Political, ecological, and species boundaries: implications for the identification of minimum requirements for representative protected areas

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Abstract

Various jurisdictions in Canada are currently undertaking, or have recently completed, planning for representative reserve networks. These exercises are often confined to designs within political boundaries. Others have used ecologically defined regions, such as ecozones or ecosystems, which themselves may be defined by different criteria than those used in the representative reserve network analysis. Here, we illustrate the differences in representative reserve networks for disturbance-sensitive mammals in Ontario when regions bounded ecologically versus politically are used as the target zones to identify near-optimal solutions for protected areas across multiple spatial scales. The scale of the target region has an effect on the minimum number of protected areas required to achieve representation; larger regions require more protected areas to represent all of the mammals than do smaller regions. However, for very large target regions, the total number of protected areas is less than the sum of the parts. We also illustrate how inherent boundaries in the data used for identifying representative areas may be the most efficient means to identify minimum representative networks. Constraining reserve network planning to politically bounded target regions may not result in either efficient nor effective protected area systems, but neither may be ecologically defined regions at certain scales.

Introduction

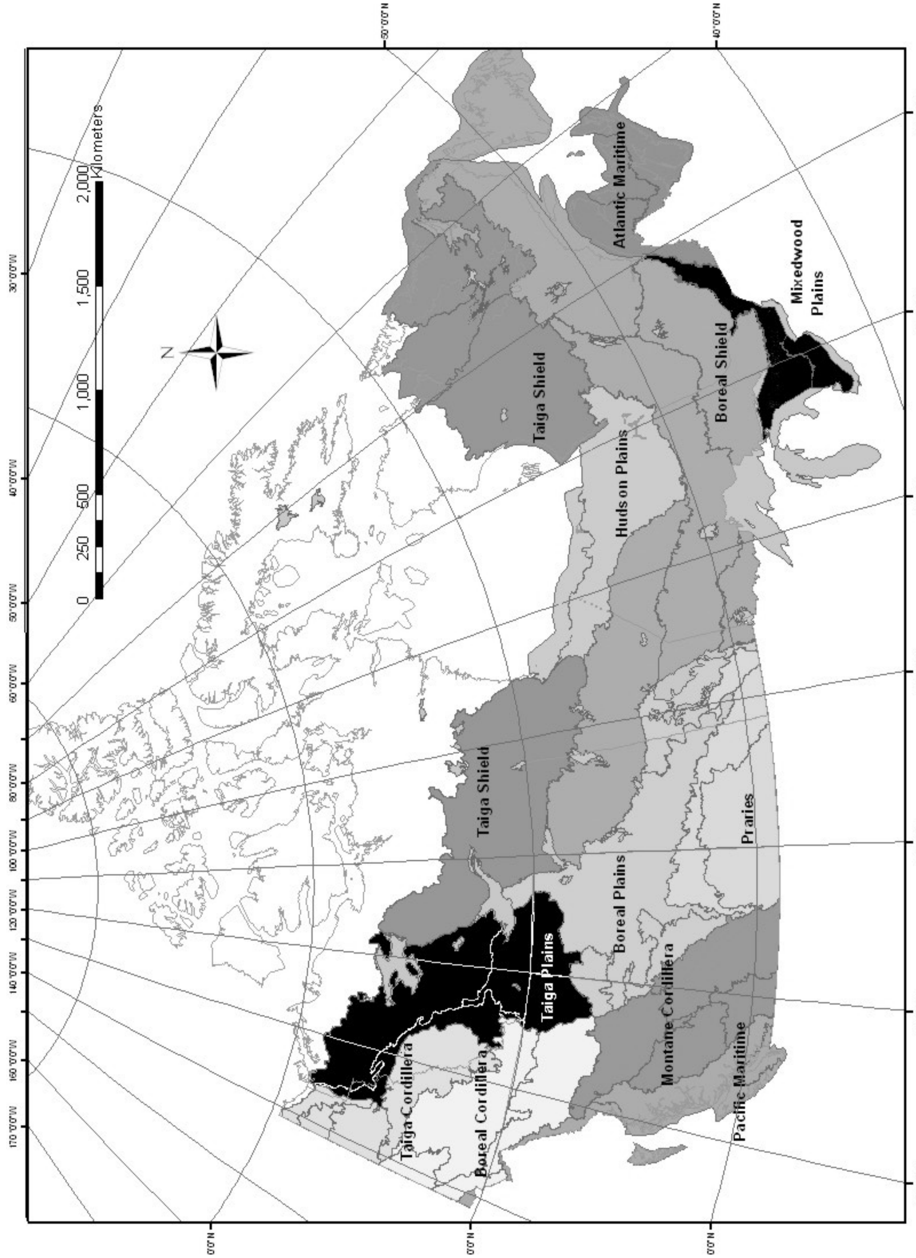
Planning for representative protected areas is often focused within politically-bounded regions (e.g., YPAS 1998; Northwest Territories Protected Areas Strategy Advisory Committee 1999) for the simple reason that implementation and management of these areas is carried out by agencies working within specific political regions (provinces, territories, nations). However, given that we know that species do not generally recognize political boundaries, using ecologically defined regions as the target areas within which to identify representative protected areas may be more appropriate.

The literature on representative protected areas design is vast, and much of it is focused on the question of finding near-optimal solutions to the problem of maximizing species representation with a minimum amount of area. These approaches have made use of a variety of computerized techniques, including heuristic algorithms (Margules *et al.* 1988; Pressey *et al.* 1996, 1997), simulated annealing (e.g., McDonnell *et al.* 2002) and linear programming (e.g., Possingham *et al.* 2000). We have been carrying out work on protected areas in Canada for a number of years. Our work on representative protected areas design has taken a slightly different approach than that presented in much of the literature. Rather than ask where representative areas should be located, and then consider design elements to ensure species persistence, we have first asked "what is the minimum reserve area that is predicted to allow for species persistence?" and then asked "how many of such sized areas are needed to represent all species of interest?". We referred to the work of Gurd *et al.* (2001) to estimate minimum reserve area (MRA), and used sites that met MRA size requirements (2700-13,000 km^2) to identify minimum reserve networks within the mammal provinces of Canada using heuristic reserve selection algorithms (Wiersma and Nudds, in press). While our work on representative protected areas design has been carried out within the mammal provinces of Canada (Hagmeier 1966), most other jurisdictions prefer to use Canadian Ecosystem Framework (Ecological Stratification Working Group 1996), which divides the country into ecozones (Figure 1), ecoregions and ecodistricts as the basis for identifying ecologically defined target areas. In this study, we apply work done previously within the mammal provinces to the ecozones shown in Figure 1 which overlap with Ontario, namely the Mixedwood Plains, the Boreal Shield, and the Hudson Plains.

Intuitively, ecologically defined regions seem more appropriate as target regions for planning representative protected areas than politically bounded regions, but such areas are still somewhat arbitrarily defined. There are any number of ways to classify and delineate ecologically bounded regions, based on patterns of similarity and dissimilarity in a range of different features, including topography, soils, vegetation, climate, and species composition (e.g., the National Ecological Framework for Canada [Ecological Stratification Working Group 1996], the Soil Landscapes of Canada [Soil Landscapes of Canada Working Group 2006], Plant Hardiness Zones, or the Geological Provinces of Canada). Some of these classification systems may be more or less appropriate to use as target regions for developing representative protected areas networks, depending on the goals and objectives of a particular protected areas strategy. In addition, recent research has shown that, for some species, dissimilarity gradients do not vary any more significantly within ecoregions in North America, than they do between them, illustrating that these boundaries may be somewhat in the eye of the beholder (McDonald *et al.* 2005).

Despite that ecologically defined regions may be somewhat arbitrary; we investigated the effects of varying the type and size of target region on the minimum requirements for representative protected areas in Ontario. Research

Figure 1. The ecozones of Canada, excluding the arctic ecozones.



in landscape ecology consistently emphasizes the scale-dependent nature of ecological processes (Wiens 1989). Scale is comprised of two elements, grain, defined as "the finest level of spatial resolution possible within a given data set" (Turner *et al.* 2001: 29); and extent, defined as the "size of the study area... under consideration" (Turner *et al.* 2001: 29). Wiersma and Nudds, (in press) showed that variation in grain size did not significantly affect the number of protected areas required to represent individual mammal provinces. Here, we examine the effect of variation in the extent of the target region.

Methods

We used sample plots of 2700 km^2 to correspond to the lowest 95% confidence interval for the MRA estimate of Gurd *et al.* (2001). We overlaid these plots on range maps representing current species ranges (Patterson *et al.* 2003) using ArcGIS (v. 9.1, ESRI) in each of the three terrestrial ecozones that overlap with the province of Ontario (Hudson Plains, Boreal Shield, Mixedwood Plains). The overlay analysis gave data on species richness and composition for the suite of candidate plots in each of the target regions. In addition, we sampled the province of Ontario for mammal species to see how the locations for representative areas varied when politically-bounded versus ecologically-bounded target regions were used.

A minimum representative network at the extents of the national and mammal provinces was identified from the suite of candidate sites using both a richness-based and a rarity-based heuristic algorithm (Margules *et al.* 1988; Pressey *et al.* 1993). Details for the algorithms can be found in our previous papers (Wiersma and Nudds, in press). We then examined whether there was a correlation between the number of sites required to represent mammals in each of the 3 ecozones and their area.

Results

The number of protected areas needed to represent each ecozone varied (Table 1). As with previous studies (Wiersma and Nudds, in press), the rarity-based algorithm was more efficient than the richness-based one. The sum of the protected areas needed within the Ontario portion of the ecoregions was 4 when the rarity-based algorithm was used, and 12 using the richness-based algorithm. However, when the province as a whole was considered as a target region, only 2-3 sites were needed to represent all mammals, using the rarity-based and richness-based algorithms respectively (Figure 2).

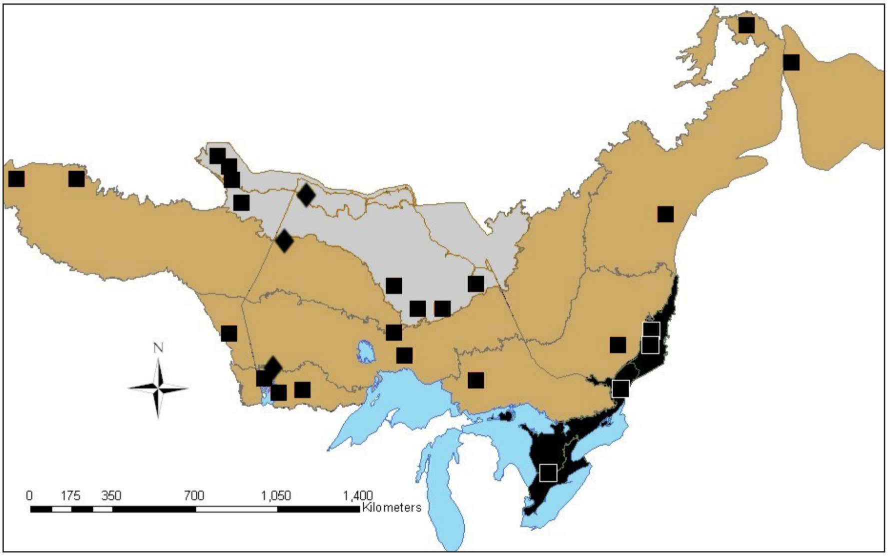
Conclusions

Similar work by Wiersma and Urban (2005) showed that size of the target region did not predict the number of protected areas required to represent all the mammals in ecoregions. Here, however, at the scale of whole ecozones, larger ecozones required more protected areas for minimum respresentation

Table 1. Ecozones, area, and number of protected areas required to represent each of them as identified using a richness-based and rarity-based heuristic reserve selection algorithm. Data is given for all of the ecozones overlapping Ontario, as well as with the portion of each that lies within the political boundaries of the province.

Target region	area (km^2)	# sites (richness based)	*# sites (rarity based)*
Mixedwood Plains	168,913	4	3
Hudson Plains	446,528	8	3
Boreal Shield	2,072,417	13	7
Within Ontario			
Mixedwood Plains (ON)	83,028	2	2
Hudson Plains (ON)	262,774	4	1
Boreal Shield (ON)	635,445	6	1
Sum of Ontario Portion of Ecozones	**981,247**	**12**	**4**
Province of Ontario	**981,247**	**3**	**2**

Figure 2. Location for representative protected areas (shown as black squares) in the 3 ecozones that overlap with Ontario as identified using a richness-based heuristic algorithm. The sites with black diamonds are those identified when the province as a whole is considered as the target region.



of all disturbance-sensitive mammals in the ecozone. Further, for no ecozone could mammals be represented in any system of protected areas bounded by Ontario borders. Nevertheless, there appears to be an 'economy of scale': far fewer sites were needed to represent all of the larger target region (Ontario) than were needed to represent the sum of the component parts (Ontario portion of the 3 ecozones). At smaller extents, protected areas may have some redundancies between ecozones in terms of which species they are representing. However, such redundancies may be desirable from a conservation standpoint, as they may conserve genetic diversity or act as an insurance against stochastic events. The redundancies observed here are in terms of representation of mammals, and these sites may not be redundant in terms of other features that occur on a finer scale on the landscape. Further consideration of issues of scale is important, then, in the context of identifying goals and targets for representative protected areas.

Sites selected as representative tend to be located near the boundaries of ecozones, or along the boundaries of ecoregions. However, not all of the representative sites are located along ecologically defined boundaries. This may be because some species' ranges follow the same underlying "signals" of climate, geology, etc. that are used to delineate the ecoregions, while others do not. An examination of Bray-Curtis dissimilarity values, which are a measure of turnover in species composition (i.e., beta diversity) across a south to north gradient shows that a number of the sites not located along the ecozones/ecoregions boundaries are located in areas with high mammal species turnover (Figure 3). Thus, measures of dissimilarity such as the Bray-Curtis measure can be used as an alternative way of identifying ecological boundaries for species, independent of ecozone's/ecoregion's boundaries. Previous work has suggested that beta diversity may be a useful predictor for identifying the number and location of representative protected areas required within a given region (Wiersma and Urban 2005).

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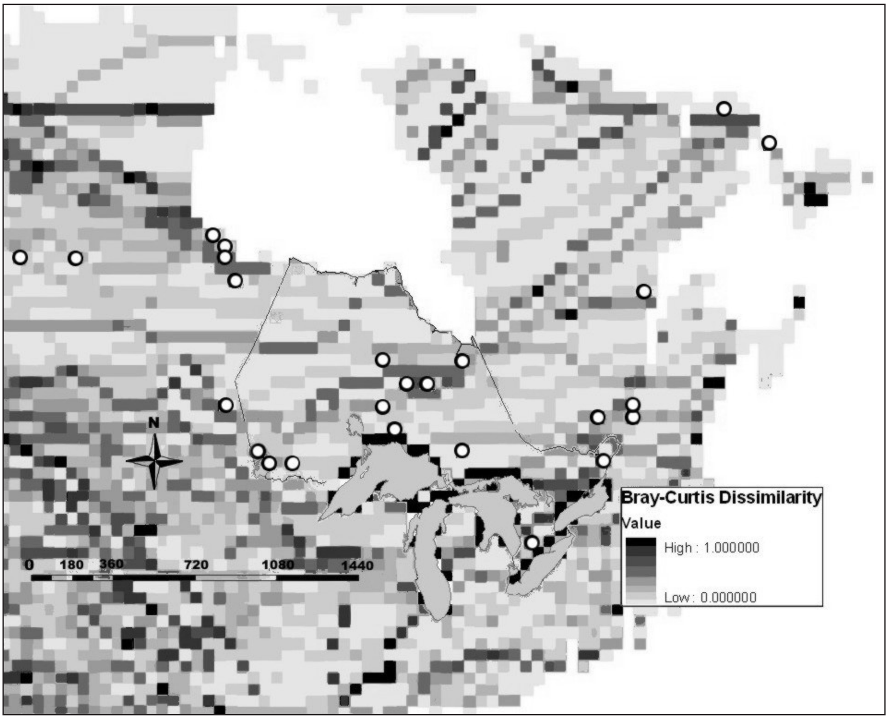
Figure 3. A map showing Bray-Curtis dissimilarity values (a measure of beta diversity, or turnover in species composition across a gradient) together with the representative sites in Figure 2. Note that a number of the representative sites coincide with areas of high turnover in species composition.



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