ORTHOPTERANS (ORTHOPTERA), GROUND BEETLES (COLEOPTERA: CARABIDAE), AND SPIDERS (ARANEAE) IN BURNED AND UNBURNED ALVAR WOODLANDS – THE IMPORTANCE OF POSTFIRE SUCCESSION TO INSECT DIVERSITY

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Abstract *J. ent. Soc Ont.* 141: 27-37

To contribute to understanding the importance of successional habitat to insect diversity and assist biodiversity management in globally imperilled alvar ecosystems, we surveyed three groups of arthropods in an Ottawa Valley, Ontario, alvar landscape. Using pitfall traps and sweeping, we compared grasshopper (Orthoptera), ground beetle (Coleoptera: Carabidae), and spider (Araneae) diversity in two sites on the same successional gradient: an unburned climax alvar woodland and a corresponding burned woodland that had developed into alvar shrubland nine years after fire. Between-site species similarity was 47.4% for orthopterans (9 species), 6.9% for ground beetles (2 species), and 40.9% for spiders (10 species). Both sites included regionally rare orthopterans and ground beetles. For all three groups species richness and density was higher on the burned site. The value of Brillouin's biodiversity index was higher for both orthopterans and ground beetles in the burned site but higher for spiders in the unburned alvar woodland. These results provide evidence for: (1) the importance of successional habitat to insect diversity, (2) the value of alvar shrublands to overall alvar landscape biodiversity, and (3) the potential value of fire in maintaining alvar biodiversity.

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Introduction

Fire was a major ecological factor in much of southeastern Canada during pre-settlement times (Day 1953; Wein & MacLaren 1983), maintaining a variety of seral stages across the landscape. In the absence of fire, much of the landscape is now dominated by woodlands. Since biodiversity is considered to be higher during middle and later stages of vegetational succession in general (Bormann and Likens 1979; Brown 1984) and specifically for insects (Brown 1984; Strong et al. 1984; Kayna & Gürkan 2007), the loss of middle and late stages may be contributing to the decline in insect diversity. We chose an imperilled alvar ecosystem to investigate this hypothesis and to improve understanding of the importance of successional habitat to insect diversity. Specifically, the objective of our work was to clarify the importance of fire and subsequent succession to insect diversity through a comparative study. This involved three groups of arthropods, orthopterans (Orthoptera), ground beetles (Coleoptera: Carabidae), and spiders (Araneae) in two different habitats representing different temporal positions on the same successional gradient: an early successional alvar shrubland ("burned woodland", nine years post-fire) and a nearby climax alvar woodland ("unburned woodland").

Materials and Methods

The study area

The Burnt Lands, approximately 40 km SW of Ottawa in the Ottawa Valley of eastern Ontario, is one of the richest (in terms of species number and rare species) and most extensive alvar landscapes in the Great Lakes region. Alvars are globally imperilled ecosystems with a fragmented distribution in North America (Catling and Brownell 1995, 1999; Reschke et al. 1999; Brownell and Riley 2000). Evidence of past fire is common in alvars (Catling and Brownell 1998; Jones and Reschke 2005) and, considering the high plant diversity in successional alvar habitats, large scale biomass removal may significantly contribute to biodiversity protection (e.g. Catling et al. 2001, 2002; Catling and Sinclair 2002). The insect fauna of alvars is distinctive and significant (Bouchard 1997a, b, 1998; Bouchard et al. 1998, 2001, 2005), making information on the importance of alvar succession to insects particularly relevant.

The climax woodland study site included four hectares centered at 45.2569, –76.1437. The burned woodland study site, also 4 hectares in size, is centered at 45.2507, –76.1437, 0.5 km southeast of the climax site. Both sites are located in Burnt Lands Provincial Park, Lanark County, Ontario, and are part of the Burnt Lands Alvar landscape (Brunton 1986). Based on personal observations (annually 1985 to 1995) and examination of aerial photographs obtained from the National Air Photo Library of Natural Resources Canada (e.g., number A 16525-105, 29 May 1959), both of these study sites were semi-open, mixed boreal forest until 23 June 1999 when a fire burned 152 hectares, including the burned woodlands study site. The forest (Figure 1a) was dominated by *Abies balsamea* (L.) P. Mill., *Picea glauca* (Moench) Voss, *Pinus strobus* L., *Thuja occidentalis* L., and *Populus tremuloides* Michx. with an understory of mosses including *Pleurozium schreberi* (Brid.) Mitt., and *Dicranum polysetum* Sw., and occasional depauperate shrubs including

FIGURE 1. Burned (a) and unburned (b) alvar woodland on the Burnt Land Alvar west of Ottawa. a)Fallen and dead standing trees are *Abies balsamea, Picea glauca, Pinus strobus*, and *Thuja occidentalis*, regrowth on upper left is *Populus tremuloides* and *Arctostaphylos uva-ursi* can be seen flowering in the foreground. b)The forest is dominated by *Abies balsamea, Picea glauca, Pinus banksiana, Pinus strobus, Populus tremuloides* and *Thuja occidentalis*. Shrubs of *Juniperus communis* are present in the foreground. (a) Area burned on 23 June 1999 was taken at 45.2507, –76.1437. The right photo was taken at 45.2569, –76.1437 in late May. Both photograps by P. M. Catling.

Juniperus communis L. var. *depressa* Pursh. Nine years after the fire, the burned area had developed into a species-rich, open grassy shrubland dominated by graminoid plants such as *Danthonia spicata* (L.) Beauv. ex Roemer & J. A. Schultes and *Carex richardsonii* R. Br., herbs such as *Packera* (*Senecio*) *paupercula* (Michx.) A. & D. Lőve, and *Solidago nemoralis* Ait. var. *nemoralis*, and shrubs such as *Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer var. *compacta* (Nielsen) McKay and *Prunus virginiana* L. Additional information on the vegetation of the two study sites is in Catling (in press).

The Burnt Lands area is subject to fire because of its shallow soils and location on an elevated plateau of porous limestone rock. It was named by settlers in 1870 following an extensive fire. Additional background information on the Burnt Lands Alvar is in White (1979), Brunton (1986), and Catling et al. (2001, 2002).

Collection and identification of insects

(1) Traps: Ten pitfall traps (15 cm x 10 cm x 5 cm deep) were buried 10 m apart in east–west transects in each of the burned and unburned alvar woodlands. The traps were buried so that the tops were flush with the ground surface and there were no nearby obstructions. Each trap was filled with antifreeze and a drop of soap to half depth. Five days

after setting, the traps were checked. The survey continued from spring through summer to fall with several gaps. The dates of checking the traps were 16 May; 1, 9 June; 1, 5, 12 July; 16, 21, 26 August; and 8, 13 September 2008. These traps, set out and checked by PMC and BK, provided the entire basis for a comparison of Coleoptera and Araneae and most of the information on Orthoptera.

(2) Sweeping: To additionally sample Orthoptera, at each site on each visit, 15 minutes was spent sweeping vegetation less than 1.5 m tall. Sweeping was always done on vegetation selected randomly along the same 100 m transect.

Orthopterans were identified by PMC using Vickery and Kevan (1985). Ground beetles were identified by HG (1961, 1963, 1966, 1968, 1969a, 1969b), Bousquet and Larochelle (1993), and Goulet & Bousquet (2004). Spiders were identified by RB using primary taxonomic literature and available regional keys (e.g., Dondale and Redner 1978, 1982, 1990; Paquin and Dupérré 2003; Platnick and Dondale 1992). Ninety-one juvenile spiders and 52 juvenile orthopterans, unidentifiable to species, were excluded from the analysis. Voucher specimens were deposited in the Canadian National Collection of Insects at Agriculture and Agri-Food Canada (CNCI) in Ottawa.

Comparing biodiversity

Biodiversity was compared with respect to: (1) total number of species and numbers of individuals within species, (2) the presence of regionally rare species (confined to alvars or known from less than four locations in the Ottawa valley), (3) the extent of distinctive composition, and (4) by applying Brillouin's Index which includes consideration of heterogeneity (species richness and evenness), is relatively sensitive to the abundance of rare species, and assumes a finite sample and collection of that sample without replacement of individuals (Krebs 1999, 2008). Replacement in this case is expected to have been the same in both habitats, would not likely have been from substantial distances (i.e., over 100 m) for these ground dwelling species, and would not have involved second generations since most of these species have a single generation in a year.

Results

Overall, 19 species of orthopterans, 29 species of ground beetles, and 42 species of spiders were recorded (Tables 1–3). Species composition differed between the burned and unburned sites. The sites shared 9, 2, and 10 grasshopper, ground beetle, and spider species, respectively (Tables 1–3), or 47.4 %, 6.9 %, and 40.9 % of all collected grasshopper, ground beetle, and spider species. For species in common, the number of individuals was generally highest in the burned woodland for orthopterans and ground beetles but not for spiders. At each site certain unique species were common, e.g., the grasshopper *Tetrix ornata* (Say), the spider *Schizocosa avida* Walckenaer in the burned site, and the ground beetle *Synuchus impunctatus* (Say) in the unburned site.

Four regionally rare grasshopper species were present at each site (Table 1). Of these, *Melanoplus keeleri luridus* (Dodge), *Spharagemon bolli bolli* Scudder, and *Encoptolophus sordidus* (Burmeister) were found only in the burned site and *Melanoplus*

TABLE 1. Species and number of individuals of orthopterans (Orthoptera) recorded in burned and unburned woodland on the Burnt Lands. Species marked with an asterisk (*) are regionally rare.

Species	Burned	Unburned
Acrididae		
Chloealtis conspersa Harris*	-	5
Chortophaga viridifasciata (De Geer)	13	-
Encoptolophus sordidus (Burmeister)*	5	-
Melanoplus bivitattus (Say)	3	1
M. dawsoni (Scudder)*	-	8
M. fasciatus (F. Walker)*	1	1
M. keeleri luridus (Dodge)*	33	-
M. punctulatus (Scudder)*	-	1
M. sanguinipes (Fabricius)	3	-
Spharagemon bolli bolli Scudder*	16	-
Gryllidae		
Allonemobius fasciatus (De Geer)	19	2
Gryllus pennsylvanicus Burmeister	32	8
G. veletis (Alexander & Bigelow)	22	6
Oecanthidae		
Oecanthus quadripunctatus (Beutenmüller)	3	2
Phaneropteridae		
Scudderia curvicauda (De Geer)	1	1
S. furcata furcata Brunner von Wattenwyl	1	1
Rhaphidophoridae		
Ceuthophilus cf. maculata (Harris)	-	7
Tetrigidae		
Nomotettix cristatus cristatus (Scudder)	3	1
Tetrix ornata ornata (Say)	23	-
Totals	**178**	**44**

dawsoni (Scudder), *M. punctulatus* (Scudder), and *Chloealtis conspersa* Harris only in the unburned site. Similarly, of the 6 regionally rare ground beetle species collected during the study, *Harpalus indigens* Casey, *Selenophorus gagatinus* Dejean, *S. opalinus* (LeConte), and the southern *Calathus opaculus* LeConte were found only in the burned woodland, while the boreal species *Harpalus fulvilabris* Mannerheim and the alvar-restricted species *Pterostichus novus* Straneo were found only in the unburned woodland. All collected spiders were members of wide-ranging and relatively common species.

Species richness was greater in the burned woodland for all three groups. With respect to orthopterans, the burned woodland had 15 species and unburned woodland had 13 species (Table 1, Figure 2). For spiders, the difference was greater with 31 species in the burned compared to 22 species in the unburned site (Table 3, Figure 2). Ground beetles provided the greatest contrast in species richness, with 21 species in the burned area compared to 9 species in the unburned area (Table 2, Figure 2).

In all three groups there were more individuals in the burned area (Table 3). This was most pronounced in the case of orthopterans with 3.55 times as many in the burned woodland, and least for spiders with 1.69 times as many in the burned woodland.

TABLE 2. Number of various species of ground beetles (Coleoptera: Carabidae) in 10 pitfall traps in each of a burned and unburned alvar woodland. Species marked with an asterisk (*) are regionally rare.

Species	Burned	Unburned
Agonum cupripenne (Say)	2	-
Amara pennsylvanica Hayward	2	-
Anisodactylus rusticus (Say)	5	-
Calathus gregarius (Say)	2	6
C. opaculus LeConte*	1	-
Calosoma calidum Fabricius	2	-
Carabus nemoralis O.F. Müller	35	8
Chlaenius emarginatus Say	1	-
Cicindela punctulata Olivier	5	-
C. purpurea Olivier	1	-
C. sexguttata Fabricius	3	-
Diplocheila obtusa (LeConte)	1	-
Harpalus faunus Say	34	-
H. fulvilabris Mannerheim*	-	1
H. indigens Casey*	3	-
H. laevipes Zetterstedt	1	-
H. laticeps LeConte	10	-
H. opacipennis (Haldeman)	1	-
H. pensylvanicus (De Geer)	9	-
Notiophilus aeneus (Herbst)	-	1
Poecilus lucublandus (Say)	-	8
Pterostichus novus Straneo*	-	1
P. mutus (Say)	1	-
P. pensylvanicus LeConte	-	5
Selenophorus gagatinus Dejean*	4	-
S. opalinus (LeConte)*	1	-
Sphaeroderus stenostomus lecontei Dejean	-	2
Synuchus impunctatus (Say)	-	34
Totals	**124**	**66**

The value of Brillouin's biodiversity index was higher for both orthopterans and ground beetles in the burned site but higher for spiders in the unburned woodland (Figure 2).

Discussion

In some cases the much greater presence of a species in either habitat is to be expected on the basis of known ecological associations of a general or specific nature. For example, the orthopterans found only in woodland (*Chloealtis conspersa* and *Melanoplus punctulatus*) are known to require wood for oviposition, and the latter species is found mostly on tree trunks (Vickery and Kevan 1985). The ground beetles present are mostly normal to one site or the other (Lindroth 1961). The large number of *Carabus nemoralis* in the open areas may be a result of greater abundance of earthworms in the more mineral substrates of the open area as compared to the more acidic needle litter of the woodland. *Harpalus faunus*, which collects small seeds, may be more abundant in the burned area as a

TABLE 3. Numbers of various species of spiders (Araneae) in 10 pitfall traps in each of a burned and unburned alvar woodland.

Species	Burned	Unburned
Agelenidae		
Agelenopsis potteri (Blackwall)	7	6
Agelenopsis utahana (Chamberlin & Ivie)	1	-
Clubionidae		
Clubiona mixta Emerton	1	-
Elaver excepta (L. Koch)	-	2
Corinnidae		
Castianeira longipalpa (Hentz)	3	-
Gnaphosidae		
Callilepis pluto Banks	1	-
Drassodes neglectus (Keyserling)	13	-
Drassylus depressus (Emerton)	1	-
D. niger (Banks)	-	1
D. socius Chamberlin	-	2
Haplodrassus bicornis (Emerton)	-	2
H. signifer (C.L. Koch)	8	-
Herpyllus ecclesiasticus Hentz	-	1
Gnaphosa muscorum (L. Koch)	24	5
Micaria laticeps Emerton	1	-
Z. fratris Chamberlin	2	11
Z. hentzi Barrows	7	17
Hahniidae		
Neoantistea magna (Keyserling)	-	5
Liocranidae		
Agroeca ornata Banks	-	4
A. pratensis Emerton	1	6
Lycosidae		
Alopecosa aculeata (Clerck)	2	10
Hogna frondicola (Emerton)	-	11
P. distincta (Blackwall)	9	16
P. moesta Banks	-	1
Schizocosa avida (Walckenaer)	76	-
S. crassipalpata Roewer	10	-
S. saltatrix (Hentz)	14	6
Trochosa ruricola (De Geer)	3	-
T. terricola Thorell	3	23
Oxyopidae		
Oxyopes scalaris Hentz	-	1
Philodromidae		
Thanatus formicinus (Clerck)	2	1
Salticidae		
Evarcha hoyi (Peckham & Peckham)	-	1
Habronattus viridipes (Hentz)	8	-
Phidippus purpuratus Keyserling	2	-
Thomisidae		
Xysticus alboniger Turnbull et al.	5	-
X. ampullatus Turnbull et al.	9	-
X. canadensis Gertsch	2	-
X. elegans Keyserling	3	8
X. luctuosus (Blackwall)	1	-
X. pellax O. P.-Cambridge	15	-
X. punctatus Keyserling	1	-
X. triguttatus Keyserling	2	-
Totals	**237**	**140**

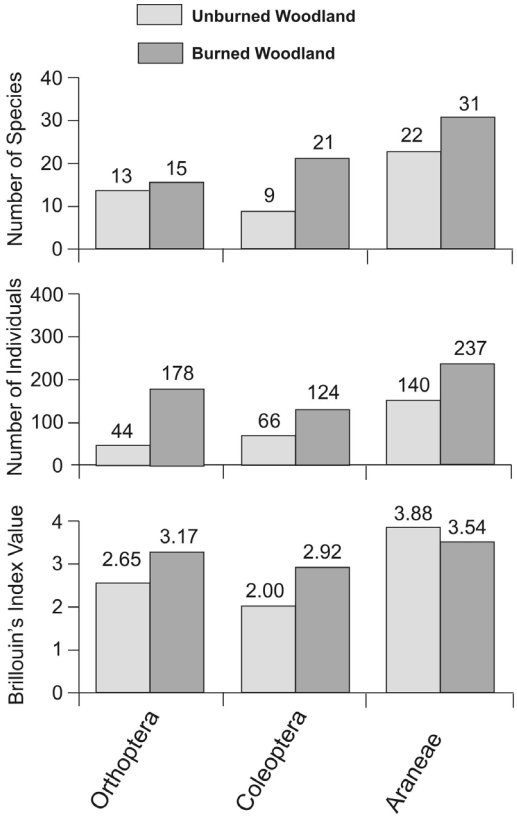

FIGURE 2. Number of species, number of individuals, and the value of Brillouin's Index for three arthropod groups in burned and unburned alvar woodland.

result of greater numbers of herbs with small seeds in that area. The abundance of *Synuchus impunctatus* in the unburned woodland and its absence from the burned area is anticipated on the basis of its association with deep litter (Lindroth 1961), which was removed by fire from the burn. Likewise with respect to the spiders, some of the major differences were anticipated based on known species and habitat associations, such as the relationship of many *Schizocosa* and *Xysticus* species with dry, open habitats.

Our results suggest that the relatively long lasting successional shrubland that follows burning of alvar woodland differs from the original woodland in species composition, higher species richness and density, and higher biodiversity index values for some arthropod groups. The fact that the Brilluoin Index has a slightly lower value for spiders in the burned area than in the unburned is a consequence of less evenness in the number of individuals of different species in that site, despite higher diversity and species number. Other studies similarly found highest insect diversity in middle successional stages (e.g., Brown 1984; Kayna & Gürkan 2007) and qualitative differences between burned and unburned sites (e.g., Burger et al. 2005). The importance of succession and differing species compositions in different seral stages is not surprising considering that opposite ends of the sere are characterized by organisms with different life history strategies (Brown 1984).

The tendency for insect diversity to track plant diversity (e.g. Knops et al. 1999) may help to explain the generally higher insect diversity in the burned woodland, which had higher vascular plant diversity than the unburned alvar woodland (Catling in press). With regard to herbivorous insect diversity, which is tracked by predator and parasite diversity (e.g., Knops et al. 1999), other explanatory factors associated with high plant diversity may include increased insect richness per plant host and higher average plant host specificity (Lewinsohn et al. 2005), as well as increased structural diversity of plant hosts (Southwood et al. 1979).

The evidence presented here for the importance of succession to ground-dwelling insects on alvars is based on a single location and a rather limited sampling procedure. However, the relationship seems to hold for other alvar sites in the Ottawa valley based on general comparative surveys (Catling, unpublished data). Although management of alvar vegetation with succession-initiating fire seems appropriate, it may also have negative impacts (Siemann et al. 1996), especially if it does not allow survival of some species in unburned patches that serve as refugia. Fire or any form of biomass removal should be part of a broad, long-term landscape management plan that takes many species and species groups into account.

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