Manitoba's endangered alvars: an initial description of their extent and status

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Abstract

Alvars are rare in Canada and uncommon globally. This study represents the first formal attempt to describe and delineate the extent of alvars in Manitoba. A systematic examination of the Interlake region's edaphic and biological characteristics, using a geographic information system, resulted in the identification of 67 sites warranting further field study. Of these sites, 61 were surveyed and information was collected on vegetation composition and structure, soil characteristics, land ownership, and land use. Alvar was confirmed at 28 sites, extending over approximately 3930 ha in five geographically distinct clusters. Four putative types of alvar communities are described: grassland, shrubland, savannah, and wetland. Livestock grazing is the dominant land use and occurs across more than three-quarters of Manitoba alvar. Approximately 12% coincide with mining claims or quarry leases. Two-thirds occur on publicly owned land.

Key words: Alvar; karst; endangered ecosystem; Manitoba; Interlake; limestone; dolomite

Introduction

Alvars are globally uncommon ecosystems that are distinctive for their unusual plant species composition and associations and natural openness in otherwise forested regions (Catling and Brownell 1995; Reshcke *et al.* 1999), although alvar woodlands and the associated successional stages are also important components (Catling and Brownell 1999a; Catling *et al.* 2002; Brunton and Catling 2017). Alvars have thin or absent soils underlain by flat limestone or dolomitic bedrock that restricts drainage; thus, they are subject to extreme variations in moisture availability that range from drought conditions to periodic flooding (Brunton 1988; Catling and Brownell 1995; Reschke *et al.* 1999; Catling 2009a). The physical structure and species composition of alvar plant communities can vary; Great Lakes alvars, for example, have been differentiated into 13 types (Reschke *et al.* 1999). In Manitoba, alvar-like ecosystems that support species characteristic of both prairie and boreal forest, with a limited occurrence of trees and occasional exposure of dolomitic pavement, have been described (Hamel and Foster 2004).

In Canada, alvars are found in the Great Lakes region, Quebec (Reschke *et al.* 1999), and the Northwest Territories (Catling 2009a). The presence of alvar in Manitoba was noted by Catling (2009a), but no information on its extent was provided. Although the precise extent of alvars in North America is not yet known, their distribution is fragmented and loosely follows the edge of the Canadian Shield where postglacial meltwaters have exposed limestone bedrock (Catling 2009a). Before our study, alvar-like ecosystems associated with near-surface dolomitic limestone pavement and inland cliffs had been documented at five locations in Manitoba between the southern basins of Lakes Manitoba and Winnipeg, i.e., the Interlake region (Hamel and Foster 2004). In 2011, an Ontario alvar expert (John Riley) accompanied us to one of these locations and confirmed that the ecosystem shared characteristics consistent with alvar ecosystems in Ontario and were worthy of further study and formal description.

In 2015, the Manitoba government listed alvar as endangered under the Manitoba *Endangered Species and Ecosystems Act* using the authors' unpublished information to support determination of its conservation status.

The results of this study were previously published in a technical report (Manitoba Alvar Initiative 2012). This paper refines those results and confirms the findings in the context of the established body of knowledge on North American alvars. The objectives of this study were to survey and map alvars in the Interlake region of Manitoba; to describe their physical structure and species composition; and to determine land ownership and land uses of Manitoba alvars.

Methods

We used a geographic information system (GIS) to identify and delineate 67 sites of potential alvar encompassing 6313 ha (Figure 1) in the south Interlake and adjacent regions. We examined spatial data layers of geomorphologic and vegetative features representative of alvar-like sites identified by Hamel and Foster (2004). Layers included orthophotographs (to assess vegetation cover), soil classification data (to determine soil depth and the presence of near-surface limestone bedrock), and a digital elevation model (to identify the location of ridges; Manitoba Conservation and Water

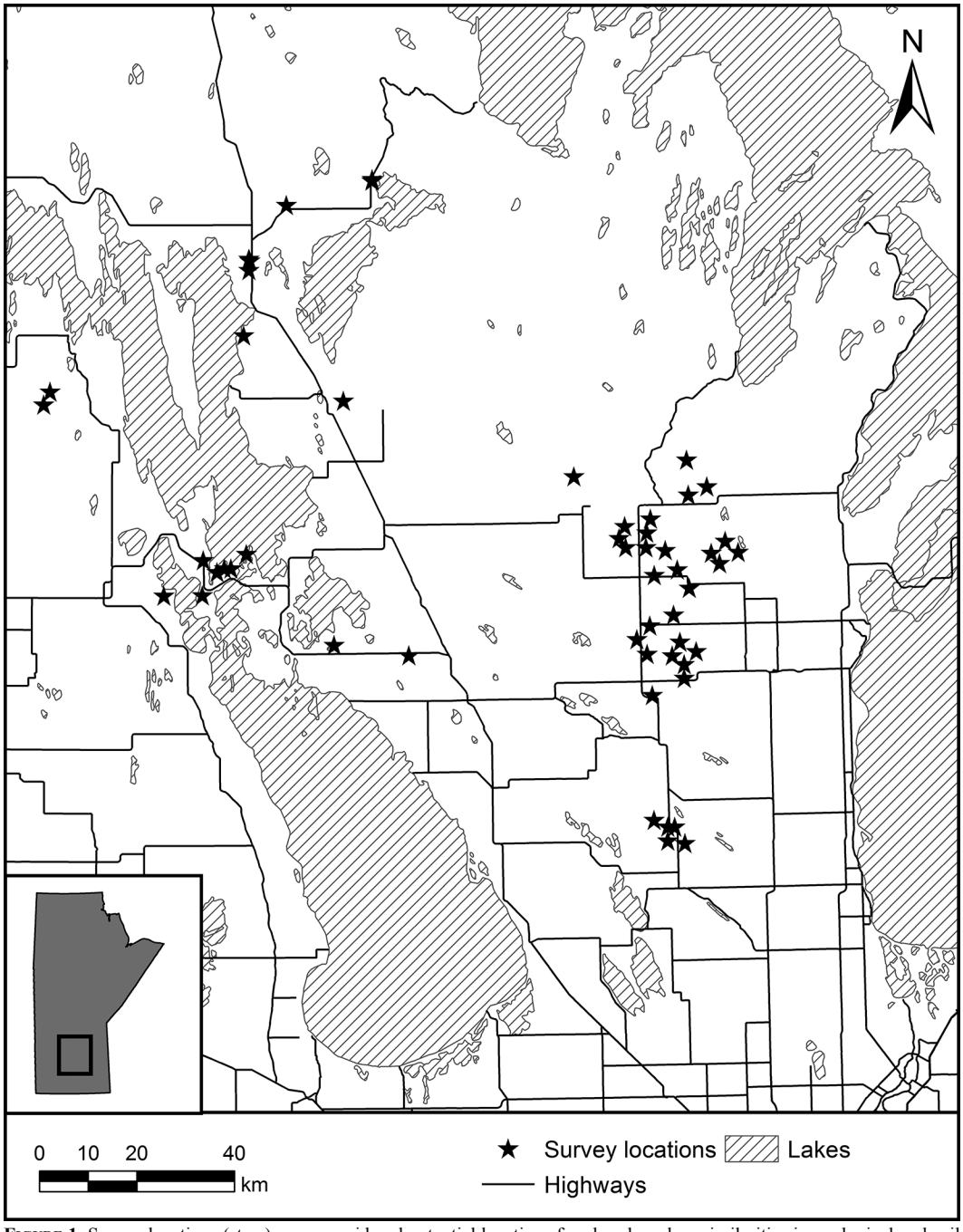

FIGURE 1. Survey locations (stars) were considered potential locations for alvar based on similarities in geological and soil characteristics to previously confirmed communities in Manitoba.

Stewardship 2012a). Between June and August 2012, we surveyed and assessed 61 sites to determine whether they supported alvar. We attempted to visit all potential sites regardless of ownership, but we did not receive permission to access six private land parcels.

A site was determined to be alvar if it met the following criteria: presence of flat limestone or dolomite bedrock that restricts drainage; soil thin—with a depth up to 15 cm that is not the result of mechanical removal—or absent (criterion used by Brunton 1988; Catling and Brownell 1995; Reschke *et al.* 1999); and tree canopy cover <60% (criterion used by Reschke *et al.* 1999). Although alvars can occur on soil deeper than 15 cm (Reschke *et al.* 1999), such sites were not in-

cluded in the estimation of extent for this study because they could not be confirmed as being alvars without more detailed analyses of the species composition and/or investigation of other ecologically distinct characteristics resulting from the influence of an underlying bedrock pavement.

If not visible at the surface, limestone pavement was detected by digging small test holes. We determined soil depth by pressing a metal rod into the soil and measuring depth at impact with bedrock. Evidence of extreme moisture variability was based on observations of standing water following rain events, the presence of algae on dry pavement, thin bare soil (without evidence of disturbance), and restricted vegetation and lichen growth patterns. We recorded qualitative observations of the dominant plant species, soil depth, unique topographic features, land use, and patterns of flooding, drought, and drainage.

The potential extent of alvar at each survey site was mapped as polygons in GIS. Boundaries were delineated by using ground-truthed global positioning system coordinates and interpreting orthophotographs. These maps indicate the estimated maximum extent of the alvar communities observed. Within mapped habitat patches, there may be areas without alvar, or an area may represent a mosaic of alvar and other ecosystems.

Dominant physiognomic characteristics were used to categorize alvars into types to better describe the variation observed. Alvar types were characterized first by growth form (tree, shrub, forb, or graminoid), then vertical structure (<10% tree canopy or 10–60% tree canopy, comparable to thresholds used to distinguish savannah from other upland ecosystems found in the Interlake region; Minnesota Department of Natural Resources 2005), and, finally, by wetland or upland species affinities. Putative descriptions of each type's composition and variation were prepared using the data collected during site surveys. We used vegetation survey plots at a small sample of sites to supplement the general survey data and test the accuracy of these descriptions. Nine 20 m × 50 m plots, distributed among four sites, were randomly placed in what appeared to be unique subtypes of alvar. Each plot was divided into six subplots: one 20 m × 20 m; four 10 m × 10 m; and one 20 m × 10 m. The canopy cover of vascular plants, bryophytes, and lichens was recorded by visual observation within the four 10 m × 10 m subplots using the following cover classes: <0.1%, 0.1 to <1%, 1 to <2%, 2 to <5%, 5 to <10%, 10 to <25%, 25 to <50%, 75 to <95% and ≥95%. The additional two plots were used to capture the cover class of any species not recorded in the initial four plots. Soil depth was recorded on the centre line and at 10 m and 30 m along the plot starting from the 10 m × 20 m end. Voucher specimens obtained for vascular plants, bryophytes, and lichens were deposited in the University of Manitoba herbarium (WIN). A statistical analysis was not completed.

The bedrock composition of the limestone underlying alvar was compared at each site by overlaying the mapped alvar polygons with a GIS shapefile of the geological periods of bedrock formation (Manitoba Mineral Resources 2012a) to identify patterns related to alvar type and distribution.

Results and Discussion

Extent and distribution

Alvar was found at 28 of the 61 survey locations, with a maximum extent of ~3934 ha. Alvars >16 ha often supported internal patches of non-alvar ecosystems, such as forest or prairie, where soil depth was greater than 15 cm.

We mapped 101 spatially distinct units of alvar, varying from 0.4 ha to 809 ha and grouped these units into five geographically distinct sites (Figure 2). The Marble Ridge Alvar, referred to as Marble Ridge A, B, and C Alvars, follows a limestone formation of the same name, along which inland limestone cliffs are also found. The Peguis Alvar is immediately east of the Peguis First Nation Reserve, and the Sylvan Alvar is almost completely within the boundaries of the Sylvan Dale Community Pasture. The Poplarfield Alvar represents a group of small, isolated units near Poplarfield. The Clematis Alvar is located in and around the Clematis and Sandridge Wildlife Management Areas.

Alvar types

Alvars were categorized into four putative types: grassland (graminoid dominated, <10% tree cover, upland affinity), shrubland (shrub dominated, <10% tree cover, upland affinity), savannah (shrub dominated, >10% tree cover, upland affinity), and wetland (graminoid dominated, <10% tree cover, wetland affinity). Many sites supported multiple types of alvar occurring in combination. A list of plant and lichen species observed in each alvar type is shown in Table 1, but quantitative values are not presented as the plot data are not fully representative of the variation that exists within the types described.

Grassland alvars have nearly continuous vegetative cover, with soil depth typically ranging from 5 cm to 10 cm, and only occasional patches of limestone pavement (Figure 3). They are dominated by upland graminoid species, with high forb and low shrub cover. Trees are typically absent or restricted to the periphery. Moss provides significant ground cover among and beneath other vegetation. Bare soil, exposed limestone, and bryophyte and lichen growth directly on the limestone pavement were uncommon. These sites are generally flat, although some areas have small (typically <1 m in height) outcrops along the edges of plateau formations. We observed less evidence of flooding following rain compared with other alvars, although drainage is restricted and water pools on the limestone pavement. We did not observe conditions immediately following spring melt.

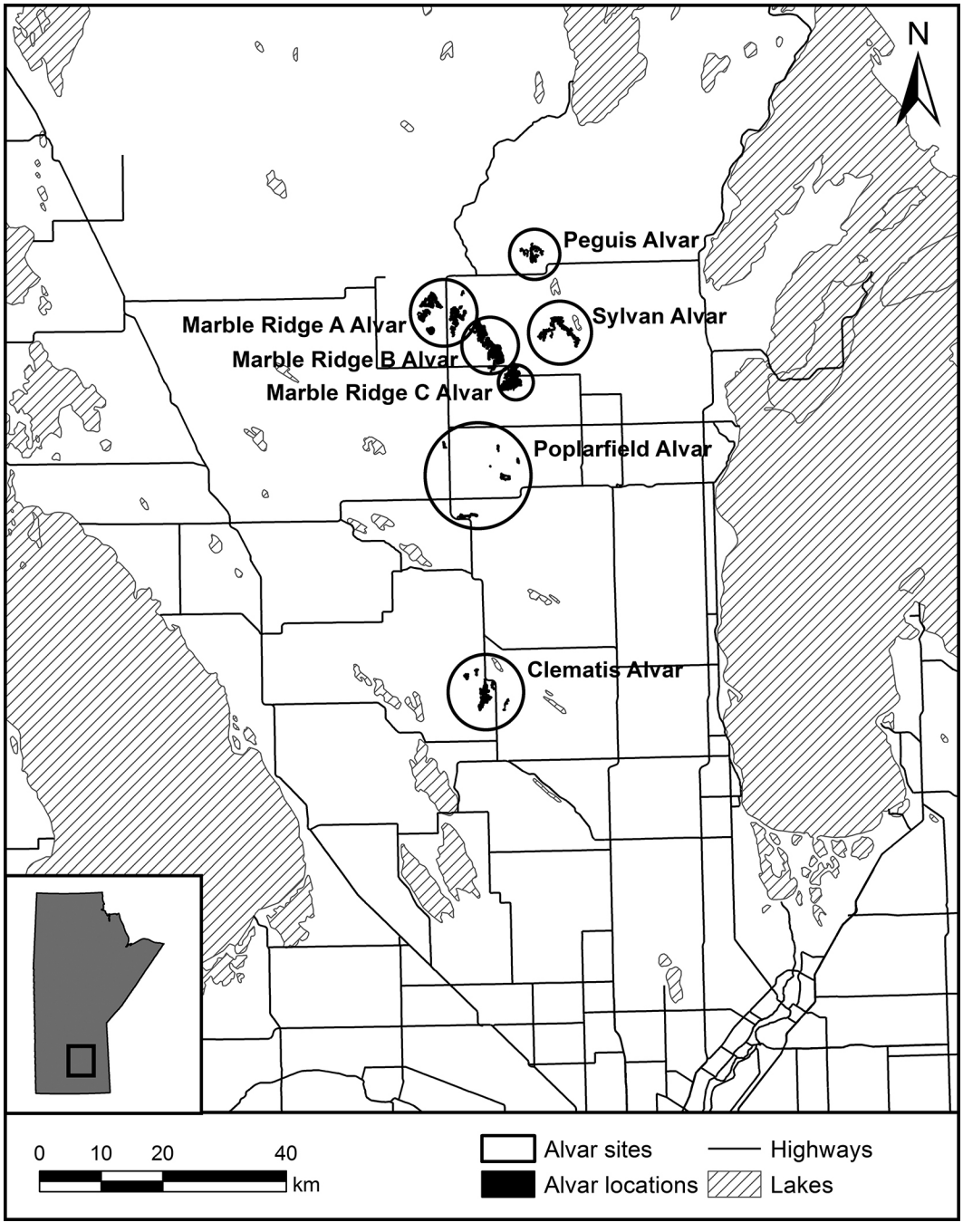

FIGURE 2. Confirmed locations of alvar in Manitoba. Individual patches of alvar have been grouped into five sites. Marble Ridge A, B, and C together constitute a single site.

In shrubland alvars (Figures 4, 5, and 6) vegetative cover is generally patchy and often restricted to cracks and seams in the bedrock with deeper soils. Soil depth is shallower than in grassland alvars, typically <5 cm, and limestone pavement is frequent. Shrubs are the dominant vascular plant cover, followed by forbs, with graminoids frequent, but not as abundant as in grassland alvars. Tree cover is greater than in grassland alvars, but still low, and trees generally appear to be stunted. Cover of bryophytes, lichens, and bare soil is much higher

TABLE 1. Vascular plants, bryophytes, and lichens observed in each type of alvar.

Species		Conservation status*		Alvar type			
Scientific name	Common name	Global	Subnational	Grassland	Shrubland	Savannah	Wetland
VASCULAR PLANTS							
Achillea millefolium L.	Common Yarrow	G5	S5	X	X	X	
Agoseris glauca (Pursh) Rafinesque	Pale Agoseris	G5	S4S5		X	X	
Agrostis scabra Willdenow	Rough Bentgrass	G5	S5		X	X	
Agrostis stolonifera L.	Creeping Bentgrass	G5	SNA		X	X	
Allium stellatum Fraser ex Ker Gawler	Autumn Onion	G5	S5	X	X	X	
Allium textile A. Nelson & J.F. Macbride	Prairie Onion	G5	S3		X	X	
Amelanchier alnifolia (Nuttall) Nuttall ex M. Roemer	Saskatoon	G5	S5		X	X	
Ambrosia spp.	Ragweed species			X	X	X	
Andropogon gerardi Vitman	Big Bluestem	G5	S5		X	X	
Anemonastrum canadense (L.) Mosyakin	Canada Anemone	G5	S5		X	X	
Anemone cylindrica A. Gray	Long-headed Anemone	G5	S5		X	X	
Anemone multifida Poiret	Cut-leaved Anemone	G5	S5		X	X	
Antennaria spp.	Pussytoes species			X	X	X	
Anticlea elegans (Pursh) Rydberg	Mountain Death Camas	G5	S5		X	X	
Apocynum androsaemifolium L.	Spreading Dogbane	G5	S5		X	X	
Arabis hirsuta (L.) Scopoli	Hairy Rockcress	G5	S5		X	X	
Arabis sp.	Rockcress species				X	X	
Arctostaphylos uva-ursi (L.) Sprengel	Common Bearberry	G5	S5		X	X	
Artemisia campestris L.	Field Wormwood	G5	S4S5		X	X	
Artemisia ludoviciana Nuttall	Silver Wormwood	G5	S5		X	X	
Asclepias sp.	Milkweed species				X	X	
Betula occidentalis Hooker	Water Birch	G5	S3S5		X	X	
Betula papyrifera Marshall	Paper Birch	G5	S5		X	X	
Betula pumila L.	Bog Birch	G5	S5		X	X	
Bromus inermis Leysser	Smooth Brome	G5	SNA		X		
Bromus porteri (J.M. Coult) Nash	Porter's Brome	G5	S2S3	X	X	X	
Campanula gieseckeana (Vest ex Shultes)	Giesecke's Bellflower	G5	S5	X	X	X	
Carex spp.	Sedge species			X	X	X	X
Cerastium arvense L.	Field Chickweed	G5	S5		X	X	
Chenopodium spp.	Goosefoot species				X		
Cirsium drummondii Torrey & A. Gray	Drummond's Thistle	G5	S4		X	X	
Cirsium sp.	Thistle species				X	X	
Comandra umbellata (L.) Nuttall	Bastard Toadflax	G5	S5		X	X	
Corylus americana Walter	American Hazelnut	G5	S4		X	X	
Cypripedium sp.	Lady's Slipper				X	X	
Dalea purpurea Ventenat	Purple Prairie-clover	G5	S5		X	X	
Danthonia spicata (L.) P. Beauvois ex Roemer & Schultes	Poverty Oatgrass	G5	S4S5	X	X	X	
Dasiphora fruticosa (L.) Rydberg	Shrubby Cinquefoil	G5T5	S5	X	X	X	X
Deschampsia cespitosa (L.) Palisot de Beauvois	Tufted Hairgrass	G5	S4S5	X	X	X	X

TABLE 1. (*continued*)

Species		Conservation status*		Alvar type			
Scientific name	Common name	Global	Subnational	Grassland	Shrubland	Savannah	Wetland
Drymocallis arguta (Pursh) Rydberg	Tall Wood Beauty	G5	S5		X	X	
Eleocharis spp.	Spikerush species			X		X	X
Elymus trachycaulus subsp. *subsecundus* (Link) Á. Löve & D. Löve	One-sided Wildrye	G5	S5	X	X	X	
Elymus trachycaulus (Link) Gould ex Shinners	Slender Wildrye	G5T5	S5	X			
Erigeron philadelphicus L.	Philadelphia Fleabane	G5	S5		X	X	
Erigeron spp.	Fleabane species				X	X	
Festuca hallii (Vasey) Piper	Plains Rough Fescue	G4	S3		X	X	
Fragaria virginiana Miller	Wild Strawberry	G5	S5		X	X	
Gaillardia aristata Pursh	Great Blanketflower	G5	S5		X	X	
Galium boreale L.	Northern Bedstraw	G5	S5	X	X	X	
Geum triflorum Pursh	Three-flowered Avens	G5	S4S5	X	X	X	
Grindelia squarrosa (Pursh) Dunal	Curly-cup Gumweed	G5	S5	X			
Helianthus sp.	Sunflower species				X	X	
Helictochloa hookeri (Scribner) Romero Zarco	Hooker's Oatgrass	G5	S3S4		X		
Heuchera richardsonii R. Brown	Richardson's Alumroot	G5	S5		X	X	
Hieracium umbellatum L.	Umbellate Hawkweed	G5	S5		X	X	
Juncus dudleyi Wiegand	Dudley's Rush	G5	S5	X			X
Juniperus communis L.	Common Juniper	G5	S5		X	X	
Juniperus horizontalis Moench	Creeping Juniper	G5	S5	X	X	X	X
Koeleria macrantha (Ledebour) Schultes	Prairie Junegrass	G5	S5	X	X	X	
Lathyrus sp.	Vetch species				X	X	
Lepidium sp.	Peppergrass species			X	X	X	
Liatris ligulistylis (A. Nelson) K. Schumann	Meadow Blazing-star	G5?	S4		X	X	
Lilium philadelphicum L.	Wood Lily	G5	S4		X	X	
Linnaea borealis L.	Twinflower	G5	S5		X	X	
Linum lewisii Pursh	Lewis' Wild Blue Flax	G5	S4		X	X	
Lithospermum canescens (Michaux) Lehmann	Hoary Puccoon	G5	S5	X	X	X	
Lonicera dioica L.	Limber Honeysuckle	G5	S5		X	X	
Maianthemum canadense Desfontaines	Wild Lily-of-the-valley	G5	S5		X	X	
Maianthemum stellatum (L.) Link	Starflower False Solomon's Seal	G5	S5		X	X	
Medicago lupulina (L.)	Black Medick	GNR	SNA		X	X	
Melampyrum lineare Desrousseaux	American Cow-wheat	G5	S3S5		X	X	
Monarda fistulosa (L.)	Wild Bergamot	G5	S5		X	X	
Orthocarpus luteus Nutall	Yellow Owl's-clover	G5	S4S5		X	X	
Oryzopsis asperifolia Michaux	Rough-leaved Mountain Rice	G5	S5		X	X	
Pediomelum esculentum (Pursh) Rydberg	Large Indian Breadroot	G5	S3S4		X	X	
Pellaea gastonyi Windham	Gastony's Cliffbrake	G2G3	S1		X		
Pellaea glabella subsp. *occidentalis* (E.E. Nelson) Windham	Western Dwarf Cliffbrake	G5T4	S2		X		
Phleum pratense (L.)	Common Timothy	GNR	SNA	X	X	X	
Phlox hoodii Richardson	Hood's Phlox	G5	S3		X	X	

TABLE 1. (*continued*) Vascular plants, bryophytes, and lichens observed in each type of alvar.

Species		Conservation status*		Alvar type			
Scientific name	Common name	Global	Subnational	Grassland	Shrubland	Savannah	Wetland
Picea glauca (Moench) Voss	White Spruce	G5	S5		X	X	
Pinus banksiana Lambert	Jack Pine	G5	S5		X	X	
Poa annua L.	Annual Bluegrass	GNR	SNA	X	X	X	
Poa pratensis L.	Kentucky Bluegrass	G5	S5	X	X	X	
Poa sp.	Bluegrass species				X	X	
Polygala senega L.	Seneca Snakeroot	G4G5	S4		X	X	
Populus tremuloides Michaux	Trembling Aspen	G5	S5		X	X	
Potentilla anserina (L.) subsp. *anserina*	Common Silverweed	G5	S5		X	X	
Potentilla bipinnatifida Douglas ex Hooker	Bipinnate Cinquefoil	G5	SU	X			
Potentilla gracilis Douglas ex Hooker	Slender Cinquefoil	G5	S4	X			
Potentilla pensylvanica L.	Pennsylvania Cinquefoil	G5	SU	X	X		
Potentilla sp.	Cinquefoil species			X			X
Prunus pensylvanica L. f.	Pin Cherry	G5	S5		X	X	
Prunus virginiana L.	Chokecherry	G5	S5		X		
Quercus macrocarpa Michaux	Bur Oak	G5	S5		X	X	
Rhus glabra L.	Smooth Sumac	G5	S3S4		X	X	
Ribes oxyacanthoides L.	Canada Gooseberry	G5	S5		X	X	
Rosa acicularis Lindley	Prickly Rose	G5	S5	X	X	X	
Rubus idaeus L.	Red Raspberry	G5	S5		X	X	
Rudbeckia hirta L.	Black-eyed-Susan	G5	S5		X	X	
Salix spp.	Willow species				X	X	
Sanicula marilandica L.	Maryland Sanicle	G5	S5		X	X	
Selaginella densa Rydberg	Prairie Spikemoss	G5	S3		X		
Shepherdia canadensis (L.) Nuttall	Soapberry	G5	S5		X	X	
Sisyrinchium montanum Greene	Strict Blue-eyed-grass	G5	S5		X	X	
Smilax lasioneura Hooker	Hairy-nerved Carrionflower	G5	S4S5		X	X	
Solidago hispida Muhlengerg ex Willdenow	Hairy Goldenrod	G5	S5		X	X	
Solidago missouriensis Nuttall	Missouri Goldenrod	G5	S5		X	X	
Solidago nemoralis Aiton	Grey-stemmed Goldenrod	G5	S5		X	X	
Solidago ptarmicoides (Torrey & A. Gray) B. Boivin	Upland White Goldenrod	G5	S4S5		X	X	
Solidago spp.	Goldenrod species				X	X	
Symphoricarpos sp.	Snowberry species				X	X	
Symphyotrichum spp.	Aster species			X	X	X	
Symphyotrichum ericoides (L.) G.L. Nesom	White Heath Aster	G5	S4	X			
Symphyotrichum laeve (L.) Á. Löve & D. Löve	Smooth Aster	G5	S5		X	X	
Taraxacum officinale F.H. Wiggers	Common Dandelion	G5	SNA		X	X	
Thalictrum venulosum Trelease	Veiny Meadow-rue	G5	S5		X	X	
Toxicodendron radicans var. *rydbergii* (Small ex Rydberg) Erskine	Western Poison Ivy	G5	S5		X	X	
Viburnum rafinesqueanum Schultes	Downy Arrowwood	G5	S4S5		X	X	
Vicia americana Muhlenberg ex Willdenow	American Vetch	G5	S5		X	X	

TABLE 1. (*continued*)

Species		Conservation status*		Alvar type			
Scientific name	Common name	Global	Subnational	Grassland	Shrubland	Savannah	Wetland
Vicia sp.	Vetch species			X	X	X	
Viola spp.	Violet species				X		
Zizia aptera (A. Gray) Fernald	Heart-leaved Alexanders	G5	S5		X	X	
Zizia aurea (L.) W.D.J. Koch	Golden Alexanders	G5	S4S5		X	X	
MOSSES							
Abietinella abietina (Hedw.) Fleisch.	Wiry Fern Moss	G4G5	S4S5	X	X	X	
Aulacomnium palustre (Hedw.) Schwaegr.	Ribbed Bog Moss	G5	S4S5		X	X	
Barbula convoluta Hedw.	Lesser Bird's-claw Beard Moss	G5	SU	X	X	X	
Brachythecium campestre (C. Müll.) Schimp. in B.S.G	Field Ragged Moss	G4G5Q	SU		X	X	
Brachythecium salebrosum (Web. & Mohr) Schimp	Golden Ragged Moss	G5	S4S5		X	X	
Brachythecium sp.					X	X	
Bryum sp.				X	X	X	
Campylium polygamum (Schimp.in B.S.G) C. Jens.	Campylium Moss	G5	S4S5	X	X	X	
Ceratodon purpureus (Hedw.) Brid.	Red Roof Moss	G5	S4S5		X	X	
Dicranum polysetum Sw.	Wavy-leaf Broom Moss	G5	S4S5		X	X	
Didymodon rigidulus Hedw.	Rigid Beard Moss	G5	SU	X	X	X	
Encalypta procera Bruch	Slender Candlesnuffer Moss	G4G5	SU		X	X	
Eurhynchium pulchellum (Hedw.) Jenn.	Elegant Beaked Moss	G5	S4S5		X	X	
Grimmia teretinervis Limpr.	Round-nerved Grimmia	G3G5	SNR		X	X	
Hedwigia ciliata (Hedw.) P. Beauv.	Ciliate Hedwig's Moss	G5	SU		X	X	
Hylocomium splendens (Hedw.) Schimp. in B.S.G	Stairstep Moss	G5	S4S5		X	X	
Pleurozium schreberi (Brid.) Mitt.	Red-stemmed Feather Moss	G5	S4S5		X	X	
Ptychostomum pseudotriquetrum (Hedw.) J.R. Spence & H.P. Ramsay	Tall Clustered Thread Moss	G5	S4S5	X			
Sanionia uncinata (Hedw.) Loeske	Sickle Moss	G5	S4S5		X	X	
Syntrichia norvegica Web.	Norway Screw Moss	G5	SU		X	X	
Tortella fragilis (Hook. & Wils. in Drumm.) Limpr.	Fragile Twisted Moss	G5	S4S5	X	X	X	
Tortella tortuosa (Hedw.) Limpr.	Frizzled Crisp Moss	G5	SU		X	X	
Tortula ruralis (Hedw.) Gaertn. *et al.*	Hairy Screw Moss	G5	S4S5	X	X	X	
LICHENS							
Biatora vernalis (L.) Fr.	Spring Dot Lichen	G5	S3S5		X		
Mycobilimbia sabuletorum (Schreb.) Hafellner	Six-celled Moss Dot Lichen	G5	S2S4		X		
Caloplaca holocarpa (Hoffm. ex Ach.) A. E. Wade	Firedot Lichen	G5	S3S5		X	X	
Caloplaca jungermanniae (Vahl) Th. Fr.	Jungermann's Firedot Lichen	G4G5	S2S4		X		
Cladina arbuscula (Wallr.) Hale & Culb.	Reindeer Lichen	G5	S5		X	X	
Cladonia botrytes (K. G. Hagen) Willd.	Wooden Soldiers Lichen	G5	S4			X	
Cladonia cariosa (Ach.)	Split-peg Lichen	G5	S5		X		
Cladonia cervicornis ssp. verticillata (Hoffm.) Ahti	Ladder Lichen	G5T5	S4		X		
Cladonia chlorophaea (Flörke ex Sommerf.)	Mealy Pixie-cup Lichen	G5	S5		X		
Cladonia cristatella Tuck.	British Soldiers	G5	S5			X	

TABLE 1. (*continued*) Vascular plants, bryophytes, and lichens observed in each type of alvar.

Species		Conservation status*		Alvar type			
Scientific name	Common name	Global	Subnational	Grassland	Shrubland	Savannah	Wetland
Cladonia macrophyllodes Nyl.	Large-leaved Pixie Lichen	G4G5	SU		X		
Cladonia multiformis G. Merr.	Sieve Lichen	G5	S5		X		
Cladonia pocillum (Ach.) Grognot	Rosette Pixie-cup Lichen	G5	S4		X	X	
Cladonia pyxidata (L.) Hoffm.	Pebbled Pixie-cup	G5	S5		X		
Cladonia ramulosa (With.) J. R. Laundon	Branched Pixie-cup Lichen	G5?	SU			X	
Cladonia symphycarpa (Flörke) Fr.	Split-peg Lichen	G5	S4		X	X	
Peltigera praetextata (Flörke ex Sommerf.) Zopf	Scaly Pelt Lichen	G5	SU		X		
Peltigera rufescens (Weiss) Humb.	Felt Lichen	G5	S5		X	X	
Physcia adscendens (Fr.) H. Olivier	Hooded Rosette Lichen	G5	S5		X	X	
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	Hoary Rosette Lichen	G5	SU		X	X	
Physcia phaea (Tuck.) J. W. Thomson	Black-eyed Rosette Lichen	G4G5	SU	X			
Sarcogyne regularis Körber	Frosted Grain-spored Lichen	G5	S3S5		X		
Stereocaulon paschale (L.) Hoffm.	Easter Foam Lichen	G5	SU		X		
Verrucaria muralis Ach.	Wart Lichen	G5	S2S4		X		
Xanthoparmelia cumberlandia (Gyelnik) Hale	Cumberland Rock-shield	G5	SU		X		
Xanthoria polycarpa (Hoffm.) Th. Fr. ex Rieber	Pincushion Sunburst Lichen	G5	S4		X	X	
LIVERWORTS							
Cephaloziella rubella (Nees) Warnst	Red Threadwort	G5	SU		X	X	

*Global (NatureServe 2016) and subnational (Manitoba Conservation Data Centre unpubl. data) conservation status ranks.

FIGURE 3. Grazed grassland alvar at the Sylvan Alvar site. Photo: Nature Conservancy of Canada.

FIGURE 4. Shrubland alvar at the Clematis Alvar site. Photo: Nature Conservancy of Canada.

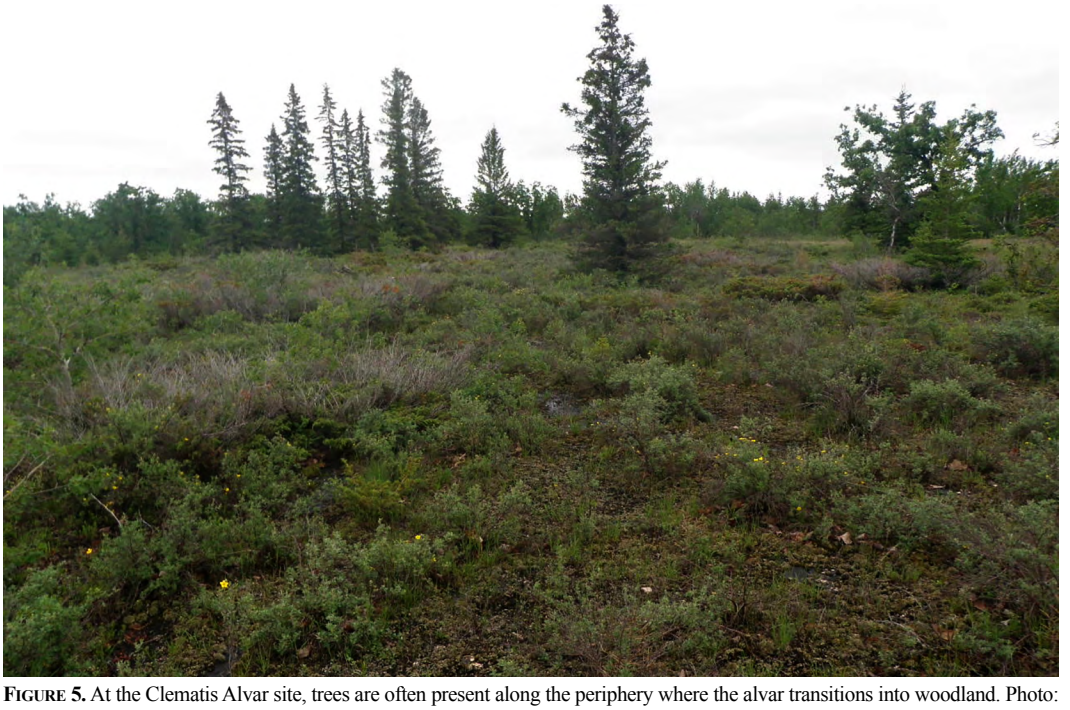

FIGURE 5. At the Clematis Alvar site, trees are often present along the periphery where the alvar transitions into woodland. Photo: Nature Conservancy of Canada.

FIGURE 6. Shrubland alvar at the Marble Ridge Alvar site. Some of the scattered boulders support Gastony's Cliffbrake (*Pellaea gastonyi*) or Western Dwarf Cliffbrake (*Pellaea glabella* ssp. *occidentalis*) or both. Photo: Nature Conservancy of Canada.

than in grassland alvars, although the abundance of each varies among sites. Sites vary from flat to having table-top limestone outcrops and scattered limestone boulders. Drainage is restricted at these sites, which are periodically flooded. In the absence of rain, drought-like conditions were observed.

Savannah alvars (Figures 7 and 8) are similar to shrubland alvars in their patchy distribution of vegetation. Soil depth is usually <5 cm, but frequently deeper in cracks and seams. Limestone pavement is frequent. Shrubs are dominant, followed by forbs, with graminoids less abundant. Unlike shrubland alvars, distribution of trees is regular, although still amounting to <60% cover, and tall shrubs can occur frequently. Bryophyte and lichen cover is variable and generally less dominant than in shrubland alvars. Like shrubland alvars, savannah alvars vary from being flat to having scattered boulders or table-top outcrops, but are more frequently associated with the latter than shrubland alvars. These sites flood periodically and exhibit drought-like conditions; however, extremes in moisture variability at sites with greater tree abundance are not as pronounced.

Like grassland alvars, wetland alvars have nearly continuous vegetative cover, with soils about 5 cm deep and occasional patches of exposed limestone pavement (Figure 9). They are dominated by wetland graminoids and mosses, with few forbs or shrubs and no trees. These are low areas that grade into other alvar types. They are often partly bordered by willow-dominated swamps and marsh. Despite similar soil depths and cover as grassland alvars, these sites remain saturated enough to support wetland vegetation, but are not permanently flooded. It is unknown whether the difference is a result of increased water catchment from the surrounding topography or a difference in the degree of drainage restriction by the underlying bedrock.

Bedrock geology

Survey sites coincided with limestone bedrock from the Jurassic, Permian, Devonian, Silurian, and Ordovician geologic periods. Alvar was located only on Silurian and Ordovician bedrock, which consist primarily of dolomite (Manitoba Mineral Resources 2012a).

The Clematis Alvar and two units of the Poplarfield Alvar occur on Silurian bedrock, which consists of micritic, fossiliferous, stromatolitic, and biostromal dolomites, whereas the other alvars occur on Ordovician bedrock comprising various dolomites including argillaceous, nodular, and laminated dolomite (Manitoba Mineral Resources 2012a).

Alvars occur on four Ordovician formations. The Marble Ridge Alvar site and the rest of the Poplarfield Alvar sites are primarily located within the western

FIGURE 7. Savannah alvar with White Spruce (*Picea glauca*) at the Poplarfield Alvar site. Photo: Nature Conservancy of Canada.

FIGURE 8. Savannah alvar with Jack Pine (*Pinus banksiana*) at the Marble Ridge Alvar site. Photo: Nature Conservancy of Canada.

FIGURE 9. Wetland alvar at the Marble Ridge Alvar site. Photo: Nature Conservancy of Canada.

Stony Mountain Formation and the East Arm Formation, whereas the Peguis and Sylvan Alvars fall into the eastern Stony Mountain Formation and the Red River Formation (Manitoba Mineral Resources 2012a).

Significant species

Twenty-four globally, nationally, or provincially rare and uncommon species (NatureServe 2016; Manitoba Conservation Data Centre unpubl. data) were documented at survey sites during this study or previously by Caners (2011). Globally uncommon and provincially endangered Gastony's Cliffbrake (*Pellaea gastonyi* Windham; Friesen and Murray 2015) and globally uncommon Grimmia Dry Rock Moss (*Grimmia teretinervis* Limpricht; Caners 2011) were observed growing on limestone cliffs and boulders at the Marble Ridge Alvar sites. Vascular plant species assessed as provincially uncommon or rare (Manitoba Conservation Data Centre unpubl. data) observed during this study include: Dwarf Western Cliffbrake *(Pellaea glabella* ssp. *occidentalis* (E.E. Nelson) Windham), Rough Fescue (*Festuca hallii* (Vasey) Piper), Porter's Chess (*Bromus porteri* (J.M. Coulter) Nash), Wild White Onion (*Allium textile* A. Nelson & J.F. Macbride), Spring Birch (*Betula occidentalis* Hooker), Spike-oat (*Avenula hookeri* (Scribner) Holub), American Cow-wheat (*Melampyrum lineare* Desrousseaux), Large Indian Breadroot (*Pediomelum esculentum* (Pursh) Rydberg), Smooth Sumac (*Rhus glabra* L.), and Dense Spikemoss (*Selaginella densa* Rydberg; Table 1). Six species of lichens observed during this study and six species of bryophytes documented by Caners (2011) are also assessed as nationally or provincially rare or uncommon (NatureServe 2016; Manitoba Conservation Data Centre unpubl. data).

Six non-native plant species were observed in alvars. Timothy (*Phleum pratense* L.) was observed often, but never as a dominant species. Kentucky Bluegrass (*Poa pratensis* L.) was observed in some grass-dominated alvars. Annual Bluegrass (*Poa annua* L.) was observed in some alvars, often occurring on sparsely vegetated patches of shallow, bare soil. Garden Bird's-foot Trefoil (*Lotus corniculatus* L.) was found on the periphery of two alvars and, at a third site, there were a few scattered plants on the alvar itself. Awnless Brome (*Bromus inermis* Leysser) and Creeping Bentgrass (*Agrostis stolonifera* L.) were each observed once in a grazed alvar.

Overall, it appears that non-native species in Manitoba alvars are infrequent, and invasive species that are of high priority for detection and control in Manitoba (Invasive Species Council of Manitoba 2018) are not currently present in these ecosystems. Non-native or invasive plant species can result in reduced biodiversity and function in natural ecosystems and are becoming increasingly widespread in open habitats in the prairie provinces (Canadian Food Inspection Agency 2008; Sinkins and Otfinowski 2012; DeKeyser *et al.* 2013). The relatively limited presence of non-native or invasive species in Manitoba alvars represents a rare opportunity to prevent further establishment and maintain the exceptional biodiversity of these habitats.

Management and conservation context

Alvars make up 0.3% (3934 ha) of the south Interlake. Each alvar type supports its own complement of plants and contributes uniquely to the biological diversity of Manitoba. The significance of alvar habitat and the threats it faces across Canada have been extensively documented (Catling and Brownell 1995, 1999b; Reschke *et al.* 1999; Catling 2014; Catling *et al.* 2014; Brunton and Catling 2017). Protection and conservation efforts in Manitoba should initially focus on preserving representatives of each type. In addition to supporting vascular plant species assemblages distinct from other ecosystems in Manitoba, different types of alvar support a range of other species groups. For example, we observed grassland-obligate birds, a group undergoing steep population declines in North America (North American Bird Conservation Initiative 2016), on grassland alvars; Eastern Whip-poor-will (*Antrostomus vociferus*) and Common Nighthawk (*Chordeiles minor*), both threatened species (SARA Registry 2018a,b), have been documented in shrubland and savannah alvars with sparse vegetation (Manitoba Conservation Data Centre unpubl. data). Alvars associated with inland cliffs, outcrops, and boulders, such as along Marble Ridge, provide a wide range of microhabitats not found in other alvar types, and support a number of bryophytes that are expected to remain uncommon in the region (Caners 2011).

Approximately one third (1261 ha) of alvar in Manitoba occurs on privately owned land, with the remainder on public land including wildlife management areas, community pastures, and undesignated provincial Crown land.

No alvar sites identified in this study are located within the boundaries of protected areas (IUCN Protected Areas Classification level IV or higher; Manitoba Conservation and Water Stewardship 2012b) or are protected from all types of development. A 2560-ha ecosystem protection zone that encompasses most of the Marble Ridge Alvar site has been proposed.

Approximately 12% of the Manitoba alvar habitat identified in this study falls under mining and/or quarry leases (Manitoba Mineral Resources 2012b) and, thus, may be exposed to habitat destruction from mining activities. At the time of our survey, near-surface limestone had been commercially extracted immediately adjacent to or within alvar communities at six locations.

Approximately 76% (2985 ha) of alvar habitat identified in this study was being grazed at the time of the survey or exhibited signs of having been grazed recently. Another 11% (432 ha) did not appear to be grazed by domestic livestock. Most observed grazing animals were cattle, but horses and bison were also observed. Land use at the other locations (13%) could not be determined. Pre-European settlement grazing histories for

the Interlake area are unclear (Henderson and Koper 2014), but grazing by large ungulates has likely always contributed to the disturbance regime of Manitoba alvars and may play an important role in maintaining their openness, as it does in alvars elsewhere (Reschke *et al.* 1999). However, current grazing management using livestock is unlikely to mirror historical patterns (Henderson and Koper 2014), and grazing at incompatible frequencies, intensities, or durations may result in alterations to species composition and facilitate the spread of non-native species (Reschke *et al.* 1999).

No evidence of recent natural fire, an important ecological requirement of many alvar habitats (Catling and Brownell 1998; Catling *et al.* 2002; Jones and Reschke 2005; Catling 2009b), was observed in or near any of the alvars. Trembling Aspen (*Populus tremuloides* Michaux) encroachment was observed at some locations in the Clematis Alvar and Poplarfield Alvar sites. Long-term fire suppression is probably negatively impacting the ecological integrity and biodiversity of alvar habitat here, as it is in other open habitats in southern Manitoba (e.g., Koper *et al.* 2010) and throughout North America.

The current mix of public and private land ownership, history of fire suppression, and the economic potential of alvars for grazing and mineral resources highlight the need for the involvement and cooperation of a range of stakeholders, including industry and private landowners, in alvar conservation.

Further research

This study presents only a first approximation of the various types of alvar present in Manitoba, and there is a need for classification of alvar habitat in the province using a quantitative data-based scheme. This would help to refine the conservation status of alvar types/subtypes and to inform site-condition metrics, compatible land-management activities, and conservation opportunities. Faunal surveys to further assess the biodiversity of these sites are also needed. The selection of appropriate conservation management options in Manitoba requires full investigation of the relation between the ecological integrity of alvar habitat and ecological processes, such as grazing and fire suppression.

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