Vascular Plants of a Successional Alvar Burn 100 Days After a Severe Fire and Their Mechanisms of Re-establishment

PAUL M. CATLING[1,2], ADRIANNE SINCLAIR[1], and DON CUDDY[3]

[1] Biology Department, University of Ottawa, 30 Marie Curie Street, P.O. Box 450, Station A, Ottawa, Ontario K1N 6N5 Canada
[2] Agriculture and Agri-food Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6 Canada
[3] Ontario Ministry of Natural Resources, Concession Road, Postal Bag 2002, Kemptville, Ontario K0G 1J0 Canada

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In order to describe the vascular plant community 100 days after a severe fire in alvar woodland near Ottawa, Ontario, we set out fifty one m square quadrats at 5 m intervals along transects at each of five sites and recorded presence and cover of vascular plant species in each quadrat. The woodlands that burned were dominated by *Thuja occidentalis*, *Populus tremuloides*, *Abies balsamea*, *Picea glauca*, and *Pinus strobus* in approximate order of importance. The post-fire flora was diverse and mostly native. Although substantial variation occurred in presence, frequency and cover of species between the sites, there was remarkable similarity in a distinctive group of dominants including *Populus tremuloides*, *Geranium bicknellii*, and *Corydalis aurea.* Rare species present in the burned woodland included *Astragalus neglectus*, *Calystegia spithamaea*, *Carex richardsonii*, *Corydalis aurea*, *Muhlenbergia glomerata*, *Panicum flexile*, *Panicum philadelphicum*, *Petasites frigidus*, *Scutellaria parvula*, and *Viola nephrophylla*. Of these, *Corydalis aurea* and *Calystegia spithamaea* were frequent. The development of vascular flora following the fire was a consequence of growth from roots, rhizomes, and root crowns that survived the fire, and seeds buried in the soil. Although abundant in the burned woodland, *Corydalis aurea* and *Dracocephalum parviflorum* had not been previously recorded at the site, suggesting that these species are adapted to early post-fire succession, surviving periods of up to 130 years between fires as seeds in a very large and widespread subterranean seed bank. Not only is post-fire succession well underway within a hundred days of a fire, but even in its earliest stages, it appears to serve as a specific niche for a distinctive group of species including some that are rare and restricted. A diverse native flora is involved indicating the importance of management involving removal of woody biomass.

Key Words: alvar, fire, flora, species diversity, rare species, succession, management, biomass removal, prescribed burn, Great Lakes, Ontario, Canada.

Periodically burned woodlands associated with alvar landscapes (i.e., landscapes with more or less drought-maintained open areas on thin soil over essentially flat limestone, dolostone or marble) have recently been recognized as an important part of the alvar ecosystem with regard to protection of rare species and biodiversity and have been termed "successional alvar burns" (Catling and Brownell 1998). Although their importance is generally accepted, the information upon which it is based is limited to common sense, anecdotes, and a single evaluation including data analysis (Catling and Brownell 1998).

On 23 June 1999, 152 hectares of mostly forested terrain in the Burnt Lands near Almonte (Figure 1) was burned. This was a major fire. A shower of ash rained down on streets in downtown Ottawa 40 km away and the fire moved at a rate of 15 m/min. The flames reached well over 30 m into the air and an area at least 1 km in length was severely burned. This area was last burned in 1870. Dry conditions in the relatively shallow soil over porous limestone rock led to a relatively slow return to a mixed boreal and fire prone forest type following the 1870 fire, and it seems likely that fire and post-fire succession has been going on in the area for many hundreds (or thousands) of years.

Brunton (1986*) suggested that the Burnt Lands was a "fire-dependent environment of great provincial significance" that "will require continued renewal by periodic burning if its important natural values are to be preserved." The recent (1999) fire in the Burnt Lands provided an opportunity to gather information related to this suggestion. There are conflicting views about fire in alvar woodland that range from the creation of a long lasting desert to almost immediate return to the pre-fire floristic composition. We agree fully with Brunton's suggestion and further suggest that successional changes occur over decades providing high floristic and faunistic biodiversity as well as spatial-temporal habitat for rare and restricted species. Information on the specific effects of fire is currently insufficient to allow informed choices between management options. The nature of succession in successional alvar burns is not documented with respect to timing of changes or floristic composition, and thus the importance of the succession to biodiversity protection is poorly understood. The compositional changes also relate to the required frequency of implementation of management actions. Finally, biomass removal by fire management is potentially important, not just to the management of biodiversity, but also to the protection of people and property (from catastrophic fire) where fire-prone vegetation exists in semi-urban areas.

The present study was designed to document the earliest stages of succession thereby providing an indication of its rapidity and potential biodiversity significance including a consideration of whether or not there are species which are adapted to the very earliest stages of the succession. This information is needed for the protection and management of alvars, which are a globally imperilled ecosystem (Brownell 2000) confined in North America to a restricted portion of the Great Lakes region (Catling and Brownell 1995, 1999). Specifically, it is required for the management of the Burnt Lands alvar landscape which has been designated as a provincially significant life science Area of Natural and Scientific Interest (ANSI), with intent to increase protection through designation of provincial crown lands and former federal properties as a provincial nature reserve (Brownell 2000). This requires increasingly comprehensive management and monitoring of significant natural resources.

Methods

Fifty-one m^2 quadrats at 5 m intervals along transects were set out in alvar woodland at each of five sites. The only criteria for determining placement of transect lines was complete burning of all vegetation, separation from each other by more than 300 m, and adequate representation of the burned area through coverage of the eastern, western, northern, southern and central portions. These regions were characterized by different pre-fire tree composition as described below. For each quadrat the total cover (dm^2 estimated as the upper leaf surface area) of each plant species was recorded. Using an estimate of the photosynthetic surface area of the plants rather than the surface area of the quadrat covered by that species permits a more direct correlation between cover values and biomass. The total cover and total frequency for each species at each site was calculated and total overall cover and total overall frequency were tabulated (Table 1). To determine the composition of the original woodland, the tree in each of four quadrants closest to the quadrat centre was identified and measured (dbh-diameter at breast height). The data were then tabulated by species frequency and range of dbh for each site (Table 2). Field work was done on 1–7 October 1999, approximately 100 days after the fire and prior to the first severe frosts. There was no perceptible loss of post-fire vegetation due to dieback in the burned areas sampled.

Status information on the species recorded is provided on a spatial scale of rarity (N,P,R,S,O, see Table 1) with N = nationally rare (Brownell and Larson 1995*); P = provincially rare (Brownell and Larson 1995*); R = regionally rare (eastern Ontario in Brownell and Larson 1995*); S = rare in the St. Lawrence-Ottawa physiographic region (i.e., MNR 6–11 and 6–12, Brownell and Larson 1995*); and O = rare in Ottawa-Carleton (Brunton 1997*). Species listed were also distinguished as native or introduced.

To determine the methods of colonization, plants were excavated and examined 50 days after the fire at site 1 and 100 days after the fire at all sites. Although not quantitative, the observations are considered reliable and useful, and included here since they provide the only source of information on this aspect that is available. Voucher specimens for species recorded were deposited in the vascular plant herbarium of Agriculture and Agri-food Canada (DAO) in Ottawa.

Results and Discussion

General observations

The woodlands that burned were dominated by *Thuja occidentalis*, *Populus tremuloides*, *Abies balsamea*, *Picea glauca*, and *Pinus strobus* in approximate order of importance (Table 2). Similar woodlands are present on alvar landscapes elsewhere in Ontario but often also have Bur Oak (*Quercus macrocarpa* Michx.), and those on the Napanee Plain also have Eastern Red Cedar (*Juniperus virginiana* L.), and those on the Bruce Peninsula and Manitoulin Island also have Jack Pine (*Pinus banksiana* Lamb.) and Red Oak (*Quercus rubra* L.).

Despite variation between sites there was remarkable similarity with respect to a distinctive group of dominants (Table 1). Approximately 100 species were recorded in the quadrats and only 16 of these were introduced. Of the total species, 19 exceeded 5% overall frequency with only 3 of the 19 being introductions. The majority of the plants and over 90% of the cover at each site was comprised of native species. Thus the flora developing after the fire was comprised largely of native species and it was relatively diverse (Table 1).

Variation between sites

The species which re-colonize a burn and the means of colonization can be expected to vary depending upon the intensity of the fire. There is natural variation in the amount of heat generated, and fire-fighting efforts (such as water bombing) undoubtedly will locally reduce the penetration of heat into the soil. This may add to the fine scale variation in patterns of re-colonization but is unlikely to alter the range of means observed over 50 quadrats. Consequently variation in post-fire colonization between sites is most likely to be related to factors other than fire intensity.

Surface coverage of plants varied from approximately 10–50% among the five sites and species with cover values exceeding 1% of quadrat surface varied from three to eight in number at a site. The

*See Documents Cited section.

TABLE 1. Total cover (dm^2) in 50 quadrats, percentage frequency, and status (N = nationally rare (Brownell 1995); P = provincially rare (Brownell 1995); R = regionally rare (eastern Ontario in Brownell 1995); S = rare in the St. Lawrence-Ottawa physiographic region (i.e., MNR 6–11 and 6–12, Brownell 1995); O = rare in Ottawa-Carleton (Brunton 1997)) for vascular plant species in the herb layer (less than 1 m above ground) in five burned woodlands approximately 100 days after a fire in the Burnt Lands near Almonte, Ontario. The data are based on 50 one m^2 quadrats at each site laid out along transects within an area of approximately 1 hectare. Species are listed in descending order of overall cover. Species marked with an asterisk (*) are introduced. Note that *Pinus banksiana* is a native species that is believed to be introduced at this site based on absence of older trees in surrounding forests and past plantings.

	Total Cover (dm^2)					Total	% Frequency					Mean
Scientific Name	1	2	3	4	5	Overall	1	2	3	4	5	Overall
Populus tremuloides Michx., Trembling Aspen	329.4	417.3	1296.6	255.9	64.4	2363.6	74	86	96	64	42	72.4
Geranium bicknellii Britton, Bicknell's Crane's-bill	18.9	297.6	572	198.9	240.8	1328.2	26	78	94	80	74	70.4
Pteridium aquilinum (L.) Kuhn var. *latiusculum* (Desv.) L. Underw. ex A. Heller, Eastern Bracken-fern	–	156.1	247	–	–	403.1	–	38	28	–	–	13.2
Corydalis aurea Willd. ssp. *aurea*, Golden Corydalis (**SO**)	83.1	15.9	88.2	48.8	26.9	262.9	66	14	32	30	26	33.6
Aster macrophyllus L., Large-leaved Aster	32.2	61.9	46.8	–	–	140.9	14	32	8	–	–	10.8
Medicago lupulina L., Black Medick (*)	2.5	2.5	58	0.4	–	63.4	4	2	28	2	–	7.2
Rosa acicularis Lindl. ssp. *sayi* (Schwein.) W. Lewis, Prickly Rose	–	–	55.6	6.4	0.2	62.2	–	–	46	12	2	12.0
Symphoricarpos albus (L.) S. F. Blake, Snowberry	22.4	17.9	19.5	–	0.5	60.3	24	36	20	–	2	16.4
Apocynum cannabinum L., Indian Hemp	28	13.2	8	–	–	49.2	4	12	8	–	–	4.8
Dracocephalum parviflorum Nutt., Small-flowered Dragonhead	–	33.2	–	2.3	10.7	46.2	–	28	–	2	14	8.8
Populus balsamifera L. ssp. *balsamifera*, Balsam Poplar	–	–	29.8	0.7	–	30.5	–	–	12	2	–	2.8
Rhus rydbergii Small ex Rydb., Poison-ivy	9.5	–	14.8	1.8	0.4	26.5	26	–	30	10	2	13.6
Petasites frigidus (L.) Fr., Sweet-coltsfoot (**S**)	–	–	15.8	9.3	–	25.1	–	–	6	8	–	2.8
Aralia nudicaulis L., Wild Sarsaparilla	–	11.1	13	–	–	24.1	–	14	18	–	–	9.2
Aster ciliolatus Lindl., Ciliolate Aster	3	–	1.6	11.2	7.8	23.6	2	–	6	10	10	5.6
Taraxacum officinale G. Weber, Common Dandelion (*)	13.2	1.8	2.8	3.0	–	20.8	16	4	6	6	–	6.4
Senecia pauperculus Michx., Balsam Groundsel	–	–	–	1.2	19.6	20.8	–	–	–	4	7	2.2
Cirsium vulgare (Savi) Ten., Bull Thistle (*)	–	–	–	7	11	18.0	–	–	–	4	4	1.6
Hieracium piloselloides Vill., Glaucous King Devil (*)	1	2	6	1.8	4.4	15.2	2	2	8	6	14	6.4
Campanula rotundifolia L., Harebell	1.5	–	3.7	3.0	6.7	14.9	6	–	10	12	16	8.8
Aquilegia canadensis L., Wild Columbine	4	–	3.3	0.1	6.6	14.0	4	–	4	2	12	4.4
Verbascum thapsus L., Common Mullein (*)	1.5	–	11.9	–	2	15.4	2	–	12	–	2	3.2
Waldsteinia fragarioides (Michx.) Tratt., Barren Strawberry	2	4	3.4	–	2.5	11.9	8	6	10	–	14	7.6
Chenopodium simplex (Torr.) Raf., Maple-leaved Goosefoot	1	–	9	1.3	–	11.3	2	–	6	2	–	2.0
Rubus pubescens Raf., Dwarf Raspberry	–	–	–	8.4	–	8.4	–	–	–	18	–	3.6
Celastrus scandens L., Climbing Bittersweet	–	–	8	–	–	8.0	–	–	6	–	–	1.2
Hypericum sp., St. John's-wort	–	8	–	–	–	8.0	–	2	–	–	–	0.4
Rubus cf. *pubescens* Raf., Dwarf Raspberry	–	–	8	–	–	8.0	–	–	16	–	–	3.2
Rhus typhina L., Staghorn Sumac	7.2	–	–	–	–	7.2	18	–	–	–	–	3.6
cf. *Danthonia spicata* (L.) P. Beauv. ex Roem. & Schult., Poverty Oat Grass	–	–	7	0.7	–	7.7	–	–	2	6	–	1.6

continued

TABLE 1. *continued*

Scientific Name	Total Cover (dm^2) 1	2	3	4	5	Total Overall	% Frequency 1	2	3	4	5	Mean Overall
Lonicera sp., Honeysuckle	–	–	7	–	–	7.0	–	–	2	–	–	0.4
Aquilegea canadensis L., Wild Columbine	–	–	–	–	6.6	6.6	–	–	–	–	12	2.4
Prunus cf. *virginiana* L. ssp. *virginiana*, Choke Cherry	–	–	6	–	0.2	6.2	–	–	2	–	2	0.8
Panicum acuminatum Sw. var. *acuminatum*, Acuminate Panic Grass	1.7	–	2	0.2	3.7	7.6	10	–	4	4	10	5.6
Viola adunca Sm., Hooked-spur Violet	2.7	–	3.1	–	–	5.8	10	–	22	–	–	6.4
Solidago nemoralis Aiton, Gray-stemmed Goldenrod	–	–	5	–	0.7	5.7	–	–	4	–	8	2.4
Rubus cf. *idaeus* L. ssp. *melanolasius* (Dieck) Focke, Wild Red Raspberry	–	–	4	–	2	6.0	–	–	2	–	2	0.8
Cirsium sp., thistle	1.5	2	2	1.4	–	6.9	2	2	4	6	–	2.8
Rosa sp., rose	2	3.5	–	–	–	5.5	2	10	–	–	–	2.4
Clinopodium vulgare L., Wild Basil	–	–	5	–	–	5.0	–	–	2	–	–	0.4
Vicia sp., Vetch (*)	5	–	–	–	–	5.0	2	–	–	–	–	0.4
Trichostema brachiatum L., False Pennyroyal	–	–	–	–	5	5.0	–	–	–	–	2	0.4
Viburnum rafinesquianum Schult., Downy Arrow-wood	–	–	5	–	–	5.0	–	–	2	–	–	0.4
Carex sp., sedge	–	1	3	0.4	–	4.4	–	2	24	8	–	6.8
Panicum linearifolium Nash, Narrow-leaved Panic Grass	–	–	1.3	–	3	4.3	–	–	6	–	2	1.6
Vicia cracca L., Tufted Vetch (*)	–	–	3.4	0.5	0.1	4.0	–	–	8	2	2	2.4
Maianthemum canadense Desf., Wild Lily-of-the-valley	2	–	1.5	0.3	0.1	3.9	4	–	20	4	2	6.0
cf. *Lilium philadelphicum* L., Wood Lily	–	–	3	–	0.2	3.2	–	–	6	–	4	2.0
Prunus cf. *pensylvanica* L., f. Pin Cherry	–	–	3.1	–	–	3.1	–	–	12	–	–	2.4
Calystegia spithamaea (L.) Pursh ssp. *spithamaea*, Low Bindweed (**RSO**)	3.1	–	–	–	–	3.1	–	26	–	–	–	5.2
Cornus stolonifera Michx., Red-osier Dogwood	–	–	3	–	–	3.0	–	–	8	–	–	1.6
Astragalus neglectus (Torr. & A. Gray) E. Sheld., Neglected Milkvetch (**PRSO**)	–	–	3	–	–	3.0	–	–	2	–	–	0.4
Panicum philadelphicum Bernh. ex Trin., Wood Panic Grass (**S**)	–	–	3	–	–	3.0	–	–	2	–	–	0.4
Carex cf. *intumescens* Rudge, Bladder Sedge	–	–	3	–	–	3.0	–	–	2	–	–	0.4
Amelanchier alnifolia (Nutt.) Nutt. ex R. Roem ssp. *compacta* (Nielsen) McKay, Juneberry	–	2	2.3	0.6	–	4.9	–	2	6	2	–	2.0
Solidago juncea Aiton, Early Goldenrod	–	–	–	–	2.3	2.3	–	–	–	–	4	0.8
Solidago hispida Muhl. var. *hispida*, Hairy Goldenrod	–	–	1.3	–	2.2	3.5	–	–	2	–	6	1.6
Solidago ptarmicoides (Nees) B. Boivin, Upland White Goldenrod (**S**)	–	–	–	–	2.1	2.1	–	–	–	–	6	1.2
unidentified rosette 2	–	–	2	–	–	2.0	–	–	2	–	–	0.4
Cornus canadensis L., Bunchberry	–	–	2	–	–	2.0	–	–	2	–	–	0.4
Antennaria sp., Pussytoes	2	–	–	–	–	2.0	–	2	–	–	–	0.4
Fragaria virginiana Miller ssp. *virginiana*, Scarlet Strawberry	–	–	–	1.0	0.9	1.9	–	–	–	2	4	1.2
Carex richardsonii R. Br., Richardson's Sedge (**SO**)	–	–	–	0.6	1.2	1.8	–	–	–	10	10	4.0

continued

TABLE 1. *continued*

Scientific Name	Total Cover (dm²) 1	2	3	4	5	Total Overall	% Frequency 1	2	3	4	5	Mean Overall
Panicum flexile (Gattinger) Scribn., Wiry Panic Grass **(S)**	–	–	–	–	1.8	1.8	–	–	–	–	8	1.6
Solidago sp., goldenrod	1.5	–	–	–	–	1.5	2	–	–	–	–	0.4
Rosa blanda Aiton, Smooth Rose	–	–	–	1.1	0.3	1.4	–	–	–	6	2	1.6
Trifolium sp., Clover (*)	–	–	1.2	–	0.1	1.3	–	–	6	–	2	1.6
Sanicula sp., snakeroot	–	–	1.3	–	–	1.3	–	–	4	–	–	0.8
Agrostis hyemalis (Walter) B.S.P., Colonial Bent Grass	–	–	–	0.7	0.6	1.3	–	–	–	2	4	1.2
Carex pellita Willd., Woolly Sedge	–	–	–	0.7	0.5	1.2	–	–	–	6	4	2.0
Spiraea alba Du Roi, Narrow-leaved Meadow-sweet	–	–	1.2	–	–	1.2	–	–	2	–	–	0.4
Rhamnus frangula L., Glossy Buckthorn (*)	–	–	–	1.2	–	1.2	–	–	–	2	–	0.4
Danthonia spicata (L., P. Beauv. ex Roem. & Schult., Poverty Oat Grass	–	–	–	1.0	1.0	2.0	–	–	–	8	1.6	1.9
Diervilla lonicera Miller, Bush Honeysuckle	–	–	1	–	–	1.0	–	–	2	–	–	0.4
Viola cf. *renifolia* A. Gray, Kidney-leaved Violet	–	–	1.0	–	–	1.0	–	–	2	–	–	0.4
Trifolium cf. *repens* L., White Clover (*)	–	–	1	–	–	1.0	–	–	2	–	–	0.4
Equisetum scirpoides Michx., Dwarf Scouring-rush	–	–	1	–	–	1.0	–	–	2	–	–	0.4
unidentified rosette 1	–	–	1	–	–	1.0	–	–	2	–	–	0.4
Chaenorrhinum minus (L.) Lange Dwarf Snapdragon (*)	–	–	–	–	0.8	0.8	–	–	–	–	6	1.2
unidentified rosette 3	–	–	–	0.7	–	0.7	–	–	–	6	–	1.2
grass	–	–	–	–	0.7	0.7	–	–	–	–	4	0.8
Viola nephrophylla Greene, Northern Bog Violet **(RS)**	–	–	–	–	0.6	0.6	–	–	–	–	4	0.8
Arctostaphylos uva-ursi (L.) Spreng., Common Bearberry	–	–	–	–	0.6	0.6	–	–	–	–	4	0.8
Houstonia sp.	–	–	–	0.5	–	0.5	–	–	–	2	–	0.4
Muhlenbergia glomerata (Willd.) Trin., Glomerate Satin Grass **(S)**	–	–	–	–	0.5	0.5	–	–	–	–	2	0.4
Carex castanea Wahlenb., Chestnut Sedge	–	–	–	0.5	–	0.5	–	–	–	2	–	0.4
Hypericum perforatum L., Common St. John's-wort (*)	–	–	–	–	0.5	0.5	–	–	–	–	4	0.8
unidentified rosette 4	–	–	–	–	0.4	0.4	–	–	–	–	2	0.4
Glyceria sp., Manna Grass	–	–	–	0.3	–	0.3	–	–	–	2	–	0.4
Pinus banksiana Lamb., Jack Pine (*)	–	–	–	–	0.3	0.3	–	–	–	–	4	0.8
Carex sect. *Ovales*	–	–	–	0.3	–	0.3	–	–	–	2	–	0.4
unidentified shrub	–	–	–	–	0.2	0.2	–	–	–	–	2	0.4
Plantanthera sp., orchid	–	–	–	0.2	–	0.2	–	–	–	4	–	0.8
Panicum sp.	–	–	–	–	0.1	0.1	–	–	–	–	2	0.4
Prunella vulgaris L. ssp. *vulgaris*, Common Heal–all (*)	–	–	–	0.1	–	0.1	–	–	–	2	–	0.4
Scutellaria parvula Michx., Small Skullcap **(S)**	–	–	–	0.1	0.1	0.2	–	–	–	2	6.4	1.7
cf. *Rhamnus cathartica* L., Common Buckthorn (*)	–	–	–	0.1	–	0.1	–	–	–	2	–	0.4

total species recorded in quadrats at a site varied from approximately 18 to approximately 50 (Table 1). These data are approximate because only portions of sites were sampled, some small immature plants could not be identified accurately, and some species noted at sites were not recorded within quadrats.

Site 1, previously dominated by White Spruce and Trembling Aspen (Table 2) had a relatively low diversity of 25 species. This site had the lowest cover of *Geranium bicknellii,* a relatively high cover of *Corydalis aurea* and the highest cover values for *Apocynum cannabinum* and *Symphoricarpos alba* (Table 1).

Site 2 was previously dominated by Trembling Aspen and Eastern White Cedar (Table 2). *Aster macrophyllus* and *Dracocephalum parviflorum* reached their highest cover values here. *Corydalis aurea* had its lowest cover value at this site. Diversity was lowest at this site with 18 species recorded in quadrats (Table 3).

Site 3, previously dominated by Eastern White Cedar and Balsam Fir (Table 2), had a relatively high diversity of approximately 50 species. This site had the highest cover of Trembling Aspen regrowth, the highest cover of *Geranium bicknellii* and *Corydalis aurea*, highest cover of many other species such as *Rosa acicularis*, *Chenopodium simplex* and *Petasites frigidus*. This site also had a relatively high cover value for some weeds such as *Medicago lupulina* and *Verbascum thapsus* (Table 1).

Eastern White Cedar had previously dominated site 4 (Table 2). Approximately 40 species were recorded here. This site had the highest cover values for *Aster ciliolatus* and *Rubus pubescens*. *Aster macrophyllus* and *Symphoricarpos albus* were conspicuously absent.

Site 5 had been a wooded edge of an alvar opening that was dominated by Eastern White Cedar and White Spruce. Not surprisingly, being a wooded edge, it was the only site, or the site with largest cover values, for a number of species characteristic of alvar openings such as *Aquilegia canadensis, Carex richardsonii, Panicum flexile, Senecio pauperculus, Solidago juncea,* and *Trichostema brachiatum.*

Dominant species

The species accounting for the highest frequency and cover 100 days after the fire were *Populus tremuloides, Geranium bicknellii* and *Corydalis aurea* (Table 1). These three were present at all of the five burned woodland sites, and their frequency values ranged from 33.6 to 72.4% of the total 250 quadrats. Each of these species had cover values exceeding 1%. Other species were much less important in terms of cover (Table 1), or in the cases of *Aster macrophyllus* and *Pteridium aquilinum*, were not present at all sites and had a much lower mean frequency (Figure 1).

Significant Species

The rare species recorded in quadrats at the five sites included *Astragalus neglectus, Calystegia spithamaea, Carex richardsonii, Corydalis aurea, Muhlenbergia glomerata, Panicum flexile, Panicum philadelphicum, Petasites frigidus, Scutellaria parvula*, and *Viola nephrophylla.* Only the first mentioned is provincially rare, the others being rare regionally (Table 1 and methods). Most of these rare species were infrequent, but *Corydalis aurea* had a relatively high overall frequency (33.3 %) and a relatively high overall cover (Table 1). *Calystegia spithamaea* was also frequent with 5.25 % frequency overall but 26 % frequency at one site. The early post-fire flora thus includes 10 rare species of which two are relatively frequent, one of them being a dominant.

Not only was the regionally rare *Corydalis aurea* a dominant of the recently burned woodland, it was not recorded in a relatively comprehensive checklist of the Burnt Lands area (Brunton 1986*), nor was it listed by White (1979) in an enumeration of the rare species of the site. It is a rather uncommon and puzzling native species often associated with disturbed ground, such as bulldozed tracks though dry calcareous woodland, where it occurs with introduced weeds. *Corydalis aurea* is evidently a species of successional alvar burns that becomes abundant due to release from the seedbank in the early post-fire succession, only to disappear again in the later stages of succession explaining why earlier botanists documenting the flora did not find it. They needed a fire

TABLE 2. Tree frequencies and dbh range (cm) of fire–killed trees in four quadrants of each of 50 points laid out along transects within an area of approximately 2 acres in each of four burned woodlands approximately 100 days after a severe fire in the Burnt Lands near Almonte, Ontario.

Species	% Frequency/DBH range			
	1	2	3	4
Picea glauca (Moench) Voss, White Spruce	17/8–36	1.5/15–20	11.5/6–23	1.5/16–17
Pinus strobus L., Eastern White Pine	3.5/9–28	1.5/6–23	2.5/30–40	2.5/14–32
Populus tremuloides Michx., Trembling Aspen	20.5/5–23	14/9–25	9/7–28	4/11–26
Thuja occidentalis L., Eastern White Cedar	5.5/7–21	21.5/5–31	17.5/5–32	55/5–25
Abies balsamea (L.) Miller, Balsam Fir	4.5/6–20	5.5/6–18	20/5–18	6.5/5–14
Betula papyrifera Marshall, White Birch	–	–	0.5/17	–

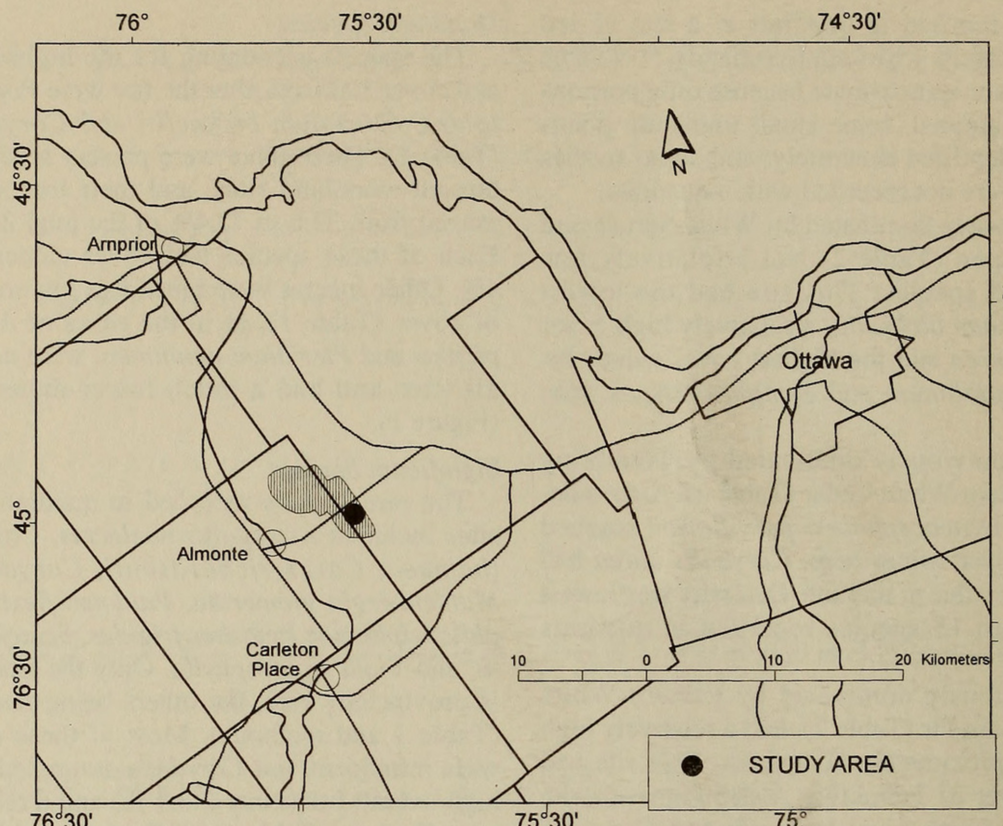

FIGURE 1. Ottawa region of eastern Ontario showing the location of the Burnt Lands (shaded) and the study area (dot).

to see it and there had not been one for more than a hundred years.

Another particularly interesting case is that of *Dracocephalum parviflorum* which was also not listed by Brunton (1986*). It appears to be very similar to *Corydalis aurea* in its natural habitat and niche. Although not found previously in the area it had a frequency of 28% at site 2 and an overall frequency of 8.8%, and it also had the 10th highest cover value of all species.

Although we have highlighted the abundant rare species in the early post-fire succession, it is to be noted that species may be rare in a particular successional stage, but may also be largely or entirely dependent on that stage, and even characteristic of it. This may be true for *Chenopodium simplex* and *Astragalus neglectus*. The quadrats under-represent significance since the sampled ground is so small that population size is not adequately accounted for. At least 100 plants of *Astragalus neglectus* were seen in the burned woodland but frequency and cover was so low as to prevent this species from being well represented in the quadrat sample of 250 m^2. Although present, *Cirsium discolor* was not represented in any of the quadrats, and it was possibly too late in the season to discern *Cypripedium arietinum*. The quadrat sample, although ensuring an accurate and quantitative assessment provides only a minimal picture of early post-fire diversity and significant flora.

Means of colonization

The development of vascular flora following the fire was a consequence of growth from: (1) roots as in the case of the root suckers of *Populus tremuloides* and *Populus balsamifera*; (2) rhizomes and root crowns as in *Apocynum cannabinum, Aralia nudicaulis, Aster ciliolatus, Aster macrophyllus, Pteridium aquilinum, Petasites frigidus, Symphoricarpos albus*; and (3) an ancient soil seed bank as in *Corydalis aurea, Dracocephalum parviflorum* and *Geranium bicknellii.* In the case of many species, especially those of the woodland edge, such as *Senecio pauperculus* and *Campanula rotundifolia*, the relative contribution of seeds and rhizomes was unclear.

Of the introduced species, *Medicago lupulina* appeared to have developed from seed in the soil whereas *Taraxacum officinale* and *Hieracium piloselloides* appeared to have developed entirely from root crowns and/or rhizomes. Regrowth of *Rhamnus frangula* from roots or root crowns at one site varied from 1–1.5 m after 100 days. There is a potential for this species to have a significant negative influence on native species diversity in the post-fire succession and to present problems in the management involving removal of woody biomass, but there was little evidence of it in the burned woodlands (Table 1).

Species that might have provided seed sources from the current year produced seed too late (e.g.,

FIGURE 2. Alvar woodland previously dominated by White Spruce and Trembling Aspen, 100 days after a severe fire. The herb layer is dominated by *Populus tremuloides, Corydalis aurea*, and *Apocynum cannabinum*. Photo by P. M. Catling.

Apocynum cannabinum), or were insufficiently abundant to allow the level of colonization (e.g., *Corydalis aurea* and *Dracocephalum parviflora* which were not present prior to the fire) or could not provide the cover observed in so short a time (e.g., *Populus tremuloides* with relatively small seeds). The only tree seedlings observed were Jack Pine in the burned woodland edge (Table 1).

With respect to the ancient seed bank, for so many seeds to have survived continuously, avoiding predation, rotting, and drying out over a period of more than a hundred years, there must have been many thousands added to each square metre of the soil early after the last fire. The development of the flora after 100 days, provides strong evidence for such an enormous seed input.

Conclusions

The present observations provide further support for the beneficial effects of fire (with some restrictions: see Catling and Brownell 1998), or other woody biomass removal methods, on alvar landscapes. Not only is post-fire succession well underway within a hundred days of a spring or early summer fire, but even in its earliest stages, it appears to serve as a specific niche for a distinctive group of species including some that are rare and restricted. This phenomenon is not confined to alvar woodland. In a review of the literature relating to post-fire succession and buried seeds, Abrams and Dickman (1984) note that germination of many species is restricted to the first year after a fire. Some of these early post-fire colonizers are absent during the later post-fire succession and in some cases not present during the second year. The fact that the natural recovery of alvar woodland is so rapid and involves a diverse and distinctive group of predominantly native species in the initial stages further suggests the importance of fire as a natural process in alvar woodlands, and its importance as a potentially valuable management option.

As in the alvar woodland studied here, *Geranium bicknellii* dominates the vegetation cover during the first year after a fire in Jack Pine woodlands of northern lower Michigan, but disappears subsequently. The seeds were found to be dependent on heat from the fire for germination and reduced dependence on heat in seed from other regions suggested ecotypic variation in germination behaviour (Abrams and Dickman 1984). It appears that a similar mechanism may operate for other species reported here as dominant early colonizers such as *Corydalis aurea* and *Dracocephalum parviflorum*. Subtle local adaptations to natural processes such as heat from fires suggests that management using the natural processes is most desirable. For example, woody biomass may be removed by cutting but the heat required for germination is then not provided. Since alvar woodlands are naturally prone to fire, the management of woody biomass using prescribed burn is necessary for protection of people and their property (from fire) as well as the protection of significant natural resources.

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