Characterizing Whitebark and limber pine Habitat in Alberta: Mapping highly localized tree species across a large study area

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Abstract

The endangered white pines, whitebark pine (*Pinus albicaulis)* and limber pine *(Pinus flexilis),* are crucial for Alberta alpine ecosystems. A province-wide species distribution map for whitebark and limber pine does not exist and will be important for future management strategies. An initial attempt to model whitebark and limber pine using the pre-existing dataset found that an insufficient density of presence data for the province resulted in an oversimplified, overabundant estimation of whitebark and limber pine presence. To address this, our study conducted ground surveys and acquired high resolution aerial imagery throughout the foothills and mountain ranges of Alberta. This data was analyzed and filtered to produce a large, high-precision inventory of whitebark and limber pine locations in Alberta. Through field observations, aerial photo analysis and extensive literature review, whitebark and limber pine habitat was characterized as having a multivariate dependency on elevation, hillslope profile, hydrologic regime, natural disturbance regime, and the relative abundance of lodgepole pine *(Pinus contorta),* alpine larch *(Larix lyallii),* alpine fir *(Abies lasiocarpa),* and Engelmann spruce *(Picea engelmannii).*

Background and Relevance

Whitebark pine (*Pinus albicaulis)* and limber pine *(Pinus flexilis)* have an important role in the alpine ecosystems of Alberta for watershed protection, shelter for both plants and animals, and as a food source for squirrels, grizzly bears, and nutcrackers (Tomback & Achuff, 2010). Both species have been severely impacted by the introduction of an exotic fungus that has infected whitebark pine across its entire range in Alberta (field observations, 2010). As a result, whitebark and limber pine are expected to decline throughout the province and have been listed as endangered species since 2008 (Wilson, 2007). Currently, initiatives are being outlined with the intention to conserve and restore the health of Alberta whitebark and limber pine communities, starting with a detailed inventory of both species (Wilson, 2007). To date, the only maps that exist for whitebark and limber pine distribution in Alberta are either imprecise or restricted to small regions for which there is an exhaustive collection of ground-truth data (McDermid & Smith, 2008). A complete province-wide inventory of high-precision ground-truth data for whitebark and limber pine is unrealistic due to the high cost and difficulty of accessing the high alpine regions that these trees inhabit. Yet it may be possible to acquire enough reliable data to permit a precise characterization of whitebark and limber pine habitat in terms of several key explanatory variables. Such controls are likely to include topographic factors that contribute to undeveloped soil, drought conditions and cyclic disturbance by rockslides and avalanches (Tomback & Achuff, 2010; Callaway, 1998). This study presents the methods and results of data collection and analysis for the purpose of characterizing whitebark and limber pine habitat in Alberta.

Methods and Data

The study area is comprised of the full range of the Rocky Mountains and foothills of Alberta. This includes Waterton, Banff, and Jasper National Parks and the surrounding wilderness areas.

At the outset of this study, we performed a rough decision tree classification of whitebark pine presence using Landsat TM imagery and digital elevation data. The classifier was trained with ground observation data that consisted of 520 whitebark pine and 210 limber pine presence polygons collected by various agencies from 1950 to 2010. The centroids of these polygons were assumed to be points of whitebark and limber pine presence. Absence points were generated programmatically at random locations outside the natural elevation range of whitebark pine. The model was run on a total of 20 explanatory variables, which included 15 spectral variables from Landsat-TM imagery and 5 topographic variables from a digital elevation model. Using IDL programming, the final output was a binary raster image of presence and absence.

From mid-June to late August of 2010, a field campaign aimed at obtaining whitebark and limber pine presence points was conducted over the entire study area.[1] The field methods in this study had to address the logistics of difficult access, an extensive study area, and a limited budget. A cluster sampling design was used accommodate both the data requirements and the fiscal limitations of the survey. To reduce the probability of travelling long distances on foot without finding whitebark and limber pine trees, the data used in the preliminary classification (above) was used as a guide for planning access. Two crews were dispatched on 40 day-trips to take pictures and record a few key properties of whitebark and limber pines and their surrounding environment. The location, landform classification, species composition, crown closure, cone count, and tree heights were recorded for a 30 metre radius sample plot. In addition, observations were made with respect to the characteristics and variability of habitat variables associated with whitebark and limber pine occurrence. Distance samples were also obtained by identifying trees on adjacent slopes using binoculars and employing optical-rangefinders and inclinometers to pin down the location.

Beginning on July 24 (2010), 300 kilometres of aerial transects were flown to collect 5-10 cm resolution RGB imagery in remote parts of the province. These images were viewed stereoscopically and visually scanned for whitebark and limber pine presence and absence. The sample locations were entered into the database along with a cropped image of the sample and an estimation of species composition and crown closure.

Finally, a comprehensive review of field observations and literature was carried out in order to develop a working hypothesis with respect to whitebark and limber pine habitat characterization. This review was aimed at identifying the characteristics of whitebark and limber pine habitat that can be reconstructed from transformations on digital elevation data and spectral analysis of data from Landsat TM. In particular these characteristics included species composition and abiotic conditions that could be defined in terms of reflectance or terrain.

[1] Except for Waterton National Park, for which sufficient ground-truth data already exists.

Results

The results of the preliminary decision tree classification indicated that the sparse and largely inaccurate data set had the effect of reducing the usable explanatory variables to a single elevation variable. Thus, the final output was no better than a truncated digital elevation model. Upon visiting these data sites in the field, it was found that many of the samples were not located over whitebark and limber pine stands. In some cases, the sample locations seemed to be the result of misidentification of lodgepole pine, alpine fir, and spruce as whitebark and limber pine.

The 2010 field season yielded 350 ground-truth points in roughly 70 clusters scattered about the province. In combination with points collected in 2007 and 2009, the new dataset spans the province from Waterton National Park to the Willmore Wilderness Area north of Jasper National Park.

Aerial photo analysis is increasing the sampling density throughout the study region. Based on the results so far, it seems that many stands of non-characteristic trees can not be identified as whitebark pine with certainty. These are being classified as "possible presence" and will be re-examined as additional means of interpretation is developed to distinguish these trees. However, the aerial dataset in proving useful for sampling a large area of remote whitebark pine habitat in the Willmore Wilderness Area as well as improving the sampling density in the Crowsnest Pass and southern Kananaskis regions.

Discussion

Observations that were made during the 2010 field season have resulted in several key considerations related to the characterization of whitebark and limber pine habitat. First, both whitebark and limber pines occur in three distinct phenotypes. The large-form type is typically 10-20 metres tall with a large fanning crown. The mid-form type ranges from 3-9 metres tall, with a full and bushy branch structure that tapers outward from top to bottom. The final form is stunted trees that range in height from 0-2 metres. These trees do not have a well defined trunk and usually appear as a clustered series of branches arching out of the ground. Although elevation is a strong factor in which form of tree is expected, it is not an exclusive predictor and it is likely that each of these phenotypes will have to be modeled separately.

Another important issue for habitat modeling is that whitebark and limber pines rarely occur in pure stands. Over the course of the field season a completely pure stand of whitebark and limber pine trees was not observed in Alberta. In the case of whitebark pine there were very few stands in which whitebark and limber pine was the dominant tree species. As a result, any attempt to classify whitebark and limber pine trees from spectral data will be hampered by the inclusion of signatures from other trees.

The sampling density that is needed in order to successfully model whitebark pine across Alberta cannot be achieved by field operations alone. According to a 2008 study of the Greater Yellowstone Area, a successful model for whitebark pine habitat requires adequate training data and the use of highly-evolved computer learning methods (Landenburger *et al.*, 2008). Landenburger *et al.* (2008) used a similar approach to the preliminary model performed at the outset of this study, combining 16 spectral variables and 3 topographic variables in a decision tree classification model. However, the sampling density in the Yellowstone study was much greater than is fiscally possible for Alberta. In lieu of a high sampling density, the second phase of this study is aimed at using information on the habitat characteristics of whitebark and limber pine (from a combination of literature review and field observations) to reduce the area over which the classification is run. It is hypothesized that both reducing the model area and supplementing the existing number of samples with samples from aerial photos will increase the accuracy of prediction by the model.

Conclusions

The pre-existing whitebark and limber pine presence dataset was insufficient for modeling whitebark and limber pine distribution across the province. Cluster sampling and aerial photo interpretation is a cost-effective method of acquiring whitebark and limber pine presence data across large regions that are inaccessible by vehicle. Whitebark and limber pine presence is dependent on elevation, hillslope profile, hydrologic regime, natural disturbance regime, and the relative abundance of lodgepole pine, alpine larch, alpine fir and engelmann spruce. It is hypothesized that all of these variables are needed to characterize the habitat of whitebark and limber pine. Additionally, three separate combinations of these variables may be needed explain the occurrence of the three distinct whitebark and limber pine phenotypes.

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