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Potential Spatial Overlap of Heritage Sites and Protected Areas in a Boreal Region of Northern Canada

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Abstract: *Under article 8-J of the Convention on Biological Diversity, governments must engage indigenous and local communities in the designation and management of protected areas. A better understanding of the relationship between community heritage sites and sites identified to protect conventional conservation features could inform conservation-planning exercises on indigenous lands. We examined the potential overlap between Gwich'in First Nations' (Northwest Territories, Canada) heritage sites and areas independently identified for the protection of conventional conservation targets. We designed nine hypothetical protected-area networks with different targets for woodland caribou (*Rangifer tarandus caribou*) habitat, high-quality wetland areas, representative vegetation types, water bodies, environmentally significant area, territorial parks, and network aggregation. We compared the spatial overlap of heritage sites to these nine protected-area networks. The degree of spatial overlap (Jaccard similarity) between heritage sites and the protected-area networks with moderate or high aggregation was significantly higher (*$p < 0.001$*) than random spatial overlap, whereas the overlap between heritage sites and the protected-area networks with no aggregation was not significant or significantly lower (*$p < 0.001$*) than random spatial overlap. Our results suggest that protected-area networks designed to capture conventional conservation features may protect key heritage sites but only if the underlying characteristics of these sites are considered. The Gwich'in heritage sites are highly aggregated and only protected-area networks that had moderate and high aggregation had significant overlap with the heritage sites. We suggest that conventional conservation plans incorporate heritage sites into their design criteria to complement conventional conservation targets and effectively protect indigenous heritage sites.*

Keywords: biodiversity, boreal, community-based planning, complementarity, Gwich'in, protected-areas strategy, systematic conservation planning, target-based planning, traditional ecological knowledge

Potencial Traslape Espacial de Sitios de Patrimonio Histórico y Áreas Protegidas en una Región Boreal del Norte de Canadá

Resumen: *De acuerdo con el Artículo 8-J de la Convención de Diversidad Biológica, los gobiernos deben involucrar a las comunidades indígenas y locales en la designación y gestión de áreas protegidas. Un mejor entendimiento de la relación entre sitios de patrimonio artístico y sitios identificados para la protección de los rasgos convencionales de la conservación podría informar a los ejercicios de planificación en tierras nativas. Examinamos el potencial traslape entre sitios de patrimonio histórico en las Primeras Naciones Gwich'in (Territorios del Noroeste, Canadá) y sitios identificados independientemente para la protección de objetivos de conservación convencionales. Diseñamos nueve redes de áreas protegidas con diferentes objetivos para:*

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hábitat de Rangifer tarandus caribou, *áreas de humedales de alta calidad, tipos de vegetación representativos, cuerpos de agua en el área, áreas ambientalmente significativas, parques territoriales y agregación de redes. Comparamos el traslape espacial de los sitios de patrimonio histórico con estas nueve redes de áreas protegidas. El grado de traslape espacial (similitud de Jaccard) entre los sitios de patrimonio artístico y las redes de áreas protegidas con agregación moderada o alta fue significativamente mayor* ($p < 0.001$) *que el traslape espacial aleatorio, mientras que el traslape entre sitios de patrimonio histórico y las redes de áreas protegidas sin agregación no fue significativa o fue significativamente menor* ($p < 0.001$) *que el traslape espacial aleatorio. Nuestros resultados sugieren que las redes de áreas protegidas diseñadas para capturar rasgos convencionales de la conservación pueden proteger sitios de patrimonio histórico claves sólo si son tomadas en cuenta las características fundamentales de estos sitios. Los sitios de patrimonio histórico de Gwich'in están muy agregado y sólo las redes de áreas protegidas con agregación moderada o alta tuvieron un traslape significativo con los sitios de patrimonio histórico. Sugerimos que los planes de conservación convencionales incorporen a los sitios de patrimonio histórico en sus criterios de diseño para complementar los objetivos de conservación convencionales y proteger efectivamente a los sitios nativos de patrimonio histórico.*

Palabras Clave: biodiversidad, boreal, conocimiento ecológico tradicional, estrategia de áreas protegidas, Gwich'in, planificación basada en comunidades, planificación basada en objetivos, planificación de conservación sistemática

Introduction

Historically, many conservation agencies have alienated indigenous peoples (Kuhn & Duerden 1997; Wells & McShane 2004), the primary users and communities of protected areas on indigenous lands, resulting in disaffection of indigenous peoples toward protected areas (Stadel et al. 2002; Whiting 2004). Nevertheless, indigenous and local communities are increasingly being included in the designation and management of protected areas with the advent of article 8-J of the Convention on Biological Diversity (Ferraro 2002), which requires governments to engage indigenous and local communities in the designation and management of protected areas (UNEP 1992) and because traditional ecological knowledge held by local peoples can improve conservation planning (e.g., Berkes et al. 2000; Huntington 2000; Herrmann 2006). Incorporating indigenous and local interests in protected-areas design and management is particularly critical in regions that have high overlap with indigenous lands. Here we considered indigenous lands equivalent to indigenous reserves, settlement areas, or land claims.

In Canada 12% of national, provincial, and territorial parks overlap indigenous lands. Indigenous lands also cover 40% of the Canadian landscape. Indigenous peoples play an especially important role in boreal Canada because there are more than 600 indigenous communities in this region (Canadian Boreal Initiative 2005). Canada's boreal region also has high conservation potential because it supports some of the last large-scale wilderness areas in the world (Sanderson et al. 2002) in a system that has been typically overlooked with respect to global conservation values. In addition, it contains approximately one-quarter of all intact forests remaining globally (Bryant et al. 1997). In boreal Canada the current and expected expansion of resource extraction (Schneider et al. 2003) is being countered with increasing efforts to identify more areas for permanent protection (Canadian Boreal Initiative 2005). Nevertheless, many indigenous communities in the boreal region seek to manage their lands through community-based land-planning processes (Deh Cho 2001; Sahtu Land Use Planning Board 2002; Gwich'in Land Use Planning Board 2003; Taku River 2003). Consequently, protected-areas design in boreal regions of Canada must be done in conjunction with community-based land-use planning.

Community-based land-use planning involves communities in every step of the planning process (Kuhn & Duerden 1997; Berkes 2004). In general the approach reflects a host of values, including social, cultural, and economic interests, and incorporates traditional and scientific knowledge (Berkes 2004). In the Northwest Territories, Canada, community land-use plans identify management zones, such as general use and special management zones, where commercial resource extraction can occur in accordance with certain conditions, and conservation and heritage conservation zones, where commercial resource extraction is prohibited (Sahtu Land Use Planning Board 2002; Gwich'in Land Use Planning Board 2003). Conservation zones are informed by the scientific community and might include areas high in biodiversity that are representative of a region's ecosystems. Heritage conservation zones are identified by the community, receive the highest level of protection, and include community heritage sites (i.e., areas of cultural and social significance). Conservation and heritage conservation zones are managed separately in most community conservation plans in the Northwest Territories, but to what extent do these areas have similar values?

Some authors suggest that indigenous cultures support the protection of biodiversity and ecological processes because areas of high cultural diversity may correspond with areas of high biodiversity (Alcorn 1993; Oveido & Brown 1999; Garibaldi & Turner 2004). One might expect, therefore, that the protection of heritage sites also confers protection to biodiversity and supporting ecological processes (Watson et al. 2003) and vice versa (Huntington 2002).

The government of the Northwest Territories (GNWT) has developed a protected-areas strategy that follows the principles of community-based land-use planning (Northwest Territories Protected Areas Advisory Committee 1999; Stadel et al. 2002). The primary goals of the strategy are to protect special natural and cultural areas and protect core representative areas in each ecoregion. The GNWT has worked with communities to identify key natural and cultural areas (i.e., community heritage sites) and plans to complement these assessments with conventional conservation planning to identify additional representative areas in each ecoregion. A better understanding of the relationship between community heritage sites and sites identified to protect conventional conservation features could inform the GNWT Protected-Areas Strategy.

We quantified the relationship between heritage sites and sites independently identified to protect other conservation features. To assess this, we undertook a case study in the Gwich'in settlement area in the Northwest Territories, comparing community heritage sites identified by the Gwich'in to hypothetical protected-area networks that we designed to protect focal species and to achieve environmental representation that included identified environmentally significant areas and territorial parks. Our goal was to better understand the similarities, differences, and complementarities in sites recognized as sacred or important for the Gwich'in and sites selected for their conventional conservation value.

Methods

Study Area

The study area was 22,000 km^2 in the northwest region of the Northwest Territories (northern region of the Gwich'in Settlement Area) (Fig. 1). The main towns in the area are Inuvik, Fort McPherson, and Tsiigetchic. The northern boundary of the study area was determined by the northern boundary of the Gwich'in Settlement Area, the eastern boundary by the extent of available earth cover data, and the western and southern boundaries by the extent of the Gwich'in heritage site analysis. The area is bordered by the Inuvialuit Settlement Region to the north and the Sahtu Settlement Area to the east. The landscape is flat, wet, and dominated by black spruce bogs and scattered lakes. Permafrost is continuous. The dominant tree species is black spruce (*Picea mariana* Mill.) followed by white spruce (*Picea glauca* Moench), white birch (*Betula papyrifera* Marsh.), and tamarack (*Laryx laricina* [Du Roi] K.Koch). Shrubs are abundant in the area, and the main species are bog birch (*Betula glandulosa* Michx.), labrador tea (*Ledum* spp. L.), bearberry (*Arctostaphylos rubra* Rehd. & Wils.), and blueberries (*Vaccinium* spp. L.). The area has long, cold winters (−20° C to −30° C) and short, cool summers (10–15° C). Fire is the dominant natural disturbance on the landscape (Nagy et al. 2005).

Data

PROTECTED-AREAS DESIGN

We surveyed the study area for the best available species and Earth cover data because both are valuable in protected-areas design (Pressey 2004). A 30-m resolution,

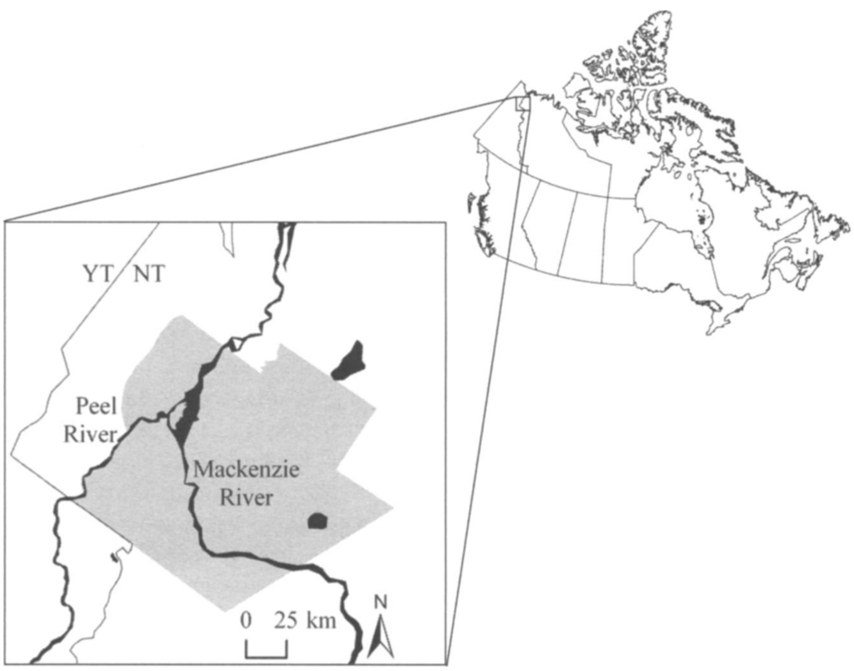

Figure 1. Study area in the northern boreal region of Canada shown as gray polygon. The study area is 22,000 km^2 and is in the Northwest Territories (NT) with sections bordering the Yukon Territory (YT).

34-category earth cover map of the study area (Ducks Unlimited 2002, 2003) was reclassified to 10 cover types and rescaled to 500-m resolution by a majority threshold filter (Parody & Milne 2004). The 500-m resolution was sufficient for caribou habitat models (below) and minimized the aggregation and loss of unique earth cover types. Earth cover types were distinct tree, shrub, and grass communities, wetlands, and permanent water. We focused on protecting high-density wetlands because two duck genera that breed in this area, Scaup (*Aythya* spp.) and Scoter (*Melanitta* spp.), have declined significantly across their range (Decarie 1995; Austin et al. 2000) and high-density wetlands are the most productive duck habitat (Johnson & Grier 1988). We used the original 30-m resolution map to calculate per-cell wetland edge density for the rescaled map. Cells with densities above the regional median (3.77 km/km^2) were considered high-quality wetlands for this region.

We calculated per-cell slope, aspect (flat, north, south, east, west), and elevation from a digital elevation model (Natural Resources Canada 2000). We estimated per-cell seismic line density from the National Energy Board (1999). Seismic lines are semipermanent linear features created by exploration for oil and natural gas.

Woodland caribou (*Rangifer tarandus caribou*) occurrence data were obtained from satellite collars on eight females. Mapped special elements included wildlife areas of special interest (Ferguson 1987), key migratory bird terrestrial habitat sites (Alexander et al. 1991), and existing territorial parks.

COMMUNITY HERITAGE SITES

The Gwich'in First Nation assembled a database on heritage sites in the Mackenzie Valley region of their land claim (Andre & Kritsch 1992). Community members were interviewed and asked to describe and map heritage sites. All heritage sites were later digitized using a geographic information system. The data include camps ($n = 299$), interconnected trails ($n = 299$), and other culturally significant places ($n = 201$). The heritage sites encompassed 14% of the landscape.

Conventional Protected-Area Networks

We developed nine hypothetical protected-area networks for the study area based on conventional protected-areas planning methods. The conventional application of systematic conservation planning (sensu Margules & Pressey 2000) uses site-selection algorithms (Possingham et al. 2000) to identify regions of high conservation priority, typically based on conservation targets for any combination of focal species (e.g., endangered species), landscape features (e.g., vegetation types), and special elements (e.g., pristine sites) (Groves et al. 2002; Noss et al. 2002; Warman et al. 2004). The nine networks were developed with a heuristic algorithm that combined targets for (1) the relative probability of occurrence of woodland caribou; (2) the representation of high-quality wetlands, vegetation types, and water bodies; (3) the inclusion of environmentally sensitive areas (i.e., migratory bird areas and wildlife areas) and territorial parks; and (4) the aggregation of protected areas in a network (Fig. 2).

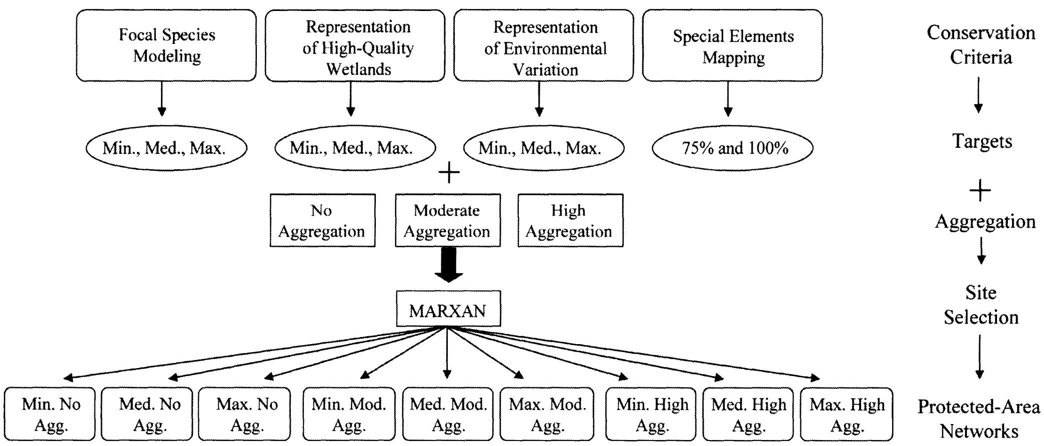

Figure 2. Conservation planning approach adopted to design protected-area networks in the Mackenzie River valley, Northwest Territories. The targets for focal species, representation of high-quality wetlands, representation of environmental variation, special elements mapping, and network aggregation were incorporated in the site-selection software (MARXAN) to identify nine protected-area networks that met the targets: minimum no aggregation; medium no aggregation; maximum no aggregation; minimum moderate aggregation; medium moderate aggregation; maximum moderate aggregation; minimum high aggregation; medium high aggregation; maximum high aggregation (min., minimum; med., medium; max., maximum; mod., moderate; agg., aggregation).

Planning units provide the framework for constructing a protected-areas network, but there is no strong theoretical basis for selecting the size and shape of planning units (Pressey & Logan 1998). We used planning units of uniform size and geometry (2 × 2 km; $n = 5679$). With planning units of this resolution, we were able to run our heuristic algorithm on the entire study area. Each planning unit contained 16 map cells.

RELATIVE PROBABILITY OF OCCURRENCE OF WOODLAND CARIBOU

We chose boreal woodland caribou as a focal species in our analyses because they are wide ranging, medium-sized ungulates distributed across the boreal forest and are listed as threatened in Canada (COSEWIC 2003). The core study area for modeling habitat selection by this species was defined by generating a minimum convex polygon (MCP) around GPS and ARGOS satellite caribou locations (animals, $n = 8$; locations, $n = 10,559$) from 1 May 2002 to 13 October 2005. We buffered this core area with an additional 3176 m (the 95th percentile distance traveled by GPS-collared caribou in 8 hours; Nagy et al. 2006). We developed a habitat model for the winter season (15 January to 30 April) because the availability of winter habitat is likely most limiting for woodland caribou in our study area (Nagy et al. 2005). Although part of the buffered MCP fell outside our study area, we used all winter season data in the buffered MCP to develop the habitat selection model. We generated random points ($n = 60,385$) at a density of 2/km^2 within the buffered core modeling area to represent available habitat.

We developed the caribou habitat model by pooling data for all caribou and generating a landscape-level resource selection function (RSF) (Manly et al. 2002) based on a suite of earth cover and terrain covariates (Table 1). A fine-scale analysis of caribou habitat selection in the study area has been conducted (Nagy et al. 2006), but we required a model commensurate with the resolution at which other conservation features were being assessed. The caribou use and random points were overlaid on the 500-m resolution map grid, and habitat variables were assigned to locations. We tested for correlation and colinearty of variables prior to model development and found no significant correlations.

We used logistic regression to fit an RSF model (Boyce et al. 2002), taking the form

$$w(x) = \exp(\exists_1 x_1 + \exists_2 x_2 + \ldots\ldots + \exists_n x_n), \qquad (1)$$

where $x_{\hat{n}}$ are the covariates and $\exists_{\hat{n}}$ are the coefficients. We then used a linear stretch of the form

$$w = [(w(x) - w_{\min})/(w_{\max} - w_{\min})], \qquad (2)$$

where $w(x)$ is the product of Eq. 1 and $w_{\min}$ and $w_{\max}$ represent the smallest and largest RSF value available on the landscape, respectively (Johnson et al. 2004). The w values for the random data were sorted in ascending order, partitioned into 10 equal size bins, and assigned a bin rank between 1 and 10 (1, lowest w values 10, highest w values). The use locations were assigned to the appropriate bins and assigned the appropriate bin rank. We used the chi-squared test to determine if the distribution of caribou-use locations among the 10 bins was significantly different than would be expected if the caribou had used habitats in proportion to availability.

We separated the RSF values from the model into 10 quantile bins that represented an index of increasing relative habitat use for caribou (Nielsen et al. 2006). Similar to Nielsen et al. (2006), we considered RSF values in bins 5 to 10 to be suitable habitat for caribou.

Table 1. Coefficients and test statistics of the resource selection function model for woodland caribou selection of habitat variables during the winter season (15 January to 30 April).

Variable	*Coefficient*	*SE*	p > z
Slope (%)	−0.265	0.016	<0.001
Aspect flat	0		
Aspect north	0.872	0.203	<0.001
Aspect east	0.981	0.202	<0.001
Aspect south	1.447	0.201	<0.001
Aspect west	1.063	0.201	<0.001
Median elevation (m)	−0.001	0	0.010
Seismic lines (km/km^2)	−0.164	0.023	<0.001
Closed spruce	0		
Open spruce	2.384	0.380	<0.001
Mixed	0.651	0.465	0.162
Tall shrub	0		
Low shrub	0.504	0.391	0.197
Herbaceous	−0.509	0.805	0.527
Burn	1.572	0.391	<0.001
Wetland	0		
Water	1.514	0.386	<0.001
Other	0.715	0.419	0.088
Constant	−5.588	0.426	<0.001

AGGREGATION OF PROTECTED AREAS

Aggregation of protected areas in a network is a key consideration in reserve design (McDonnell et al. 2002; Cabeza 2003; van Teeffelen et al. 2006). In site-selection tools such as MARXAN (Ball & Possingham 2000), the user can modify the relative level of aggregation desired for protected areas in a network by changing the boundary length modifier (Possingham et al. 2000; McDonnell et al. 2002). We assigned varying levels to the boundary length modifier to examine the influence of aggregation on the congruence between heritage sites and potential protected areas.

CONSERVATION TARGETS

We used varying targets to develop the nine hypothetical protected-area networks to represent a range of potential conservation options in the study area. We set conservation targets of 25%, 50%, and 75% protection for the planning units with suitable woodland caribou habitat (i.e., bins 5–10) and high-quality wetlands. We also set conservation targets of 10%, 20%, and 30% of each rescaled vegetation type and water body in the study area. We set a fixed target of capturing 75% of all environmentally sensitive areas and 100% of all territorial parks in our protected-area networks. This resulted in development of three protected-area networks with minimum, medium, and maximum targets for each conservation feature. In addition, because there is evidence that protected-area aggregation can influence the efficacy of a network (Cabeza 2003; van Tefflen et al. 2006), we designed each set of minimum-, medium-, and maximum-target networks with no boundary length modifier (i.e., no aggregation), a moderate boundary length modifier (i.e., moderate aggregation), and a high boundary length modifier (i.e., high aggregation), resulting in a total of nine protected-area networks: minimum no aggregation, medium no aggregation, maximum no aggregation, minimum moderate aggregation, medium moderate aggregation, maximum moderate aggregation, minimum high aggregation, medium high aggregation, and maximum high aggregation.

CONSTRUCTION OF PROTECTED AREAS

We combined targets for our focal species, high-quality wetlands, vegetation types, water bodies, special elements, and protected-area aggregation into MARXAN (version 1.8.2) (Ball & Possingham 2000) and used the CLUZ (version 1.11) interface to build our networks (Smith 2004). MARXAN is a site selection tool that facilitates the identification and selection of candidate protected areas designed to satisfy a suite of conservation targets. MARXAN uses a global heuristic algorithm, in this case simulated annealing, to identify the minimum number of sites or area to achieve all stated targets (i.e., minimum area problem; Cabeza & Moilanen 2001). A simulated annealing algorithm begins by generating a random set of sites. Then, at each iteration, a site is removed or added to the random set and the value of the new set is compared to the initial one (Possingham et al. 2000; Cabeza & Moilanen 2001). The site is either added or removed from the set based on the comparison. We performed 100 runs of 1,000,000 iterations of the simulated annealing algorithm in MARXAN to select the minimum amount of area needed to capture stated conservation targets and identify the most irreplaceable sites (i.e., sites that contribute most to the conservation targets for the features contained) for our protected-area networks.

Comparison of Heritage Sites and Conventional Protected Areas

To determine the spatial overlap of Gwich'in heritage sites and each protected-area network identified to capture conventional conservation targets, we used a Jaccard coefficient defined as [number of shared planning units/(number of shared planning units + number of additional planning units for heritage sites + number of additional planning units for protected areas)] × 100 (van Jaarsveld et al. 1998; Warman et al. 2004). The study area was composed of 87,430 planning units, including 12,439 planning units encompassing heritage sites and between 2,669 and 63,295 planning units encompassing the nine protected-area networks. We randomly selected, without replacement, 1,000 sets of 12,439 planning units (i.e., a number equivalent to that occupied by actual heritage sites) and a variable number of planning units equal to the number of planning units encompassing each of the nine protected-area networks. We generated Jaccard values for these 1,000 random sets and compared the random distribution of Jaccard values to the observed Jaccard value for each heritage site and protected-area network comparison to determine the probability of obtaining the observed value by chance.

To explore the overlap of heritage sites and conventional conservation features further, we calculated the percentage of each conservation feature in heritage sites and determined the difference between the percentage of the heritage sites composed of each conventional conservation feature and the percentage of the landscape composed of each conventional conservation feature.

Results

Woodland Caribou RSF Model

The RSF model indicated that caribou selected open spruce, riparian areas, recent burns, and south-facing aspects and avoided herbaceous vegetation cover, steep slopes, and high densities of seismic lines (Table 1). Planning units with an RSF value >0.09, the cutoff for inclusion in bin 5, were considered planning units with suitable habitat for caribou, resulting in 15,688 km^2 of suitable habitat for woodland caribou in our study area. The distribution of caribou use and random locations among RSF bins were significantly different than random (chi-square $p < 0.001$). Eighty-seven percent of use locations occurred in the upper five bins, with 49% of these occurring in the upper two bins, indicating that the model had good predictive ability (Johnson et al. 2004).

Protected-Area Networks

Our protected-area networks varied in total area coverage and aggregation (Fig. 3). Protected areas with minimum targets covered 21–23% of the landscape, protected areas with medium targets covered 43–46% of the landscape, and protected areas with maximum targets covered 65–72% of the landscape. The total coverage increased with aggregation for all target levels (Fig. 3).

Spatial Overlap of Heritage Sites and Protected-Area Network

The degree of spatial overlap (calculated as Jaccard coefficient) between heritage sites and the conventional protected-area networks was between 9.37 and 15.02 (Table 2). The spatial overlap of the protected-area networks

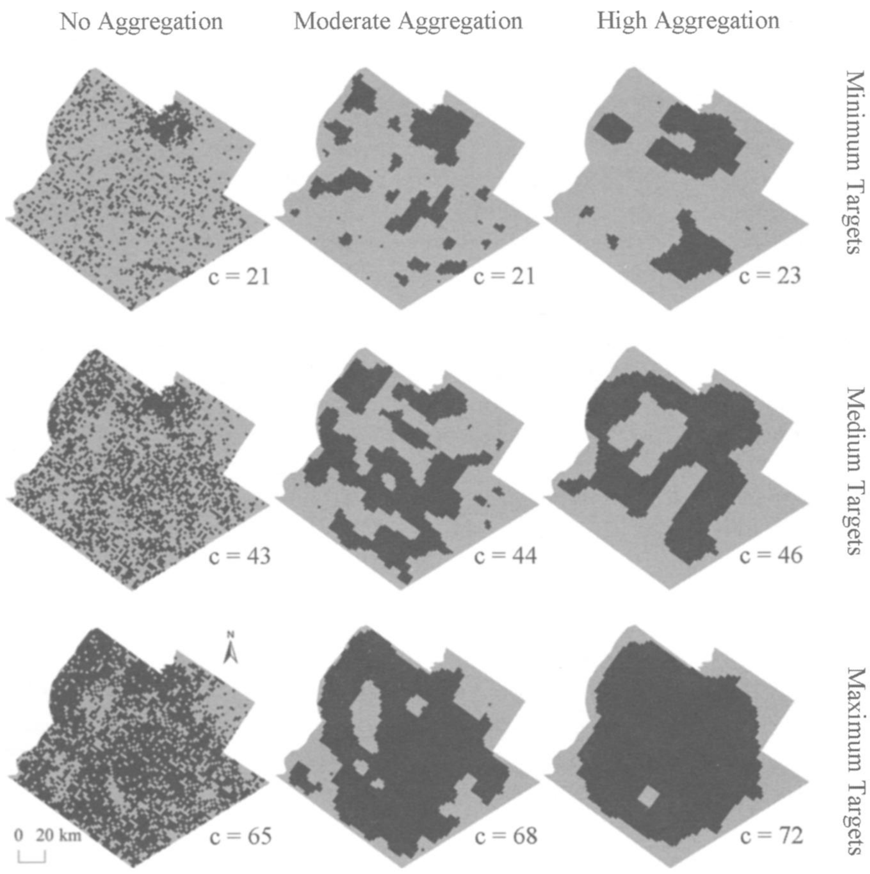

Figure 3. Results of protected-area networks (black) developed with MARXAN based on targets for suitable woodland caribou habitat, high-quality wetlands, vegetation types, water bodies, environmentally significant areas, and territorial parks (c, percent coverage of each network).

designed with no aggregation and heritage sites was not significant for the minimum-targets network ($p = 0.409$) but was significantly lower than random for the medium- and maximum-target networks ($p < 0.001$). The spatial overlap of all protected-area networks with moderate and high aggregation was significantly higher than random spatial overlap ($p < 0.001$).

The heritage sites (14% of the study area) were composed of a relatively high percentage of the available migratory bird areas (61%), water (35%), and terrestrial parks (30%) and a low percentage (<20%) of the remaining conventional conservation features (Fig. 4). At a landscape level, heritage sites were composed of a lower percentage of open spruce (18%) and high-quality wetlands (6%) and a higher percentage of water (27%) than the study area (Fig. 5), whereas the remaining conservation features were represented by percentages similar to those of the heritage sites and the study area (<± 5% difference).

Discussion

Systematic conservation planning is a framework that permits the incorporation of indigenous heritage sites into protected-areas planning, most often as special elements

Table 2. Results of overlap analysis between heritage sites and nine protected-area networks.[a]

Protected-area networks	*Observed Jaccard*	*Mean Jaccard of random sample*	*SD of Jaccard of random sample*	z	p
Minimum no aggregation	9.37	9.34	0.16	0.28	0.409
Medium no aggregation	11.50	11.94	0.13	−3.41	<0.001[b]
Maximum no aggregation	12.32	13.21	0.09	−10.32	<0.001[b]
Minimum moderate aggregation	10.68	9.36	0.16	8.32	<0.001
Medium moderate aggregation	12.60	12.02	0.12	4.83	<0.001
Maximum moderate aggregation	15.02	13.49	0.08	19.65	<0.001
Minimum high aggregation	11.01	9.71	0.16	8.11	<0.001
Medium high aggregation	14.20	12.21	0.12	17.31	<0.001
Maximum high aggregation	15.02	13.49	0.08	19.65	<0.001

[a] *We compared the observed Jaccard coefficient for each observed comparison to the mean Jaccard coefficient of the random comparisons to determine statistical significance of the observed spatial overlap.*
[b] *Significantly lower than random.*

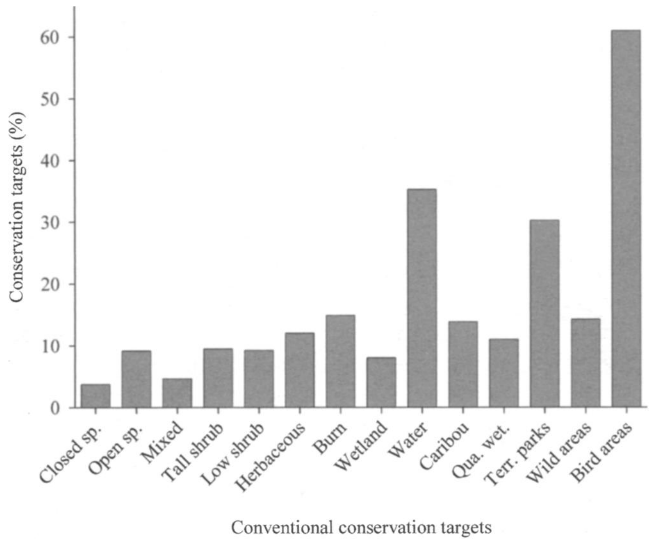

Figure 4. Percentage of all available conservation features present in all heritage sites (closed sp., closed spruce; open sp., open spruce; caribou, suitable woodland caribou habitat; qua. wet., high-quality wetlands; terr. parks., territorial parks; wild areas, wilderness areas of special interest; and bird areas, key migratory bird terrestrial habitat sites).

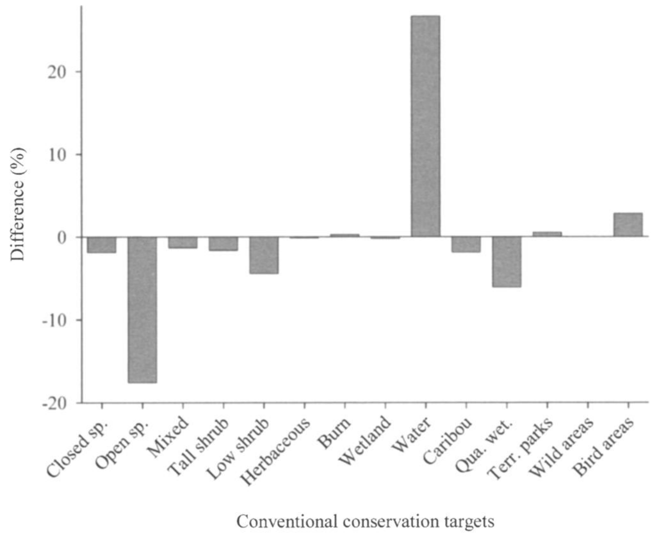

Figure 5. Difference between the percentage of the heritage sites composed of each conventional conservation feature and the percentage of the landscape composed of each conventional conservation feature. Positive values indicate the conservation feature made up a higher percentage of the heritage sites than the landscape. See Fig. 4 legend for description conventional conservation target abbreviations.

in the planning process (Groves et al. 2002; Noss et al. 2002; Pressey et al. 2003). Nevertheless, many conservation plans that identify areas of interest for conservation of conventional features, such as biodiversity, on landscapes overlapping indigenous lands do not explicitly consider indigenous interests (e.g., Warman et al. 2004; Venevsky & Venevskaia 2005; Wiersma & Urban 2005). Such approaches do not advance recommendations under Article 8-J of the Convention on Biological Diversity that states that governments must engage indigenous and local communities in the designation and management of protected areas. If areas of conventional protection overlap spatially with indigenous heritage sites, protection for both may be achieved by targeting only one. Alternatively, if there is little overlap, then it is necessary to explicitly consider both types of conservation values in the design process. At minimum it is necessary to understand the relationship between the two to develop conservation plans that address both ecological and cultural values.

We undertook a quantitative assessment of the overlap between heritage sites and protected areas designed to capture conventional conservation features in a boreal landscape in northern Canada. Our results suggest that protected-area networks designed to capture conventional conservation features such as focal species and environmental variation may effectively protect key heritage sites and vice versa, but not without considering the spatial aggregation of conservation features and heritage sites. The overlap between heritage sites and protected areas was significantly higher than random for all protected-area networks designed with moderate or high aggregation. In this case the target levels had less influence on the overlap because even networks designed with minimum targets and moderate or high aggregation had significantly higher overlap than random. Conversely, protected-area networks designed without a requirement for aggregation (i.e., no boundary length modifier) showed no significant or significantly lower than random overlap with heritage sites. Even the maximum targets, no aggregation network, which covered 65% of the study area, had significantly lower overlap with heritage sites than random. These results may reflect the aggregated pattern of the Gwich'in heritage sites. The heritage sites include many trails and entire lakes, which have a high degree of aggregation. This study provides an example of the influence of aggregation on the effectiveness of protected-area networks at capturing multiple conservation values.

Limitations

We provide one case study of the spatial overlap between indigenous heritage sites and protected areas that are designed on the basis of conventional conservation features. Gwich'in heritage sites were highly aggregated, and concentrated on or near water bodies, likely because water bodies are important for harvesting fish and animals and for travel and other cultural reasons. These characteristics may be specific to the Gwich'in heritage sites; therefore, additional case studies are required to understand the general relationship between indigenous heritage sites and conventional conservation features. Studies that incorporate data on species that are harvested by indigenous communities may observe stronger overlap between heritage sites and conventional conservation features.

The scaling of our data sets may have resulted in overestimation of the overlap of heritage sites and protected areas because our minimum mapping unit was 25 ha, but some heritage sites are much smaller than 25 ha (e.g., cabins). Comparisons at a finer scale may reveal different patterns of overlap. Likewise many indigenous communities have relationships with the landscape at larger scales, with corresponding large-scale heritage sites data (e.g., Sahtu Land Use Planning Board 2002). It would be valuable to investigate the relationship between heritage sites and conventional conservation features at larger scales. Similarly, evaluating the influence of our modeling approach on characterization of suitable habitat for caribou would be worth exploring. We generated coarse-scale models commensurate with the resolution of other biophysical data that capture conservation values, but modeling selection at finer scales and choosing stricter criteria for suitability might influence the outcome of our analyses. Finally, we investigated the static relationship between heritage sites and protected areas, but the influence of system dynamics such as natural disturbance may influence the long-term overlap of heritage sites and protected areas.

Implications for Conservation Planning

Successful design and management of protected areas on indigenous lands depends on the cooperation and support of local communities (Brandon & Wells 1992). Protected-area planning that incorporates heritage sites should allow continuation of traditional activities that occur in heritage sites. In fact some consider indigenous peoples an essential part of the ecosystem on indigenous lands (Schwartzman et al. 2000; Huntington 2002; Hermann 2006). Establishment of protected areas can effectively preserve the relationship between humans and ecosystems (Watson et al. 2003), especially if this traditional relationship is considered during the planning process (Whiting 2004). Protected-areas design can proceed independently of community-based planning, but we believe such efforts are likely to fail, alienate indigenous communities, and foster resentment toward protected areas. Parks Canada has recently begun working with aboriginal communities to identify aboriginal cultural landscapes on indigenous lands (Parks Canada 2004) to overcome problems associated with previous protected-areas designations that largely excluded aboriginal interests. In addition, countries that have signed the Convention on Biological Diversity have obligations to engage local communities in protected-areas design and management.

Our findings agree with suggestions that other types of knowledge can contribute to developing conservation plans that more effectively protect natural and cultural features (Ludwig et al. 2001; Pfister 2002). To better capture community heritage sites, conventional conservation planning methods can explicitly incorporate representation targets based on areas of importance to local communities. In areas where indigenous activities are prevalent, heritage sites could be afforded the highest conservation priority (e.g., Folke 2004). In isolation, however, heritage sites in our study area did not capture a high percentage of other conservation features, including suitable woodland caribou habitat, high-quality wetland areas, and certain earth cover types (e.g., open spruce and low shrub). Protecting heritages sites, therefore, may not provide comprehensive protection of conventional conservation features. If communities wish to protect such features, they may need to identify additional areas for protection to complement their heritage sites. Conventional protected-areas design methods can be used to identify such areas (e.g., Deh Cho 2001; Taku River 2003).

It is challenging for conservation planners to incorporate the interests of remote communities, but to achieve conservation, local interests cannot be ignored (Alcorn 1993; Schwartzman et al. 2000; Brosius 2004). To facilitate the exchange of information between conservation biologists and communities, we suggest developing cooperative working groups with government agencies and other organizations that are linked to communities to better understand community interests. By forging these relationships, conservation planners will be able to design protected areas that will more effectively capture both cultural and natural features (Whiting 2004). Likewise, communities that seek to protect biodiversity and ecological processes may benefit from using conventional protected-areas design methods. Collaboration and exchange of information among conservation biologists and local peoples can be mutually beneficial (Drew 2005).

In the Mackenzie Valley, Northwest Territories, Canada, a portion of which falls within our study area, the design of protected-area networks to effectively maintain ecological and cultural values is critical. Although much of the region presently exists in a relatively pristine state, exploration and development of mineral and oil and gas resources is expanding rapidly, and a major pipeline transecting the Mackenzie Valley is in the final stages of environmental review. Completion of a protected-areas network in advance of the pipeline development is a requisite of proactive conservation planning for the region.

The GNWT has worked with nongovernmental organizations and local communities to incorporate community interests at the beginning of the conservation planning process for the Mackenzie Valley region (Northwest Territories Protected Areas Advisory Committee 1999; Stadel et al. 2002; Northwest Territories Protected-Areas Strategy Secretariat 2003). The GNWT is also applying other protected-areas criteria and analysis to complement potential protected areas identified by communities. This process draws on the strengths of community land-use planning and systematic conservation planning to identify potential protected-area networks with a high probability of being implemented, as opposed to being mere paper parks (Alcorn 1993; Schwartzman et al. 2000). Such an approach could be a model for designing effective protected-area networks on indigenous lands. Here we have clearly identified the advantages of such complementarities in achieving a broad range of conservation objectives.

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