Designing Protected Areas Networks in the North: Identifying Representative Area and the Use of Focal Species in a Yukon Case Study

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Abstract: The science of conservation biology has made many contributions to improving biodiversity conservation within protected areas around the globe. Northern ecosystems are unique, and principles for protected areas design developed for temperate and tropical ecoregions may not readily be extrapolated to northern regions. Recent increases in ecological threats to the Canadian North have spurred interest in improving conservation and representation of northern ecosystems. Here, I present an overview of issues relevant to protected areas planning in the Canadian North, with a focus on the Yukon. I highlight recent Northern Research Institute-supported research on protected areas design in the Yukon, with a particular focus on the issue of representation and an examination of the potential utility of so-called "focal" species in identifying the location of representative protected areas. I show how Geographic Information Systems (GIS) may be applied to test questions of how many protected areas may be required to adequately represent mammal diversity in the ecoregions of the Yukon. I also use two different approaches to identify focal species for the Yukon to show that there is a great deal of ambiguity involved in how these species are identified.

Introduction

The Canadian North is perceived as a vast wilderness by many, yet is also under increased pressure from resource activities (logging, mining) and from global phenomena such as climate change. Since the early part of the twentieth century there has been interest in protecting northern biodiversity and ecosystems. The motivation for protection, and the methods employed in identifying potential protected areas have changed over time. Recent emphasis in protected areas planning is on setting aside large tracts of land that are representative of northern biodiversity. The challenge is deciding how large these protected areas should be, and where they should be located in order to be most effective. Past practices for designation of protected areas were ad hoc (McNamee 2002) and often based on economic opportunities and/or feasibility. Over time, the influence of the science of conservation biology has resulted in the incorporation of the notion of minimum size and representation requirements (Diamond 1975; Wiersma et al. 2005). This paper briefly traces the history of northern protected areas. The paper then outlines how current principles from conservation biology, coupled with cutting-edge software tools, can be applied to improve planning.

Specifically, I address two of the key issues in protected areas design using data to delineate potential protected areas within the Yukon. The first issue is that of biodiversity representation and how many protected areas are necessary to adequately represent natural regions. The second question addresses whether focal species are an appropriate tool for identifying potential protected areas. These questions have been extensively examined in the conservation biology literature; this contribution is uniquely focused on how they apply in the North.

History of Northern Protected Areas

The first protected areas in the Canadian North were federally-designated areas (national parks, national wildlife areas, migratory bird sanctuaries), established in the early part of the twentieth century to protect significant populations of species of interest—for example, wood bison in Wood Buffalo National park (1922), snow geese in Hannah Bay Migratory Bird Sanctuary (1939), and muskoxen in the Thelon Game Sanctuary (1927). These were generally established without consultation with local people (since this was not the practice of the day) and, in many cases, Aboriginal peoples were removed from lands designated as protected (Sandlos 2007), often because they were perceived not be part of the "natural wilderness" (Catton 1993; Sandlos 2007). The first three northern national parks (Kluane, Nahanni, and Auyuittuq) were established in the 1970s under then-Indian Affairs minister Jean Chrétien. These parks were as much about asserting and protecting Arctic sovereignty as they were about protecting biodiversity (McNamee 2002). Although token efforts were made in some cases to involve consultation with local communities, these parks were largely established where the government felt it was most advantageous from the perspective of preserving key wildlife (e.g., Wood Buffalo) or providing an attraction for tourism (e.g., Nahanni). The Mackenzie Valley Pipeline Inquiry (the Berger

Inquiry) in 1974–75 highlighted the need to protect northern wilderness and gave a sense of urgency to the process. J. Hugh Faulkner took over the parks portfolio in 1978 and set a goal for the establishment of six new northern parks that would conserve northern ecosystems (known as the "6 North of 60" program; McNamee 2002). Four of these—Ivvavik , Quttinirpaaq (formerly known as Ellesmere Island), Aulavik, and Tuktut Nogait—were established by the late 1990s (McNamee 2002). A fifth, Ukkusiksalik, was established in 2003. Many of these were established as part of land claims settlements with Aboriginal peoples.

Recent activities in protected areas planning have taken a consultative approach with local communities. For example, the Northwest Territories Protected Areas Strategy (NWT-PAS) calls for a largely community-driven process that asks communities to identify sites that are ecologically and/or culturally important. Government scientists provide a regional context for identifying representative sites and lend expertise as necessary (Northwest Territories Protected Areas Strategy Advisory Committee 1999). The Yukon Protected Areas Strategy (YPAS 1998) was similar in its spirit of combining western scientific expertise with community involvement in identifying protected areas. The Yukon process was shelved after a change in government in 2002; but the initial strategy served as an excellent model, and was well regarded by both researchers and practitioners. This paper takes the Yukon Protected Areas Strategy as a starting point, and evaluates how well the strategy would meet its stated goals for biodiversity representation. The paper also evaluates whether focal species might be a useful tool for protected areas planning in the Yukon.

Why Have Northern Protected Areas?

Although resource activities can add to the economy of the North, protected areas themselves can contribute to the economy of northern communities (Dixon and Sherman 1990). They also can provide critical habitat for threatened species, function as stopovers for migratory birds, and provide non-ecological benefits to humans. These include economic values for tourism, recreational values for outdoor pursuits, and spiritual and aesthetic values (Dearden 1995).

Ecological integrity is a phrase used to describe the health of a natural system. A natural system, such as a forest, has ecological integrity when it all of its component "parts" (i.e., certain kinds of plants, animals, and so on) are present, as well as supporting ecological processes such as fire, nutrient flow, and river and stream flow. The formal definition for ecological integrity as incorporated into recent amendments to the National Parks Act states that "an ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes" (Parks Canada Agency 2000, p. I-15). It is possible to have a system with ecological integrity that still accommodates human use (i.e., sustainable use); however, in the absence of a benchmark against which to compare, it is impossible to determine whether human activities such as resource extraction are negatively affecting the ecological integrity of the boreal forest. Thus, protected areas play an important role as "ecological benchmarks" against which the effects of humans can be compared, allowing ecologists and resource managers to infer whether observed phenomena (such as declines in the population of a species) are due to human activities, or are part of a natural fluctuation in ecological dynamics.

The challenge for protected areas planners is to balance the scientific, ecological requirements in order for parks to have ecological integrity, with human values and emotions about specific places. These values and requirements may or may not coincide. As well, planners and managers have to balance ecological and socio-economic concerns about what activities should and should not be allowed on any given parcel of land, both in areas identified as "protected," and in adjacent areas.

Planners also face challenges from a scientific perspective with respect to identifying and designing protected areas for ecological integrity in the North. Two main factors contribute to scientific uncertainty with respect to northern protected areas planning. The first has to do with the lack of accurate, spatially-referenced data on species occurrences across the vast regions that make up the North. The second factor is that much of the research in the conservation biology literature has focused on protected areas planning in temperate and tropical regions of the globe. It is uncertain whether principles from these regions can easily be extrapolated to northern regions. Nevertheless, there has been some research on northern protected areas (some of which is highlighted below) and the best available data and scientific knowledge should be applied to northern protected areas. Investments in northern-specific research (such as research funded by the Northern Research Institute) are to be commended, and should continue.

Scientific Research on Northern Protected Areas Design

Issues of Size

If protected areas are to serve as effective ecological benchmarks, they must have ecological integrity and be designed in such a way to ensure that ecological integrity is maintained over time (Rodrigues et al. 2000). That is, protected areas must be sufficiently large to contain their historical assemblage of species and to allow ecological processes to continue unimpeded (Parks Canada Agency 2000). In the southern parts of Canada, protected areas often function as habitat "islands," surrounded by a sea of human development (agriculture, suburbanization, intensive resource activities, roads). Research in these parks has shown that many of them have lost species compared to similarly sized areas that are still located within a connected landscape (Gurd and Nudds 1999; Wiersma and Nudds 2001). This is consistent with theory from Island Biogeography (MacArthur and Wilson 1967), which demonstrates that oceanic islands consistently have lower species richness than an equivalent sized area of mainland. Thus, parks that are small and/or have become isolated from surrounding habitat have their ecological integrity compromised (Wiersma et al. 2004).

Estimating how big is "big enough" for parks not to suffer species losses is challenging. There have been several approaches in the scientific literature. One method is to estimate minimum critical area (MCA) necessary to provide space for a minimum viable population (i.e., one that will persist even in the face of random environmental events such as storms or disease outbreaks; Landry et al. 2001). Another method is to focus on dynamic ecological processes (e.g., fire in the boreal forest) and estimate the minimum dynamic area (MDA) that would allow for such a process to take place unimpeded—usually between two and ten times the maximum size of any potential disturbance (Pickett and Thompson 1978). A final method examines historical and present-day species area-relations in fragmented patches of habitat to estimate minimum reserve area (MRA) based on how large a patch ("island") has to be before it no longer acts as an island (Gurd et al. 2001). Estimates in the literature for the MCA for North American species vary from 1,000 km^2 for timber wolf (Shoenwald-Cox et al. 1988) to 13,500 km^2 for grizzly bear (Shaffer and Samson 1985). However, even within one species, estimates vary. Where habitat quality is higher, minimum area estimates are lower. Estimates of the MDA for the boreal forest range from 70–7,000 km^2 (Hunter 1993) depending on local variation in fire cycles. Estimates of the MRA based on island biogeography range from 2,700–13,000 km^2 (Gurd et al. 2001).

This wide discrepancy in size estimates may give the impression that there is too much uncertainty and, thus, that recommendations from scientists for minimum size standards for protected areas can be ignored. There is uncertainty in estimating minimum area requirements; this is due largely to variation in methodology and in the specific location for which estimates were derived. However, under a precautionary approach, the literature suggests that it is prudent to make protected areas as large as possible, at least on the order of several thousand square kilometers, and ensure that they are surrounded by as connected a landscape as possible (Wiersma et al. 2004). Not all protected areas need be thousands of square kilometers in size; where protected areas are set aside to represent geological features, or species with small home ranges, ecological integrity of these biodiversity elements can be maintained with much smaller area. In some cases, such as for migratory caribou, a single protected area will never be adequate and other management strategies will have to be implemented for these kinds of species (Environment Canada 2007).

Issues of Representation

A key feature of recent protected areas planning, both in the North and elsewhere (e.g., Pressey et al. 1993), has been the concept of *representation*. Protected areas are called to be representative components of a larger region, be it a political region (province, territory) or, more commonly, an ecologically-defined region, such as an ecozone (e.g., the Taiga Cordillera) or ecoregion (e.g., the Peel River ecoregion). There are numerous types of ecologically-defined regions in use in Canada, delineated based on soils, geology, vegetation, or topography. The most common system is the ecological stratification system, which divides the country into hierarchically-nested units of ecozones, ecosystems, and ecodistricts based on a combination of vegetation and topographical patterns (Wiken 1986; Ecological Stratification Working Group 1996). For example, "protected areas should attempt to capture the full range of ecosystem types that are present in the ecoregion," as the original Yukon Protected Areas Strategy explained (YPAS 1988); and one of the goals of the NWT-Protected Areas Strategy is "to protect core representative areas within each ecoregion" (NTW-PAS Advisory Committee 1999).

Within some agencies, there have been calls for a specific percentage of each target region to be set aside as protected. These percent targets trace their origins back to the Bruntland Commission (World Commission on the Environment and Development 1987), which called for a tripling of the 4 percent of the earth's surface then under formal protection. The so-called "12% target" was adopted in Canada by the World Wildlife Fund's Endangered Spaces Campaign (Hummel 1995) as well as by various provincial, territorial, and federal agencies. The academic literature includes a range of percentages deemed to be appropriate (see Svancara et al. 2005 for a summary). However, recent research in Canada has shown that there are no consistent percentage targets that can be universally applied in all regions of the country, and recommends abandoning percentage targets as a policy goal (Wiersma and Nudds 2006).

Much of the work to delineate protected areas that are representative of regional biodiversity is in response to a recognition that many protected areas in North America were designed "by default" in areas of the country that were unproductive for agriculture, logging, or mining. As a result, many of the large northern parks are essentially "rock and ice" parks, and conserve very low amounts of biodiversity, while more productive parts of the North (such as lowlands or river valleys) remain unprotected (Wiersma et al. 2005). The goals stated in the Yukon and Northwest Territories protected areas strategies therefore represent a progressive step in their recognition of the need for representative areas. Moreover, both of these northern strategies avoid any call for minimum percentage targets, which have been shown in the literature to be ineffective at promoting ecological integrity (Wiersma and Nudds 2006).

The Use of Focal Species Approaches to Identifying Protected Areas

"Focal species" (also referred to as surrogate species) is a broad phrase to refer to species that are used as "replacements" for other types of information such as overall biodiversity, habitat connectivity, or ecological integrity (Caro and O'Doherty 1999). Focal species can be one of several types; definitions are listed in Box 1. Focal species have been advocated in the protected areas literature because they represent an attractive "shortcut" if data collected on a relatively small subset of species can yield information about larger sets and systems (Miller et al. 1998/99). However, most of the literature suggests that focal species approaches are not an effective strategy for delineating protected areas, especially across large regions such as the North (Simberloff 1998). Others have suggested that instead of examining species, environmental diversity should be used as the surrogate (Faith 2003). Most focal species studies have been conducted within relatively restricted regions (e.g., Kremen 1992; Fleishman et al. 2000; 2001; Kintsch and Urban 2002; Suter et al. 2002), and not across broad landscapes such as the North. Thus, transferring the focal species approach to large northern regions may not be successful. However, one project examining the use of different species in reserve (protected area)selection across broad regions suggested that designing a protected area network for one taxon (e.g., birds, mammals, amphibians, reptiles) generally captured 75–96 percent of other taxon, suggesting there might be some utility for focal species at broad scales (Warman et al. 2004). Thus, in certain contexts, a focal species approach may have some utility.

The challenge with using a focal species approach lies in selecting the right suite of focal species. Research all agrees that a suite of focal species is preferable to a single species. Some advocate the use of top carnivores (e.g., wolf), others of charismatic megafauna and/or wide-ranging species (e.g., grizzly bear, caribou). Still others feel that rare species (e.g., wolverine) or species that play a key role in ecosystem functions (e.g., beaver) should be used as a focal species. Again, there has been very little literature documenting which focal species might be appropriate as biodiversity surrogates in northern ecosystems.

Box 1. Definitions of Focal Species

Umbrella species: large, wide-ranging species. The assumption is that protection of habitat for these species will automatically protect habitat for a range of species.

Indicator species: species whose presence, absence, or abundance indicates particular (often biophysical) information about their environment.

Keystone species: a species that plays a key role in the stability of a food web, ecological community, or ecosystem. Examples include top predators, or species that make dramatic changes to their habitats (e.g., beavers).

Flagship species: a charismatic species chosen for its public appeal in attracting attention to an issue.

A Yukon Case Study

1. Representative Protected Areas

The Yukon Protected Areas Strategy originally called for the establishment of one protected area in each ecoregion, situated so as to be representative of each of the territory's nineteen ecoregions. Four of the territory's twenty-three ecoregions lie largely outside of the political boundaries of the Yukon, and thus are not targets for representative protected areas. In research funded by the Northern Research Institute (NRI), I set out to test whether it was possible to represent the diversity of mammals in each of the nineteen ecoregions using a single protected area within each ecoregion, using protected areas that were predicted to be large enough to ensure ecological integrity (Fig. 1).

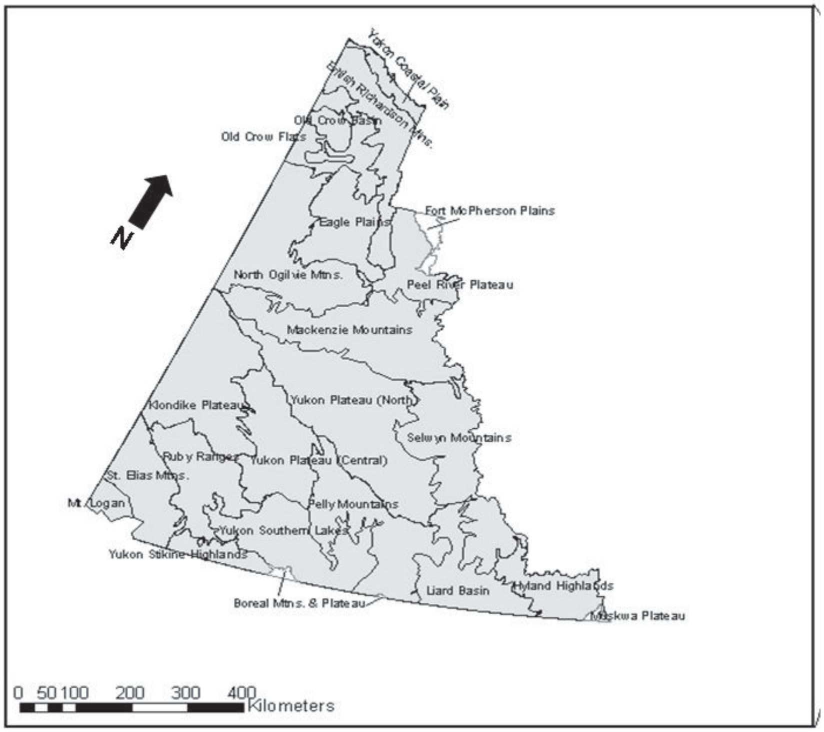

Figure 1. The twenty-three ecoregions of the Yukon Territory. The following four ecoregions were excluded from this study: Mt. Logan, Fort McPherson Plains, Boreal Mountains and Plateau, and Muskwa Plateau, as the majority of their area lies outside of the political boundaries of the territory.

Methods. This research was carried out using a Geographic Information System (GIS), a software package for computerized mapping that allows one to overlay location data (e.g., species ranges, habitat, topography) on a base map. From these, the researcher can query the data and elucidate patterns that might otherwise not be apparent. Mammals were used as the target species for identifying representative protected areas since they generally have the largest habitat area requirements compared to birds or plants and thus are the most sensitive to habitat loss (Schmiegelow and Nudds 1987). Range maps for disturbance-sensitive mammals (those not normally found near areas of human settlement or in highly altered habitats) from the Mammal Atlas of Canada (Banfield 1974) were digitized to allow analysis within the GIS (Mammals included in the analysis are listed in table 1).

Table 1. List of disturbance-sensitive mammals included in the analysis. Nomenclature follows that found in Banfield (1974).

Scientific name	Common Name
Sorex cinereus	Masked shrew
Sorex obscurus	Dusky shrew
Sorex palustris	American water shrew
Sorex arcticus	Arctic shrew
Microsorex hoyi	Pigmy shrew
Ochotona princeps	American pika
Lepus americanus	Snowshoe hare
Eutamias minimus	Least chipmunk
Marmota caligata	Hoary marmot
Spermophilus parryii	Arctic ground squirrel
Tamiasciurus hudsonicus	American red squirrel
Glaucomys sabrinus	Northern flying squirrel
Castor canadensis	American beaver
Neotoma cinerea	Bushy-tailed wood rat
Clethrionomys rutilus	Northern red-backed vole
Lemmus sibiricus	Brown lemming
Synaptomys borealis	Northern bog lemming
Phenacomys intermedius	Heather vole
Ondatra zibethicus	Muskrat
Microtus longicaudus	Long-tailed vole
Microtus chrotorrhinus	Rock vole
Zapus princeps	Western jumping mouse
Canis lupus	Wolf
Ursus arctos	Grizzly bear
Ursus maritimus	Polar bear
Martes americana	American marten
Mustela nivalis	Least weasel
Gulo gulo	Wolverine
Lontra canadensis	River otter
Felis concolor	Mountain lion
Lynx lynx	Lynx
Rangifer tarandus	Caribou
Odocoileus hemionus	Mule deer
Alces alces	Moose
Oreamnos americanus	Mountain goat
Ovis dalli	Dall's sheep

These range maps were overlaid with sample plots of 2,700 km^2, the minimum reserve area as estimated by Gurd et al. (2001). The overlay analysis allowed for extraction of data tables listing the composition of species within each sample plot, by sample plot number. Sample plots were presumed to be available for setting aside as protected areas. In reality, many parts of the territory overlapping these sample plots already have designated land uses, such as settlements, or timber, mining, and trapping leases. However, the purpose of this exercise was not to develop a definitive model for where Yukon protected areas should be located, but rather to carry out a theoretical exercise to test the hypothesis that the diversity of each ecoregion could be captured with a single protected area.

The data tables listing species composition by plot number for each ecoregion were then used as input in a reserve selection process. Reserve selection attempts to develop a representative network of protected areas from a suite of candidate sites, and is often carried out with the aid of computer programs. Generally, the goal of reserve selection is to maximize the number of species represented with a minimum number of sites, using a set of algorithms known as "greedy heuristic algorithms." These algorithms select possible sites in sequence using a step-by-step set of user-defined rules. Rules are generally based on species richness (number of species in a site) or species rarity (presence of regionally rare species in a site). Where there is a need for a "tie-breaker" in selecting a possible site, the decision is based on maximizing the overall diversity in the set of sites. That is, if a decision was between two sites with the same number of species, the site with the higher number of species not yet represented in the set of reserves already selected would be chosen over one that was more redundant with existing protected areas (i.e., sites are chosen to be maximally complementary to each other).

A simple example of a greedy heuristic algorithm is illustrated in figure 2. In this example, there are four sample plots, containing species A through G. A richness-based algorithm would select the site with the highest overall species richness first—in this case, plot 1. Plot 3 has the next highest species richness, and adds species C and E to the representative network, leaving species D unrepresented. Plots 2 and 4 have identical species richness, but only plot 4 contains species D, so it is selected for the network. Simple heuristic algorithms can be calculated by hand, but more complex ones require the use of computer software. In this research, I made use of the PORTFOLIO software package (Urban 2002) when data sets were too large to be computed by hand.

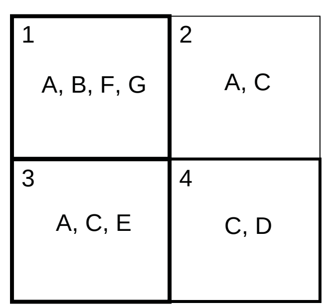

Figure 2. Simplified example of reserve selection via a heuristic algorithm. In this case there are four candidate sites, containing species A through G. Setting aside sites 1, 3, and 4 represents the most efficient way to represent all species at least once.

Results. Application of heuristic reserve selection algorithms in the Yukon ecoregions showed that nine of the nineteen ecoregions could have their mammal diversity represented with a single protected area, so long as that area was at least 2,700 km^2 and was optimally located. The remaining ten ecoregions needed at least two protected areas in order to represent all mammals at least once (table 2).

Table 2. Spatial extent (km^2) and the minimum number of representative protected areas to capture all species in at least one protected area for each target ecoregion in the Yukon.

Target Ecoregion	Area (km^2)	Number of Protected Areas
British Richardson Mountains	22,989	2
Eagle Plains	20,394	1
Hyland Highlands	14,660	2
Klondike Plateau	38,206	2
Liard Basin	21,121	2
Mackenzie Mountains	190,238	1
North Olgilvie Mountains	39,203	1
Old Crow Basin	14,589	2
Old Crow Flats	5,964	1
Peel River Plateau	14,812	1
Pelly Mountains	34,194	2
Ruby Ranges	22,720	1
Selwyn Mountains	35,541	2
St. Elias Mountains	17,603	1
Yukon Coastal Plain	4,402	1
Yukon Plateau (Central)	26,803	2
Yukon Plateau (North)	57,037	2
Yukon Southern Lakes	29,899	2
Yukon Stikine Highlands	6,972	1

Discussion. The research described above illustrates the risks inherent in setting broad policy targets—such as "one protected area per ecoregion"—for protected areas across large northern landscapes. The heterogeneity of the North dictates that design principles for protected areas may not be universal. Replication of protected areas may be desirable from a conservation standpoint, as this can act as an "insurance" against stochastic events, and conserve distinct populations of a given species. Moreover, this analysis is not complete, as it only addressed minimum representation requirements for mammals, and did not include data on other biodiversity (e.g., vegetation, birds, fish) or cultural features in the analysis. Thus, there may be a need for additional protected areas beyond those selected in this analysis.

2. Analysis of Potential Focal Species

The challenge with identifying the location and minimum requirements for representative protected areas is the need for reliable, geographically-referenced data on biodiversity features. These are not always available, particularly over wide, remote regions, such as northern Canada, which have not been systematically surveyed for all species. Thus, many conservation biologists and protected areas practitioners recommend a focal species approach for delineating protected areas (Cluff and Paquet 2003). As part of my work on Yukon protected areas, I investigated whether a focal species approach might be a useful component of northern protected areas planning.

In a second component of the NRI-funded research on protected areas in the Yukon, I set out to test whether two different methods to identify focal species would yield similar results. Here, I looked for focal species that would be biodiversity indicators; that is, species that, if protected, would automatically protect a wide suite of other species.

Methods. Two methods for identifying biodiversity indictors were used and compared for similarities. The first technique followed the umbrella species selection process outlined by Fleishman et al. (2000), and was based on three components: rarity, sensitivity to human disturbance, and mean percentage of co-occurring species. Rarity was measured as the proportional occurrence of each species across all ecoregions. Sensitivity to human disturbance was scored following Fleishman et al. (2000), with "1" indicating low sensitivity, and "4" indicating high sensitivity. Scores were given for dispersal ability, dependence on complex (i.e., old-growth forest) habitat, and sensitivity to habitat fragmentation. Scores were assigned based on life history information given in Banfield (1974), and on data from Wiersma and Nudds (2001) on the number and identity of species that had gone missing from national parks across Canada, south of the sixtieth parallel, where habitat fragmentation has already taken place around many parks. The average number of mammals present in each ecoregion divided by the maximum number of mammals in all the ecoregions was used to calculate the percentage of co-occurring species.

The second method to identify a suite of focal species involved iteratively selecting potential protected areas across the Yukon Territory as a whole using heuristic algorithms—sets of rules to select possible combinations of protected areas (reserves) to maximize species representation (described above). In this case, subsets of the territorial list of thirty-six mammals (table 1) were used as inputs in the PORTFOLIO software (Urban 2002), based on the following categories: 1) all carnivores; 2) all ungulates; 3) all carnivores and all ungulates combined; and 4) all rodents. As well, subsets were derived by paring down from the thirty-six species to subsets of 5, 7, 8, 10, 12, 15, 17, 19, 20, and 24 species based on regional rarity.

These sets of data were input into the PORTFOLIO software to identify minimum representative sets of protected areas for the territory as a whole, using methods identical to those described above. These sets were compared to the minimum set identified using the full suite of species. The smallest minimum set of species that yielded the same results for the minimum representative network were deemed to be an appropriate set of focal species for reserve design.

Results. The umbrella species identification process following methods similar to those outlined by Fleishman et al. (2000) yielded a list of five candidate umbrella species: arctic shrew (*Sorex arcticus*), pigmy shrew (*Microsorex hoyi*), least chipmunk (*Eutamias minimus*), northern flying squirrel (*Glaucomys sabrinus*), and heather vole (*Phenacomys intermedius*).

When heuristic reserve-selection algorithms were applied to candidate sites across the territory using data from all thirty-six species, four sites were needed to represent all species at least once. This represents the "ideal" set of sites that would maximize biodiversity conservation with a minimum amount of protected areas. The results from the heuristic algorithm did not differ with the list of species input into the PORTFOLIO process until less than eight of the rarest species were used. The eight rarest species are listed in table 3. The use of carnivores as an input yielded only one of the "ideal" sites; after this site was selected, all remaining sites were considered equally suitable by PORTFOLIO. Similarly, the use of ungulates only selected one site (which coincided with one of the "ideal" sites using the full suite of data), after which all sites were considered equally suitable. The use of carnivores and ungulates combined selected two sites, one of which coincided with the "ideal" sites. When rodents were used as the input list of mammals, three sites were selected, two of which coincided with the "ideal" sites.

Table 3. Biodiversity indicators selected from the list of thirty-six disturbance-sensitive mammals in the Yukon using two different methods: an umbrella-species selection method, as outlined by Fleishman et al. (2000), and an iterative reserve site-selection process.

Umbrella Selection		Iterative reserve-selection process	
Scientific name	Common name	Scientific name	Common name
Sorex arcticus	Arctic shrew	*Neotema cinera*	Bushy-tailed wood rat
Microsorex hoyi	Pigmy shrew	*Phenacomys intermedius*	Heather vole
Eutamias minimus	Least chipmunk	*Microtus chrotorrhinus*	Taiga vole
Glaucomys sabrinus	Northern flying squirrel	*Zapus princes*	Western jumping mouse
Phenacomys intermedius	Heather vole	*Ursus maritimus*	Polar bear
		Felis concolor	Mountain lion
Source: Fleishman et al. 2000		*Odocoeileus hemionus*	Mule deer
		Oreamnos americanus	Mountain goat

Discussion. The results from this analysis illustrate the uncertainty associated with the use and selection of biodiversity indicators/focal species. The two methods for identifying biodiversity indicators generated lists that had only one species in common (table 3). When the list of five mammals identified using the umbrella-selection process was used as the input data in the PORTFOLIO iterative reserve-selection process, the resulting set of candidate protected areas did not coincide with the "ideal" set. Additionally, the suite of sites chosen using the umbrella species did not capture six of the species present in the Yukon, all of which appeared on the list of eight rarest species chosen using the iterative reserve-selection process. Thus, it appears that these eight species might serve as suitable biodiversity indicators for the full suite of mammals in the Yukon, but that those five selected using the umbrella-selection methods might not. These eight species represent a range of taxonomic groups and trophic levels, and vary in their habitat use, home range, activity periods, and winter habits (table 4).

Table 4. Life history of the eight species selected as biodiversity indicators using the iterative reserve-selection process. Nomenclature and life history data are taken from Banfield (1974). Home range data are taken from Banfield (1974), and the University of Michigan Museum of Zoology website (www.animaldiversity.ummz.umich.edu).

Species	Order and Family	Trophic Level[1]	Habitat	Home range and habits	Activity period[2]	Winter habit
Bushy-tailed wood rat (*Neotema cinerea*)	Order Rodentia Family Muridae	H	Cliffs, talus, rock outcrops	Solitary, territorial; 0.8–2 ha	C	Active year round
Heather vole (*Phenacomys intermedius*)	Order Rodentia Family Muridae	H	Dry coniferous forest, shrubby vegetation, moist meadows	Solitary, family groups in winter; < 1000 m^2	C	Active year round
Taiga vole (*Microtus xanthognathus*)	Order Rodentia Family Muridae	H	Damp rocky talus or rock outcrops in forest, near springs or rivulets	Isolated colonies; < 1000 m^2	D	Active year round
Western jumping mouse (*Zapus princeps*)	Order Rodentia Family Dipodidae	G	Mountain meadows, stream banks, alder and willow groves	0.15–1.1 ha	N	Hibernates
Polar bear (*Ursus maritimus*)	Order Carnivora Family Ursidae	C	Edge of ice pack	Solitary; 1000s of km	D	Females hibernate, males active most of winter
Mountain lion (*Felis concolor*)	Order Carnivora Family Felidae	C	Mountainous terrain, coniferous forest	Solitary, 14–230 km^2	N	Active year round
Mule deer (*Odocoileus hemionus*)	Order Artiodactyla Family Cervidae	H	Open coniferous forest, sub-climax brush, parklands, river valleys	Matriarchal herds, 36–243 ha	D	Altitudinal migration
Mountain goat (*Oreamnos americanus*)	Order Artiodacytla Family Bovidae	H	Rugged mountain terrain, rocky ridges, alpine meadows	Moderately gregarious, 6–24 km^2	D	Altitudinal migration

1. H: Herbivore, G: Granivore, C: Carnivore
2. D: diurnal (daytime); C: crepuscular (dawn/dusk); N: nocturnal (nighttime)

In this analysis, "putative" focal groups (carnivores, ungulates, rodents) did not appear to have a high degree of specificity as a focal species group. None of the representative networks selected using a specific group (carnivores, ungulates, rodents, or carnivores/ungulates combined) was sufficiently extensive to capture all other species in the territory. Thus, protected areas networks that are representative for carnivores, for example, are likely not to be representative for all mammals.

This study illustrates the importance of using a suite of biodiversity indicators (e.g., a variety of species of mammals, birds, plants, and so on) instead of a single focal species, as no one species will be an adequate surrogate for everything else. What is interesting about this suite is that few of the species exemplify the wide-ranging, top carnivore species that are normally chosen as umbrellas (Lambeck 1997). This discrepancy illustrates that the assumptions about the effectiveness of focal species for use in biodiversity conservation may not have been adequately tested, and that the use of any kind of focal species (umbrella, indicator) should be approached with caution.

Conclusions

Work to date on northern protected areas issues has garnered some preliminary conclusions about protected areas design in the North, and has pointed to priorities for future research (Wiersma et al. 2005). In general, this research shows that broad generalizations for minimum protected areas requirements (e.g., "one per region") are not guaranteed to be successful at capturing representative suites of biodiversity in all cases. There is general agreement in the literature that northern protected areas should be as large as possible, although additional, smaller protected areas within a region can play important roles in conserving features that occur at a finer degree of resolution on the landscape (e.g., special geological features, unique habitats such as wetlands, collections of rare plants). However, there is still much uncertainty as to exactly how large protected areas should be, and where they should be located. This is due in part to the lack of data on many northern species. Vast parts of the North have not been systemically surveyed for biodiversity, and this information is needed to make informed decisions about protected areas. Early protected areas work completely ignored (and often explicitly excluded) Aboriginal peoples. A strictly science-based approach to protected areas design risks making similar mistakes. A better approach is to integrate western scientific and traditional/local knowledge to address some of these data gaps. Focal species are not generally perceived to be reliable as indicators of biodiversity; where a focal species approach is used, it should be done with a suite of species instead of a single one, to improve the effectiveness of the approach.

Overall, the Canadian North represents an incredible opportunity to carry out state-of-the art protected areas planning. Unlike southern Canada, where habitat is largely fragmented, much of the northern ecosystems are still relatively intact. Thus, by taking what we have learned from protected areas research in the past, and developing innovative methods for protected areas design that acknowledge the unique features and processes in northern ecosystems and that work closely with local communities, it will be possible to design and delineate protected areas that have ecological integrity and thus serve as ecological benchmarks for the boreal forest.

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