species:

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
APOAND= *Apocynum androsaemifolium*
BETPAP= *Betula papyrifera*
CORALT= *Cornus alternifolia*
CORCOR= *Cornus cornuta*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
KALPOL= *Kalmia polifolia*
FRAPEN= *Fraxinus pensylvanicus*
LEDGRO= *Ledum groenlandicum*
LONDIO= *Lonicera dioca*
PICEA= *Picea glauca*
POPTRE= *Populus tremuloides*
PRUNUS= *Prunus* sp.
RHAALN= *Rhamnus alnifolia*
RIBAME= *Ribesamericanum*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
RIBTRI= *Ribes trist*
RUBIDA= *Rubus idaeus*
ROSA= *Rosa* sp.
SALIX= *Salix* sp.
SYMPHO= *Symphoricarpos alba*
VACMYR= *Vaccinium myrtilloides*
VIBEDU= *Viburnum edule*
VIBRAF= *Viburnum rafinesquianum*

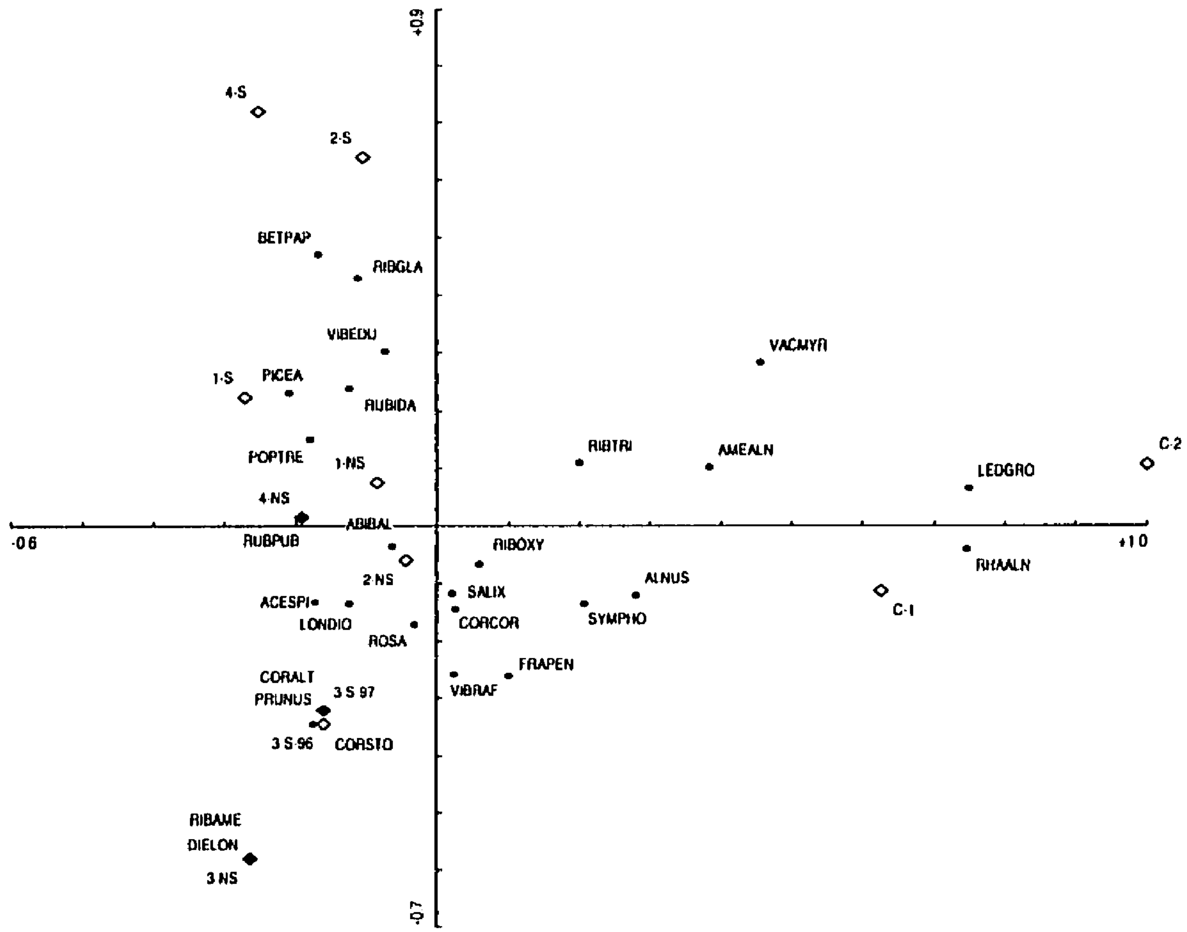

+0.9
-0.7
-0.6
+1.0
4-S
2-S
BETPAP
RIBGLA
VIBEDU
VACMYR
1-S
PICEA
RUBIDA
RIBTRI
AMEALN
C-2
POPTRE
1-NS
LEDGRO
4-NS
ABIBAL
RUBPUB
RIBOXY
RHAALN
ALNUS
2-NS
SALIX
C-1
ACESPI
LONDIO
CORCOR
SYMPHO
ROSA
FRAPEN
CORALT
3 S 97
PRUNUS
VIBRAF
3 S 96
CORSTO
RIBAME
DIELON
3 NS

Figure 29: Shrub vegetation data. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.361=18.4%, and the second axis (vertical) has an eigenvalue of 0.264=13.6%.

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
APOAND= *Apocynumandrosaemifolium*
BETPAP= *Betula papyrifera*
CORALT= *Cornus alternifolia*
CORCOR= *Cornus cornuta*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
KALPOL= *Kalmia polifolia*
FRAPEN= *Fraxinus pensylvanicus*
LEDGRO= *Ledum groenlandicum*
LONDIO= *Lonicera dioca*
PICEA= *Picea glauca*
POPTRE= *Populus tremuloides*
PRUNUS= *Prunus* sp.
RHAALN= *Rhamnus alnifolia*
RIBAME= *Ribes americanum*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
RIBTRI=*Ribes triste*
RUBIDA= *Rubus idaeus*
ROSA= *Rosa* sp.
SALIX= *Salix* sp.
SYMPHO= *Symphoricarpos alba*
VACMYR= *Vaccinium myrtilloides*
VIBEDU= *Viburnum edule*
VIBRAF= *Viburnum rafinesquianum*

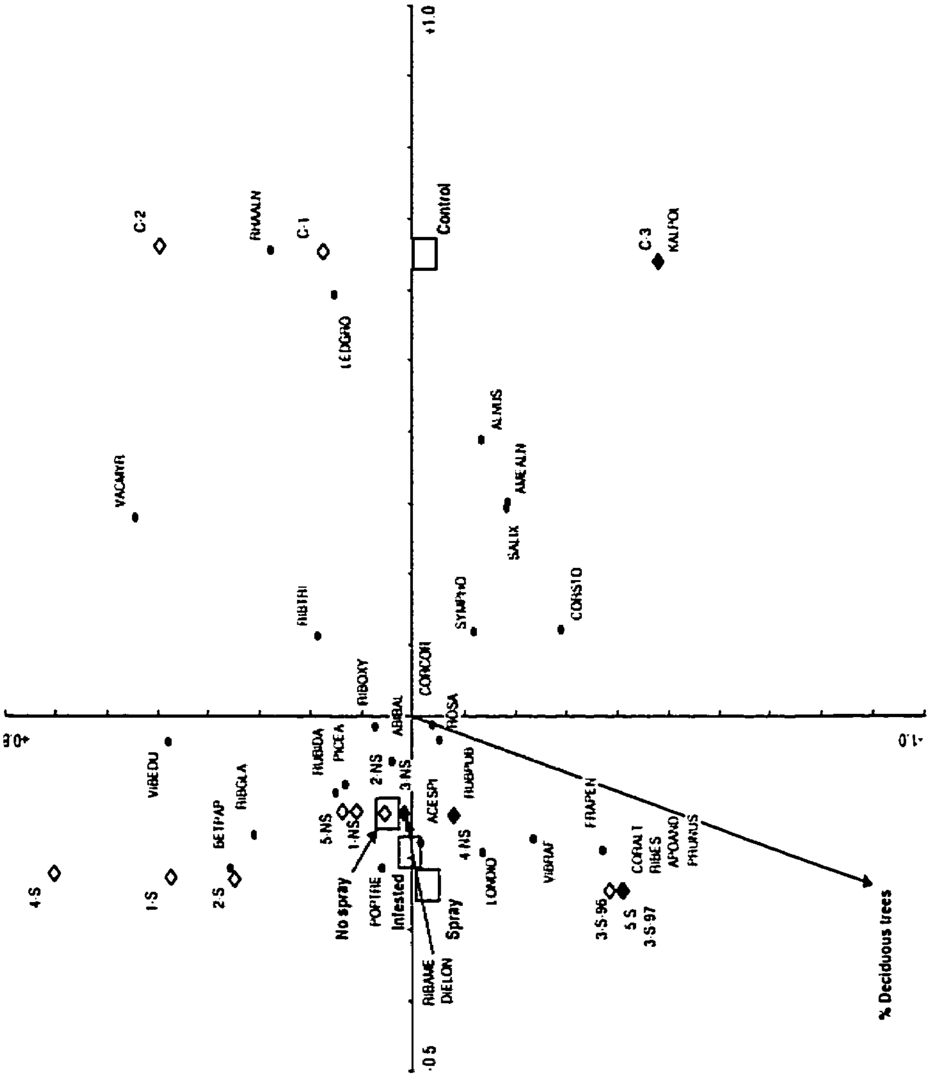

+1.0
-0.5
+0.8
-1.0
C-2
RHAALN
C-1
Control
C-3
KALPOL
LEDGRO
ALNUS
AMEALN
SALIX
VACMYR
RIBTRI
SYMPHO
CORSTO
RIBOXY
CORCOR
ABIBAL
ROSA
VIBEDU
RUBIDA
PICEA
2-NS
3-NS
RUBPUB
RIBGLA
BETPAP
ACESPI
FRAPEN
5-NS
1-NS
4-NS
VIBRAF
CORALT
RIBES
APOAND
PRUNUS
4-S
1-S
2-S
No spray
POPTRE
Infested
LONDIO
Spray
3-S-96
5-S
3-S-97
RIBAME
DIELON
% Deciduous trees

Figure 30: Shrub vegetation data with Whiteshell sites excluded. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.361=18.4%, and the second axis (vertical) has an eigenvalue of 0.264=13.6%.

Key to species:

ABIBAL= *Abies balsamea*
ACESPI= *Acer spicatum*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
APOAND= *Apocynum androsaemifolium*
BETPAP= *Betula papyrifera*
CORALT= *Cornus alternifolia*
CORCOR= *Cornus cornuta*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
KALPOL= *Kalmia polifolia*
FRAPEN= *Fraxinus pensylvanicus*
LEDGRO= *Ledum groenlandicum*
LONDIO= *Lonicera dioca*
PICEA= *Picea glauca*
POPTRE= *Populus tremuloides*
PRUNUS= *Prunus* sp.
RHAALN= *Rhamnus alnifolia*
RIBAME= *Ribes americanum*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
RIBTRI= *Ribes triste*
RUBIDA= *Rubus idaeus*
ROSA= *Rosa* sp.
SALIX= *Salix* sp.
SYMPHO= *Symphoricarpos alba*
VACMYR= *Vaccinium myrtilloides*
VIBEDU= *Viburnum edule*
VIBRAF= *Viburnum rafinesquianum*

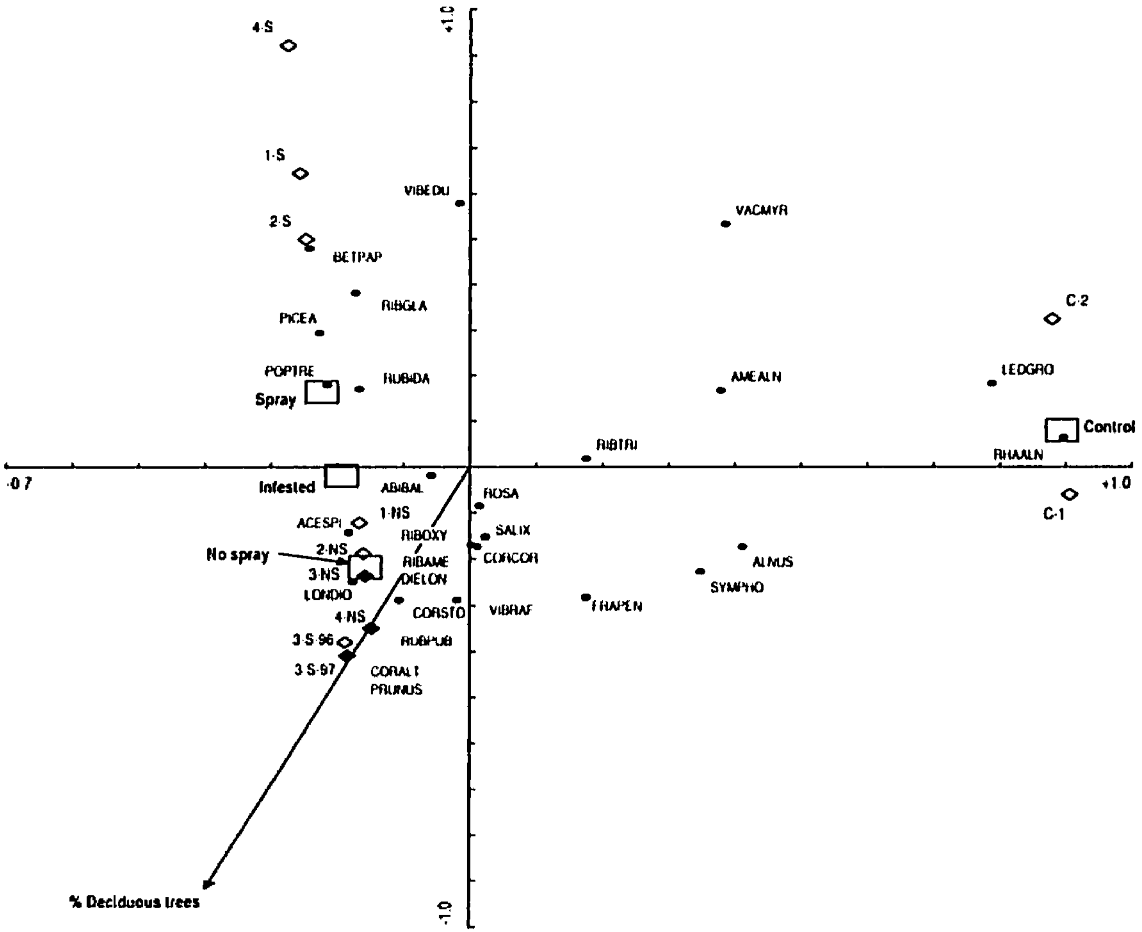

4-S
1-S
2-S
VIBEDU
VACMYR
BETPAP
RIBGLA
PICEA
C-2
POPTRE
Spray
RUBIDA
AMEALN
LEDGRO
Control
RIBTRI
RHAALN
-0.7
+1.0
+1.0
-1.0
Infested
ABIBAL
ROSA
C-1
1-NS
ACESPI
SALIX
RIBOXY
2-NS
No spray
RIBAME
CORCOR
ALNUS
3-NS
DIELON
SYMPHO
LONDIO
CORSTO
VIBRAF
FRAPEN
4-NS
3-S-96
RUBPUB
3-S-97
CORALT
PRUNUS
% Deciduous trees

Figure 31: Percent cover (Mean ± SEM) of ground vegetation in 1 m^2 for each site type.

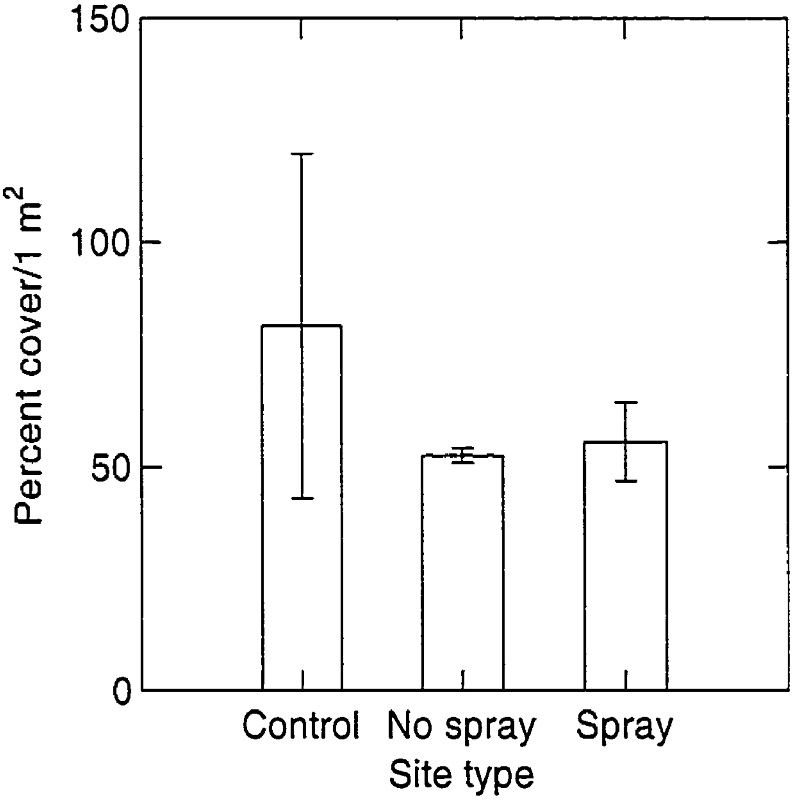

150
100
50
0
Percent cover/1 m^2
Control
No spray
Spray
Site type

Figure 32: The percent cover of ground vegetation in quadrats sampled from sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

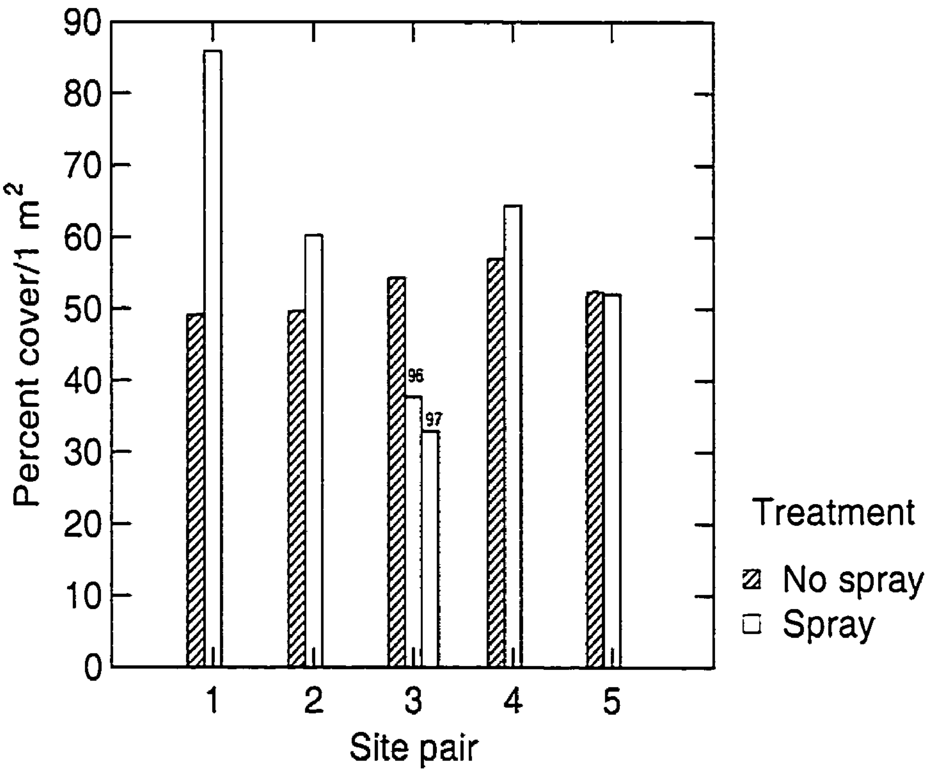

90
80
70
60
50
40
30
20
10
0
Percent cover/1 m^2
96
97
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 33: Number of species (Mean ± SEM) of ground vegetation for each site type.

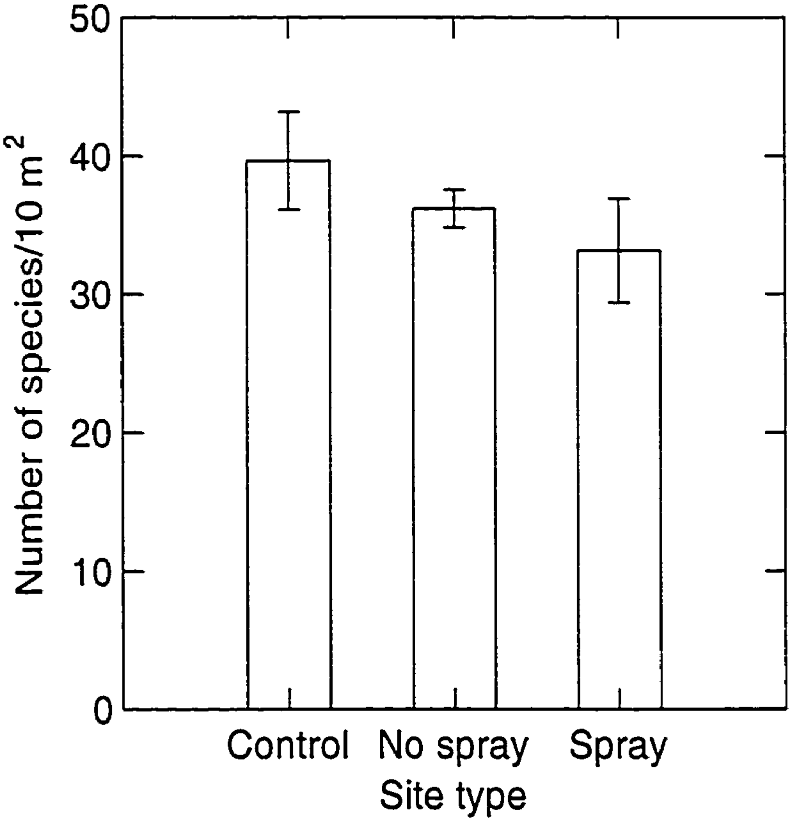

50
40
30
20
10
0
Number of species/10 m^2
Control
No spray
Spray
Site type

Figure 34: The number of species of ground vegetation in quadrats sampled from sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

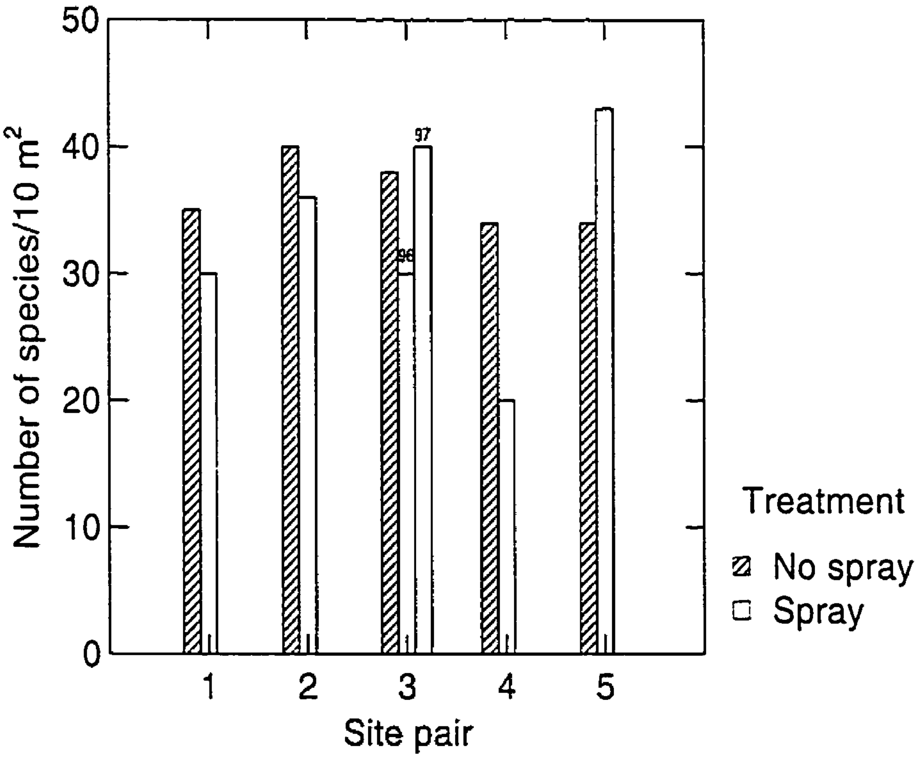

50
40
30
20
10
0
Number of species/10 m^2
96
97
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 35: Shannon Wiener index of diversity (Mean ± SEM) of ground vegetation for each site type.

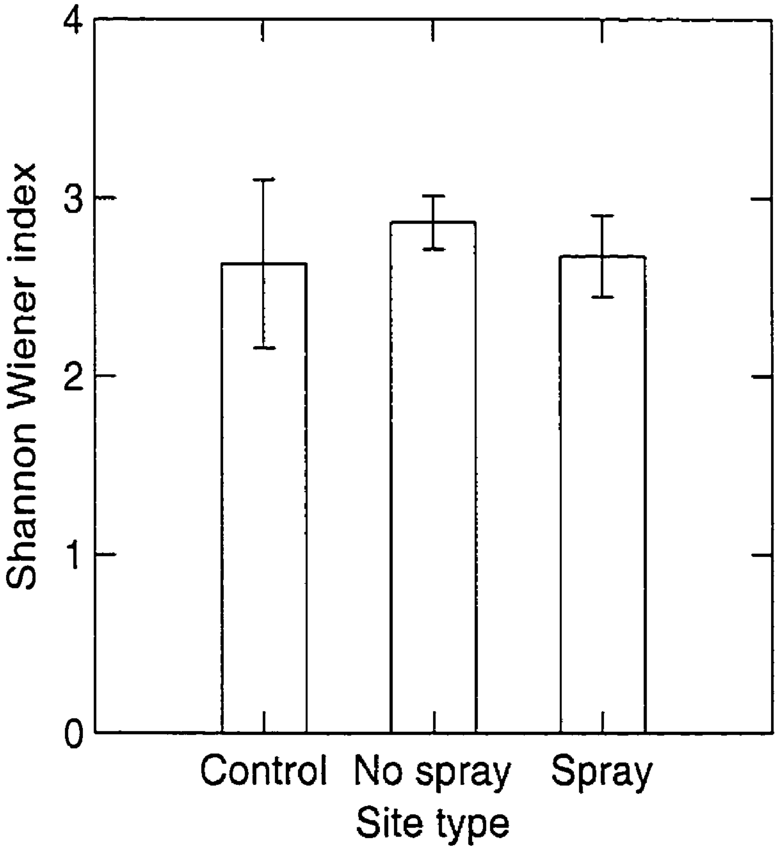

4
3
2
1
0
Shannon Wiener index
Control
No spray
Spray
Site type

Figure 36: Shannon Wiener diversity of ground vegetation in sprayed and unsprayed site pairs. Bars for 1996 and 1997 sprayed sites in site pair 3 are labelled 96 and 97 respectively.

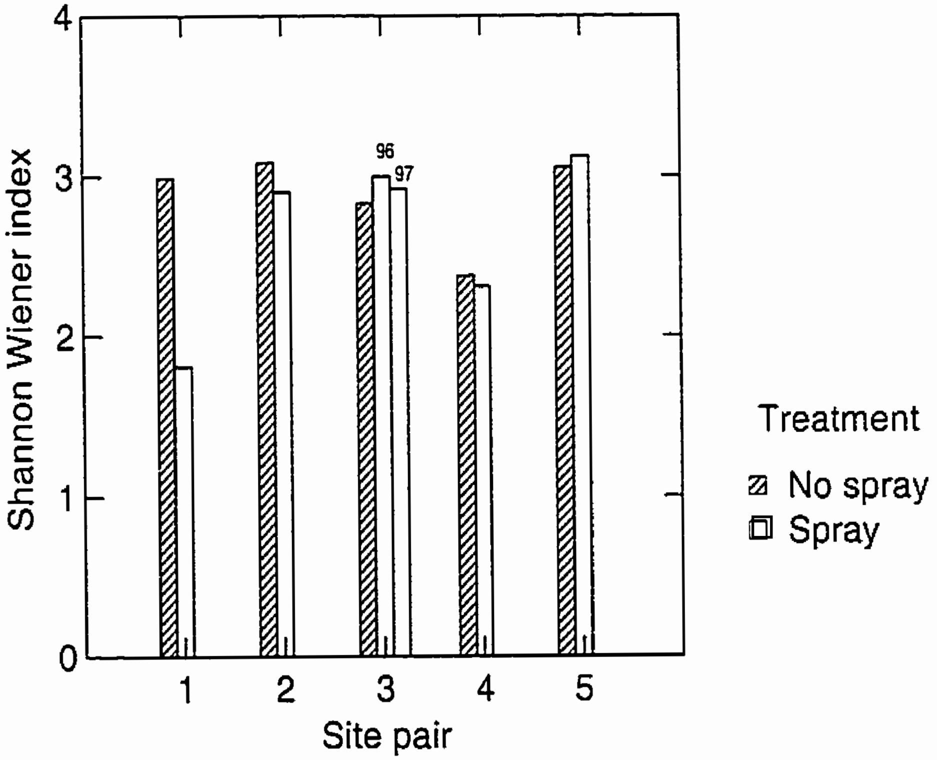

4
3
2
1
0
Shannon Wiener index
96
97
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 37: Ground vegetation data. Correspondence analysis (CA) ordination diagram with site scores (◇) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.344=19.5%, and the second axis (vertical) has an eigenvalue of 0.231=13.0%. Only selected species are shown.

ABIBAL=*Abies balsamea*
ACESPI= *Acer spicatum*
ACTRUB= *Actaea rubra*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
ANECAN= *Anemone canadensis*
ANEQUI= *Anemone quinquefolia*
APOAND= *Apocynum androsaemifolium*
ARCUVA= *Arctostaphylos uva-ursi*
ASTUMB= *Aster umbellatus*
CAREX= *Carex* sp.
CHIUMB= *Chimaphila umbellata*
CIRALP= *Circaea alpina*
CIRARV= *Cirsium arvense*
CLIBOR= *Clintonia borealis*
CORCAN= *Cornus canadensis*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
EPIANG= *Epilobium angustifolium*
EPILAE= *Equisetum laevigatum*
EQUSYL= *Equisetum sylvaticum*
FEAMOS= Feather mosses
FRAPEN= *Fraxinus pensylvanicus*
FRAVIR= *Fragaria virginiana*
GOOREP= *Goodyera repens*
IRIS= *Iris* sp.
LEDGRO= *Ledum groenlandicum*
LILPHI= *Lilium philadelphicum*
LINBOR= *Linnaea borealis*
LYCOBS= *Lycopodium obscurum*
LYSTHY= *Lysmachia thyrsiflora*
MAICAN= *Maianthemum canadense*
MENARV= *Mentha arvensis*
MERPAN= *Mertensia paniculatum*
OENBIE= *Oenothera biennis*
PETFRI= *Petasites frigidum*
PICEA= *Picea glauca*
POLVIR= *Polypodium vulgarevar.virginianum*
POPTRE= *Populus tremuloides*
PTEAQU= *Pteridium aquilinum*
PTICRI= *Ptillium crista-castrensis*
PYRMIN= *Pyrola minor*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
ROSA= *Rosa* sp.
RUBIDA= *Rubus idaeus*
RUBPUB= *Rubus pubescens*
SALIX= *Salix* sp.
SPHAG= *Sphagnum* sp.
STRROS= *Streptopus roseus*
SYMPHO= *Symphoricarpos alba*
TAROFF= *Taraxacum officinale*
TRIBOR= *Trientales borealis*
ULMAME= *Ulmus americana*
VACMYR= *Vaccimium myrtilloides*
VIBEDU= *Viburnum edule*
VICIA= *Vicia* sp.
VIOLA= *Viola* sp.

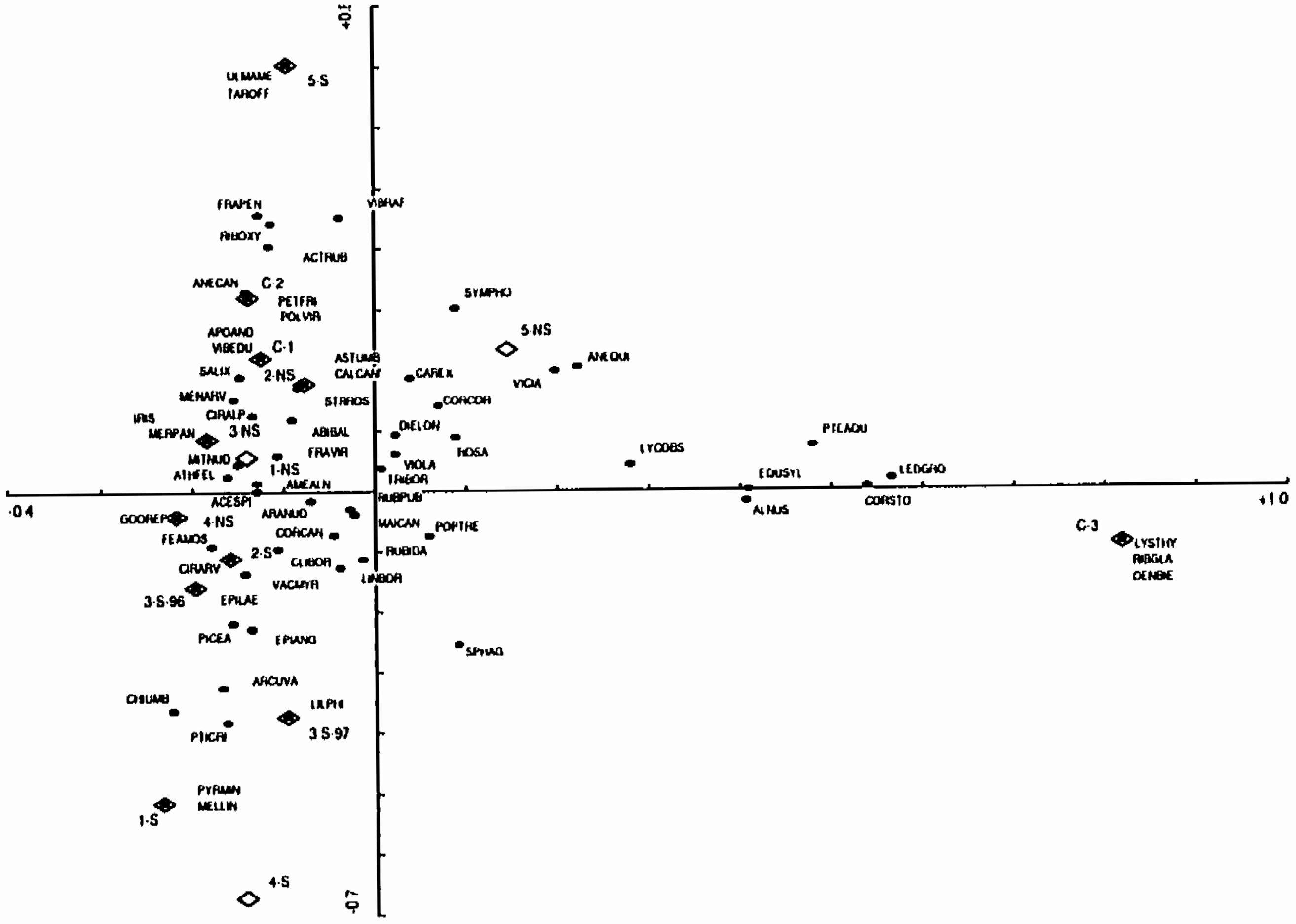

+0.1
-0.7
-0.4
+1.0
5·S
ULMAME
TAROFF
FRAPEN
VIBRAF
RIBOXY
ACTRUB
ANECAN
C·2
PETFRI
POLVIR
SYMPHO
5·NS
ANEQUI
VIOA
APOAND
VIBEDU
C·1
ASTUMB
CALCAN
CAREX
SALIX
2·NS
MENARV
STRROS
CORCOH
IRIS
CIRALP
ABIBAL
DIELON
MERPAN
3·NS
ROSA
PTEAQU
LYCOBS
FRAVIR
MITNUD
1·NS
VIOLA
TRIBOR
EDUSYL
LEDGRO
ATHFEL
AMEALN
RUBPUB
CORSTO
ALNUS
ACESPI
GOOREP
4·NS
ARANUD
MAICAN
POPTRE
C·3
LYSTHY
RIBGLA
OENBIE
FEAMOS
CORCAN
2·S
RUBIDA
CIRARV
CLIBOR
LINBOR
VACMYR
3·S·96
EPILAE
PICEA
EPIANG
SPHAG
ARCUVA
CHIUMB
LILPHI
3·S·97
PTICRI
PYRMIN
MELLIN
1·S
4·S

Figure 38: Ground vegetation data excluding the Whiteshell sites. Correspondence analysis (CA) ordination diagram with site scores (◇) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.250=17.5%, and the second axis (vertical) has an eigenvalue of 0.236=16.6%.

ABIBAL=*Abies balsamea*
ACESPI= *Acer spicatum*
ACTRUB= *Actaea rubra*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
ANECAN= *Anemone canadensis*
ANEQUI= *Anemone quinquefolia*
APOAND= *Apocynum androsaemifolium*
ARCUVA= *Arctostaphylos uva-ursi*
ASTUMB= *Aster umbellatus*
CAREX= *Carex* sp.
CHIUMB= *Chimaphila umbellata*
CIRALP= *Circaea alpina*
CIRARV= *Cirsium arvense*
CLIBOR= *Clintonia borealis*
CORCAN= *Comus canadensis*
CORSTO= *Comus stolonifera*
DIELON= *Diervilla lonicera*
EPIANG= *Epilobium angustifolium*
EPILAE= *Equisetum laevigatum*
EQUSYL= *Equisetum sylvaticum*

FEAMOS= Feather mosses
FRAPEN= *Fraxinus pensylvanicus*
FRAVIR= *Fragaria virginiana*
GOOREP= *Goodyera repens*
IRIS= *Iris* sp.
LEDGRO= *Ledum groenlandicum*
LILPHI= *Lilium philadelphicum*
LINBOR= *Linnaea borealis*
LYCOBS= *Lycopodium obscurum*
LYSTHY= *Lysmachia thyrsiflora*
MAICAN= *Maianthemum canadense*
MENARV= *Mentha arvensis*
MERPAN= *Mertensia paniculatum*
OENBIE= *Oenothera biennis*
PETFRI= *Petasites frigidum*
PICEA= *Picea glauca*
POLVIR= *Polypodium vulgarevar. virginianum*
POPTRE= *Populus tremuloides*
PTEAQU= *Pteridium aquilinum*
PTICRI= *Ptilium crista-castrensis*
PYRMIN= *Pyrola minor*

RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
ROSA= *Rosa* sp.
RUBIDA= *Rubus idaeus*
RUBPUB= *Rubus pubescens*
SALIX= *Salix* sp.
SPHAG= *Sphagnum* sp.
STRROS= *Streptopus roseus*
SYMPHO= *Symphoricarpos alba*
TAROFF= *Taraxacum officinale*
TRIBOR= *Trientales borealis*
ULMAME= *Ulmus americana*
VACMYR= *Vaccimium myrtilloides*
VIBEDU= *Vibumum edule*
VICIA= *Vicia* sp.
VIOLA= *Viola* sp.

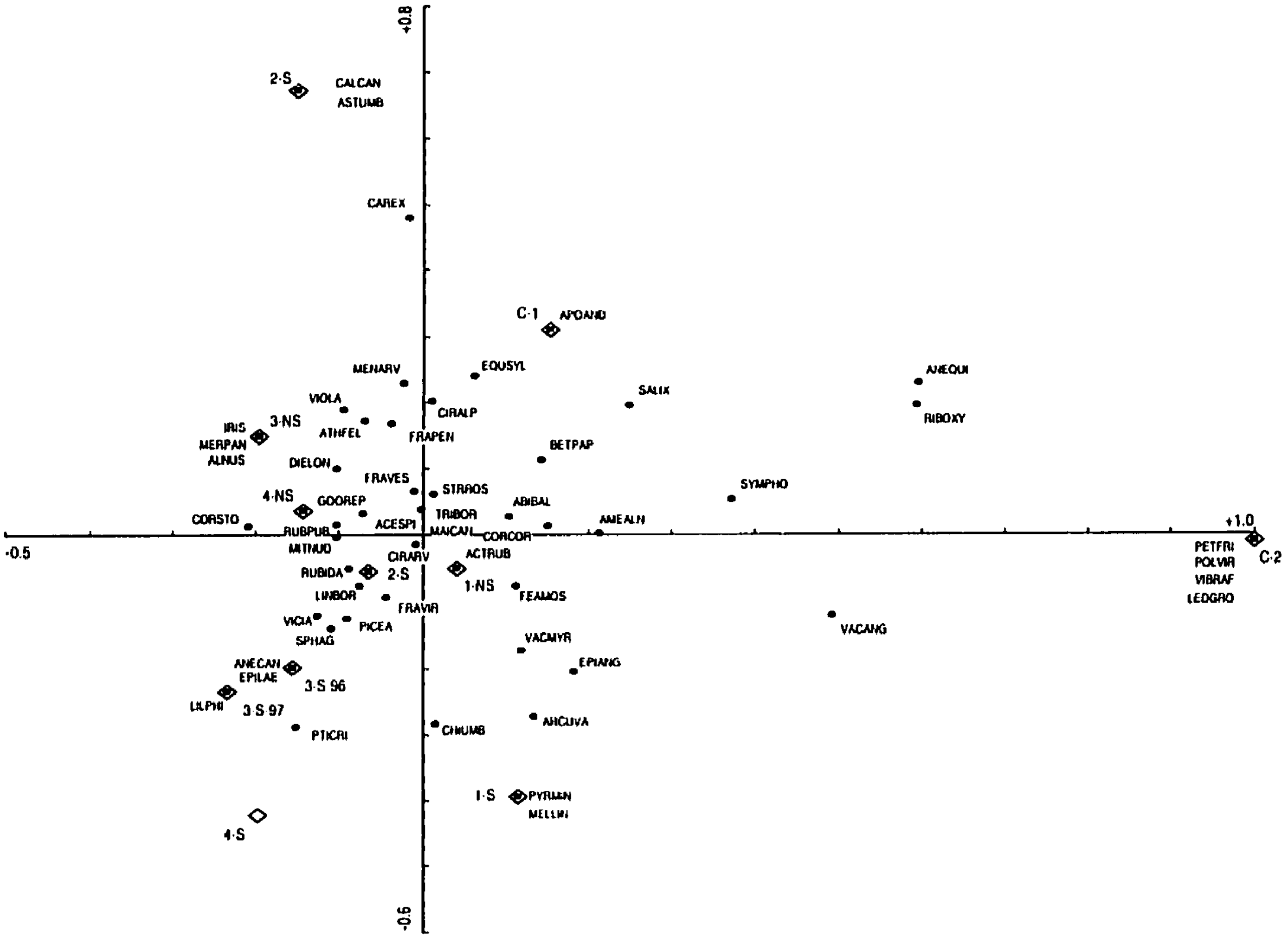

+0.8
-0.6
-0.5
+1.0
2·S
CALCAN
ASTUMB
CAREX
C·1
APOAND
MENARV
EQUSYL
ANEQUI
VIOLA
SALIX
CIRALP
RIBOXY
IRIS
3·NS
ATHFEL
FRAPEN
MERPAN
ALNUS
BETPAP
DIELON
FRAVES
SYMPHO
STRROS
4·NS
GOOREP
ABIBAL
CORSTO
TRIBOR
AMEALN
RUBPUB
ACESPI
MAICAN
CORCOR
MITNUD
CIRARV
ACTRUB
PETFRI
C·2
POLVIR
RUBIDA
2·S
VIBRAF
1·NS
LEDGRO
LINBOR
FEAMOS
FRAVIR
VACANG
VICIA
PICEA
SPHAG
VACMYR
ANECAN
EPIANG
EPILAE
3·S 96
LILPHI
3·S 97
ARCUVA
PTICRI
CHUMB
1·S
PYRMIN
MELLIN
4·S

Figure 39: Ground vegetation data. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.266=15.0%, and the second axis (vertical) has an eigenvalue of 0.147=8.4%. Only selected species are shown.

ABIBAL=*Abies balsamea*
ACESPI= *Acer spicatum*
ACTRUB= *Actaea rubra*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
ANECAN= *Anemone canadensis*
ANEQUI= *Anemone quinquefolia*
APOAND= *Apocynum androsaemifolium*
ARCUVA= *Arctostaphylos uva-ursi*
ASTUMB= *Aster umbellatus*
CAREX= *Carex* sp.
CHIUMB= *Chimaphila umbellata*
CIRALP= *Circaea alpina*
CIRARV= *Cirsium arvense*
CLIBOR= *Clintonia borealis*
CORCAN= *Cornus canadensis*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
EPIANG= *Epilobium angustifolium*
EPILAE= *Equisetum laevigatum*
EQUSYL= *Equisetum sylvaticum*
FEAMOS= Feather mosses
FRAPEN= *Fraxinus pensylvanicus*
FRAVIR= *Fragaria virginiana*
GOOREP= *Goodyera repens*
IRIS= *Iris* sp.
LEDGRO= *Ledum groenlandicum*
LILPHI= *Lilium philadelphicum*
LINBOR= *Linnaea borealis*
LYCOBS= *Lycopodium obscurum*
LYSTHY= *Lysmachia thyrsiflora*
MAICAN= *Maianthemum canadense*
MENARV= *Mentha arvensis*
MERPAN= *Mertensia paniculatum*
OENBIE= *Oenothera biennis*
PETFRI= *Petasites frigidum*
PICEA= *Picea glauca*
POLVIR= *Polypodium vulgarevar. virginianum*
POPTRE= *Populus tremuloides*
PTEAQU= *Pteridium aquilinum*
PTICRI= *Ptilium crista-castrensis*
PYRMIN= *Pyrola minor*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
ROSA= *Rosa* sp.
RUBIDA= *Rubus idaeus*
RUBPUB= *Rubus pubescens*
SALIX= *Salix* sp.
SPHAG= *Sphagnum* sp.
STRROS= *Streptopus roseus*
SYMPHO= *Symphoricarpos alba*
TAROFF= *Taraxacum officinale*
TRIBOR= *Trientales borealis*
ULMAME= *Ulmus americana*
VACMYR= *Vaccimium myrtilloides*
VIBEDU= *Viburnum edule*
VICIA= *Vicia* sp.
VIOLA= *Viola* sp.

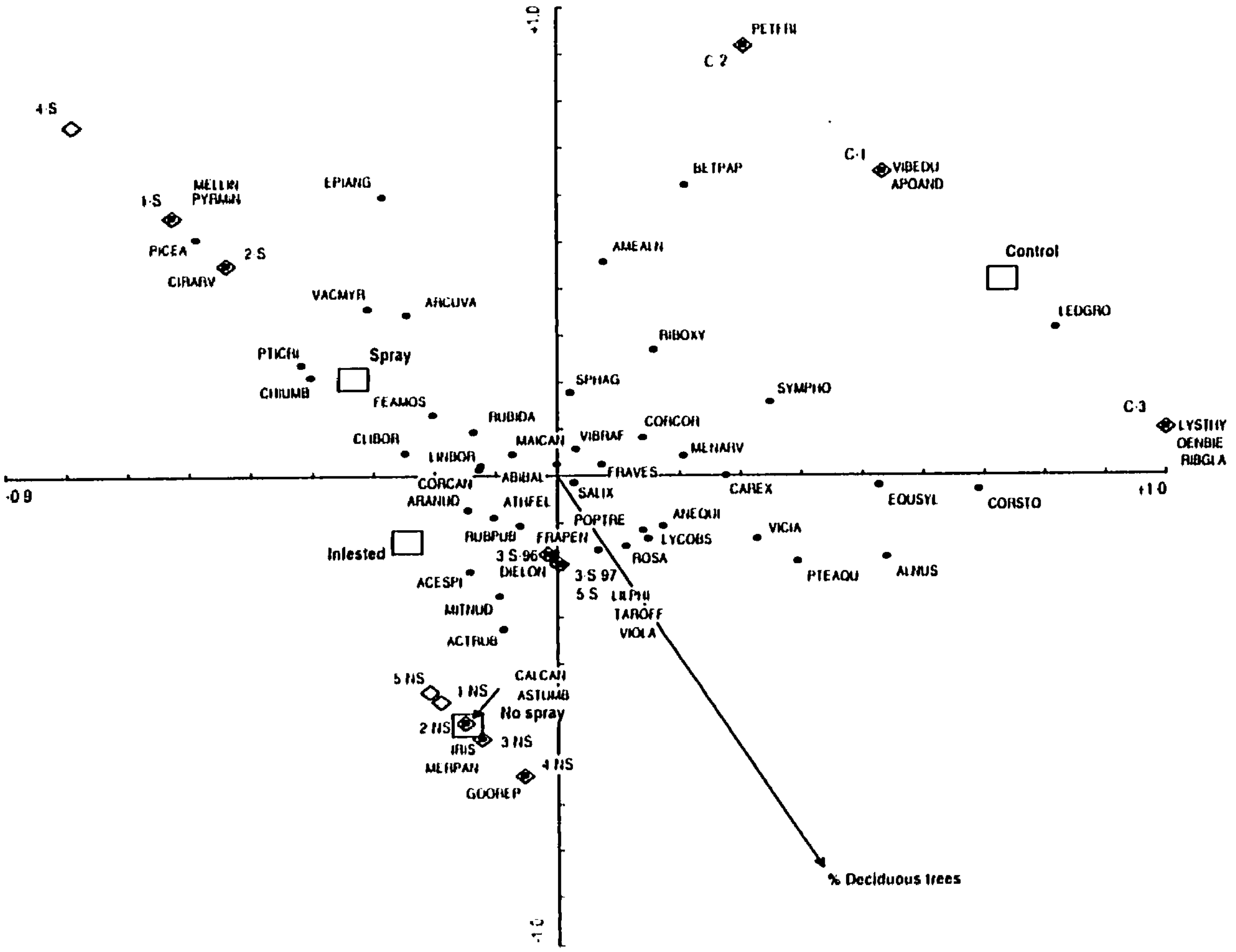

+1.0
-1.0
-0.9
+1.0
PETFRI
C 2
4 S
C-1
VIBEDU
APOAND
BETPAP
1-S
MELLIN
PYRMIN
EPIANG
PICEA
2 S
CIRARV
AMEALN
Control
VACMYR
ARCUVA
LEDGRO
RIBOXY
PTICRI
Spray
CHUMB
SPHAG
SYMPHO
FEAMOS
RUBIDA
CORCOR
C-3
LYSTHY
OENBIE
RIBGLA
CLIBOR
MAICAN
VIBRAF
MENARV
LINBOR
FRAVES
ABIBAL
CORCAN
CAREX
ARANUD
SALIX
ATHFEL
EQUSYL
CORSTO
POPTRE
ANEQUI
VICIA
RUBPUB
FRAPEN
LYCOBS
Infested
3 S-96
ROSA
ALNUS
DIELON
PTEAQU
3-S 97
ACESPI
5 S
LAPHI
TAROFF
MITNUD
VIOLA
ACTRUB
CALCAN
ASTUMB
5 NS
1 NS
No spray
2 NS
3 NS
IRIS
MERPAN
4 NS
GOOREP
% Deciduous trees

Figure 40: Ground vegetation data excluding the Whiteshell sites. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.266=15.0%, and the second axis (vertical) has an eigenvalue of 0.147=8.4%. Only selected species are shown.

ABIBAL=*Abies balsamea*
ACESPI= *Acer spicatum*
ACTRUB= *Actaea rubra*
ALNUS= *Alnus* sp.
AMEALN= *Amelanchier alnifolia*
ANECAN= *Anemone canadensis*
ANEQUI= *Anemone quinquefolia*
APOAND= *Apocynum androsaemifolium*
ARCUVA= *Arctostaphylos uva-ursi*
ASTUMB= *Aster umbellatus*
CAREX= *Carex* sp.
CHIUMB= *Chimaphila umbellata*
CIRALP= *Circaea alpina*
CIRARV= *Cirsium arvense*
CLIBOR= *Clintonia borealis*
CORCAN= *Cornus canadensis*
CORSTO= *Cornus stolonifera*
DIELON= *Diervilla lonicera*
EPIANG= *Epilobium angustifolium*
EPILAE= *Equisetum laevigatum*
EQUSYL= *Equisetum sylvaticum*
FEAMOS= Feather mosses
FRAPEN= *Fraxinus pensylvanicus*
FRAVIR= *Fragaria virginiana*
GOOREP= *Goodyera repens*
IRIS= *Iris* sp.
LEDGRO= *Ledum groenlandicum*
LILPHI= *Lilium philadelphicum*
LINBOR= *Linnaea borealis*
LYCOBS= *Lycopodium obscurum*
LYSTHY= *Lysmachia thyrsiflora*
MAICAN= *Maianthemum canadense*
MENARV= *Mentha arvensis*
MERPAN= *Mertensia paniculatum*
OENBIE= *Oenothera biennis*
PETFRI= *Petasites frigidum*
PICEA= *Picea glauca*
POLVIR= *Polypodium vulgarevar. virginianum*
POPTRE= *Populus tremuloides*
PTEAQU= *Pteridium aquilinum*
PTICRI= *Ptillium crista-castrensis*
PYRMIN= *Pyrola minor*
RIBGLA= *Ribes glandulosum*
RIBOXY= *Ribes oxyacanthoides*
ROSA= *Rosa* sp.
RUBIDA= *Rubus idaeus*
RUBPUB= *Rubus pubescens*
SALIX= *Salix* sp.
SPHAG= *Sphagnum* sp.
STRROS= *Streptopus roseus*
SYMPHO= *Symphoricarpos alba*
TAROFF= *Taraxacum officinale*
TRIBOR= *Trientales borealis*
ULMAME= *Ulmus americana*
VACMYR= *Vaccinium myrtilloides*
VIBEDU= *Viburnum edule*
VICIA= *Vicia* sp.
VIOLA= *Viola* sp.

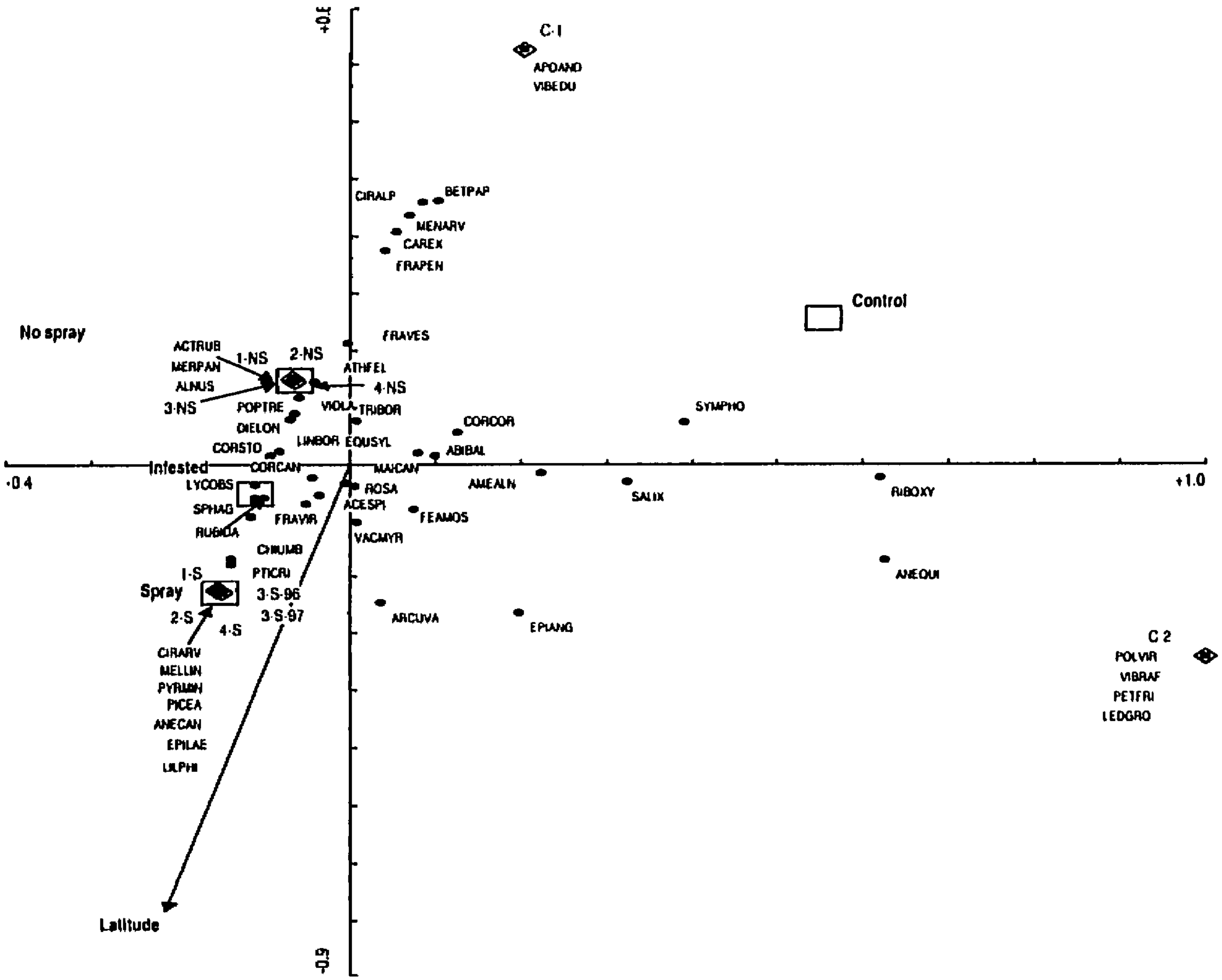

C·1
APOAND
VIBEDU
CIRALP
BETPAP
MENARV
CAREX
FRAPEN
Control
No spray
FRAVES
ACTRUB
MERPAN
ALNUS
1-NS
2-NS
3-NS
4-NS
ATHFEL
POPTRE
VIOLA
TRIBOR
DIELON
SYMPHO
CORCOR
CORSTO
LINBOR
EQUSYL
ABIBAL
Infested
CORCAN
MAICAN
AMEALN
SALIX
RIBOXY
LYCOBS
ROSA
ACESPI
SPHAG
FRAVIR
FEAMOS
RUBIDA
VACMYR
CHIUMB
PTICRI
ANEQUI
1-S
Spray
3-S-96
3-S-97
2-S
4-S
ARCUVA
EPIANG
C 2
POLVIR
VIBRAF
PETFRI
LEDGRO
CIRARV
MELLIN
PYRMIN
PICEA
ANECAN
EPILAE
LILPHI
Latitude
-0.4
+1.0
+0.9
-0.9

Figure 41: Number (Mean ± SEM) of moths for each site type in 1996 and 1997. Note the different vertical scales.

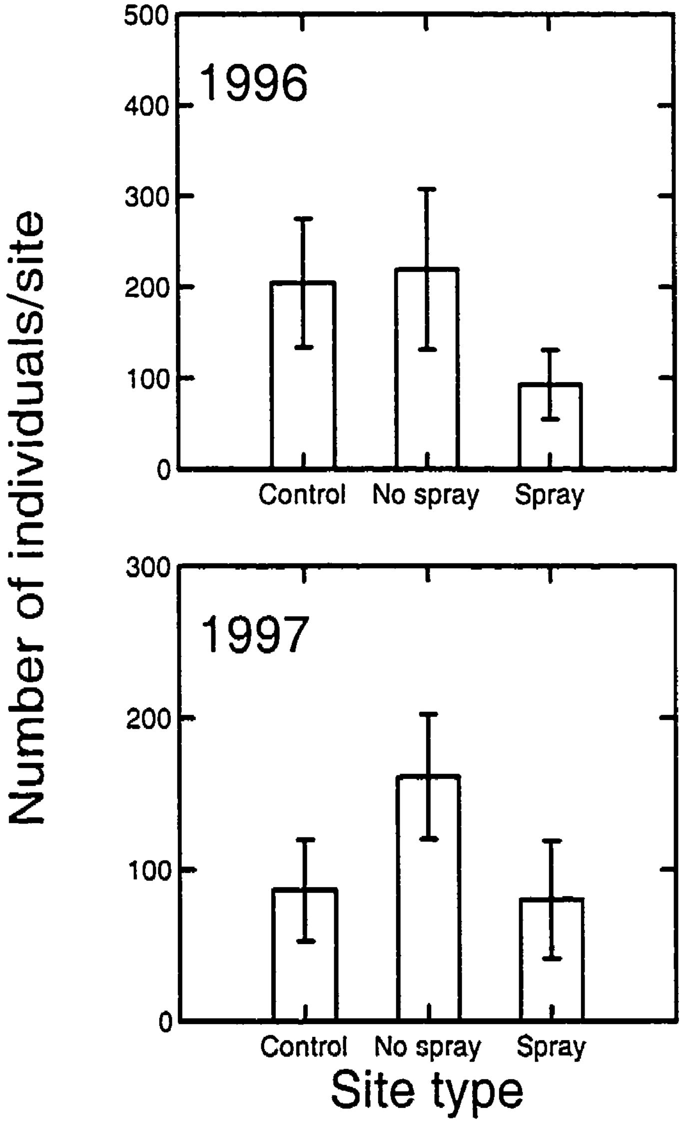

Number of individuals/site
1996
500
400
300
200
100
0
Control
No spray
Spray
1997
300
200
100
0
Control
No spray
Spray
Site type

Figure 42: The total number of moths from sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

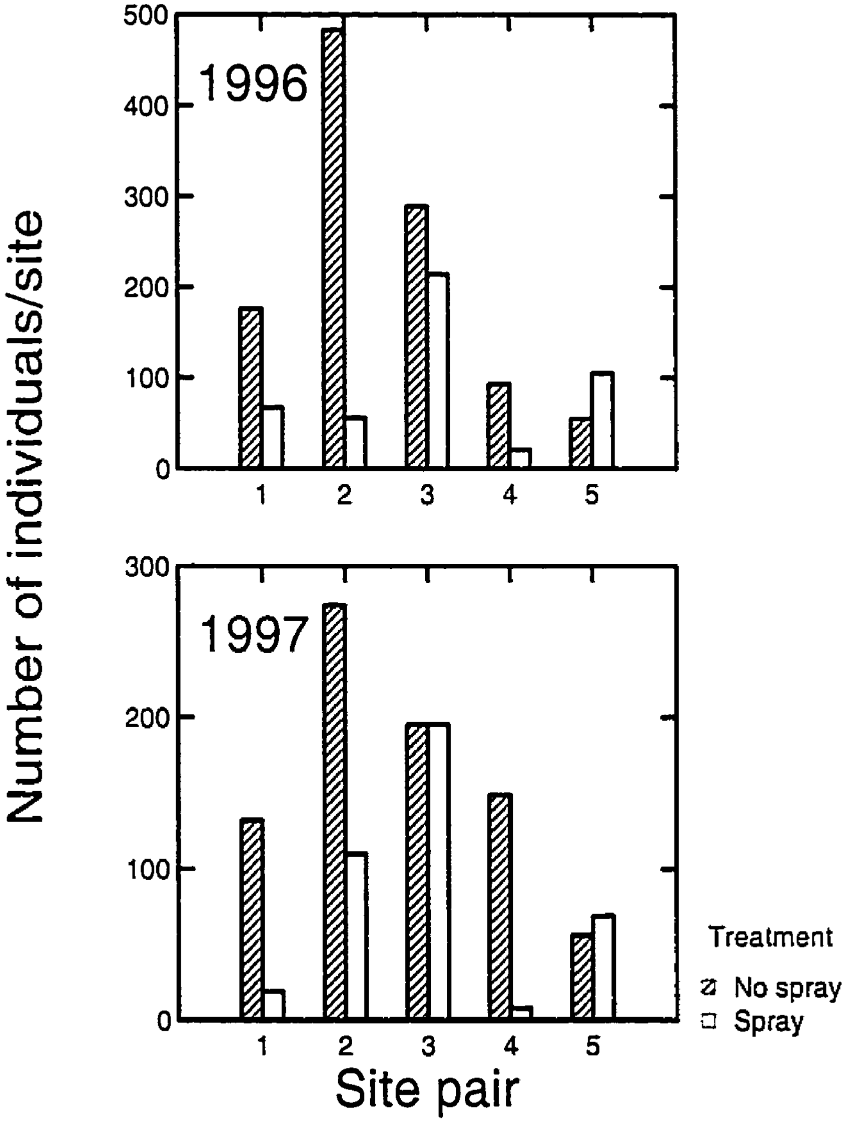

Number of individuals/site
1996
500
400
300
200
100
0
1
2
3
4
5
1997
300
200
100
0
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 43: Number (Mean ± SEM) of moth species from each site type in 1996 and 1997. Note the different vertical scales.

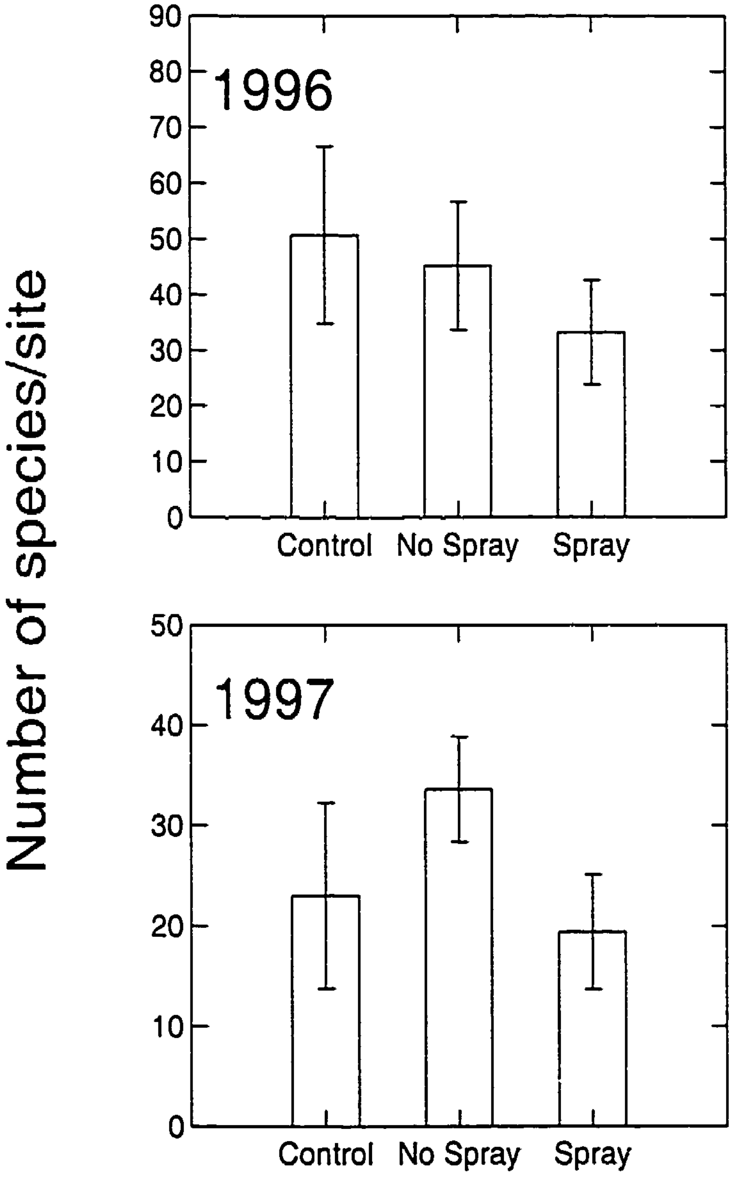

1996
1997
Number of species/site
90
80
70
60
50
40
30
20
10
0
Control
No Spray
Spray
50
40
30
20
10
0
Control
No Spray
Spray
Site type

Figure 44: The number of moth species from sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

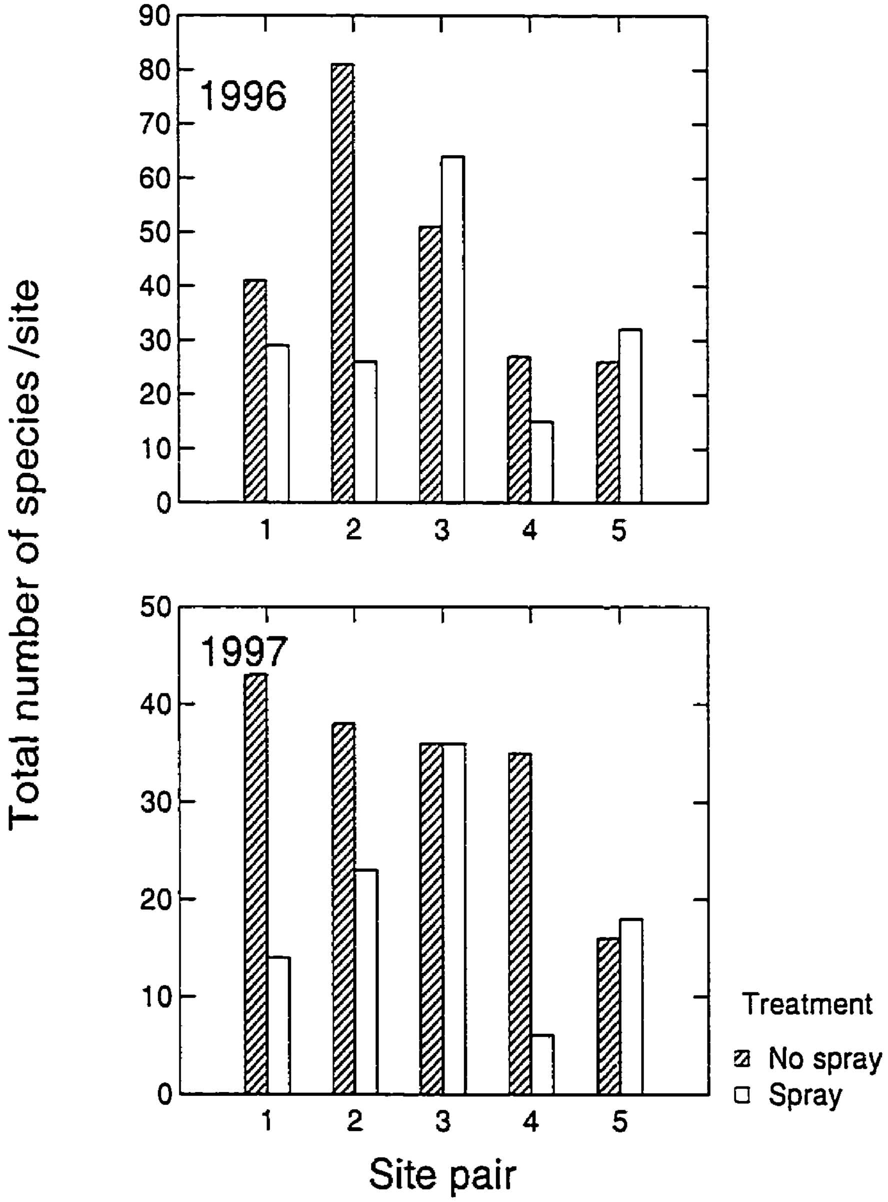

Total number of species /site
1996
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
1997
50
40
30
20
10
0
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 45: Log series alpha diversity (Mean ± SEM) of moths for each site type in 1996 and 1997. Note the different vertical scales.

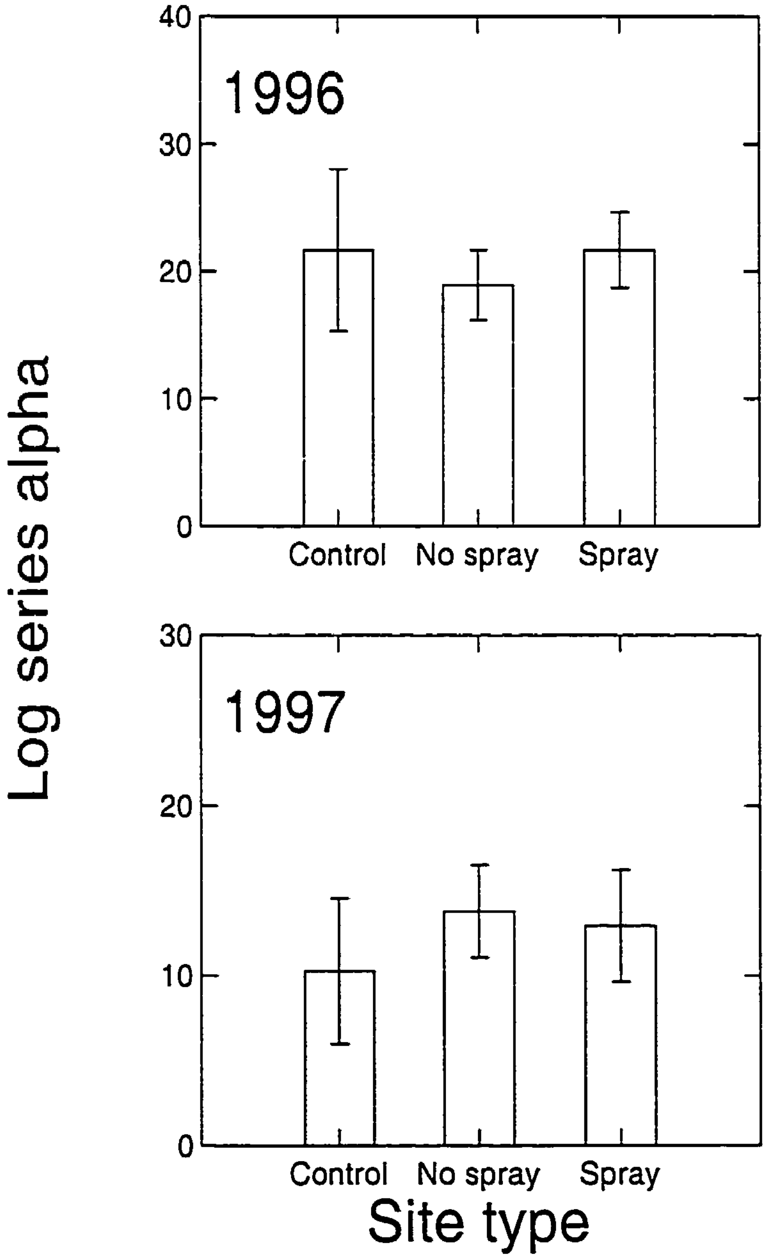

Log series alpha
1996
40
30
20
10
0
Control
No spray
Spray
1997
30
20
10
0
Control
No spray
Spray
Site type

Figure 46: Log series alpha diversity of moths in sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

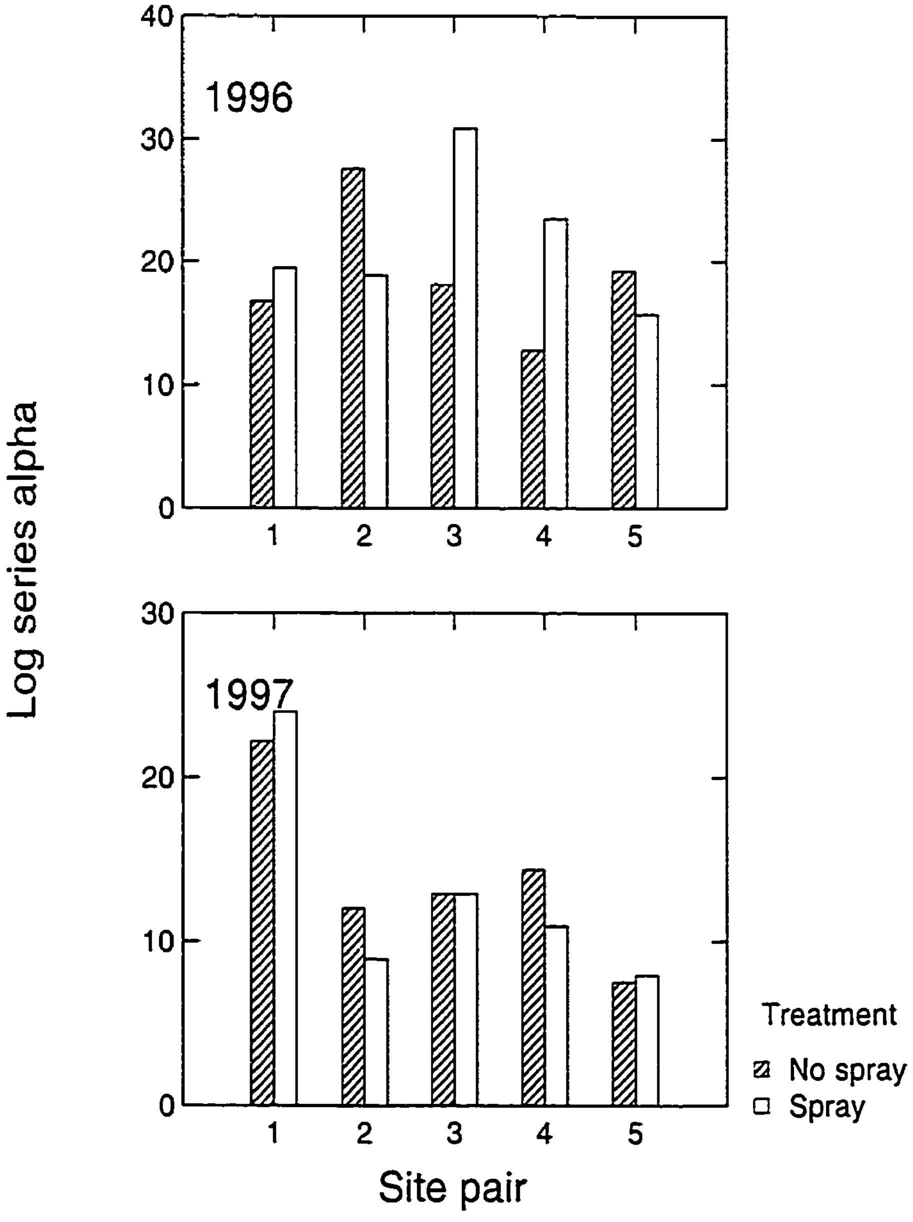

Log series alpha
1996
40
30
20
10
0
1
2
3
4
5
1997
30
20
10
0
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 47: Moth data for 1996. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.294=12.6%, and the second axis (vertical) has an eigenvalue of 0.274=11.8%.

ACTIA_LU= *Actias luna*
AGROP_LA= *Agroperina lateritia*
ANACA_EP= *Anacamptodes ephyraria*
ANACA_HU= *Anacamptodes humaria*
ANNAG_OC= *Anagoga occiduaria*
APAMEA_NI= *Apamea nigrior*
BESMA_QU= *Besma quercivoraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHORI_FU= *Choristoneura fumiferana*
CHYTO_PA= *Chytonix palliatricula*
CLOST_IN= *Clostera inclusa*
CORYP_ME= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_SP= *Drepana* sp.
DYSST_HE= *Dysstroma hersiliata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EUCHL_TI= *Euchlaena tigrinaria*
EULIT_TE= *Eulithis testata*
EUROI_OC= *Eurois occulta*
EUTHY_PU= *Euthyatira pudens*

FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_FA= *Lithophane fasciola*
LITHO_PE= *Lithophane pexata*
METAL_SA= *Metalepsis salicarium*
NEMAT_LI= *Nematocampa limbata*
NEPHE_MI= *Nephelodes minians*
ORTHO_RE= *Orthosia revicta*
PALPI_MA= *Palpita magniferalis*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
TORTR_TE= *Tortricidia testacea*
XANTH_FE= *Xanthorhoe ferrugata*
XANTH_LA= *Xanthorhoe lacustrata*
ZALE_AER= *Zale aeruginosa*

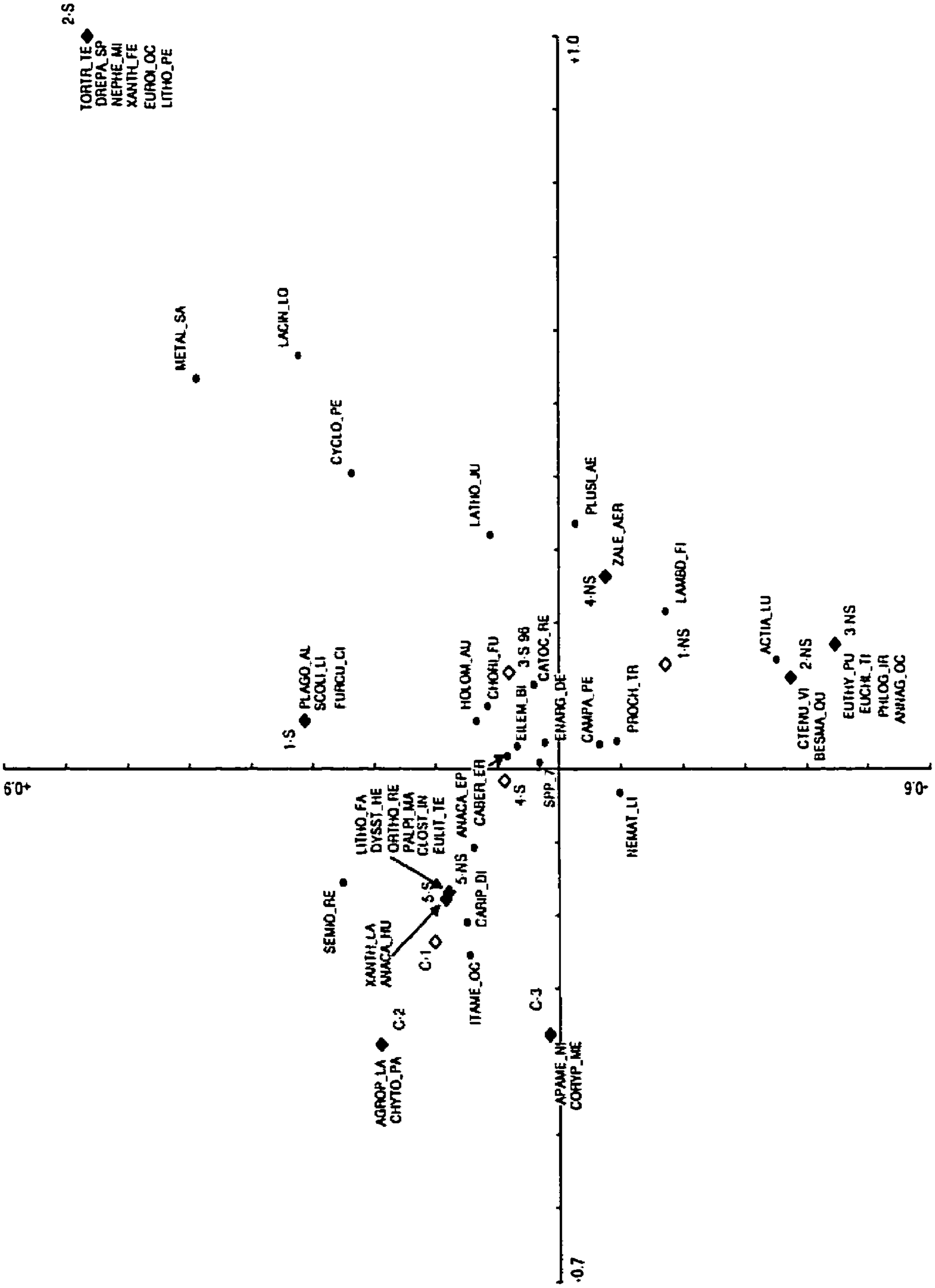

2-S
TORTR_TE
DREPA_SP
NEPHE_MI
XANTH_FE
EUROI_OC
LITHO_PE
+1.0
METAL_SA
LACIN_LO
CYCLO_PE
LATHO_JU
PLUSI_AE
ZALE_AER
4-NS
LAMBD_FI
ACTIA_LU
1-NS
3-NS
2-NS
CTENU_VI
BESMA_OU
EUTHY_PU
EUCHL_TI
PHLOG_IR
ANNAG_OC
1-S
PLAGO_AL
SCOLI_LI
FURCU_CI
HOLOM_AU
CHORI_FU
3-S 98
CATOC_RE
EILEM_BI
ENARG_DE
CAMPA_PE
PROCH_TR
+0.9
-0.6
LITHO_FA
DYSST_HE
ORTHO_RE
PALPI_MA
CLOST_IN
EULIT_TE
ANACA_EP
CABER_ER
4-S
SPP_7
NEMAT_LI
SEMIO_RE
5-S
5-NS
CARIP_DI
XANTH_LA
ANACA_HU
C-1
ITAME_OC
C-3
C-2
AGROP_LA
CHYTO_PA
APAME_NI
CORYP_ME
-0.7

Figure 48: Moth data for 1996. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The second axis (horizontal) has an eigenvalue of 0.274=11.8%, and the third axis (vertical) has an eigenvalue of 0.241=10.4%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
AGROP_LA= *Agroperina lateritia*
ANACA_EP= *Anacamptodes ephyraria*
ANACA_HU= *Anacamptodes humaria*
ANNAG_OC= *Anagoga occiduaria*
BESMA_QU= *Besma quercivoraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHORI_FU= *Choristoneura fumiferana*
CHYTO_PA= *Chytonix palliatricula*
CLOST_IN= *Clostera inclusa*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_SP= *Drepana* sp.
DYSST_HE= *Dysstroma hersiliata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
ERRAN_TI=*Erranis tiliaria*
EUCHL_TI= *Euchlaena tigrinaria*
EULIT_TE= *Eulithis testata*
EUROI_OC= *Eurois occulta*
EUTHY_PU= *Euthyatira pudens*
FURCU_CI= *Furcula cinerea*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_FA= *Lithophane fasciola*
LITHO_PE= *Lithophane pexata*
METAL_SA= *Metalepsis salicarium*
NEMAT_LI= *Nematocampa limbata*
NEPHE_MI= *Nephelodes minians*
ORTHO_RE= *Orthosia revicta*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
TORTR_TE= *Tortricidia testacea*
XANTH_FE= *Xanthorhoe ferrugata*
XANTH_LA= *Xanthorhoe lacustrata*
ZALE_AER= *Zale aeruginosa*

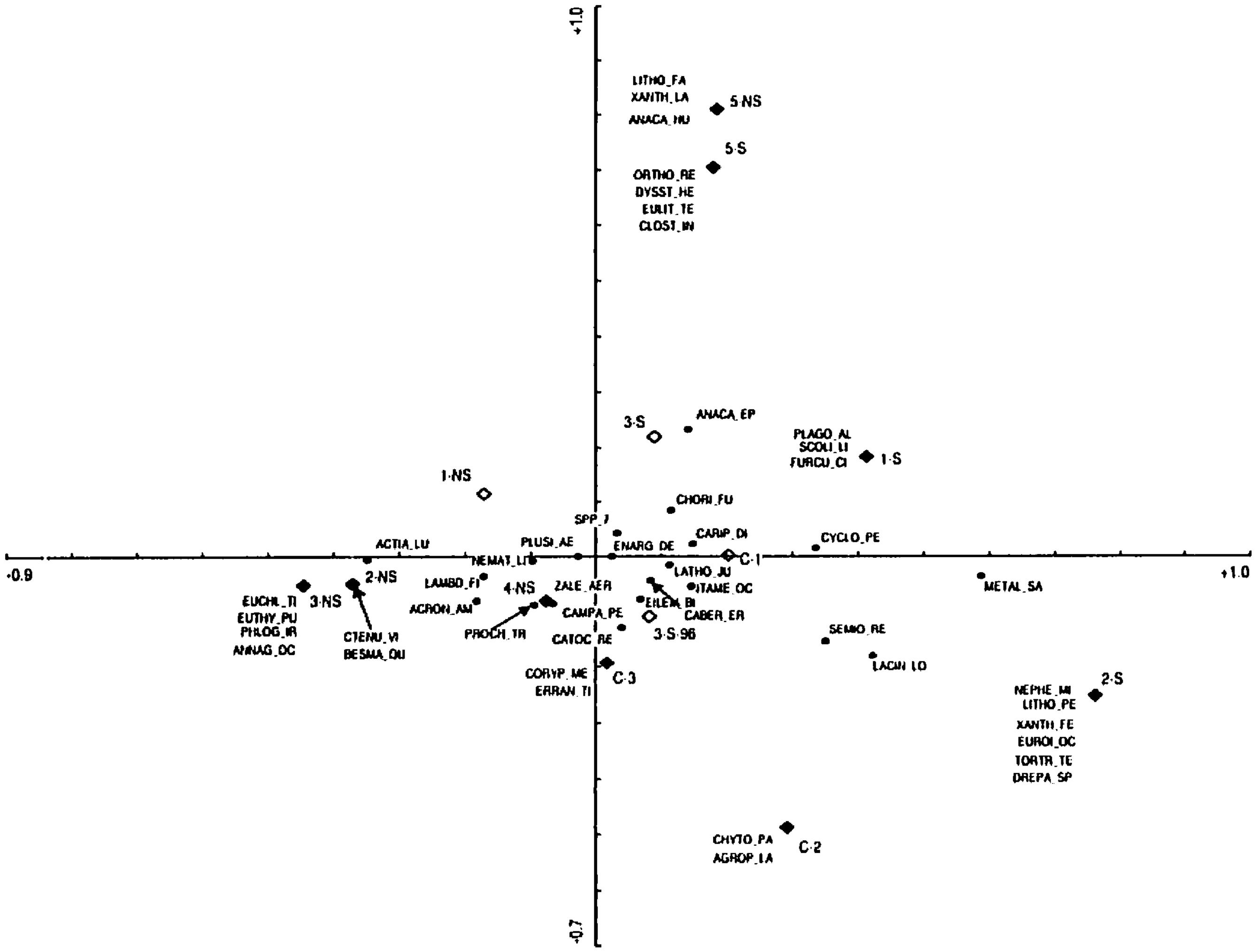

+1.0
-0.7
-0.9
+1.0
LITHO_FA
XANTH_LA
ANACA_HU
5-NS
5-S
ORTHO_RE
DYSST_HE
EULIT_TE
CLOST_IN
3-S
ANACA_EP
PLAGO_AL
SCOLI_LI
FURCU_CI
1-S
1-NS
CHORI_FU
SPP_7
CARP_DI
CYCLO_PE
ACTIA_LU
PLUSI_AE
ENARG_DE
C-1
NEMAT_LI
LATHO_JU
2-NS
LAMBD_FI
4-NS
ZALE_AER
ITAME_OC
METAL_SA
EUCHL_TI
3-NS
EUTHY_PU
PHLOG_IR
ANNAG_OC
ACRON_AM
CAMPA_PE
EILEM_BI
CABER_ER
CTENU_VI
BESMA_OU
PROCH_TR
CATOC_RE
3-S-96
SEMIO_RE
LACIN_LO
CORYP_ME
ERRAN_TI
C-3
NEPHE_MI
LITHO_PE
2-S
XANTH_FE
EUROI_OC
TORTR_TE
DREPA_SP
CHYTO_PA
AGROP_LA
C-2

Figure 49: Moth data for 1996 with the Whiteshell sites excluded from analysis. Correspondence analysis (CA) ordination diagram with site scores (◊), and species scores (●). The first axis (horizontal) has an eigenvalue of 0.331=16.3%, and the second axis (vertical) has an eigenvalue of 0.299=14.7%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
AGROP_LA= *Agroperina lateritia*
ANACA_EP= *Anacamptodes ephyraria*
ANNAG_OC= *Anagoga occiduaria*
BESMA_QU= *Besma quercivoraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHORI_FU= *Choristoneura fumiferana*
CHYTO_PA= *Chytonix palliatricula*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_SP= *Drepana* sp.
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EUCHL_TI= *Euchlaena tigrinaria*
EULIT_TE= *Eulithis testata*
EUROI_OC= *Eurois occulta*
EUTHY_PU= *Euthyatira pudens*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_PE= *Lithophane pexata*
METAL_SA= *Metalepsis salicarium*
NEMAT_LI= *Nematocampa limbata*
NEPHE_MI= *Nephelodes minians*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
TORTR_TE= *Tortricidia testacea*
XANTH_FE= *Xanthorhoe ferrugata*
ZALE_AER= *Zale aeruginosa*

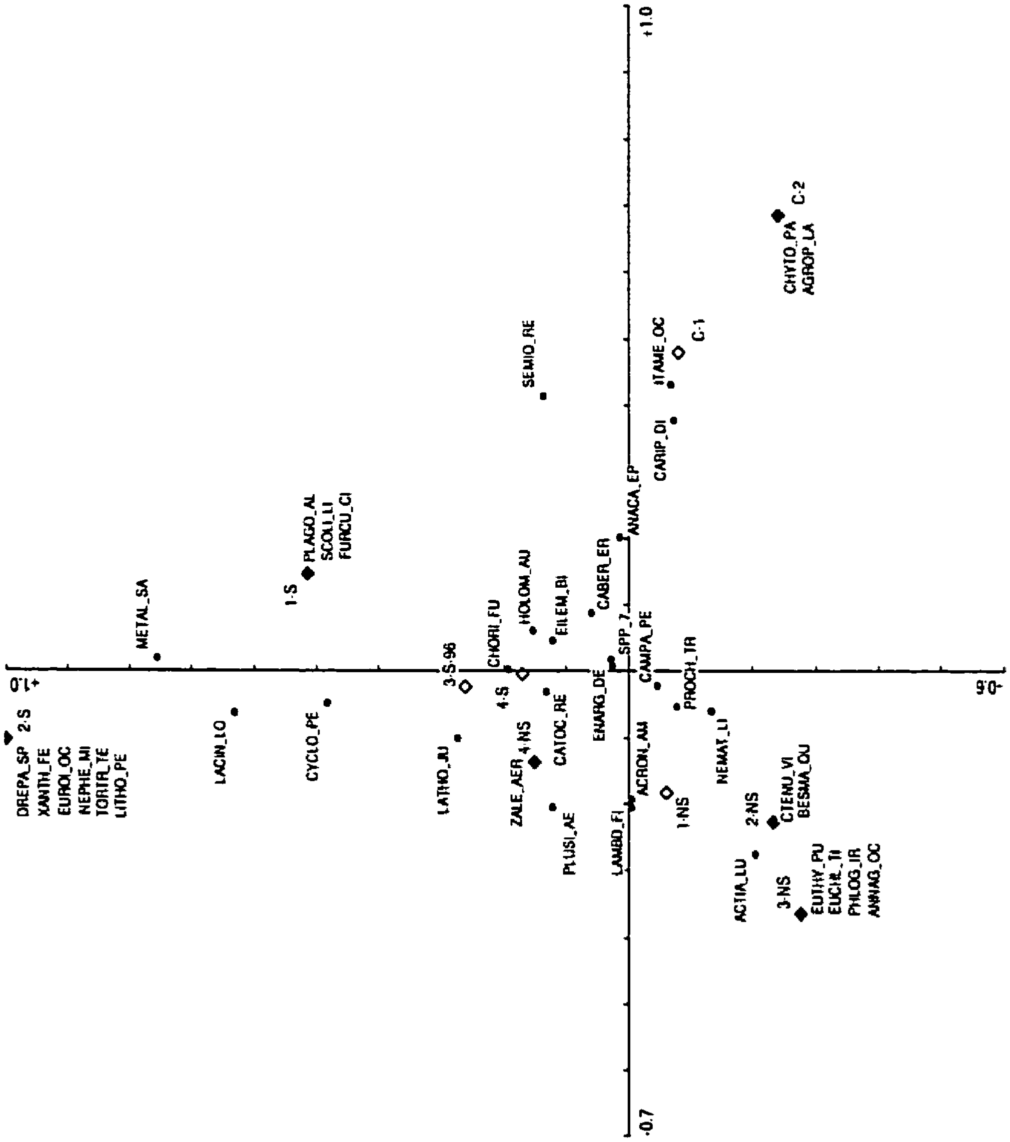

+1.0
-0.6
+1.0
-0.7
DREPA_SP
XANTH_FE
EUROI_OC
NEPHE_MI
TORTR_TE
LITHO_PE
2-S
METAL_SA
LACIN_LO
1-S
PLAGO_AL
SCOLI_LI
FURCU_CI
CYCLO_PE
LATHO_JU
3-S-96
CHORI_FU
4-S
ZALE_AER
4-NS
HOLOM_AU
CATOC_RE
PLUSI_AE
EILEM_BI
SEMIO_RE
CABER_ER
ENARG_DE
SPP_7
LAMBD_FI
ACRON_AM
CAMPA_PE
ANACA_EP
1-NS
PROCH_TR
CARIP_DI
ITAME_OC
C-1
NEMAT_LI
ACTIA_LU
2-NS
CTENU_VI
BESMA_QU
3-NS
EUTHY_PU
EUCHL_TI
PHLOG_IR
ANNAG_OC
CHYTO_PA
AGROP_LA
C-2

Figure 50: Moth data for 1997. Correspondence analysis (CA) ordination diagram with site scores (◊), and species scores (●). The first axis (horizontal) has an eigenvalue of 0.274=13.8%, and the second axis (vertical) has an eigenvalue of 0.243=12.3%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
ANACA_EP= *Anacamptodes ephyraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_BR= *Catocala briseis*
CATOC_RE= *Catocala relicta*
CHRYS_FO= *Chrysanympha formosa*
CHYTO_PA= *Chytonix palliatricula*
CLEME_AL= *Clemensia albata*
CORYP_ME= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EUROI_AS= *Eurois astricta*
EUTRA CL= *Eutralepa clemetaria*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
HYPAG_PI= *Hypagyrtis piniata*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_TH= *Lithophane thaxteri*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
NEPHE_MI= *Nephelodes minians*
ORGYI_LE= *Orgyia leucostigma*
ORTHO_RE= *Orthosia revicta*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SPILO_CO= *Spilosoma congrua*
SPP_7= Species 7
ZALE_AER= *Zale aeruginosa*

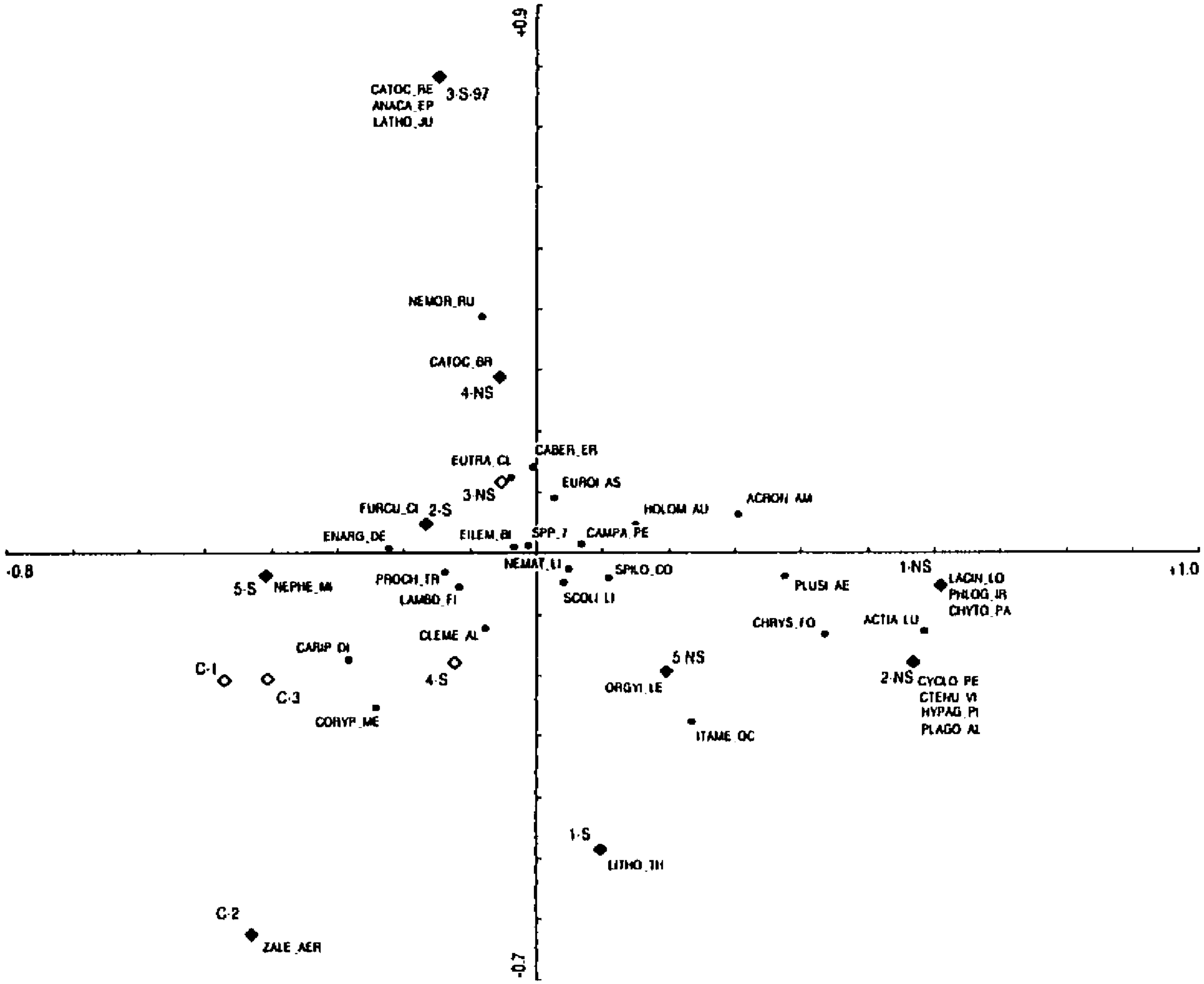

+0.9
-0.7
-0.8
+1.0
CATOC_RE
ANACA_EP
LATHO_JU
3-S-97
NEMOR_RU
CATOC_BR
4-NS
CABER_ER
EUTRA_CL
3-NS
EUROI_AS
HOLOM_AU
ACRON_AM
FURCU_CI
2-S
ENARG_DE
EILEM_BI
SPP_7
CAMPA_PE
NEMAT_LI
SPILO_CO
SCOLI_LI
PLUSI_AE
1-NS
LACIN_LO
PHLOG_IR
CHYTO_PA
5-S
NEPHE_MI
PROCH_TR
LAMBO_FI
CLEME_AL
CHRYS_FO
ACTIA_LU
CARIP_DI
C-1
C-3
4-S
5 NS
ORGYI_LE
2-NS
CYCLO_PE
CTENU_VI
HYPAG_PI
PLAGO_AL
CORYP_ME
ITAME_OC
1-S
LITHO_TH
C-2
ZALE_AER

Figure 51: Moth data for 1997 with the Whiteshell sites excluded from analysis. Correspondence analysis (CA) ordination diagram with site scores (◇), and species scores (●). The first axis (horizontal) has an eigenvalue of 0.283=15.9%, and the second axis (vertical) has an eigenvalue of 0.265=15.0%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
ANACA_EP= *Anacamptodes ephyraria*
APLEC_CO= *Aplectodes condita*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_BR= *Catocala briseis*
CATOC_RE= *Catocala relicta*
CHORI_RO= *Choristoneura rosaceana*
CHYTO_PA= *Chytonix palliatricula*
CLEME_AL= *Clemensia albata*
COYRP_ME= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
HOLOM_LA= *Holomelina laeta*
HYPOP_FU= *Hypoprepia fucosa*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_TH= *Lithophane thaxteri*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
PAONI_MY= *Paonias myops*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
SCOLI_LI= *Scoliopteryx libatrix*
SPILO_CO= *Spilosoma congrua*
SPP_7= Species 7
ZALE_AER= *Zale aeruginosa*

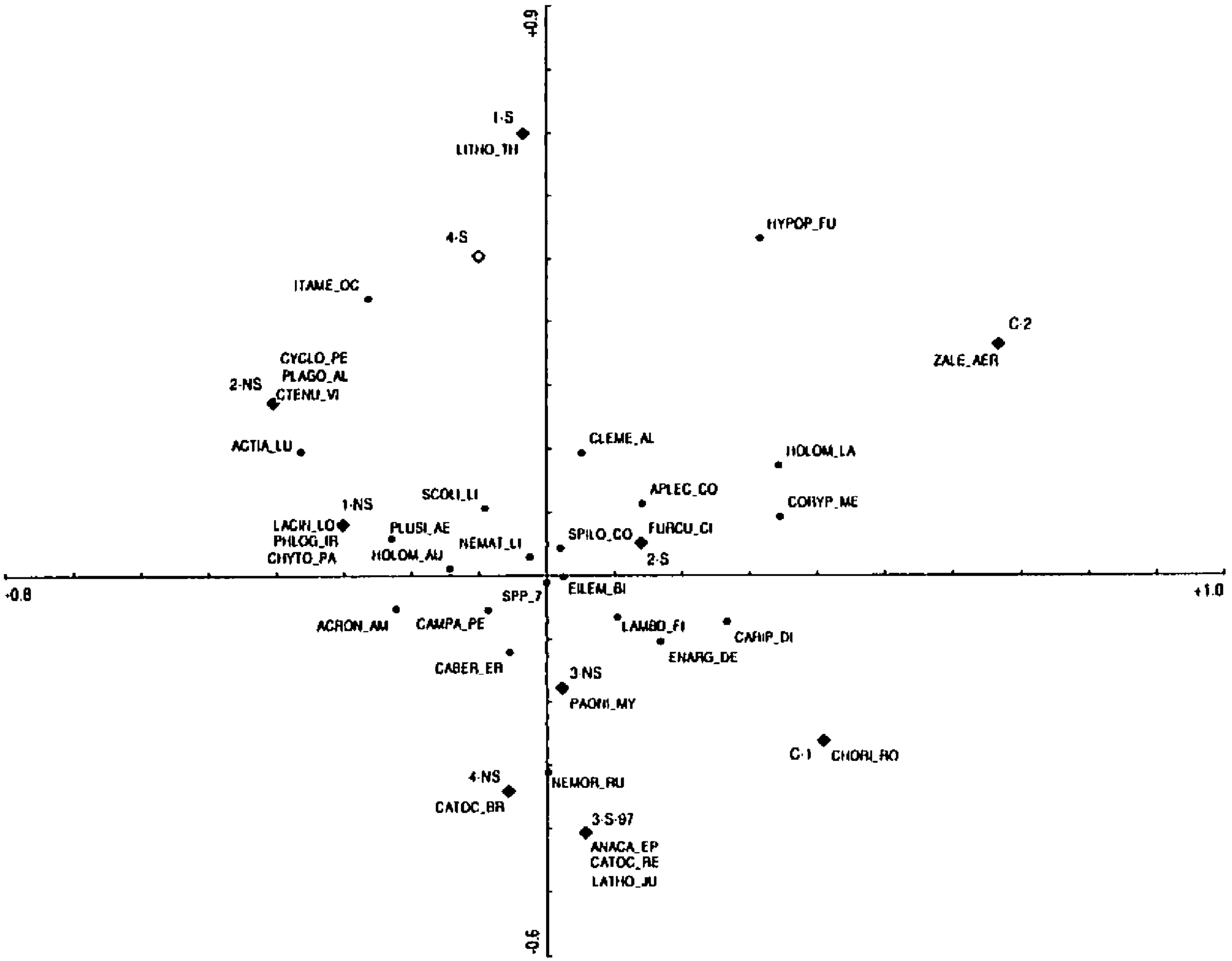

+0.9
-0.6
-0.8
+1.0
1-S
LITHO_TH
4-S
HYPOP_FU
ITAME_OC
C-2
ZALE_AER
CYCLO_PE
PLAGO_AL
2-NS
CTENU_VI
ACTIA_LU
CLEME_AL
HOLOM_LA
APLEC_CO
SCOLI_LI
1-NS
CORYP_ME
LACIN_LO
PHLOG_IR
CHYTO_PA
PLUSI_AE
HOLOM_AU
NEMAT_LI
SPILO_CO
FURCU_CI
2-S
EILEM_BI
SPP_7
ACRON_AM
CAMPA_PE
LAMBO_FI
CARIP_DI
ENARG_DE
CABER_ER
3-NS
PAONI_MY
C-1
CHORI_RO
4-NS
CATOC_BR
NEMOR_RU
3-S-97
ANACA_EP
CATOC_RE
LATHO_JU

Figure 52: Moth data for 1997 with the Whiteshell sites excluded from analysis. Correspondence analysis (CA) ordination diagram with site scores (◊), and species scores (●). The second axis (horizontal) has an eigenvalue of 0.265=15.0%, and the third axis (vertical) has an eigenvalue of 0.244=13.7%.

ACTIA_LU= *Actias luna*
ANACA_EP= *Anacamptodes ephyraria*
APLEC_CO= *Aplectodes condita*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CATOC_BR= *Catocala briseis*
CHORI_RO= *Choristoneura rosaceana*
CHYTO_PA= *Chytonix palliatricula*
CLEME_AL= *Clemensia albata*
CORYP_ME= Coryphista meadiii
CTENU_VI= *Ctenucha virginica*
CYCLO_PE= *Cyclophora pendulinaria*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
HOLOM_LA= *Holomelina laeta*
HYPOP_FU= *Hypoprepria fucosa*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_TH= *Lithophane thaxteria*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
PAONI_MY= *Paonias myops*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
SCOLI_LI= *Scoliopteryx libatrix*
SPILO_CO= *Spilosoma congrua*
SPP_7= *Species 7*
ZALE_AER= *Zale aeruginosa*

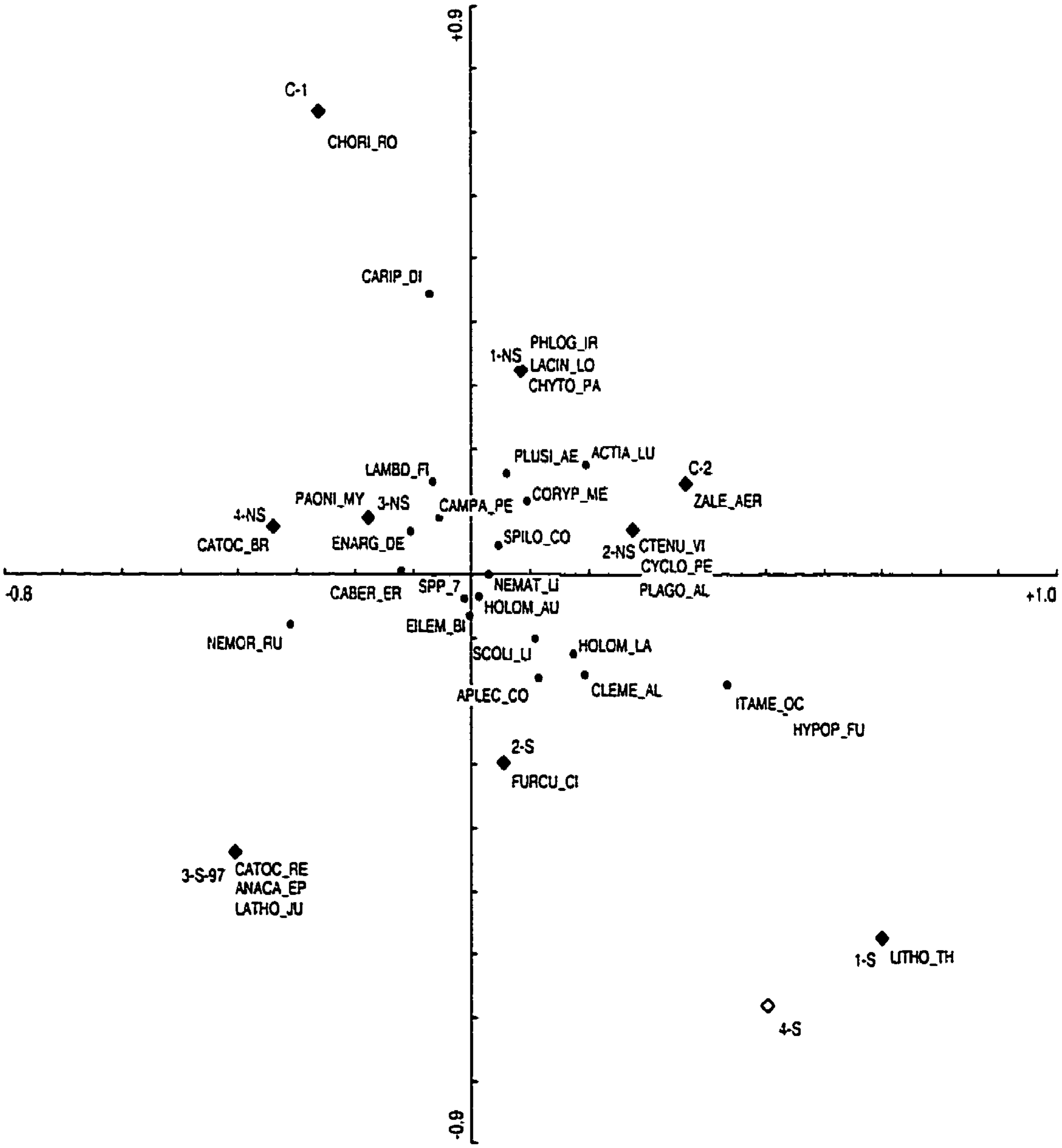

+0.9
C-1
CHORI_RO
CARIP_DI
1-NS
PHLOG_IR
LACIN_LO
CHYTO_PA
PLUSI_AE
ACTIA_LU
C-2
LAMBD_FI
ZALE_AER
PAONI_MY
3-NS
CAMPA_PE
CORYP_ME
4-NS
CATOC_BR
ENARG_DE
SPILO_CO
2-NS
CTENU_VI
CYCLO_PE
-0.8
CABER_ER
SPP_7
NEMAT_LI
HOLOM_AU
PLAGO_AL
+1.0
EILEM_BI
NEMOR_RU
SCOLI_LI
HOLOM_LA
APLEC_CO
CLEME_AL
ITAME_OC
HYPOP_FU
2-S
FURCU_CI
3-S-97
CATOC_RE
ANACA_EP
LATHO_JU
1-S
LITHO_TH
4-S
-0.9

Figure 53: Moth data for 1996. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.268=11.5%, and the second axis (vertical) has an eigenvalue of 0.226=9.7%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
AGROP_LA= *Agroperina lateritia*
AMANT_SM= *Amathes smithii*
AMPHI_PY= *Amphipyra pyramidoides*
ANACA_EP= *Anacamptodes ephyraria*
ANACA_HU= *Anacamptodes humaria*
ANNAG_OC= *Annagoga occiduaria*
APAMEA_NI= *Apamea nigrior*
APHAR_PU= *Apharetra purpurea*
APLEC_CO= *Aplectoides condita*
BESMA_QU= *Besma quercivoraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHILO_PL= *Chilo plejadellus*
CHORI_FU= *Choristoneura fumiferana*
CHRYS_FO= *Chrysanympha formosa*
CHYTO_PA= *Chytonix palliatricula*
CLEME_AL= *Clemensia albata*
CLOST_IN= *Clostera inclusa*
CORYP_ME= *Coryphista meadiii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DYSST_HE= *Dysstroma hersiliata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EOSPH_TH= *Eosphoropteryx thyatyroides*
ERRAN_TI= *Erranis tiliaria*
EUCHL_TI= *Euchlaena tigrinaria*
EULIT_TE= *Eulithis testata*
EUROI_OC= *Eurois occulta*
EUTRA_CL= *Eutralepa clemetaria*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_FA= *Lithophane fasciola*
LITHO_PE= *Lithophane pexata*
METAL_SA= *Metalepsis salicarium*
NEMAT_LI= *Nematocampa limbata*
ORETA_RO= *Oreta rosea*
ORTHO_RE= *Orthosia revicta*
PHLOG_IR= *Phlogophora iris*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
TORTR_TE= *Tortricidia testacea*
XANTH_FE= *Xanthorhoe ferrugata*
XANTH_LA= *Xanthorhoe lacustrata*
ZALE_AER= *Zale aeruginosa*

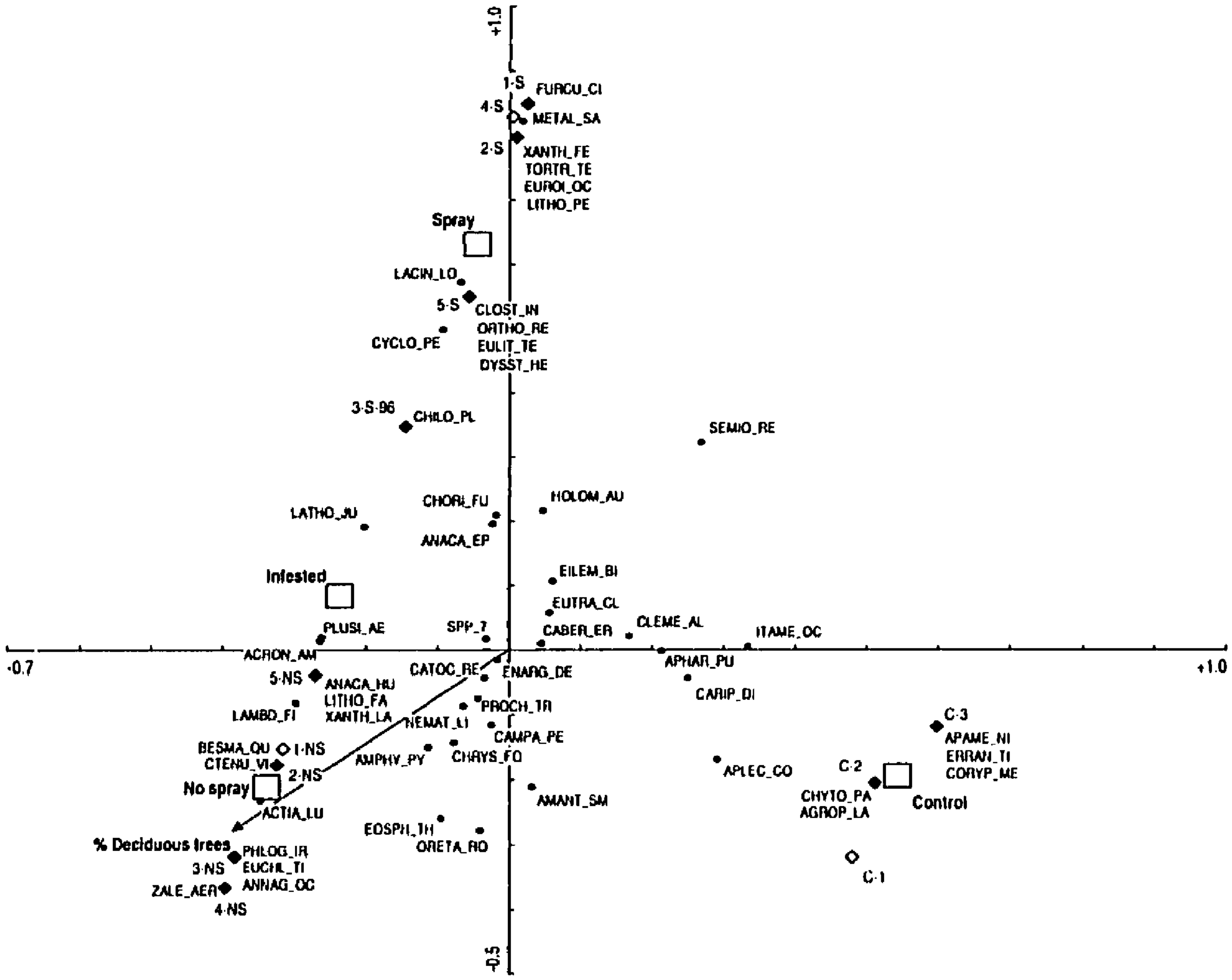

+1.0
1-S
FURCU_CI
4-S
METAL_SA
2-S
XANTH_FE
TORTR_TE
EUROI_OC
LITHO_PE
Spray
LACIN_LO
5-S
CLOST_IN
ORTHO_RE
EULIT_TE
DYSST_HE
CYCLO_PE
3-S-96
CHLO_PL
SEMIO_RE
CHORI_FU
HOLOM_AU
LATHO_JU
ANACA_EP
Infested
EILEM_BI
EUTRA_CL
PLUSI_AE
SPP_7
CABER_ER
CLEME_AL
ITAME_OC
-0.7
ACRON_AM
+1.0
5-NS
ANACA_HU
LITHO_FA
XANTH_LA
LAMBD_FI
CATOC_RE
ENARG_DE
APHAR_PU
CARIP_DI
PROCH_TR
NEMAT_LI
CAMPA_PE
C-3
APAME_NI
ERRAN_TI
CORYP_ME
BESMA_QU
1-NS
CTENU_VI
2-NS
AMPHY_PY
CHRYS_FO
APLEC_CO
C-2
No spray
AMANT_SM
CHYTO_PA
AGROP_LA
Control
ACTIA_LU
EOSPH_TH
% Deciduous trees
ORETA_RO
PHLOG_IR
3-NS
EUCHL_TI
ZALE_AER
ANNAG_OC
4-NS
C-1
-0.5

Figure 54: Moth data for 1996 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.324=15.9%, and the second axis (vertical) has an eigenvalue of 0.276=13.6%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
AGROP_LA= *Agroperina laterilia*
AMANT_SM= *Amathes smithii*
AMPHI_PY= *Amphipyra pyramidoides*
ANACA_EP= *Anacamptodes ephyraria*
ANOMO_BA= *Anomogyna badicollis*
BESMA_QU= *Besma quercivoraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHILO_PL= *Chilo plejadellus*
CHORI_FU= *Choristoneura fumiferana*
CHYTO_PA= *Chytonix palliatricula*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_BI= *Drepana bilineata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EUROI_OC= *Eurois occulta*

EUTHY_PU= *Euthyatira pudens*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_PE= *Lithophane pexata*
METAL_SA= *Metalepsis salicarium*
NEMAT_LI= *Nematocampa limbata*
NEPYT_CA= *Nepytia canosaria*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
XANTH_FE= *Xanthorhoe ferrugata*
ZALE_AER= *Zale aeruginosa*

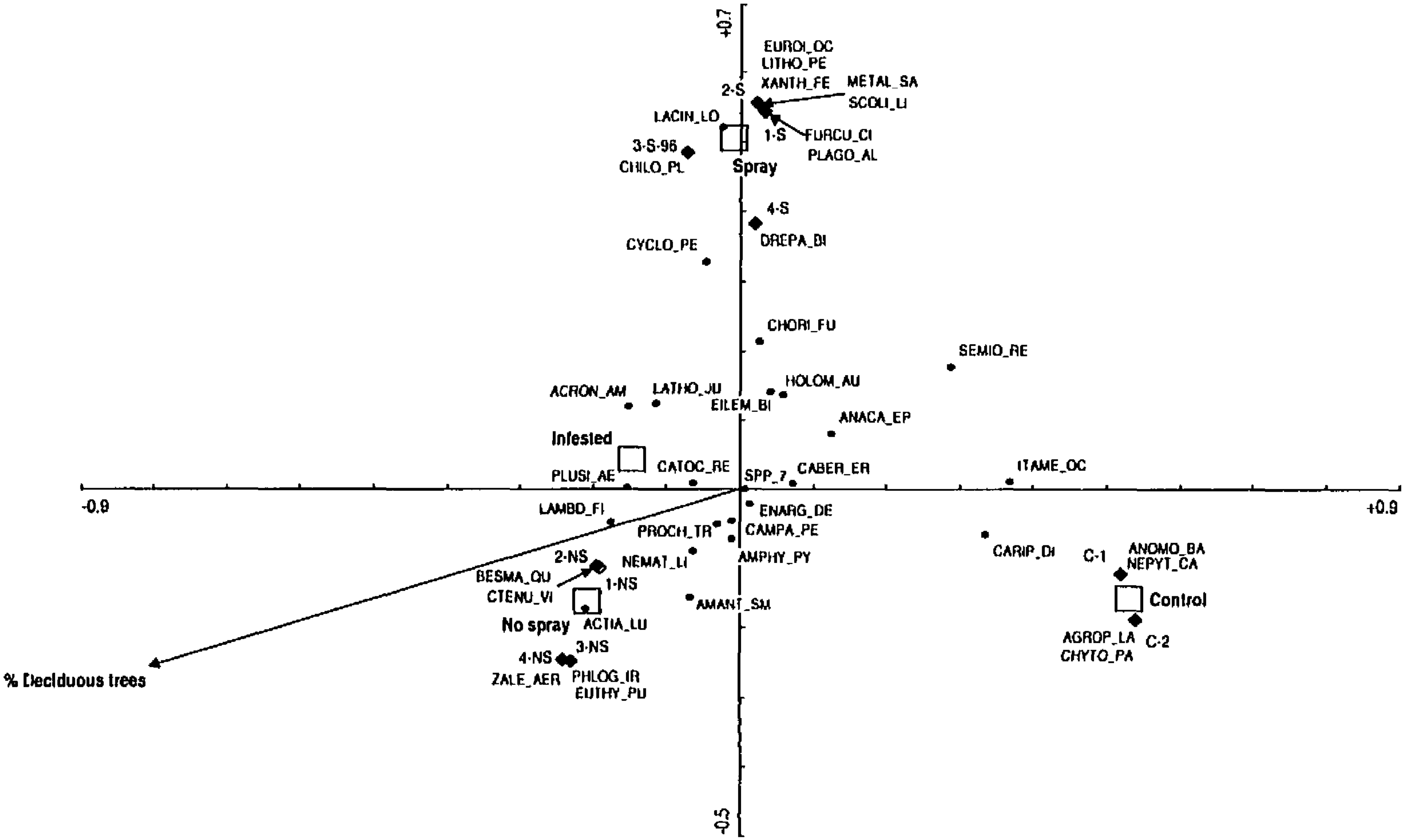

+0.7
EUROI_OC
LITHO_PE
XANTH_FE
METAL_SA
SCOLI_LI
2-S
LACIN_LO
1-S
FURCU_CI
PLAGO_AL
3-S-96
CHILO_PL
Spray
4-S
DREPA_DI
CYCLO_PE
CHORI_FU
SEMIO_RE
ACRON_AM
LATHO_JU
HOLOM_AU
EILEM_BI
ANACA_EP
Infested
PLUSI_AE
CATOC_RE
SPP_7
CABER_ER
ITAME_OC
-0.9
+0.9
LAMBD_FI
ENARG_DE
PROCH_TR
CAMPA_PE
AMPHY_PY
CARIP_DI
C-1
ANOMO_BA
NEPYT_CA
2-NS
NEMAT_LI
BESMA_QU
1-NS
CTENU_VI
AMANT_SM
Control
No spray
ACTIA_LU
AGROP_LA
C-2
CHYTO_PA
3-NS
4-NS
% Deciduous trees
ZALE_AER
PHLOG_IR
EUTHY_PU
-0.5

Figure 55: Moth data for 1997. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.257=11.6%, and the second axis (vertical) has an eigenvalue of 0.246=11.0%.

ACRON_AM= *Acronicta americana*
ACTIA_LU= *Actias luna*
AMANT_SM= *Amathes smithii*
AMPHY_PY= *Amphipyra pyramidoides*
ANACA_EP= *Anacamptodes ephyraria*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_BR= *Catocala briseis*
CATOC_RE= *Catocala relicta*
CHORI_RO= *Choristoneura rosaceana*
CHYTO_PA= *Chytonix palliatricula*
CORYP_ME= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
HOLOM_LA= *Holomelina laeta*
IDIA_AME= *Idia americalis*
IDIA_LUB= *Idia lubricalis*
ITAME_OC= *Itame occiduaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_TH= *Lithophane thaxteri*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
NEPHE_MI= *Nephelodes minians*
ORGYI_LE= *Orgyia leucostigma*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SPP_7= Species 7
ZALE_AER= *Zale aeruginosa*

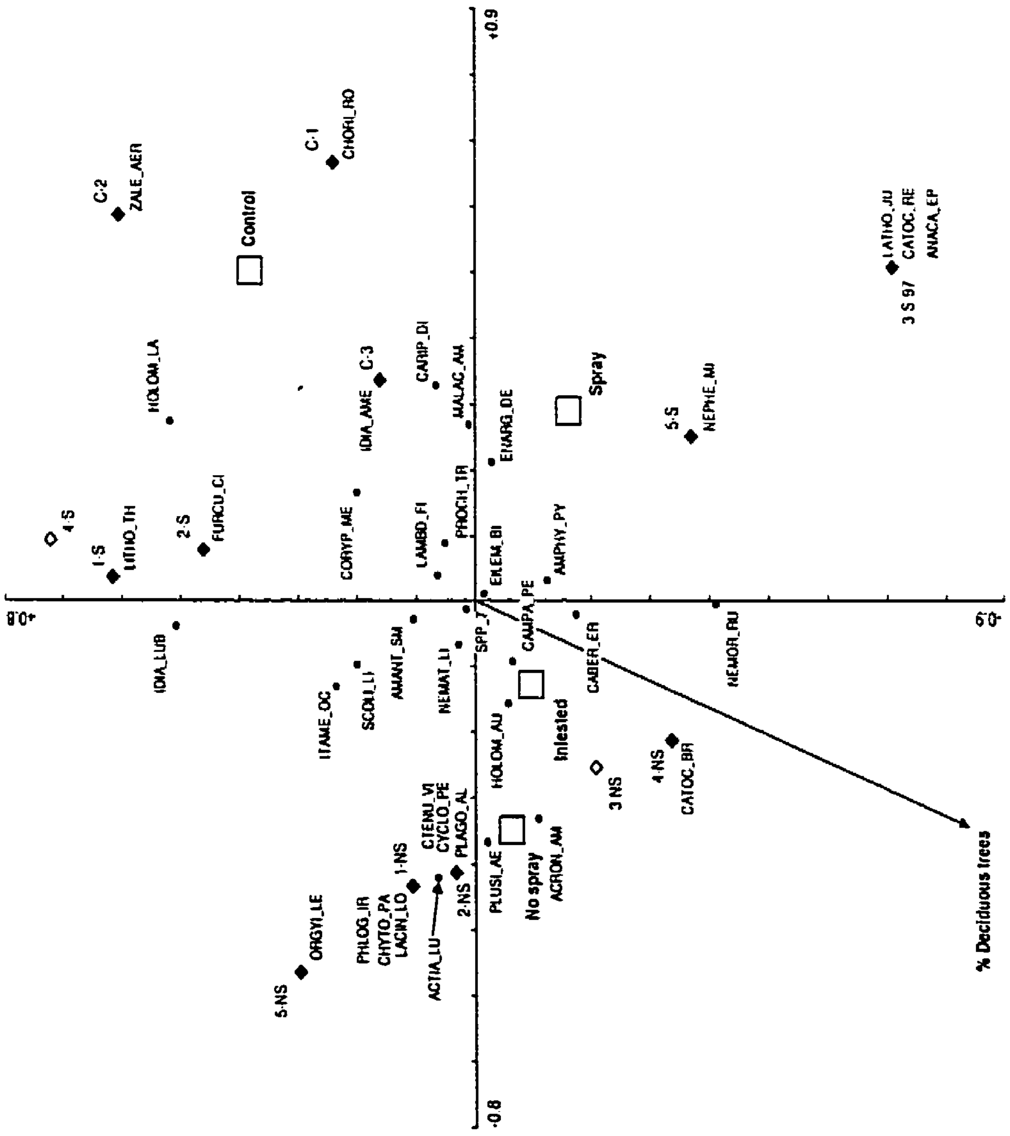

+0.9
-0.8
+0.8
-0.9
Control
Spray
Infested
No spray
% Deciduous trees
C-1
C-2
C-3
1-S
2-S
3-S 97
4-S
5-S
1-NS
2-NS
3-NS
4-NS
5-NS
ZALE_AER
CHORI_RO
LATHO_JU
CATOC_RE
ANACA_EP
HOLOM_LA
CARIP_DI
MALAC_AM
IDIA_AME
ENARG_DE
NEPHE_MI
FURCU_CI
LITHO_TH
CORYP_ME
LAMBD_FI
PROCH_TR
ELEM_BI
AMPHY_PY
IDIA_LUB
SPP_T
CAMPA_PE
CABER_ER
NEMOR_RU
ITAME_OC
SCOLI_LI
AMANT_SM
NEMAT_LI
HOLOM_AU
CATOC_BR
CTENU_VI
CYCLO_PE
PLAGO_AL
PLUSI_AE
ACRON_AM
PHLOG_IR
CHYTO_PA
LACIN_LO
ACTIA_LU
ORGYI_LE

Figure 56: Moth data for 1997 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.299=14.9%, and the second axis (vertical) has an eigenvalue of 0.274=13.5%.

ACRON_AM= *Acronicta americana*
ACRON_FR= *Acronicta fragilis*
ACTIA_LU= *Actias luna*
AMANT_SM= *Amathes smithii*
AMPHI_AM= *Amphipoea americana*
AMPHY_PY= *Amphipyra pyramidoides*
ANACA_EP= *Anacamptodes ephyraria*
APLEC_CO= *Aplectodes condita*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHORI_RO= *Choristoneura rosaceana*
CHYTO_PA= *Chytonix palliatricula*
CORYP_ME= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_AR= *Drepana arcuata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EOSPH_TH= *Eosphoropteryx thyatyroides*
FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
ITAME_LO= *Itame loricaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
MALAC_AM= *Malacasoma americanum*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
NEPHE_MI= *Nephelodes minians*
ORETA_RO=*Oreta rosea*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SPP_7= Species 7
ZALE_AER= *Zale aeruginosa*

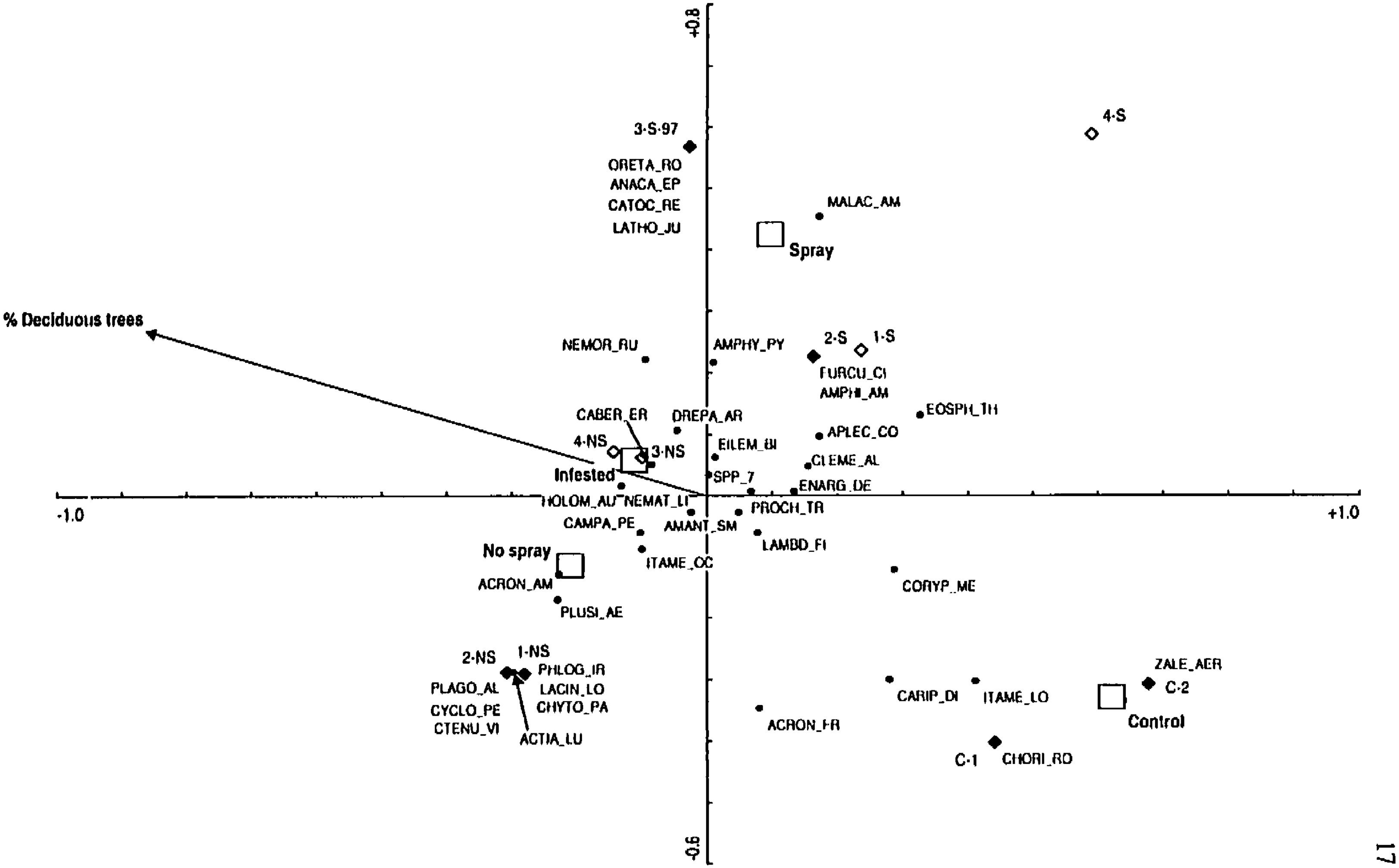

+0.8
-0.6
-1.0
+1.0
% Deciduous trees
3-S-97
ORETA_RO
ANACA_EP
CATOC_RE
LATHO_JU
4-S
MALAC_AM
Spray
NEMOR_RU
AMPHY_PY
2-S
1-S
FURCU_CI
AMPHI_AM
EOSPH_TH
CABER_ER
DREPA_AR
APLEC_CO
4-NS
3-NS
EILEM_BI
CLEME_AL
Infested
SPP_7
ENARG_DE
HOLOM_AU
NEMAT_LI
PROCH_TR
CAMPA_PE
AMANT_SM
LAMBD_FI
No spray
ITAME_OC
CORYP_ME
ACRON_AM
PLUSI_AE
2-NS
1-NS
PHLOG_IR
PLAGO_AL
LACIN_LO
CYCLO_PE
CHYTO_PA
CTENU_VI
ACTIA_LU
ZALE_AER
C-2
CARIP_DI
ITAME_LO
Control
ACRON_FR
C-1
CHORI_RO

Figure 57: Moth data for 1997 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The second axis (horizontal) has an eigenvalue of 0.274=13.5%, and the third axis (vertical) has an eigenvalue of 0.263=13.1%.

ACRON_AM= *Acronicta americana*
ACRON_FR= *Acronicta fragilis*
ACTIA_LU= *Actias luna*
AMANT_SM= *Amathes smithii*
AMPHI_AM= *Amphipoea americana*
ANACA_EP= *Anacamptodes ephyraria*
APLEC_CO= *Aplectodes condita*
CABER_ER= *Cabera erythemaria*
CAMPA_PE= *Campaea perlata*
CARIP_DI= *Caripeta divisata*
CATOC_RE= *Catocala relicta*
CHORI_RO= *Choristoneura rosaceana*
CHYTO_PA= *Chytonix palliatricula*
CLEME_AL= *Clemensia albata*
CORYP_Me= *Coryphista meadii*
CYCLO_PE= *Cyclophora pendulinaria*
CTENU_VI= *Ctenucha virginica*
DREPA_AR= *Drepana arcuata*
EILEM_BI= *Eilema bicolor*
ENARG_DE= *Enargia decolor*
EOSPH_TH= *Eosphoropteryx thyatyroides*

FURCU_CI= *Furcula cinerea*
HOLOM_AU= *Holomelina aurantiaca*
ITAME_OC= *Itame occiduaria*
ITAME_LO= *Itame loricaria*
LACIN_LO= *Lacinipolia lorea*
LAMBD_FI= *Lambdina fiscellaria*
LATHO_JU= *Lathoe juglandis*
LITHO_TH= *Lithophane thaxteri*
MALAC_AM= *Malacasoma americanum*
NEMAT_LI= *Nematocampa limbata*
NEMOR_RU= *Nemoria rubrifrontaria*
NEPHE_MI= *Nephelodes minians*
ORETA_RO= *Oreta rosea*
PHLOG_IR= *Phlogophora iris*
PLAGO_AL= *Plagodis alcoolaria*
PLUSI_AE= *Plusia aerodes*
PROCH_TR= *Prochoerodes transversata*
SCOLI_LI= *Scoliopteryx libatrix*
SEMIO_RE= *Semiothisa respecta*
SPP_7= Species 7
ZALE_AER= *Zale aeruginosa*

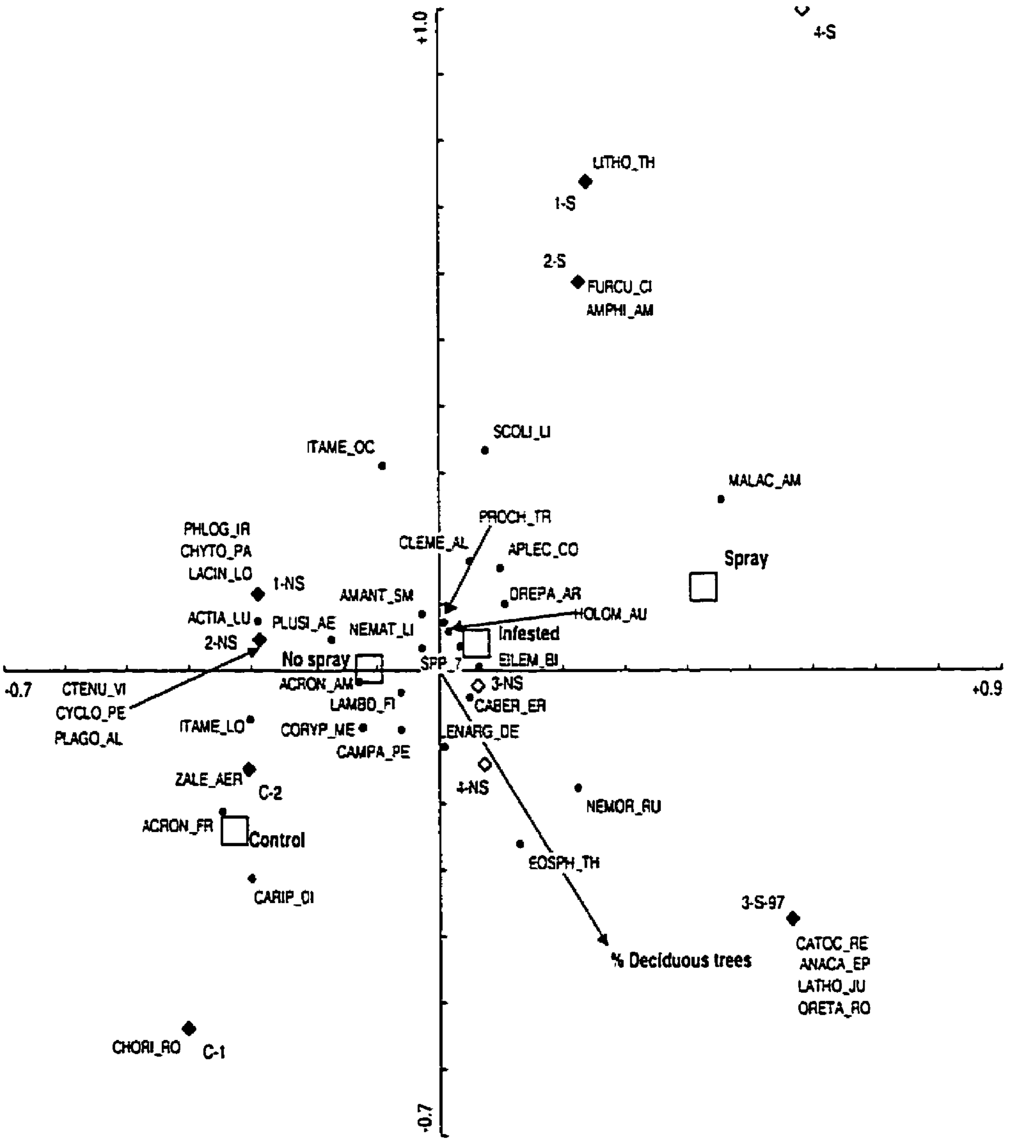

+1.0
-0.7
-0.7
+0.9
4-S
LITHO_TH
1-S
2-S
FURCU_CI
AMPHI_AM
SCOLI_LI
ITAME_OC
MALAC_AM
PROCH_TR
CLEME_AL
APLEC_CO
Spray
PHLOG_IR
CHYTO_PA
LACIN_LO
1-NS
AMANT_SM
DREPA_AR
HOLOM_AU
ACTIA_LU
PLUSI_AE
NEMAT_LI
Infested
2-NS
No spray
SPP_7
EILEM_BI
CTENU_VI
ACRON_AM
3-NS
CYCLO_PE
LAMBO_FI
CABER_ER
PLAGO_AL
ITAME_LO
CORYP_ME
ENARG_DE
CAMPA_PE
ZALE_AER
C-2
4-NS
NEMOR_RU
ACRON_FR
Control
EOSPH_TH
CARIP_CI
3-S-97
CATOC_RE
% Deciduous trees
ANACA_EP
LATHO_JU
ORETA_RO
CHORI_RO
C-1

Figure 58: Number (Mean ± SEM) of carabid beetles from each site type in 1996 and 1997. Note the different vertical scales.

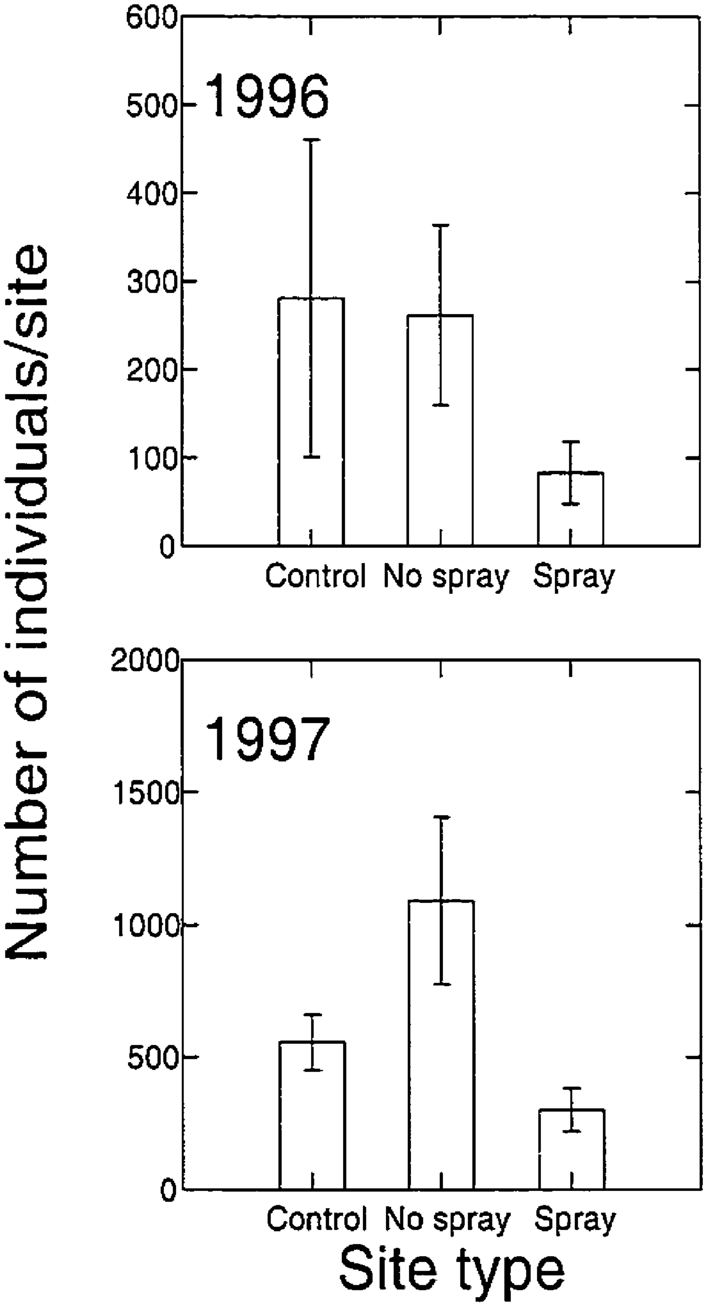

1996
1997
Number of individuals/site
Site type
Control
No spray
Spray
0
100
200
300
400
500
600
0
500
1000
1500
2000

Figure 59. Number (Mean ± SEM) of carabid beetles from each site type in 1996 and 1997 with the Whiteshell sites excluded. Note the different vertical scales.

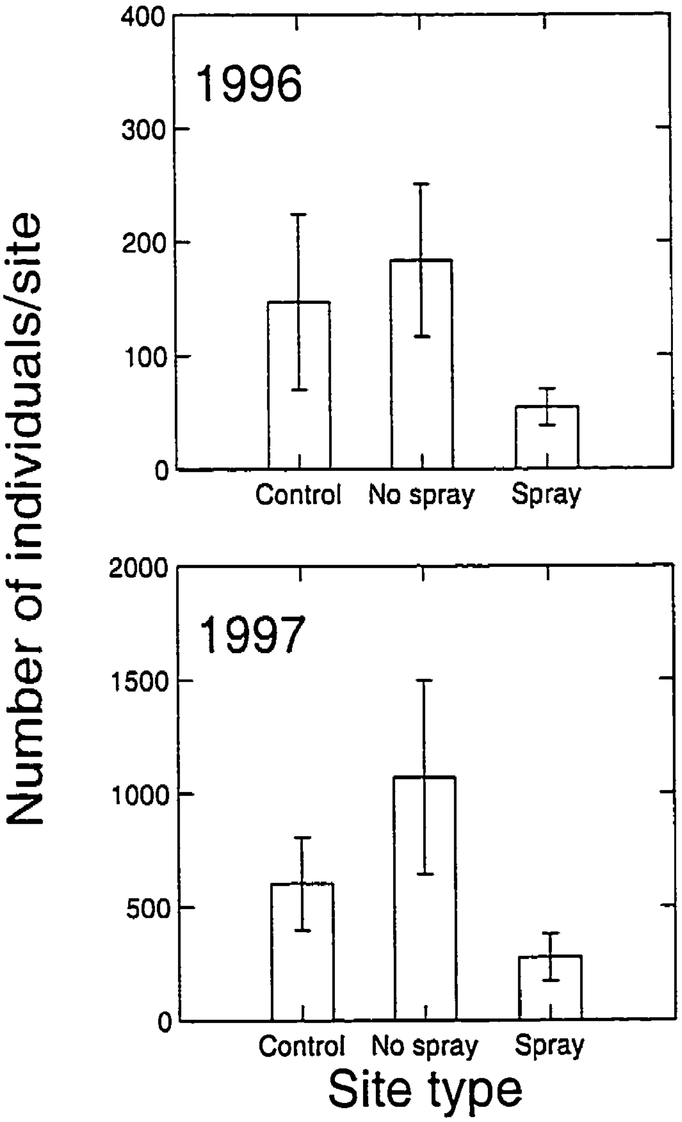

1996
400
300
200
100
0
Control
No spray
Spray
1997
2000
1500
1000
500
0
Control
No spray
Spray
Number of individuals/site
Site type

Figure 60: The number of carabid beetles in sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

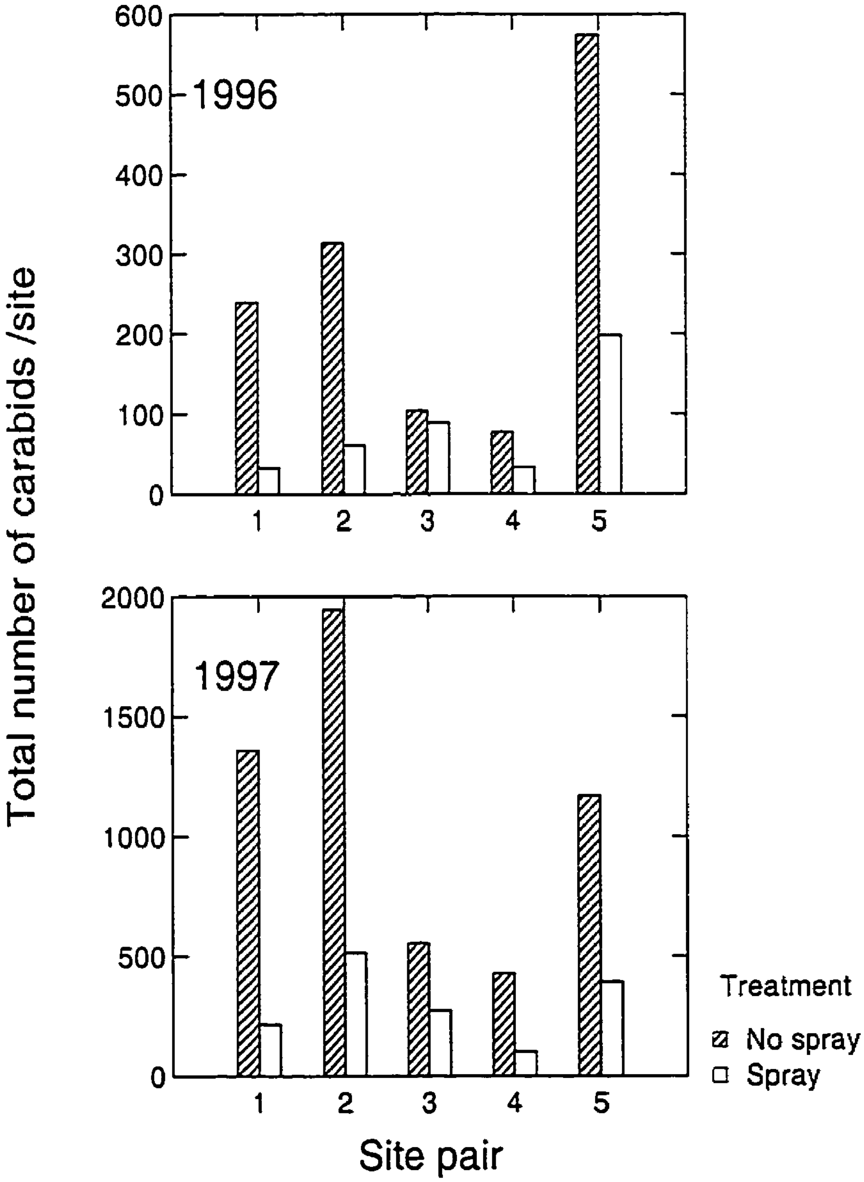

1996
1997
Total number of carabids /site
Site pair
0
100
200
300
400
500
600
0
500
1000
1500
2000
1
2
3
4
5
Treatment
▨ No spray
☐ Spray

Figure 61: The number of *Agonum retractum*, and *Sphaeroderus nitidicollis brevoorti* in sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

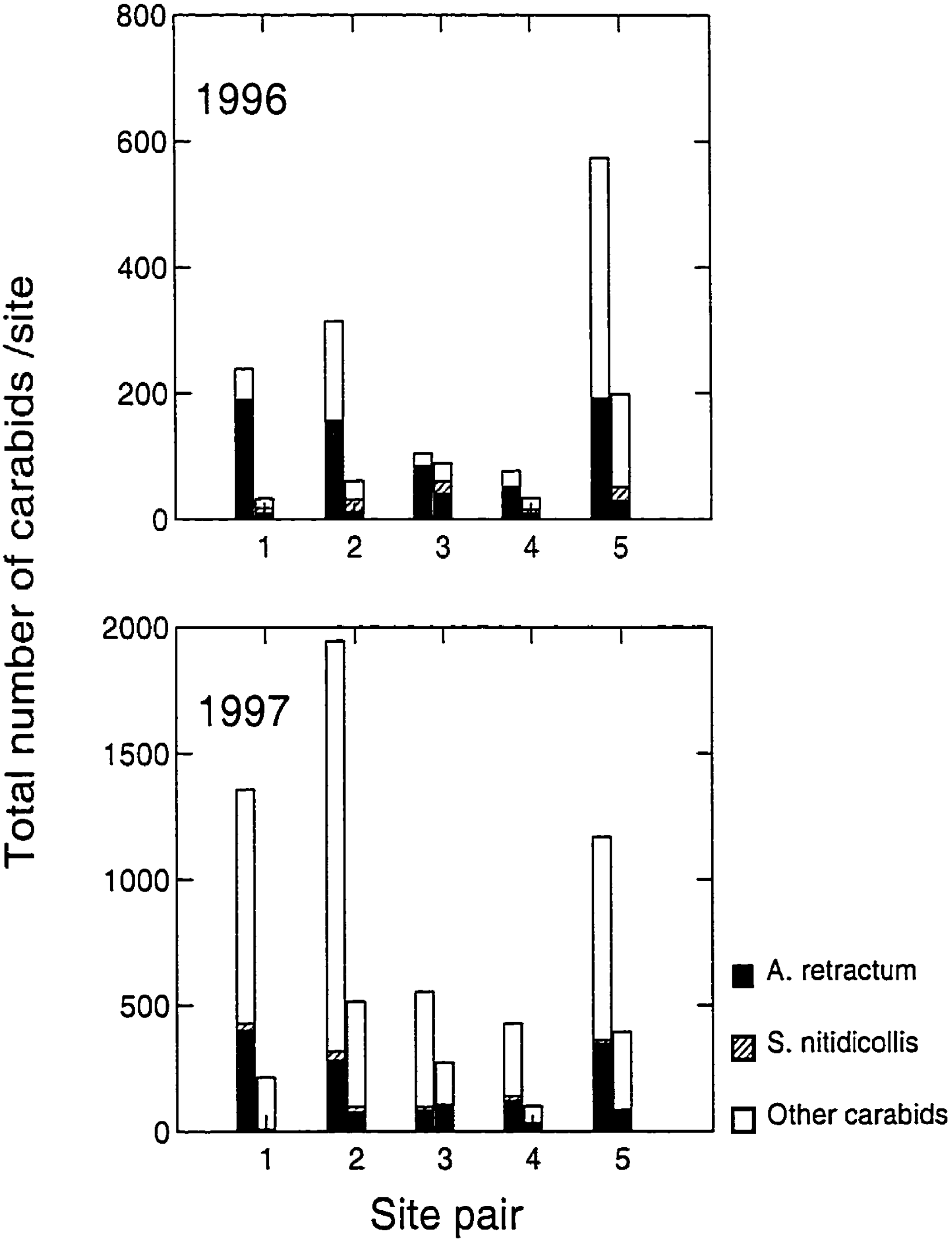

800
600
400
200
0
1996
1
2
3
4
5
2000
1500
1000
500
0
1997
1
2
3
4
5
Total number of carabids /site
Site pair
■ A. retractum
▨ S. nitidicollis
☐ Other carabids

Figure 62: Number (± SEM) of carabid beetle species from each site type in 1996 and 1997. Note the different vertical scales.

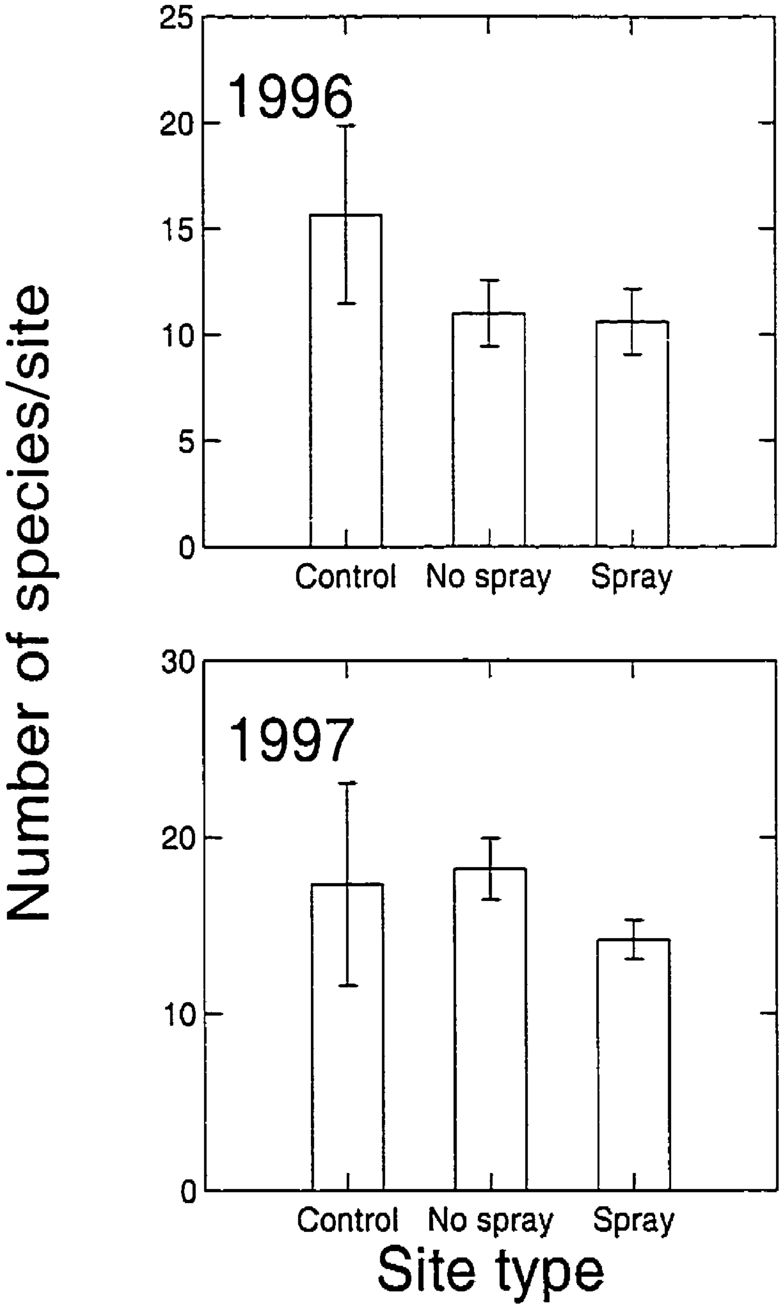

Number of species/site
1996
25
20
15
10
5
0
Control
No spray
Spray
1997
30
20
10
0
Control
No spray
Spray
Site type

Figure 63: The number of carabid beetles species in sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

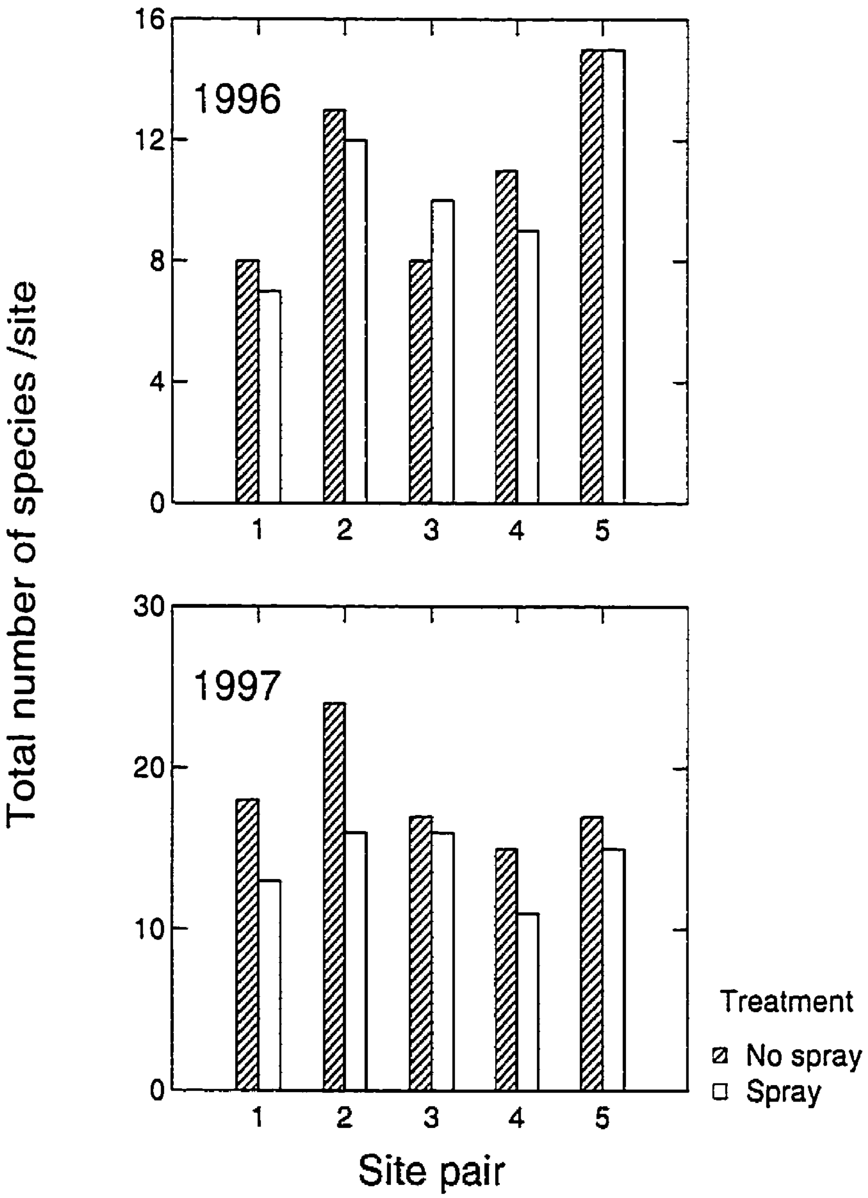

Total number of species /site
1996
16
12
8
4
0
1
2
3
4
5
1997
30
20
10
0
1
2
3
4
5
Site pair
Treatment
▨ No spray
☐ Spray

Figure 64: Log series alpha diversity (Mean ± SEM) of carabid beetles for each site type in 1996 and 1997. Note the different vertical scales.

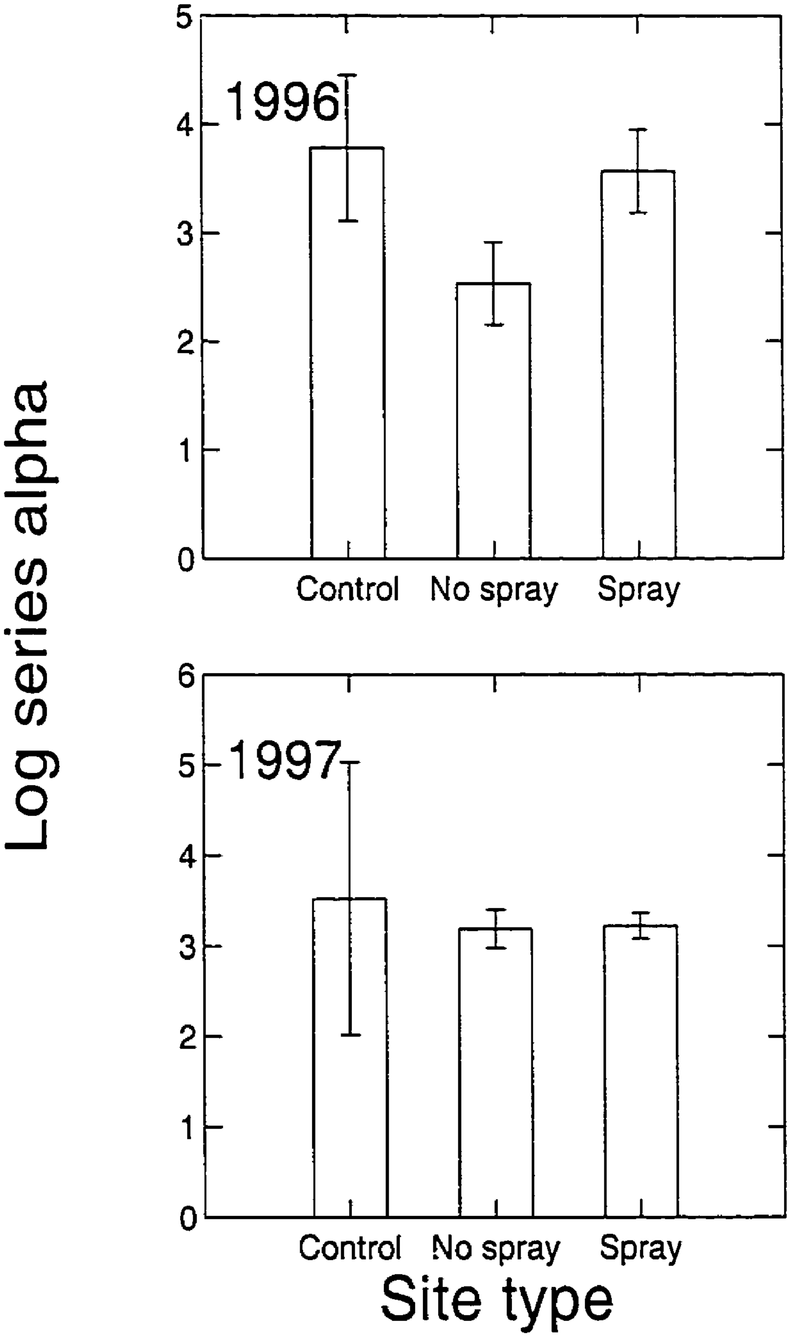

Log series alpha
1996
5
4
3
2
1
0
Control
No spray
Spray
1997
6
5
4
3
2
1
0
Control
No spray
Spray
Site type

Figure 65: Log series alpha diversity of carabid beetles in sprayed and unsprayed site pairs in 1996 and 1997. Note the different vertical scales.

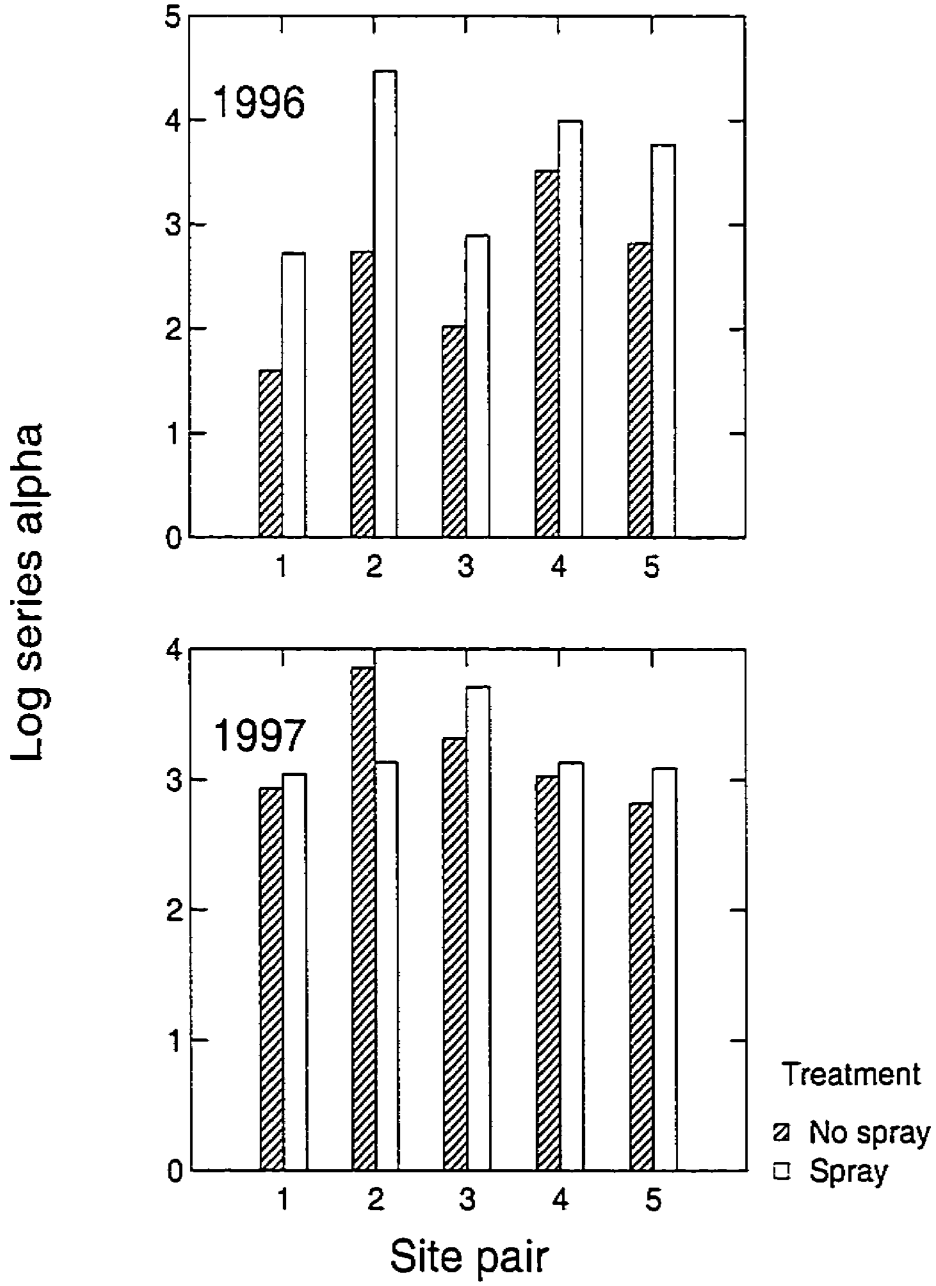

1996
1997
Log series alpha
Site pair
0
1
2
3
4
5
Treatment
▨ No spray
☐ Spray

Figure 66: Carabid data for 1996. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.169=21.7%, and the second axis (vertical) has an eigenvalue of 0.142=18.1%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

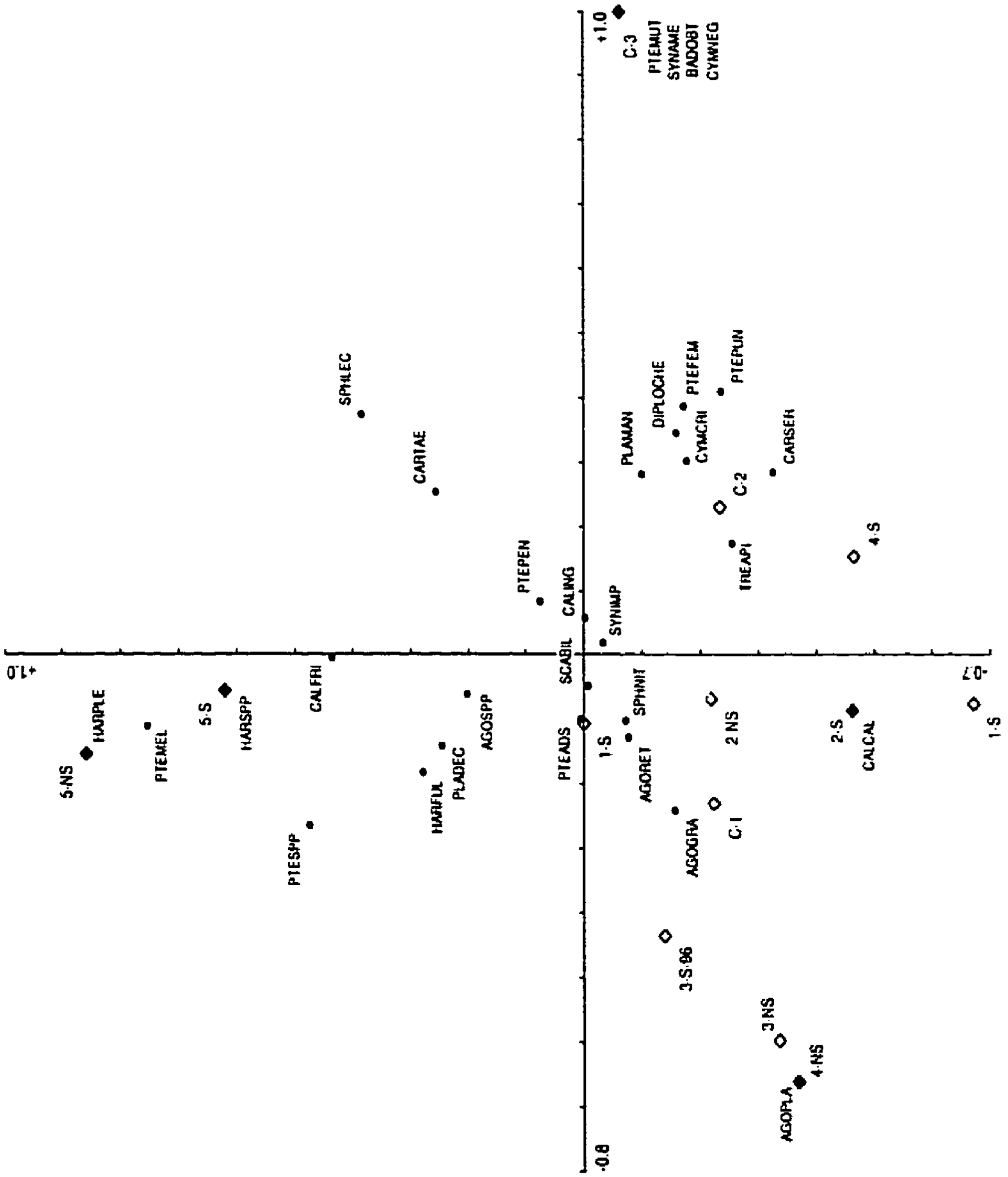

+1.0
C-3
PTEMUT
SYNAME
BADOBT
CYMWEG
SPHLEC
CARTAE
PLAMAN
DIPLOCHE
PTEFEM
CYMCRI
PTEPUN
CARSER
C-2
4-S
TREAPI
PTEPEN
CALING
SYNIMP
+1.0
-0.7
CALFRI
5-S
HARSPP
HARPLE
5-NS
PTEMEL
AGOSPP
PLADEC
HARFUL
PTESPP
SCABIL
PTEADS
1-S
SPHNIT
AGORET
2 NS
C-1
AGOGRA
2-S
CALCAL
1-S
3-S-96
3 NS
4-NS
AGOPLA
-0.8

Figure 67: Carabid data for 1996 with the Whiteshell sites excluded from analysis. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.160=22.6%, and the second axis (vertical) has an eigenvalue of 0.133=18.6%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

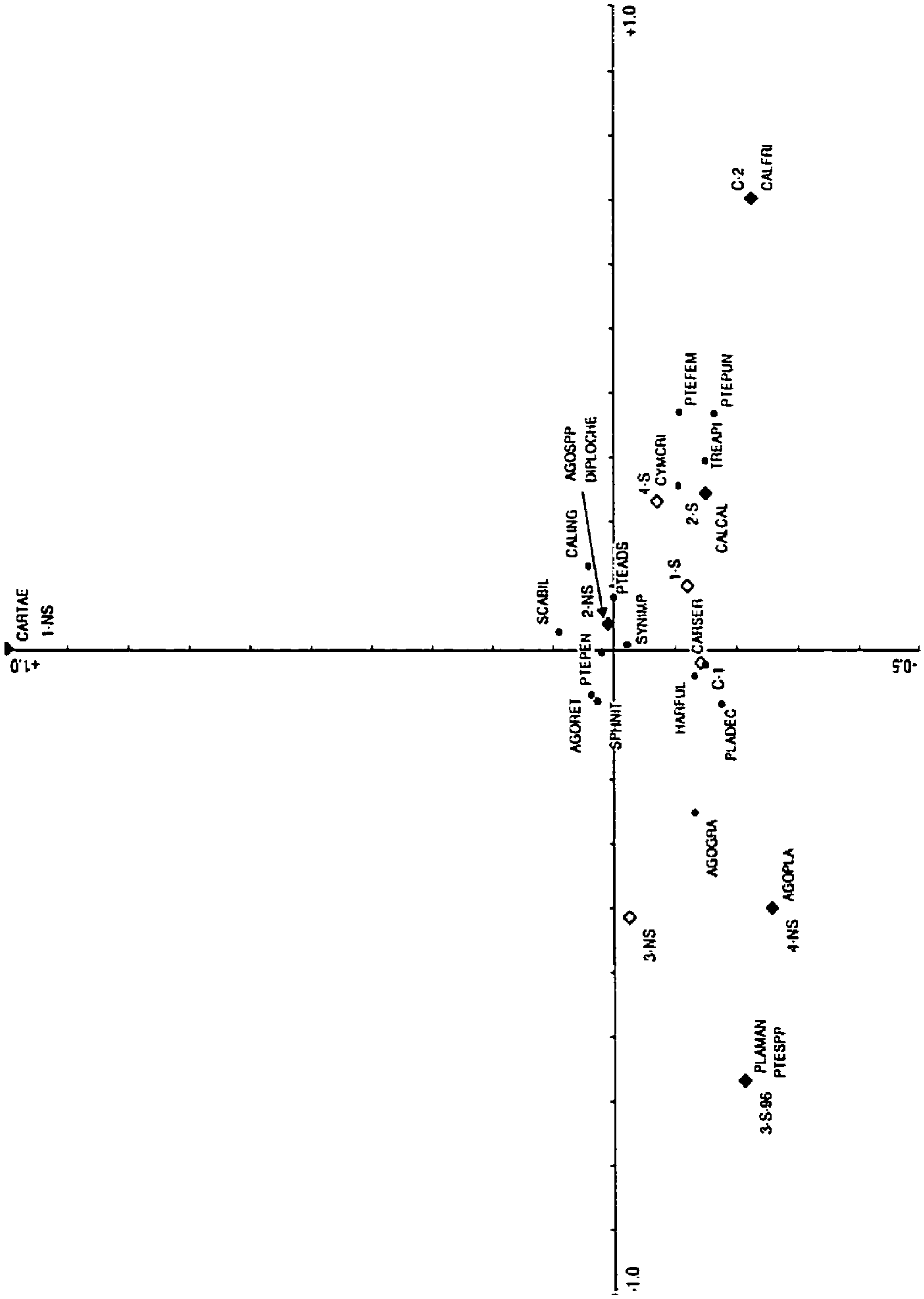

+1.0
-0.5
+1.0
-1.0
CARTAE
1·NS
SCABIL
CALING
AGOSPP
DIPLOCHE
2·NS
PTEADS
SYNIMP
PTEPEN
AGORET
SPHNIT
4·S
CYMCRI
PTEFEM
PTEPUN
TREAPI
2·S
CALCAL
1·S
CARSER
HARFUL
C·1
PLADEC
C·2
CALFRI
AGOGRA
AGOPLA
4·NS
3·NS
PLAMAN
PTESPP
3·S·96

Figure 68: Carabid data for 1997. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.134=22.0%, and the second axis (vertical) has an eigenvalue of 0.107=17.6%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

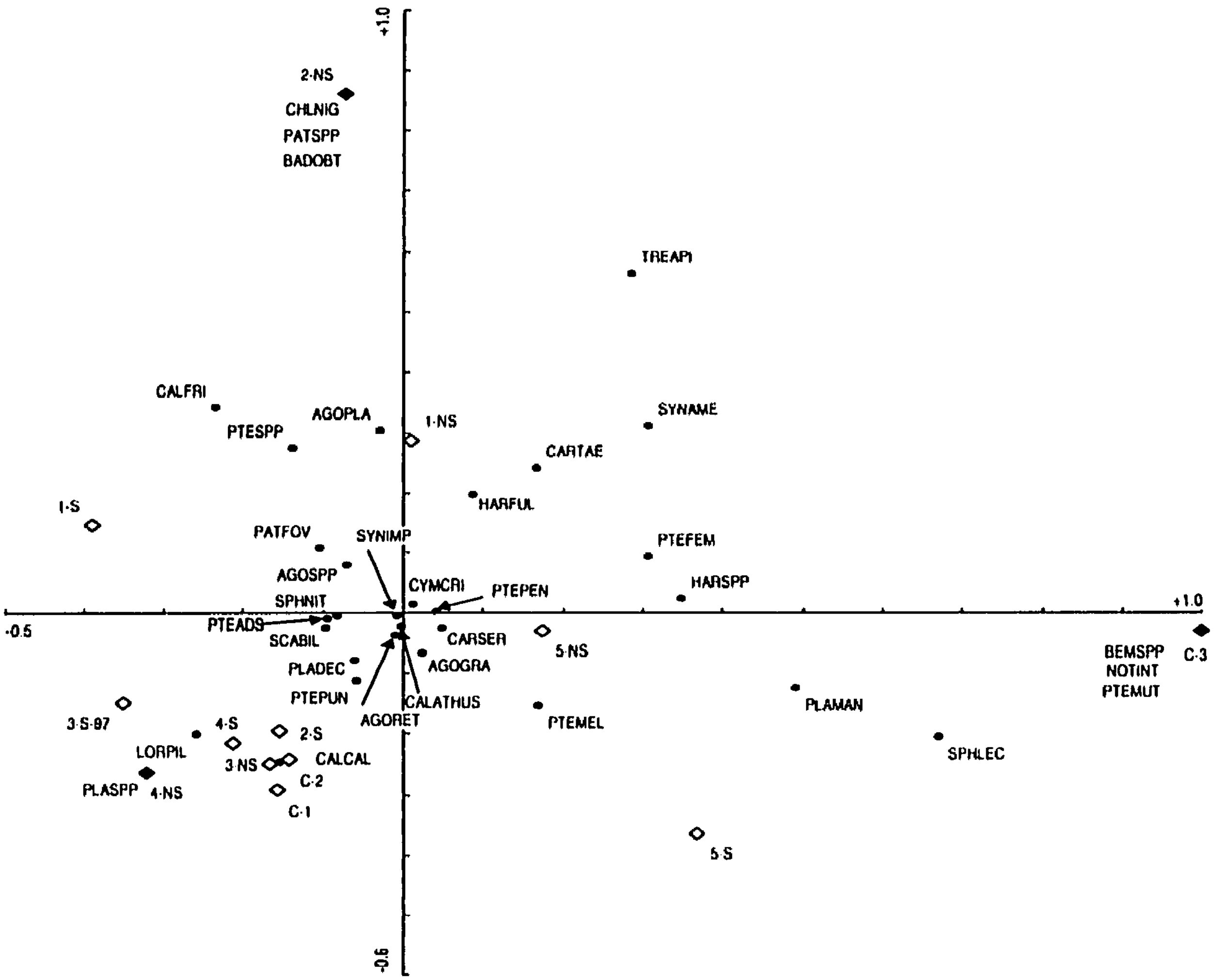

+1.0
2·NS
CHLNIG
PATSPP
BADOBT
TREAPI
CALFRI
AGOPLA
1·NS
PTESPP
SYNAME
CARTAE
HARFUL
1·S
PATFOV
SYNIMP
PTEFEM
HARSPP
AGOSPP
CYMCRI
PTEPEN
SPHNIT
+1.0
-0.5
PTEADS
SCABIL
CARSER
5·NS
BEMSPP
NOTINT
PTEMUT
C·3
PLADEC
AGOGRA
PTEPUN
CALATHUS
PLAMAN
3·S·87
AGORET
PTEMEL
4·S
2·S
LORPIL
CALCAL
SPHLEC
3·NS
C·2
PLASPP
4·NS
C·1
5·S
-0.6

Figure 69: Carabid data for 1997 with the Whiteshell sites excluded from analysis. Correspondence analysis (CA) ordination diagram with site scores (◊) and species scores (●). The first axis (horizontal) has an eigenvalue of 0.136=28.2%, and the second axis (vertical) has an eigenvalue of 0.102=21.2%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*

PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

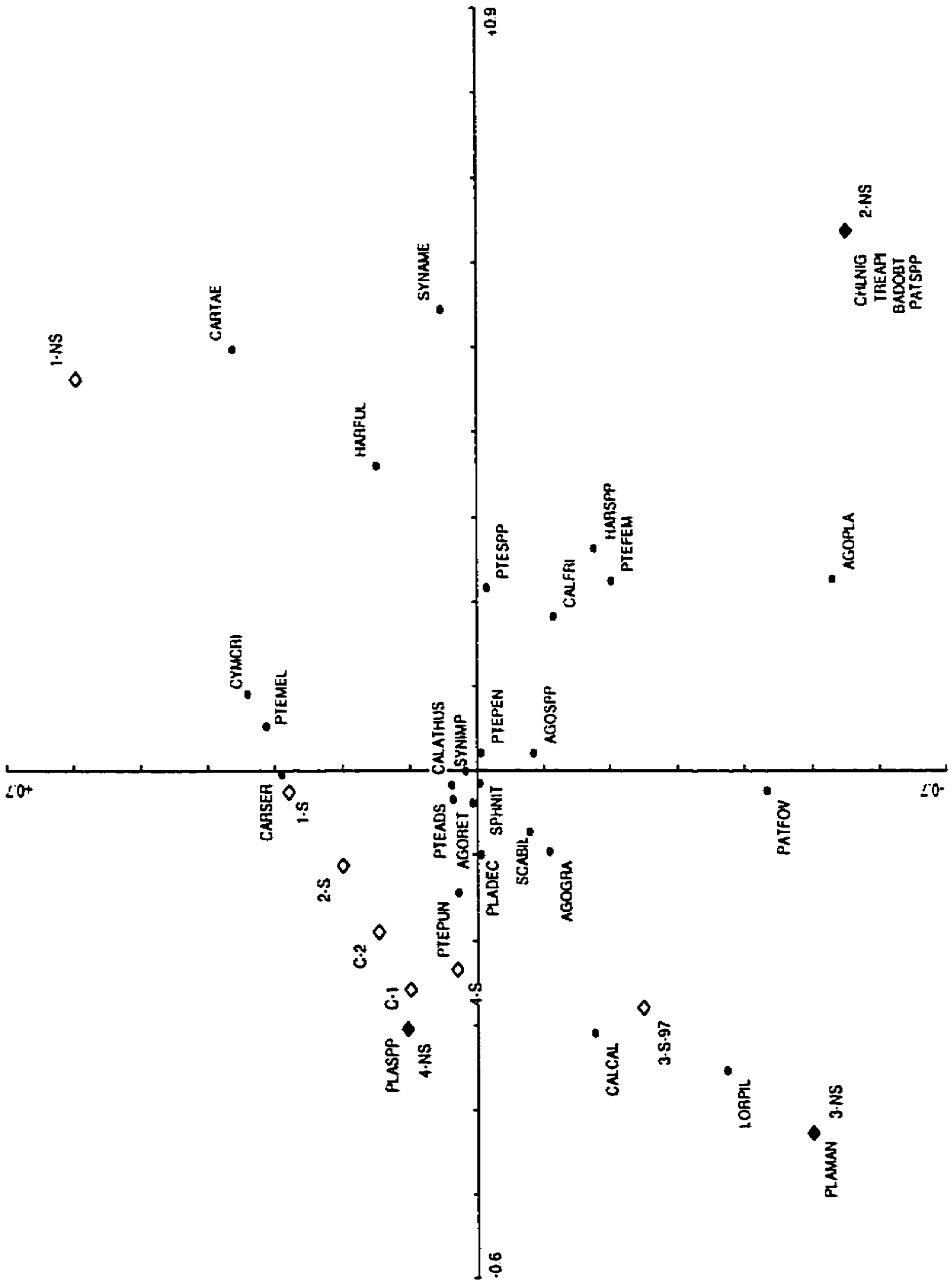

+0.9
-0.6
+0.7
-0.7
1-NS
CARTAE
SYNAME
2-NS
CHLNIG
TREAPI
BADOBT
PATSPP
HARFUL
PTESPP
HARSPP
PTEFEM
CALFRI
AGOPLA
CYMCRI
PTEMEL
CALATHUS
SYNIMP
PTEPEN
AGOSPP
CARSER
1-S
2-S
PTEADS
AGORET
SPHNIT
PLADEC
SCABIL
AGOGRA
PATFOV
C-2
PTEPUN
C-1
4-S
PLASPP
4-NS
CALCAL
3-S-97
LORPIL
3-NS
PLAMAN

Figure 70: Carabid data for 1996. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.156=20.0%, and the second axis (vertical) has an eigenvalue of 0.095=12.1%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*

PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

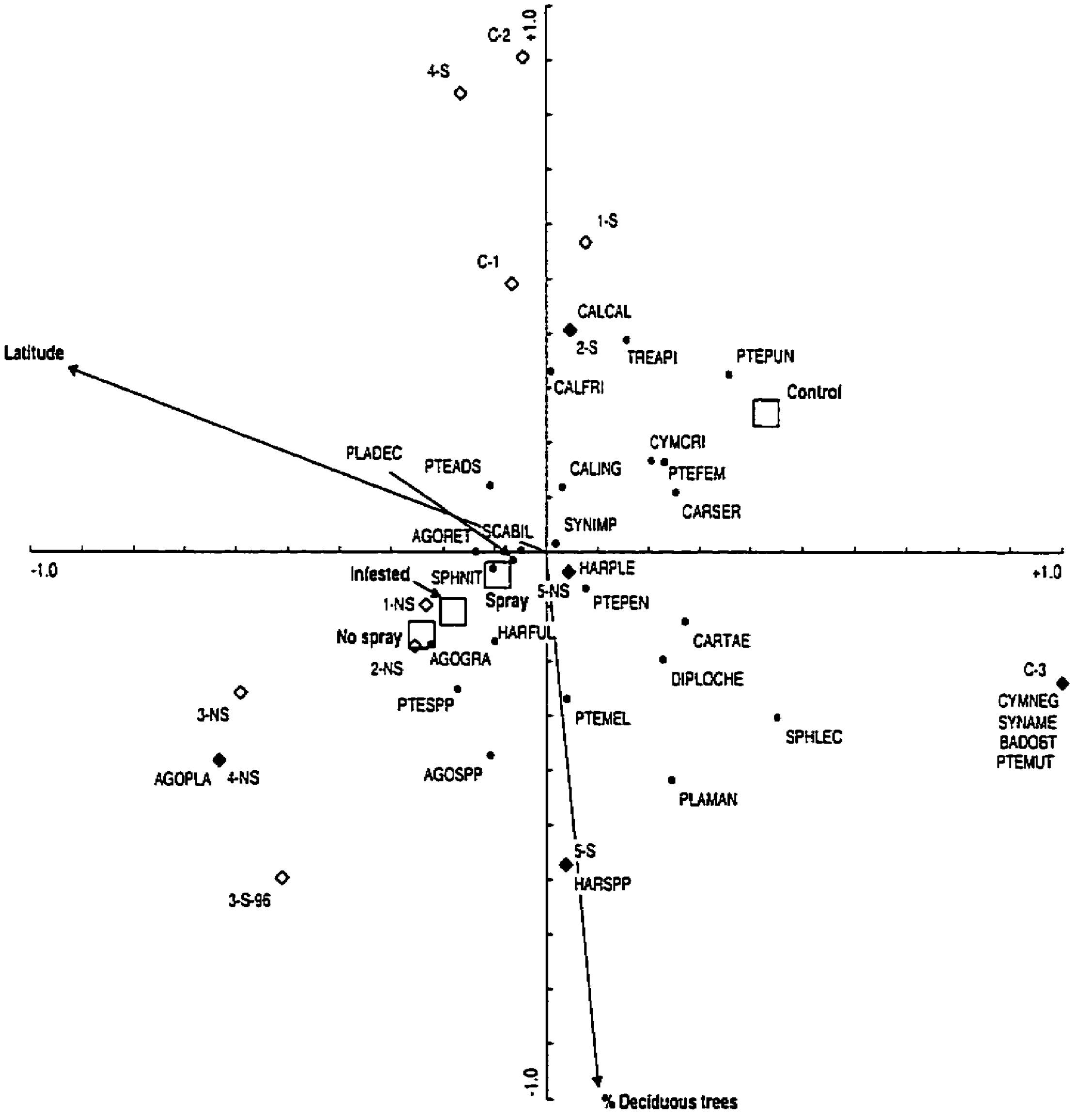

C-2
+1.0
4-S
1-S
C-1
CALCAL
2-S
TREAPI
PTEPUN
Latitude
CALFRI
Control
CYMCRI
PLADEC
PTEADS
CALING
PTEFEM
CARSER
SYNIMP
AGORET
SCABIL
-1.0
+1.0
HARPLE
Infested
SPHNIT
5-NS
PTEPEN
1-NS
Spray
No spray
HARFUL
CARTAE
2-NS
AGOGRA
DIPLOCHE
C-3
3-NS
PTESPP
PTEMEL
CYMNEG
SYNAME
SPHLEC
BADOBT
PTEMUT
AGOPLA
4-NS
AGOSPP
PLAMAN
5-S
HARSPP
3-S-96
-1.0
% Deciduous trees

Figure 71: Carabid data for 1996. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The second axis (horizontal) has an eigenvalue of 0.095=12.1%, and the third axis (vertical) has an eigenvalue of 0.061=7.9%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

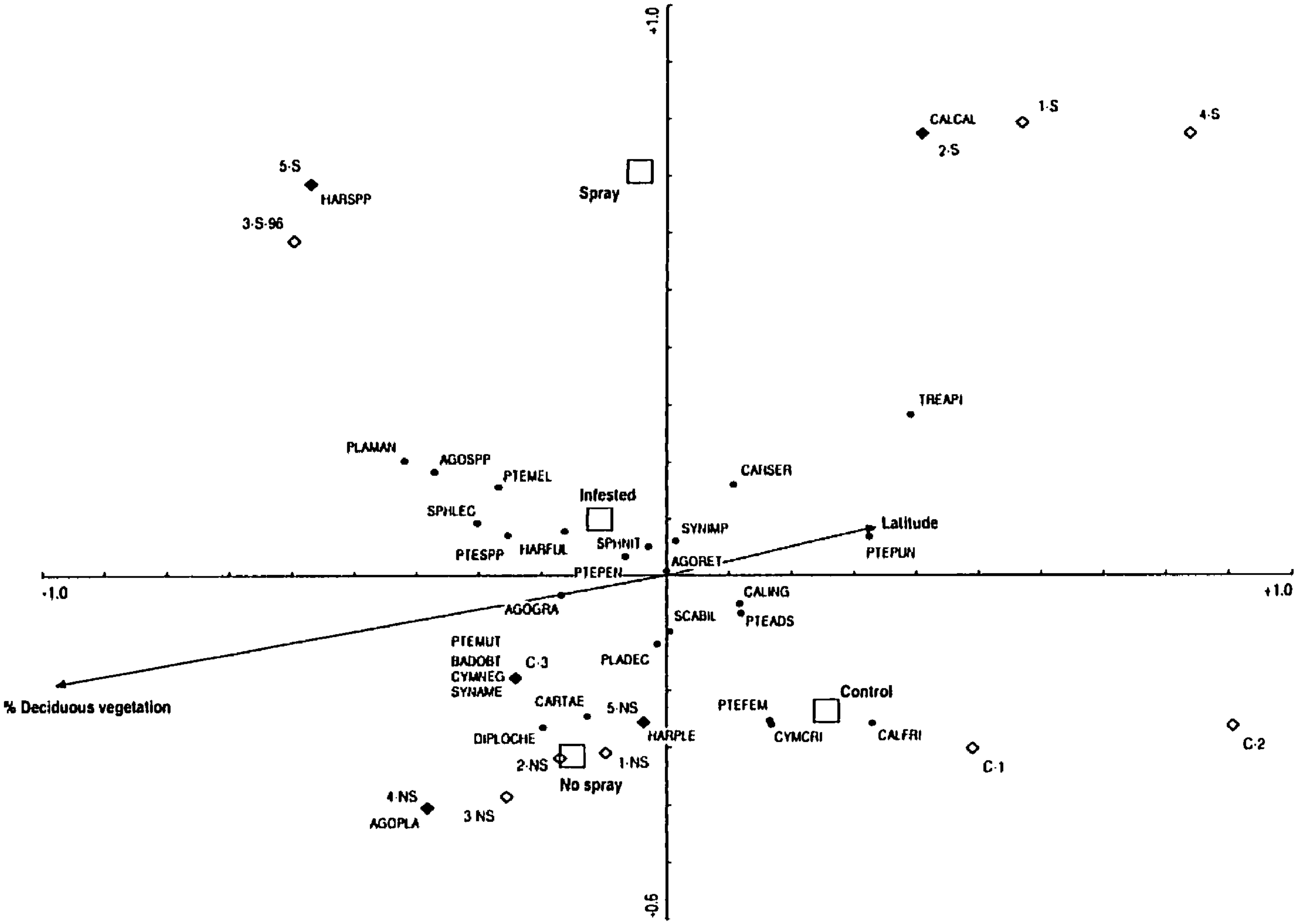

+1.0
-0.6
-1.0
+1.0
1·S
4·S
CALCAL
2·S
5·S
HARSPP
3·S·96
Spray
TREAPI
PLAMAN
AGOSPP
PTEMEL
CARSER
Infested
SPHLEC
SYNIMP
Latitude
PTESPP
HARFUL
SPHNIT
PTEPUN
AGORET
PTEPEN
CALING
AGOGRA
SCABIL
PTEADS
PTEMUT
BADOBT
C·3
PLADEC
CYMNEG
SYNAME
% Deciduous vegetation
Control
CARTAE
5·NS
PTEFEM
HARPLE
CYMCRI
CALFRI
C·2
DIPLOCHE
C·1
2·NS
1·NS
No spray
4·NS
3 NS
AGOPLA

Figure 72: Carabid data for 1996 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.146=20.5%, and the second axis (vertical) has an eigenvalue of 0.105=14.8%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*

PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

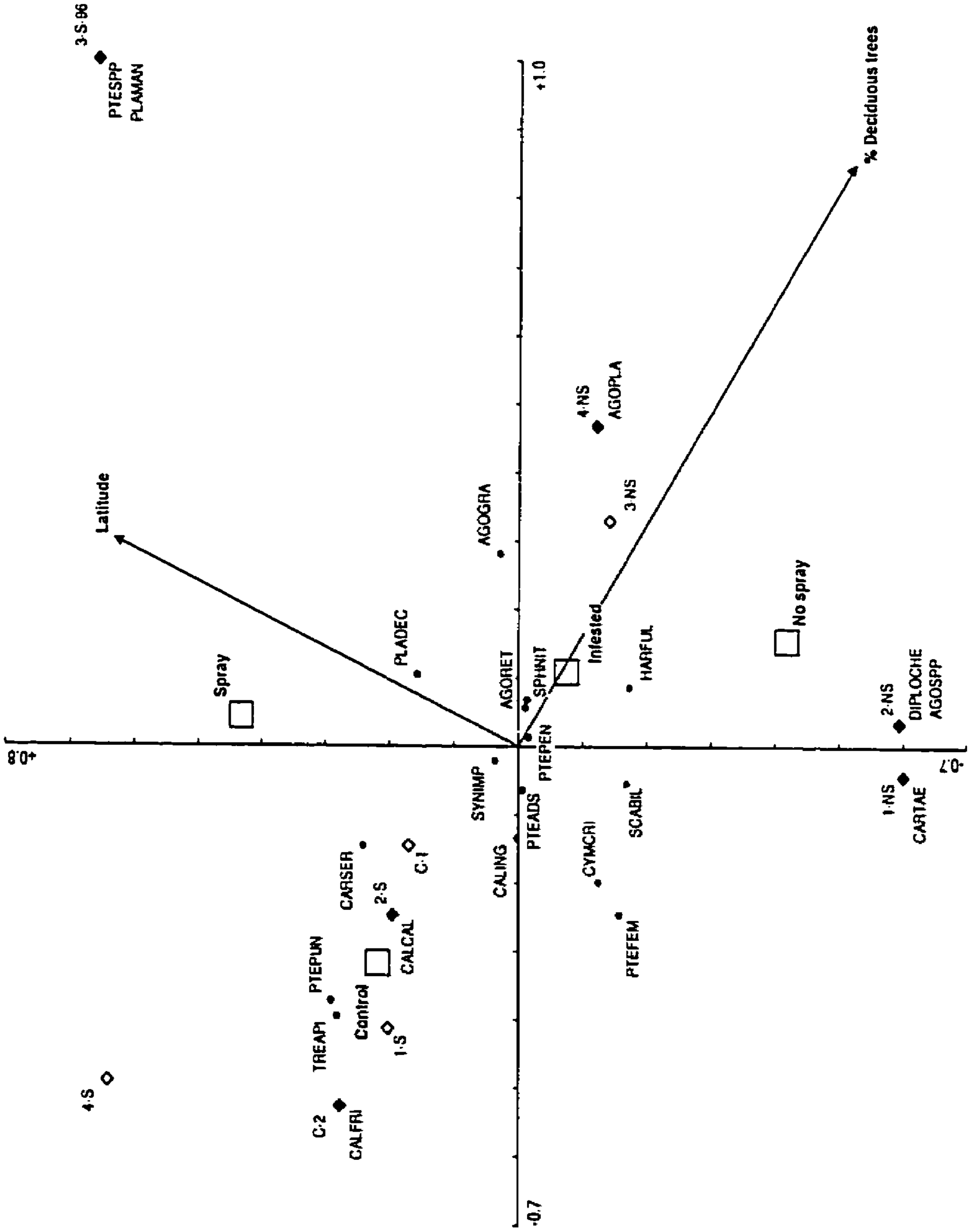

3-S-96
PTESPP
PLAMAN
+1.0
% Deciduous trees
Latitude
4-NS
AGOPLA
AGOGRA
3-NS
No spray
Infested
PLADEC
Spray
AGORET
SPHNIT
HARFUL
2-NS
DIPLOCHE
AGOSPP
+0.8
-0.7
PTEPEN
SYNIMP
PTEADS
1-NS
CARTAE
SCABIL
CYMCRI
CALING
CARSER
C-1
2-S
PTEPUN
CALCAL
Control
TREAPI
1-S
PTEFEM
4-S
C-2
CALFRI
-0.7

Figure 73: Carabid data for 1996 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The second axis (horizontal) has an eigenvalue of 0.105=14.8%, and the third axis (vertical) has an eigenvalue of 0.083=11.6%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

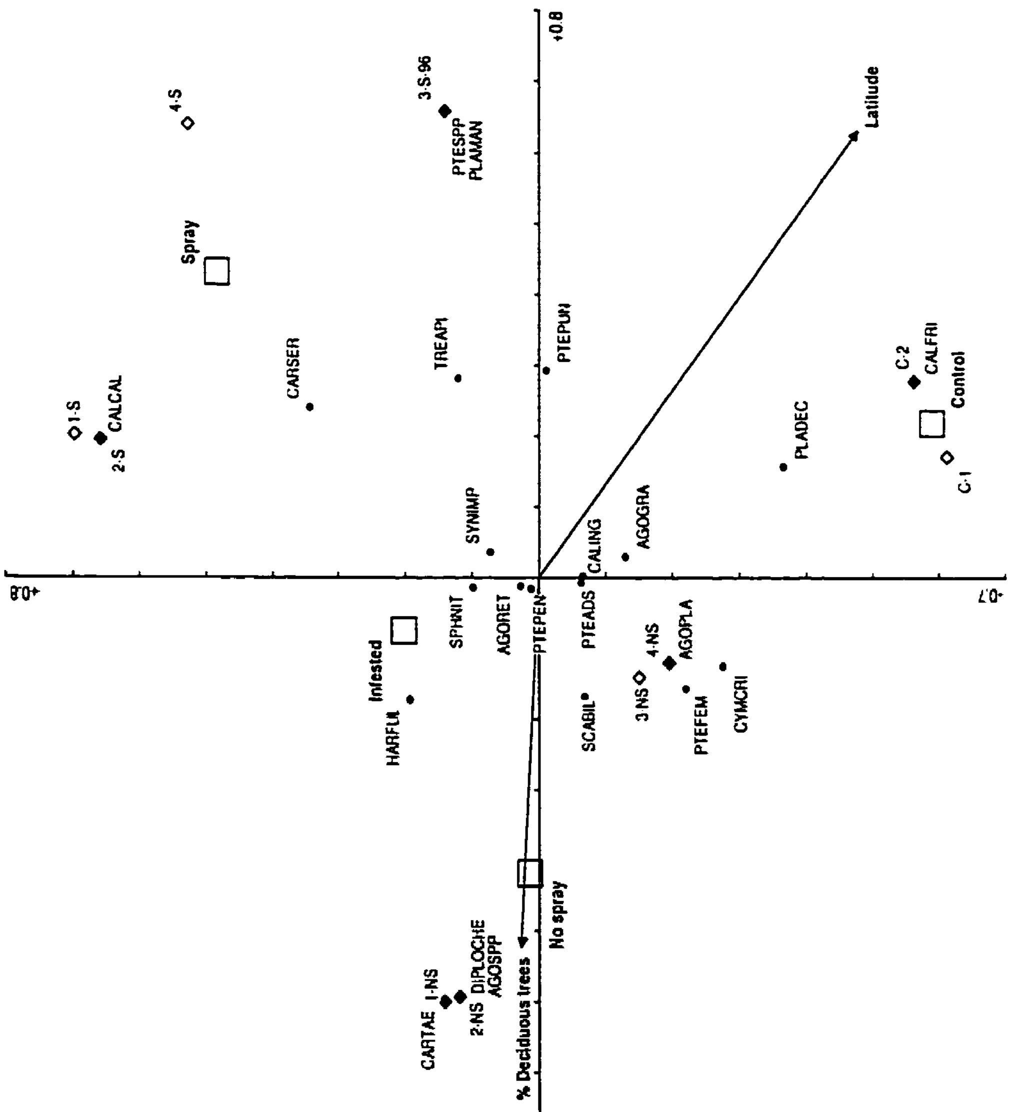

+0.8
-0.8
+0.8
-0.7
Latitude
% Deciduous trees
Spray
No spray
Infested
Control
4-S
3-S-96
1-S
2-S
C-1
C-2
1-NS
2-NS
3-NS
4-NS
PTESPP
PLAMAN
CARSER
TREAPI
PTEPUN
CALCAL
CALFRI
PLADEC
SYNIMP
AGOGRA
CALING
SPHNIT
AGORET
PTEPEN
PTEADS
AGOPLA
HARFUL
SCABIL
PTEFEM
CYMCRI
CARTAE
DIPLOCHE
AGOSPP

Figure 74: Carabid data for 1997. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.127=20.9%, and the second axis (vertical) has an eigenvalue of 0.065=10.6%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

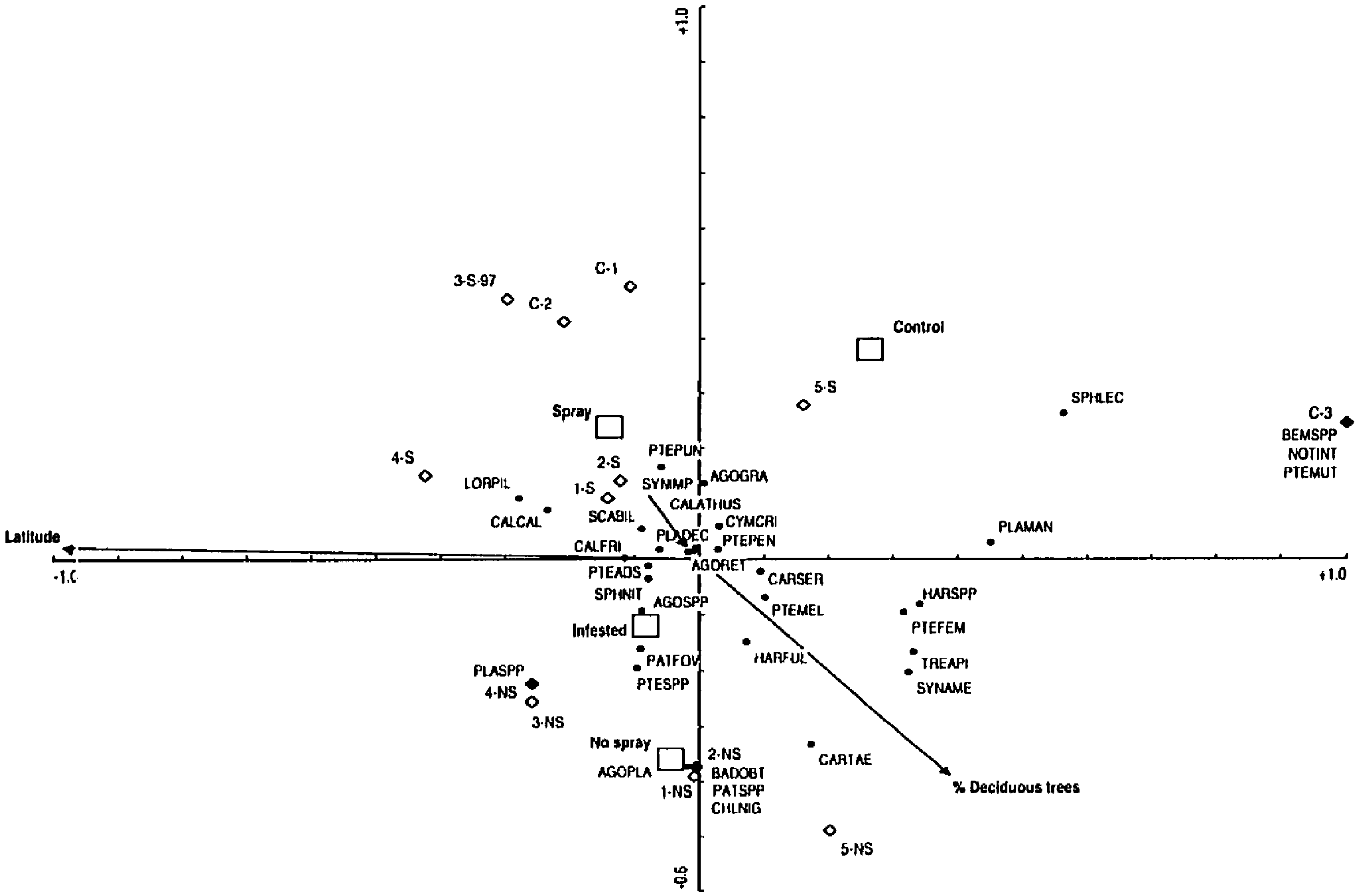

+1.0
-0.5
-1.0
+1.0
Latitude
% Deciduous trees
Control
Spray
Infested
No spray
C-1
3-S-97
C-2
5-S
4-S
2-S
1-S
C-3
BEMSPP
NOTINT
PTEMUT
SPHLEC
PLAMAN
PTEPUN
AGOGRA
SYMMP
CALATHUS
LORPIL
CALCAL
SCABIL
CYMCRI
PLADEC
PTEPEN
CALFRI
AGORET
PTEADS
CARSER
SPHNIT
AGOSPP
PTEMEL
HARSPP
PTEFEM
PATFOV
HARFUL
TREAPI
PTESPP
SYNAME
PLASPP
4-NS
3-NS
2-NS
BADOBT
PATSPP
CHLNIG
AGOPLA
1-NS
CARTAE
5-NS

Figure 75: Carabid data for 1997 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◇), species scores (●), continuous environmental variables (→), and nominal environmental variables (□). The first axis (horizontal) has an eigenvalue of 0.112=23.2%, and the second axis (vertical) has an eigenvalue of 0.063=13.1%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*
PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

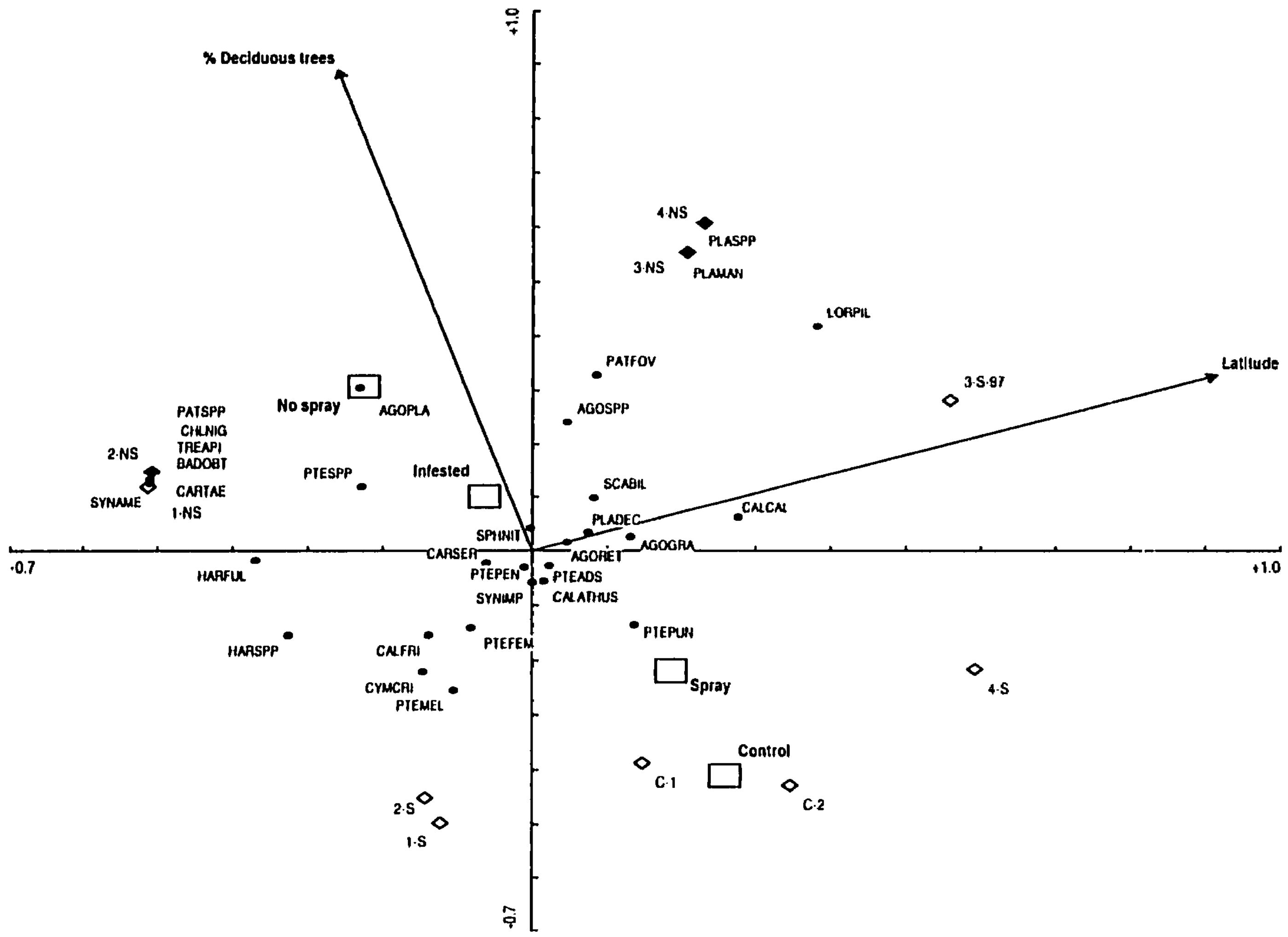

% Deciduous trees
Latitude
+1.0
-0.7
+1.0
-0.7
4-NS
PLASPP
3-NS
PLAMAN
LORPIL
PATFOV
3-S-97
AGOSPP
No spray
AGOPLA
PATSPP
CHLNIG
TREAPI
BADOBT
CARTAE
2-NS
SYNAME
1-NS
PTESPP
Infested
SCABIL
CALCAL
PLADEC
AGOGRA
SPHNIT
CARSER
AGORET
PTEPEN
PTEADS
SYNIMP
CALATHUS
HARFUL
PTEPUN
HARSPP
CALFRI
PTEFEM
CYMCRI
PTEMEL
Spray
4-S
Control
C-1
C-2
2-S
1-S

Figure 76: Carabid data for 1997 with the Whiteshell sites excluded from the analysis. Canonical correspondence analysis (CCA) ordination diagram with site scores (◊), species scores (●), continuous environmental variables (➔), and nominal environmental variables (□). The second axis (horizontal) has an eigenvalue of 0.063=13.1%, and the third axis (vertical) has an eigenvalue of 0.026=5.3%.

AGOGRA= *Agonum gratiosum*
AGORET= *Agonum retractum*
AGOPLA= *Agonum placidum*
AGOSPP= *Agonum* sp.
BADOBT= *Badister obtusus*
BEMSPP= *Bembidion* sp.
CALING= *Calathus ingratus*
CALCAL= *Calosoma calidum*
CALFRI= *Calosoma frigidum*
CARSER= *Carabus serratus*
CARTAE= *Carabus taedatus agassii*
CYMCRI= *Cymindis cribricollis*
CYMNEG= *Cymindis neglecta*
DIPLOCHE= *Diplocheila* sp.
HARFUL= *Harpalus fulvilabris*
HARPLE= *Harpalus pleuriticus*
HARSPP= *Harpalus* sp.
LORPIL= *Loricera pilicornis*
NOTINT= *Notiophilus intermedius*

PATFOV= *Patrobus foveocollis*
PATSPP= *Patrobus* sp.
PLADEC= *Platynus decentis*
PLAMAN= *Platynus mannerheimii*
PLASPP= *Platynus* sp.
PTEADS= *Pterostichus adstrictus*
PTEFEM= *Pterostichus femoralis*
PTEMEL= *Pterostichus melanarius*
PTEPEN= *Pterostichus pensylvanicus*
PTEPUN= *Pterostichus punctatissmus*
PTESPP= *Pterostichus* sp.
SCABIL= *Scaphinotus bilobus*
SPHNIT= *Sphaeroderus nitidicollis brevoorti*
SPHLEC= *Sphaeroderus stenosmus lecontei*
SYNAME= *Syntomus americanus*
SYNIMP= *Synuchus impunctatus*
TREAPI= *Trechus apicalis*

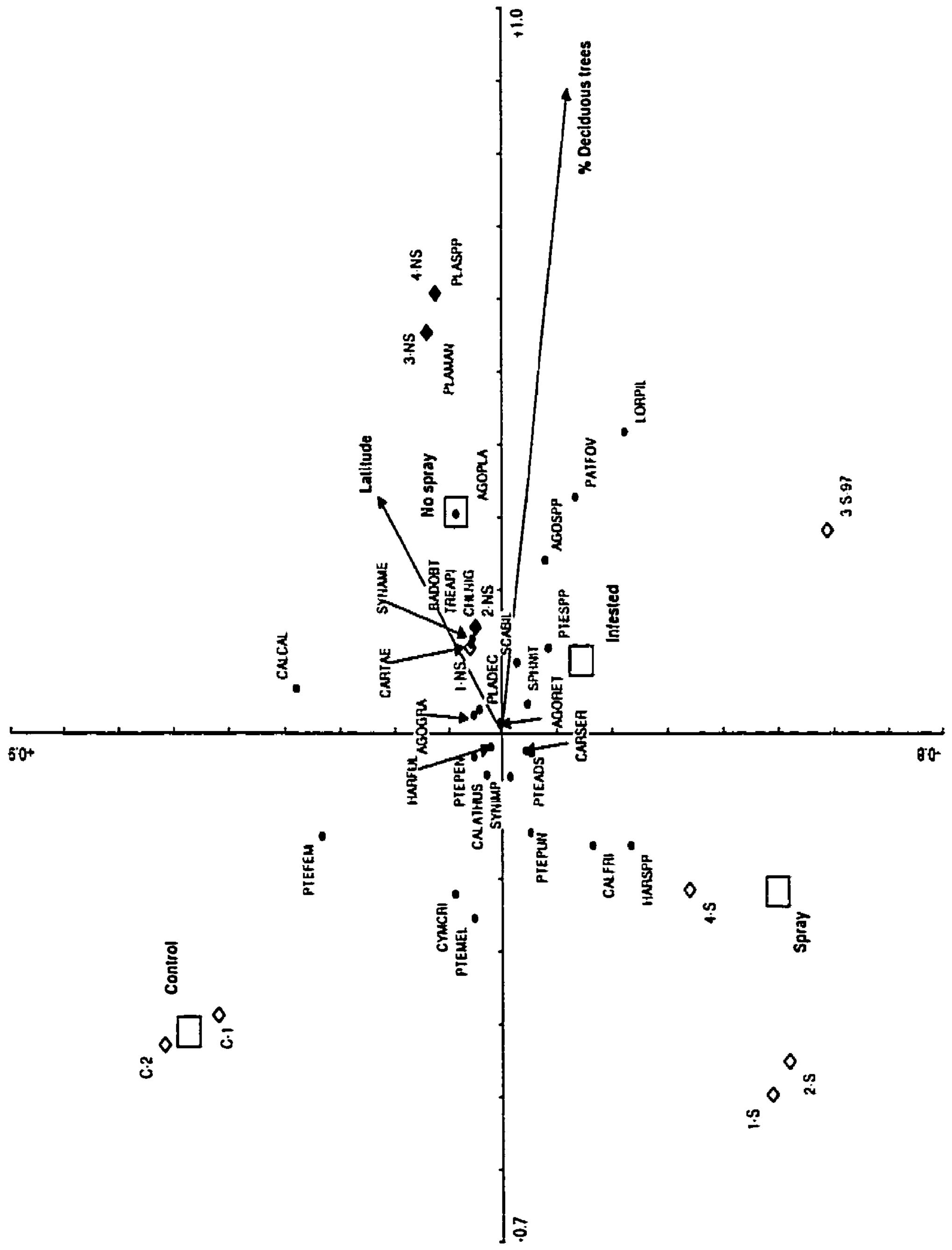

+1.0
-0.7
+0.5
-0.8
% Deciduous trees
Latitude
No spray
Infested
Control
Spray
4-NS
PLASPP
3-NS
PLAMAN
LORPIL
PATFOV
AGOPLA
AGOSPP
3 S 97
SYNAME
BADOBT
TREAPI
CHLNIG
2-NS
SCABIL
PTESPP
CALCAL
CARTAE
1-NS
PLADEC
SPHNIT
AGORET
AGOGRA
CARSER
HARFUL
PTEPEN
CALATHUS
SYNIMP
PTEADS
PTEFEM
PTEPUN
CALFRI
HARSPP
4-S
CYMCRI
PTEMEL
C-2
C-1
1-S
2-S

Figure 77: A photograph of a typical sprayed site. Note the large coniferous trees and absence of significant deciduous understory vegetation.

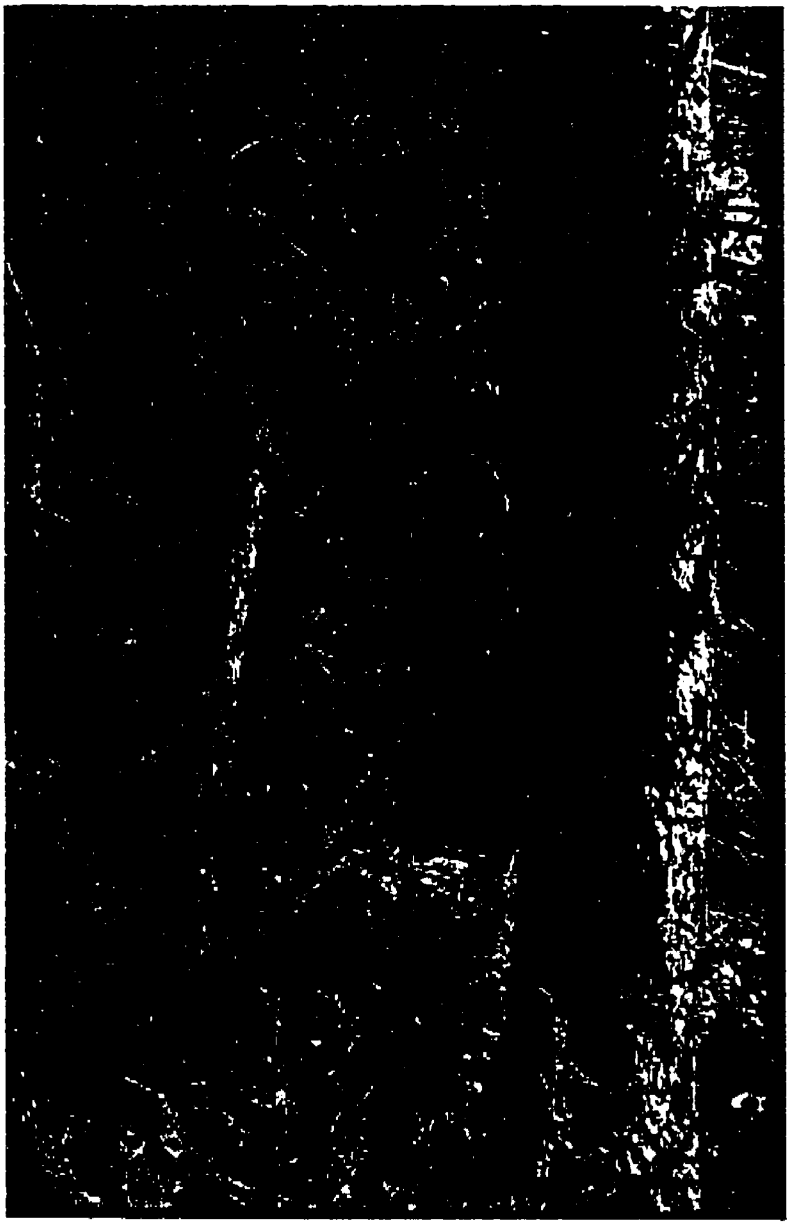


Figure 78: A photograph of a typical unsprayed site. Note the significant deciduous vegetation.

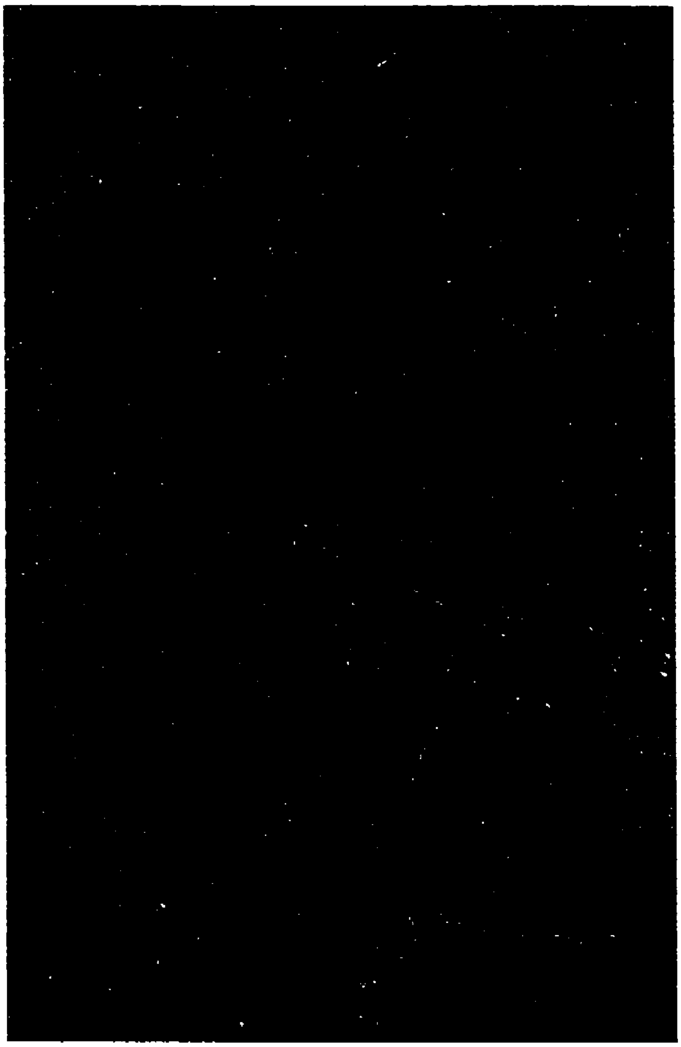


Figure 79: The proportion (Mean ± SEM) of coniferous tree stems in 500 m^2 in all site types.

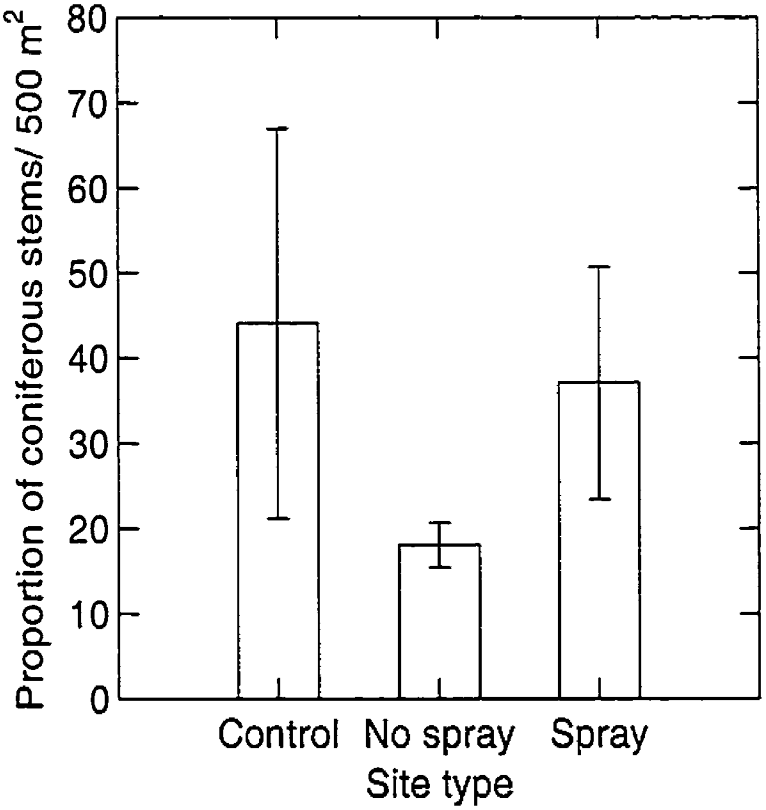
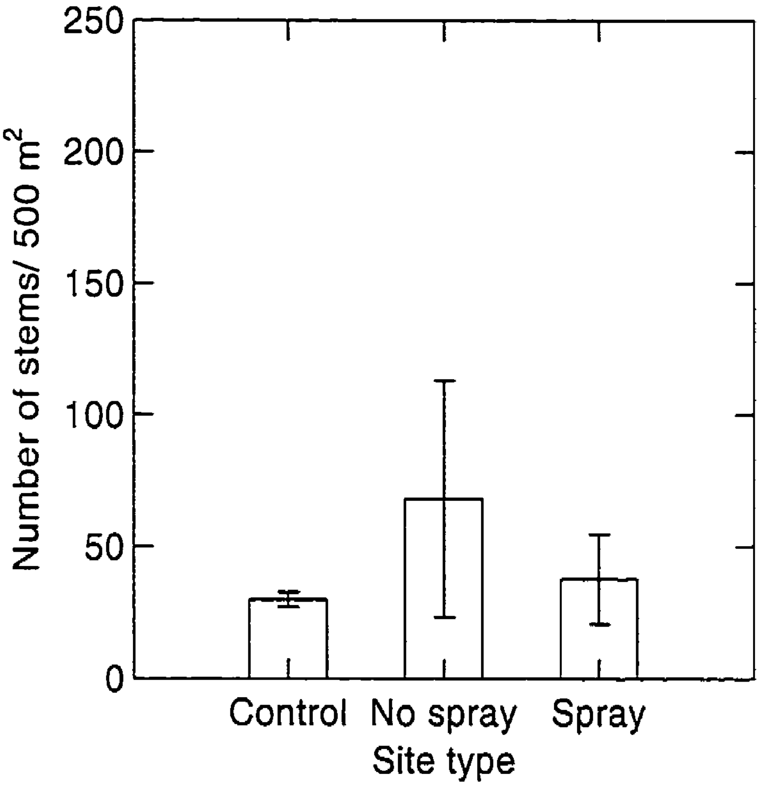

Proportion of coniferous stems/ 500 m^2
80
70
60
50
40
30
20
10
0
Control
No spray
Spray
Site type

Figure 80: The number (Mean ± SEM) of *Populus tremuloides* and *Betula papyrifera* stems in 500 m^2 in all site types.


250
200
150
100
50
0
Number of stems/ 500 m^2
Control
No spray
Spray
Site type

DISCUSSION

The discussion has five main components. Firstly the sampling methodology had implications for the interpretation of the results of this study and these implications are discussed. Secondly, once methodological issues have been resolved, the main body of discussion is presented, in which the mechanisms and implications of the results are considered. The third section is a brief synthesis of the results, and the fourth section is a brief listing of conclusions arising from the results of this study. Finally, I have presented recommendations for forest ecologists and forest managers.

Implications of methodology

Light trapping is a successful method for collecting large numbers of individuals and species of night-flying moths (Muirhead-Thomson 1991). Light traps generate biassed samples, the amount of any species caught depends on abundance and the degree of attraction to light (Kempton and Taylor 1974, Muirhead-Thomson 1991). The efficiency of a light trap is affected by the period of illumination, temperature, wind velocity and wind direction (McGeachie 1989). Light traps catches of moths have higher species richness and numbers of moths than Malaise trap samples in forest habitats (Butler *et al.* 1999).

There are many factors that can influence moth catches by light traps including moon phase, ambient temperature, local vegetation structure and position of the trap (Muirhead-Thomson 1991, Butler *et al.* 1999). Light trap catches of moths are usually lowest when the moon is full and there is no cloud cover (Muirhead-Thomson 1991, Butler *et al.* 1999). Noctuid moths appear to be unaffected by moon phase, but they are less frequently trapped on cool nights (Hardwick 1972). Butler *et al.* (1999) found lower moth numbers in light trap catches from a cool, wet year compared to a warm dry year. Light traps in wooded areas will tend to catch only local fauna (Muirhead-Thomson 1991). The height of the trap may play a role in the species composition (Taylor and French 1974, Elliott 1997). In this study, the light traps were placed approximately 2 m from the ground. Weakly flying species may not have been able to reach the traps. There will be variations in number and composition of the moths collected in light traps from site to site and year to year. However, there is no reason to believe that these effects are influenced by site type, and so light trap catches are a useful method to make comparisons of moth species richness and numbers caught between site types.

Pitfall traps are a common method used for the collection of ground dwelling insects, especially carabid beetles (Southwood 1978). Pitfall traps are a passive sampling technique, and are dependant on the activity of the beetles (Southwood 1978). Preservative is necessary when the traps are to be emptied at extended intervals. Propylene glycol was mixed with water in a 50:50 ratio and placed in each trap. This acted as a killing agent, and a preservative for the carabids and other insects. This preservative is sweet smelling, and may attract mammals to the traps. On occasion, traps were pulled out of the ground by large and small mammals. These animals are presumably attracted to the sweet smelling liquid, or may be eating the large number of invertebrates present in the pitfall trap. Many researchers use a salt water mixture as preservative, and this does not seem to attract mammals to the traps (R. E. Roughley pers. com). However, salt water traps must be emptied at more frequent intervals. In this study, salt water was not feasible, because the traps had to be emptied at two week intervals, and the propylene glycol was necessary to preserve the insects over this time period. Because the pitfall traps were emptied at two week intervals, large numbers of invertebrates and some small vertebrates were be caught in the traps. Often a single trap would collect large masses of carrion beetles (Silphidae) during one sampling interval. These silphids were predominantly one species, *Nicrophorus defodiens* Mannerheim (D. Wytrykush pers.com). Most silphid beetles are necrophagous as adults and larvae (Anderson and Peck 1985), and *N. defodiens* may have been attracted to the decaying matter in the traps. It is difficult to know whether these large masses of silphid beetles had any impact on the carabid beetle catch.

The two week sampling interval imposed by the number and separation of sites also had implications for the trapping of moths. A considerable proportion of the moths collected (19%) were not identifiable. This proportion might have been lower if traps had been emptied more frequently. During the two week sampling intervals large numbers of moths were caught in the light traps, as well as many other insect species especially certain beetles (Coleoptera), and caddisflies (Trichoptera). When large amounts of insect material accumulated in the light trap, the Vapona® may have been less effective at killing the insects. When recently caught insects move around a trap, the wings, antennae, legs, and especially scales of the moths are knocked off or destroyed, and as a result some of the moths become impossible to identify. Also, during the two week periods, there was decay of trapped insects as there was no preservative in the light traps. These decaying insects produced a strong smell, especially in light traps with large numbers of caddis flies. Often, carrion beetles (Silphidae) would be found in these traps feeding on parts of the dead moths, again making some specimens difficult, or impossible to identify. On a few occasions tree frogs entered traps and damaged the moths. Although not logistically possible for this study, emptying traps at shorter intervals may have helped to prevent large numbers of specimens becoming difficult or impossible to identify. Nevertheless, there is no reason to believe that problems in identifying moths would be more severe in one site type than another, and so comparisons among site types are not likely to be influenced by them.

Approximately 74 % of the total carabids collected during this study were collected during the 1997 field season. The 1997 field season began a few weeks earlier than the 1996 field season. Several species were collected in 1997 that were absent during the 1996 field season including: *Chlaenius niger*, *Loricera pilicornis* Fabricus, *Notiophilus intermedius*, and *Patrobus foveocollis* Eschscholtz. These species do not account for the huge increase in the number of carabids collected, because they only represent 10 individuals.

Many of the common carabid species became much more abundant during the 1997 field season. Part of this increase might be attributed to the earlier start to the sampling season in 1997. More individuals were collected when sampling began earlier. For example, in 1996, 71 individuals of *Platynus decentis* were collected. During the 1997 field season, this number increased to 879 individuals. If we consider one site as an example, site 3-NS, the increased catch of this species can be attributed to the earlier sampling schedule. In 1996, the pitfall traps were first emptied on 26 July. During this sampling year, one individual of *P. decentis* was collected on 9 August. In 1997, the pitfall traps were emptied beginning on 2 June, almost one month earlier than in 1996. Although *P. decentis* was collected at this site throughout the 1997 sampling season, almost 99 % of the 1997 total for this species, was collected before the sampling would have started in 1996.

Another example of increased catch related to the timing of sampling is *Agonum retractum*. In 1996, a total of 597 individuals of this species was collected. In 1997, 1536 individuals were collected. In site C-3 in 1996, the pitfall traps were initially emptied on 18 July and 11 individuals of the 16 collected for 1996 were collected on this date. In 1997, 83 individuals of *A. retractum*, representing more than 85 % of the 1997 total, were collected before the date sampling began in 1996.

Although part of the increase in the number of carabids collected in 1997 can be attributed to the sampling schedule, a comparison of the common sampling dates in both years shows that some species increased in number during the 1997 field season (Appendix VI). There are a number of biotic and abiotic factors that affect the distribution and abundance of carabid beetles. Carabid beetles are affected by microclimatic factors including temperature, humidity and light and moisture levels (Thiele 1977). *Pterostichus pensylvanicus* has lower egg mortality in years with a wet spring (Goulet 1974). Based upon field observations, the spring of 1997 was wetter than 1996. It is possible that reduced egg mortality as a result of spring moisture levels contributed to the increased catch of *P. pensylvanicus* in 1997. Carabid movements are also determined by the structural nature of their substrate (Thiele 1977). Carabid beetles are also affected by prey availability, and predation by other animals (Thiele 1977, Guillemain *et al.* 1997). Any of these interacting factors may have influenced carabid catches in 1997. Without detailed investigations of these factors and the biological requirements of carabid species, it is difficult to determine why carabid catches increased in 1997. The increased carabid catch in 1997 had the potential to affect the measure of diversity, but in fact did not do so to a large extent. The different lengths of sampling period in 1996 and 1997 do not affect the within-year assessments of the effects of budworm management, and the analyses focus on within-year comparisons.

Effects of treatments on community ecology

To assist the reader in comprehension of the discussion, the large number of results presented in the body of the thesis are summarized in two tables. The summary measures of the assemblages are presented in Table 5, and Table 6 summarizes the outcome of ordination analyses. For more detail than is presented in these two tables, the reader should consult the relevant sections of the thesis.

Vegetation characteristics and spruce budworm management.

Spruce budworm and its management influence the vegetation structure of the forest. On average, control sites had the highest proportion of coniferous tree vegetation (Table 2, Fig. 79, Appendix I). The control sites had no recent history of budworm outbreak and so spruce budworm defoliation had not caused the mortality of white spruce and balsam fir seen in infested sites. During sampling, moderate, but not outbreak numbers of spruce budworm were observed in the control sites C-1 and C-2. This indicates that these sites are suitable for budworm attack, and so were appropriate controls for this study.

Sprayed sites had on average a higher proportion of coniferous tree vegetation than unsprayed sites (Table 2, Fig. 79, Appendix I). This is because the spruce and fir foliage was protected from budworm attack by applications of insecticide. Sprayed sites did not have as much coniferous tree vegetation as the uninfested control sites because some tree death was caused by budworm defoliation in the infested sprayed sites. There was evidence of tree death in both sprayed and unsprayed sites, but tree death was more significant in sites that were not sprayed to protect the foliage. Typically, sprayed sites were dark, and had little deciduous understory (Fig. 77). On average unsprayed sites contained more deciduous tree stems than sprayed sites (Appendix I). Canonical correspondence analysis shows that the unsprayed sites are often associated with an increased proportion of deciduous tree vegetation. Typically, the unsprayed sites were more open and bright compared to sprayed sites (Fig. 78). This is because the canopy was opened when the spruce budworm outbreak led to white spruce and balsam fir mortality. This opening of the canopy allowed for a proliferation of deciduous species such as: *Corylus cornuta*, *Acer spicatum*, and *Betula papyrifera* (Fig 78). Correspondence analysis of the tree vegetation places the unsprayed sites near to these species on the ordination diagram (Fig. 17).

Spray application also influenced the species composition of the coniferous trees in infested sites. In this study, many sprayed sites had higher stem numbers of *P. glauca* than unsprayed sites (Appendix I). The insecticide application may have prevented white spruce mortality. However, some authors have suggested that by protecting the foliage of white spruce through insecticide application, the forest becomes more susceptible to budworm attack (Hardy *et al.* 1983). Balsam fir is able to regenerate under a white spruce canopy, whereas white spruce is unable to regenerate under its own canopy (Larsen 1980). Hence, preventing budworm defoliation by protecting the white spruce canopy may promote the regrowth of *Abies balsamea*. Budworm's preferred host is balsam fir, and stands with increased levels of balsam fir may promote budworm attack. Therefore, the spray applications may ultimately make the forest more vulnerable to future budworm attack. Hardy *et al.* (1983) suggested that applying insecticide to forest stands threatened by spruce budworm may be wasteful because in many instances, the budworm outbreak would collapse naturally before significant damage is caused.

Relationships between spruce budworm management and insect species composition

Moths

The three most common moth species were found in all three site types during both years of the study. More than 70% of the species collected belonged to two families: Noctuidae, and Geometridae. The largest number of species belonged to the Noctuidae, which is the largest family of Lepidoptera with more than 2900 species in North America (Covell 1984). Larvae of noctuid moths have a wide variety of feeding habits. Some are monophagous herbivores, and others are polyphagous herbivores, some feed on fungi, lichens, and dead leaves; others bore into roots, fruits, or stems, and others are leaf miners or leaf rollers (Covell 1984). In some species, larvae feed on other caterpillars or scale insects as well as feeding on leaves (Covell 1984). This wide range of feeding habits allows the noctuid moths to occupy many niches in the boreal forest.

One of the most common noctuid moths in all sites was *Enargia decolor* (Table 3). Although common in all site types, there were more than twice as many *E. decolor* collected in unsprayed sites than in sprayed sites. In all site pairs except for sites 5-S and 5-NS in the Whiteshell, there were more *E. decolor* collected in unsprayed sites than sprayed sites (Table 3). In the 1996 Correspondence analysis of the moth species with the Whiteshell sites excluded, *Enargia decolor* is closely associated with unsprayed sites (Fig.47). This species feeds on birch, *Betula* spp. and poplar, *Populus tremuloides* (Tietz 1972), which are common trees throughout the study area. *Enargia decolor* was more often collected in the unsprayed sites, and on average, these sites had greater numbers of birch and poplar tree stems together (Fig. 80). In the Whiteshell site pair, the sprayed site had more poplar and birch trees (Appendix I) than the unsprayed site, and also higher numbers of *E. decolor* (Table 3, Appendix IV). It appears that the distribution of this species may be highly dependant on its larval food source.

Moths that were most abundant in unsprayed sites include three species of geometrid moths: *Campaea perlata*, *Lambdina fiscellaria*, and *Nematocampa limbata* (Table 3). In the ordination diagrams that exclude the Whiteshell sites, all three species are placed near the unsprayed sites (Figs. 49, 51, 52). Both *C. perlata* and *L. fiscellaria* are generalist feeders on both deciduous and coniferous trees including alder, fir, spruce, birch, maple and oak. Species in which individuals feed on more than one host of deciduous and coniferous vegetation as hosts are referred to as "mixed" species feeders (Hammond and Miller 1998). There were more of these mixed species feeders in unsprayed sites compared to sprayed and control sites. Unsprayed sites had the highest tree diversity of all three site types, and tree diversity was highest for the unsprayed sites in each site pair (when the Whiteshell sites are excluded). The moth data for both sampling seasons shows that although *C. perlata* and *L. fiscellaria* were more abundant in unsprayed sites, they had low total catch in the Whiteshell sites.

Nematocampa limbata is a generalist feeder (but not a mixed feeder) on many species of plants including birch, hazelnut, oak, rose, strawberry, *Prunus*, *Ribes*, raspberry, maples and many other low plants and trees (Tietz 1972, Covell 1984). It was also abundant in all unsprayed sites except for the Whiteshell sites. Again, this species is placed near the unsprayed sites in ordination diagrams that have excluded the Whiteshell sites (Figs. 49, 51, 52). Thus, there appears to be a pattern for these three species that are generalist feeders: they are more abundant in sites with high diversity of trees and ground vegetation, as was observed in unsprayed sites.

There were no species that were particularly abundant only in sprayed sites, except for the spruce budworm, *Choristoneura fumiferana* (Appendix IV). This species was collected only in 1996, and was more abundant in sprayed sites. It was especially abundant in site 3-S-96 where 26 individuals were collected during 1996. Although *C. fumiferana* feeds on both white spruce and balsam fir, this site did not have significantly higher levels of these coniferous trees than the other sites. These moths could have been migrants from another area, rather than adults that emerged in the site. Dispersal of budworm is an important phenomenon that can result in the initiation of new outbreaks (Greenbank *et al.* 1980). The foliage in this area had been protected from budworm attack in the past, but insecticide has not been applied since 1990. The presence of budworm in this site may indicate the potential for a budworm outbreak in this area. Perhaps five years without foliage protection had allowed the budworm population levels to increase in this site. It is impossible to be sure what could have been happening with the budworm population in this site, because it was logged during the winter of 1996-1997 and was only suitable to be sampled during 1996.

The uninfested control sites were dominated by several moth species including *Itame occiduaria*, and *Caripeta divisata*. *Itame occiduaria* feeds on a variety of species including *Amelanchier alnifolia*, *Salix* spp., *Ribes* spp. and *Arctostaphylos* spp. (McGuffin 1972, Tietz 1972). These plants were found in various sites, however, *Salix* was more abundant in the control sites than in the other sites. It appears that *I. occiduaria* is a generalist species, and not highly dependant on one particular larval food source. *Caripeta divisata* was most abundant in uninfested control sites. This species feeds on several species of coniferous trees including: *Abies balsamea*, *Picea glauca*, and *Larix laricina* (Tietz 1972, Covell 1984). The control sites had the highest proportion of coniferous trees of all site types. *Larix laricina* was found only in two of the control sites: C-1 and C-2. *Caripeta divisata* is a specialist species on coniferous trees, and appears to be dependant on its larval food source. The adult moths of *Caripeta divisata* are most abundant in sites where the larval food source; coniferous vegetation, is most abundant.

Carabid beetles

Carabid beetle species composition was similar in all site types for both sampling years. The most common species collected (Table 4) were common in all site types and are typical forest species (Lindroth 1966, Goulet 1974). For both sampling years, there were significantly more individuals of *Agonum retractum* and *Sphaeroderus nitidicollis brevoorti* collected in unsprayed sites compared to sprayed sites. *Agonum retractum* is a small, and usually flightless carabid beetle (Lindroth 1966). Lindroth (1966) describes *A. retractum* as a true forest insect, living in leaf debris under hardwood trees. Hammond (1997) collected *A. retractum* in poplar dominated forests. Niemalä *et al.* (1992) compared carabid assemblages in different forest types, and *Agonum retractum* was collected exclusively in deciduous forests. *Agonum retractum* was more associated with mixedwood stands than lodgepole pine forest (Spence *et al.* 1996). In this study, significantly more *A. retractum* were collected in unsprayed sites, and these sites also had more deciduous trees and shrubs (Appendix I, II).

There is little information about the ecology of *Sphaeroderus nitidicollis brevoorti*. Lindroth (1961) describes it as a true forest species that prefers moist places with moss and dead leaves under deciduous trees. Several authors have suggested that this species feeds on snails (Lindroth 1961, Larochelle 1972). Carabid abundance is associated with prey abundance: when prey is more abundant, carabid beetles become more abundant (Guillemain *et al.* 1997). The higher numbers of *Sphaeroderus nitidicollis brevoorti* in unsprayed sites could be related to the higher numbers of deciduous tree stems in unsprayed sites, and the resulting microhabitat differences.

The distribution of *Pterostichus melanarius* is of some interest. In 1996, a total of eight individuals was collected from sites 5-S and 5-NS. In 1997, one individual was collected in each of 1-NS and 2-S, C-2 and 14 individuals were collected in 5-S and 17 in site 5-NS. *P. melanarius* is a nonnative carabid that was introduced from Europe (Spence and Spence 1988). This species has become common in Manitoba only in the last 25 years, and was first noticed in urban and agricultural locations (Holliday pers.com). Lindroth (1966) suggests that this species prefers open dry fields, and light forests and disturbed land. Niemalä and Spence (1991) state that *P. melanarius* is flexible in its habitat use, and this has allowed it to successfully establish throughout Canada. This species may be invading new habitats, such as the white spruce-balsam fir forests that were used in this study. Spence and Spence (1988) found negative correlations between the numbers of nonnative and native carabid species, but in another study, there was no negative association between the presence of *Pterostichus melanarius* and abundant native carabid species (Niemalä and Spence 1991). There did not seem to be decreased catches of carabid species in sites with *Pterostichus melanarius* (Appendix V).

Factors affecting insect species diversity

Moths

Spruce budworm management had no significant effect on species diversity of moths in this study. The log series alpha for the moths ranged from 4.5 to 31.1. In general, these are high values for alpha, but are similar to the log series alpha calculated for forest moths in other studies (Thomas and Thomas 1994, Elliott 1997). This high level of moth diversity in forest sites can be related to vegetation composition.

Plant architecture is correlated with diversity of phytophagous insects (Lawton 1983). Sites that are diverse architecturally are expected to have more diverse insect faunas associated with them (Southwood *et al.* 1979, Lawton 1983). Architectural diversity consists of spatial diversity, which is the size and growth form of the vegetation, and architecture, which is the structural complexity of the vegetation (Lawton 1983). The size and structural complexity of the plants decline from trees, to woody shrub vegetation, to perennial herbs, to annuals, to monocots (Lawton 1983). This is also accompanied by a decrease in the species richness of herbivorous insects (Lawton 1983). The sites in this study, with large numbers of trees, an abundance of shrub vegetation, and a well developed herbaceous layer can be considered architecturally diverse. As a result, the phytophagous insects are expected to have a high level of diversity. This high diversity can also be related to the species diversity of the vegetation. Because these sites have a wide variety of different plant species, there is also a wide variety of food sources available for phytophagous insects. Moths have a high diversity in forest stands because the habitat heterogeneity created by the vegetational complexity creates more niche space for a wider variety of moths to inhabit.

Carabid beetles

Species diversity of the carabid beetles was not affected by spruce budworm management. Although there were more carabid beetles and more carabid species in unsprayed sites than sprayed sites, diversity was higher in sprayed sites in 1996 and there was no difference in 1997. This is because some carabid species were able to become very abundant in unsprayed sites. Two of these species, *A. retractum* and *S. nitidicollis* dominated the catch in unsprayed sites, and as a result, diversity did not increase in the unsprayed sites.

Some authors have suggested that carabid beetle alpha diversity is positively correlated to habitat heterogeneity (Holliday 1992, Niemalä *et al.* 1992). Butterfield (1997) studied carabid succession through the forestry cycle in northern England. Carabid abundance and diversity peaked at the stage in which the ground flora was most structurally diverse. This study also showed that prey abundance also affects carabid diversity. Diversity and abundance of carabids peaked when the densities of other soil surface macroinvertebrates were highest (Butterfield 1997). Guillemain *et al.* (1997) found that carabid abundance was partially controlled by prey abundance. They also found that as the amount of litter increased, so did the proportion of forest carabids (Guillemain *et al.* 1997). These studies may also explain why unsprayed sites have more species. The number of species may also be related to habitat heterogeneity and prey availability. When a habitat is structurally diverse, there will be more niche space for a wider variety of carabid species to occupy. The abundance and diversity of forest carabid beetles seems to be controlled by various factors including habitat heterogeneity, and prey abundance.

Synthesis

Despite the vegetation in the sites having quite different appearance in the different treatments, there were relatively few statistically significant differences in summary measures of the vegetation assemblages . The only major differences were that there were more tree species and lower shrub diversity in unsprayed sites and higher shrub diversity in sprayed sites. Both of these effects are probably symptomatic of the dense deciduous regrowth of trees that occurred in unsprayed sites, and which provides an environment unsuited for many species of shrubs.

Like those for vegetation, the summary statistics describing insects assemblages failed to respond strongly to treatments. The only significant treatment effects on moths was that more were caught in sprayed sites in 1996. The only consistent treatment effect for carabids was that *Agonum retractum* and *Sphaeroderus nitidicollis brevoorti* were more abundant in unsprayed sites, and there fore more carabids were caught in unsprayed sites. Since there were no additional numbers of species in unsprayed sites, this tended to lower carabid diversity in these sites.

Although the summary statistics do not show clear differences, species composition and relative abundance as reflected in the ordinations were more sensitive to the treatments. The ordinations show strong influences of control versus infested sites and sprayed versus unsprayed sites on the vegetation. Ordinations of the insect assemblages show that moths are sensitive to the treatments, but carabids have a weaker response and their patterns are difficult to discern. Although there was a response of *Agonum retractum* and *Sphaeroderus nitidicollis brevoorti*, the overall carabid assemblage is not distinctly affected by the treatment imposed.

The treatment responses of the insects appear to be the result of the insects responding to the environment created by the treatment effects on the vegetation. There are strong links between treatment, vegetation and moths, but much weaker links for carabids. Moth larvae are directly dependent upon specific plant species for food (Covell 1984), and phytophagous insect assemblages also respond to plant architecture (Southwood *et al.* 1979, Lawton 1983). In contrast, carabid beetles are primarily carnivorous, and their linkage to treatment-induced vegetation changes is probably mainly through the effects on microhabitat and microclimate within the litter habitat (Thiele 1977). Carabid distribution is strongly influenced by microclimate in their epigeic habitat (Thiele 1977) A second mechanism by which vegetation may affect carabids is through its influence on the availability of prey. In general, when prey is more abundant, carabids are more abundant. The lack of a direct trophic or architectural influence of living plants on the carabid assemblage probably accounts for its weaker relationship with vegetation than was evident for the phytophagous moths.

Conclusions

1) When spruce budworm attacks a forest, foliage protection measures produce a vegetation assemblage that differs in composition from that of unsprayed sites and from similar sites that were not attacked by budworm .

2) These differences in vegetation have a strong influence on the species composition patterns of moths.

3) Except for *Agonum retractum* and *Sphaeroderus nitidicollis brevoorti*, the carabid beetles have a weaker response to the differences in vegetation.

4) Treatments have few consistent effects on diversity measures of vegetation or insect assemblages. In particular, in the long-term time frame of this study, diversity was not reduced by the application of sprays foliage protection.

5) As evidenced by the differences in responses of the Whiteshell sites, local site conditions affect the forest response and so my results may only be applicable to forest types that are very similar to those in the Nopiming Provincial Park.

Recommendations

- The overall measurements of diversity, species number, and abundance are less responsive to management treatments than the ordinations of species composition data. Therefore, criteria for forest management decisions should include both diversity and species composition indicators.
- Local site conditions are important in determining the response of assemblages to management. Therefore, forest management decisions should relate to local site conditions. The boreal forest is not a homogeneous system, and responses in one area may not represent responses in other locations.
- Budworm defoliation produces a secondary successional habitat with a unique species assemblage. To conserve this assemblage it is important to allow budworm defoliation to continue in some areas of forest.

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Appendix I: The total number of tree stems in 500 m^2 in each site.

	1		2		3			4		5		CONTROL			
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3	SUM
Aceraceae															
Acer spicatum Lam.	0	41	17	25	93	161	215	215	2	105	3	0	0	0	877
Betulaceae															
Alnus sp.	0	0	61	0	0	0	0	0	0	0	31	103	0	148	343
Betula papyrifera Marsh.	16	5	132	7	45	4	10	0	34	8	39	9	14	6	329
Corylus cornuta Marsh.	93	0	87	0	4	0	153	9	0	181	43	0	0	19	589
Caprifoliaceae															
Viburnum rafinesquianum Schultes	0	0	0	0	2	0	12	0	0	0	0	0	0	0	14
Cornaceae															
Cornus stolonifera Michx.	0	0	0	0	6	0	4	0	0	0	1	0	0	0	11
Fagaceae															
Quercus macrocarpa Michx.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Oleaceae															
Fraxinus pennsylvanicus Marsh.	0	0	0	0	4	0	0	0	0	0	112	22	0	0	138

Appendix I: continued

	1		2		3			4		5		CONTROL			
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3	SUM
Pinaceae															
Picea glauca (Moench)Voss	9	15	7	8	15	5	17	11	49	4	24	22	24	22	232
Pinus banksiana Lamb.	1	0	9	0	0	0	1	2	0	0	0	0	0	2	15
Abies balsamea (L.)Mill.	25	67	73	37	22	15	19	15	102	88	6	128	111	3	711
Larix laricina (DuRoi)K.Koch	0	0	0	0	0	0	0	0	0	0	0	13	2	0	15
Rosaceae															
Amelanchier alnifolia Nutt.	5	0	0	0	0	1	1	0	2	0	0	0	0	0	9
Prunus virginiana L.	0	0	0	0	0	0	0	0	0	0	20	0	0	0	20
Salicaceae															
Populus tremuloides Michx.	7	4	88	6	24	17	19	15	11	6	71	17	17	27	329
Salix sp.	4	1	6	0	14	0	0	0	0	0	8	7	27	12	79
∑ Number of tree stems	160	133	480	83	229	203	451	267	200	392	359	321	195	239	3712

Appendix II: Average percent cover of shrub vegetation in 4 m^2 for shrub vegetation in all sites

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Aceraceae														
Acer spicatum Lam.	1.5	4.2	8.2	2.0	16.0	8.9	8.2	12.2	0	6.2	0	0	0	0
Apocynaceae														
Apocynum androsaemifolium L.	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
Betulaceae														
Alnus sp.	0	0	1.1	0	0	0.2	0.6	0.7	0	0	0	8.5	0	6.2
Betula papyrifera Marsh.	0	0.4	0.4	4.6	0	0	0.4	0.2	2.7	0.2	0	0	0	0
Corylus cornuta Marsh.	31.7	0	5.7	0.5	4.5	3.0	19.3	0	0	11.9	0.5	3.2	1.9	2.2
Caprifoliaceae														
Diervilla lonicera Mill.	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0
Lonicera dioca L.	0.2	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Symphoricarpos alba (L.) Blake	0	0	0	0	0	0	0.2	0.2	0	0	2.0	0.4	0	0
Viburnum edule (Michx.) Raf.	0	0.5	0	0	0	0	0	0	0.3	0	0	0.2	0	0
Viburnum rafinesquianum Schultes	0	0	0	0	0	0.2	1.2	0	0	1.2	3.5	0	0.2	0
Cornaceae														
Cornus alternifolia L. f.	0	0	0	0	0	0	3.5	0	0	0	0	0	0	0

Appendix II: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Cornus stolonifera Michx.	0	0	0	0	4.0	0.8	0.2	1.5	0	0	3.5	0.2	0	14.2
Ericaceae														
Ledum groenlandicum Oeder	0	0	0	0.5	0	0	0	0	0	0	0	5.2	8.7	0.4
Vaccinium myrtilloides Michx.	0	0.2	0	0	0	0	0	0	0.3	0	0	0	0.8	0
Oleaceae														
Fraxinus pennsylvanicus Marsh.	0	0	0	0	0	0.2	0.2	0	0	0	9.4	0.2	0	0
Pinaceae														
Abies balsamea (L.)Mill.	4.0	2.4	1.5	1.7	5.5	10.2	10.6	3.4	4.4	15.5	0	3.6	0.8	1.4
Picea glauca (Moench)Voss	0.5	0.9	0	0	0	0	1.9	0.5	3.6	1.5	0	0	0	1.0
Rhamnaceae														
Rhamnus alnifolia L'Hér.	0	0	0	0	0	0	0	0	0	0	0	2.0	0.7	0
Rosaceae														
Amelanchier alnifolia Nutt.	0.2	0	0	0.2	0	0	0.2	0	0.3	2.5	0	0.6	1.0	8.1
Prunus sp.	0	0	0	0	0	0	0.2	0	0	0	4.7	0	0	0
Rosa sp.	0.6	1.2	0.2	0	2.5	3.4	0.8	0.4	0.3	0.2	1.4	1.9	0.2	0.4

Appendix II: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Rubus idaeus L.[var. *strigosus*] (Michx)Maxim.	19.7	3.4	2.7	5.9	0	0	0	0	3.7	0	1.5	0.5	0	1.2
Salicaceae														
Populus tremuloides Michx.	0	0.2	0.4	0.4	0.2	0.2	0.7	0.2	1.0	0	0.7	0	0	0
Salix sp.	0.4	0	0.4	0	0.2	0	0	0	0	0.2	0	0.2	0	2.2
Saxifragaceae														
Ribes americanum Mill.	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0
Ribes glandulosum Grauer	0.4	0	0	3.1	0	0.4	0	0.2	1.4	0	0	0.2	0	0
Ribes oxyacanthoides L.	0	0	1.7	0	0	0	0	0	0	0	0	0.2	0	0
Ribes triste Pall.	2.0	0	2.0	2.0	0	0	0	2.0	0	0	0	2.0	2.0	0

Appendix III: Average percent cover in 1 m^2 for ground vegetation in all sites.

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Bryophytes and Lichens														
Cladoniaceae														
Cladina mitis (Sandst.) Hale & Culb.	0	0.5	0	0	0	0	0	0	0	0	0	0	0.2	0
Cladina rangiferina (L.) Harm.	0	1.4	0	0	0	0	2.0	0	6.9	0	0	0	0.2	0
Cladonia spp.	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Hypnaceae														
Ptilium crista-castrensis (Hedw.) De Not.	0.5	0	0	0	0	2.1	0	0	3.4	0	0	0	0	0
Peltigeraceae														
Peltigera sp.	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0
Sphagnaceae														
Sphagnum sp.	0.4	4.3	1.5	0.2	1.5	0.7	9.6	0	20.0	0	0.0	1.9	0	35.0
Unknown species														
Feather moss	5.9	50.0	1.0	9.2	7.2	5.0	0	24.9	2.5	0	0	0.7	29.7	0
Ferns and Fern Allies														
Equisetaceae														
Equisetum laevigatum A. Br.	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0
Equisetum sylvaticum L.	0	0.2	0.7	0	0	0	0	0.4	0	0	0.2	0	0.2	5.7

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Lycopodiaceae														
Lycopodium obscurum L.	0.5	0	0.5	0	0	0	0	0	0	1.5	0	0	0	1.4
Lycopodium clavatum L.	4.7	2.0	0.2	3.8	0	2.4	0.2	1.2	1.3	1.4	0	8.7	0.4	17.1
Lycopodium complanatum L.	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0
Polypodiaceae														
Athyrium felix-femina (L.) Roth.	0	0	0.4	0.7	0	0	0	1.0	0	0	0	0.4	0	0
Dryopteris austriaca (Jacq.) Woynar	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
Dryopteris cristata (L.) Gray	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6
Gymnocarpium dryopteris (L.) Newm.	0	0	0.2	0.2	0	0	0.2	0.7	0	0	0	0	0	0
Polypodium vulgare var. *virginianum* (L.) D.C. Eaton	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
Pteridium aquilinum (L.)Kuhn	0	0	0	0	0	0	0	0	0	9.5	0	0	0	9.3
Woodsia ilvensis (L.) R. Br.	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Graminoids														
Cyperaceae														
Carex sp.	0	0	4.7	0	0.2	0	0	0	0	0	0.4	3.8	0	1.0

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Graminae														
Danthonia spicata (L.) Beauv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
Poaceae														
Calamagrostis canadensis (Michx.)Beauv.	0	0	4.0	0	0	0	0	0	0	0	0	0	0	0
Calamagrostis inexpansa A. Gray	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
Herbs and Shrubs														
Aceraceae														
Acer spicatum Lam.	0	0.4	1.2	1.4	2.5	1.1	1.5	1.7	0	1.0	0.4	0	0.5	0
Apocynaceae														
Apocynum androsaemifolium L.	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
Araliaceae														
Aralia nudicaulis L.	5.7	2.2	2.8	2.9	1.3	2.7	1.2	1.4	2.1	2.0	3.4	0.4	0.4	1.4
Asteraceae														
Aster cilliolatus Lindl.	0.4	0	0	0	0.6	0	0	0.2	0	0.2	0.8	0	0	0
Aster sp.	0	0	0.2	0	0	0.3	0	0	0	0	0	0	0	1.0
Aster umbellatus Mill.	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Bidens cernua L.	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Cirsium arvense (L.) Scop.	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Petasites frigidus (L.) Fr.	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
Petasites palmatus (Ait.) Gray	0.2	0	0.7	1.9	1.0	0	0.2	0	0	1.4	0.5	0	0.4	1.0
Taraxacum officinale Weber	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0
Unknown Asteraceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
Betulaceae														
Alnus sp.	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.3
Betula papyrifera Marsh	0	0.2	0	0	0	0	0	0	0	0	0	0.6	0	0
Corylus cornuta Marsh.	0.8	0	3.4	1.0	0	0	0.4	0	0	0.8	1.1	0.8	0.5	1.3
Boraginaceae														
Mertensia paniculatum (Ait.) G. Don	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0
Caprifoliaceae														
Diervilla lonicera Mill.	3.1	0	3.6	0.4	1.2	0	1.2	0.4	1.5	1.8	5.7	0.7	0	3.1
Linnaea borealis L.	3.2	0.4	0.4	1.2	0.2	0.3	0.6	1.7	3.2	0.4	0.2	0.9	0	1.4
Symphoricarpos alba (L.) Blake	0	0	0	0	0	0.3	0	0	0	0	1.4	0.4	0.4	0.7
Viburnum edule (Michx.) Raf.	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0
Viburnum rafinesquianum Schultes	0	0	0	0	0	0	0	0	0	0.4	0.6	0	0.4	0

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Cornaceae														
Cornus canadensis L.	4.9	2.6	4.0	13.1	0	3.7	1.4	3.5	8.4	7.1	0.4	2.3	1.1	4.9
Cornus stolonifera Michx.	0	0	0	0	0.4	0	0.2	0	0	0	0.4	0	0	6.7
Ericaceae														
Arctostaphylos uva-ursi (L.)Spreng.	0	0.7	0	0	0	0	0.5	0	0	0	0	0	0.2	0
Ledum groenlandicum Oeder	0	0	0	0	0	0	0	0	0	0	0	0	1.2	8.0
Vaccinium angustifolium Ait.	0	0.2	0	0.2	0	0	0	0	0	0.5	0	0	0.4	5.3
Vaccinium myrtilloides Michx.	0	8.3	0.4	0.4	0	0	0.2	0	0.9	0.6	0.9	0.7	0.6	0
Kalmia polifolia Wang.	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7
Iridaceae														
Iris versicolor L.	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0
Labiatae														
Mentha arvensis L.	0	0	0	0	0.2	0	0	0	0	0	0	0.2	0	0
Leguminosae														
Lathyrus sp.	0.2	0	0.2	0	0	0	0	0	0	2.0	0.9	0	0.2	0
Vicia sp.	0.2	0	0	0	0	0.3	0.2	0.2	0	0	2.0	0	0	1.7

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Liliaceae														
Clintonia borealis (Ait.) Raf.	3.6	3.5	1.9	3.4	0.7	1.0	0.4	0.4	1.9	1.5	0.2	0.7	0.4	0.3
Lilium philadelphicum L.	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Maianthemum canadense Desf.	1.8	2.9	6.0	2.2	1.9	1.1	2.5	1.2	7.1	2.4	3.2	1.6	1.9	5.6
Smilacina stellata (L.) Desf.	0	0	0	0	0.4	1.0	0.6	0.8	0	0	0	0	0	0
Smilacina trifolia (L.) Desf.	0.2	0	0	0	0	0	0.2	0	0	0	0	0	0	0
Streptopus roseus Michx.	1.3	0.2	0.4	1.1	2.2	0.3	0	0	0	2.8	1.4	0.2	0.4	0
Oleaceae														
Fraxinus pennsylvanicus Marsh.	0	0	0	0	0.2	0	0	0.4	0	0	2.6	0.4	0	0
Onagraceae														
Circaea alpina L.	0	0	0	0	1.0	0	0.2	0.6	0	0.2	0	5.2	0	0
Epilobium angustifolium L.	0	0	0	0.2	0	0	0.2	0	0.5	0	0	0	0.4	0
Oenothera biennis L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7
Orchidaceae														
Goodyera repens (L.) Br.	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0
Pinaceae														
Abies balsamea (L.)Mill.	1.0	0.2	0.6	1.2	0	1.7	0.6	0.6	0	1.3	1.6	1.6	1.4	0.6

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Picea glauca (Moench)Voss	0.0	0	0	2.0	0	0	0	0	0.3	0	0	0	0	0
Polygonaceae														
Polygonum scandens L.	0.7	0	0	0.2	0	0	0.2	0.2	0	0	0	0	0	0
Primulaceae														
Lysmachia thyrsiflora L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
Trientalis borealis Raf.	0.9	0.4	0.4	0.9	1.7	0.9	0.2	0.7	0.3	1.0	0.6	1.4	0.4	2.1
Primula spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrolaceae														
Chimaphila umbellata (L.)Bart.	0	1.1	0	0	0	0.3	0	0.2	0	0	0	0	0	0
Pyrola minor L.	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola spp.	0.5	1.2	0	1.1	0.5	0.9	0.2	0	0	0	0.4	0.4	0	0.7
Ranunculaceae														
Actaea rubra (Ait.)Willd.	0.5	0	0	0	0	0	0	0	0	0	0.6	0	0	0
Anemone canadensis L.	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0
Anemone quinquefolia L.	0	0	0.2	0	0	0.7	0	0	0	1.8	0.2	0	0.4	0.7
Aquilegia canadensis L.	0	0	0	0	0.5	0	0.2	0	0	0	0	0	0.2	0
Coptis trifolia (L.) Salisb.	0	0	0.4	0	0.5	0	0	0.2	0	0	0	0.6	0	0.6

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Rosaceae														
Amelanchier alnifolia Nutt.	0	0	0	0.2	0	0	0.2	0	0	0	0	0.2	0.2	0
Fragaria vesca L.	1.2	0	0.2	0.4	0	0.9	0.6	0.2	0	0.2	0.4	3.0	0	0
Fragaria virginiana Duchesne	0.5	0.5	0	0.4	0.7	0.7	0.6	0.7	0	1.4	1.0	0	0.2	0
Fragaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
Potentilla tridentata Ait.	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0
Rosa sp.	0.2	0	0.2	0	0.2	0.3	0.2	0.6	0.3	0.6	1.0	0	0.2	1.2
Rubus idaeus L.	0.4	0.7	1.1	2.2	0	1.3	0.2	0.2	1.1	0.2	0.4	0.2	0	1.3
Rubus pubescens Raf.	1.2	0.2	3.2	3.0	2.6	2.4	2.3	3.8	2.8	3.3	1.2	1.1	0.2	3.3
Spiraea alba Du Roi	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
Rubiaceae														
Galium boreale L.	0.6	0	0.2	0.8	0.6	0.9	0.8	0.2	0	0.6	0.6	0.4	0.2	1.0
Galium triflorum Michx.	0.4	0.4	0.6	1.2	0	0	0	0.4	0	0.8	1.0	0	0	0.7
Salicaceae														
Populus tremuloides Michx.	0.2	0.2	0	0.2	0.4	0	0.2	0.6	0	0	0	0.2	0	0.7
Salix sp.	0	0	0.2	0	0.5	0	0	0	0	0	0	0	0.4	0

Appendix III: continued

	1		2		3			4		5		CONTROL		
	NS	S	NS	S	NS	S-96	S-97	NS	S	NS	S	C-1	C-2	C-3
Saxifragaceae														
Mitella nuda L.	0.2	0	0	1.1	14.2	3.9	0.8	5.5	0.3	1.0	1.7	0.4	0.4	0
Ribes glandulosum Grauer	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
Ribes oxyacanthoides L.	0	0	0.2	0	0	0	0	0	0	0	0.8	0.2	0.7	0
Ribes triste Pall.	0	0	0.7	0.4	2.0	0.3	0	0.4	0	0	0.2	0	0	0
Scrophulariaceae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melampyrum lineare Desr.	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Ulmaceae														
Ulmus americana L.	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0
Umbelliferae														
Cicuta sp.	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
Sanicula marilandica L.	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	0.2	0
Violaceae														
Viola sp.	0.7	0.4	4.8	1.0	2.0	0	0.8	1.6	0	1.0	0.9	1.0	0	3.0

Appendix IV: Summary of moth collection data for all sites (1996 & 1997).

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Arctiidae															
Actias luna (L.)	1996	1	0	1	0	2	0	0	0	0	0	0	0	0	4
	1997	2	0	4	0	0	0	0	0	0	0	0	0	0	6
Clemensia albata Pack.	1996	0	1	10	1	0	3	0	0	0	0	2	7	5	29
	1997	0	1	14	3	1	3	0	2	0	1	0	8	5	38
Ctenucha virginica (Esper)	1996	0	0	2	0	0	0	0	0	0	0	0	0	0	2
	1997	0	0	12	0	0	0	0	0	0	0	0	0	0	12
Eilema bicolor (Grote)	1996	0	2	2	1	2	6	1	1	0	0	3	1	4	23
	1997	2	3	4	1	23	11	6	0	2	1	0	5	5	63
Grammia sp1.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Grammia sp2.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Grammia virgo (L.)	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	1	0	0	0	0	0	0	0	3	0	0	0	4
Haploa confusa (Lyman)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Haploa lecontei (Guér.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	2	0	0	0	0	0	0	0	0	3

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Holomelina aurantiaca (Hübner)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	5	1	7	1	2	3	2	0	2	2	0	0	0	25
Holomelina laeta (Guér.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	2	0	0	0	0	0	0	0	1	0	3
Hypoprepia fucosa Hübner	1996	0	1	1	0	0	0	0	0	0	0	0	0	1	3
	1997	0	1	0	0	0	0	0	0	0	0	0	1	0	2
Phragmatobia assimilans Wlk.	1996	0	9	1	0	12	3	2	1	1	0	0	0	6	35
	1997	0	0	9	3	6	4	8	0	0	0	0	2	0	32
Platarctia parthenos (Harr.)	1996	5	0	7	1	5	0	0	0	0	1	0	1	2	22
	1997	1	0	1	1	0	0	0	0	0	0	0	0	0	3
Spilosoma congrua (Wlk.)	1996	0	0	1	0	1	0	0	0	0	0	0	0	1	3
	1997	2	0	3	0	3	2	0	0	1	0	0	3	0	14
Spilosoma virginica (F.)	1996	0	0	3	0	1	2	1	0	0	0	0	2	0	9
	1997	5	0	6	0	3	3	1	0	1	0	0	0	0	19
Drepanidae															
Drepana arcuata Wlk.	1996	0	0	3	0	0	0	0	0	0	0	0	1	0	4
	1997	0	0	0	1	3	0	1	0	0	0	0	0	0	5

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Drepana bilineata (Pack.)	1996	0	0	0	0	0	0	0	1	2	2	0	0	0	5
	1997	0	0	1	1	1	1	0	0	1	0	0	1	0	6
Drepana sp.	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oreta rosea (Wlk.)	1996	1	0	0	0	2	0	0	0	0	0	2	0	0	5
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Geometridae															
Anacamptodes ephyraria (Wlk.)	1996	0	1	1	0	0	0	0	0	1	1	0	1	0	5
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Anacamptodes humaria (Gn.)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagoga occiduaria (Wlk.)	1996	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Besma quercivoraria (Gn.)	1996	0	0	2	0	0	0	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bomolocha sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Cabera erythemaria Gn.	1996	2	1	5	3	2	2	3	0	1	2	3	11	5	40
	1997	2	0	7	3	10	7	7	0	0	6	1	0	0	43
Campaea perlata (Gn.)	1996	17	0	15	1	7	4	1	0	0	0	5	3	6	59
	1997	6	0	18	0	5	4	7	0	4	2	1	1	3	51
Caripeta divisata Wlk.	1996	1	2	9	0	1	0	0	0	3	2	14	17	8	57
	1997	0	0	1	0	1	0	0	0	0	3	11	1	0	17
Coryphista meadii (Pack.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	1	0	0	0	0	0	0	1	0	2
Cyclophora pendulinaria (Gn.)	1996	1	1	0	1	0	0	0	0	0	0	0	0	0	3
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Dysstroma citrata (L.)	1996	0	0	0	0	0	0	0	0	0	0	1	1	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dysstroma hersiliata (Gn.)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dysstroma sp1.	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dysstroma sp2.	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Ennomos magnaria Gn.	1996	2	0	0	0	1	0	0	0	0	0	0	0	0	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entephria aurata Packard	1996	1	0	0	0	0	1	0	0	0	0	0	0	3	5
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erranis tiliaria (Harr.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eubaphe mendica (Walker)	1996	0	0	2	0	0	0	0	0	0	0	1	0	3	6
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchlaena obtusaria (Hübner)	1996	0	0	0	0	0	0	0	0	0	0	1	1	4	6
	1997	0	0	0	0	0	0	2	0	0	2	0	0	3	7
Euchlaena sp1.	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchlaena sp2.	1996	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchlaena tigrinaria (Gueneé)	1996	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eulithis explanata (Walker)	1996	0	3	0	0	0	0	1	0	0	0	0	0	12	16
	1997	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Eulithis serrataria	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Eulithis sp.	1996	3	0	1	0	0	0	0	0	0	0	0	0	1	5
	1997	0	0	0	0	0	0	0	0	0	1	0	1	3	5
Eulithis testata (L.)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eumacaria latiferrugata Walker	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eupithecia sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eutralepa clemetaria (J.E. Smith)	1996	2	1	0	0	0	0	0	0	4	1	1	0	3	12
	1997	4	0	0	0	5	3	8	0	0	0	1	1	1	23
Hydriomena pluviata (Gn.)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydriomena renunciata (Wlk.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypagyrtis piniata (Pack.)	1996	0	0	0	0	1	0	0	0	0	0	0	2	1	4
	1997	0	1	0	0	0	0	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Itame bitactata (Walker)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Itame loricaria (Eversmann)	1996	1	0	0	0	0	1	0	0	0	1	2	1	3	9
	1997	1	0	0	0	0	0	0	0	1	0	0	5	0	7
Itame obtussaria	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Itame occiduaria (Pack.)	1996	0	0	0	0	0	1	0	1	1	1	2	8	14	28
	1997	0	2	5	0	0	0	0	0	0	0	0	0	1	8
Itame sp.	1996	1	1	1	0	0	0	0	0	0	3	1	7	3	17
	1997	0	0	1	0	0	0	0	1	0	1	0	0	4	7
Itame subcessaria (Walker)	1996	0	0	0	0	1	0	0	0	0	0	0	1	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lambdina fiscellaria (Gn.)	1996	3	1	10	1	25	1	4	0	0	0	0	0	0	45
	1997	2	1	0	1	23	0	7	0	0	0	4	2	2	42
Melanolophia signataria (Wlk.)	1996	3	2	0	0	1	3	1	1	3	3	0	0	2	19
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metanema determinata Walker	1996	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Metanema inatomaria Gueneé	1996	0	0	3	0	1	1	0	1	0	0	0	1	5	12
	1997	1	0	3	1	0	0	0	0	0	0	1	2	0	8
Nematocampa limbata (Haw.)	1996	2	0	19	0	5	2	1	0	1	2	0	4	5	41
	1997	12	1	80	9	15	7	20	0	5	3	0	13	3	168
Nemoria rubrifrontaria (Pack.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	2	2	3	0	0	0	0	0	0	7
Nepytia canosaria (Wlk.)	1996	0	0	0	0	0	0	0	0	0	0	1	0	1	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pero honestaria (Wlk.)	1996	1	0	1	0	0	0	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plagodis alcoolaria (Gn.)	1996	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Plagodis phlogosaria (Gn.)	1996	0	0	1	0	0	0	1	0	0	0	0	0	1	3
	1997	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Probole amicaria (H.-S.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	4	0	0	0	0	0	0	0	4
Probole nyssaria (Gn.)	1996	0	1	1	0	0	0	0	0	0	2	0	0	1	5
	1997	0	0	1	0	0	1	0	0	0	0	0	0	1	3

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Prochoerodes transversata (Dru.)	1996	10	0	15	1	11	1	0	1	0	0	1	4	4	48
	1997	4	0	0	6	5	1	2	0	0	3	0	4	6	31
Protoboarmia porcelaria (Gn.)	1996	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sameodes sp.	1996	0	0	0	0	0	0	0	0	1	0	0	0	1	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scopula limboundata (Haw.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Semiothisa bisignata (Wlk.)	1996	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Semiothisa denticulata Grt.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Semiothisa resperata (Hulst)	1996	0	1	0	0	0	0	0	0	0	0	0	1	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Semiothisa signaria (Hbn.)	1996	0	0	0	0	0	0	0	0	1	1	6	5	1	14
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sicya macularia (Harr.)	1996	0	0	0	0	2	0	0	0	0	0	0	1	0	3
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Species 7	1996	50	7	87	5	33	14	29	1	17	29	16	43	37	368
	1997	41	0	65	56	18	75	39	1	28	17	0	27	26	393
Tetracis cachexiata Gn.	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetracis crocallata Gn.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Triphosa haesitata (Gn.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorhoe algidata (Möschler)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorhoe ferrugata (Clerck)	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorhoe lacustrata (Gn.)	1996	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthotype sospeta (Dru.)	1996	3	0	1	0	0	0	0	0	0	2	2	0	0	8
	1997	2	0	0	0	1	8	2	0	0	0	0	0	0	13
Xanthotype urticaria Swett	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	3	0	1	0	0	0	0	0	1	5

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Lasiocampidae															
Malacasoma americanum (F.)	1996	0	0	3	0	0	0	0	0	1	0	2	0	0	6
	1997	0	0	0	2	0	3	0	1	0	0	0	0	0	6
Phyllodesma americanum (Harr.)	1996	0	1	2	0	0	2	0	0	0	0	0	0	2	7
	1997	0	0	0	3	1	3	1	0	0	0	0	0	0	8
Limacodidae															
Tortricidia testacea Pack.	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lymantriidae															
Orgyia leucostigma (J.E. Smith)	1996	0	0	1	0	1	0	0	1	0	0	1	0	1	5
	1997	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Noctuidae															
Acronicta americana (Harr.)	1996	0	0	0	0	1	1	0	0	0	0	0	0	0	2
	1997	1	0	1	0	0	0	2	0	0	0	0	0	0	4
Acronicta fragilis (Gn.)	1996	0	0	17	0	0	0	0	0	2	0	0	0	0	19
	1997	1	0	0	0	0	0	0	0	1	0	1	0	0	3
Acronicta impressa Wlk.	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acronicta innotata (Gn.)	1996	0	0	3	0	1	0	0	0	0	0	0	0	0	4
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Acronicta sp.	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acronicta superans Gn.	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Agriopodes fallax (Herrich-Shaeffer)	1996	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	1997	1	0	5	0	1	0	0	0	0	0	0	0	0	7
Agroperina lateritia (Hufnagel)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis volubilis Harr.	1996	1	0	0	0	3	0	0	0	0	0	0	0	2	6
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aletia oxygala (Grote)	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amathes collaris (Grote & Robinson)	1996	0	0	0	0	0	0	0	0	0	1	1	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amathes smithii (Snellen)	1996	0	0	5	0	2	0	0	0	0	0	1	0	3	11
	1997	1	1	0	0	3	0	1	0	0	0	0	1	1	8
Amphipoea americana (Speyer)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Amphipyra pyramidoides Gueneé	1996	0	0	1	1	0	0	7	0	0	0	2	0	0	11
	1997	0	2	0	0	2	1	1	0	0	1	0	0	0	7
Anomogyna badicollis (Grt.)	1996	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apamea mixta (Grote)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Apamea nigrior (Smith)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apharetra purpurea McDunnough	1996	1	1	0	0	0	0	0	0	0	0	2	1	0	5
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aplectodes condita (Gueneé)	1996	1	0	1	0	0	0	0	0	0	0	0	6	3	11
	1997	1	2	0	3	0	2	1	0	1	0	0	3	0	13
Archanara subflava (Grote)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baileya doubledayi (Gueneé)	1996	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bellura obliqua (Wlk.)	1996	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Catocala blandula Hulst	1996	0	0	1	0	1	0	1	0	0	0	1	0	0	4
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Catocala briseis Edwards	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Catocala mira Grote	1996	0	0	1	0	0	1	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Catocala relicta Walker	1996	2	0	1	1	0	1	3	0	0	0	0	1	2	11
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Catocala sp.	1996	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Catocala ultriona (Hübner)	1996	0	0	1	0	1	0	0	0	0	0	0	0	0	2
	1997	1	0	0	0	0	1	0	0	0	0	0	0	0	2
Catocala unijuga Walker	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Chrysanympha formosa (Grote)	1996	6	0	0	0	0	0	0	0	0	0	0	0	1	7
	1997	6	1	5	0	1	0	0	0	0	0	0	0	0	13
Chytonix palliatricula (Gueneé)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Enargia decolor (Walker)	1996	33	1	39	11	66	13	21	0	2	27	35	24	35	307
	1997	1	0	1	7	25	18	11	0	0	22	13	20	20	138
Enargia infumata (Grote)	1996	1	0	3	0	0	0	0	0	0	0	1	1	1	7
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eosphoropteryx thyatyroides (Gueneé)	1996	1	0	1	0	2	0	0	0	0	0	2	0	0	6
	1997	0	0	0	0	0	1	0	0	0	1	0	1	0	3
Eremobina sp.	1996	0	0	2	0	1	0	0	0	0	0	0	0	0	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euclidia cuspidea (Hübner)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Euretagrotis sp.	1996	0	0	2	0	1	0	0	0	1	0	0	0	0	4
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eurois astricta Morrison	1996	2	1	3	0	11	1	1	0	0	0	1	0	5	25
	1997	6	0	3	1	7	9	2	0	0	0	0	2	3	33
Eurois occulta (L.)	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feralia sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Heliothis sp.	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heptagrotis phyllophora (Grote)	1996	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1997	3	0	5	0	0	0	1	0	1	0	0	1	0	11
Idia americalis (Gn.)	1996	2	2	2	0	0	4	2	4	3	0	4	2	8	33
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Idia lubricalis (Gey.)	1996	1	4	3	2	1	0	2	1	1	0	1	1	1	18
	1997	1	1	0	1	0	0	0	2	0	0	0	0	0	5
Lacinipolia lorea (Gueneé)	1996	0	0	0	1	0	1	0	0	0	0	0	0	0	2
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Lithacodia albidula (Gueneé)	1996	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Lithacodia carneola (Gueneé)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithomola solidaginis (Hübner)	1996	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithophane fasciola	1996	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Lithophane pexata Grote	1996	0	0	0	2	0	0	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithophane thaxteri Grote	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Macrochilo absorptalis (Wlk.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metalepsis salicarium Walker	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephelodes minians (Gueneé)	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Nycteola frigidana (Wlk.)	1996	1	0	4	0	0	0	0	1	1	0	0	0	2	9
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthosia revicta (Morr.)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palthis angulalis (Hbn.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Papaipema pterisii Bird	1996	3	1	1	0	0	0	0	0	1	0	1	0	0	7
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Philometra metonalis Walker	1996	0	0	1	0	0	0	0	0	0	1	0	1	0	3
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Phlogophora iris Gn.	1996	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Phologophora periculosa Gn.	1996	2	0	5	0	3	0	0	1	0	0	0	1	1	13
	1997	0	0	0	0	1	0	0	0	0	0	0	2	0	3
Plusia aeroides Grote	1996	5	0	0	1	1	0	0	0	0	0	0	0	0	7
	1997	1	0	1	0	1	0	0	0	0	0	0	0	0	3
Polia cristifera (Walker)	1996	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polia imbrifera (Guenеé)	1996	1	0	0	0	0	0	0	0	0	2	0	0	0	3
	1997	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Polia ingravis (Smith)	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polia nimbosa (Guenеé)	1996	0	0	0	0	0	1	0	0	0	0	0	0	1	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudospaelotis haruspica (Grote)	1996	2	0	0	0	1	0	2	0	0	1	0	1	0	7
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Raphia frater Grote	1996	1	0	6	0	0	0	0	0	0	0	0	0	1	8
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchagrotis cupida (Grote)	1996	0	0	0	0	2	0	0	0	0	2	0	0	0	4
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rivula propinqualis Gn.	1996	0	0	0	0	0	0	0	0	0	0	1	0	4	5
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scoliopteryx libatrix (L.)	1996	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	1997	1	0	1	2	2	0	0	1	0	0	0	0	1	8
Spaelotis clandestina (Harr.)	1996	1	0	1	0	2	0	2	0	0	1	0	0	1	8
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syngrapha octoscripta (Grote)	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zale aeruginosa (Gueneé)	1996	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Zale horrida Hübner	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	3	0	3
Zale lunata (Drury)	1996	1	0	4	0	3	1	1	0	1	0	0	0	0	11
	1997	1	0	1	0	2	0	1	0	0	0	0	0	0	5

Appendix IV: continued

	YEAR	1 NS	1 S	2 NS	2 S	3 NS	3 S	4 NS	4 S	5 NS	5 S	CONTROL 1	CONTROL 2	CONTROL 3	SUM
Zale submediana McDunnough	1996	3	0	0	0	0	0	1	1	0	0	0	0	0	5
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zanclognatha sp.	1996	1	1	2	0	0	0	0	0	1	1	2	1	3	12
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notodontidae															
Clostera albosigma Fitch	1996	0	0	0	0	2	0	0	0	0	0	0	0	1	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clostera inclusa (Hübner)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furcula cinerea (Wlk.)	1996	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Gluphusia septentrionis Wlk.	1996	0	0	0	0	1	0	1	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nadata gibbosa (J.E. Smith)	1996	0	0	1	0	0	1	0	0	0	0	0	1	0	3
	1997	2	0	1	0	4	1	1	0	0	0	0	0	1	10
Schizura unicornis(J.E. Smith)	1996	1	0	11	1	0	0	0	1	1	1	0	0	4	20
	1997	0	0	0	0	0	0	1	0	0	1	0	0	0	2

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Pyralidae															
Chilo plejadellus Zincken	1996	0	0	0	0	0	2	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evergestis pallida (Hufn.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Herpetogramma aeglealis Walker	1996	5	1	5	1	2	0	0	0	1	5	0	0	1	21
	1997	3	0	5	0	0	0	1	0	1	0	0	1	0	11
Palpita magniferalis (Walker)	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetralopha asperatella (Clem.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Saturniidae															
Antheraea polyphemus (Cram.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Sphingidae															
Laothoe juglandis (J.E. Smith)	1996	1	1	1	1	0	0	1	0	0	0	0	0	0	5
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Pachysphinx modesta (Harr.)	1996	0	0	1	0	1	0	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Paonias excaecatus (J.E. Smith)	1996	1	0	1	0	0	0	0	0	0	0	0	0	0	2
	1997	1	0	2	0	1	0	2	0	1	0	0	0	0	7
Paonias myops (J.E. Smith)	1996	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	1997	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Smerinthus cerisyi (Kby.)	1996	2	0	2	0	7	2	0	0	1	1	0	0	1	16
	1997	0	0	2	0	8	7	1	0	3	1	3	1	3	29
Smerinthus jamaicensis (Dru.)	1996	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<u>Thyatiridae</u>															
Euthyatira pudens (Gueneé)	1996	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudothyatira cymatophoroides(Gueneé)	1996	0	0	1	0	0	0	1	0	0	0	0	1	0	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Tortricidae															
Choristoneura fumiferana (Clem.)	1996	1	1	4	6	2	26	0	3	3	3	9	0	2	60
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choristoneura rosaceana (Harr.)	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Miscellaneous moths															
Species 1	1996	0	0	0	0	4	0	0	0	0	1	0	0	2	7
	1997	1	0	0	0	3	0	2	0	0	0	0	0	2	8
Species 2	1996	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Species 3	1996	1	0	1	0	0	0	0	0	0	0	0	0	1	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Species 4	1996	0	0	0	0	0	2	0	0	0	0	0	0	0	2
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Species 5	1996	1	0	8	1	0	1	0	0	0	0	0	1	0	12
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Species 6	1996	0	3	1	0	0	2	0	0	1	0	0	0	0	7
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Species 8	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1

Appendix IV: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Species 9	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	1	0	0	0	0	0	0	0	0	0	0	1	0	2
Unidentifiable	1996	35	15	105	12	90	18	11	6	4	9	9	26	42	382
	1997	58	16	79	17	69	55	44	27	7	10	9	18	29	438
∑ Number of species	1996	41	29	81	26	51	64	27	15	26	32	34	44	74	
	1997	43	14	38	23	36	36	35	6	16	18	10	34	25	
∑ Number of individuals	1996	236	86	476	71	340	128	104	29	64	119	145	213	298	2309
	1997	191	35	353	127	264	250	193	35	63	79	46	139	130	1905

Appendix V: Total number of carabid individuals and species collected in 1996 and 1997.

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Agonum gratiosum (Mannerheim)	1996	0	0	6	1	7	8	9	0	0	4	18	0	2	55
	1997	0	0	16	3	3	7	8	2	0	7	10	7	14	77
Agonum retractum LeConte	1996	154	10	97	12	64	41	34	9	131	29	84	11	16	692
	1997	400	6	281	75	83	97	122	30	348	79	143	88	98	1850
Agonum placidum Say	1996	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	1997	0	0	2	0	1	0	0	0	1	0	0	0	0	4
Agonum sp.	1996	0	0	1	0	0	0	0	0	0	1	0	0	0	2
	1997	3	0	3	0	2	2	2	0	0	0	0	0	1	13
Badister obtusus LeConte	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	3	0	0	0	0	0	0	0	0	0	0	3
Bembidion sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Calathus ingratus Dejean	1996	17	0	15	5	0	1	3	6	56	6	25	34	46	214
	1997	120	4	52	47	14	11	7	7	93	8	57	75	31	526
Calosoma calidum (Fabricus)	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	1	0	0	0	0	0	0	1	0	2

Appendix V: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Calosoma frigidum Kirby	1996	0	0	0	0	0	0	0	0	2	0	0	1	0	3
	1997	0	2	9	0	0	1	0	0	0	0	0	1	0	13
Carabus serratus Say	1996	0	1	0	0	0	0	1	1	0	0	0	0	3	6
	1997	3	6	0	0	0	0	4	0	1	1	0	1	3	19
Carabus taedatus agassii Leconte	1996	9	0	0	0	0	0	0	0	8	0	0	0	9	26
	1997	14	0	1	0	0	0	0	0	3	0	0	0	1	19
Chlaenius niger Randall	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Cymindis cribricollis Dejean	1996	0	0	3	0	0	0	0	0	0	0	1	2	3	9
	1997	7	1	0	1	0	0	0	0	0	0	1	2	1	13
Cymindis neglectus Haldeman	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Diplocheila oregona (Hatch)	1996	0	0	2	0	0	0	0	0	0	0	0	0	1	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Appendix V: continued

		1		2		3		4		5		CONTROL			
	YEAR	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**1**	**2**	**3**	**SUM**
Harpalus fulvilabris Mannerheim	1996	0	0	1	1	0	0	1	0	4	2	0	0	0	9
	1997	22	0	7	2	0	0	0	0	1	2	0	1	1	36
Harpalus pleuriticus Kirby	1996	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpalus sp.	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	1	1	0	0	0	0	4	1	0	0	3	10
Loricera pilicornis Fabricus	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Notiophilus intermedius Lindroth	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Patrobus foveocollis Eschscholtz	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	1	1	0	0	1	0	0	0	0	4
Patrobus sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1

Appendix V: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Platynus decentis (Say)	1996	0	0	0	0	1	1	2	0	55	3	6	2	1	71
	1997	52	11	32	38	293	51	170	2	181	44	99	153	7	1133
Platynus mannerheimii (Dejean)	1996	0	0	0	0	0	1	0	0	0	0	0	0	1	2
	1997	0	0	0	0	4	0	0	0	0	0	0	0	7	11
Platynus sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Pterostichus adstrictus Eschscholtz	1996	7	1	12	4	1	2	4	1	90	2	9	28	1	162
	1997	232	117	113	147	55	36	66	19	128	4	23	56	5	1001
Pterostichus femoralis (Kirby)	1996	0	0	1	0	0	0	0	0	0	0	0	1	1	3
	1997	0	0	1	0	0	0	0	0	3	0	0	1	2	7
Pterostichus melanarius (Illiger)	1996	0	0	0	0	0	0	0	0	5	3	0	0	0	8
	1997	1	0	0	1	0	0	0	0	17	14	0	1	0	34
Pterostichus mutus (Say)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Pterostichus pensylvanicus LeConte	1996	4	0	66	2	1	6	0	4	52	66	15	2	169	387
	1997	266	8	675	16	41	18	5	7	172	133	75	191	188	1795

Appendix V: continued

		1		2		3		4		5		CONTROL			
	YEAR	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**1**	**2**	**3**	**SUM**
Pterostichus punctatissima (Randall)	1996	0	0	0	3	0	0	0	1	0	0	1	4	14	23
	1997	1	2	1	23	4	4	1	3	0	0	3	15	6	63
Pterostichus sp.	1996	0	0	0	0	0	1	0	0	2	0	0	0	0	3
	1997	8	1	10	1	1	1	1	0	0	0	0	0	0	23
Scaphinotus bilobus (Say)	1996	6	1	9	10	4	0	1	0	6	5	5	3	4	54
	1997	1	2	4	1	4	5	4	0	0	2	0	5	1	29
Sphaeroderus nitidicollis brevoorti LeConte	1996	0	7	59	20	21	19	17	6	61	22	12	2	22	268
	1997	35	3	36	23	14	9	18	3	13	6	7	3	1	171
Sphaeroderus stenosmus lecontei Dejean	1996	0	0	0	0	0	0	0	0	6	15	0	0	34	55
	1997	0	0	0	0	0	0	0	0	0	6	0	0	5	11
Syntomus americanus (Dejean)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	5	0	4	0	0	0	0	0	1	0	0	0	5	15
Synuchus impunctatus (Say)	1996	7	10	42	10	5	9	4	5	95	38	12	12	216	465
	1997	192	53	687	134	32	17	18	24	199	79	73	113	77	1698
Trechus apicalis Motschulsky	1996	0	3	0	1	0	0	0	1	0	1	1	3	2	12
	1997	0	0	3	0	0	0	0	0	0	0	0	0	1	4

Appendix V: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
∑ Number of species	1996	8	6	13	12	8	10	11	9	15	15	12	13	22	
	1997	17	13	23	15	17	15	14	9	15	14	10	17	26	
∑ Number of Individuals	1996	204	33	314	70	104	89	77	34	574	198	189	105	549	2575
	1997	1362	216	1944	513	554	261	427	97	1166	386	491	714	463	8559

Appendix VI: Total number of carabid individuals and species collected during the common sampling dates (12 July-27 September) in 1996 and 1997.

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Agonum gratiosum (Mannerheim)	1996	0	0	2	0	3	3	1	0	0	4	16	0	2	31
	1997	0	6	6	2	1	2	7	0	0	3	9	6	7	49
Agonum retractum LeConte	1996	15	0	7	7	4	4	2	0	48	18	62	11	15	193
	1997	217	3	179	43	10	6	27	6	168	26	90	64	20	859
Agonum sp.	1996	0	0	1	0	0	0	0	0	0	1	0	0	0	2
	1997	3	0	2	0	1	1	0	1	0	0	0	0	1	9
Badister obtusus LeConte	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Calathus ingratus Dejean	1996	9	0	12	5	0	0	1	1	49	6	24	33	32	172
	1997	97	3	46	31	1	0	0	4	57	0	19	45	9	312
Calosoma calidum (Fabricus)	1996	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calosoma frigidum Kirby	1996	0	0	0	0	0	0	0	0	2	0	0	1	0	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carabus serratus Say	1996	0	1	0	0	0	0	1	0	0	0	0	0	3	5
	1997	0	4	0	0	0	0	0	0	1	0	0	0	0	5
Carabus taedatus agassii Leconte	1996	9	0	0	0	0	0	0	0	8	0	0	0	8	25
	1997	11	0	1	0	0	0	0	0	1	0	0	0	1	14

Appendix VI: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Cymindis cribricollis Dejean	1996	0	0	2	0	0	0	0	0	0	0	1	1	2	6
	1997	6	1	0	1	0	0	0	0	0	0	0	2	0	10
Cymindis neglectus Haldeman	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplochelia oregona (Hatch)	1996	0	0	2	0	0	0	0	0	0	0	0	0	1	3
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpalus fulvilabris Mannerheim	1996	0	0	1	1	0	0	0	0	4	2	0	0	0	8
	1997	18	0	4	1	0	0	0	0	0	0	0	1	0	24
Harpalus pleuriticus Kirby	1996	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpalus sp.	1996	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	1997	0	0	1	1	0	0	0	0	2	0	0	0	0	4
Patrobus foveocollis Eschscholtz	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Patrobus sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Platynus decentis (Say)	1996	0	0	0	0	1	0	1	0	54	2	6	2	1	67
	1997	1	1	1	0	1	0	0	0	3	1	1	4	0	13

Appendix VI: continued

		1		2		3		4		5		CONTROL			
	YEAR	NS	S	NS	S	NS	S	NS	S	NS	S	1	2	3	SUM
Platynus mannerheimii (Dejean)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterostichus adstrictus Eschscholtz	1996	1	0	6	4	0	0	2	0	79	2	8	27	1	130
	1997	49	18	26	34	1	1	4	3	7	0	6	4	0	153
Pterostichus femoralis (Kirby)	1996	0	0	1	0	0	0	0	0	0	0	0	0	1	2
	1997	0	0	1	0	0	0	0	0	0	0	0	1	0	2
Pterostichus melanarius (Illiger)	1996	0	0	0	0	0	0	0	0	5	3	0	0	0	8
	1997	1	0	0	1	0	0	0	0	9	3	0	1	0	15
Pterostichus pensylvanicus LeConte	1996	1	0	12	2	0	0	0	2	33	34	13	2	128	227
	1997	130	6	353	7	0	0	0	2	9	1	18	29	6	561
Pterostichus punctatissima (Randall)	1996	0	0	0	3	0	0	0	0	0	0	1	4	1	9
	1997	0	0	1	10	0	0	0	0	0	0	1	6	1	19
Pterostichus sp.	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1997	8	1	10	1	0	0	0	0	0	0	0	0	0	20
Scaphinotus bilobus (Say)	1996	6	1	9	1	2	0	0	0	6	3	5	3	4	40
	1997	1	1	2	1	1	2	1	0	0	1	0	4	0	14
Sphaeroderus nitidicollis brevoorti LeConte	1996	24	6	37	15	13	3	9	2	34	5	12	2	14	176
	1997	24	2	25	20	2	3	13	1	3	0	4	3	0	100

Appendix VI: continued

		1		2		3		4		5		CONTROL			
	YEAR	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**1**	**2**	**3**	**SUM**
Sphaerodurus stenosmus lecontei Dejean	1996	0	0	0	0	0	0	0	0	5	8	0	0	21	**34**
	1997	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Syntomus americanus (Dejean)	1996	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Synuchus impunctatus (Say)	1996	7	10	42	10	5	9	2	5	95	37	12	12	214	**460**
	1997	189	52	671	131	29	14	16	22	170	50	72	113	59	**1588**
Trechus apicalis Motschulsky	1996	0	1	0	0	0	0	0	0	0	1	0	0	1	**3**
	1997	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
∑ Number of species	1996	8	5	13	10	6	4	8	4	14	16	11	11	21	
	1997	14	11	20	14	9	8	6	7	11	8	9	14	8	
∑ Number of individuals	1996	72	19	134	49	28	19	19	10	423	127	160	98	453	1611
	1997	755	92	1333	284	47	30	68	39	430	86	220	283	104	3771