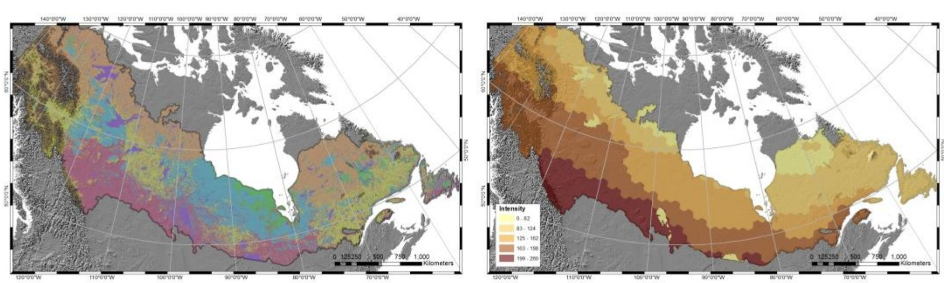
Development of pan-boreal indictors of environmental diversity for assessing current protected area representativeness and future protection initiatives

(1) Background

I received a BSc in Geography from the University of Victoria in 2006. During my BSc I specialized in Remote Sensing, Spatial Statistics, GIS, and wetland classification. Building upon my B.Sc work, I completed a MSc from the University of Calgary in 2009, where my (NSERC and iCORE supported) research involved employing a Geographic Object-Based Image Analysis (GEOBIA) approach to estimate the differences in detected wetlands when high-resolution imagery (<5m) and medium-resolution (>10m) imagery are used. As a PhD student at UBC, my current research focus is on the application of GIS and Remote Sensing to biodiversity assessment and reserve selection across Canada's boreal forests.

(2) Project overview:

Here we looked at developing an approach for identifying areas important for biodiversity conservation within the Canadian boreal forest in regards to two types of boreal-wide biodiversity surrogates: *(i)* satellite-derived environmental domains (Figure 1a), which consist of 15 clusters (i.e., environmentally unique areas) based eight remote sensing datasets and *(ii)* mammalian and avian species richness index (Figure 1b), which comprises of presence/absence information of 101 mammal species and 334 bird species. This work was conducted by Ryan Powers during June 2011 for the Nature Conservancy.



(a) (b)

Figure 1: Maps of the biodiversity surrogates; (a) 15 clusters, (b) Species richness

(3) Methods: Data processing & cluster analysis

ArcGIS [ESRI, 2011, Redlands, version 10] was used to assemble the eight remote sensing indicators (landcover, spring and autumn snow cover, three measures of vegetation productivity, and ruggedness) and the species range maps (mammal and bird) into a common 1 km spatial resolution grid that contained 4,604,910 pixels. The coefficient of variation (CV) of elevation (i.e., ruggedness) was also computed in ArcGIS and was used to better differentiate topography between different environments across the boreal forest. High CV values indicate areas with extreme changes in elevation, whereas low CV values represent areas with minimal elevation differences.

The values of the eight indicators within the 4,604,910 1 km cells were then converted into a table format using ArcGIS's sampling function and classified using a clustering procedure in PASW Statistics 18 software [SPSS, Inc., 2010, Chicago, IL, version 18.0.2]. A cluster is a set of cells or locations, not necessarily spatially contiguous, which share a range of distinct environmental conditions as described by the indicator variables. The clustering procedure imposes a tradeoff between precision and generality, which is determined largely by the number of clusters generated. Forming too few clusters means that considerably different kinds of environments are not distinguished. Forming too many clusters makes it difficult to identify trends or to describe environmental uniqueness in a useful way. We adopted the two-step approach of Zhang et al. (1996), which is able to handle large datasets with both continuous and categorical variables. Fifteen clusters were selected as they represent a level of organizational detail useful for aiding large area conservation planning within the boreal and commensurate the fifteen expert derived terrestrial ecozones regularly used in Canada. The final clusters were brought back into ArcGIS for visualization and analysis via linking the classified table to the 4,604,910 1 km cells (see map on pg 4).

(4) Methods: Identifying areas for prioritization

The Canadian Boreal region (as defined by Brandt, 2009) was partitioned using ArcGIS into 5x5 km polygon squares for a total of 213,448 candidate priority areas (i.e., planning units). We then used Marxan (Possingham et al., 2000), a freely downloadable decision-support tool, to identify areas that meet our biodiversity targets (e.g., 15% of each conservation feature) at an efficient cost. ArcGIS was used to create the Marxan input files. These files included (*i*) the planning unit shape file (i.e., the 5x5 km polygon squares), (*ii*) a file that contained information about the quantity of the clusters and species present within each polygon planning unit, and (*iii*) a boundary file that specified each polygon planning unit's neighbours and their respective shared boundary length.

This project was carried out in two phases: *(i)* using only cluster and *(ii)* using both clusters and species richness data. In phase *(i)* we ran Marxan ten times for nine different scenarios that varied in either *boundary length modifier (BLM)* or *target amount* (Table 1). A BLM of one, two, and three was used to alter the structural connectivity of the reserve system. In this respect, a larger BLM contributes to a greater importance being placed on the reserve system's compactness (i.e. lowering the boundary length between candidate priority areas) than cost efficiency. We set conservation targets for each cluster type (1-15) based on three area weightings for 15%, 20% and 30% of the total cluster area.

Table 1: Marxan with varying BLM and cluster target amounts

Scenarios	Boundary Length Modifier	Cluster Target Amount (%)
1,2,3	1	15, 20 and 30
4,5,6	2	15, 20 and 30
7,8,9	3	15, 20 and 30

Similarly, in phase *(ii)* we also ran MARXAN ten times, but for three scenarios that varied in BML. We set targets of 30% for those areas with the highest species richness index (i.e., areas with 199-261 observed species) and used an area weighting for the cluster types for 15% of the total cluster area.

(5) Marxan output:

The "best" solution (or rather a very good solution) out of the ten Marxan runs was inputted into ArcGIS to visually depict the reserve system's structure and extent for each scenario in both phases (Figures 2 and 3). A visual comparison of the different scenarios confirms that the BLM could be used to place greater emphasis on areas that are structurally compact when applied to a variety of target amounts. All targets were met for each scenario. Figure 4 illustrates the areas already protected to those conserved for one scenario in each phase. Using ArcGIS, we determined that there was a 4,482 km^2 (~13%) and 4,872 km^2 (~13.7%) overlap with protected areas for Figure 4a and Figure 4b respectively.

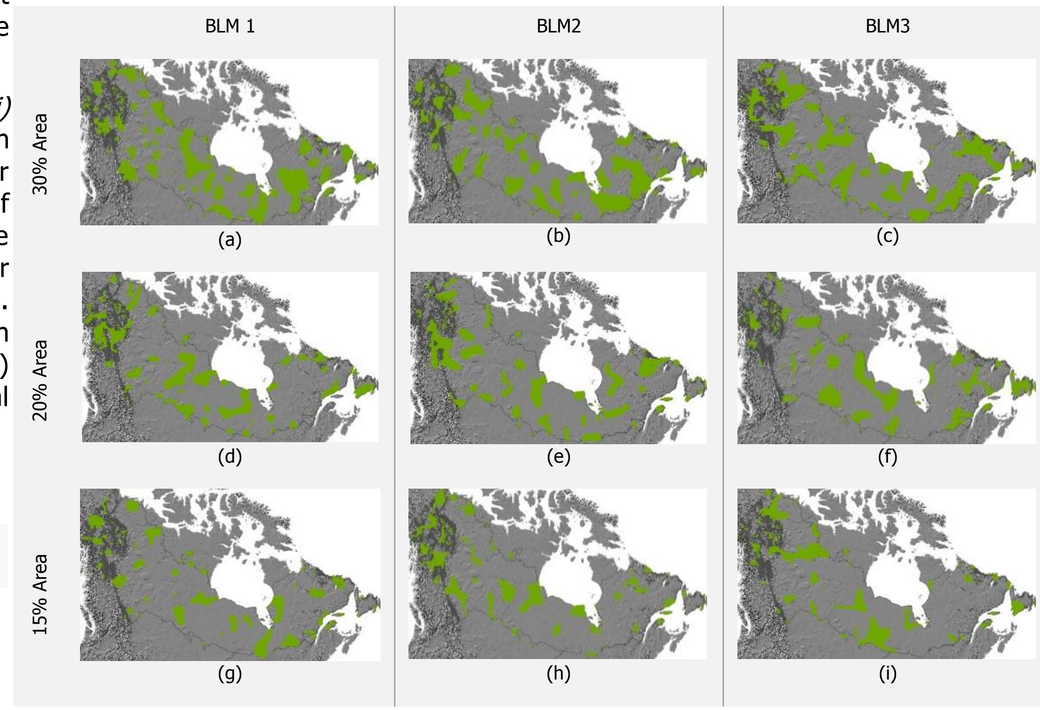


Figure 2: Maps of best solution from all runs for the nine Marxan scenarios where green represents those areas conserved; (a-c) 30% of total cluster area representation for BLM 1,2, and 3, (d-f) 20% of total cluster area representation for BLM 1,2, and 3, (g-i) 15% of total cluster area representation for BLM 1,2, and 3

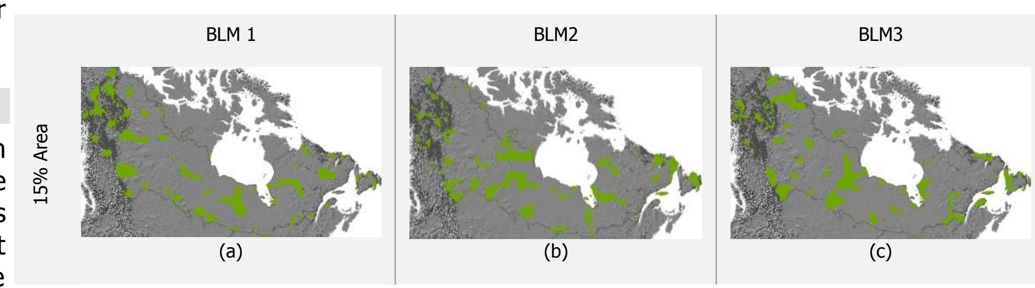


Figure 3: Maps of best solution from all runs for the three Marxan scenarios where green represents those areas conserved; (a-c) 30% of areas with a high specie richness index (199-261 species observed) and 15% of total cluster area are represented for BLM 1,2, and 3

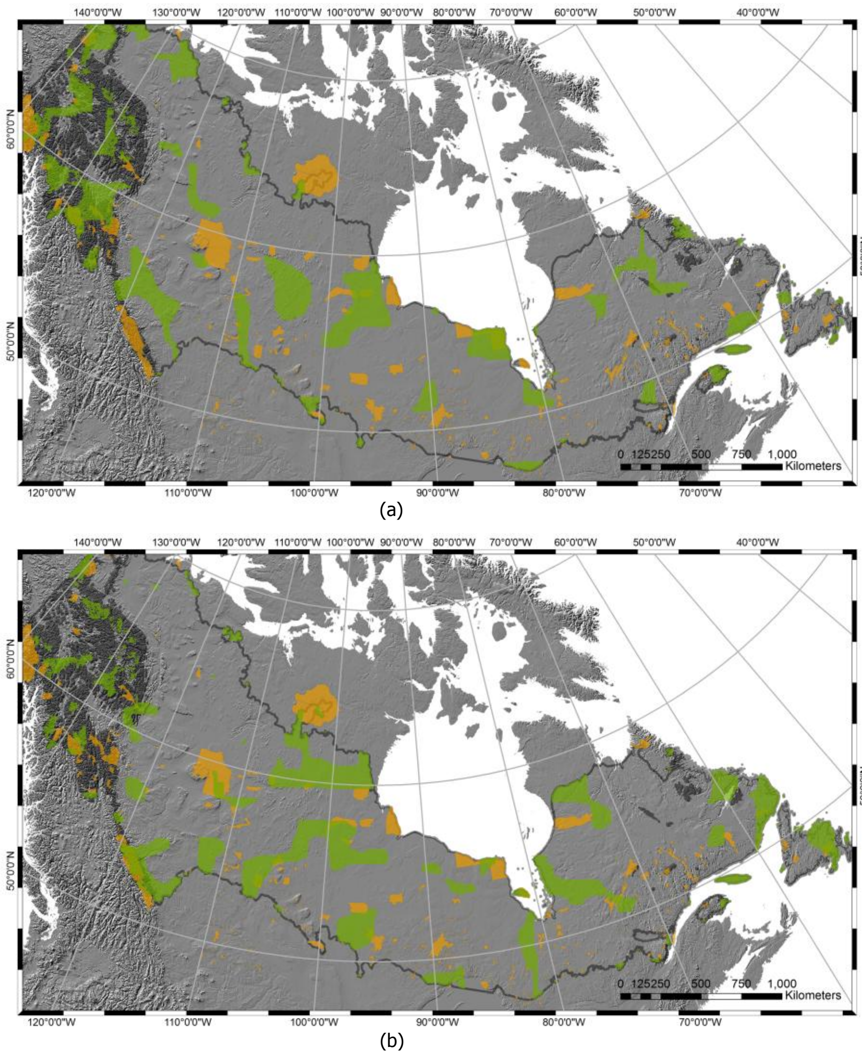


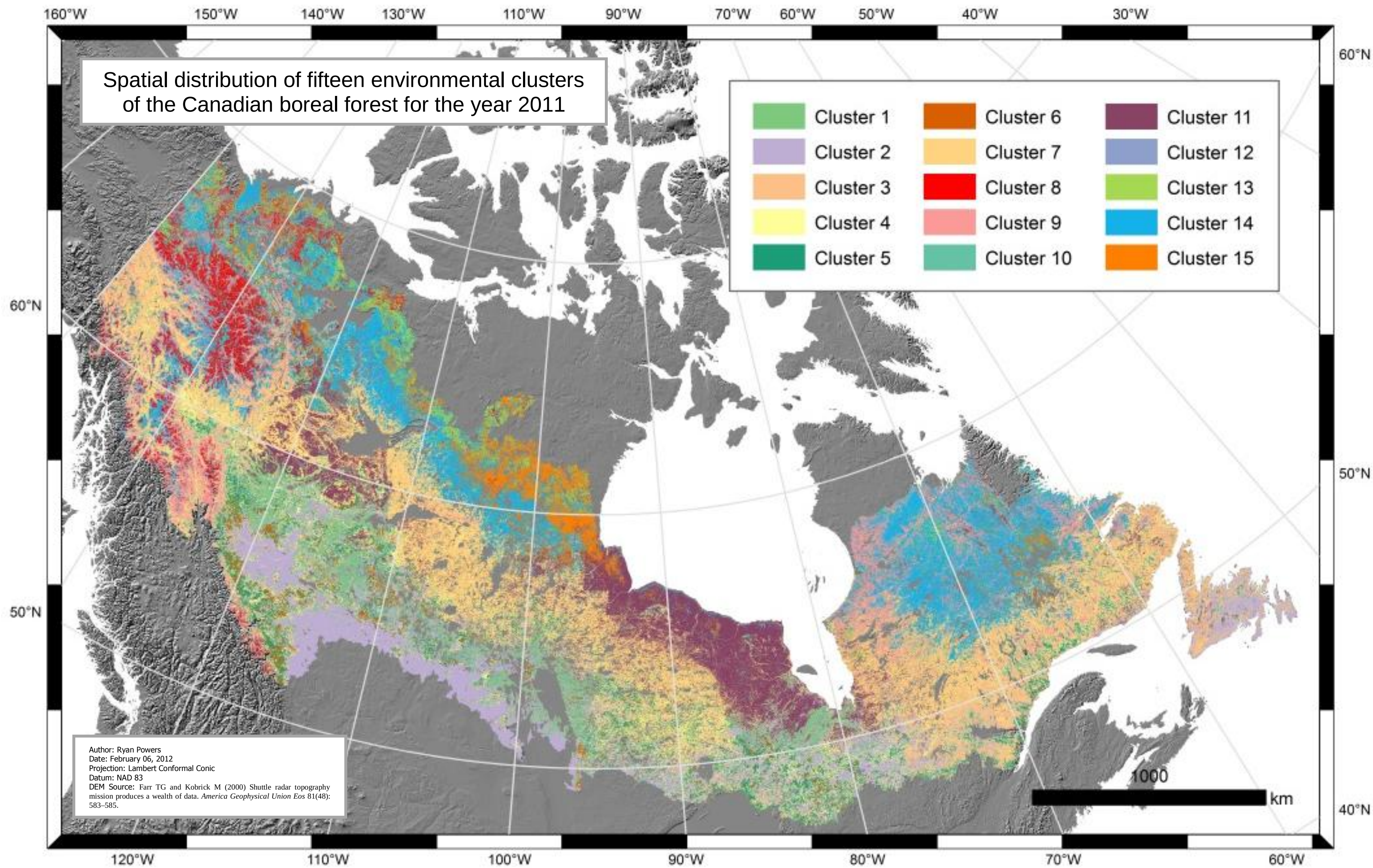
Figure 4: Maps of currently protected areas and best solution for two Marxan scenarios where orange and green represent those areas that are currently protected and areas suitable for conservation based on this analysis respectively; (a) 15% of total cluster area representation for BLM 2, (b) 30% of areas with a high species richness index (199-261 species observed) and 15% of total cluster area are represented for BLM 2

(6) Summary:

In an effort to identify areas that are important for conserving biodiversity and to contribute to the on-going Canadian boreal forest research, my scientific objective of this project was to evaluate the application of remote sensing imagery to biodiversity assessment and its use within a Spatial Conservation Prioritization (SCP) framework (i.e., Marxan) for the selection of new ecologically meaningful protected areas. Specifically, the research was carried out in two sections that (*i*) reviewed and assessed the suitability of a variety of remotely derived biodiversity indicators for characterizing biodiversity within the Canadian boreal forest, and (*ii*) developed approaches that incorporate satellite-derived clusters (i.e., environmentally unique areas/groupings) and spatial species data with SCP. I perceive this research as a novel contribution that builds upon my existing GIS and remote sensing experience, the need to establish new protected areas within the Canadian boreal forest, and overcomes the limitations of traditional approaches to complex large-area conservation problems.

(7) References:

- Brandt, J.P. (2009) The extent of the North American boreal zone. *Environmental Reviews.* 17: 754-767
- Possingham HP, Ball I, Andelman S (2000) Mathematical methods for identifying representative reserve networks. *Quantitative Methods for Conservation Biology*. Ferson S, Burgman M, eds. Springer-Verlag. pp 291-305
- Zhang T, Ramakrishnan R and Linvy M (1996) BIRCH: An Efficient Data Clustering Method for Very Large Databases. In: Jagadish HV and Inderpal Singh Mumick (eds), *Proceedings of the 1996 ACM SIGMOD International Conference on Management of Data*, Montreal, Canada, 4-6 June 1996, New York: ACM Press.



Spatial distribution of fifteen environmental clusters of the Canadian boreal forest for the year 2011
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Cluster 6
Cluster 7
Cluster 8
Cluster 9
Cluster 10
Cluster 11
Cluster 12
Cluster 13
Cluster 14
Cluster 15
160°W
150°W
140°W
130°W
110°W
90°W
70°W
60°W
50°W
40°W
30°W
60°N
50°N
40°N
120°W
110°W
100°W
90°W
80°W
70°W
60°W
1000
km
Author: Ryan Powers
Date: February 06, 2012
Projection: Lambert Conformal Conic
Datum: NAD 83
DEM Source: Farr TG and Kobrick M (2000) Shuttle radar topography mission produces a wealth of data. America Geophysical Union Eos 81(48): 583–585.