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Tree and forest encroachment into fescue grasslands on the Cypress Hills plateau, southeast Alberta, Canada

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ABSTRACT

Tree encroachment into rough fescue (*Festuca campestris*) grassland has been identified as an ecological concern on the Cypress Hills plateau in southeastern Alberta, Canada. A combination of field sampling (109 transects), a dendrochronological assessment (1361 trees), and a time series analysis of remotely sensed images from five different time periods (1950–2002) were used to determine the extent and rate of tree encroachment and forest development. Tree cover increased by 768 ha (~51%) between 1950 and 2007, representing 10% of the study area, from 1502 ha of pre-1950 forest. Post-1950 tree invasion also created an ingress zone of 750 ha (~10% of study area) based on field transects. Forest cover increased at a consistent rate of 14.3 ha/year. Lodgepole pine (*Pinus contorta* var. *latifolia*) was the most common tree species associated with encroachment. Invasion based on the number of established trees occurred at an exponential rate of 3.1%/year after 1890, with density increased by filling spaces adjacent to and between trees within the grassland vegetation. The rate of tree establishment increased to 4.4%/year after 1980, suggesting a change occurred in environmental conditions. Annual atmospheric temperatures increased 0.55 °C from 1929 to 2005 ($P < 0.001$), with winter (December–February) and spring (March–May) temperatures accounting for most of the increase ($P < 0.001$), whereas summer (June–August) temperatures slightly decreased ($P < 0.050$, 0.34 °C) and precipitation increased ($P < 0.005$, 30 mm). Cattle and elk (*Cervus elaphus*) grazing was not considered a primary factor for explaining tree encroachment. Based on multidimensional scaling, lodgepole pine establishment was associated with warmer spring temperatures and greater fall (October–November) precipitation. A landscape devoid of wildfires, combined with greater moisture availability, and a longer frost-free season is likely conducive to the sustained establishment of coniferous trees and forest development within the Cypress Hills fescue grassland ecosystem. Long-term conservation of the fescue grasslands could be possible by reintroducing fire.

1. Introduction

Tree and forest encroachment into rough fescue (*Festuca campestris* – plant taxonomic nomenclature follows Kartesz, 1998) grasslands has been identified as an ecological concern in the Cypress Hills of southeastern Alberta (Korpela, 2001; Western Ecological Services Ltd., unpublished[2]; O_2 Planning, unpublished[3]). Fescue grasslands are considered an important element of diversity in the area, and an endangered ecosystem in Canada (Trottier, 2002), because <5% of its original extent remains (Holcroft Weerstra, 2003). A combination of ecological processes and land-use activities such as fire suppression, plains bison (*Bison bison bison*) extirpation, agricultural and urban development, overgrazing, exotic species invasion, and woody plant encroachment have either destroyed or irrevocably altered these ecosystems elsewhere in western Canada (Bailey and Wroe, 1974; Campbell et al., 1994; Vujnovic, 1998; Downing and Pettapiece, 2006). Besides contributing to landscape diversity, fescue grasslands provide important habitat for Sprague's pipit (*Anthus spagueii*), a "threatened" species; and mountain plover (*Charadius montanus*) and burrowing owl (*Athene cunicularia*), which have "endangered" status in Canada (COSEWIC, 2009). Fescue grasslands also provide highly palatable and nutritious forage, supporting both domestic and wild grazers (elk – *Cervus elaphus*, white-tailed deer – *Odocoileus virginianus*, and mule deer – *Odocoileus hemionus*), which has permitted the recent colonization

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[2] Western Ecological Services Ltd., unpublished. A grazing management plan for Cypress Hills Provincial Park, Alberta (1980). Prepared for Alberta Recreation and Parks, Edmonton, Alberta.
[3] O_2 Planning + Design Inc., unpublished. Cypress Hills management plan (2007 draft). Prepared for Alberta Tourism, Parks, Recreation and Culture, Medicine Hat, Alberta.

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of the area by cougar (*Puma concolor*) (M.M. Bacon, University of Alberta, Department of Biological Sciences, personal communication). Of the factors that influence the long-term survival of the grasslands, tree and forest encroachment is least understood and the more difficult to control from a resource management perspective.

Discussion and some research regarding tree and forest encroachment in the Cypress Hills have occurred for several decades. Newsome and Dix (1968) reported *Populus tremuloides* (trembling aspen) invading the grasslands >40 years ago, with Scace (1972) speculating on the relationship between encroachment and fire suppression. The early 1990s brought renewed interest in the topic (Peterson and Peterson, 1993, unpublished[4]) and the recognized need for research and improved documentation of the ecological processes associated with encroachment, but resulted in no comprehensive action. Hull (2002) reiterated the need for tree encroachment research, and indicated the importance of tree invasion to grassland bird habitat selection, species diversity, and population dynamics. A field and spatial analysis was conducted by Korpela (2001) to characterize encroachment, but the results were not considered adequate to guide management decisions. The general consensus is that fire suppression has permitted tree encroachment (Strauss, 2001; O_2 Planning, unpublished), as postulated in other studies (e.g., Burkhardt and Tisdale, 1976; Briggs et al., 2002). In contrast, several other studies in western North America and elsewhere identified climate change as the likely cause for tree encroachment (Wearne and Morgan, 2001; Kennedy and Sousa, 2006; Zier and Baker, 2006; Coop and Givnish, 2007; Strong et al., 2009).

The purpose of this research was to evaluate tree and forest encroachment into fescue grasslands on the Cypress Hills plateau of southeastern Alberta, Canada. This research attempted to (i) determine the quantity and rate of tree and forest encroachment; (ii) determine the pattern of tree establishment; and (iii) identify what ecological mechanisms or land-use practices may be promoting encroachment. Considered potential causal factors included livestock and elk grazing, fire regime, and climate change. If the environmental factors that promote tree encroachment can be identified, it is possible that the fescue grasslands of the Cypress Hills and their associated biodiversity can be maintained by arresting or reversing tree encroachment.

2. Materials and methods

2.1. Study area

The Cypress Hills form a 2590 km^2 upland that straddles the southern Alberta–Saskatchewan boundary (center 49°37.5′N, 110°′W). Bold escarpments define the northern, western, and eastern limits of the plateau. The study area (~7847 ha) was located entirely on the plateau and within the Alberta portion of Cypress Hills Interprovincial Park, with an average elevation of 1415 m that occurred ~310 m above the surrounding plains. The upland belongs to the Montane ecoregion of Alberta, which represents <1% of the province (Strong, 1992).

The western and northern escarpments of the Cypress Hills are heavily forested, whereas the southern slope and the plateau are grasslands intermixed with forest patches. *Pinus contorta* var. *latifolia* (lodgepole pine) is the most common tree on the plateau. Stands of *P. tremuloides* sometimes occurred along the margins of *P. contorta* stands. *Picea albertiana* (western white spruce—Strong and Hills, 2006) did not form pure stands on the plateau, but are present in grassland and forest vegetation (Breitung, 1954; Newsome and Dix, 1968). The grasslands are dominated by *F. campestris*. Within the grasslands occurred *Danthonia intermedia*, *Elymus trachycaulus* ssp. *subsecundus*, *Festuca idahoensis*, *Helictotrichon hookeri*, and *Koeleria macrantha*; however, *Dasiphora floribunda* is also abundant. Black Chernozemic soils are associated with grasslands, whereas Gray Luvisols occur with long-established forests (Greenlee, 1981).

Forest fire frequency in the Cypress Hills from 1740 to 2000 averaged ~45 years (range 24–65 years), with frequent, low severity burns, and infrequent, high severity fires (Strauss, 2001). Most existing forests established following fires in the late 1880s and early 1890s (Newsome and Dix, 1968; Strauss, 2001). Before the arrival of Euro-Canadians in the late 1800s, the area was occupied by indigenous Plains people (Scace, 1972), who used fire to maintain horse and bison forage (Oetelaar and Oetelaar, unpublished[5]). From 1969 to 2007, 35–40 ha of fescue grassland burned on the plateau in a single event (L. Weekes, Alberta Tourism, Parks and Recreation, personal communication). Domestic livestock grazing has occurred since the 1890s (Western Ecological Services Ltd., unpublished). Elk became an important grazer after being reintroduced in 1938 (Keith, 1977).

2.2. Field and dendrological methods

Prior to field work, the oldest available aerial photographs of the study area (1950, 1:40,000-scale) were scanned and imported into ArcGIS (ESRI Ltd., 2006) to facilitate data analysis and mapping. Two hundred potential sampling transects located perpendicular to the perimeter of the plateau were identified and marked on the scanned images. Each transect was initially 200 m in length, unless it crossed the width of the plateau. In the latter case, transects were subdivided mid-way through the grass-dominated section. Transects covering forest islands and grassland vegetation were also identified (10% of pool). From the pool of potential transects, 100 were randomly selected for sampling based on a 90/10 split, respectively. Transects were located in the field using a hand-held global positioning system unit. The first sampling point for each transect was located on the 1950 forest boundary, unless transects traversed a forest island or grassland vegetation. Each transect then extended in a straight-line in a predetermined direction.

Sampling occurred at 10-m intervals along one-side of each transect. The side with the most level topography was sampled. At each sampling point, three size-classes of trees based on basal diameter were measured: <25 mm; 25–49 mm; and ≥50 mm. Only the nearest representative of each size-class located at a right-angle (±50 cm of line) and within 15 m of the transect was sampled. For each tree, its species and basal diameter were determined. Increment cores were collected immediately above the root collar from trees ≥50 mm basal diameter, whereas basal disks were collected from smaller trees. If a tree was encountered within the last 60 m of a transect, an additional 60 m was added until no additional trees were encountered. The health of individual trees was qualitatively assessed (Good, Average, Poor) based on a visual inspection of general tree physiognomy and foliage abundance; the presence/absence of cones was also noted for conifers.

Increment cores were glued to wooden mounts and sanded, and clipped stems were sanded. Aging was conducted using a binocular dissecting scope. When cores did not intersect the pith, missing rings were estimated using species-specific templates derived from complete cores with similar ring patterns (Haugo and Halpern, 2007). No more than four rings were added to counts

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[5] Oetelaar, G.A., Oetelaar, D.J., unpublished. Indigenous stewardship: lessons from yesterday for the parks of tomorrow. University of Calgary, Calgary, Alberta.