INSECT DIVERSITY OF FOUR ALVAR SITES ON MANITOULIN ISLAND, ONTARIO

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DEDICATION

I would like to dedicate this thesis to my parents, Denise and Ghislain, for their unconditional support through all of my past and present projects.

TABLE OF CONTENTS

ABSTRACT

Alvars are naturally open habitats which are found in the Great Lakes region in North America and in Scandinavia. The insect fauna of four types of alvars (grassland, grassland savanna, shrubland and pavement) was sampled in the summer of 1996 on Manitoulin Island, Ontario. A total of 9791 specimens from four target insect groups (Coleoptera: Carabidae, Homoptera: Auchenorrhyncha, Hymenoptera: Symphyta and Lepidoptera: Papilionoidea and Hesperioidea) was identified. Results showed that the grassland savanna and grassland alvars supported the highest number of insect specimens whereas the pavement alvar supported the highest number of species. The origin of the fauna differed between the taxa depending on their closer association with specific microclimatic conditions (Carabidae) or on the presence of host plants (Auchenorrhynca). This first inventory of alvar insects in North America revealed the presence of a high number of species of interest to conservation (rare, disjunct or restricted species).

RESUME

Les alvars sont des habitats naturellement ouverts qui se trouvent dans la region des Grands Lacs en Amerique du Nord et aussi en Scandinavie. Les insectes de quatres types d'alvars a été échantillonée durant la saison estivale 1996 sur l'Ile Manitoulin, Ontario. Un total de 9791 specimens de quatres groupes d'insectes (Coleoptera: Carabidae, Homoptera: Auchenorrhyncha, Hymenoptera: Symphyta et Lepidoptera: Papilionoidea et Hesperioidea) ont été identifiés. Les résultats suggèrent que les types d'alvar "prairie savanne" et "prairie" supportent le plus grand nombre de specimens d'insectes alors que que le type "pavé" supporte le plus grand nombre d'espèces. L'origine de la faune diffère entre les groupes dépendamment de leur prédominante association avec un microhabitat spécifique ou la présence de leur plante hôte. Ce premier inventaire des insectes des alvars de l'Amerique du Nord a indiqué la présence de plusieurs espèces significatives pour la conservation.

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LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Alvars are naturally open areas of thin soil lying over flat bedrock, mostly limestone or dolostone. The vegetation is generally sparse and is usually dominated by shrubs, grasses and sedges. Trees seldom grow in these habitats because of the restricted soil available and drought conditions during the growing season, but when present, they can be found in the deeper and wider cracks in the bedrock where soil has accumulated over time (Catling and Brownell, 1995).

Alvar communities can be found in the Baltic Sea region on islands in southwestern Sweden, in Estonia and in small areas in western Russia (Rosén, 1995); and around the Great Lakes in North America (Catling and Brownell, 1995). Similar habitats can also be found in the southeastern United States where they are called cedar glades due to their association with red cedar (*Juniperus virginiana* L.: Cupressaceae). Well-developed cedar glades occur in Kentucky, Tennessee, Alabama and Georgia with the most numerous, extensive and floristically rich sites occurring in the Central Basin of Tennessee (Baskin and Baskin, 1985).

In the Great Lakes region, the sedimentary bedrock on which most of the alvars can be found was deposited by ancient seas about 450 million years ago and overlies the granite and quartzite of the Precambrian shield. This limestone was scraped by glaciers, which covered the area until about 12000 years ago (Morton and Venn, 1984). The alvars around the Great Lakes can be thought as isolated remnants of a "prairie-like" community which covered a wide area in North America during the Hypsithermal period (a time of warmer and drier climate, approximately 8000 - 4000 years before present) (Morton and

Venn, 1984). Since then, the boreal and deciduous forests have colonized most of the area (Scudder, 1979), leaving open only a few patches unsuitable for tree growth. These patches, or alvars, have been maintained as natural openings until now by a variety of environmental factors including the lack of soil, fires, grazing by large herbivores and a pattern of flood-drought-flood experienced during different seasons (spring-summer-fall).

The number of alvar sites known in the Great Lakes region is estimated to be between 250 and 300 covering an estimated 1100 km^2 (Catling and Brownell, 1995). Most of these sites are in southern Ontario, but others can be found in the states of New York, Michigan, Vermont and Ohio (Catling and Brownell, 1995). Small and isolated sites are also known from the province of Quebec (Huggett, 1993) and from Vermont (Catling and Brownell, 1995). Six different types of alvars have been recognized (Catling and Brownell, 1995; Nature Conservancy, unpublished data) based on the percentage of herb and shrub cover, the percentage of exposed bedrock and the percentage of tree cover (Table 1). Two types (grassland and pavement alvars) have been classified as globally imperiled and imperiled in Ontario by the Nature Conservancy and most savanna alvars in Ontario have been classified as critically imperiled globally by the same organization (Catling and Brownell, 1995). In the Great Lakes region, about 35 % of the total original area covered by alvars can be found on Manitoulin Island (400 km^2) (Catling and Brownell, 1995). This island is situated in the northern part of Lake Huron and is approximately 136 km long and between 5 and 80 km wide, making it the largest freshwater island in the world (Ontario Ministry of Natural Resources, 1984). Manitoulin Island holds some of the most pristine alvars in the world because the habitat has been largely undisturbed and most of the island is still relatively unpopulated. Four of the six types of alvars can be found on the island (shrubland, grassland, pavement and savanna grassland alvars).

The first account of the flora of alvars in the Great Lakes region was in 1975 when Catling et al. provided a list of vascular plants found in seven sites in southern Ontario. This list has grown extensively since then and the number of native vascular plant species has reached 347, of which 28% are considered characteristic of alvars (Catling and Brownell, 1995). The lack of introduced European flora in alvars is very noticeable to a knowledgeable observer although many invading species, such as the Tartarian honeysuckle (*Lonicera tatarica* L.: Caprifoliaceae) and lilac (*Syringa vulgaris* L.: Olaceae), have colonized the Great Lakes alvars recently because of artificial (i.e. man made) stresses. Due to the unusual conditions found on alvar sites (geology, hydrology, etc.) plants from northern, western and southern regions coexist together. A number of endemic plant species are now restricted to alvars; one of these, the lakeside daisy (*Hymenoxys herbacea* (Greene): Compositae), can be found only in small areas in Ohio, the Bruce Peninsula and on Manitoulin Island (Catling and Brownell, 1995).

Most of the information on alvar arthropods has been obtained through intensive research which started about six decades ago in Sweden mainly on two islands, Öland and Gotland (Ander, 1931; Ardo, 1948; Bruce, 1964; Coulianos, 1973, and many more). The largest and most comprehensive study on alvar arthropods was carried out between 1977 and 1979 on the Great Alvar of Öland Island. The study was done to increase the available knowledge of the fauna of alvars as a base for future management and conservation strategies (Sylvén, 1983). The spiders (Araneae) and several insect groups (Psocoptera, Heteroptera, Coleoptera, Lepidoptera, Diptera (Cecidomyiidae and Brachycera) and Hymenoptera (Chalcidoidea and Aculeata)) were used as environmental indicators (results summarized in Entomologisk Tidskrift, vol. 104, 1983). The Öland alvars were shown to support a number of biogeographically important species of insects (species with restricted or disjunct distributions, rare species in other habitats but common in alvars, new species, species found nowhere else in northern Europe, etc.). It was concluded that the conservation of the natural vegetation against non-natural stresses was essential to preserve the great biodiversity of arthropods (Coulianos, 1983).

The study of alvar arthropods in the Great Lakes region has been patchy with no major comprehensive surveys. Brunton (1986) provided a useful analysis of moths and butterflies of the Burnt Lands alvar (near Ottawa) which included several rare, restricted or disjunct species including one new species of Owlet Moth (Noctuidae). The garita skipper (*Oarisma garita* (Reakirt): Hesperiidae) which occurs on the La Cloche Island alvar is a disjunct from a population that occurs 1040 km west where it has a fairly continuous range throughout the prairies and the Rockies (Catling, 1977). The Napanee Plain alvar in Ontario has the majority of the population of the olive hairstreak (*Mitoura gryneus* (Hubner): Lycaenidae), a very localized butterfly in Ontario, and two other butterflies with restricted occurrence in Ontario are associated with alvars: the hoary elfin (*Incizalia polios* Cook and Watson: Lycaenidae) and the mottled duskywing (*Erynnis martialis* (Scudder): Hesperiidae) (Catling and Brownell, 1995). One species of ground beetle, *Chlaenius p. purpuricollis* Randall (Carabidae) is very rare and restricted in eastern Canada but was found in the Burnt Lands alvar where it is a disjunct of western populations (H. Goulet, pers. comm.). The sawfly *Blennogeris spissipes* (Cresson) (Tenthredinidae) is another western disjunct that can be found in the Ottawa valley alvar but nowhere else in Ontario (H. Goulet, pers. comm.). The Great Lakes alvars also have a number of disjunct and rare species of leafhoppers that are normally associated with western prairie communities (Hamilton, 1994, 1995). These documented examples are probably only a fraction of the rare, restricted, disjunct and undescribed species associated with alvars (Catling and Brownell, 1995). The present study started in 1996 as part of the International Alvar Conservation Initiative (funded and coordinated mainly by The Nature Conservancy), the goal of which is to characterize the biodiversity and ecology of alvar habitats to help in future management and conservation decisions.

The choice of indicator taxa in a study is critical for getting the largest amount of information about an ecosystem by looking only at a few groups. Pearson (1994) identified the basic characteristics of good indicator taxa. The group should be taxonomically well-known and stable so that populations can be reliably defined. The biology and the general life history of the species within the group should be well understood; we should have a good indication on the limiting resources, enemies, physical tolerances, and the different stages for most of the species. The group should be readily collectable by non-experts so a great amount of information can be gathered quickly by professionals and non-professionals. The group should occur over a broad geographical range and types of habitats at higher taxonomic levels (i.e. order, family, tribe, genus). The members of the group should show a great deal of specialization within a narrow type of habitat at lower taxonomic levels (i.e. species, subspecies). Another important aspect is that there should be some evidence that the taxa chosen show similar patterns of diversity to other groups.

Insects have been used extensively in the past as indicators because of their great abundance in all terrestrial habitats. The taxa selected for this study, based on the requirements listed above, included the ground beetles (Coleoptera: Carabidae), the leafhoppers and allies (Homoptera: Auchenorrhyncha), the sawflies (Hymenoptera: Symphyta) and the butterflies (Lepidoptera: Papilionoidea and Hesperioidea). The choice of Manitoulin Island as a sampling area for this study was based on both the high quality and diversity of the alvars present.

The specific objectives of this study were:

1) to conduct a preliminary assessment of the species richness in alvar habitats for the different target groups (this study represents the first full season duration, multitaxon investigation of insects in North American alvars),
2) to compile data on the status of the species collected (i.e. rare species, species restricted to alvars, species with disjunct distributions or at the extreme limit of their range, new species, etc.),
3) to compare the species composition of the four different types of alvars on Manitoulin Island,
4) to assess the potential importance of alvars for Canadian and North American biodiversity for future conservation purposes.

MATERIALS AND METHODS

Study area

Four different alvar types were sampled on Manitoulin Island (Figure 1). The first site was located on the south shore of the island within the Misery Bay Provincial Park (45°47'26"N; 82°45'00"W) and is referred to as a pavement alvar (Table 1). It is characterized by the presence of flat dolostone (mostly bare or covered by mosses and lichens), a few grass patches growing in cracks and a few shrubs. The sampling was done in an open area although some jack pine (*Pinus banksiana* Lamb.: Pinaceae) stands were interspersed over most of the park. The second site is a shrubland alvar, about ten kilometers west of Evansville (45°49'18"N; 82°41'04"W). Roughly 65% of the area is covered by shrubs such as the common juniper (*Juniper communis* L.: Cupressaceae) and the remaining 35% is almost entirely open limestone bedrock with some eastern white cedars (*Thuja occidentalis* L.: Cupressaceae) and white pines (*Pinus strobus* L.: Pinaceae) noticeable. This site has some very narrow and deep cracks in the bedrock (about 5 centimeters wide and 1.5 - 2 meters deep) and is referred to as "deep-crack" alvar in the text. The third site sampled (about 10 km southwest of Gore Bay: 45°52'12"N; 82°31'48"W) was a bur-oak grassland savanna alvar, which is characterized by about 65% of ground cover consisting of grasses and sedges, with the rest of the habitat covered by bur-oak trees (*Quercus macrocarpa* Michx.: Fagaceae) and a few bare rock openings. Unlike the first two types of alvars, the bur-oak grassland savanna alvar has a thicker layer of soil sometimes reaching 20 - 25 cm in depth. The fourth site was located about 10 km west of Gore Bay (45°53'45"N; 82°34'41"W) and is a grassland alvar with soil depth similar to the bur-oak alvar. Herbaceous vegetation covers close to 95% of the area but no trees are present. The vegetation, hydrology and the geological features on the grassland site enabled rainwater to remain trapped in temporary pools during most of the sampling season. The first three sites are on Silurian dolostone while the grassland alvar is on Ordovician limestone.

Sampling techniques

Because this project is a multitaxon biodiversity assessment, several standard collecting techniques were required to maximize the number of specimens and diversity of arthropods sampled (Marshall et al., 1994; Danks, 1996). On each of the four sites 16 pitfall traps consisting of white plastic beer cups (top diameter of 9 cm), 16 pan traps (yellow 12 Oz. "Party Bowls") and two flight intercept traps (80 X 80 cm squares of commercial polystyrene black window screen supported by two wooden sticks and twine with a yellow painted wallpaper tray as collecting bowl) were used. The pitfall traps, pan traps and flight intercept traps were filled approximately half way with commercial plumbing antifreeze (propylene glycol), as a preserving fluid, and a few drops of detergent or Kodak Photoflo® as a wetting agent. One Malaise trap was also used on each of the sites. The preserving agent used in the Malaise trap was ethylene glycol. Because of the lack of available soil, it was impossible to set the traps in a grid system as would have been preferable. All of the traps were emptied twice a month and specimens were preserved in 70% ethanol until their preparation for identification. No control open areas (i.e. agricultural field, marsh, etc.) were sampled on Manitoulin Island to compare the insect fauna of alvars with. The investigation for potential sampling sites occurred in the last week of April 1996. All of the traps were in place from mid-May until mid-September of 1996. The results in this manuscript are based entirely on one season of sampling.

Sweeping with an aerial net was done for one to two hours during each visit to the sites in order to maximize the number of Auchenorrhyncha collected and to sample the butterfly fauna. Butterflies were placed in a stamp envelope and then put in a killing jar containing ethyl acetate.

Trap residues from each site and each trap type were sorted in the laboratory. Individuals of the target taxa were processed as follows: the ground beetles and the leafhoppers and allies were dried on paper towels directly from 70% ethanol for an hour or two and then pinned or pointed. The sawflies were sent to Dr. H. Goulet (Agriculture and Agri-Food Canada, Ottawa) where they were critical point dried and pinned. Specimens of Lepidoptera were put in a relaxing chamber, then pinned and spread. All of the specimens are stored either in the Lyman Entomological Museum and Research Laboratory (Ste-Anne-de-Bellevue, Quebec) or at the Canadian National Collection of Insects (Ottawa, Ontario).

Reference material used and confirmation of identifications by specialists.

1) Specimens of the family Carabidae were identified and their distribution and status determined using Lindroth (1961, 1963, 1966, 1968, 1969a, 1969b) and Bousquet and Larochelle (1993). All of the identifications were confirmed by both Dr. H. Goulet and Dr. Y. Bousquet (Agriculture and Agri-Food Canada, Ottawa).

2) Specimens of the suborder Auchenorrhyncha were partially identified by the author and all of the identifications were confirmed by Dr. K. G. A. Hamilton (Agriculture and Agri-Food Canada, Ottawa). Details on the distribution and status of the various species were also obtained from Hamilton (1982, 1990, 1994, 1995), Panzer et al. (1995) and unpublished data from Dr. Hamilton. Host plant associations were provided by K.G.A. Hamilton (unpublished data).

3) Specimens from the suborder Symphyta were identified by Dr. H. Goulet and data on the status and distribution of the species was obtained from Goulet (1986, 1992), Smith (1969a, 1969b, 1969c, 1971, 1989), Ross (1938, 1943), Gibson (1980), Townes (1951) and unpublished data from Dr. Goulet.

4) Specimens of the superfamilies Papilionoidea and Hesperioidea were identified by the author using Audubon Society Field Guide to North American Butterflies (1990) and Laplante (1985). The information on the status and distribution of the species was obtained from Holmes et al. (1991) and the Toronto Entomological Association yearly butterfly sighting list (Hanks, 1996, 1997).

Quantitative analysis

Species diversity within each of the sites was calculated using the Shannon Diversity Index (Magurran, 1988). The Shannon Index was used in this study because it assumes that the data represent a random sample (although the traps in this study could not be placed in a random fashion) from a large (infinite) population, and because the index values incorporate rare species (i.e. richness of a community) rather than being heavily influenced by dominant (i.e. abundant) species. The corresponding evenness value, which represents the ratio of observed diversity to maximum diversity (Magurran, 1988) was also calculated for each site. A Student's t-test was used to test for significant difference between the diversity indices of different alvar sites (Hutcheson, 1970). Jaccard's Similarity Index (Magurran, 1988), which considers only the presence or absence of species shared between sites, and Sorensen's Quantitative Index of Similarity (Magurran, 1988), which considers both the number of species and the number of shared specimens, were used to quantify the similarity between the faunas of each alvar type for the two most abundant families, Carabidae and Cicadellidae (Auchenorrhyncha). Dendrograms based on the similarity indices were constructed following the methods outlined in Spellerberg (1991).

RESULTS

1- FAMILY CARABIDAE

Species diversity and significant taxa

A total of 3538 ground beetles, representing 90 species, was collected in 1996 (Table 2). This was a higher number of species than initially expected, given that a total of 95 species of carabid beetles was collected in several decades of sampling on the Great Alvar of Öland, Sweden (Lundberg, 1983). Among the 90 species collected in 1996, 12 were identified as significant (i.e. rare species, species restricted to alvars, species with disjunct distributions, etc.); notes on each of these significant species follow.

Agonum nutans **(Say):** This eastern North American species occurs from Ontario south to Florida. According to Lindroth (1966) the true habitat of *Agonum nutans* was still unknown. Most of the specimens collected before the present study were from drift material on the shore of lake Erie according to Lindroth (1966). It was collected in large numbers in the grassland alvar west of Gore Bay (N=370) (Table 2). The 1996 data showed a peak of abundance of adults in mid August and the presence of teneral adults from mid July until mid September (figure 2). There was an additional peak of adult activity in early summer, probably due to the emergence from hibernation of overwintering adults. Blatchley (1910) reported that adults of *A. nutans* hibernate in Indiana; the 1996 results were consistent with Blatchley's observations. The numerous specimens collected indicate that I collected the largest number of specimens of this species in any collection in the world.

***Bembidion rapidum* LeConte:** One specimen was collected at the pavement alvar site. This species has its main range in western Canada, but has also been recorded in southern Ontario. The species was unexpected on Manitoulin Island and it may be disjunct in its distribution. Lindroth (1966) suggested that the habitats of this species are sandy lake shores and clay river banks.

***Carabus serratus* Say:** A total of 47 specimens was collected with at least two specimens in each of the four sites. Most specimens were taken on the pavement alvar (Table 2). This species is widespread in North America, but difficult to find in large numbers throughout its range. Adults usually live in dry open habitats, which makes well-drained alvars an attractive habitat for this species.

***Carabus sylvosus* Say:** Ten specimens of this species were collected, all on the pavement alvar. The presence of this species in alvars is unusual as it is usually restricted to pristine forests, at least in southern Ontario (Lindroth, 1961). It is distributed in eastern North America from Florida north to Petawawa, Ontario and Quebec City; the species is at or close to its northern limit on Manitoulin Island. The individuals collected probably came from a stand of jackpine close to some of the traps on the pavement alvar. Given that this is a large and obvious beetle, and that there have been many professional and amateur coleopterists active in Ontario and Quebec over the years, it appears that this is a rare species in these provinces.

***Chlaenius p. purpuricollis* Randall:** This widespread North American species has been described as rare and very local (Lindroth, 1969). Blatchley (1910) reported *C. p. purpuricollis*. as a rare species occurring along the shores of Lake Michigan. The ecology of *Chlaenius p. purpuricollis* is not known (Lindroth, 1969). It was found in dominant numbers in the bur-oak savanna grassland site but also in small numbers in the pavement and grassland sites (Table 2). In Ontario, it has only been collected from alvars. Once again, this is the largest collection of this species in the world. *Chlaenius p. purpuricollis* appears to be spring breeder according to the 1996 data. Adult abundance peaked in early June (Figure 3) as overwintering adults emerged from hibernation. The few teneral adults collected were taken between mid July and early September. Lindroth (1969) assumed that adult hibernation occurs in all species of *Chlaenius* occurring in Canada and the seasonal abundance of *C. p. purpuricollis* is consistent with that assumption.

***Cicindela denikei* Fabricius:** Twenty-one specimens were collected, 14 from the deep-crack alvar, which has very little soil, and the rest from the bur-oak alvar where more soil is available. Many more adult specimens were seen on bare limestone especially during warm sunny days (they were most active during June and July). *Cicindela denikei* is very similar to the closely related, and more widespread species *Cicindela sexguttata*, and was treated as a subspecies of *C. sexguttata* until Kaulbars and Freitag (1993) elevated it to full species status. This species was previously known only from northwestern Ontario and southeastern Manitoba (Wallis, 1961); Manitoulin Island represents a major range extension. Larvae of *C. denikei* are unusual in that the opening of their burrow is under rocks, not exposed as in other tiger beetles. Specimens of *C. sexguttata* have been collected in Gore Bay (M. Kaulbars, pers. comm.) so Manitoulin

Island would be the first area in which both species have been recorded in such close proximity to each other.

***Cicindela p. purpurea* Olivier:** Five specimens were collected, two in the pavement alvar and three in the bur-oak alvar. This insect is widely distributed in temperate regions of North America, but it is usually difficult to find in cold temperate regions of eastern Canada. It is more common in the western part of its range. Gunderman (1997) reported collecting only one specimen of this species in Ontario over the course of a long collecting career in the province. Manitoulin Island is at the northern limit of this species' range in Ontario. Its preferred habitat has been described as fields with clay or hard-packed soil adjacent to a field habitat (Gunderman, 1997). In the alvar sites, adults are very hard to see because of their cryptic colour pattern on favored hunting sites (black organic soil, lichens and scattered grass clumps). However, on bare limestone they are more easily seen. Alvars may be a preferred habitat of this species in Ontario.

***Cymindis americanus* Dejean:** One specimen was collected on the pavement alvar. This eastern North American species is very rare in Ontario (21 specimens are known from Ontario and Quebec in the Canadian National Collection). Its habitat has been described as open, well drained areas with a sand base. Manitoulin Island is at the northern limit of its range in Ontario.

***Harpalus fallax* LeConte:** Forty-one specimens were collected from three alvar sites (pavement, bur-oak, and grassland alvars), with most specimens taken on the pavement alvar. Adults are rarely collected generally but are not restricted to alvars. Because of problems with the taxonomic status of this species the preferred habitat is not well understood although it seems to be associated with open meadows. This species is very closely related to *H. somnulentus* and is considered a synonym by Noonan (1991). Based on large series of specimens from Manitoulin Island and the Sudbury region, there is evidence that the two are distinct species, as assumed by Lindroth (1969a).

Harpalus faunus **Say:** A total of 29 specimens was collected from the pavement, bur-oak and grassland alvars, with most specimens taken on the bur-oak alvar. This beetle is associated with open areas such as gravel pits and it is rarely collected.

Harpalus puncticeps **Stephens:** Seven specimens of this species were collected in the pavement, bur-oak and grassland alvars. It is an introduced European species whose range in North America is rapidly expanding; it occurs in open areas. Potential effects of this species on native species has yet to be evaluated.

Pterostichus novus **Straneo:** The global distribution in North America is incompletely known (Lindroth, 1966) although all evidence seems to point towards a eastern central representation (Bousquet and Larochelle, 1993). *Pterostichus novus* appears to be associated with all types of alvars (one of only two ground beetle species that have been found in all of the alvar sites investigated), but was most abundant in the open and dry habitats of the pavement alvar and savanna grassland alvar (Table 2). It was found in dominant numbers in three sites on Manitoulin Island in 1996 (Table 5). Lindroth (1966) reported collecting four specimens of *P. novus* in a "moist hardwood forest among dead leaves near a small brook at Aweme, Manitoba. Other than that report, there is little published information on the natural history of this species. It seems very rare in southern Ontario and the distribution and habitat preferences of this species are not well known. Both adult abundance and the number of teneral adults peaked in mid August in 1996 (figures 4). There was no appreciable peak of adult activity early in the season, suggesting that adults may not overwinter, or that they do so in relatively low numbers.

Geographic affinities

Of the 90 species of Carabidae collected, over half are widespread in North America (Table 2). Twenty-seven species (30% of the fauna) are eastern North American (including two introduced European species: *Harpalus puncticeps* and *Trechus quadristriatus*). The next largest component of the alvar fauna is northern (boreal), with eight species (9% of the fauna). Three species, *Bembidion rapidum*, *Carabus sylvosus* and *Harpalus caliginosus*. *Pterostichus novus* is not included in the above figures because its distribution is incompletely known.

Five of the carabid species (5.5%) are introduced European species: *Agonum muelleri*, *Carabus nemoralis*, *Harpalus puncticeps*, *Pterostichus melanarius* and *Trechus quadristriatus*. The proportion of European species is quite low compared to many other eastern North American habitats, mirroring the pattern seen in the alvar plant flora. The introduced carabids, particularly *P. melanarius*, are usually associated with fields that have been used previously for agriculture. Most of the specimens were collected in the bur-oak and grassland alvars; none of the European species was found on the deep-crack alvar.

Composition of carabid fauna within alvar types

The deep-crack alvar had the fewest total specimens (478) and total species (21) of all sites; all other sites had much greater numbers of specimens and species, to a maximum of 52 species in the grassland alvar, and 1201 specimens in the bur-oak alvar (Table 2). Although the abundance of beetles, roughly reflected in total number of trapped specimens, was very similar in the bur-oak and grassland alvars, the latter site, with 52 species, had a much higher species richness (total number of species).

The Shannon Indices of the pavement, bur-oak and grassland alvars are not significantly different from each other, whereas the deep-crack alvar is significantly less diverse than the other three sites (t-test, $p>0.001$) (Table 3). The low evenness numbers suggest that the species sampled are not equally represented in any of the sites; this was expected because, unlike species diversity, species evenness tends to decrease with sample size (Hurlbert, 1971). The site with the lowest evenness value is the deep-crack alvar (Table 3) in which 67% (318 of 478) of the specimens collected belong to a single species, *Pterostichus coracinus*.

Comparison of fauna between alvar types

Both Jaccard's and Sorensen's Index indicate that the carabid species assemblages of the bur-oak and grassland alvars are most similar to each other than to any other sites (39.13 and 43.44 % similarity for Jaccard's and Sorensen's Index, respectively) (Table 4, Figure 5), both in shared species as well as the abundance of those species. The results from the two indices do not correspond on the placement of the pavement alvar. Jaccard's Index places this site closer to the bur-oak and grassland group (Fig. 5a), whereas

Sorensen's Index groups the pavement alvar with the deep-crack alvar (Fig. 5b). The fact that the pavement and deep-crack alvars share three species that were present in dominant numbers (*Calathus gregarius*, *Pterostichus coracinus* and *P. novus*) has a strong influence on the clustering of the two sites based on Sorensen's Index. Overall, the dendrograms of both indices show that the carabid fauna shared between sites is relatively low.

An additional method for characterizing the carabid fauna of different alvar types is to examine which species is dominant in which sites. In this study, dominant species were those constituting at least 5% of the total carabid abundance in that site (Frank and Nentwig, 1995). Each of the sites has either four (deep-crack and grassland alvars) or five (pavement and bur-oak alvars) carabid species which are dominant (Table 5). None of the ten species listed were dominant in all of the sites although two were dominant in three of the sites (*Calathus gregarius* and *Pterostichus novus*). Conversely, four of the species are dominant only in one type of alvar: *Carabus serratus* and *Synuchus impunctatus* in the pavement alvar, *Agonum nutans* in the grassland alvar and *Chlaenius p. purpuricollis* in the bur-oak site.

2- SUBORDER AUCHENORRHYNCHA

Species diversity and significant taxa

A total of 5874 specimens of the suborder Auchenorrhyncha were identified from the four types of alvars in 1996. The majority of these (5257) belong to the family Cicadellidae while the remaining 517 come from eight smaller families (Table 6). From the 116 species listed, eleven (nine Cicadellidae and two Delphacidae) were found to be prairie endemics (i.e. species of interest).

***Aflexia rubranura* (DeLong)**: This species feeds exclusively on *Sporobolus heterolepis* (Gray) (Gramineae (Poaceae)) and is known only from "prairie relicts" in Ontario and Manitoba in Canada and also in four American States (South Dakota, Minnesota, Wisconsin and Illinois) (Hamilton, 1995). The presence of the host plant at a site does not ensure the presence of these leafhoppers since they are not always found where the host is (*S. heterolepis* can be found in several alvar regions around the Great Lakes (Catling and Brownell, 1995)). Specimens had previously been collected from Manitoulin Island before (see Hamilton, 1995) but I collected specimens in two new sites in Ontario: the Misery Bay pavement alvar and the bur-oak alvar south of Gore Bay. This species exhibits wing polymorphism and individuals with long wings were only known to occur in the Chicago region where the species has two distinct generations per year (K.G.A. Hamilton, pers. comm.). I found the first long-winged individuals of this species ever recorded in Canada: one at Misery Bay and seven in the grassland alvar. Most of the long-winged *A. rubranura* occur in the first generation in the United States where about 10% of the population consists of long-winged specimens (K.G.A. Hamilton, pers. comm.). No explanation has been proposed for the presence of long-winged specimens in Ontario since only one generation per year is known. Panzer et al. (1995) described this species as typical of xeric / mesic prairie habitats, and highly dependent on open, native-plant dominated vegetation remnants.

Auridius n.sp.: This species is restricted to a few sites in Alberta, southern Manitoba and northern Minnesota in North America as well as several alvar sites in northern Michigan and Ontario. Outside of alvars, it is only known from the sanhill system near Madawaska (Ontario) (Hamilton, 1994). I collected a total of 49 specimens from the pavement alvar of Manitoulin Island (1996). The host plant for this leafhopper is in the genus *Poa* (bluegrasses: Gramineae (Poaceae)).

***Flexamia delongi* Ross and Cooley**: This species was found in two alvars: pavement (6 specimens) and grassland (196 specimens). In Ontario it is only known from the Bruce Peninsula and the LaCloche and Manitoulin Islands (Hamilton, 1995). The pavement alvar in Misery Bay is a new site for this species. Its Canadian range is restricted to the provinces of Ontario and Manitoba where it feeds on *Andropogon scoparius* Michx. (Gramineae (Poaceae)). One specimen was collected during a visit to the pavement alvar at Belanger Bay (south shore of Manitoulin Island) constituting a new site as well. This species is thought to inhabit xeric prairies and is highly dependent on the presence of natural prairie-like remnants (Panzer et al., 1995).

***Laevicephalus unicoloratus* (Gillette and Baker)**: This species, which feeds on *Andropogon spp.* (blue-stems: Gramineae (Poaceae)), is known in Canada only from Manitoba and Ontario. Specimens had previously been collected by K.G.A. Hamilton on the grassland alvar so no new sites are reported. This is another example of a highly restricted species which only occurs where prairie-remnants have been maintained (Panzer et al., 1995).

***Limotettix urnura* Hamilton**: This species is distributed from Saskatchewan to Ontario in Canada and feeds on *Eleocharis elliptica* Kunth (Cyperaceae). Specimens had previously been collected by Hamilton on Manitoulin Island before but two new sites were identified in 1996, the pavement alvar of Misery Bay and the bur-oak alvar. This species can occur in large populations on alvars as I collected a total of 412 specimens on Manitoulin Island. Panzer et al. (1995) mentioned that this species is more typical of "wet prairies" with high dependence on prairie relicts.

Memnonia n.sp.: In Ontario, this species is restricted to the Bruce Peninsula, one site in Eastern Ontario (Almonte alvar), Great LaCloche and Manitoulin Islands. A new site (pavement alvar) was identified in 1996 but most of the specimens collected were found in the grassland alvar west of Gore Bay. This species is often found with *Aflexia rubranura* and feeds on *Sporobolus heterolepis*. It is known from Manitoba and Ontario in Canada.

***Mocuellus americanus* Emeljanov**: This species is restricted to the northern mixed-grass prairies in North America and occurs from Alberta and Montana in the west east to southern Manitoba and Wisconsin. It is only found in alvars of Manitoulin and surrounding Islands in eastern North America. I found 71 specimens in the pavement alvar of Misery Bay in 1996. The host plant for this species is *Leymus trachycaulus* (KGA Hamilton, pers. comm.).

***Paraphlepsius lobatus* (Osborn)**: A total of 21 specimens were collected from Manitoulin Island alvars in 1996 (12 from Misery Bay and 9 from the grassland alvar). Even with the collecting of Hamilton on Manitoulin Island in previous years, specimens were never found there. It has been collected almost entirely in alvars in Ontario and Michigan although it has also been found in deep soil prairie remnants (i.e. Ipperwash P.P. and Pinery P.P.) (Hamilton, 1995). These leafhoppers feed on *Andropogon scoparius* Michx. (Gramineae (Poaceae)) and are only known from Manitoba and Ontario in Canada. This species has been identified as moderately dependent on native prairie-like remnants which is typical of the wet prairies in the Chicago area (Panzer et al., 1995).

***Texananus marmor* (Sanders and DeLong)**: The largest number of specimens of this species was collected at the pavement alvar of Misery Bay (13) although three specimens were also collected from the grassland alvar west of Gore Bay. Once again, this species had not previously been collected on Manitoulin Island. It is only known from the northern mixed-grass prairies of Alberta, Saskatchewan, Manitoba and Montana; in the east, it occurs only on Manitoulin and surrounding Islands as well as on the Bruce Peninsula.. It feeds on the creeping juniper (*Juniperus horizontalis* Moench: Cupressaceae).

***Liburnia parvula* (Ball)**: This species was collected on two alvar sites on Manitoulin Island: three specimens in the pavement alvar and 56 in the grassland alvar. This insect feeds on bluestems (*Andropogon spp.*: Gramineae (Poaceae)) and can be found almost everywhere the host plant is. It has been collected in several areas in Ontario and Manitoba.

***Caenodelphax nigriscutellata* (Beamer)**: This very rare prairie endemic species is known from three alvars in Ontario (one specimen from Almonte, one from Wikwemikong Indian Reserve on Manitoulin Island and 11 specimens from Dyers Bay on the Bruce Peninsula). I found six additional specimens in 1996, all from a new site at the grassland alvar (four males and two females). Other Canadian records include one specimen from Manitoba and three from Alberta. Potential hosts for this species in Ontario include *Eleocharis compressa* Sulliv. (Cyperaceae) and *Sporobolus heterolepis*.

Geographic affinities

Apart from the 11 species of Auchenorrhyncha which are endemic to the western prairies, all of the other species can be considered widespread in North America. Of the species recorded, eight are of European origin: two in the family Cercopidae (*Neophilaenus lineatus* and *Philaenus spumarius*) and six in the family Cicadellidae (*Anoscopus flavostriatus*, *Anoscopus serratulae*, *Aphrodes sp.*, *Athysanus argentarius*, *Doratura stylata* and *Elymana sulphurella*).

Composition of Cicadellidae fauna within alvar types

The number of individuals of Auchenorhynca collected on the four sites varied greatly. The bur-oak and grassland alvars support the highest number of specimens once again, with the pavement coming third and the deep-crack alvar representing by far the poorest site for abundance of Auchenorrhyncha. However, the presence of more specimens on the bur-oak and grassland sites does not necessarily mean that the number of species is higher there. In the present case, the pavement alvar has the highest number of species with 63 as compared to 51 and 49 for the bur-oak and grassland sites respectively. A total of 35 species was recorded in the deep-crack alvar.

Data from the family Cicadellidae (the most abundant family in the Auche-norrhynca) were used for quantitative analysis. Results show that the pavement and deep-crack alvars are significantly more diverse than the other two sites (note also that they have higher evenness numbers) (Table 7). The bur-oak alvar was the least diverse site of the four with a diversity index of 1.972. Based on these results it could be hypothesized that, although the sites with more vegetation can support a significantly higher number of specimens (or biomass) of leafhoppers, they do not necessarily support a higher number of species, they simply have more specimens of their dominant species (see Table 9).

Comparison of fauna between alvar types

The patterns obtained from the similarity indices with the family Cicadellidae were almost identical to those obtained for the family Carabidae (Table 8 and Figure 6). The bur-oak and grassland alvars are grouped together using both Jaccard's and Sorensen's indices. The pavement alvar is placed either as the closest to the bur-oak and grassland group (using Jaccard's index) or grouped with the deep-crack alvar (using Sorensen's index). The percentage of similarity in the leafhopper fauna among the four alvar sites is low using both indices but especially so using Sorensen's index (12 and 11 % for the bur-oak/grassland and the pavement/deep-crack groups respectively) (Figure 6b).

A total of 19 dominant species of Auchenorrhyncha (17 Cicadellidae. 1 Cercopidae and 1 Derbidae) were recorded and listed in Table 9. Each of the sites had between four and six dominant species: four for the bur-oak, five for the grassland and six for the pavement and deep-crack alvars. The four dominant species in the bur-oak alvar account for 76% of the total number of specimens recorded which is higher than the dominant species assemblage of any other site and is consistent with the low diversity numbers obtained on that site (Table 7). Of the dominant species of Cicadellidae, only two out of 17 (*Limotettix urnura* and *L. arctostaphili*) are present in dominant numbers on more than one alvar site. This explains the low similarity percentages obtained with the Sorensen's index (i.e. the number of specimens shared by any two sites is very small).

3- SUBORDER SYMPHYTA

Species diversity and significant taxa

The reason that the sawflies were selected as a target group for this study was because of the presence of two prairie sawflies which had been found in Almonte alvars near Ottawa and Quyon (near Aylmer, Quebec) by Dr. Henri Goulet. These species (*Blennogeneris spissipes* (Cresson) and *Zachizonyx montana* (Cresson)), which feed on *Symphoricarpos* (Caprifoliaceae) plants were unfortunately not collected on Manitoulin Island alvars in 1996 although the host plant is present in the bur-oak and pavement alvars (J. Jones, pers. comm.). Of 262 specimens of sawflies, 48 species were identified from the four alvar sites sampled (Table 10). The host plant is known for 32 of the species (Table 11). A list of vascular plant species recorded on each of the sites (J. Jones, unpublished data) was used to assess if the presence of a certain sawfly species is an accident (if host plant has not been reported from that site) or if the sawfly species is expected on that site (host plant recorded there). Although no prairie sawflies were collected, some taxa of interest were identified.

***Sterictiphora serotina* Smith** (Argidae): This species, which is rarely found in Canada, feeds on black cherry trees (*Prunus serotina* Ehrh.: Rosaceae) and was found on the bur-oak alvar even though the host plant has not been recorded from the site. This sawfly would be expected to occur on the pavement alvar of Misery Bay because the host plant is present on that site (Table 11).

***Empria candidata* MacGillivray** (Tenthredinidae): This boreal species is thought to be at the southern limit of its range on Manitoulin Island and feeds on *Betula sp.* (birches: Betulaceae). One specimen was collected in the pavement alvar site but it is thought to be an accidental occurrence there. This species would be expected to occur in the deep-crack alvar (Table 11).

***Eutomostethus luteiventris* (Klug)** (Tenthredinidae): This European species (host plant = *Juncus sp.* (rushes: Juncaceae)) is at the northwestern limit of its range on Manitoulin Island. Samples from the bur-oak alvar, the expected habitat, contained one specimen of this species. The specimen collected on the grassland alvar is thought to be an accident.

***Periclista albicollis* (Norton)** and ***P. diluta* (Cresson)** (Tenthredinidae): Members of this genus are very rarely caught both in Ontario and Quebec. Both species feed on oaks but the previously known host plant for *P. diluta* was the white oak which is not found on Manitoulin Island (Morton and Venn, 1984). *Periclista albicollis* (host plant = *Quercus macrocarpa*) was collected only on the bur-oak alvar where it was expected. This species was also expected on the grassland alvar but not collected there (Table 11).

Genus *Tenthredo spp.* (Tenthredinidae): This genus contains more than 50 species in southern Ontario and Quebec and has been very uncommon in trap catches since the early 1980's (H. Goulet, pers. comm.). In the Ottawa and Montreal region, members of this genus usually represent less than 1% of the total number of sawflies collected. Surprisingly, 98 of the 262 specimens collected (nine species, at least one present in each of the four sites) on the Manitoulin Island alvars were from the genus *Tenthredo*. The individuals in this genus feed mainly on herbaceous vegetation and are usually quite specific as to their host plants. Adults feed on other insects and the extensive usage of herbicides and insecticides in agricultural regions such as Ottawa and Montreal is believed to have had a detrimental effect on the populations of *Tenthredo* (H. Goulet and L. Masner, pers. comm.). Manitoulin Island supports agricultural practices also but the pristine nature of alvars might help to preserve refuge populations of this genus.

Geographic affinities

Of the 48 species of sawflies collected, there are distribution data on 36 (see list of references in Materials and Methods section). Of these species, 14 species (39% of the fauna) are widespread in North America (Table 10). Twenty-one native species (58%) are found east of the Rocky mountains in temperate regions (eastern). The last component of the alvar fauna is northern (boreal) (3%), with one species. There are no prairie or southern species recorded. Several eastern species are near the northern limit of their distribution.

Two of the sawfly species (5 %) are accidentally introduced from Europe: *Pristiphora pallipes* and *Eutomostethus luteiventris*. The proportion of European species is quite low compared to the southern Ontario average (11%) (Goulet, 1996). Moreover, these species are rare, mirroring the pattern seen in the alvar plant flora. The two introduced sawflies are usually associated with fields that have been used previously for agriculture. All of the specimens were collected in the bur-oak and grassland alvars; none of the European species was found on the deep-crack and pavement alvars. The first two sites have been used in the past (more than seven years ago) as pasture fields.

Composition of Symphyta fauna within alvar types

The highest number of specimens collected was on the pavement alvar (123) with the bur-oak (70), grassland (37) and deep-crack (32) sites following. Although the bur-oak alvar had 50 specimens less than the pavement alvar, it was the richest site with 32 species recorded there. The deep-crack and the grassland alvars had the lowest species richness of all the sites. Because of the small number of specimens collected from the suborder Symphyta, no quantitative analysis was performed (i.e. diversity index, similarity indices, or dominant species).

4- SUPERFAMILIES PAPILIONOIDEA AND HESPERIOIDEA

Species diversity and significant taxa

In Table 12, a list of the 40 species of butterflies and skippers collected and sighted on the various alvars of Manitoulin Island is given. Brunton (1986) reported 41 butterfly species from the Burnt Lands alvars and 54 species have been found in association with the Carden alvars in approximately the last 10 years (Bob Bowles, pers. comm.). Some species of interest include

***Erynnis lucilius* (Scud. and Burg.)** (Hesperiidae) : Seven specimens of this species were collected in Manitoulin Island alvars in 1996 (two in the pavement and five in the deep-crack sites). This species, which feeds on wild columbine (*Aquilegia canadensis* L. : Ranunculaceae), is considered to have stable populations in Ontario (S5 in Holmes et al., 1991) and is at the northern limit of its range on Manitoulin Island. It was only recorded from the pavement and deep-crack alvars. Nancy K. Ironside (pers. comm.) has found this species in large numbers on limestone outcrops in the Carden region alvars.

***Hesperia comma* (Linnaeus)** (Hesperiidae): One specimen was collected in the pavement and one in the grassland alvars in 1996. Only three specimens of this species were listed in the records of Lepidoptera by the Toronto Entomologist Association (Hanks, 1996) although it is listed as non-threatened by Holmes et al. (1991). This species is near the southern limit of its range on Manitoulin Island.

***Incisalia polia* Cook and Watson** (Lycaenidae): This species was collected on both the pavement and deep-crack alvars in 1996. The hoary elfin, which feeds on bearberry (*Arctostaphylos uva-ursi* (L.): Ericaceae), has been identified as a subarctic species in Brunton (1986) which would put it close to the southern limit of its range on Manitoulin Island. It is of restricted occurrence in Ontario (Catling and Brownell, 1995) although it is not threatened according to Holmes et al. (1991).

***Epidemia dorcas* (Kirby)** (Lycaenidae): Specimens of this species were collected in three of the four alvar sites investigated in 1996: eight in the pavement site, two in the bur-oak site and three in the grassland alvar. This species was collected only in one Ontario locality (Brantford) in 1995 (Hanks, 1996). Adults were found in great numbers mainly in August and were seen on the shrubby cinquefoil (*Potentilla fruticosa* L.: Rosaceae) which is the main larval food plant. Large populations seem to be living in all alvar sites except the deep-crack alvar. The status S5 given by Holmes et al. (1991) shows that it is not under any threat in Ontario.

***Euchloe ausonides* Lucas** (Pieridae): Only one specimen of this species was collected on Manitoulin Island alvars in 1996 (pavement alvar). The large marblewing is at the southern limit of its range on Manitoulin Island. The adults can be found in the spring during a very short period. In 1995, only 2 specimens were recorded in Ontario (Hanks, 1996) and both individuals had been collected flying across Little Lake Huron road inside the Misery Bay Provincial Park which is also where I collected my only specimen. No records were reported for the 1996 field season for the province of Ontario (Hanks, 1997). The food plant for this insect is the rock cress (*Arabis spp.*: Cruciferae).

***Euchloe olympia* (Edwards)** (Pieridae): The bur-oak alvar is the only site where this species was collected. The Olympia marblewing is at the northern limit of its range on Manitoulin Island. Holmes et al. (1991) listed this species as S4 (apparently secure) and mentioned that it is associated with dry limestone or sandy areas between Lake Huron and Eastern Ontario. The larvae feed on rock cress (*Arabis spp.*) and other plants of the mustard family (Cruciferae).

***Oneis chryxus* (Doub. and Hew.)** (Satyridae): Eight specimens of this species were collected on the pavement alvar of Manitoulin Island in 1996. This subarctic species was also recorded on the Burnt Lands alvars (Brunton, 1986) and is close to the southern limit of its range on Manitoulin Island. The Poverty grass (*Danthonia spicata* (L.): Gramineae (Poaceae)) is one of the favorite host plants of the larvae. Holmes et al. (1991) listed it as S4 and in 1995 it was only found in one locality (Matachewan, Ont.) in jack pine barrens (Hanks, 1996) which is consistent with my data since all of my specimens were collected in the pavement alvar of Misery Bay.

Geographic affinities

Most of the butterflies and skippers recorded on Manitoulin Island alvars have a widespread distribution (35) although a small number of boreal (4) and southern (1) species were also recorded. European species recorded on the alvars included *Thymelicus lineola*, *Pieris rapae* and *Nymphalis antiopa*.

Composition of Papilionoidea and Hesperioidea fauna within alvar types

The greatest diversity and abundance of butterflies and skippers was found at the pavement alvar site (Table 12). As for the suborder Symphyta, the bur-oak alvar was the second richest site, with the deep-crack and grassland alvars coming last. Because of the small number of specimens collected from this target group, no quantitative analysis was performed.

DISCUSSION

Arthropods as biological indicators

Terrestrial arthropods, especially insects, possess many qualities that make them particularly useful as biological indicators when compared to vertebrates (Landres et al., 1988; Pearson and Cassola, 1992; Oliver and Beatie, 1996). Arthropods are usually short lived, have wide variations in populations (related to perturbations in their habitat, disease, predation levels, etc.), dominate all terrestrial ecosystems (in number of species and biomass), occupy the widest possible diversity of microhabitats and niches, often play key ecological roles in their communities, can be sampled easily by non-professionals and are often very habitat specific (Holloway and Stork, 1991; Kremen et al., 1993; Danks, 1996). However, insects are generally so diverse and numerous, that it would take an inordinate amount of time, and human and financial resources to study them all simultaneously (Danks, 1996). The proper choice of indicator taxa, in any biodiversity study, is thus crucial in order to be able to answer the questions asked in the planning phase. Some of the most important characteristics to consider when selecting an indicator taxon are the availability of systematic support, their manageable collecting, sorting, preparation and identification time and the potential value of the ecological insights they can provide (Marshall et al., 1994; Pearson, 1994; Danks, 1996). All of the taxa selected for this study have some of the most extensive systematic support among Canadian insects, and their ecological preferences, host plants (for phytophagous insects) and distributions are well understood for most of the species.

Overall abundance and richness of insects in Manitoulin Island alvars

A total of 9791 specimens were identified from the target taxa selected for this study. The bur-oak alvar supported the largest number of specimens with 4290 (44%), followed by the grassland, pavement and deep-crack alvars (2940, 1842 and 719 specimens respectively). These differences in abundance (especially for the phytophagous Auchenorrhyncha) can be attributed to the percentage and thickness of vegetation cover on the various sites. The bur-oak and grassland alvars had only a small percentage of their area occupied by open bedrock whereas the pavement and deep-crack alvars had restricted vascular vegetation cover due to their large area occupied by denuded bedrock. Belcher et al. (1992) reported that the average vascular plant biomass levels in alvar habitats, were strongly correlated with soil depth. The bur-oak alvar can support a higher vegetation biomass than the grassland alvar due to the much thicker layer of soil available on the bur-oak site (average soil depth 8 cm and over 16 cm for the grassland and bur-oak sites, respectively, J. Jones unpublished data).

Within a defined community type, species richness (i.e. number of species) is thought to increase in direct relation to the number of individuals collected (Schluter and Ricklefs, 1993). If this were the case, the bur-oak and grassland alvars would support the largest number of species of the four sites sampled. However, the pavement alvar was the richest site with 152 species followed by the bur-oak, grassland and deep-crack sites which supported 145, 126 and 81 species respectively. The surprisingly high number of species (compared to abundance of specimens) found in the pavement alvar could be explained by "environmental heterogeneity". Under conditions of extremely low productivity, there is not much habitat or resource heterogeneity because the landscape is bare. Similarly, areas with uniformly distributed resources will not harbor a species rich community because of the reduction in heterogeneity of resources and microhabitats (Rosenzweig and Abramsky, 1993).

As found by Belcher et al. (1992), the species richness of plants increased with biomass until a certain point at which species richness decreased at maximum biomass. Assuming that plant and insect biomass and diversity are directly correlated (i.e. availability of food, shelter, etc. for the insects will depend on the type and density of vegetation cover) it could be predicted that alvars with almost no soil available (i.e. deep-crack alvar) will not support many insect specimens and species and that sites with more or less uniformly thick soil (i.e. bur-oak alvar) will support a high number of specimens but will not be the richest in species number because of the relative homogeneity in the available resources. In the pavement alvar of Misery Bay, the occurrence of pavement bedrock plant species (e.g. *Minuartia michauxii* (Fenzl): Caryophyllaceae) and taller grasses such as *Sporobolus heterolepis* in close proximity shows that species from both ends of the soil depth gradient are represented (Belcher et al., 1992). This close association of plant species demonstrates the heterogeneity of the critical resource, in this case soil, and therefore the availability of many different microhabitats for insects to exploit.

Also important in determining the arthropod fauna of a particular site, is the presence and persistence of water bodies. For example, the grassland alvar had the highest number of species of ground beetles with 52 and this can be attributed to the presence of temporary ponds on that site for a large portion of the summer. Species such as *Agonum harrisi, A. trigeminum, Bembidion mimus, Brachinus cyanochroatichus, Chlaenius impunctifrons* and others are strongly associated with the presence of water and, therefore, are absent from the other better drained alvar sites.

Comparison between the families Carabidae and Cicadellidae

Even more benefits from a biodiversity study can be obtained if more than one trophic level (or guild) can be assessed simultaneously. This is because groups in different guilds, such as predators and herbivores might show differences in their habitat requirements (Danks, 1996).

The two most abundant families in this study were the ground beetles (Carabidae) and the leafhoppers (Auchenorrhyncha: Cicadellidae) (3538 and 5574 specimens respectively). These families represent two very distinct guilds in alvar (and many other) communities, the ground beetles being generalist predators hunting on the surface of the ground, and the leafhoppers being a phytophagous group which inhabit the vegetation layer. Comparison between the two families was done using a diversity index as well as two similarity indices.

The use of diversity indices has been widespread in recent literature (e.g. Magurran, 1988; Spellerberg, 1991) although not always without criticism (Hurlbert, 1971). Different results were obtained using Shannon's index to quantify the diversity within the Carabidae and the Cicadellidae. In the ground beetles, the pavement, bur-oak and grassland sites were all equally diverse and were all significantly more diverse than the deep-crack alvar (Table 3). In the family Cicadellidae, the deep-crack alvar was surprisingly as diverse as the pavement alvar and significantly more diverse than the bur-oak and grassland alvars. The difference in the diversity numbers from one family to the other could be explained by the evenness numbers. In the family Carabidae, the deep-crack alvar supported one very dominant species (*Pterostichus coracinus*) which lowered the family's evenness value, whereas in the family Cicadellidae, the deep-crack alvar did not harbor a particularly dominant species which increased its evenness value higher than any other sites. As mentioned previously, although the bur-oak alvar contained the highest number of individuals of leafhoppers, it was not particularly diverse, but instead supported larger dominant populations (as exemplified by the lowest evenness value obtained by the bur-oak site for the family Cicadellidae: 0.559).

One of the objectives of this study was to evaluate the similarity between the four alvar types sampled on Manitoulin Island, in order to support the classification of alvar types as shown in Table 1. Comparing diversity indices partially answered this question but the use of similarity indices and the comparison of dominant taxa provided additional resolution. Even between distantly related taxa, such as the families Carabidae and Cicadellidae, which occupy completely different niches and microhabitats, it was possible to observe similar faunal assemblages among the different alvar sites. Using Jaccard's and Sorensen's indices, it was clear that the grassland and bur-oak alvars share the highest percentage of both their ground beetle and leafhopper faunas. What was not clear, however, was the placement of the pavement alvar. Is it closer to the bur-oak and grassland group (Jaccard's index) or to the deep-crack alvar (Sorensen's index)? Although this question cannot be fully resolved at this point, it is essential to note that the percentages of similarity are generally low within all of the dendograms obtained. This, plus the fact that the dominant ground beetle (Table 5) and leafhopper (Table 9) species differ considerably from one site to another (especially for the Auchenorrhyncha) confirms the need to consider the different types of alvars as distinct from one another.

I predict that the combination of dominant species of ground beetles and leafhoppers within each type of alvar will be consistent throughout the range of alvars and will, therefore, help in characterizing the different types on a global level.

Significant insect species

Because more emphasis should be given to the ecological importance of the species themselves, rather than their numbers alone (Terborgh, 1988), a list of biologically significant species from each target group was gathered. As for the arthropod fauna of Swedish alvars (see Entomologisk Tidskrift, vol. 104, 1983), a surprisingly high number of rare species, species with disjunct distributions or at the extreme limits of their range and species restricted to alvar habitats were found on the four Manitoulin Island alvar sites investigated in 1996. A total of 44 such species were identified. The highest number of significant species was found on the pavement site (31), with the bur-oak alvar (24) second and the grassland (20) and deep-crack (9) alvars third and fourth. Based on present data, it could be suggested that the conservation priorities should be in favor of the pavement alvar, with the deep-crack alvar given lowest priority, but further analysis (including the likelihood of reproduction of each of the species on a particular site, the presence of the species in more than one site, etc.) must first be considered.

Of the 12 species of interest identified from the family Carabidae, the greatest number (ten) was collected in the pavement alvar, followed by the bur-oak (eight species), grassland (seven species) and deep-crack alvars (three species). The pavement alvar had three species of interest which were not found on any of the other sites (*Bembidion rapidum, Carabus sylvosus* and *Cymindis americanus*) and the grassland alvar had one (*Agonum nutans*). Additionally, the pavement site supported two species of interest in dominant numbers (*Carabus serratus* and *Pterotichus novus*), and the deep-crack, bur-oak and grassland alvars one each (*P. novus*, *Chlaenius p. purpuricollis* and *A. nutans*, respectively) (Table 5). Only three species of interest are found in the deep-crack alvar of which the most significant is the tiger beetle *Cicindela denikei*. This species was most abundant in the deep-crack alvar, and adults were seen frequently on sunny days at the site.

The large number of specimens of *Agonum nutans*, *Chlaenius p. purpuricollis* and *Pterostichus novus* collected in this study allowed the determination of the seasonal abundance characteristics of those species for the first time. Adults of *Agonum nutans* were collected from 20 May until 15 September and the seasonal distribution of specimens shows one small peak in adult activity in late May and another in mid to late August (Figure 2). This pattern of seasonal distribution identifies the species as an "autumn breeder" characterized by summer reproduction, thermic diapause during larval development and hibernation in both immature and adult stages (Bousquet, 1986). For *C. p. purpuricollis*, there was a single peak of adult activity in late May to early June (Fig. 3), identifying the species as a "spring breeder" characterized by spring and early summer reproductive activity, continuous larval development and overwintering in the adult stage

(Bousquet, 1986). The species *P. novus* is also an "autumn breeder" (Figure 4) confirmed by the peak of adult abundance towards the end of the summer season.

Although 12 species of Carabidae were considered significant for a variety of reasons, two of these (*Chlaenius purpuricollis* and *Pterostichus novus*) are so abundant in alvars, and so rare elsewhere in the Great Lakes region, that they can be considered as potentially useful indicator species for alvars. Any record of these two species might indicate strong support for assuming the presence of an alvar in a specific area. *Agonum nutans* is also a rare insect which is found in largest numbers in alvars but being a strong flier (found occasionally outside of alvars), its indicator status is not as good as the first two.

Of the eleven prairie endemic species of Auchenorrhyncha recorded, nine were found in the pavement and grassland alvars, two in the bur-oak and none in the deep-crack alvar. Two of these (*Auridius sp.n.* and *Mocuellus americanus*) were found only on the pavement alvar and two others (*Laevicephalus unicoloratus* and *Caenodelphax nigriscutellata*) only on the grassland alvar. Moreover, the species *Aflexia rubranura*, *Flexamia delongi* and *Memnonia sp.n.* were found in dominant numbers on the grassland alvar and *Limotettix urnura* was collected in dominant numbers in the bur-oak and grassland alvars. These highly specialized prairie endemic species are thought to be some of the best indicators of habitat quality in native grasslands (Whitcomb et al., 1994; Panzer et al., 1995).

Among the 14 species of significance in the suborder Symphyta, the highest number (12) was found on the bur-oak alvar, followed by the pavement (6), the deep-crack (4) and the grassland (2) alvars. Adult sawflies are short-lived, which means that when they emerge, they disperse in all directions in the search for potential mates or host plants when copulation has occurred. Although this characteristic reduces the usefulness of sawflies as bioindicators, the close association of the immature stages with their host plants makes it possible to suggest whether the capture of a species within a certain habitat type is accidental or not. Two sawflies of interest were collected in a site where their host plant was recorded (Table 11); these were *Eutomostethus luteiventris* and *Periclista albicollis* both collected on the bur-oak alvar.

Of the species of butterflies and skippers of significance, the pavement alvar supported two species (*Euchloe ausonides* and *Oneis chryxus*) not shared by other sites and the bur-oak alvar one (*Euchloe olympia*).

From the analysis of the significant species within the different target groups, it could be demonstrated that the pavement and grassland alvars should be considered the two "most important" ecosystems biologically because they support a number of significant species which are not shared by any other site sampled and sustain dominant populations of many of those species. The loss of both types of alvars on Manitoulin Island would result in the extirpation of at least ten species of interest which are not shared by the other types of alvars based on the present data.

Origin of alvar insect fauna on Manitoulin Island

Because of unique conditions that have affected and still affect Manitoulin Island (i.e. post glacial history, geological features, past and present climatic conditions, etc.), the alvars found there support a flora which consists mostly (in order of proportion) of southern, northern and western plant species (Morton and Venn, 1984; Catling and Brownell, 1995). The presence of plants from many geographical areas on Manitoulin Island alvars is somewhat expected since on the islands of Öland and Gotland, it has long been known that the alvars support many plant species with clear disjunct ranges (e.g. arctic-alpine and southeastern European steppe species) (Pettersson, 1965). The Carabidae collected on Manitoulin Island, with only minor southern and western faunal elements, do not show the same geographic pattern as the plants. Most ground beetles are generalist predators and are usually associated with specific microclimatic conditions rather than prey or plant species (Lovei and Sunderland, 1996). As a result, close correspondence between geographic affinities of carabids and plants was not expected. Evidence for the post glacial occurrence of western prairie vegetation in southern Ontario (Catling and Brownell, 1995) is found in the presence of 11 prairie endemic Auchenorrhyncha (especially the flightless leafhoppers *Aflexia rubranura* and *Memnonia n.sp.*). None of the butterflies and skippers found on Manitoulin Island alvars had particular associations with western plants although Catling (1977) found a good example when he recorded the presence of the Garita skipper (*Oarisma garita*) on the pavement alvar of Great LaCloche Island, at least 1040 kilometers east of any previously known population. The northern component of the vegetation was exemplified by the presence of three species of butterflies, one species of skipper and one species of sawfly which have boreal distributions; whereas *Euchloe olympia* (Pieridae) was found to be at the northern limit of its range on Manitoulin Island alvars. The uniqueness observed in the numerous origins of plant species found on Manitoulin Island alvars seem to be supported by the presence of insects which occupy a wide range of "geographical regions" outside of these sites.

The number of European introduced insect species collected on Manitoulin Island alvars was low. Only 18 European species of a total of 422 were recorded (4.3%). In the family Carabidae, the most abundant introduced species was *Pterostichus melanarius* (138 specimens) which was found on the four alvar sites in various numbers. The only two European introduced sawflies *Pristiphora pallipes* and *Eutomostethus luteiventris* were also collected in the bur-oak and grassland alvars. In the Auchenorrhyncha, the bur-oak alvar supported by far the largest European fauna with 1457 specimens, most of which belong to two dominant species on that site (*Anoscopus flavostriatus* and *Aphrodes sp.*). The European froghopper, *Philaenus spumarius*, was found in large numbers on the pavement alvar where it was observed feeding on the endemic and threatened Lakeside Daisy. The most abundant introduced butterfly was the European skipper (*Thymelicus lineola*) which was recorded in very high densities during the month of July on all of the sites (as well as any other open habitat on Manitoulin Island).

Because one of the major goals in the management of natural areas is to maintain the diversity found in pristine ecosystems (Kremen et al. 1993), it would be ideal if no introduced species were present. Unfortunately, the presence of such fauna (exemplified by generalist, opportunistic species) is an integral component of all North American human-dominated landscapes (Turnbull, 1979; Panzer, 1988). These species will be kept to a minimum naturally if only limited non-natural disturbances (e.g. vehicle tracks) affect the sites. It is hypothesized that the native species restricted to alvars, which are well adapted for life in the extreme conditions found in these habitats, will not be displaced by the competition with introduced fauna under natural circumstances.

Alvar conservation

Throughout the world, alvars are very restricted in distribution (Baltic and Great Lakes regions) and high quality sites are relatively few (Coulianos, 1983; Catling and Brownell, 1995). In the Great Lakes region, alvars are confined to the major limestone plains (Catling, 1995). Manitoulin Island is one of seven North American alvar regions which have been identified by Catling and Brownell (1995), the others being the Bruce Peninsula, the Carden Plains, the Smith Falls Plains, western New York, the Napanee Plains and western Lake Erie. Within each of these geographical subdivisions, the quality and quantity of the sites vary greatly (Catling and Brownell, 1995).

Many factors have to be taken into consideration when assessing the quality of a particular site for conservation and management purposes (Margules and Usher, 1981). The most important factors include the diversity and rarity of the organisms present within the site and their "naturalness". It has been suggested that diversity is a measure of habitat complexity and that more diverse areas are also more stable (Steiner, 1994; McCreary-Waters, 1994). Tilman and Downing (1994) have presented evidence that a higher plant biodiversity in grasslands will increase the stability of a particular site after a major drought. The argument behind this assumption is that more diverse ecosystems are more likely to contain some species that can thrive during an environmental perturbation, whereas in the species-poor sites, the loss of species due to the perturbation will have a progressively greater impact on ecosystem stability. The actual species present in the site will greatly influence the future stability of the site. For example, a stand containing a more natural (or native) vegetation probably will have better resiliency after a severe drought (as observed by Tilman and Downing, 1994) than a more diverse site which supports many introduced species. The presence of a high number of introduced species usually reveals past disturbance from non-natural factors and certain "alien" plants (especially shrubs) have been found to have a negative influence on the native alvar flora (Catling and Brownell, 1995).

However, it should be made clear that the greatest possible diversity should not be the optimal criterion when selecting a particular site for conservation purposes. Coulianos and Sylvén (1983) mentioned that the insect diversity was highest in alvars with rich vegetation but the most unique species are often found in sites with poor, low-growing vegetation. The present study clearly shows that alvars support a relatively high number of rare insect species and species which are restricted to this type of habitat. But unfortunately, the mere presence of such species on a site does not mean that it reproduces or it will sustain its populations if the site is preserved. In fact, for many populations, a large number of individuals regularly occur in what are called "sink habitats" where within-habitat reproduction is insufficient to account for local mortality (Pulliam, 1988). In order to confirm that a rare species of insect will have sustainable populations within a site for many years to come, we could look for certain clues. For example, the sites which have dominant populations of significant species should be prioritized because population density is one of the most readily observed indicators of population viability (Winston and Angermeier, 1995). The rarest species of the log normal distribution are more likely to have insufficient abundance of critical resources if the habitat is disturbed (Rosenzweig and Abramsky, 1993). Using the two most abundant groups in this study as examples, we could also look for evidence of emergence (i.e. teneral specimens in ground beetles) and the presence of immatures (i.e. nymphs of Auchenorrhyncha) to conclude that the entire life cycle of the insect occurs on the site. The presence of significant species in small numbers does not necessarily exclude the possibility that the species reproduces and has a sustainable density on that site, but instead, it might reveal limitations in the collecting methods used. One of the best examples can be found in the species *Caenodelphax nigriscutellata* (Auchenorrhyncha: Delphacidae), a prairie endemic which has been collected occasionally in Ontario alvars (including the grassland alvar of Manitoulin Island). The highest number of specimens collected in one site is 11 (Dyer's Bay, Bruce Peninsula: Canadian National Collection). This species is tiny and probably feeds close to the roots of its host plant which makes it extremely hard to collect by sweeping with a butterfly net (K.G.A. Hamilton, pers. comm.). A better evaluation of population sizes could be done using a vacuum suction sampler (Marshall et al., 1994) which is commonly used for studies on Auchenorrhyncha (e.g. Waloff and Solomon, 1973).

Alvars (and especially dry grassland alvars) are thought to be among the most species rich communities in the world in the small scale (10 to 100 cm2) and are of extraordinary protection value (Rosén, 1995). Catling and Brownell (1995) suggested that within each of the alvar regions around the Great Lakes, it would be necessary to protect two or three sites within each in order to achieve adequate representation of the association types. Alvars are constantly exposed to harsh climatic conditions such as periodic droughts (Stephenson and Herendeen, 1986; Rosén, 1995), flooding and scraping of flora by ice slabs in the winter (especially on lake shores, see Morton and Venn (1984)) which makes them very dynamic communities that change over time. In the event that only two or three alvar sites are preserved within a given region and all the rest are destroyed, then what are the chances that a particular site will regain its original characteristics after a catastrophe (let's assume a natural one) occurs?

Being distributed in isolated patches, all the alvar sites within a region should be viewed as sets of spatially separated subpopulations that are connected by dispersal (Wiens, 1997). As consequences of natural stresses, local subpopulations may suffer local extinction, but under proper management practices, colonization from other subpopulations will reestablish populations in those patches.

According to metapopulation modeling, no local population is so large that its expected lifetime is longer in relation to that of a metapopulation as a whole (Wiens, 1997). What this means is that conservation decisions should include questions which will help understand the population dynamics of the significant taxa. How much exchange between patches is there at the regional level? How much exchange is there between the different alvar regions? What are the dispersal potentials of the various significant species that we are trying to protect? How many sites of a certain alvar type are necessary to protect in order to preserve sustainable populations of target species? How many community types are necessary to protect within a region in order to preserve the highest genetic diversity of the species? The answers to these questions are beyond the scope of this study but a simple look at the ground beetle and Auchenorrhyncha species of interest shows that their various dispersal potentials vary greatly (i.e. presence of strong flyers vs. poor flyers or flightless taxa) and should deserve more attention in the future.

Finally, the time and human resources needed to assess all of the variables listed above before taking conservation decisions might be too great when considering the potential threats that some of the sites are under (for details see Belcher and Keddy, 1992; Catling and Brownell, 1995; Reid, 1996). Therefore, the balance between ideal management considerations (i.e. protect representative examples of all native ecosystems across their natural range of variation (Finnamore, 1996)) and the time left before certain high quality sites are destroyed or degraded further should be carefully evaluated at a regional basis.

Future work and recommendations

One of the most stimulating aspects of this project is that it showed the great potential for future work. Inventory and monitoring are two essential activities necessary for sound conservation planning (Kremen et al., 1993). Inventory programs help in documenting the distribution of biologically significant species which, in turn, help in the selection and design of reserves. Such programs should therefore be emphasized in the next few years in all of the different alvar regions. On the other hand, monitoring programs are useful to assess the changes in ecosystem structure, composition and function in response to natural factors, human disturbances or management activities over time (Kremen et al., 1993). There exists a small number of protected alvar sites in the province of Ontario (Belcher and Keddy, 1992) which offer great potential for the long-term monitoring of natural fluctuations of the habitat in response to natural stresses. The ecological requirements of a number of rare insect species found in alvars are completely unknown; therefore, by putting more effort into learning about the needs of these species (probably easier with species with high densities), it will be easier to make informed and relevant conservation decisions. An example of future investigation of habitat requirements using ground beetles could be done by performing mark - recapture experiments. The dispersal potentials of the significant insect species could be investigated using suction or rotary traps (Marshall et al., 1994) (for an example using Auchenorrhyncha, see Waloff, 1973). Measurements of gene flow or connectivity between patches (or subpopulations) could be assessed using mitochondrial genetic variations (Roderick, 1996). Knowing that important changes in the insect fauna of moderately to heavily grazed alvars in Sweden have been observed (Coulianos, 1983; Bornfeldt, 1995), it would be interesting to find out if these effects are present in North American alvars as well and to what extent. The presence of rare and significant species of insects presented in this study should be seen as tools to understand the origin and present "health" or quality of the Great Lakes alvars. Even more crucial would be to combine these data with observations on other groups such as vascular plants, birds and other invertebrates as well as including knowledge about the topography, geology, hydrology, soil characteristics, geochemistry of the various sites in order to make the best possible management decisions (Scott et al., 1987; Roberts, 1988; Meyer, 1997).

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Table 1- Alvar community types in the Great Lakes region. Numbers refer to the percentage of ground cover.

	open : <10% trees	savanna : 10-50% trees
>50% exposed bedrock <50% herbs <50% shrubs	pavement alvar	pavement savanna alvar
<50% exposed bedrock >50% herbs usually <25% shrubs	grassland alvar	grassland savanna alvar
<50% exposed bedrock <50% herbs >25% shrubs	shrubland alvar	shrubland savanna alvar

Table 2. Carabidae collected on Manitoulin Island alvars in 1996. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar, TOT- total, STA- status (C- common, U- uncommon, R- rare), DIST- distribution (E- eastern, W- western, N- northern, S- southern, WS- widespread, INC- incompletely known). * = spp. of interest.

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Acupalpus partiarius (Say)	0	0	0	1	1	U	E
Agonum cupreum Dejean	0	0	3	35	38	U	N
Agonum cupripenne (Say)	4	0	218	64	286	C	Ws
Agonum harrisi LeConte	0	0	0	3	3	C	Ws
Agonum melanarium Dejean	0	0	2	2	4	C	Ws
Agonum metallescens (LeConte)	0	0	1	0	1	C	Ws
Agonum muelleri Herbst	0	0	1	0	1	C	Ws
Agonum nutans (Say) *	0	0	0	370	370	U	E
Agonum placidum (Say)	5	0	0	1	6	C	Ws
Agonum trigeminum Lindroth	0	0	0	2	2	C	E
Amara aeneopolita Casey	1	0	0	0	1	U	N
Amara cupreolata Putzeys	7	0	12	12	31	U	Ws
Amara impuncticollis (Say)	0	0	1	7	8	C	E
Amara latior Kirby	2	0	0	0	2	C	Ws
Amara obesa Say	6	0	0	0	6	C	Ws
Amara pallipes Kirby	0	0	0	7	7	C	Ws
Anisodactylus harrisi LeConte	0	0	1	0	1	U	Ws

Table 2 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Badister neopulchellus Lindroth	0	0	1	4	5	C	Ws
Badister notatus Haldeman	1	0	0	1	2	C	E
Bembidion mimus Hayward	0	0	0	4	4	C	E
Bembidion mutatum Gem. and Har.	0	0	1	0	1	C	N
Bembidion nitidum (Kirby)	0	0	1	0	1	C	N
Bembidion rapidum LeConte *	1	0	0	0	1	R	S
Bembidion versicolor (LeConte)	0	0	2	3	5	C	N
Brachinus cyanochroaticus Erwin	0	0	0	2	2	C	Ws
Bradycellus lecontei Csiki	0	0	0	1	1	U	N
Calathus gregarius (Say)	114	47	256	7	424	C	E
Calosoma calidum (Fabricius)	1	0	7	6	14	U	Ws
Carabus meander Fisher von Wald.	0	1	0	4	5	C	N
Carabus nemoralis O.F. Mueller	0	0	9	0	9	C	W/E
Carabus serratus Say *	36	3	6	2	47	R	Ws
Carabus sylvosus Say *	10	0	0	0	10	U	SE
Chlaenius impunctifrons Say	0	0	0	6	6	C	E
Chlaenius l. lithophilus Say	0	0	0	1	1	C	Ws
Chlaenius p. pensylvanicus Say	0	0	0	1	1	C	Ws
Chlaenius p. purpuricollis Rand. *	13	0	115	6	134	R	Ws
Chlaenius s. sericeus (Forster)	0	0	2	1	3	C	Ws

Table 2 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Chlaenius t. tomentosus (Say)	0	0	1	0	1	C	Ws
Chlaenius t. tricolor Dejean	1	0	0	3	4	C	Ws
Cicindela denikei Fabricius *	0	14	7	0	21	R	N
Cicindela l. longilabris Say	0	9	3	0	12	C	Ws
Cicindela limbalis Klug	0	3	0	0	3	U	E
Cicindela p. purpurea Olivier *	2	0	3	0	5	U	E
Clivina fossor Linne	0	0	0	1	1	C	Ws
Cymindis americanus Dejean *	1	0	0	0	1	R	E
Cymindis cribricollis Dejean	1	0	0	0	1	C	Ws
Cymindis neglectus Haldeman	1	0	1	0	2	U	E
Diplocheila obtusa (LeConte)	1	0	1	1	3	C	Ws
Diplocheila striatopunctata (LeC.)	0	1	0	8	9	C	Ws
Dromius piceus Dejean	1	0	0	0	1	C	Ws
Dyschirius globulosus (Say)	1	0	6	1	8	C	Ws
Elaphropus granarius (Dejean)	0	0	3	0	3	U	E
Elaphropus incurvus (Say)	0	0	0	2	2	C	Ws
Harpalus bicolor Fabricius	9	0	4	4	17	C	E
Harpalus caliginosus Fabricius	0	1	0	0	1	U	S
Harpalus fallax LeConte *	21	0	8	12	41	U	E
Harpalus faunus Say *	1	0	20	8	29	R	E

Table 2 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Harpalus herbivagus Say	3	0	0	0	3	C	Ws
Harpalus opacipennis (Haldeman)	4	1	2	0	7	C	Ws
Harpalus pensylvanicus DeGeer	7	1	2	0	10	C	Ws
Harpalus plenalis Casey	0	2	0	0	2	C	Ws
Harpalus puncticeps Stephens *	4	0	1	2	7	R	E
Lebia fuscata Dejean	0	1	0	0	1	U	Ws
Lebia pumila Dejean	0	1	0	0	1	C	Ws
Lophoglossus scrutator (LeConte)	0	0	0	5	5	C	E
Myas cyanescens Dejean	3	0	0	0	3	C	E
Notiophilus aeneus (Herbst)	0	0	2	0	2	C	E
Notiophilus semistriatus Say	25	2	0	0	27	C	Ws
Patrobus longicornis Say	0	1	0	0	1	C	Ws
Poecilus l. lucublandus (Say)	1	1	309	322	633	C	Ws
Pterostichus caudicalis (Say)	0	0	0	2	2	C	Ws
Pterostichus commutabilis (Motsc.)	0	0	22	26	48	C	Ws
Pterostichus coracinus (Newman)	63	329	0	1	393	C	E
Pterostichus corvinus (Dejean)	0	0	0	1	1	C	Ws
Pterostichus femoralis (Kirby)	0	0	1	34	35	C	Ws
Pterostichus luctuosus (Dejean)	0	0	0	23	23	C	Ws
Pterostichus melanarius (Illiger)	5	24	43	138	210	C	Ws

Table 2 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Pterostichus mutus (Say)	0	0	1	0	1	C	E
Pterostichus novus Straneo *	294	33	108	2	437	R	INC
Pterostichus pensylvanicus LeConte	0	0	0	1	1	C	Ws
Pterostichus tristis (Dejean)	0	1	0	0	1	C	E
Sphaeroderus nitidicollis brevoorti Guer.-Men.	1	0	0	0	1	U	NE
Sphaeroderus stenostomus lecontei Dejean	5	0	0	1	6	C	E
Stenolophus comma (Fabricius)	3	0	0	0	3	C	Ws
Stenolophus conjunctus (Say)	0	0	2	2	4	C	Ws
Stenolophus fuliginosus Dejean	0	0	1	1	2	C	Ws
Stenolophus ochropezus Say	2	0	0	0	2	C	E
Syntomus americanus (Dejean)	1	0	3	1	5	C	Ws
Synuchus impunctatus (Say)	39	2	7	0	48	C	Ws
Trechus quadristriatus Schrank	2	0	1	1	4	C	E
Total number of specimens	703	478	1201	1156	3538		
Total number of species	41	21	44	52	90		

Table 3. Shannon Diversity Index and Evenness for ground beetle fauna in alvar sites. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

	PAV	D-C	B-O	GR
Diversity Index (H)	2.205[a]	1.260[b]	2.206[a]	2.197[a]
Evenness (E)	0.594	0.414	0.583	0.556

Values with [a] are significantly higher than those with [b] (p>0.001).

Table 4. Quantitative similarity of ground beetle fauna between alvar sites. Jaccard's Index above, Sorensen's Index below. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar

	PAV	D-C	B-O	GR
PAV	---	0.1923	0.3710	0.3286
D-C	0.2676	---	0.1818	0.1250
B-O	0.3109	0.1453	---	0:3913
GR	0.0742	0.0477	0.4344	---

Table 5. Dominant species of Carabidae in alvar sites. * - dominant on that site. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

Species	PAV	D-C	B-O	GR	TOT
Agonum cupripenne (Say)	4	0	218*	64*	286
Agonum nutans (Say)	0	0	0	370*	370
Calathus gregarius (Say)	114*	47*	256*	7	424
Carabus serratus Say	36*	3	6	2	47
Chlaenius p. purpuricollis Randall	13	0	115*	6	134
Poecilus l. lucublandus (Say)	1	1	309*	322*	633
Pterostichus coracinus (Newman)	63*	329*	0	1	393
Pterostichus melanarius (Illiger)	5	24*	43	138*	210
Pterostichus novus Straneo	294*	33*	108*	2	437
Synuchus impunctatus (Say)	39*	2	7	0	48

Table 6. Auchenorrhyncha collected on Manitoulin Island alvars in 1996. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar. TOT- total, DIST- distribution (E- eastern, W- western, N- northern, S- southern, WS- widespread, INC- incompletely known). * = spp. of interest.

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Family Cicadellidae						
Aceratagallia humilis Oman	0	0	61	20	81	Ws
Aceratagallia sp.	0	0	0	4	4	Ws
Aflexia rubranura (DeLong) *	10	0	3	597	610	W
Agalliota quadripunctata (Provancher)	0	0	0	1	1	Ws
Amplicephalus (Endria) inimicus (Say)	2	0	5	0	7	Ws
Anoscopus flavostriatus (Donovan)	0	0	446	3	449	Ws
Anoscopus serratulae (Fabricius)	0	0	46	0	46	Ws
Aphrodes sp.	4	3	734	33	774	Ws
Arboridia sp.	0	3	0	0	3	Ws
Athysanus argentarius Metcalf	7	2	22	24	55	Ws
Auridius sp.n. *	43	0	0	0	43	W
Balclutha sp.	5	1	1	2	9	Ws
Chlorotettix sp.	1	0	0	0	1	Ws
Chlorotettix unicolor (Fitch)	7	0	0	19	26	Ws
Cicadula melanogaster (Provancher)	2	0	0	0	2	Ws

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Colladonus youngi Nielson	2	3	0	0	5	Ws
Deltocephalus balli VanDuzee	0	0	2	0	2	Ws
Dikraneura mali (Provancher)	0	0	2	0	2	Ws
Diplocolenus (Verdanus) evansi (Ashmead)	2	0	788	12	802	Ws
Doratura stylata (Boheman)	0	0	125	10	135	Ws
Draeculacephala angulifera (Walker)	1	0	0	0	1	Ws
Elymana sulphurella (Zetterstedt)	0	0	4	0	4	Ws
Empoasca sp.	18	3	0	1	22	Ws
Evacanthus orbitalis Fitch	1	0	0	0	1	Ws
Extrusanus extrusus (VanDuzee)	0	10	0	0	10	Ws
Flexamia delongi Ross and Cooley *	6	0	0	196	202	W
Forcipata loca Delong and Caldwell	1	0	0	0	1	Ws
Forcipata sp.	2	0	0	0	2	Ws
Forcipatra triquetra DeLong and Caldwell	0	0	2	71	73	Ws
Graphocephala teliformis (Walker)	4	14	0	0	18	Ws
Gyponana salsa DeLong	5	0	1	0	6	Ws
Gyponana sp.	1	0	0	0	1	Ws
Hecalus major (Osborn)	0	0	1	1	2	Ws
Idiocerus pallipus Fitch	1	0	1	0	2	Ws
Idiocerus sp.	0	0	1	0	1	Ws

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Idiocerus venosus Hamilton	0	0	1	1	2	Ws
Idiodonus kennecottii (Uhler)	1	0	0	1	2	Ws
Idiodonus morsei (Osborn)	3	0	0	13	16	Ws
Laevicephalus acus (Sanders and Delong)	0	0	0	11	11	Ws
Laevicephalus melsheimerii (Fitch)	4	0	0	11	15	Ws
Laevicephalus sp.	0	0	0	1	1	Ws
Laevicephalus unicoloratus (Gill. & Bak.) *	0	0	0	74	74	W
Latalus ocellaris (Fallen)	0	0	0	1	1	Ws
Latalus personatus Beirne	69	0	3	2	74	Ws
Latalus sp.	197	0	1	1	199	Ws
Limotettix (Neodrylix) urnura Hamilton *	1	0	291	120	412	W
Limotettix (Scleroracus) sp.	2	4	0	0	6	Ws
Limotettix arctostaphyli (Ball)	117	18	0	0	135	Ws
Limotettix ferganensis Dubovsky	1	0	0	0	1	Ws
Limotettix osborni (Ball)	0	0	2	0	2	Ws
Limotettix vaccinii (VanDuzee)	0	0	0	6	6	Ws
Macropsis sauroni Hamilton	3	0	0	0	3	Ws
Macropsis viridis (Fitch)	0	0	1	0	1	Ws
Macrosteles borealis (Dorst)	0	0	0	2	2	Ws
Macrosteles quadrilineatus (Forbes)	4	0	3	4	11	Ws

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Memnonia sp.n. *	10	0	0	107	117	W
Mocuellus americanus Emeljanov *	71	0	0	0	71	W
Neocoelidia tumidifrons Gillette and Baker	2	0	0	6	8	Ws
Neokolla hieroglyphica (Say)	0	13	0	0	13	Ws
Neokolla sp.	0	1	0	0	1	Ws
Norvellina novica Medler	3	0	0	0	3	Ws
Norvellina seminuda (Say)	15	0	0	0	15	Ws
Oncopsis cinctifrons (Provancher)	5	12	0	0	17	Ws
Oncopsis citra Hamilton	1	5	0	0	6	Ws
Oncopsis dorsalis (Provancher)	0	0	2	0	2	Ws
Oncopsis variabilis (Fitch)	0	4	0	0	4	Ws
Osbornellus auronitens (Provancher)	0	1	0	0	1	Ws
Paluda gladiola (Ball)	1	0	0	0	1	Ws
Paraphlepsius fulvidorsum (Fitch)	61	2	51	9	123	Ws
Paraphlepsius lobatus (Osborn) *	12	0	0	9	21	W
Paraphlepsius truncatus (Van Duzee)	0	0	2	1	3	Ws
Pendarus punctiscriptus (VanDuzee)	4	0	0	31	35	Ws
Platymetopius twiningi (Uhler)	0	1	0	0	1	Ws
Platymetopius vitellinus (Fitch)	2	0	1	0	3	Ws
Ponana pectoralis (Spangberg)	0	0	5	1	6	Ws

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Psammotettix lividellus (Zetterstedt)	1	0	89	3	93	Ws
Scaphoideus cyprius Ball	0	1	0	0	1	Ws
Scaphoideus sp.	0	1	0	0	1	Ws
Scaphytopius acutus (Say)	9	2	0	0	11	Ws
Scaphytopius latus (Baker)	1	1	79	6	87	Ws
Scaphytopius magdalensis (Provancher)	2	0	0	0	2	Ws
Texananus arctostaphylae (Ball)	23	5	1	0	29	Ws
Texananus marmor (Sand. and DeLong) *	13	0	0	3	16	W
Typhlocyba gillettei (Van Duzee)	0	1	0	0	1	Ws
Xestocephalus nigrifrons Osborn	0	1	0	0	1	Ws
Xestocephalus superbus (Provancher)	19	0	2	166	187	Ws
Family Caliscelidae						
Bruchomorpha tristis Stal	0	0	1	0	1	Ws
Peltonotellus histrionicus Stal	0	0	0	6	6	Ws
Family Cercopidae						
Aphrophora cribrata (Walker)	3	7	1	0	11	Ws
Aphrophora parallella (Say)	0	0	0	1	1	Ws
Clastoptera proteus Fitch	1	0	1	0	2	Ws
Neophilaenus lineatus (Linnaeus)	8	0	14	12	34	Ws
Philaenus spumarius (Linnaeus)	54	4	66	17	141	Ws

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Family Cicadidae						
Okanagana canadensis (Provancher)	4	4	0	0	8	Ws
Tibicen canicularis (Harris)	0	2	2	1	5	Ws
Family Cixiidae						
Cixius missellis Van Duzee	0	2	0	0	2	Ws
Cixius sp.	0	6	0	0	6	Ws
Oliarus quinquelineatus (Say)	1	6	0	0	7	Ws
Family Delphacidae						
Caenodelphax nigriscutellata (Beamer) *	0	0	0	6	6	W
Laccocera vittipennis VanDuzee	33	0	1	0	34	Ws
Liburnia campestris VanDuzee	0	0	23	8	31	Ws
Liburnia parvula (Ball) *	3	0	0	56	59	W
Liburnia sp.	1	0	0	0	1	Ws
Liburniella ornata (Stal)	13	0	1	25	39	Ws
Megamelus sp.	1	0	1	0	2	Ws
Pissonotus sp.	0	1	0	0	1	Ws
Family Derbidae						
Cedusa sp.	0	1	0	0	1	Ws
Cedusa vulgaris (Fitch)	0	30	0	0	30	Ws
Family Dictyopharidae						

Table 6 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Scolops sulcipes (Say)	0	0	1	0	1	Ws
Family Membracidae						
Carynota stupida (Walker)	0	0	1	0	1	Ws
Cyrtolobus sp.	0	0	76	0	76	Ws
Ophiderma sp.	1	0	0	0	1	Ws
Telamona monticola (Fabricius)	0	0	3	0	3	Ws
Telamona spereta Goding	0	0	2	0	2	Ws
Telamona univittata (Harris)	0	0	4	0	4	Ws
Telamona westcotti (Goding)	0	0	1	0	1	Ws
Total number of specimens	905	175	2978	1716	5774	
Total number of species	63	35	51	49	116	

Table 7. Shannon Diversity Index and Evenness for the family Cicadellidae in alvar sites. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

	PAV	D-C	B-O	GR
Diversity Index (H)	2.740[a]	2.757[a]	1.972[b]	2.289[c]
Evenness (E)	0.697	0.856	0.559	0.620

Values with an [a] are significantly higher than values with [b] and [c] and values with [b] is significantly lower than value [c] ($p>0.001$).

Table 8. Quantitative similarity of Cicadellidae fauna between alvar sites. Jaccard's Index above, Sorensen's Index below. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

	PAV	D-C	B-O	GR
PAV	---	0.2258	0.2687	0.3582
D-C	0.1141	---	0.1132	0.1017
B-O	0.0483	0.0069	---	0.3962
GR	0.0955	0.0118	0.1173	---

Table 9. Dominant species of Auchenorrhyncha in alvar sites. * - dominant on that site. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

SPECIES	PAV	D-C	B-O	GR	TOT
Family Cicadellidae					
Aflexia rubranura (DeLong)	10	0	3	597*	610
Anoscopus flavostriatus (Donovan)	0	0	446*	3	449
Aphrodes sp.	4	3	734*	33	774
Diplocolenus evansi (Ashmead)	2	0	788*	12	802
Extrusanus extrusus (VanDuzee)	0	10*	0	0	10
Flexamia delongi Ross and Cooley	6	0	0	196*	202
Graphocephala teliformis (Walker)	4	14*	0	0	18
Latalus personatus Beirne	69*	0	3	2	74
Latalus sp.	197*	0	1	1	199
Limotettix urnura Hamilton	1	0	291*	120*	412
Limotettix arctostaphili (Ball)	117*	18*	0	0	135
Memnonia n.sp.	10	0	0	107*	117
Mocuellus americanus Emeljanov	71*	0	0	0	71
Neokolla hieroglypha (Say)	0	13*	0	0	13
Oncopsis cinctifrons (Provancher)	5	12*	0	0	17
Paraphlepsius fulvidorsum (Fitch)	61*	2	51	9	123
Xestocephalus superbus (Provancher)	19	0	2	166*	187

Table 9 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT
Family Cercopidae					
Philaenus spumarius (Linnaeus)	54*	4	66	17	141
Family Derbidae					
Cedusa vulgaris (Fitch)	0	30*	0	0	30

Table 10. Symphyta collected on Manitoulin Island alvars in 1996. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar. TOT- total, DIST- distribution (E- eastern, W- western, N- northern, S- southern, WS- widespread, INC- incompletely known). * = spp. of interest.

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Family Argidae						
Arge cerulea (Norton)	0	17	1	0	18	E
Arge pectoralis (Leach)	3	1	0	0	4	Ws
Sterictiphora serotina Smith *	0	0	1	0	1	E
Family Cimbicidae						
Cimbex americana Leach	0	1	0	0	1	Ws
Zaraca inflata Norton	1	0	0	0	1	Ws
Family Diprionidae						
Monoctenus suffusus (Cresson)	30	2	4	4	40	E
Family Tenthredinidae						
Allantus mellipes (Norton)	0	0	3	0	3	Ws
Amauronematus sp. 1	0	0	3	3	6	INC
Amauronematus sp. 2	0	0	5	5	10	INC
Amauronematus sp. 3	1	1	0	0	2	INC
Amauronematus sp. 4	0	0	2	1	3	INC
Amauronematus sp. 5	0	0	1	0	1	INC

Table 10 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Aneugmenus flavipes (Norton)	0	0	1	0	1	E
Aphilodyctium fidum (Cresson)	2	0	0	2	4	Ws
Caliroa nr. obsoleta (Norton)	0	0	2	0	2	INC
Dimorphopteryx abnormis Rohwer	1	1	0	0	2	E
Dolerus apricus (Norton)	0	0	1	0	1	Ws
Dolerus tibialis conjugallus MacGill.	0	0	1	0	1	Ws
Empria candidata MacGillivray *	1	0	0	0	1	N
Empria maculata (Norton)	0	0	2	0	2	Ws
Empria multicolor (Norton)	2	0	0	0	2	Ws
Empria obscurata (Cresson)	6	0	2	0	8	Ws
Eutomostethus luteiventris (Klug) *	0	0	1	1	2	INC
Hoplocampa halcyon (Norton)	0	0	1	0	1	Ws
Hoplocampa montanicula Rohwer	0	0	1	0	1	E
Macremphytus tarsatus (Say)	0	0	0	1	1	E
Macrophya cassandra Kirby	0	0	1	0	1	E
Macrophya fuliginea Norton	2	2	7	1	12	E
Macrophya intermedia (Norton)	1	0	2	0	3	E
Macrophya trisyllaba (Norton)	0	1	0	0	1	Ws
Macrphya succincta Cresson	0	0	2	2	4	Ws
Nematus sp.	1	0	0	0	1	INC

Table 10 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	DIST
Periclista albicollis (Norton) *	0	0	1	0	1	E
Periclista diluta (Cresson) *	0	0	3	0	3	E
Pikonema alaskensis (Rohwen)	2	0	0	13	15	Ws
Pristiphora pallipes Lepeletier	0	0	0	1	1	INC
Pristiphora sp. 1	0	0	0	1	1	INC
Pristiphora sp. 2	0	0	0	1	1	INC
Pristiphora sp. 3	0	0	1	0	1	INC
Tenthredo basilaris Say *	0	0	1	1	2	E
Tenthredo castanea Kirby *	64	1	6	0	71	E
Tenthredo nr. Leucostoma Kirby *	1	0	0	0	1	E
Tenthredo piceocincta (Norton) *	0	1	2	0	3	E
Tenthredo ruficolor Norton *	2	1	1	0	4	E
Tenthredo rufipes Say *	2	3	8	0	13	E
Tenthredo rusticana MacGillivray *	0	0	1	0	1	E
Tenthredo varipicta Norton *	0	0	1	0	1	E
Tenthredo verticalis Say *	1	0	1	0	2	E
Total number of specimens	123	32	70	37	262	
Total number of species	18	12	32	14	48	

Table 11- Host plant / sawfly associations. + = species expected on site and captured, (+) = species expected on site but not captured, - = species not expected but found on the sites and 0 = species not expected and not found on the sites. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar.

SPECIES	PAV	D-C	B-O	GR
Arge cerulea	0	-	-	0
Arge pectoralis	-	+	0	0
Sterictiphora serotina	(+)	0	-	0
Cimbex americana	(+)	+	(+)	(+)
Zaraea inflata	-	(+)	0	0
Monoctenus suffusus	+	+	+	+
Allantus mellipes	0	(+)	+	(+)
Amauronematus sp. 1	0	0	-	-
Amauronematus sp. 2	0	0	-	-
Amauronematus sp. 3	-	-	0	0
Amauronematus sp. 4	0	0	-	-
Amauronematus sp. 5	0	0	-	0
Aneugmenus flavipes	0	0	-	0
Aphilodyctium fidum	-	(+)	(+)	+
Dimorphopteryx abnormis	+	+	(+)	(+)
Dolerus apricus	0	0	-	0

Table 11 (continued)

SPECIES	PAV	D-C	B-O	GR
Dolerus tibialis conjugallus	0	0	-	0
Empria candidata	-	(+)	0	0
Empria maculata	(+)	(+)	+	(+)
Empria multicolor	-	(+)	0	0
Empria obscurata	-	(+)	+	(+)
Eutomostethus luteiventris	0	0	+	-
Hoplocampa halcyon	(+)	0	+	(+)
Hoplocampa montanicola	(+)	(+)	+	(+)
Macremphytus tarsatus	0	(+)	(+)	-
Macrophya cassandra	0	0	-	0
Macrophya fuliginea	-	-	-	-
Macrophya trisyllaba	0	-	0	0
Periclista albicollis	0	0	+	(+)
Periclista diluta	0	0	-	0
Pikonema alaskensis	0	(+)	0	+
Pristiphora pallipes	0	0	0	-

Table 12. Papilionoidea and Hesperioidea collected on Manitoulin Island alvars in 1996. PAV- pavement alvar, D-C- deep-crack alvar, B-O- bur-oak alvar, GR- grassland alvar, TOT- total, STA- status (C- common, U- uncommon, R- rare), DIST- distribution (E- eastern, W- western, N- northern, S- southern, WS- widespread, INC- incompletely known). * = spp. of interest. @ = sighted but not collected on that site.

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Family Danaidae							
Danaus plexippus (Linnaeus)	1	0	@	@	1	C	Ws
Family Hesperiidae							
Amblycirtes vialis (Edwards)	5	3	0	0	8	C	Ws
Erynnis icelus (Scudder and Burgess)	4	3	0	0	7	C	Ws
Erynnis juvenalis (Fabricius)	0	1	4	0	5	C	Ws
Erynnis lucilius (Scud. and Burg.) *	2	5	0	0	7	C	Ws
Euphyes vestris (Boisduval)	4	0	0	0	4	C	Ws
Hesperia comma (Linnaeus) *	1	0	0	1	2	U	N
Hesperia saussacus Harris	1	0	0	0	1	U	Ws
Poanes hobomok (Harris)	3	1	1	0	5	C	Ws
Polites mystic (Edwards)	0	0	0	1	1	C	Ws
Polites themistocles (Latreille)	0	0	1	0	1	C	Ws
Thorybes pylades (Scudder)	0	0	1	0	1	C	Ws
Thymelicus lineola (Ochsenheimer)	3	3	9	4	19	C	Ws

Table 12 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
<u>Family Lycaenidae</u>							
Celastrina ladon (Cramer)	1	5	0	0	6	C	Ws
Glauchopsyche lygdamus (Doub.)	0	1	0	0	1	C	Ws
Harkenclenus titus (Fabricius)	1	0	0	0	1	C	Ws
Incisalia augustinus Westwood	8	6	1	0	15	C	Ws
Incisalia polia Cook and Watson *	8	3	0	0	11	U	Ws
Epidemia dorcas (Kirby) *	8	0	2	3	13	R	Ws
<u>Family Nymphalidae</u>							
Basilarchia archippus (Cramer)	0	0	0	1	1	C	Ws
Basilarchia arthemis (Drury)	3	@	@	0	3	C	Ws
Charidryas harisii (Scudder)	3	0	0	0	3	U	Ws
Clossiana selene (Den. and Schiff)	2	0	1	1	5	C	Ws
Nymphalis antiopa (Linnaeus)	@	@	@	0	0	C	Ws
Phyciodes batesii (Reakirt)	4	0	0	1	5	U	Ws
Phyciodes tharos (Drury)	19	3	0	1	22	C	Ws
Speyeria aphrodite (Fabricius)	5	0	1	0	6	C	Ws
Speyeria atlantis (Edwards)	7	0	0	0	7	C	Ws
Speyeria cybele (Fabricius)	1	0	0	0	1	C	Ws
<u>Family Papilionidae</u>							
Papilio glaucus (Linnaeus)	2	0	@	0	2	C	Ws

Table 12 (continued)

SPECIES	PAV	D-C	B-O	GR	TOT	STA	DIST
Family Pieridae							
Colias interior Scudder	2	0	0	0	2	C	Ws
Euchloe ausonides Lucas *	1	0	0	0	1	R	N
Euchloe olympia (Edwards) *	0	0	1	0	1	U	S
Pieris napi (Linnaeus)	2	0	1	0	3	C	Ws
Pieris rapae (Linnaeus)	1	0	0	0	1	C	Ws
Family Satyridae							
Cercyonis pegala (Fabricius)	0	0	4	3	7	C	Ws
Coenonympha inornata Edwards	0	0	13	15	28	C	Ws
Enodia anthedon Clark	1	0	0	0	1	C	Ws
Megisto cymela (Cramer)	0	0	1	0	1	C	Ws
Oneis chryxus (Doub. and Hew.) *	8	0	0	0	8	U	N
Total number of specimens collected	111	34	41	31	217		
Total number of species (including sightings)	30	13	18	11	40		

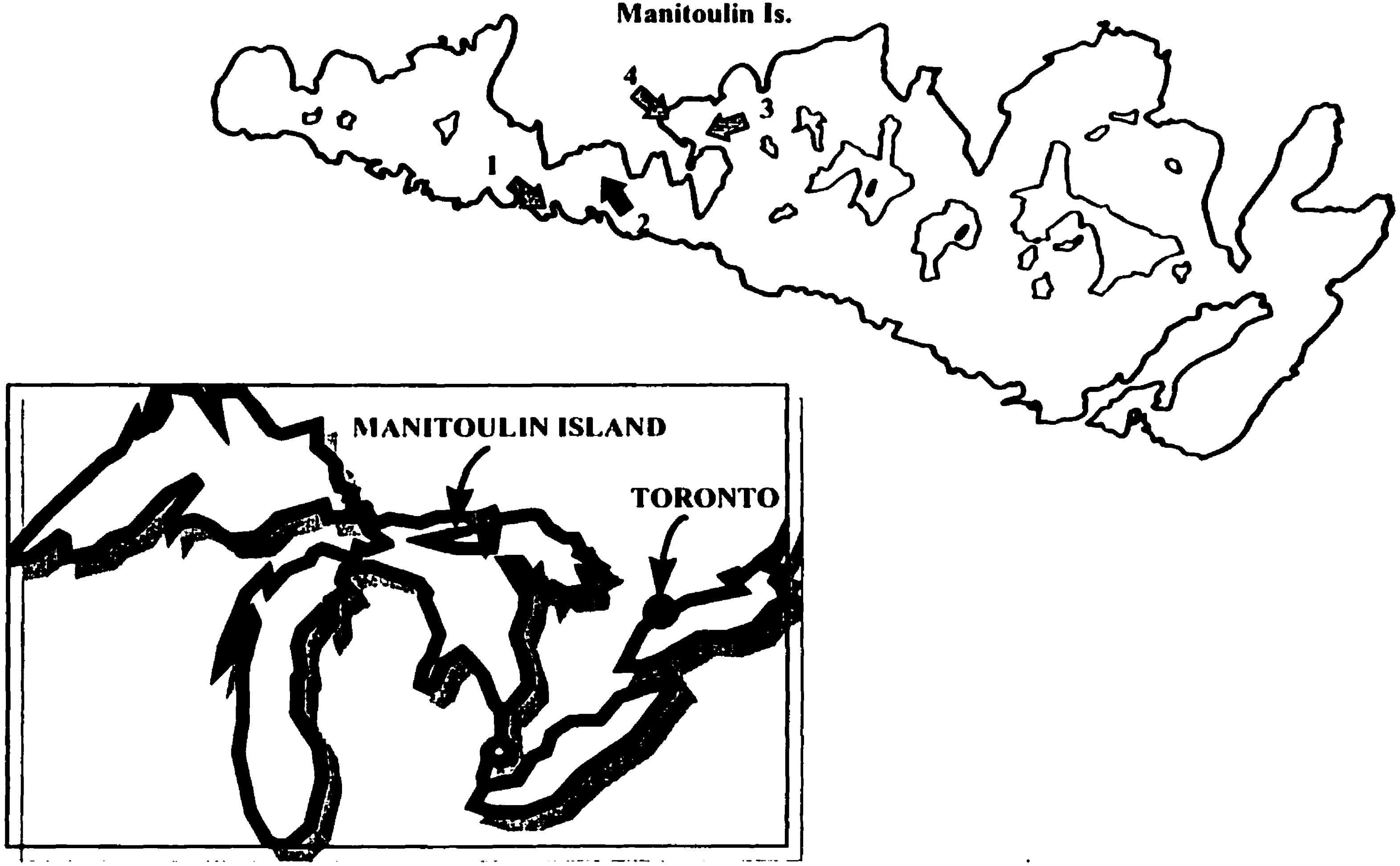

Figure 1 - Location of the four alvar sites sampled on Manitoulin Island (Ontario, Canada) in 1996: 1- pavement, 2- shrubland (deep-crack), 3- bur-oak grassland savanna and 4- grassland alvars.

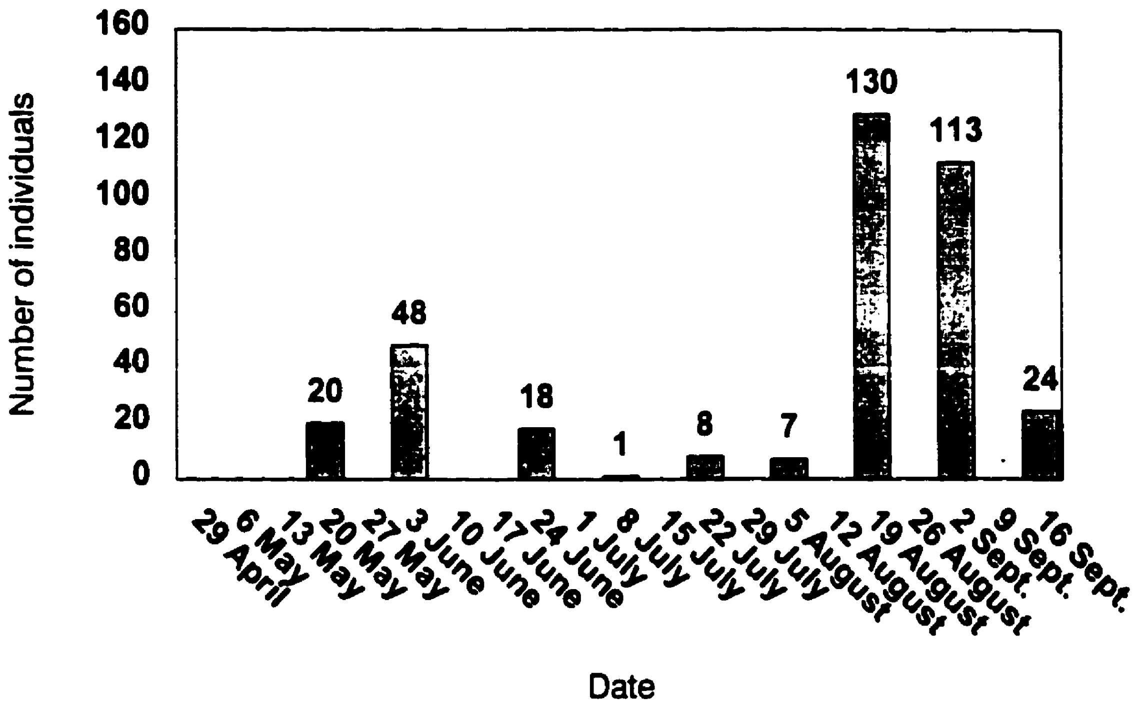

Figure 2- Seasonal abundance of adults of *Agonum nutans* (Say) (Coleoptera: Carabidae) collected on Manitoulin Island, Ontario, Canada, based on trap samples.

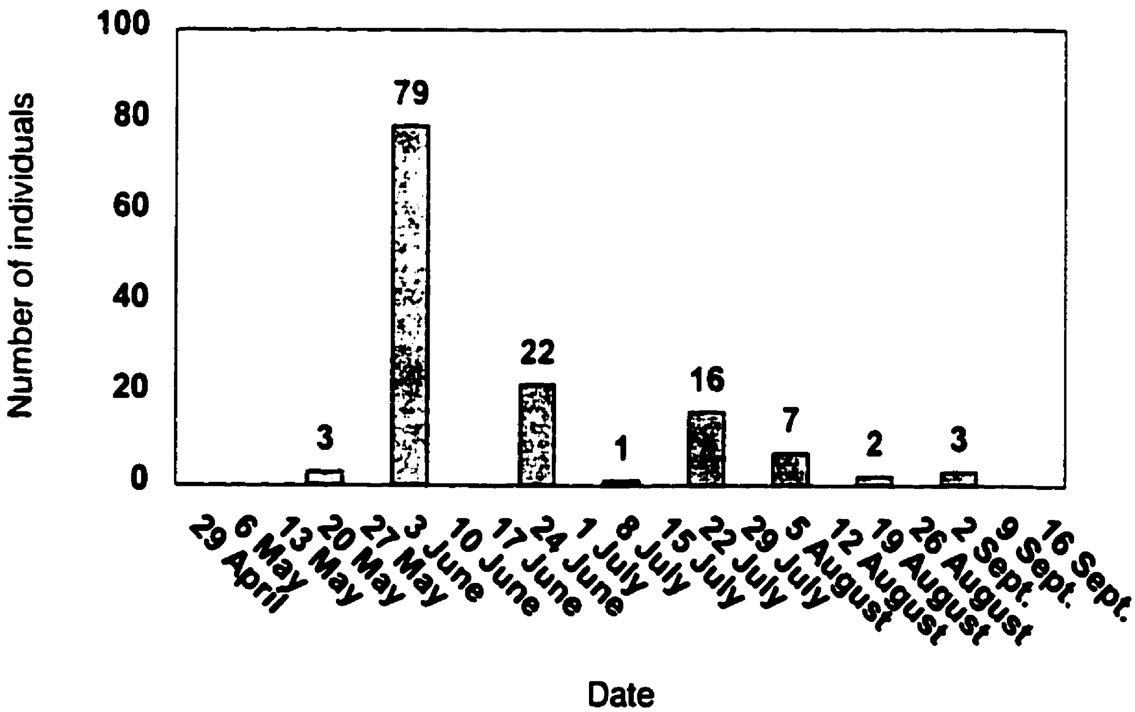

Figure 3- Seasonal abundance of adults of *Chlaenius p. purpuricollis* Randall (Coleoptera: Carabidae) collected on Manitoulin Island, Ontario, Canada, based on trap samples.

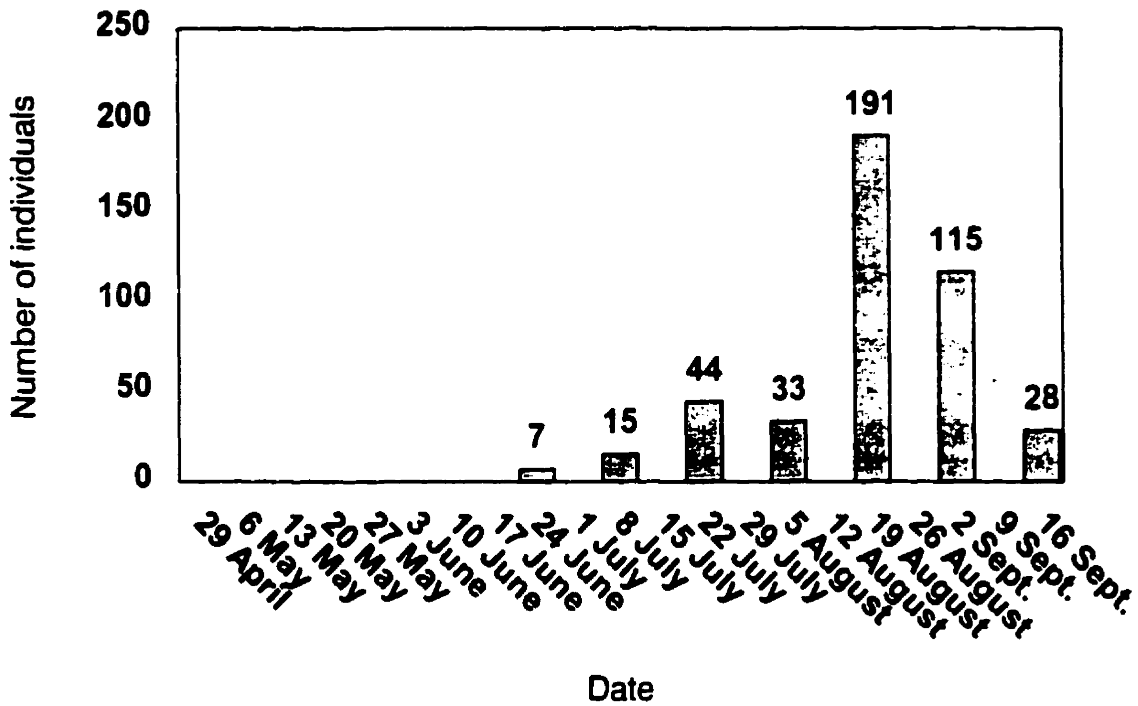

Figure 4- Seasonal abundance of adults of *Pterostichus novus* Straneo (Coleoptera: Carabidae) collected on Manitoulin Island, Ontario, Canada, based on trap samples.

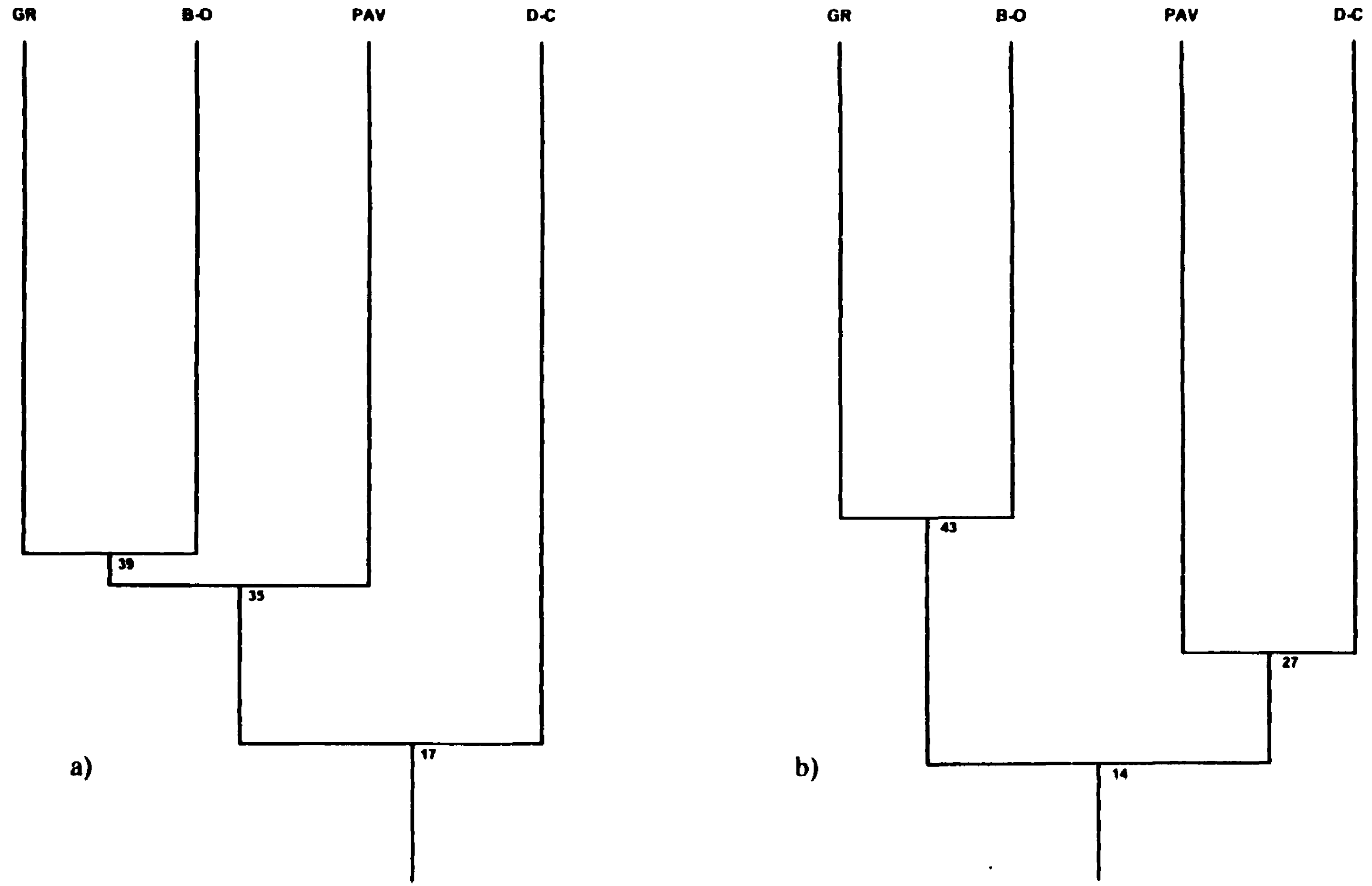

Figure 5- Dendograms showing the similarity among the ground beetle fauna (Coleoptera: Carabidae) collected in four alvar sites in 1996 on Manitoulin Island, Ontario, using : a) Jaccard's and b) Sorensen's index. PAV = pavement, B-0 = bur-oak, GR = grassland and D-C = deep-crack alvars. Numbers on the branches indicate the percentage of similarity.

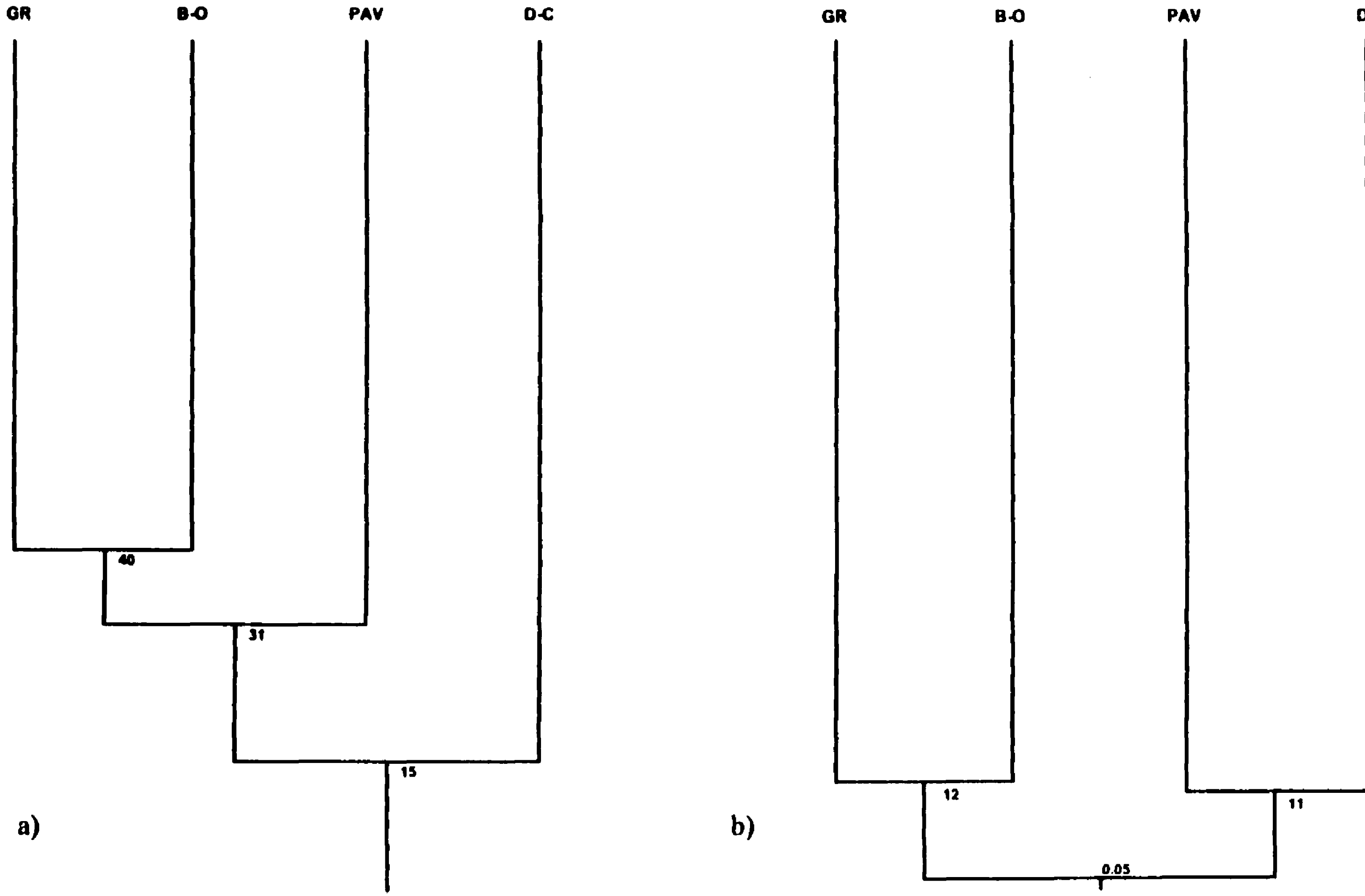

Figure 6- Dendograms showing the similarity among the Auchenorrhyncha fauna (Homoptera) collected in four alvar sites in 1996 on Manitoulin Island, Ontario, using : a) Jaccard's and b) Sorensen's index. PAV = pavement, B-0 = bur-oak, GR = grassland and D-C = deep-crack alvars. Numbers on the branches indicate the percentage of similarity.