BIG ANIMALS and SMALL PARKS: Implications of Wildlife Distribution and Movements for Expansion of Nahanni National Park Reserve

John L. Weaver

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Implications of Wildlife Distribution and Movements

for Expansion of Nahanni National Park Reserve

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This project was one of the most exciting and rewarding experiences in my professional career. It is my hope that the information in this report will help Parks Canada and native people of the Dehcho and Sahtu communities in their decisions about the future of the Nahanni.

To each of you, my sincere thanks for your vital contribution.

SUMMARY

The boundaries of Nahanni National Park Reserve, in the Northwest Territories of Canada, were established quickly in 1972 to protect the spectacular waterfalls and canyons of the famed South Nahanni River. The focus at the time was to protect the river corridor from destruction by a proposed dam and reservoir. Consequently, the Park Reserve was <8 km wide in some sections while encompassing only 4765 km^2 (about 14%) of the South Nahanni River watershed. In 1978, the United Nations (UNESCO) recognized Nahanni National Park Reserve as a World Heritage Site. Parks Canada has mandated responsibility for ensuring the ecological integrity of national parks, and the native people of the Dehcho First Nations and Sahtu communities have expressed a strong interest in conserving the integrity of Nahʔą Dehé (Slavey name for the South Nahanni River area) in their traditional territories.

Nahanni National Park Reserve itself, however, represents a classic example of the 'boundary problem' that confronts many national parks and other protected areas across the world: it is too small and too narrow. The problem is particularly acute for large carnivores and northern ungulates that typically range widely, occur at low population densities, and possess little resiliency to human impacts. Consequently, they require large, secure areas to sustain populations. With major industrial developments across the Mackenzie River basin imminent, there is a time-limited opportunity to address the problem of the Park's inadequate boundary by designing a better blueprint for conservation of wildlife and ecological integrity.

I conducted field studies during 2002-2005 on grizzly bears, Dall's sheep, and woodland caribou. The research goal was to develop spatially-explicit, scientific data about the distribution and seasonal movements of these landscape species that could inform decisions regarding Park expansion and land use plans of the Dehcho and Sahtu. For planning purposes, Parks Canada and the Dehcho delineated an area (40,000 km^2) called the 'Greater Nahanni Ecosystem' (GNE), which included all of the South Nahanni River watershed plus an area north of the lower canyons known as the Nahanni Karstlands.

Grizzly bears range across a wide variety of habitats, but they have a very low reproductive rate – especially in the north – and cannot readily compensate for increased mortality. Consequently, grizzlies have low resiliency in the wake of human developments, and areas of high security have emerged as a key conservation strategy for this species. Our research team surveyed grizzly bears across the entire watershed using non-invasive hair snaring methods and DNA analysis to identify individual bears and modeled the distribution of the grizzly population using terrain and land cover variables.

We detected grizzly bears at 49% of 225 stations and estimated the overall density at 17.3 bears per 1000 km^2. Diverse mountain landscapes in the north-central and northwest sectors of the Greater Nahanni Ecosystem (mostly outside the present Park) had the

highest occurrence and density of grizzly bears, whereas boreal forests in the southern sector had the lowest occurrence and density. Through supplemental collection of bear hair on natural rub trees, we documented that many grizzly bears also used the main valleys along the South Nahanni and Flat River valleys and the Rabbitkettle Lake area. Multiple detections of individual bears suggested that male grizzly bears may range over 2000 km^2. A combination of 'moderate →very high' density classes yielded 75% of the estimated population by covering 59% of the Greater Nahanni Ecosystem.

Dall's sheep are habitat specialists that use alpine tundra habitat near cliffs which provide adequate escape from predators. They possess moderate resistance to human impacts but low resiliency if a local population is reduced or extirpated. During the last ice age, the Mackenzie Mountains served as a key refugium for Dall's sheep, which resulted in a diverse and distinctive genetic structure. I compiled data from various sheep surveys and delineated 27 sheep ranges that covered 3159 km^2 (7.9%) of the Greater Nahanni Ecosystem. Key ranges harboring some of the larger populations (Liard Range, Tlogotsho Plateau, Headless and Funeral Ranges, and Nahanni Plateau) were located primarily in the northern and eastern sectors of the ecosystem where winter snow pack is shallow and/or windblown. Average density of Dall's sheep was low but representative of sheep densities throughout the Mackenzie Mountains; the total population in the Greater Nahanni Ecosystem may be 800-1200 animals. Importantly, only a small portion of the primary sheep ranges lie within the present boundaries of Nahanni National Park Reserve (<10%), and several extensive ranges lie entirely outside the boundary.

Extending northward from First Canyon along the lower South Nahanni River is a limestone landscape that exhibits the most diverse and striking karst features anywhere in the arctic or sub-arctic regions of the world. During our sheep surveys in 2005, we discovered a new area with a high concentration of karst caves that were used by Dall's sheep. One of the most noticeable features was the lush carpet of grasses and forbs at the entrance of most caves, which appeared as oases in a desert of stone. These karst caves on the Nahanni and Ram Plateaus provided both security and food for ewe-lamb pairs, which may enhance survivorship of lambs. Based upon conversations with leading sheep biologists across North America, I concluded that this concentration of karst caves used by Dall's sheep is unique on the continent.

Woodland caribou rely heavily upon terrestrial or arboreal lichens, especially in winter when they seek out windblown alpine sites or mature conifer forests at lower elevations where snow pack is shallow. They possess comparatively low potential for population growth, which limits their capacity to rebound from impacts. Woodland caribou populations are especially vulnerable to loss and fragmentation of key habitats and high mortality from predation, hunting, and poaching. Woodland caribou have low resiliency and their range in some parts of Canada has receded over the past 100 years coincident with the expanding footprint of industrial logging and other human activities. The Northern Mountain population of woodland caribou is listed as one of 'special concern'. Three different herds of woodland caribou use the Greater Nahanni Ecosystem: (1) Redstone herd, (2) Upper Nahanni herd, and (3) Lower Nahanni herd which consists of the Coal and LaBiche groups.

The Redstone caribou herd is one of the largest herds of the mountain type of woodland caribou in the Northwest Territories and may number 5,000-10,000 animals. Satellite tracking of collared animals during 2002-2005 revealed that they used the headwaters region of the South Nahanni River as a traditional calving area in late May and early June, and the upper reaches of Clearwater/ Cathedral/ Wrigley Creeks as a traditional area during the fall rut and winter. Both of these areas are outside the present park boundary.

The Upper Nahanni caribou herd occupied a range of 17,500 km^2 across the northern and center sections of the South Nahanni River watershed. Based on aerial surveys in 2001, biologists estimated 940-1140 animals in this herd. Aerial and satellite tracking of collared caribou 1995-2001 showed that during the calving period, most animals moved into the upper part of the South Nahanni River watershed (Little Nahanni River basin), where they used a diverse landscape of subalpine open woodland, spruce-lichen woodland, subalpine shrubland, and tundra types. During summer and the fall rut, caribou remained in this same area which is outside the park boundary. Between mid-October and mid-November, they migrated approximately 160-170 km down the main South Nahanni River valley into Nahanni National Park Reserve. In most years, this caribou herd wintered in the montane spruce-lichen woodlands along the South Nahanni River valley above Virginia Falls and lower reaches of the adjacent Clearwater-Cathedral Creek basin. During spring migration, they essentially re-traced their fall migration routes. Members of the Upper Nahanni caribou herd showed strong fidelity over time to these seasonal ranges and migration routes.

The Lower Nahanni herd (comprised of the Coal River and LaBiche groups) occupied a range of nearly 32,000 km^2 that straddled the Yukon-Northwest Territories border (about 45% on the NT side). Based on aerial surveys carried out by Yukon biologists in 1993 and 1997 over part of the area, it's likely that this herd numbered at least 731-878 caribou at that time. Satellite tracking of collared caribou 2000-2005 revealed that during summer and the fall rut, most of the caribou resided on alpine plateaus and subalpine basins scattered across a 240-km arc in southeast Yukon. Some animals, however, did spend the summer along the Territorial divide. After the rut, caribou migrated as far as 240 km eastward from southeast Yukon over the divide and into the Greater Nahanni Ecosystem. In harsher winters, animals moved earlier and further east to a core winter range centered on the confluence of the Flat River and the South Nahanni River in Nahanni National Park Reserve. Most caribou locations at this season were in the montane spruce – lichen woodlands at 400-900 m elevation. During spring migration, collared members of the Lower Nahanni caribou re-traced their fall migration routes. The expansive boreal forest in the southwest sector of the Greater Nahanni Ecosystem, located in a 'snow shadow' in the lee of prevailing winter storms from the southwest, provided crucial habitat for this trans-border herd from November to May.

One of the most robust messages emerging from conservation science in recent years is that populations of large animals need large spaces. Most national parks around the world are simply too small to protect the values therein. Indeed, one of the leading causes of contemporary declines in wildlife populations has been fragmentation of habitat and diminished security for vulnerable populations. Clearly, our research findings reveal that Nahanni National Park Reserve is too narrow and too small to protect these wide-ranging, vulnerable wildlife. Hence, to secure ecological integrity of Nahanni National Park Reserve, it is necessary to expand the park to protect critical seasonal ranges of these wildlife species from loss and fragmentation of habitat, contribute substantially to sustaining viable populations, and safeguard unique phenomena.

Based upon the empirical data, sound principles of conservation science, and my own extensive field experience across the Greater Nahanni Ecosystem and other national parks in the Rocky Mountains, I recommend that Nahanni National Park Reserve be expanded to include the entire South Nahanni River watershed and the adjacent Nahanni Karstlands. This recommendation does not include some areas along the eastern side of the GNE which do not appear to be important for the conservation of these particular wildlife species. The recommended area comprises about 38,000 km^2, or approximately 95% of the Greater Nahanni Ecosystem. Such an expansion would:

- ✓ Protect important ranges and habitat for several wide-ranging wildlife species that are vulnerable to human impacts due to their low resiliency (grizzly bears and woodland caribou) and/or their reliance on special landscapes (Dall’s sheep).
- ✓ Safeguard the high level of genetic diversity present in these wildlife populations.
- ✓ Encompass the variety of land cover types and landscape features that are representative of the Mackenzie Mountains.
- ✓ Protect the unique assemblage of caves used by Dall’s sheep as well as other world-class karst features.
- ✓ Safeguard the natural integrity of the entire South Nahanni River watershed which is one of the most spectacular and intact wild landscapes in North America, a place where natural processes continue to mold the land and the life therein.
- ✓ Provide room for plants and animals to move and shift northward and higher in elevation in response to climate change.

SOMMAIRE

Les limites territoriales de la réserve de parc national Nahanni, située dans les Territoires du Nord-Ouest au Canada, ont été tracées à toute vitesse en 1972 afin de protéger les spectaculaires chutes d'eau et canyons de la célèbre rivière Nahanni Sud. À l'époque, le but visé était de prévenir la destruction du couloir fluvial devenue imminente par la construction d'un barrage et l'aménagement d'un réservoir. En conséquence, la réserve de parc s'étendait sur moins de 8 kilomètres en largeur dans certains secteurs et ne protégeait que 4765 km^2 (environ 14 %) du bassin hydrographique de la rivière Nahanni Sud. En 1978, la réserve de parc national Nahanni fut reconnue par les Nations Unies (UNESCO) comme un site du patrimoine mondial. Parcs Canada est responsable d'assurer l'intégrité écologique des parcs nationaux et les peuples autochtones des Premières nations Deh Cho et les collectivités du Sahtu ont exprimé un vif intérêt pour la conservation de l'intégrité de la Nahʔą Dehé (expression slave désignant la région de la rivière Nahanni Sud) sur leurs territoires traditionnels.

Cependant, la réserve de parc Nahanni elle-même représente un exemple typique du « problème limitrophe » auquel nombre de parcs nationaux et d'autres aires protégées sont confrontés partout dans le monde : elle est trop petite et trop étroite. Le problème affecte particulièrement les grands carnivores et ongulés nordiques qui se déplacent habituellement sur de grands territoires, dont la densité des populations est faible et qui sont peu résilients aux impacts anthropiques. En conséquence, leurs populations ont besoin de vastes aires sécuritaires pour survivre. Vu l'imminence des activités de développement industriel autour du bassin du fleuve Mackenzie, le temps presse pour s'attaquer au problème des limites inadéquates du parc en concevant un meilleur plan de conservation de la faune et de l'intégrité écologique.

À la demande de l'équipe de consensus *Nah¾Ȩ̈ Deh*é et de Parcs Canada, j'ai mené des études de terrain sur des grizzlis, des mouflons de Dall et des caribous des bois de 2002 à 2005. La recherche avait pour objectif de recueillir des données scientifiques spatiales explicites sur la distribution et les déplacements saisonniers de ces espèces territoriales pouvant permettre la prise de décisions éclairées concernant l'agrandissement du parc et les plans d'occupation des sols des collectivités Deh Cho et Sahtu. Pour des fins de planification, Parcs Canada et la Première nation Deh Cho ont délimité une région de 40 000 km^2 nommée l'écosystème de la grande région Nahanni, laquelle région englobait l'ensemble du bassin hydrographique de la rivière Nahanni Sud en plus d'une section au nord du canyon First connue sous le nom de Nahanni Karst.

Des grizzlis occupent une grande diversité d'habitats, mais leur taux de reproduction est très faible – surtout en régions nordiques – et ne peut adéquatement compenser une hausse du taux de mortalité. En conséquence, les grizzlis sont peu résilients aux activités anthropiques, et une stratégie de conservation clé de cette espèce comporte des zones de sécurité. Notre équipe de chercheurs a étudié des grizzlis dans l'ensemble du bassin hydrographique à l'aide de méthodes non invasives de collecte de poils au collet et d'analyse d'ADN afin d'identifier des ours individuellement. Elle a ensuite modélisé la distribution de la population de grizzlis à partir de variables sur le terrain et la couverture terrestre.

Nous avons détecté la présence de grizzlis à 49 % des 225 postes pour ensuite estimer la densité totale à 17,3 ours par 1000 km^2.

Divers paysages montagneux dans les régions nord-centre et nord-ouest de l'écosystème de la grande région Nahanni (principalement à l'extérieur des limites actuelles du parc) affichaient l'occurrence et la densité les plus élevées de grizzlis tandis que l'occurrence et la densité les plus faibles ont été rapportées dans les forêts boréales plus au sud. En collectant d'autres poils d'ours sur des arbres, nous avons trouvé que de nombreux grizzlis occupent également les principales vallées de la rivière Nahanni Sud et de Flat River ainsi que la région autour du lac Rabbitkettle. La détection de plusieurs ours individuels laisse entendre qu'un grizzli mâle puisse parcourir un territoire de plus de 2000 km^2. Une combinaison de catégories de densité de « modérée → très forte » a produit 75 % de la population estimée sur 59 % de l'écosystème de la grande région Nahanni.

Les mouflons de Dall habitent la toundra alpine près de falaises, qu'ils utilisent pour se protéger adéquatement contre des prédateurs. Ils sont moyennement résistants aux impacts anthropiques, mais leur résilience est faible lorsqu'une population locale est réduite ou extirpée. Durant la dernière ère glaciale, les monts Mackenzie ont servi de refuge clé pour des mouflons de Dall, ce qui a eu pour effet de produire une structure génétique diversifiée et distincte chez cet animal. J'ai compilé des données de diverses études menées sur les mouflons et dénombré un total de 27 aires de répartition couvrant 3159 km^2 (7,9 %) de l'écosystème de la grande région Nahanni. Les grandes aires de répartition abritant quelques-unes des populations plus nombreuses (monts Liard, plateau Tlogotsho, chaînes Headless et Funeral et plateau Nahanni) se trouvent principalement dans le nord et l'est de l'écosystème où l'accumulation de neige pendant l'hiver est faible et/ou la neige qui s'y accumule est soufflée par le vent. La densité moyenne des populations de mouflons de Dall était faible mais néanmoins représentative des densités de populations de mouflons à l'échelle des monts Mackenzie. L'écosystème de la grande région Nahanni pourrait abriter de 800 à 1200 têtes. Il est important de souligner que seule une petite partie (moins de 10 %) des principales aires de répartition des mouflons se trouve circonscrite à l'intérieur des limites actuelles de la réserve de parc national Nahanni tandis que plusieurs grandes aires se trouvent entièrement à l'extérieur des limites.

S'étendant vers le nord depuis le canyon First et longeant la portion inférieure de la rivière Nahanni Sud est un massif calcaire qui présente les caractéristiques de Karst les plus diversifiées et saisissantes de toute région arctique ou subarctique sur la planète. Dans le cadre de nos études menées sur les mouflons en 2005, nous avons découvert une nouvelle aire ayant une forte concentration de grottes Karst occupées par des mouflons de Dall. L'une des caractéristiques les plus remarquables de cette aire était l'exubérance d'herbes et de plantes herbacées tapissant l'entrée de la plupart des grottes (il s'agissait en quelque sorte d'oasis dans un désert de pierres). Ces grottes Karst sur les plateaux Nahanni et Ram assuraient à la fois sécurité et source de nourriture aux jeunes brebis, ce qui pourrait se traduire par un meilleur taux de survie des brebis. À la suite de conversations que j'ai eues avec des biologistes de renom spécialisés dans l'étude des mouflons partout en Amérique du Nord, je suis arrivée à la conclusion que cette concentration de grottes Karst habitées par des populations de mouflons est un phénomène unique sur le continent.

La survie du caribou des bois dépend en très grande mesure de la présence de lichens terrestres ou corticoles, surtout pendant l'hiver lorsqu'il recherche des sites alpins balayés par le vent ou des forêts de conifères matures à des altitudes plus basses où l'enneigement est faible. Le potentiel d'accroissement des populations de caribous des bois est relativement faible, ce qui limite leur résilience aux impacts anthropiques. Les populations de caribous des bois sont particulièrement vulnérables à la perte et au morcellement de leurs principaux habitats et à une mortalité excessive attribuable à la prédation, à la chasse et au braconnage. Ainsi, le caribou des bois est peu résilient et son aire de répartition dans certaines régions du Canada s'est rétrécie au cours du dernier siècle en même temps que l'empreinte laissée par la foresterie industrielle et d'autres activités anthropiques s'est agrandie. La population de caribous des bois dans les montagnes nordiques est considérée « préoccupante ». Trois troupeaux de caribous des bois différents se partagent l'écosystème de la grande région Nahanni : le troupeau Redstone, le troupeau Haute Nahanni et le troupeau Basse Nahanni, qui compte les groupes Coal et LaBiche.

Le troupeau de caribous des bois Redstone est l'un des plus gros troupeaux de caribous des bois « montagneux » dans les Territoires du Nord-Ouest et pourrait compter de 5000 à 10 000 têtes. Entre 2002 et 2005, le suivi par satellite d'animaux sur lesquels un collier avait été installé a révélé que ces animaux utilisaient la région autour du cours supérieur de la rivière Nahanni Sud pour mettre bas à la fin de mai et au début de juin. De plus, ils utilisaient la région du cours amont des criques Clearwater, Cathedral et Wrigley pendant le rut d'automne et l'hiver. Ces deux régions sont à l'extérieur des limites actuelles du parc.

Le troupeau de caribous Haute Nahanni occupait une aire de répartition de 17 500 km^2 s'étendant dans le nord et le centre du bassin hydrographique de la rivière Nahanni Sud. À partir de levés aériens remontant à 2001, des biologistes ont estimé à entre 940 et 1140 le nombre d'individus formant ce troupeau. Le suivi aérien et satellitaire de caribous portant un collier entre 1995 et 2001 a permis de conclure que durant la période de mise bas, la plupart des animaux se déplaçaient vers la partie supérieure du bassin hydrographique de la rivière Nahanni Sud (le bassin de la petite rivière Nahanni), une région caractérisée par divers paysages de forêts ouvertes subalpines, de forêts d'épinettes et à lichens, d'arbustes subalpins et de toundra. Durant l'été et le rut d'automne, les caribous demeuraient au même endroit situé à l'extérieur des limites du parc. Entre la mi-octobre et la mi-novembre, ils migraient vers le Sud sur quelque 160 à 170 kilomètres en empruntant la principale vallée de la rivière Nahanni Sud pour aboutir dans la réserve de parc national Nahanni. La plupart des années, ce troupeau de caribous passait les mois d'hiver dans les forêts alpestres d'épinettes et à lichens le long de la vallée de la rivière Nahanni Sud au nord de Virginia Falls de même qu'au bassin adjacent du crique Clearwater-Cathedral. Pendant la migration printanière, ils empruntaient essentiellement les mêmes voies de migration qu'à l'automne. Au fil du temps, des caribous du troupeau Haute Nahanni se sont montrés très fidèles à ces aires de répartition saisonnières et voies de migration.

Le troupeau Basse Nahanni occupait une aire de répartition de près de 32 000 km^2 à cheval sur la frontière séparant le Yukon des Territoires du Nord-Ouest (quelque 45 % de l'aire se trouvant du côté des TNO). À partir de levés aériens effectués par des biologistes du Yukon en 1993 et 1997 d'une partie de la région, j'ai évalué à plus de 1000 le nombre de caribous formant le troupeau Basse Nahanni. Le suivi satellitaire de caribous portant des colliers entre 2000 et 2005 a révélé que durant l'été et le rut automnal, la majorité des caribous occupait les plateaux alpins et bassins subalpins parsemés sur un arc de 240 kilomètres dans le sud-est du Yukon. Toutefois, certains membres du troupeau passaient l'été le long de la frontière territoriale. Après la période de rut, les animaux se déplaçaient plus tôt et plus à l'est vers une grande aire d'hivernage située exactement à la confluence des rivières Mary et Nahanni Sud dans la réserve de parc national Nahanni. À cette saison de l'année, la plupart des caribous occupaient les forêts alpestres d'épinettes et à lichens à une altitude variant de 400 m à 900 m. Durant la migration printanière, des caribous du troupeau Basse Nahanni portant des colliers ont essentiellement repris la voie de migration qu'ils avaient empruntée l'automne précédent. Les vastes étendues de forêt boréale dans le sud-ouest de l'écosystème de la grande région Nahanni, situées dans un « abri-sous-neige » dont la face était protégée des tempêtes hivernales provenant principalement du sud-ouest, se sont avérés des habitats essentiels pour ce troupeau transfrontière de novembre à mai.

Un des principaux constats de la science de la conservation véhiculé au cours de récentes années est que la majorité des parcs nationaux dans le monde sont tout simplement trop petits pour protéger leurs valeurs naturelles intrinsèques. En effet, l'une des principales causes expliquant le déclin contemporain de populations fauniques est le morcellement des habitats et la diminution du niveau de protection des populations vulnérables. Évidemment, les conclusions de notre recherche indiquent que la réserve de parc national Nahanni est trop étroite et trop petite pour protéger ces espèces fauniques à distribution étendue. Pour protéger l'intégrité écologique future de la réserve de parc national Nahanni, le parc devra être agrandi afin d'y protéger des aires de répartition saisonnières cruciales contre la perte et le morcellement d'habitats, de contribuer de façon considérable au maintien de populations viables et de sauvegarder des phénomènes uniques.

En fonction des données empiriques, des principes rationnels de la science de la conservation et de ma vaste expérience sur le terrain de l'écosystème de la grande région Nahanni et d'autres parcs nationaux des Rocheuses, je recommande l'agrandissement de la réserve de parc national Nahanni afin d'y inclure l'ensemble du bassin hydrographique de la rivière Nahanni Sud et la section adjacente nommée Nahanni Karst. Sont exclues de cette recommandation la majeure partie du drainage de la rivière Tetcela et des portions du crique Sundog qui ne semblent pas jouer un rôle important dans la conservation de ces espèces fauniques sélectionnées. La région recommandée couvre quelque 38 000 km^2 ou encore 95 % de l'écosystème de la grande région Nahanni. Un tel agrandissement aurait pour avantages :

- ✓ De protéger de grandes aires et de grands habitats de plusieurs espèces fauniques à distribution étendue qui sont vulnérables aux impacts anthropiques en raison de leur faible résilience (grizzlis et caribous des bois) et/ou de leur dépendance de paysages particuliers (mouflons de Dall).
- ✓ De préserver la grande diversité génétique de ces populations fauniques
- ✓ D'englober les divers types de couverture terrestre et les éléments paysagers représentatifs des monts Mackenzie
- ✓ De protéger l'assemblage unique de grottes utilisées par les mouflons de Dall ainsi que d'autres caractéristiques uniques à la section nommée Karst
- ✓ De préserver l'intégrité naturelle de l'ensemble du bassin hydrographique de la rivière Nahanni Sud, soit l'un des paysages sauvages les plus spectaculaires et intacts en Amérique du Nord, un endroit où des processus naturels continuent de façonner la nature et la vie qu'elle abrite
- ✓ D'assurer l'espace nécessaire pour accommoder la migration vers le Nord et en altitude d'espèces végétales et animales en réaction au changement climatique

Chapter 1 – INTRODUCTION

BACKGROUND AND CONSERVATION ISSUES

The boundaries of Nahanni National Park Reserve (NNPR), in the Northwest Territories of Canada, were established quickly in 1972 to protect the spectacular waterfalls and canyons of the famed South Nahanni River. The focus at the time was to protect the river corridor from destruction by a proposed dam and reservoir. Consequently, the Park Reserve was <8 km wide in some sections while encompassing only 4765 km^2 (about 14%) of the South Nahanni River watershed (Map 1). In 1978, the United Nations (UNESCO) recognized Nahanni National Park Reserve as a World Heritage Site. This status granted international recognition for '… superlative natural phenomena, formations, and features of exceptional natural beauty' (see Keough and Keough 1988).

The people of the Dehcho First Nations and Sahtu communities also have a strong interest in conserving the integrity of the land and waters of Nahʔą Dehé (South Slavey name for the South Nahanni River watershed) in their traditional territories (Dehcho Land Use Planning Committee 2006). Although Nahanni was gazetted officially into the National Parks Act in 1976, it is termed a 'Reserve' pending settlement of Dehcho land and governance claims with the government of Canada within the next few years. Meanwhile, the Park remains fully protected under interim reserve status.

Under the Canada National Parks Act, Parks Canada has mandated responsibility for ensuring the ecological integrity of national parks (Statutes of Canada 2000). What is meant by the term 'ecological integrity'? Under the act, ecological integrity was defined as 'a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes'.

Contemporary thinking about ecological integrity has coalesced around several organizing principles: (Woodley et al. 1993, Meffe and Carroll 1997, Pimentel et al. 2000, Groves 2003):

- Maintain full range of biological diversity from genes to populations to species
- Allow ecological processes such as fire and floods within natural range of variability
- Attain representation of ecological types or associations and their successional stages
- Provide sufficient habitat and security for viable populations of native plant and animal species in natural patterns of distribution, abundance, and connectivity
- Protect 'special elements' (e.g., hot springs, caves)
- Ensure potential for evolutionary adaptation to changing environments.

In 2001, Canada and the Dehcho First Nations established the Nahʔą Dehé Consensus Team composed of representatives appointed by Parks Canada and the Dehcho First Nations. The Consensus Team developed the following vision statement for Nahʔą Dehé, which embraces the central tenets of ecological integrity (Parks Canada Agency 2004):

> Nahʔą Dehé will protect a wilderness watershed in the Mackenzie Mountains where natural processes such as fires and floods will remain the dominant forces shaping the park's ecosystems. Special features of the park, including waterfalls, hotsprings, glaciers, plateaux, canyons, karst landscapes and cultural/spiritual sites will be preserved. Naturally-occurring plant communities will thrive and native animal species, including woodland caribou and grizzly bears, will be sustained at viable population levels.

Nahanni National Park Reserve itself, however, represents a classic example of the 'boundary problem' that confronts many national parks and other protected areas across the world (Newmark 1985): it is too small and too narrow. Parks Canada has recognized this problem since the first management plan for Nahanni in 1987 (Parks Canada 1987). It is particularly acute for large carnivores and northern ungulates that typically range widely, occur at low densities and possess little resiliency to human impacts and thus require large, secure areas to sustain viable populations (Weaver et al. 1996). Conflicts with people along the boundaries of reserves are the major cause of mortality for wildlife in many parks around the world (Woodroffe and Ginsberg 1998, Revilla et al. 2001).

Currently, Nahanni National Park Reserve lies within one of the last, large wilderness areas in North America. The only existing industrial 'footprints' are the Tungsten mine site on the western edge of the watershed (accessed by a road from the Yukon) and the Prairie Creek mine site in the northeast sector (inoperative mine accessed in the early 1980s by a winter road) (Map 1). Interest is increasing, however, to exploit the mineral potential in certain areas of Nahanni and other commodity resources (oil and gas and timber) in adjacent areas of the Mackenzie River basin.

Hence, conservation of Nahanni/ Nahʔą Dehé is at a critical juncture. With industrial developments looming on the horizon, there is a time-limited opportunity to address the problem of the Park's inadequate boundary in a proactive manner by designing a blueprint for conservation of wildlife and ecological integrity.

NAHANNI NATIONAL PARK RESERVE and the GREATER NAHANNI ECOSYSTEM

Nahanni National Park Reserve is located in the southwest corner of the Northwest Territories, within the traditional territory of the Dehcho (Map 1). Gahnįhthah Mįe or Rabbitkettle Lake, at the northwest corner of the Park Reserve, lies 320 km (200 mi) west of Park headquarters in Ft. Simpson or Łíídlįį Kų́ę́ on the Mackenzie River. There are no roads within the Park and only short trails at Rabbitkettle and Virginia Falls; access to the area is by aircraft. The Park Reserve is 4765 km^2 in size, which is about 14% of the South Nahanni River watershed. Náįlįcho or Virginia Falls in the center of the Park is an icon in Canadian culture. Canada's system of national parks seeks to protect representative areas of each of the country's natural regions. Nahanni National Park Reserve protects a portion of the Mackenzie Mountains Natural Region.

For planning purposes, Parks Canada and the Dehcho have delineated an area called the 'Greater Nahanni Ecosystem' (GNE), which includes all of the South Nahanni River watershed (35,910 km^2) and an area north of the lower canyons known as the Nahanni

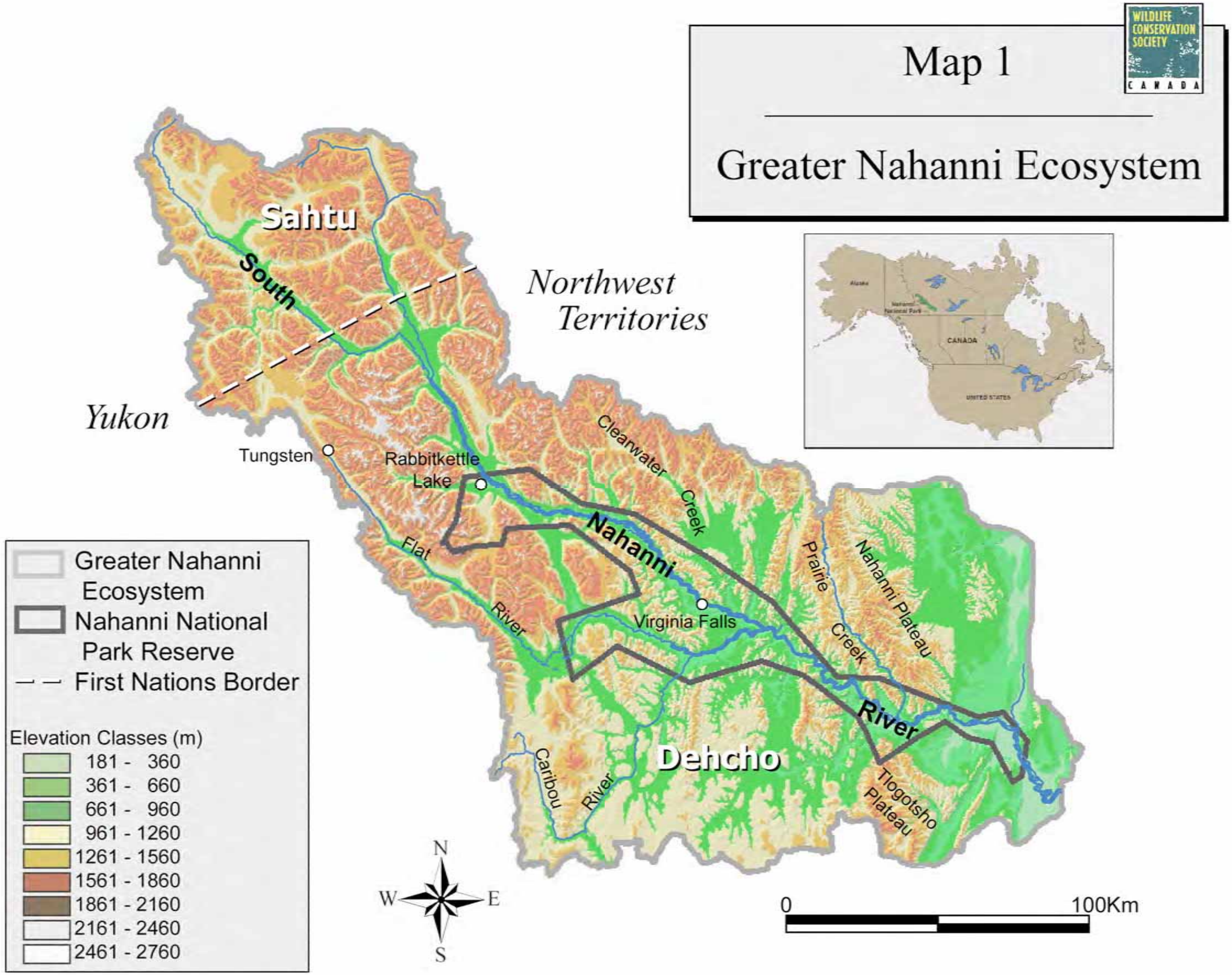
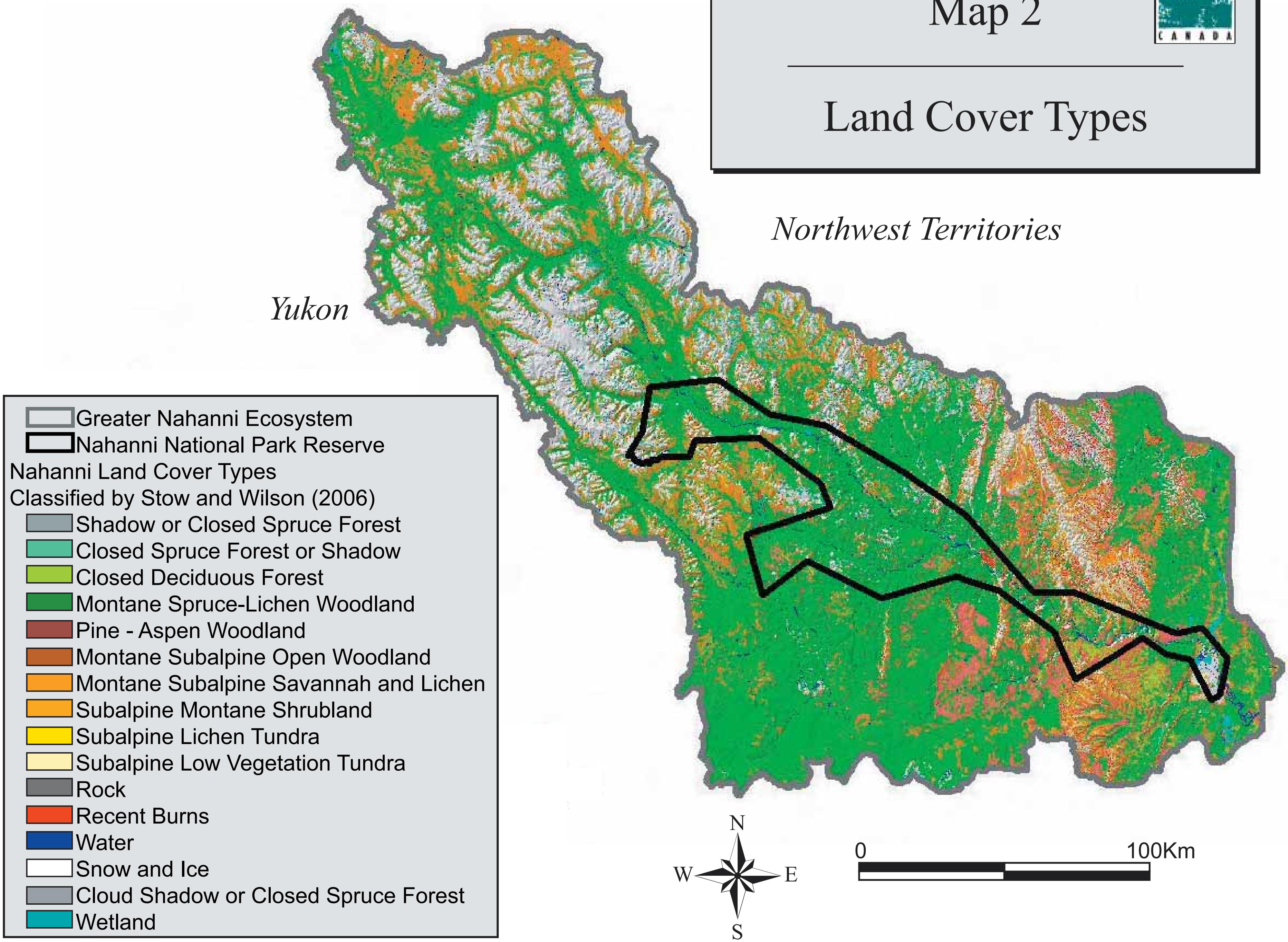

Map 1
Greater Nahanni Ecosystem
WILDLIFE CONSERVATION SOCIETY CANADA
Sahtu
South
Northwest Territories
Yukon
Tungsten
Rabbitkettle Lake
Clearwater Creek
Nahanni
Flat River
Virginia Falls
Prairie Creek
Nahanni Plateau
River
Dehcho
Caribou River
Tlogotsho Plateau
CANADA
UNITED STATES
Greater Nahanni Ecosystem
Nahanni National Park Reserve
First Nations Border
Elevation Classes (m)
181 - 360
361 - 660
661 - 960
961 - 1260
1261 - 1560
1561 - 1860
1861 - 2160
2161 - 2460
2461 - 2760
N
E
S
W
0
100Km

Table 1-1. Description and extent of land cover types, Greater Nahanni Ecosystem (GNE), Northwest Territories. Adapted from classification developed by Stow and Wilson (2006).

Land Cover Type	% Area	Description
Shadow or Closed Spruce Forest	4.4	shadowed areas on steep northern slopes that may be closed forests of white spruce (see below) or adjacent to it
Closed Spruce Forest or Shadow	3.8	mature, closed and open forests of white spruce, mostly on northern slopes in the valleys of the northern GNE
Closed Deciduous Forest	1.5	closed deciduous forests of aspen and poplar, interspersed with white spruce, on moderate terrain in valleys and bottomlands, particularly in the southeast end of the GNE
Montane Spruce-Lichen Forest	44.6	moderately dense woodland of mature white or black spruce (depending upon drainage and elevation) in valley bottoms and on lower slopes, patchy at higher elevations and interspersed with open woodland and savannah/ abundant lichens in the understory/ most common land cover in the GNE
Pine-Aspen Woodland	6.5	mixed open woodland of lodgepole or jack pine – aspen with some spruce (depending on aspect) regenerating from old burns
Montane Subalpine Open Woodland	6.6	open woodland of white spruce on steep slopes of southerly aspect at mid elevation, lichen in understory
Montane Subalpine Savannah and Lichen	9.4	savannah with sparse density of spruce and ground cover dominated by lichens, primarily in high montane and subalpine areas on steep slopes with a southerly aspect
Subalpine Montane Shrubland	1.1	open and sparse shrubland, interspersed with tundra, in very high montane and subalpine areas on steep slopes with southerly aspect
Subalpine Lichen Tundra	0.9	tundra and lichen barrens, interspersed with bare rock, alpine- subalpine areas on steep slopes with southerly aspect
Subalpine Low Vegetation Tundra	5.1	low tundra vegetation, bare soil and rock in alpine areas
Rock	7.1	rock outcrops interspersed with small patches of various plant communities (e.g., low vegetation tundra)
Recent Burns	1.2	either patchy burns interspersed with spruce woodland at lower elevations or shadowed northern slopes at higher elevations (similar spectral responses)
Water	0.9	larger water features
Snow and Ice	6.4	permanent snow or ice
Wetland	0.5	

Map 2

Land Cover Types



Karstlands (3959 km²). Altogether, the Greater Nahanni Ecosystem totals approximately 39,869 km². About 82% of the Greater Nahanni Ecosystem occurs within the Dehcho traditional territory, and 18% at the headwaters of the South Nahanni (Bégádeh) lies within the traditional territory of the Sahtu (Map 1).

The Greater Nahanni Ecosystem has a continental climate: long, cold, rather dry winters and short, mild summers with moderate amounts of precipitation. For the period 1951-1980, average temperatures at the Tungsten mine site on the western edge of the GNE ranged from -24° C in January to 11° C in July. Average levels of monthly precipitation varied from 12 mm in February to 90 mm in July. Precipitation decreases along a gradient from the Yukon-NT divide on the west to the lower slopes of the Mackenzie Mountains on the east. Elevations range from 2760 m at the height of the Ragged Range to 180 m at the lower end of the South Nahanni River.

There has been a history of pioneering botanical surveys in the Greater Nahanni Ecosystem, but these have been limited to a few local sites such as Glacier Lake (Raup 1947) and Rabbitkettle Lake (Marsh and Scotter 1976). In contrast, efforts to devise a broad classification and map of land cover types for the Greater Nahanni Ecosystem have either been limited in scope to Nahanni National Park Reserve (NNPR) itself or limited in ecological/spectral resolution for the larger region (GNWT). Recently, Stow and Wilson (2006) developed a new classification and map from imagery of 6 Landsat ETM+ scenes by the Canada Centre for Remote Sensing (CCRS) (Orazietti and Fraser 2005). They placed 100 random sample points in map areas classified by CCRS that also had information from the NNPR inventory and GNWT data. They conducted a cluster analysis using terrain features (elevation, slope, aspect) and several vegetation variables (e.g., percent conifer cover). They modified the clusters based upon previous descriptions and comments by researchers with field experience in the Nahanni area. These efforts notwithstanding, it must be acknowledged that there has not been much ground-truthing of these types or their occurrence. I provide a brief description of the land cover types (adapted from Stow and Wilson 2006) (Table 1-1) and their occurrence (Map 2).

The classification identifies 15 land cover types. The most common and widespread type is the ‘montane spruce-lichen woodland’ (45%). Other types with a terrestrial lichen (*Cladina* and *Cladonia* spp.) understory occur on another 17% of the land. Past fires are evident across much of the landscape, resulting in mosaics of variable-sized patches of different cover types including pine and aspen. A shrub savannah composed of scrub birch (*Betula glandulosa*), willow (*Salix* ssp.), and scattered white spruce (*Picea glauca*) and subalpine fir (*Abies lasiocarpa*) covers much of the subalpine area.

RESEARCH: GOAL, OBJECTIVES, AND APPROACHES

In order to rectify the problem of inadequate boundaries of Nahanni National Park Reserve, the Nahʔą Dehé Consensus Team and the Nahanni Expansion Working Group affirmed the need for more information. The Nahanni area has not received as much research attention as some other Canadian parks due to its remoteness and lack of roads or trails which makes field research expensive and challenging. So how do you develop a blueprint for conservation of ecological integrity in a cost-effective manner?

The Wildlife Conservation Society has woven together several lines of contemporary thinking about focal species (Lambeck 1997, Carroll et al. 2001) into a concept called ‘landscape species’ (Sanderson et al. 2002). It is based on the notion that species that use large, ecologically diverse areas can serve as useful ‘umbrellas’ or surrogates for conservation of other species**.** Importantly, a suite of species is chosen considering area requirements, heterogeneity of habitats, ecological functionality, and socioeconomic significance.

Another consideration is how ‘resilient’ different species are to various kinds of human disturbance. Resilience refers to the capability of species for adsorbing disturbance and still persisting (Holling 1973). Wildlife evolved in ecosystems where natural disturbances resulted in varying spatial and temporal patterns of change (Pickett et al. 1989). Over millennia, wildlife developed important behaviors and life history traits that imbued them with resilience to certain kinds and levels of disturbance (see Weaver et al. 1996 for development of this concept for carnivores). Basic mechanisms of resilience exist at three levels: individual – behavioral flexibility in foraging, (2) population – demographic compensation, and (3) metapopulation – dispersal. In reference to human impacts upon wildlife, behavioral flexibility addresses the problem of habitat loss; demographic compensation, the problem of overexploitation; and dispersal, the problem of habitat fragmentation at a landscape scale. Each species has a distinctive profile of resiliency that can indicate its relative level of vulnerability to human impacts and the potential importance of core protected areas in a larger conservation strategy (Soulé and Terborgh 1999).

The Nahʔą Dehé Consensus Team identified several wildlife species for strategic research, including grizzly bear or sahcho (South Slavey language) (*Ursus arctos horribilis*), Dall’s sheep or doo (*Ovis dalli dalli*), and woodland caribou or medzih (*Rangifer tarandus caribou*) (Parks Canada Agency 2004). Each of these is a ‘landscape’ species because it uses a large, ecologically diverse or distinctive area and has socioeconomic importance. Moreover, each species is highly vulnerable to impacts from human development. I initiated field studies of grizzly bears in 2002 and extended the research to Dall’s sheep and woodland caribou in 2004.

The goal of the research was to develop spatially-explicit, scientific data about the distribution and seasonal movements of the selected suite of landscape species that could inform decisions regarding Park expansion and land use plans of the Dehcho and Sahtu. The specific objectives were to survey and map: (1) distribution and relative density of grizzly bears, (2) distribution and relative density of Dall’s sheep, and (3) distribution and seasonal movements of woodland caribou. As happens often in ecological research (with good luck), our team made some interesting discoveries along the way that augmented our initial objectives.

This research was largely and unabashedly descriptive and empirical. Basic observation or description is the first and most fundamental step in the scientific process or the indigenous process of living on the land. Empirical data on selected species provides a more credible basis for conservation planning than arbitrary political targets (Svancara et al. 2005). I deployed a variety of research tactics, ranging from leading-edge techniques in DNA identification of grizzly bear hair to satellite reception of transmitter signals from collared caribou. I also compiled and synthesized data available from other sources (e.g., published research reports, Park records, etc.) to develop a richer picture. I give a nuanced description of where each species occurred because it provides Parks Canada more detail, accords with the tradition of stories in the culture of the Dehcho and Sahtu people, and hopefully contributes to a sense of place. Hence, the purpose of this report is to provide data, maps, and narrative about the distribution of grizzly bears, Dall's sheep, and woodland caribou that will inform decisions about expansion of Nahanni National Park Reserve. In separate chapters on each species, I profile its resiliency and current status, describe the particular research methods, present and discuss results, and cite relevant literature. In the final chapter, I pull together these separate pictures into a combined view that suggests new boundaries for Nahanni National Park Reserve to conserve key wildlife areas and ecological integrity.

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Chapter 2 – GRIZZLY BEAR

INTRODUCTION

Grizzly bears have low resiliency (Weaver et al. 1996 and citations therein) and are especially vulnerable where human developments and activities dominate the landscape (Herrero 2005). In many areas of interior North America, grizzlies rely on berries in late summer and autumn to gain the weight and fat deposition necessary for successful hibernation and reproduction. During years of poor berry production, bears move widely in search of food which can bring them in contact with humans and increase the risk of mortality. Grizzly bears have a very low reproductive rate – especially in the north – and cannot readily compensate for increased mortality. Consequently, keeping mortality rates of adult female grizzlies at a low level is critical for the persistence of grizzly bear populations. Young female grizzlies do not disperse far, often establishing a home range within or adjacent to their mother's range. In recognition of the vulnerability of grizzly bear populations, bear researchers and managers have promoted security areas as a key element in conservation strategies for this species (Gibeau et al. 2001, Nielsen et al. 2006).

The overall distribution of grizzly bears in Canada has receded northwesterly in response to spreading human developments and activities (Hummel and Pettigrew 1991) but appears to be stationary in the Northwest Territories (Ross 2002). Currently, the status of grizzly bears (Northwestern population) is listed by the 'Committee On the Status of Endangered Wildlife In Canada' (COSEWIC) as 'special concern' (COSEWIC 2002). This status is conferred upon species whose 'characteristics make it particularly sensitive to human activities or natural events'. Hunting of grizzly bears by non-residents of the Northwest Territories has been prohibited in the Mackenzie Mountains since 1982 (Veitch 1999).

METHODS

In the late 1990's, Canadian bear researchers and geneticists pioneered a new technique for surveying bears using non-invasive, scented stations to collect hair for DNA analysis (Woods et al. 1999). I followed their protocols for using this technique to survey bears.

DNA analysis of bear hair can provide a rich set of information on the species, gender, individual identity, and genetic diversity of bears. From data on occurrence of species (grizzly bear or black bear), researchers can delineate the distribution of each species across broad zones of habitat. With data on gender and identity of individual grizzlies, researchers can estimate the size and composition of the population, chart movements between locations, document seasonal use of habitats, and determine the genetic diversity of the population. With this package of information, researchers can begin to gauge the status of the bear population and assess its range.

Field Survey

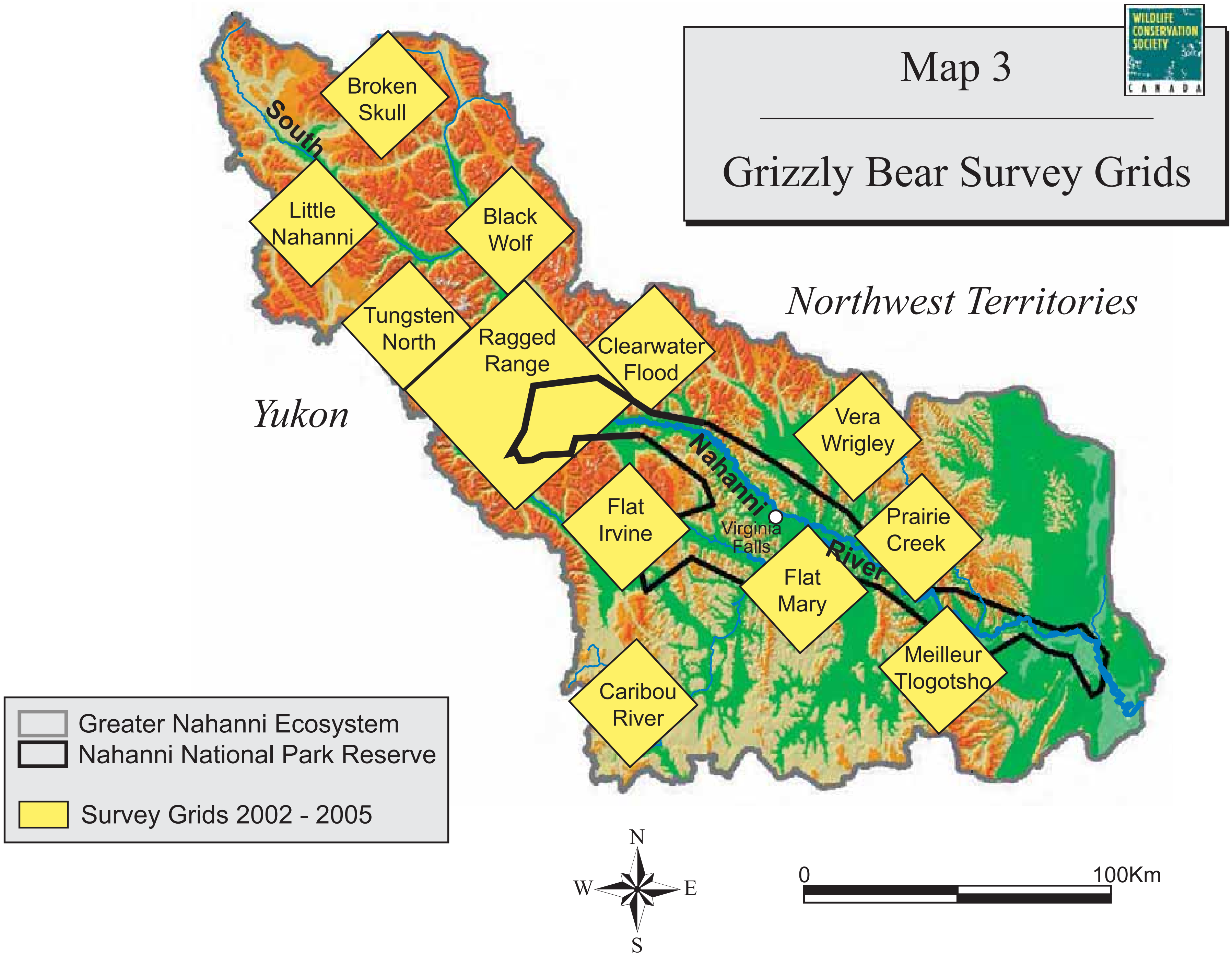
In order to obtain a representative sample of grizzly bear occurrence, I surveyed grizzlies in numerous grids throughout the Greater Nahanni Ecosystem during June of each year 2002-2005 (Map 3). Each survey area consisted of a 4 x 4 grid of 16 cells, wherein each cell was 8 km x 8 km in size (64 km^2); the total size of each grid was 1024 km^2. (In the first year, we surveyed a 7 x 7 grid of 49 cells in the Ragged Range but weighted the results equal to all of the subsequent grids). The size of each cell was smaller than the average home range of female grizzly bears in the Mackenzie Mountains during springtime (Miller et al. 1982), which suggests that (theoretically) all bears had some chance of being detected. In each cell, I chose the site that I judged to have the best likelihood of 'catching' a grizzly bear. Our field team piled up logs, brush, and moss and poured 3 liters of rotted cattle blood and 1 liter of rotted fish oil over the mound. We enclosed the site by running a single strand of barbed wire around several trees about 5 m out from the mound and uniformly about 50 cm above the ground (see Fig. 1 in Woods et al. 1999). Using a Bell 206B helicopter for access in this remote area, we established stations during the first 10 days of June and checked them approximately 20 days later during late June. Over the 4 years, we sampled 42% (225) of the total 531 units (64-km^2) in the South Nahanni River watershed. In 2005, we replicated the June survey on 3 grids by repeating the survey at the same locations during berry season late July – early August. We assumed that detectability of stations was constant across habitats. To supplement data from the grids, park personnel and I also gleaned hair samples from natural rub trees along the South Nahanni River and elsewhere across the Greater Nahanni Ecosystem on an opportunistic basis.

During the mid-1990s, bear researchers reported a number of bear rub trees on the trails around Rabbitkettle Lake, which is one of the primary entry points for people floating down the South Nahanni River (MacDougall et al. 1997). In early June 2002, I located 35 bear rub trees along the 3.2-km trail from the South Nahanni River past Rabbitkettle Lake warden cabin and over to the tufa mounds. In order to assess the number and timing of grizzly bears using this trail as well as the role of Rabbitkettle valley in the larger landscape for grizzly bears, I placed barbed wire vertically on 25 of these trees to obtain hair for DNA analysis. Thereafter, park personnel and I continued to collect fresh hair from these trees at an interval of roughly every 2 weeks from May through August each year.

DNA Analyses

The Wildlife Genetics International (WGI) lab in Nelson, BC, under the direction of Dr. David Paetkau, conducted the DNA analyses. Dr. Paetkau has published extensively on genetics of North American bears (Paetkau and Strobeck 1994, Paetkau et al. 1995, Paetkau et al. 1998a, Paetkau et al. 1998b) and DNA analyses of bear hair (Woods et al. 1999, Paetkau 2003, Waits and Paetkau 2005). To ensure rigorous and reliable identification of individual grizzly bears, the WGI lab selected a set of specific genetic markers that exceeded a high threshold of heterozygosity, culled marginal samples at an early stage in the process, scrutinized similar pairs of genotypes, and adhered to high laboratory standards for quality control (Paetkau 2003, Waits and Paetkau 2005).

Selection of Hair Samples and DNA Extraction. -- WGI personnel selected hair samples for DNA extraction using three


Map 3
Grizzly Bear Survey Grids
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
South
Nahanni River
Virginia Falls
Broken Skull
Little Nahanni
Black Wolf
Tungsten North
Ragged Range
Clearwater Flood
Vera Wrigley
Flat Irvine
Prairie Creek
Flat Mary
Meilleur Tlogotsho
Caribou River
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Survey Grids 2002 - 2005
N
W
E
S
0
100Km

criteria. The technician inspected hairs visually and excluded glossy black guard hairs because prior testing indicated that such hairs have a 98% likelihood of being from black bears (Woods et al. 1999). Next, (s)he examined hairs under a dissecting microscope to determine if sufficient roots existed to merit extraction. Additionally, there was a likelihood of redundancy when a bear left hair on adjacent barbs as it walked under the wire. For those samples that occurred in a consecutive series of adjacent barbs on the barbwire corral sets and appeared to be the same color, the technician initially selected the best sample of every three in that series. All adjacent samples of different color as well as all non-adjacent hairs were selected. All selected samples were extracted using QIAGEN's DNeasy kits.

Species Determination. -- WGI has established from thousands of known grizzly and black bear samples across North America that the microsatellite marker G10J is diagnostic of species: grizzly bears have even-numbered alleles while black bears have odd-numbered alleles. WGI determined the species of all extracted samples and eliminated black bear samples from further analysis .

Marker Selection and Power. – Careful selection of genetic (microsatellite) markers optimizes the cost-effectiveness of identifying individual bears with high accuracy. The more variability between individuals at specific markers, the greater the ability to accurately identify individuals from field samples with a minimum combination of markers. From a set of 16 microsatellite markers that have been useful in DNA studies of bears, WGI examined data from study areas that bracketed Nahanni geographically: the Richardson Mountains to the north, Kluane National Park to the west, and the Prophet River area to the south (Paetkau et al. 1998b, Poole et al. 2001). They tested 10 of the more promising markers for variability among individuals by analyzing 12 hair samples that likely represented different individuals in the Nahanni survey. The six-locus marker system selected for this project (G10J plus five others) displayed an exceptional level of genetic variability with an average of 8.2 alleles observed per locus and an average expected heterozygosity (H_e) of 80% (Table 2-1). This surpassed WGI's threshold of 72% heterozygosity (roughly 1 in 1 million chance that two *unrelated* individuals exhibit the same genotype at these 6 loci). Only grizzly bears from Kluane National Park have exceeded this high level of genetic heterozygosity exhibited by Nahanni grizzly bears (Paetkau et al. 1998b, David Paetkau, personal communication).

Table 2-1. Average expected heterozygosity (H_e) and average number of alleles observed per locus (A) for six microsatellite markers selected for grizzly bear DNA analyses, Greater Nahanni Ecosystem, Northwest Territories. n = 31 individuals.

Marker	H_e	A
MU59	0.86	9
G1D	0.86	11
G10B	0.82	7
G10H	0.80	7
MU50	0.78	8
G10J	0.71	7
Mean	0.80	8.2

Microsatellite Analyses and Error-checking of Individual Identification. -- WGI personnel genotyped the grizzly bear hair samples for individual identity using a step-down process of exclusion to ensure rigorous and conservative determination of identity. First, they excluded samples that produced strong signals at only 2 of 5 loci (other than G10J) because such samples are prone to genotyping errors. Next, they conducted a second round of analysis in an attempt to produce more complete genotypes for samples that initially produced adequate signal at 3 or 4 loci. They eliminated all samples that still yielded only a 3-locus genotype. Next, they reviewed any samples that produced clear alleles at 4 loci; on a case-by-case basis, they decided whether to declare a unique individual. A second, highly experienced person confirmed scoring of all complete (5-locus) genotypes that comprised the final data set.

WGI conducted a thorough, computerized comparison of all pairs of identified individuals (unique genotypes) to check those that were suspiciously similar. All pairs of genotypes that differed at only two loci were scrutinized for possible error and re-analyzed if identification of an individual was based on only one available sample. All identified individuals that differed from another at just one locus were re-analyzed completely (including PCR, electrophoresis and scoring) -- regardless of how many samples had been observed with those particular genotypes. Finally, WGI selectively re-analyzed samples with unique genotypes when those genotypes were homozygous (same set of alleles) for more than half of the six loci (a possible sign of failure to amplify some alleles) -- even when those genotypes were not highly similar to other genotypes. All individual grizzly bears declared in this report differed at three or more of the six loci, thereby assuring that errors of identification were highly improbable.

Determination of Gender. -- For each individual grizzly bear thus identified, WGI selected 1 extraction of good quality to determine gender based on a size polymorphism in the amelogenin gene (Ennis and Gallagher 1994).

Modeling Distribution of the Grizzly Bear Population – Clayton Apps and John Weaver

In order to extrapolate the findings of our field survey beyond the specific survey grids, Clayton Apps (Aspen Wildlife Research, Calgary, Alberta) and I developed a model to predict the distribution and abundance of grizzly bears across the Greater Nahanni Ecosystem. We used the results of our extensive grizzly bear surveys and applied a multivariate/GIS modeling approach previously developed by Apps et al. (2004) to predict spatial patterns of grizzly bear abundance and distribution in British Columbia. Subsequently, we derived an equation for converting our index of bear occurrence to an estimate of density. We mapped variation in estimated density of grizzlies across the Greater Nahanni Ecosystem to assess relative contribution toward a more viable population of grizzly bears.

Landscape Attributes. – To characterize the landscape inhabited by grizzly bears, we used a 1:50,000 digital elevation model (DEM) and a land cover (LC) classification and map developed for the Greater Nahanni Ecosystem from Landsat imagery (Table 1-1) (Map 2) (see Stow and Wilson 2006 for details). For modeling purposes, we condensed the 10 vegetated LC classes into 8 vegetated LC classes (Table 2-2). We aggregated the ‘Montane Subalpine Open Woodland’ and ‘Montane Subalpine Savannah and Lichen’ into a single type called ‘Montane Subalpine Woodland’ (MSW). Also, we aggregated ‘Subalpine Lichen Tundra’ and ‘Subalpine Low Vegetation Tundra’ into a single type called ‘Alpine Tundra’ (AT). We developed an index of land cover diversity (Turner 1989) and added standard terrain variables (elevation, slope, and aspect). We derived an index of topographic ruggedness calculated as the standard deviation of elevations within a circular moving window (size varied with different scales of analysis). Also, we derived an index of terrain curvature which was the maximum rate of change of a slope curve through each pixel (Pellegrini 1995). Positive values corresponded to ridges and negative values to valleys.

Table 2-2. Independent variables considered for analysis of grizzly bear distribution in the Greater Nahanni Ecosystem, Northwest Territories, 2002-2005. See Table 1-2 for description of land cover types.

Variable	Description
LC_CSF	Closed spruce forest
LC_CDF	Closed deciduous forest
LC_MSLW	Montane spruce – lichen woodland
LC_PAW	Pine – aspen woodland
LC_MSW	Montane subalpine woodland
LC_SMS	Subalpine – montane shrubland
LC_AT	Alpine tundra
LC_RSI	Rock/snow/ice
LC_RB	Recent burns
LC_W	Wetland
LC_DIVERS	Land cover diversity index
ELEV	Elevation (m)
SLOPE	Slope (%)
ASP_SE	Northwest □ southeast aspect (0□100)
ASP_SW	Northeast □ southwest aspect (0□100)
TERRAIN	Topographic ruggedness index
CURVA	Terrain curvature index

Mutli-scale Design. – Animals use different-sized areas during various time periods. In recognition of these different spatial and temporal scales, we employed a multi-scale design for the analysis (consistent with methods of Apps et al. 2004 where possible). At level 1 – the broadest scale of analysis – we used a 12-km radius circle to circumscribe a 450-km^2 landscape which approximates the lifetime home range size of female grizzly bears in the Mackenzie Mountains (Miller et al. 1982). At level 2, we used an 8-km radius circle to depict a 200-km^2 landscape which corresponds to the average annual home range size of female grizzly bears in the Mackenzie Mountains (Miller et al. 1982). At level 3, we used a 2-km radius circle to delineate a 13-km^2 landscape which corresponds to the daily movements of female grizzly bears in mountainous landscapes (Gibeau et al. 2001).

We derived each variable at these 3 spatial scales by aggregating data using a moving window routine (Bian 1997). Pixels thus reflected each variable’s mean attribute value or proportional composition within a circular landscape surrounding each sampling station. For each variable and scale, we used *t*-tests to examine differences in landscape composition between stations where grizzly bears were and were not detected. In describing grizzly bear associations with landscape variables, we considered the significance (unadjusted) of *P*-values along with average differences between detections and non-detections. We compared landscape attributes associated with grizzly bear occurrence between the pre-berry (June) and berry (late July- early August) seasons. We determined the average value of each variable at sites where grizzly bears were detected (weighted according to detection frequency) and compared differences using t-tests.

Multivariate modeling using resource selection function. --We used multivariate analyses to define linear combinations of terrain and land cover variables that best explain and predict grizzly bear distribution and density across the Greater Nahanni Ecosystem (*sensu* Apps et al. 2004). We had two basic sets of variables available: (1) terrain characteristics and (2) land cover types. From the scientific literature on grizzly bears, our own knowledge and experience with grizzly bears, and conditions in Nahanni, we hypothesized the following relationships:

> H_1: Grizzly bears will be detected with higher probability at higher elevations (more grizzly bears in the mountains).
> H_2: Grizzly bears will be detected with lower probability in areas with more conifer cover (fewer grizzly bears in boreal forests).

Next, we inspected results of the univariate analysis to ascertain which variables (at which spatial scale) displayed significant differences between sites where grizzlies were detected and where they were not detected. *A priori*, we developed 32 candidate models to explain differences in detection of grizzly bears across the study area. We derived each candidate model using the software SPSS 12.0 (SPSS Inc. 2003).

We used an information-theoretic approach (Burnham and Anderson 2002) with Akaike's Information Criterion (AIC) to rank candidate models in terms of parsimony and prediction. To account for model uncertainty, we applied Akaike weights to average parameter coefficients among all competing models such that each model's contribution to prediction of grizzly bear occurrence or density was proportional to the evidence that it was best-fit to the data (Burnham and Anderson 2002). We recognized the possibility of non-linear relationships between grizzly bear occurrence and the independent variables. To minimize extreme and questionable predictions for under-sampled landscapes, we constrained variable values within the GIS to within 1 standard deviation of the mean as sampled at DNA hair-snag stations.

For the full sample of 225 stations, we treated grizzly bear detection per station as simply presence and absence. We used multiple logistic regression (MLR) to discriminate landscapes where grizzly bears were detected or not detected (Hosmer and Lemeshow 1989). Hair samples from the Broken Skull and Little Nahanni grids surveyed in 2004 were not available for DNA analysis. For the remaining subset of 193 stations, we had DNA confirmation of the number of different grizzly bears detected per station. We used least-squares regression (LSR) for these abundance data rather than zero-inflated Poisson regression (Jones et al. 2002) due to software limitations. It should be noted that we sampled a larger grid (3136-km^2) in the Ragged Range area in the first year compared to grids (1024-km^2) surveyed in subsequent years elsewhere across the ecosystem (Map 3). To achieve more balanced ecological representation, we weighted data from the Ragged Range grid on an equal basis with the other grids.

We then applied averaged-model parameters across the study area using algebraic overlays within the GIS. Each pixel thus reflected either the probability of detecting grizzly bear presence (MLR approach) or the probability of detecting a certain number of grizzly bears (1-5) at a site (LSR approach). In the latter case, we forced any predictions with a negative sign to zero. To summarize, these models predict relative potential of broad landscapes across the Greater Nahanni Ecosystem to support grizzly bears and the spatial distribution of the grizzly bear population.

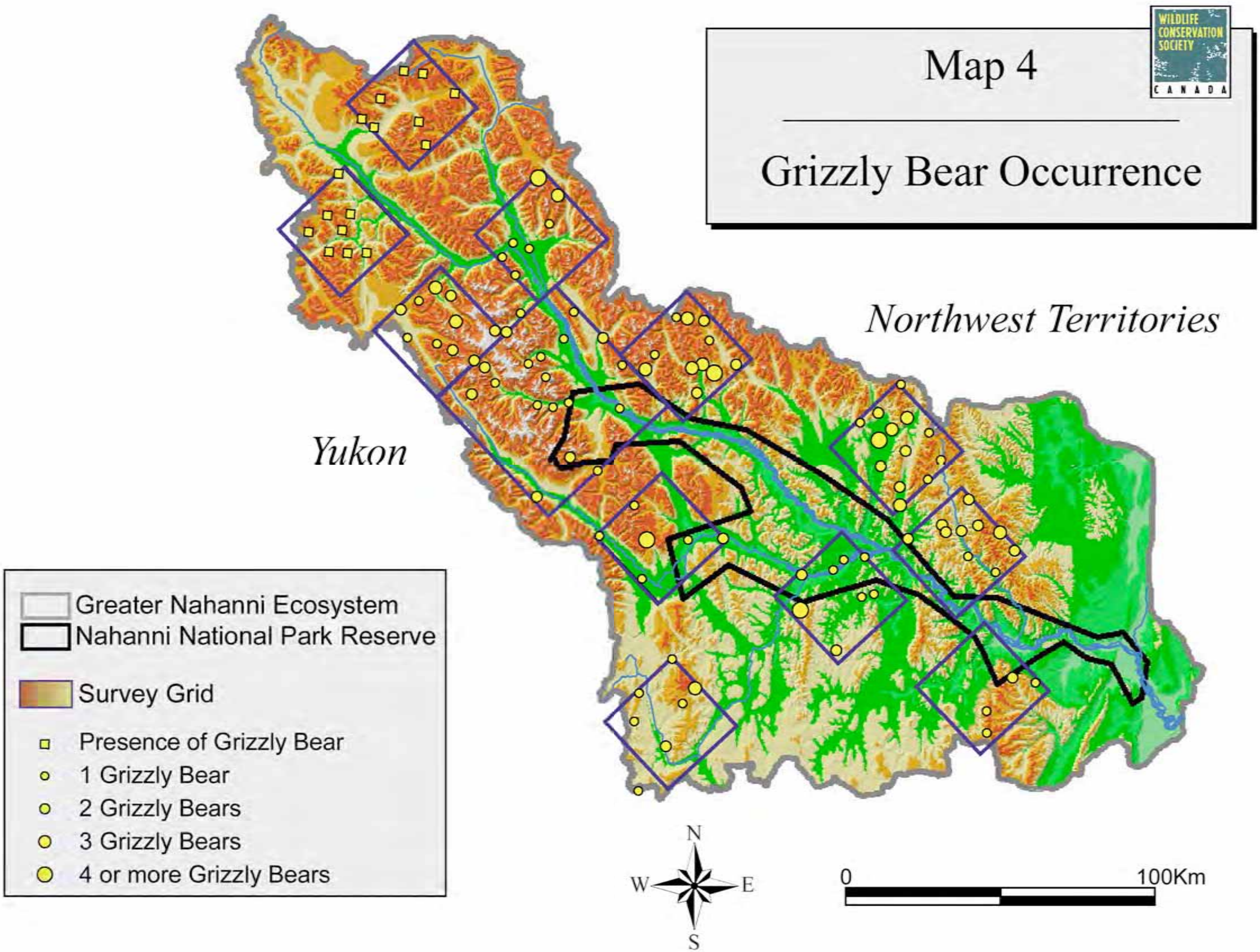
Spatial Inference of Grizzly Bear Density. -- Our initial purpose in surveying grizzly bears in the South Nahanni River watershed was to provide managers with cost-effective information on grizzly bear occurrence in specific areas of overlapping resource interest. Accordingly, we conducted only a single sampling session each year to derive an index of relative abundance. To estimate the size of a grizzly bear population, however, requires multiple sample sessions which was prohibitively expensive for an area as remote as Nahanni.

We conducted a meta-analysis of other grizzly bear studies to derive a relationship between number of individuals detected (from a single sample session) and the estimate of population size (from multiple sample sessions). We selected 3 studies that estimated density of grizzly bears and were similar to Nahanni in terms of size of grid cells, field protocols, DNA laboratory, and personnel: (1) the upper Columbia River (1996 survey; Boulanger et al. 2004), (2) the Foothills Model Forest and Jasper National Park, Alberta (Gordon Stenhouse and Garth Mowat, unpublished data), and (3) the Prophet River area of northern British Columbia (Poole et al. 2001). Upon the suggestion of the Prophet River researchers, we separated their data between Northern Boreal Mountains (NBM) and Taiga Plains (TP) ecoprovinces because <1% of bears were detected in both areas. We examined several empirical relationships between the number of individuals detected and the 'super' population estimate. We used the best-fit regression model to predict the number of grizzly bears in our combined sampling areas (Pearce and Ferrier 2000), then adjusted the estimate to account for likely bear movements beyond the small grids (lack of geographic closure). We distributed the estimated grizzly bear population across the Greater Nahanni Ecosystem according to our model of landscape potential (*sensu* Boyce and McDonald 1999, Apps et al. 2004).

RESULTS AND DISCUSSION

Occurrence of Grizzly Bears across the Greater Nahanni Ecosystem

June survey grids. -- We detected the presence of grizzly bears at 49% (111) of stations, while we did not detect grizzlies at the other 51% (114) stations (Table 2-3, Map 4). For stations where we had data on individual identity of bears, we detected 103 different grizzly bears (58 males, 45 females) (Table 2-3, complete Ragged Range grid). Interestingly, there was a high correlation between (a) the occurrence of grizzly bears and number of individual grizzlies ($Y = 1.071X + 0.518$; df = 1,8; $p = 0.0001$; $r^2 = 0.86$), and (b) the frequency of visits and number of individual grizzlies ($Y = 0.414X + 3.211$; df = 1,8; $p = 0.0001$; $r^2 = 0.89$) on these survey grids. This indicated that both presence of grizzly bears and frequency of visits were good predictors of the actual number of individual grizzlies detected at stations. On the 2 grids (Broken Skull and Little Nahanni) in the upper South Nahanni River watershed (Sahtu area), we collected grizzly bear hair at 8 stations each but the samples were destroyed inadvertently prior to DNA analysis. Using eq. a (above), we estimated that 9 individual grizzlies would have been tallied on each of those grids.



Map 4
Grizzly Bear Occurrence
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Survey Grid
Presence of Grizzly Bear
1 Grizzly Bear
2 Grizzly Bears
3 Grizzly Bears
4 or more Grizzly Bears
N
W
E
S
0
100Km

Table 2-3. Number of grizzly bears detected on 16-cell grids surveyed during a 20-day session in June, Greater Nahanni Ecosystem, Northwest Territories, 2002-2005.

Survey grid	Year	Number of stations with grizzly bears	Mean number of grizzly bears per cell	Number of individuals	Male:Female
Ragged Range[a]	2002	6	0.50	5	3:2
Prairie Creek	2003	10	1.19	10	6:4
Caribou River	2003	7	0.63	7	3:4
Tungsten North	2003	10	1.19	12	8:4
Black Wolf	2003	7	0.75	9	6:3
Clearwater Flood	2003	11	1.50	14	8:6
Broken Skull	2004	8	n.d.	n.d.[b]	n.d.
Little Nahanni	2004	8	n.d	n.d.[b]	n.d.
Meilleur Tlogotsho	2004	4	0.25	4	1:3
Vera Wrigley	2005	13	1.69	13	10:3
Flat Irvine	2005	6	0.63	8	5:3
Flat Mary	2005	8	0.81	10	3:7
Totals		98		92	53:39
Mean or Ratio		8.2	0.91	9.20	58:42
SE		0.7	0.14	1.04	
Range		4-13	0.25-1.69	4-14	

[a] The Ragged Range grid covered 3136 km^2 with 49 stations. For comparative purposes, we weighted the data for this grid proportionate to the size of other grids.
[b] We estimate 9 individuals based on regression equation; see text for details.

Table 2-4. Differences in land cover and terrain variables between landscapes at 3 spatial scales [a], where grizzly bears were and were not detected in the Greater Nahanni Ecosystem, Northwest Territories, 2002 – 2005.

	Level 1					Level 2					Level 3				
	Detection		Non-detection			Detection		Non-detection			Detection		Non-detection		
Variable	mean	SE	mean	SE	Diff [b]	mean	SE	mean	SE	Diff	mean	SE	mean	SE	Diff
lc_at	0.09	0.01	0.06	0.00	+++	0.08	0.01	0.05	0.00	+++	0.04	0.01	0.03	0.01	o
lc_cdf	0.00	0.00	0.01	0.00	o	0.00	0.00	0.01	0.00	o	0.00	0.00	0.01	0.00	o
lc_csf	0.05	0.00	0.04	0.00	o	0.05	0.00	0.04	0.00	o	0.02	0.00	0.03	0.00	-
lc_msw	0.22	0.01	0.18	0.01	++	0.23	0.01	0.18	0.01	+++	0.28	0.02	0.19	0.02	+++
lc_mslw	0.38	0.02	0.50	0.02	- - -	0.40	0.02	0.52	0.02	- - -	0.50	0.02	0.60	0.02	- - -
lc_paw	0.03	0.00	0.06	0.01	- -	0.03	0.01	0.06	0.01	- -	0.05	0.01	0.07	0.01	o
lc_rb	0.01	0.00	0.01	0.00	+	0.01	0.00	0.01	0.00	o	0.01	0.00	0.01	0.00	o
lc_rsi	0.20	0.02	0.11	0.01	+++	0.17	0.01	0.09	0.01	+++	0.07	0.01	0.02	0.00	+++
lc_sms	0.01	0.00	0.02	0.00	o	0.02	0.00	0.02	0.00	o	0.02	0.00	0.02	0.00	o
lc_w	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	-	0.01	0.00	0.01	0.00	o
lc_divers	1.49	0.03	1.36	0.04	+	1.44	0.04	1.28	0.04	++	1.04	0.03	0.90	0.04	++
elev	1367.68	21.07	1280.23	20.27	++	1363.80	22.07	1247.82	21.27	+++	1206.63	21.91	1111.34	23.24	++
slope	36.09	0.62	33.60	0.66	++	35.99	0.70	32.86	0.73	++	33.40	1.05	28.78	0.94	++
asp_se	50.57	0.16	50.54	0.18	o	50.64	0.21	50.76	0.27	o	51.64	0.40	51.56	0.56	o
asp_sw	49.65	0.19	49.57	0.20	o	49.52	0.25	49.67	0.30	o	50.57	0.51	49.11	0.80	o
terrain	29.67	0.51	27.59	0.54	++	29.51	0.57	26.97	0.59	++	27.38	0.86	23.55	0.77	++
curva	18.68	8.14	-42.52	8.64	+++	-2.06	7.75	-54.23	8.48	+++	-102.53	6.76	-77.99	6.82	-
curva-elev [c]	42806	11889	-40413	10637	+++	11188	10882	-54114	10147	+++	-122578	9015	-80575	8187	- - -
curva-terr [c]	814.88	256.53	-969.23	235.30	+++	142.59	221.14	-1243.8	228.40	+++	-3176.91	273.61	-1974.5	212.95	- - -

[a] Broad (level 1) to fine (level 3) spatial scales.

[b] Significance (*t*-tests) is indicated by +++/- - - ($P < 0.001$), ++/-- ($P < 0.01$), +/- ($P < 0.1$), or "o" ($P \geq 0.1$).

[c] Variable interaction.

Occurrence of grizzly bears varied up to 3-fold among grids (Table 2-3). Survey grids in the diverse mountain landscapes of north-central (Vera Wrigley, Clearwater Flood, and Prairie Creek) and northwest (Tungsten North) Greater Nahanni Ecosystem had the highest occurrence of grizzly bears (Table 2-3, Map 4). Grids in the southwest sector of the GNE that consisted mostly of boreal forest (Meilleur-Tlogotsho and Caribou River) had the lowest occurrence of grizzly bears, and those few bears were associated usually with mountainous terrain. Males comprised 58% of the grizzly bears visiting stations, which was not surprising given the wide-ranging movements of males, especially during the June breeding season.

At the broader landscape scales (levels 1 and 2), grizzly bears occurred at higher elevations in rugged landscapes in association with subalpine/alpine cover types during the early summer (Table 2-4). Grizzly bears did not occur as commonly in boreal forests dominated by the spruce-lichen woodland or pine-aspen types. At the finer scale (level 3), grizzly bears occurred more in the valleys at higher elevation. These results were consistent with our hypotheses.

Seasonal Variation in Occurrence. -- In 2005, we sampled the 3 grids (Vera Wrigley, Flat Irvine, and Flat Mary: see Map 3) both in June (pre-berry season) and again in late July-early August as berry foods became available. We tallied 31 grizzly bears during the first session and 21 grizzlies during the second session (Table 2-5). The number of male bears detected declined from 18 in session I to 9 in session II, whereas the number of females rose from 9 in early summer to 12 during the berry season. The greater number of males in the first session was not surprising as males likely roam farther during the June breeding season. The greater number of females detected at high elevation sites in the latter session may have represented a behavioral response to fewer males.

Table 2-5. Seasonal difference in number of grizzly bears detected on 3 survey grids, Greater Nahanni Ecosystem, Northwest Territories, June and late July - early August, 2005.

Survey Grid	Session I		Session II	
	Males	Females	Males	Females
Vera Wrigley	10	3	3	5
Flat Irvine	5	3	1	5
Flat Mary	3	7	5	2
Totals	18	13	9	12

At 30 (62%) of the 48 sites, there was no change in either presence (16) or absence (14) of grizzly bears between the 2 survey sessions, although the number of individuals decreased at several sites (9) where grizzlies still visited. During the berry season, grizzly bears visited 7 sites (15%) that they had not visited earlier in the summer, whereas they did not visit 11 sites (23%) again during the berry season.

On these 3 grids, there were few and only slight differences in landscape attributes at sites where grizzly bears visited during the pre-berry season and the berry season (Table 2-6). We chose not to include data from the berry season (session II) in the grizzly bear model because the seasonal differences were inconsequential and the data from June surveys were more representative of the entire Greater Nahanni Ecosystem.

Table 2-6. Differences in land cover and terrain variables between landscapes at 3 spatial scales [a], where grizzly bears were detected during pre-berry season (June: session I) versus berry season (late July-early August: session II) on 3 survey grids within the Greater Nahanni Ecosystem, Northwest Territories, 2005. A positive difference indicates a greater mean value or proportional composition of a given variable during the berry season relative to the pre-berry season.

	Level 1					Level 2					Level 3				
	Pre-berry Season		Berry Season			Pre-berry Season		Berry Season			Pre-berry Season		Berry Season		
Variable	mean	SE	mean	SE	Diff [b]	mean	SE	mean	SE	Diff	mean	SE	mean	SE	Diff
lc_at	0.05	0.01	0.05	0.01	o	0.03	0.01	0.03	0.01	o	0.01	0.01	0.01	0.01	o
lc_cdf	0.00	0.00	0.00	0.00	+	0.00	0.00	0.00	0.00	+	0.00	0.00	0.00	0.00	o
lc_csf	0.05	0.01	0.04	0.00	o	0.06	0.01	0.04	0.01	o	0.05	0.01	0.03	0.01	+
lc_msw	0.14	0.02	0.15	0.02	o	0.13	0.02	0.14	0.02	o	0.08	0.02	0.12	0.02	o
lc_mslw	0.55	0.03	0.55	0.03	o	0.57	0.03	0.59	0.03	o	0.68	0.04	0.66	0.03	o
lc_paw	0.06	0.01	0.04	0.01	+	0.06	0.01	0.04	0.01	o	0.05	0.02	0.03	0.01	o
lc_rb	0.03	0.00	0.02	0.00	o	0.03	0.01	0.02	0.00	+	0.01	0.00	0.00	0.00	++
lc_rsi	0.11	0.02	0.13	0.02	o	0.09	0.02	0.12	0.02	o	0.09	0.02	0.11	0.02	o
lc_sms	0.01	0.00	0.01	0.00	o	0.01	0.00	0.01	0.00	o	0.00	0.00	0.01	0.00	o
lc_w	0.00	0.00	0.00	0.00	o	0.00	0.00	0.00	0.00	o	0.00	0.00	0.00	0.00	+
lc_divers	1.28	0.07	1.24	0.06	o	1.19	0.06	1.12	0.06	o	0.75	0.05	0.76	0.05	o
elev	1080.78	29.89	1110.60	26.50	o	1061.36	31.50	1104.58	33.46	o	890.50	35.64	954.52	39.64	o
slope	31.25	0.74	31.52	0.71	o	31.14	0.94	30.90	0.94	o	25.97	1.86	25.28	1.56	o
asp_se	50.64	0.52	50.96	0.36	o	50.03	0.59	50.64	0.41	o	52.86	0.81	53.10	0.80	o
asp_sw	49.28	0.47	50.12	0.40	o	50.31	0.63	50.52	0.52	o	47.94	1.37	51.02	0.88	-
terrain	25.58	0.61	25.86	0.61	o	25.61	0.78	25.28	0.76	o	21.22	1.50	20.74	1.29	o
curva	-22.17	12.53	-16.06	12.99	o	-32.22	19.22	-11.02	18.49	o	-95.06	9.32	-82.18	8.58	o

[a] Broad (level 1) to fine (level 3) spatial scales.

[b] Significance (*t*-tests) is indicated by +++/- - - ($P < 0.001$), ++/-- ($P < 0.01$), +/- ($P < 0.1$), or "o" ($P \geq 0.1$).

[c] Variable interaction.

Model of Grizzly Bear Distribution and Density across the Greater Nahanni Ecosystem

The model we developed predicted the distribution of grizzly bears across the entire Greater Nahanni Ecosystem for the early summer period. It would be inappropriate to infer habitat selection by individual animals at finer scales. For example, some areas predicted to have a high density of grizzly bears could include sites of low suitability that may be used rarely by grizzly bears. Conversely, some broad areas predicted to have a low density of grizzlies may have local enclaves used intensively at times (such as the Rabbitkettle Lake area during berry season).

The top models (MLR) for predicting the occurrence of grizzly bears across the Greater Nahanni Ecosystem included the 'negative' or inverse variables of boreal forest cover types at broad scales along with the 'positive' variables associated with subalpine/alpine cover types and land cover diversity at broader scales and terrain features (essentially curvature) at finer scales (Table 2-7). Basically, the most influential factors were those that indicated where grizzly bears would *not* occur – the boreal forests. Some modelers suggest that models with Δ AIC <2 have 'strong' support relative to competing models (Anderson and Burnham 2002). The top 3 MLR models met this criterion and contributed 50% to the total inference (*w*) of all the competing models (Table 2-7). All the models correctly classified occurrence of grizzly bears in about 60% of cases.

The same key variables of (1) boreal forests (negative influence) and diversity of land cover types at broader scales, and (2) terrain curvature and slope at finer scales also influenced the number of grizzly bear detections at stations (LSR models) (Table 2-8). It's interesting, however, that the relative contribution of each model to multi-model inference was more evenly distributed among the various top models (i.e., no single model was dominant) and that models were less parsimonious (i.e., incorporated more factors). The top 7 models met the suggested criterion for 'strong' support but contributed only 46% to the total inference (*w*) of all the competing models (Table 2-8).

We combined the MLR and LSR models to project the probability of grizzly bear occurrence across the Greater Nahanni Ecosystem. Specifically, we re-scaled the LSR model to a 0→1 continuum, consistent with the MLR output. Each pixel thus reflected the midpoint between the predictions of the 2 models.

Areas with a higher likelihood ($P > 0.5$) of grizzly bear occurrence included the mountains and higher valleys along the north and northwest sectors of the ecosystem, mostly outside the present Park (Map 5). According to this model, the area extending from the upper Clearwater River eastward past upper Prairie Creek had the highest occurrence of grizzly bears. In contrast, the boreal forests south and east of the Park had a comparatively low likelihood of grizzly bear occurrence.

From our meta-analysis of several grizzly bear studies, we compared a variety of survey detection parameters with those for Nahanni (Table 2-9). We explored several empirical relationships between number of individuals detected (from a single sample session) and the estimate of 'super' population size (unadjusted for edge effect) and derived the following regression equations:

Table 2-7. Top 10 competing multiple logistic regression (MLR) models of factors influencing the occurrence of grizzly bears across the Greater Nahanni Ecosystem, Northwest Territories, 2002–2005. Models are ranked according to Akaike Information Criterion (AIC). Akaike weights (*w*) indicate the contribution of each model to multi-model inference of parameter coefficients.[a] Model fit is indicated by the Nagelkerke coefficient of determination (R_N^2) and classification success (CS). A constant is included in all models.

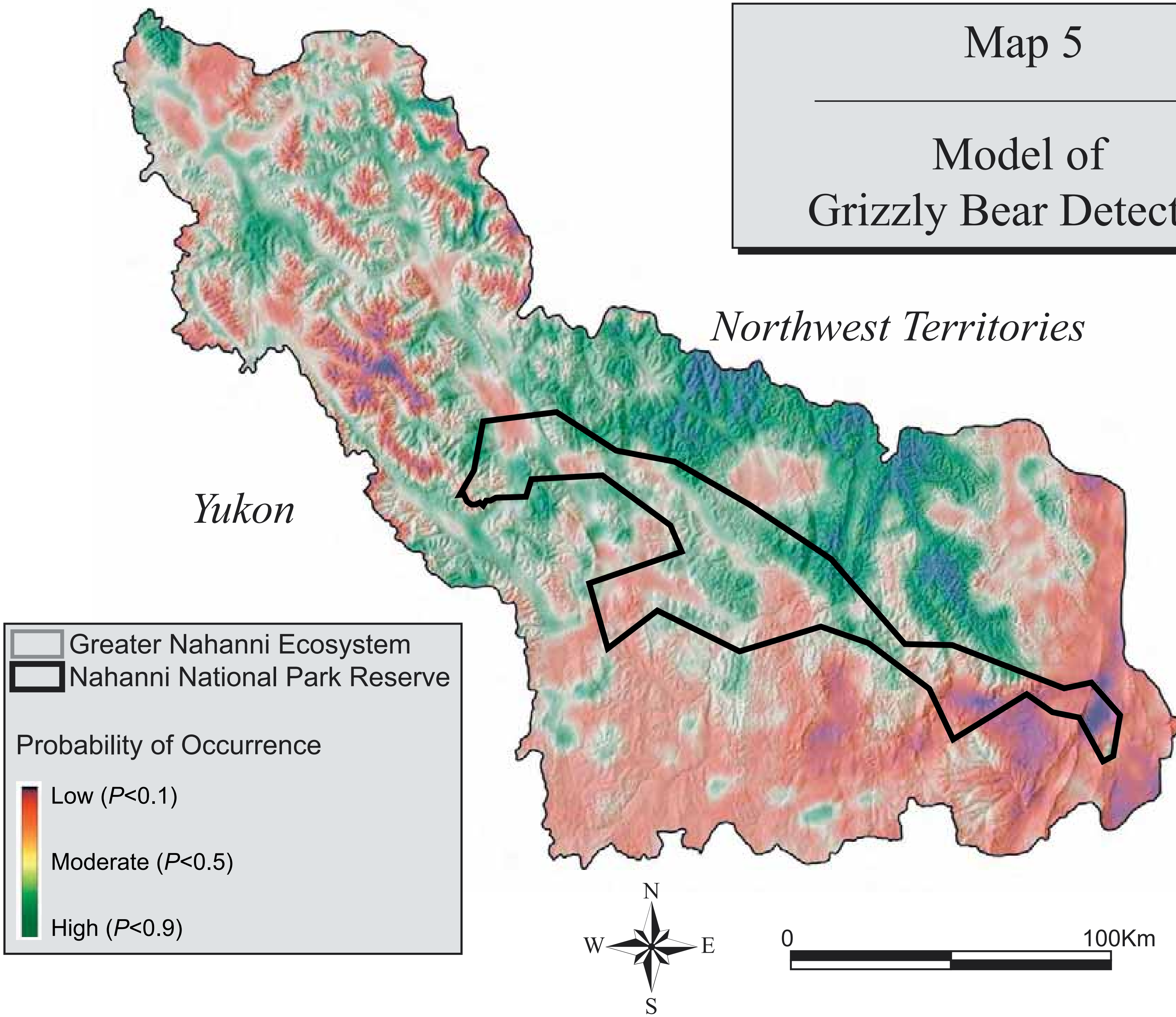
Model Rank	V1	V2	V3	V4	V5	V6	V7	Δ AIC	*w*	R_N^2	CS
1	LC_MSLW^2	LC_PAW^2						0.0	0.285	0.103	59.9
2	LC_AT^2	LC_MSLW^2	LC_PAW^2					2.0	0.105	0.103	60.5
3	LC_MSW^3	LC_MSLW^2	LC_PAW^2					2.0	0.105	0.103	59.9
4	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2			2.2	0.093	0.115	59.2
5	CURVA^3	TERRAIN^3	SLOPE^3	LC_DIVERS^2	LC_MSLW^2	LC_PAW^2		2.5	0.083	0.121	61.1
6	CURVA^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2		3.1	0.059	0.119	61.8
7	TERRAIN^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2		3.9	0.040	0.116	60.5
8	SLOPE^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2		3.9	0.040	0.116	59.9
9	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2				4.0	0.039	0.103	60.5
10	CURVA^3	TERRAIN^3	SLOPE^3	LC_DIVERS^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2	4.3	0.032	0.121	61.7

Table 2-8. Top 10 competing least squares regression (LSR) models of factors influencing grizzly bear population distribution across the Greater Nahanni Ecosystem, Northwest Territories, 2002–2005. Models are ranked according to Akaike Information Criterion (AIC). Superscripts denote the spatial scale (level) at which variables are represented. Akaike weights (*w*) indicate the contribution of each to multi-model inference of parameter coefficients.[a] Model fit is indicated by the coefficient of determination (R^2). A constant is included in all models.

Model Rank	V1	V2	V3	V4	V5	V6	V7	Δ AIC	*w*	R^2
1	CURVA^3	TERRAIN^3	SLOPE^3	LC_DIVERS^2	LC_MSLW^2	LC_PAW^2		0.0	0.112	0.093
2	LC_MSLW^2	LC_PAW^2						0.3	0.096	0.051
3	SLOPE^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2		1.2	0.062	0.087
4	TERRAIN^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2		1.4	0.056	0.086
5	CURVA^3	TERRAIN^3	SLOPE^3	LC_DIVERS^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2	1.5	0.053	0.096
6	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2			1.9	0.044	0.074
7	CURVA^3	TERRAIN^3	SLOPE^3	LC_DIVERS^2	LC_AT^2	LC_MSLW^2	LC_PAW^2	2.0	0.041	0.093
8	LC_AT^2	LC_MSW^3						2.2	0.038	0.041
9	LC_AT^2	LC_MSLW^2	LC_PAW^2					2.2	0.037	0.052
10	CURVA^3	SLOPE^3	LC_DIVERS^2	LC_AT^2	LC_MSW^3	LC_MSLW^2	LC_PAW^2	2.3	0.036	0.092

Map 5

Model of Grizzly Bear Detection



(Eq. 1) $Y = 73.964\, X_1 + 3.094$ $r^2 = 0.73$

Where Y = estimate of the 'super' population

X_1 = number of grizzly bears detected per cell during session I

(Eq. 2) $Y = 96.635\, X_2 + 0.824$ $r^2 = 0.84$

Where Y = estimate of the 'super' population

X_2 = number of grizzly bears detected per cell on average for all sessions

(Eq. 3) $Y = 1.235\, X_3 - 0.950$ $r^2 = 0.98$

Where Y = estimate of the 'super' population

X_3 = number of grizzly bears detected per 1000 days (CPUE)

The best correlation used the catch-per-unit-effort (CPUE) which adjusts for the length of survey session. Sessions in the other studies varied 10-14 days in length whereas our session in Nahanni lasted 20 days. A correction for length of session assumes that the scent attractant was working throughout that time. For the 3 grids in Nahanni in 2005, we detected 14 individual grizzlies during the 30-day period between session I and session II when no fresh lure was applied. Five of these bears had not been detected during the initial session, which suggests that they had no prior experience at the sites. This shows that bears were still visiting stations sometime 21-50 days after initial scenting. Thus, we believe that bears were still attracted to scented stations through day 20.

Using equation 3 and the Nahanni data for 2002-2005 (X_3 = 28.8 from 92 grizzly bears detected in 3200 sample days) yielded an estimated density of 34.6 grizzly bears per 1000 km^2. This estimate was inflated, however, because the small grids were not geographically closed as bears certainly could move off the grids during a 20-day period. Hence, the unadjusted estimate did not account realistically for the area actually used by bears that were detected within the relatively small grids.

To adjust the area actually sampled by grids, one standard approach has been to add a buffer strip to the edge of the grid. We measured the maximum straight-line distance between locations for grizzly bears detected >1 time. The average maximum distance was 16.1 km for males (n = 28) and 8.8 km for females (n = 19). Weighting this by the proportion of each gender in the sample of detected animals yielded a distance of 13.1 km, or a radius of 6.55 km. This expanded the size actually sampled by each grid from 1024 km^2 to 2034 km^2 for an increase of 1.99-fold. Obviously, this was a minimum estimate (especially for males) because the determination of distance was constrained by the size of the grid. We divided the estimated density of 34.6 grizzly bears per 1000 km^2 by the derived factor of 2.0 (rounded) to adjust the estimated density to 17.3 bears per 1000 km^2 within the 2002-2005 survey grids.

According to a variety of detection indices, we had high levels of grizzly bear visits in Nahanni compared to the reference study areas (Table 2-9).

- 'Incidence' refers to the percent of stations visited by a grizzly bear. In Nahanni, 49% of the stations were visited by grizzly(s) compared to 13-22% of the stations in session 1 (18-22% across all sessions) for the reference study areas.
- 'Occurrence of Visits' refers to the number of grizzly bears per cell, independent of individual identity (i.e., the same individual can appear at >1 station). Occurrence of Visits in Nahanni was 0.87 compared to 0.31 (range 0.24-0.38) in session 1 for the reference studies (0.32 across all sessions).
- 'Visit Rate' refers to the average number of visits by an individual bear. In Nahanni, individual bears averaged 1.60 visits compared to 1.22 (range 1.14-1.28) visits per bear during session 1 (1.56 across all sessions).
- 'Occurrence of Individual Bears' refers to the number of unique individuals detected per cell. In Nahanni, the number of individuals per cell was 0.50 compared to 0.25 (range 0.21-0.28) during session 1 and 0.27 (range 0.26-0.28) across sessions for the reference areas.

The higher rates of scent-station visits for the Nahanni grizzly bear survey compared to the other studies might suggest that the estimated density also should be higher. This interpretation certainly is possible. We note, however, that Nahanni grizzlies – especially males -- ranged very widely both within and occasionally between grids. The net effect would be to inflate the visitation parameters but not necessarily the estimated density.

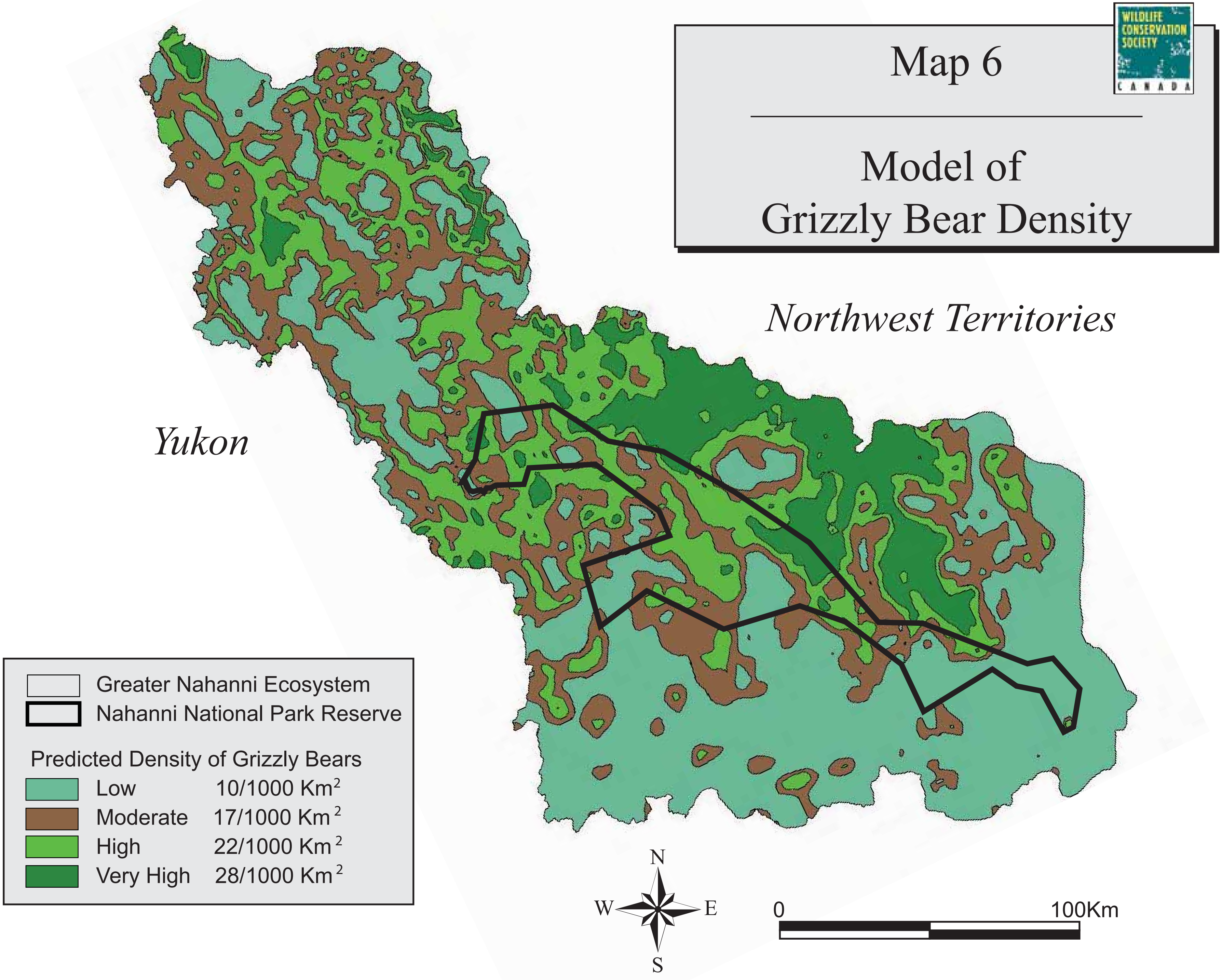
The estimated density of 17.3 grizzly bears /1000 km^2 for the entire Nahanni ranked below the Northern Boreal Mountains of the Muskwa-Kechika (34.7) but comparable to the West Slopes area including parts of Glacier and Yoho National Parks (18.8) and above the Yellowhead area including part of Jasper National Park (11.4) and the boreal plains east of the Alaska Highway in northeast British Columbia (10.3). The estimated density of 9-11 grizzly bears/1000 km^2 in the northern sector of the Mackenzie Mountains was not directly comparable because it was derived using very different techniques (Miller et al. 1982).

We depicted distribution of the grizzly bear population using 4 classes of density: low, moderate, high, and very high (Map 6). The model projected the highest density of grizzly bears to occur in the mountainous areas north of the park boundary between Prairie Creek and Clearwater Creek. It predicted a mix of moderate to high grizzly densities throughout much of the northern South Nahanni River watershed above the Flat River and the lowest densities in the boreal forests in the south-southwest sector of the Ecosystem. The few areas of moderate grizzly density in the boreal forests were associated with isolated mountain ranges. Other studies have also reported higher densities of grizzly bears in mountainous areas and lower densities in boreal forests (Nagy and Haroldson 1989, Poole et al. 2001, Apps et al. 2004, Mowat et al. 2005).

The model also suggested low density of grizzly bears along the major river valleys (South Nahanni and Flat) of the Greater Nahanni Ecosystem. We are not convinced that this is true, especially for the river valleys above the confluence of the Flat and Nahanni Rivers where we did detect grizzlies at several grid stations (Map 4). Also, we have documented several grizzly bears using the Rabbitkettle Lake area adjacent to the South Nahanni River throughout the

Table 2-9. Various parameters of four grizzly bear surveys and populations compared with those for the Greater Nahanni Ecosystem, Northwest Territories.

Parameter	West Slopes	Yellowhead	Prophet NBM	Prophet TP	Nahanni
Year	1996	1999	1998	1998	2002-2005
Study Area (km^2)	4096	5184	3054	5413	10240
Cell Size (km^2)	64	81	81	81	64
No. Cells	64	64	38	65	160
No. Sessions	4	3	5	5	1
Total Stations	256	192	190	325	160
Session Length (Days)	10	14	12	12	20
Unit Effort (Station Days)	2560	2688	2280	3900	3200
Cells w/Griz S_1 (%)	10 (16)	14 (22)	8 (21)	5 (8)	82 (51)
Cells w/Griz S_x (%)	11 (18)	13 (21)	14 (37)	8 (12)	
Min. Griz Total	54	40	70	34	92
%Male:%Female S_1	56:44	50:50	53:47	50:50	55:45
No. Griz/Cell S_1 (independent visits)	0.31	0.38	0.47	0.11	0.91
No. Individual Griz/Cell S_1	0.25	0.28	0.42	0.09	0.58
No. Individuals (from MinTotal)/Cell/Session	0.21	0.21	0.37	0.10	0.58
Catch Per Unit Effort (CPUE) (per 1000 days)	21.1	14.9	30.7	8.7	28.8
Pop Est ('Super')	108	77	113	60	
95% CI	78-177	52-138	91-148	42-104	
Density (per 1000 km^2)	26.3	14.9	37.0	11.1	34.9
Adj Density (per 1000 km^2)	18.8	11.4	34.7	10.3	17.5
%Edge Cells: %Core Cells	44:56	38:62	35:65	35:65	75:25


Map 6
Model of Grizzly Bear Density
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Predicted Density of Grizzly Bears
Low 10/1000 Km2
Moderate 17/1000 Km2
High 22/1000 Km2
Very High 28/1000 Km2
N
W
E
S
0
100Km

summer, but particularly during late July and August when soapberries (*Shepherdia canadensis*) become ripe. We present and discuss supplemental data for these areas in subsequent sections.

The 'low' density class comprised 41% of the area yet only 25% of the population, whereas the combination of 'moderate, high, and very high' density classes covered 59% of the area but yielded 75% of the estimated population (Table 2-10). Thus, the diverse mountain-valley landscapes mostly north and northwest of the present boundaries of Nahanni National Park Reserve make an especially important contribution toward a viable population of grizzly bears. In contrast, the boreal forest that comprises a large area across the widest section of the GNE contributed fewer grizzly bears per unit area.

Table 2-10. Population attributes for 4 classes of grizzly bear density, Greater Nahanni Ecosystem, Northwest Territories.

Class	Percent Area	Percent Density	Area (km^2)	Estimated Density	Estimated Population
Low	41	25	16, 378	10.3	168
Moderate	27	28	10, 624	17.5	188
High	21	28	8, 462	22.1	185
Very High	11	19	4, 395	28.2	124
Total	100	100	39, 859	16.7	665

Grizzly Bear Occurrence along the South Nahanni River

During canoe trips down the South Nahanni River, Park personnel and I collected bear hair from natural rub trees on a rather systematic basis. We documented 21 individual grizzly bears (19 males: 2 females) at 15 sites, usually at the confluence of a tributary (Map 7). The majority was found along the middle section of the South Nahanni River from Flood Creek up to the Little Nahanni River. Although the date when bears made these rubs could not be determined, the findings clearly demonstrated that grizzly bears – particularly males – travel the main South Nahanni valley sometime during the year. Importantly, we collected hair from 5 of these individual bears at the scented stations on the survey grids; this revealed a spatial connection between the river valley and the mountain landscapes. Also, we gleaned hair from natural rub trees on an opportunistic basis at 9 sites elsewhere in the Greater Nahanni Ecosystem and identified another 11 grizzly bears (9 males: 2 females) (Map 7). Rubs by male grizzly bears comprised 88% of these 32 samples which underscores the wide-ranging movements of male bears and perhaps a stronger behavioral tendency to scent-mark trees (see section below on bear movements).

Grizzly Bear Occurrence along Rabbitkettle Lake Trails

During 2002-2005, Park wardens and I collected 125 samples of grizzly bear hair on the natural rub trees along the Rabbitkettle Lake trail over to the tufa mounds, and the WGI lab made individual identification on 112 (90%) of these samples. All of the rub trees were white spruce that averaged 13 cm dbh (range 5-33 cm). Although each of the 25 wired trees was rubbed at least once during the period, grizzly bears rubbed more on certain trees along certain segments of the trail (Map 8a). Rub trees # 1-3 near the South Nahanni River landing, rub trees # 8-10 near Emerald Lake, and rub trees # 20-22 near Rabbitkettle River received high use. One

Map 7

Grizzly Bear Rub Trees

common characteristic appeared to be proximity to other travel routes (along the rivers); the spruce forest near Rabbitkettle River also has a very lush understory of horsetail (*Equisetum arvense*), a favorite food of bears.

An average of 7 different grizzly bears (range 5-8) used the Rabbitkettle Lake trail each of the 4 years (Map 8b). Altogether, a total of 16 different grizzly bears walked this trail during 2002-2005. The number of grizzly bears per month averaged 1.0-1.5 during April – June but rose to 2.75 and 2.5 in July and August, when the local crop of soapberry/buffaloberry became ripe. Interestingly, when the soapberry production in 2005 dropped by 42% from the previous year, several grizzly bears paid a visit during berry season but apparently moved elsewhere. Four new bears were among those that passed through Rabbitkettle that year. There are a number of intra- and inter-species behavioral relationships that I will be describing in a separate paper.

Thus, the Rabbitkettle Lake area served both as a (1) cross-roads for bears traveling through in early summer, and (2) a destination for bears coming to feed on soapberries later in summer.

Movements of Individual Grizzly Bears

In the absence of telemetry data from radio-collared animals to derive home ranges, data on multiple locations of individual bears can suggest the magnitude of space they may use in the Nahanni country. The hair samples collected by our team at various sites (grid stations and natural rub trees at Rabbitkettle Lake, along the South Nahanni River, and elsewhere) enabled me to identify certain individual grizzly bears at multiple locations. I 'connected the dots' to plot straight-line distances for 16 examples involving 14 individual male bears (Map 9). The average distance was 52.3 km (± 4.4 km SE), while the maximum distance was 91 km. Eight of these cases (6 bears) illustrate how the Rabbitkettle Lake area functioned as a hub for bears traveling from all directions. These and the other line segments clearly show movements of bears across the present boundary of Nahanni National Park Reserve (Map 9). Using the average distance of 52.3 km as the diameter of a circular home range, I computed size of a hypothetical home range to be 2147 km^2. This indicates that male grizzly bears roamed far and wide across the Greater Nahanni Ecosystem. For the northern Mackenzie Mountains, Miller et al. (1982) also reported long movements and large home ranges. They recorded movements of 155 km by one radio-collard male bear and 94 km by another male. For three adult females with multiple years of telemetry data, they calculated estimates (Minimum Convex Polygon) of home ranges of 409 km^2, 457 km^2, and 560 km^2.

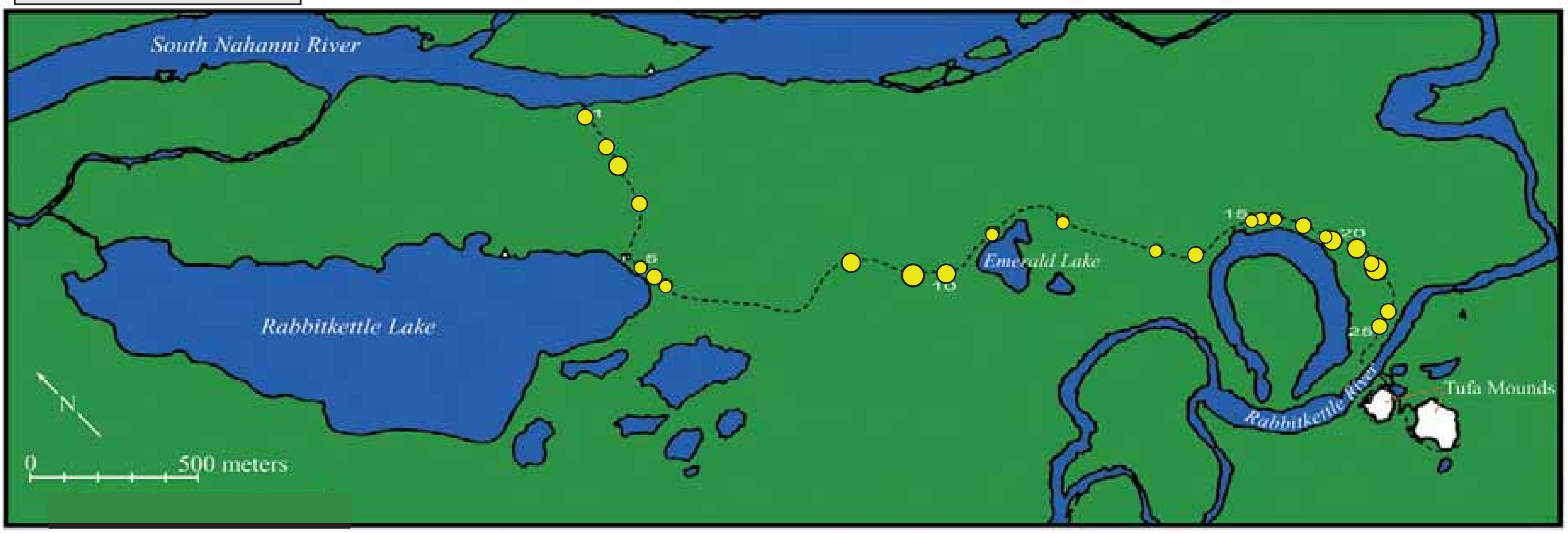
Grizzly Bear Visits 2002 - 2005

- 1 - 3
- 4 - 6
- 7 - 9
- 10 - 12

10 rub tree number
trail
warden cabin

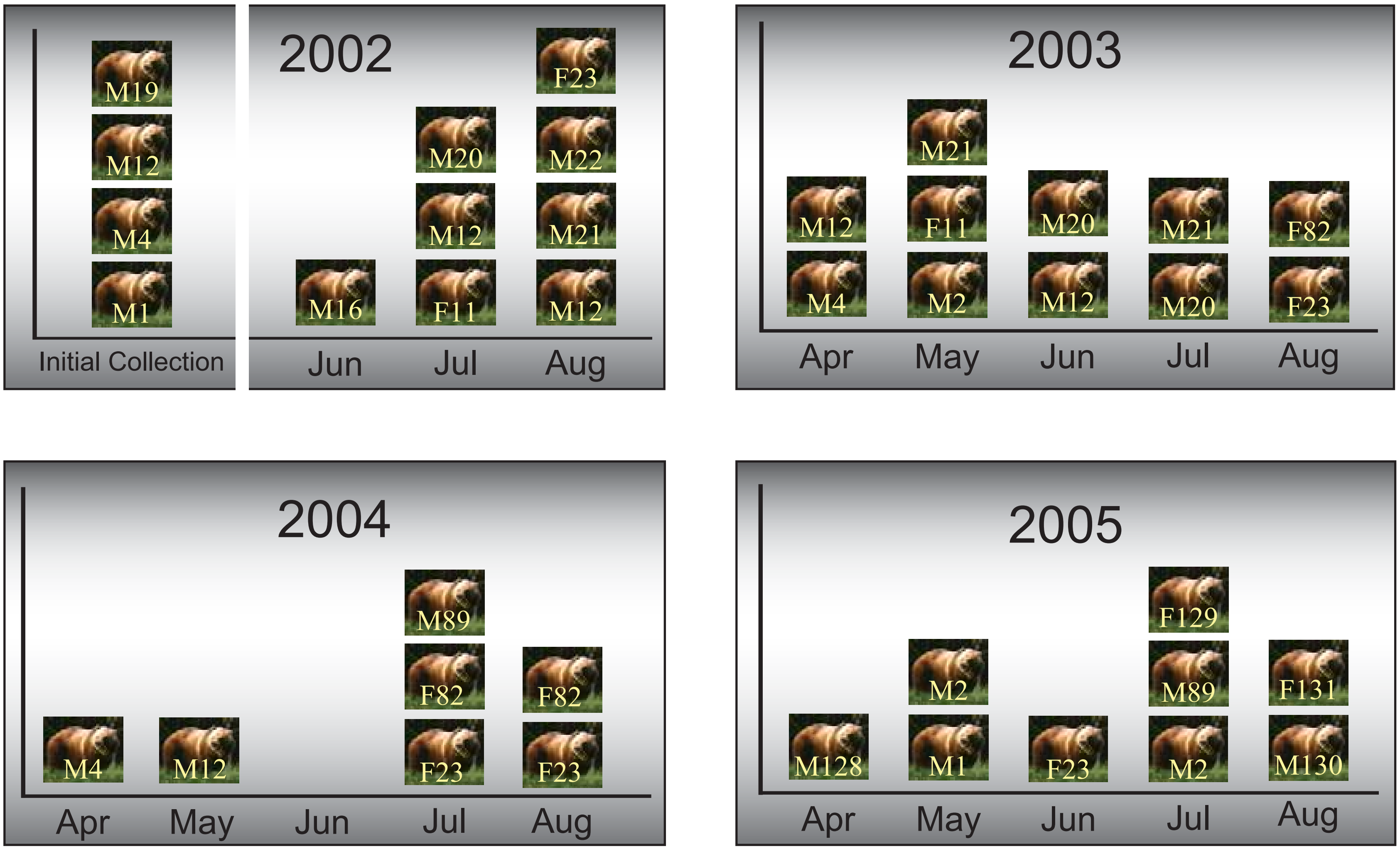
Map 8a

Grizzly Bear Rub Trees Rabbitkettle Lake Trail



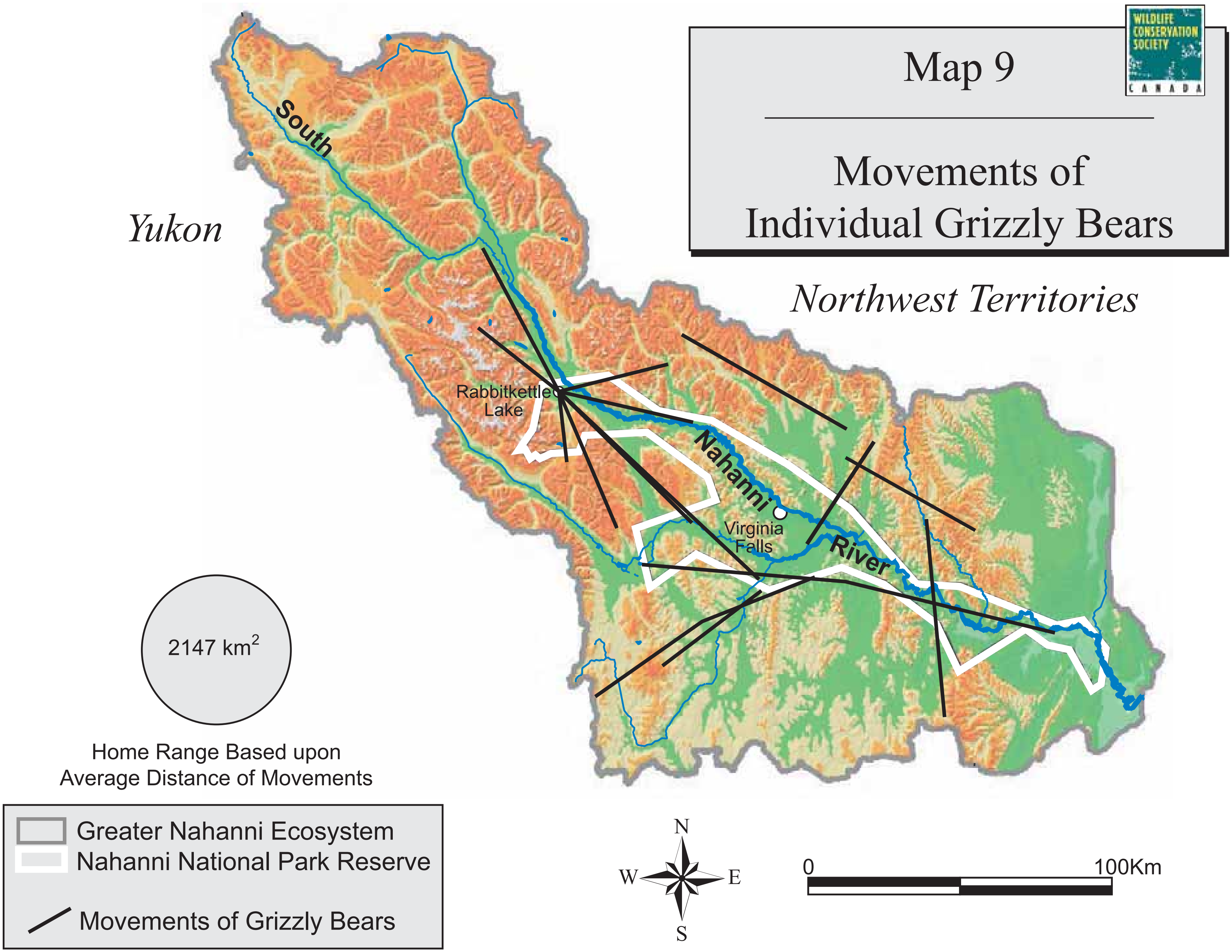
Map 8b

Monthly Visits by Grizzly Bears Rabbitkettle Lake Trail 2002 - 2005



Map 9

Movements of Individual Grizzly Bears



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Chapter 3 - DALL'S SHEEP

INTRODUCTION

Dall's sheep possess moderate resistance to human impacts but low resiliency if a local population is reduced or extirpated. Dall's sheep are habitat specialists that use alpine tundra habitat near cliffs which provide adequate escape from predators. They appear well-adapted to the treeless landscapes that characterized the periglacial environments of the Pleistocene period (Geist 1971). In winter, sheep select foraging sites where snow accumulation is shallow due to light snowfall or high wind (Nichols and Bunnell 1999). Sheep may travel long distances to mineral licks to obtain crucial mineral nutrients (Jones and Hansen 1985), and such sites may influence the distribution of 'nursery' bands of ewes, lambs, and yearlings during summer (Simmons 1982, Nichols and Bunnell 1999). Dall's sheep do not have much flexibility in switching habitats and occur in discrete 'islands' or patches of suitable habitat. Because suitable sites represent stable plant communities and enduring terrain features, mountain sheep (particularly females) tend to be highly philopatric ('stay at home') and not disperse very far (Geist 1971). Thus, sheep populations may be structured spatially and genetically by groups of related females occupying distinct, traditional ranges (Bleich et al. 1996). Adult ewes usually have a single lamb, which rather limits their capacity for reproductive response (compared to moose). Dall's sheep appear capable of habituating to harmless human activities that are routine in space and time (Nichols and Bunnell 1999).

Dall's sheep still occupy their historic range at historic population levels (Bowyer and Leslie 1992) and are not listed as a species at risk. Biologists have estimated that 14,000-26,000 sheep occur in the Mackenzie Mountains, where they are highly sought by non-resident hunters (Veitch et al. 1998).

METHODS AND DATA SOURCES

Over past millennia, Dall's sheep have played out an evolutionary 'tale' in the ecological 'theater' of the Mackenzie Mountains. To appreciate the legacy of the Mackenzie Mountains (including the Nahanni region) as ancient refugia, I have reviewed recent scientific evidence (Worley et al. 2004, Loehr et al. 2005).

To depict the general distribution of Dall's sheep in the Greater Nahanni Ecosystem, I compiled information from a wide variety of sources. Norman Simmons pioneered surveys of Dall's sheep in the Mackenzie Mountains during 1966-1973 (Simmons 1982). Most of his efforts centered on the northern part of the Mackenzie Mountains, with surveys in the southern Mackenzies (Greater Nahanni Ecosystem) limited primarily to the Tł´ogotsho or Tlogotsho Plateau. Although Simmons depicted the summer and winter distribution of sheep throughout the Mackenzie Mountains on large-scale maps in his 1982 report (Figs. 2 & 7, respectively), apparently there are no archived overlays that match these maps exactly (Alasdair Veitch, personal communication). I used available year-round data from the Norman Simmons collection (scans and digitized points, courtesy of the Yellowknife office of WWF Canada), his published maps (Simmons 1982), and information in an earlier report (Scotter et al. 1971).

I also incorporated 567 year-round observations of sheep recorded by Nahanni Park wardens on boundary and river patrols during 1977-1989 (Comin 1981, NNPR files) and summer surveys of selected areas by Park wardens (Kozachenko 1983) and wildlife biologists with the Government of the Northwest Territories (Case 1989, Danny Allaire, Nic Larter, and Garth Hildebrand, personal communication), and environmental assessment reports (Ker, Priestman, and Associates 1980). In summer 2005, Park wardens and I conducted helicopter and ground surveys of Dall's sheep on the Nahanni and Ram Plateaus of the Greater Nahanni Ecosystem. The amount of data available varied substantially between sheep ranges.

I delineated the year-round ranges of Dall's sheep across the Greater Nahanni Ecosystem by digitizing a polygon around a spatially-distinct cluster of sheep locations. With a GIS-derived map of topographic complexity as a reference to cliff features, I traced the boundary along elevation contour lines that separated alpine areas from forested subalpine areas. In the Mackenzie Mountains, winter range typically is a smaller subset of the summer range (Simmons 1982). These ranges depicted here represent a general (rather than a definitive) distribution of sheep; there may be locales within the ranges that do not support sheep and small bands of sheep may occur outside the depicted ranges.

Finally, I present information on a unique phenomenon that we discovered in the course of our sheep surveys in 2005.

RESULTS AND DISCUSSION

Dall's sheep in the Mackenzie Mountains: an Ice Age Legacy

Dall's sheep in the Mackenzie Mountains, especially at the southern end in the Nahanni region, provide an interesting legacy from the last ice age. During the latter period of the Wisconsinan glaciation (25,000 to 14,000 years BP), the Mackenzie Mountains represented the 'eastern arm' of ice-free Berengia between the Laurentide and Cordilleran ice sheets (Dyke and Prest 1987, Duk-Rodkin and Hughes 1991). Recent genetic analyses have shown that the Mackenzie Mountains served as a key refugium for Dall's sheep during that period (Loehr et al. 2005). As a consequence, Dall's sheep in the Mackenzie Mountains possess (1) a genetic structure distinct from sheep populations in other major mountain ranges (e.g., Brooks Range in Alaska) (Worley et al. 2004), and (2) high levels of genetic diversity within the Mackenzie Mountain population, due perhaps to the large expanse of this refugium (Worley et al. 2004, Loehr et al. 2005). This illustrates how major ice sheets can isolate animal populations, which can lead to greater biodiversity on a broad scale (Hewitt 2000).

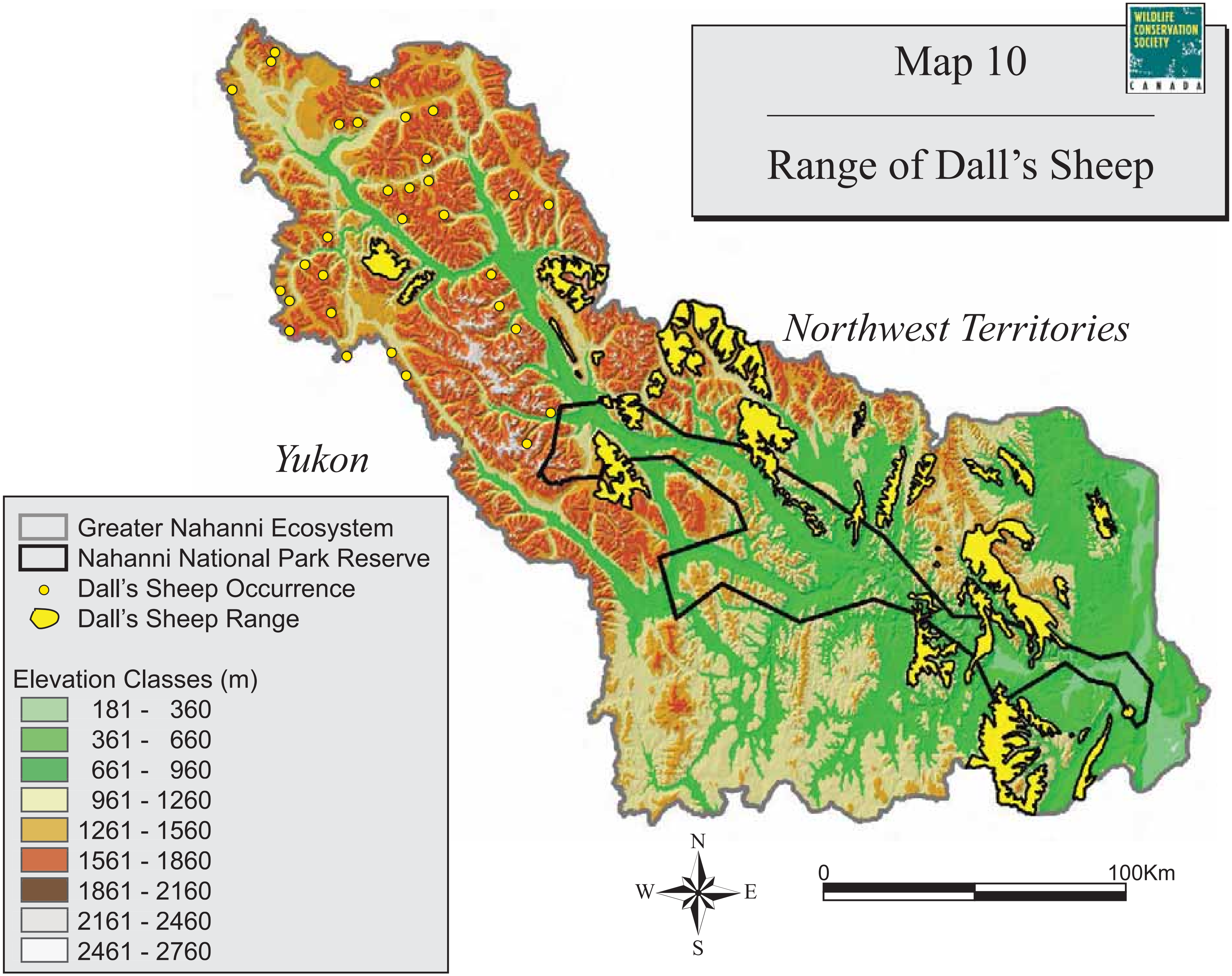
Dall's sheep in the Greater Nahanni Ecosystem occur at the 'peninsular tip' of the Mackenzie Mountains that were not covered by glaciers during the Wisconsin period, which effectively determined the southeast terminus of the species' distribution in North America. At the very end of this tip on the Tlogotsho Plateau, Dall's sheep exhibit a slight but significantly different genetic structure than sheep elsewhere in the Mackenzie Mountains, including 5 unique alleles (Worley et al. 2004). Some of the sheep samples assigned to the Tlogotsho Plateau group in this analysis also came from the Nahanni Plateau on the north side of the South Nahanni River. It's not clear whether such genetic structure resulted from isolation during more distant or more recent times. During the Wisconsin period, Laurentide ice blocked the South Nahanni River and formed Glacial Lake Tetcela, which inundated the lower canyons and perhaps increased the extent of tundra (Ford 1973). Although the Lake's surface was frozen during winter, its open expanse may have intimidated some sheep, thereby constraining their movements and gene flow. In more recent times, the two plateaus have been separated by the rugged canyons of the lower South Nahanni River and the lower sides of the plateaus have become more forested, which may constrain sheep movements (Geist 1971). The Ram Plateau, which is separated from the Nahanni Plateau by 30 km of forested valley, has a small sheep population of about 30 animals. It's possible that sheep on the Ram Plateau have a similarly unique genetic structure. We collected samples of faeces and shed hair from sheep there to test that hypothesis, but DNA analyses are pending.

Distribution and Abundance of Dall's Sheep across the Greater Nahanni Ecosystem

I delineated 27 sheep ranges located primarily in the northern and eastern sectors of the Greater Nahanni Ecosystem (Map 10). These averaged 117 km^2 in size but ranged from 1 km^2 to 493 km^2. Altogether, they covered 3159 km^2 or 7.9% of the ecosystem. I have also illustrated points of 'sheep occurrence' that represent single/ few observations (from the Simmons' data base) primarily in the headwaters portion of the South Nahanni River. Little is known about group size, persistence, or movements of sheep represented by these points. Simmons (1982) believed that many of the sheep summering along the Yukon divide vacated those areas during winter.

Across the Greater Nahanni Ecosystem, Dall's sheep occur in suitable patches of alpine habitat -- mostly in the northern and eastern sectors of the ecosystem (Mackenzie Mountains) where winter snow pack is shallow and/or windblown (Map 10). Important areas harboring some of the larger populations include: Liard Range, Tlogotsho Plateau, Headless and Funeral Ranges, and Nahanni Plateau. It appears that the mountainous divide at the head of Clearwater and Flood Creeks may serve as a landscape-level linkage for sheep in Nahanni to other sheep bands further north in the Mackenzie Mountains (Simmons 1982). Sheep on the Tlogotsho and Nahanni Plateaus (and possibly the Ram Plateau) harbor a distinct genetic structure.

To derive an estimate of average density, I compiled information from various sheep surveys for 8 mountain ranges in the Greater Nahanni Ecosystem (Table 3-1). The average density (weighted per area surveyed) was 0.37 sheep/ km^2 and varied from 0.08 to 4.33 sheep/ km^2. The highest density occurred in the Liard Range which is a long but narrow ridge about 89 km^2 in size where 385 sheep were counted (Case 1989). If this group were deleted, the revised estimate of average density would drop to 0.25 sheep/ km^2. For the entire Mackenzie Mountains, Veitch et al. (1998) reported an average density of 0.39 sheep/ km^2 (range 0.19-0.53) for 10 surveys of sheep on summer range. Thus, the density of Dall's sheep in the Greater Nahanni Ecosystem appears low but representative of sheep densities throughout the Mackenzie Mountains. Assuming that the average


Map 10
Range of Dall's Sheep
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Dall's Sheep Occurrence
Dall's Sheep Range
Elevation Classes (m)
181 - 360
361 - 660
661 - 960
961 - 1260
1261 - 1560
1561 - 1860
1861 - 2160
2161 - 2460
2461 - 2760
N
W
E
S
0
100Km

density (as estimated) is representative of conditions across the ecosystem, then the total population of Dall's sheep in the Greater Nahanni Ecosystem may be 800-1200 animals.

Importantly, only a small portion of the primary sheep ranges lie within the present boundaries of Nahanni National Park Reserve (Map 10). Indeed, only 8 of the sheep ranges depicted on Map 10 have even a small portion within the present Park boundary (<10%), and several extensive ranges lie entirely outside the boundary. Comin et al. (1981) reported that 72% of 904 sheep counted on various seasonal surveys 1977-1979 occurred outside the Park Reserve. They estimated that only 50-55 sheep resided within the Park Reserve.

Table 3-1. Estimates of Dall's sheep density for various mountain ranges, Greater Nahanni Ecosystem, Northwest Territories.

Mountain Range	Surveyed Area (km^2)	No. Sheep	Density (sheep/km^2)	Source
Tlogotsho Plateau	400	336	0.84	Case 1989
Liard Range	89	385	4.33	Case 1989
Nahanni Plateau	1345	107	0.08	Case 1989
Ram Plateau [a]	62	27	0.44	This report
Headless Range	24	54	2.25	Kozachenko 1983
Funeral Range	130	62	0.48	Kozachenko 1983
Ragged Range (S)	187	34	0.18	Kozachenko 1983
Ragged Range (N)	689	77	0.11	Environcon 1981
Total/Wt. Mean	2926	1082	0.37	

[a] a few sheep may have remained hidden in caves during surveys

Use of Karst Caves by Dall's Sheep: A Continentally-Unique Phenomenon

Extending northward from First Canyon along the lower South Nahanni River is a limestone landscape that exhibits the most diverse and striking karst features anywhere in the arctic or sub-arctic regions of the world (Ford 2005). Here, one can find karst 'streets' (up to 9 km long), complex labyrinths, cenotes and dolines (sinkholes), poljes, rock towers, and hundreds of caves formed by water dissolving its way through Palaeozoic limestone and dolomite (Ford 1973, Brook 1976, Brook and Ford 1978, Keough and Keough 1988).

Grotte Valerie, located high on the walls of first Canyon, is the most famous of the Nahanni caves. Discovered in 1970 by a Montreal speleological team (Jaubert and Poirel 1971), it contains 4 separate passages that coalesced over time to form 2 km of passages. One of the passages, located more than 250 m from the closest entrance and beyond a 1.5-m high ice fall, is named Dead Sheep Gallery. Here, Poirel discovered more than 80 dead sheep; subsequent investigations documented the eerie remains of 103 Dall's sheep that wandered in and died in that particular section (Churcher 1974). Radio-carbon dating of hair, cartilage, and horn obtained by George Scotter from one sheep revealed an average date of 2373 years B.P. (Churcher 1974).

During aerial surveys of sheep in the Nahanni Range (east of Ram Plateau) in June 1985, biologists noticed at least 48 sheep in or around caves at 12 locations; ewes with lambs in particular, associated consistently with caves (Case 1989). K. Davidge later investigated 2 of these caves and found 2 ewes in the first cave and a group of 14 ewes and lambs plus 1 ram inside the second cave. He reported evidence of sheep bedding at the back of this cave some 40-45 m from the entrance (*in* Case 1989).

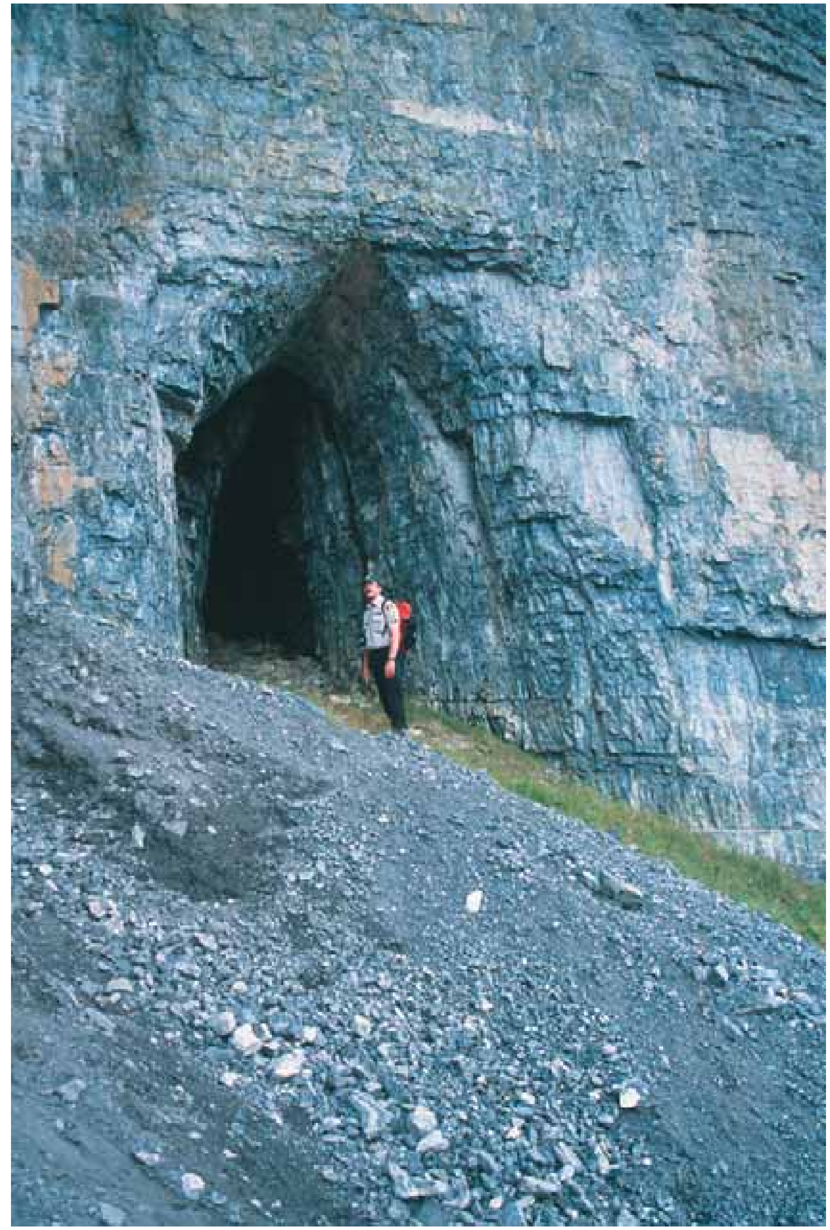
While flying sheep surveys over the Ram and Nahanni Plateaus in summer 2005, we discovered a large number of karst caves being used by nursery sheep (ewes and lambs). On the Ram Plateau, we located 9 caves at 6 locations (at some sites, 2 caves were <100 m apart). We observed the following nursery groups at 4 caves at 4 different locations: (1) 1 ewe, (2) 1 ewe + 1 lamb, (3) 2 ewes + 2 lambs, and (4) 1 ewe + 2 yearlings. We found faeces and/or hair of sheep at 3 of the other caves. Elevation of these caves on the Ram Plateau averaged 1125 m (3465 ft, range 3000-3800 ft).

Our most exciting discovery, however, occurred on the northeast side of the Nahanni Plateau. Here, just off the edge of a low alpine plateau, we discovered 22 karst caves in a tributary canyon only 2 km long by 1 km wide. Just over the ridge, we found another 8 karst caves in the adjacent canyon and then 5 caves in the next canyon – a total of 35 caves. Most of the caves in the first two canyons occurred at the 1100-1170 m elevation (3300-3600 ft), while those in the last canyon occurred at 1330 m (4100 ft).

This area is located about 20 km beyond the known extent of the Nahanni karst mapped by Dr. Derek Ford (Derek Ford, personal communication). Although we did not visit every one of these caves in 2005, we did observe sheep trails at most of them and collected sheep hair and pellets at 5 of them. We counted 63 sheep on the adjacent plateau (64 km^2 in size), which provides excellent habitat.

These karst caves (including the ones on the Ram Plateau) varied in size of the entrance as well as height, width, and length of the main passage. Many appeared to be the 'fossil phreatic' type created by ancient rivers coursing underground along bedding-planes in the Nahanni limestone formation (Brook 1976). They were like underground water slides or tubes: 2-5 m diameter and upwards of 125 m long. Most had a silt deposit on the floor, while a few had ice. Some had entrances enlarged to 10 m high x 15 m wide presumably by frost shattering. We found sheep hair as far back as 40 m in one cave, but most sign occurred within 20 m of the entrance.

One of the most noticeable features was the lush carpet of grasses and forbs at the entrance of most caves, which appeared as oases in a desert of stone. These green 'porches' varied from a few square meters to over 100 m^2. Deep deposition of sheep faeces provided 'fertilization' whereas water dripping from the front edge of the cave roof provided 'irrigation'.



There could be several benefits for sheep using these caves. The caves offer a moderate environment and shelter during both summer and winter. Most of them were located at sites that would be difficult for predators (wolves and bears) to access. The green ‘porches’ would provide ample forage for a ewe and newborn lamb. Sheep ewes typically select extremely rugged terrain for lambing to minimize risk of predation; usually, however, the trade-off is less forage. These karst caves on the Nahanni and Ram Plateaus provide both security and food for ewe-lamb pairs, which may enhance survivorship of lambs.

After discovering this dense concentration of karst caves being used by Dall’s sheep on the Nahanni Plateau, I queried several leading sheep biologists from Arizona to the Yukon. None of them knew of any place where more than the occasional odd cave was used by sheep. Thus, this combination of available karst caves and local sheep populations has resulted in a phenomenon that is unique on the continent.

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Chapter 4 - WOODLAND CARIBOU

INTRODUCTION

Woodland caribou have low resiliency and are particularly vulnerable where human developments and activities dominate the landscape (see Thomas and Gray 2002 and citations therein). They rely heavily upon either terrestrial or arboreal lichens, especially during winter. In the northern mountains of western Canada, caribou forage primarily upon terrestrial lichens (*Cladonia* and *Cladina* spp.), either on windblown alpine sites or in mature conifer forests at lower elevations where snow pack is shallow (Farnell et al. 1996, Kuzyk et al. 1999, Gullickson and Manseau 2000, Johnson et al. 2001, Florkiewicz et al. 2004).

Woodland caribou populations can be quite vulnerable to excessive predation, primarily by wolves and bears (Bergerud 2000 and citations therein). Adult female caribou have only a single calf (compared to moose that have twins under optimal conditions), which rather limits their capacity for reproductive response. Caribou populations decline if calf survivorship falls below about 35% (or 26 calves per 100 adult females) or annual survivorship of adult females drops below about 85-90% over successive years (Hayes et al. 2003, McLoughlin et al. 2003).

Consequently, woodland caribou deploy a variety of strategies to minimize risk of predation (Bergerud and Page 1987, Seip 1992, Bergerud 2000). These include: (1) spacing away from predators by moving to habitats that other prey and predators use less frequently (rugged alpine sites, peat or wetland complexes, and old boreal forests), (2) spacing out across the landscape in small groups which results in low density that increases search effort by predators, and (3) adult females spacing away from one another at calving time. Caribou move widely between seasons, yet display strong fidelity to key ranges that maximize survivorship (Gullickson and Manseau 2000, Schaefer et al. 2000).

Extensive timber harvesting can have a double impact on caribou populations by (1) decreasing the area of older forests with lichens, and (2) creating young forests which provide more habitat for principal prey of wolves and bears which, in turn, sustain more predators. Increased access (roads, ATV trails, seismic lines, etc.) into caribou range can displace caribou from key habitats (Dyer et al. 2001) and lead to increased mortality due to predation, over-hunting or poaching, and vehicular collisions (Edmonds 1988, James and Stuart-Smith 2000, McLoughlin et al. 2003). The range of woodland caribou in eastern and southwest Canada has receded over the past 100 years coincident with the expanding footprint of industrial logging and other human activities (Thomas and Gray 2002).

To summarize: Woodland caribou populations are especially vulnerable to loss and fragmentation of key habitats and excessive mortality from predation, hunting, and poaching. They possess comparatively low potential for population growth, which limits their capacity to rebound from impacts. Large, intact landscapes appear crucial for long-term persistence of caribou (Canadian Boreal

Initiative and Wildlife Conservation Society Canada 2006).

The status of the Northern Mountain population of woodland caribou is listed by COSEWIC as 'special concern' (COSEWIC 2002). This status is conferred upon species whose 'characteristics make it particularly sensitive to human activities or natural events'. Most caribou herds are hunted under varying regulations and intensity. Like the Dall's sheep, woodland caribou throughout the Mackenzie Mountains share a similar and highly diverse genetic structure that is another legacy from the ice-free refugium that existed there during the last glaciation period (Zittlau 2004).

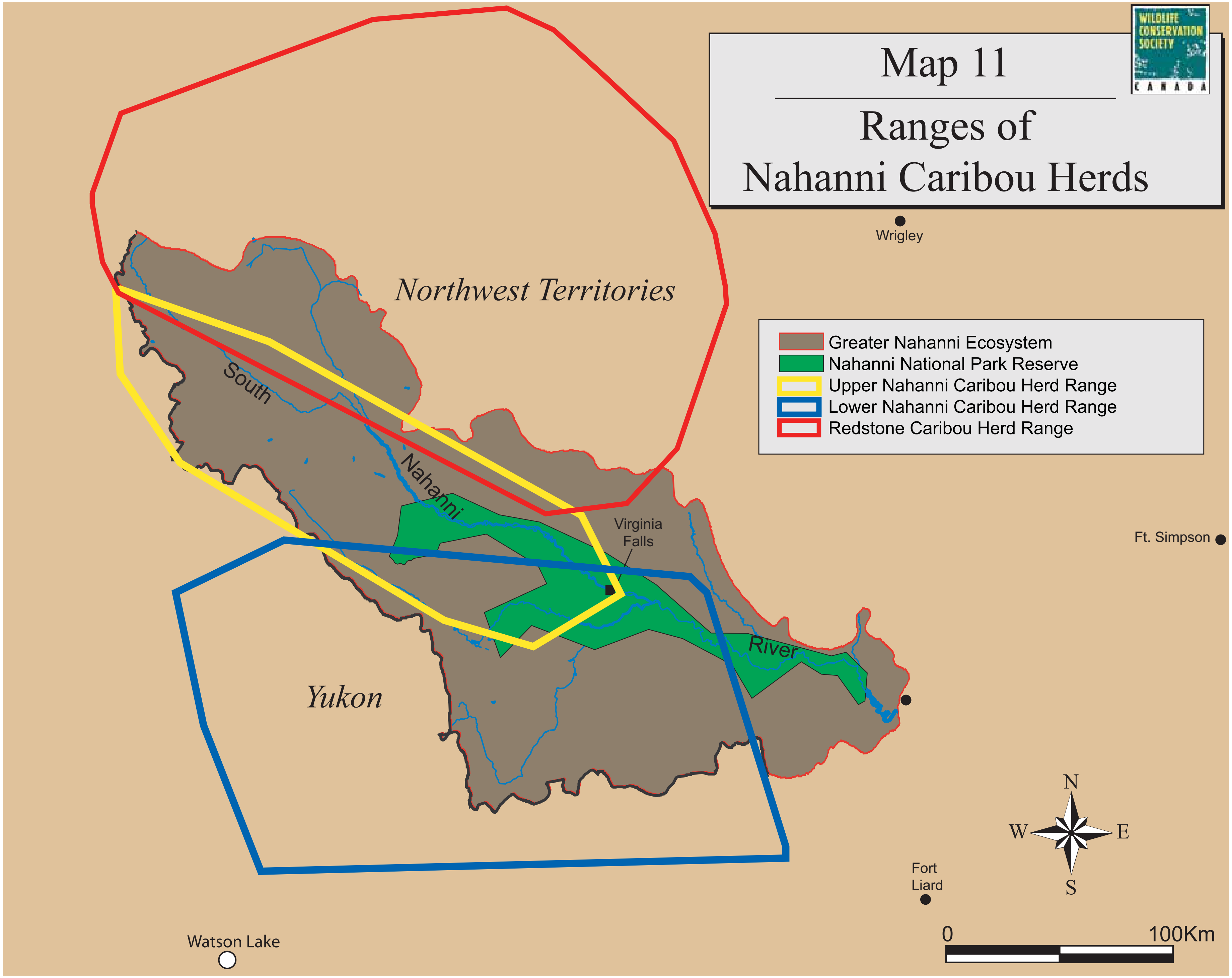
METHODS AND DATA SOURCES

Depending upon how 'herds' of caribou are defined, there are 3-4 caribou herds that use the Greater Nahanni Ecosystem for all or part of their annual range (Map 11). I have followed Farnell and Russell (1984) in defining a 'herd' of woodland caribou as a 'group of caribou that use a common winter range and occupy a geographic area that is distinct from other herds' (sometimes, caribou do not fit completely within our tidy designations and spatial structure can be fuzzy: Schaefer et al. 2001). I have designated 3 herds that use the Nahanni area: (1) Redstone herd, (2) Upper Nahanni herd, and (3) Lower Nahanni herd, which consists of the Coal River and LaBiche groups that were considered previously to represent distinct herds. In this chapter, I present information on the seasonal distribution and movements for each of these caribou herds.

Over the past 10 years, wardens from Parks Canada and biologists from the Northwest and Yukon Territorial governments have captured varying numbers of adult female caribou with nets fired from helicopters (Barrett et al. 1982) and fitted them with either conventional (VHF) or satellite radio-collars (PTT type). Here, I provide a brief chronology of those efforts.

Parks Canada initiated the first telemetry study of woodland caribou in the Greater Nahanni Ecosystem (Gullickson and Manseau 2000). In late March 1995, Grant Lortie and park wardens captured 25 adult female caribou of the Upper Nahanni herd and fitted them with conventional (VHF) radio-collars. They captured these caribou on winter range along the South Nahanni River above Virginia Falls in Nahanni National Park Reserve and adjacent areas of lower Clearwater-Cathedral Creek basin. From June 1995 to February 1998, park wardens made 1-2 flights during each season to track these caribou. Additional details are provided in Gullickson and Manseau (2000).

In October 1998, biologists from the Northwest Territories and the Yukon Territory captured 20 adult female caribou from the same herd on their rut area and fitted them with conventional (VHF) collars (Gunn et al. 2002). Four of these animals were re-captures from the earlier period. In late March 1999, biologists captured 2 more adult female caribou and fitted them with VHF collars. During the rut period each year 1999-2001, biologists made one or more flights to obtain locations of these caribou. In addition, biologists fitted one of the caribou (#22120) from the Upper Nahanni herd captured in October 1998 and another one (#10804) in March 2000 with satellite (PTT) radio-collars. These transmitters provided locations during an 8-hr period every 5 days. Further details are provided in Gunn et al. (2002).



Map 11
Ranges of
Nahanni Caribou Herds
WILDLIFE CONSERVATION SOCIETY CANADA
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Upper Nahanni Caribou Herd Range
Lower Nahanni Caribou Herd Range
Redstone Caribou Herd Range
Northwest Territories
Wrigley
South
Nahanni
River
Virginia Falls
Ft. Simpson
Yukon
Fort Liard
Watson Lake
N
W
E
S
0
100Km

In early March 2000 and mid October 2001, biologists with the Yukon Department of Environment captured 9 adult female caribou of the Lower Nahanni herd (some in southeast Yukon and some near the South Nahanni River south of the Flat River) and fitted them with satellite (PTT) radio-collars (Jan Adamczewski, personal communication). Parks Canada contracted this team to capture another 18 adult female caribou along the Yukon Territory-Northwest Territories divide in October 2004. Three of these animals turned out to be members of the Finlayson caribou herd that ranged further north in the Yukon.

In late March 2002, biologists with the Northwest Territories captured 10 adult female caribou of the Redstone caribou herd and fitted them with satellite (PTT) radio-collars. They programmed the transmitters to acquire locations during an 8-hr period every 3 days.

Under a cooperative agreement between Parks Canada and the Territorial governments as well as permission from the Sahtu Renewable Resources Board, I have compiled and analyzed all locations up to December 31, 2005. For data analysis, I selected the last, best-quality location during a transmission period, which was the same protocol selected by the Territory biologists. Service Argos (2005) advertised the following accuracy for location classes (LC) of varying quality: LC 3: <150 m, LC 2: 150-350 m, and LC 3: 350-1000 m (Service Argos 2005).

In addition, I reviewed general locations of caribou depicted by Scotter et al. (1971) and 244 observations of caribou recorded by Park wardens 1977-1989 that occurred within the ranges of the Upper and Lower Nahanni herds (Comin et al. 1981, NNPR records). Most of these locations fell within the seasonal ranges of the radio-collared animals.

To describe the seasonal movements of caribou, I divided the year into 6 seasons based upon (a) biological events (e.g., calving and rut), and (b) sharp differences in the average rate of daily movement (Ferguson and Elkie 2004) (see Table 4-1). Locations during fall and spring migration are shown on an elevation map, whereas locations during seasons of limited movement (e.g., winter) are shown on a land cover map. To facilitate comparisons with other caribou herds, I calculated estimates of home range size using the Minimum Convex Polygon (MCP) method in animal movement extension (Hooge and Eichenlaub 1997) of ArcView.

Table 4-1. Inclusive dates of defined seasons for woodland caribou, Greater Nahanni Ecosystem, Northwest Territories.

		Start Date	End Date
Summer	Calving	May 21	Jun 5
	Post-Calving	Jun 6	Sep 24
Rut		Sep 25	Oct 15
Fall Migration		Oct 16	Dec 31
Winter		Jan 1	Apr 15
Spring Migration		Apr 16	May 20

For each of the herds, I describe their seasonal ranges and migrations followed by a series of seasonal maps.

RESULTS AND DISCUSSION

Redstone Herd: Seasonal Distribution and Movements

The Redstone caribou herd may be one of the largest herds of the mountain type of woodland caribou in the Northwest Territories. Although a complete census has not been conducted, the herd may number 5,000-10,000 animals (Alasdair Veitch, personal communication). The herd occupies a tremendous annual home range (MCP) of nearly 90,000 km^2 across the northern portion of the Mackenzie Mountains west of the Mackenzie River.

Four of the caribou captured and collared near Drum Lake in the traditional territory of the Sahtu used portions of the Greater Nahanni Ecosystem. The transmitters remained active for an average of 3.0 years (range 1.1-3.8 years) and provided an average of 30 locations per animal (range 8-55) (Table 4-2). For all locations obtained during 2002-2005 (n = 119), 45 % were Class 3, 40% Class 2, and 15% Class 1.

Table 4-2. Chronology of satellite (PTT) locations for 4 adult female caribou of the Redstone caribou herd within the Greater Nahanni Ecosystem, Northwest Territories, 2002-2005. Data courtesy of the Sahtu Renewable Resources Board.

Collar Number	Start Date	End Date	Duration (years)	n Locs
25049	Mar 28, 2002	May 19, 2003	1.1	8
25443	Mar 28, 2002	Dec 31, 2005	3.8	55
25617	Mar 28, 2002	Jul 22, 2005	3.3	32
25619	Mar 28, 2002	Dec 31, 2005	3.8	24
Totals			12.0	119

During 2002-2005, these 4 radio-collared caribou occupied an area of 44,000 km^2 (Map 11). Several of their seasonal movements brought them into the Greater Nahanni Ecosystem (Map 12).

Summer. — During the calving period, these collared caribou moved into the headwaters of the South Nahanni River (area known locally as The Moose Ponds) (Map 12). Here, they used dwarf birch shrublands interspersed with open spruce-lichen woodlands at subalpine elevations between 1200 and 1500 m. We also observed several non-collared caribou at the headwaters of the Broken Skull River during grizzly bear surveys on June 5-6, 2004. Some of the collared caribou moved into this area in summer, too. Notably, each of the collared caribou returned to this calving area in successive years. Later on in summer, the collared caribou headed back north and east into the Redstone River country beyond the South Nahanni River watershed. Prior to the rut, they began moving southward again toward the South Nahanni watershed.

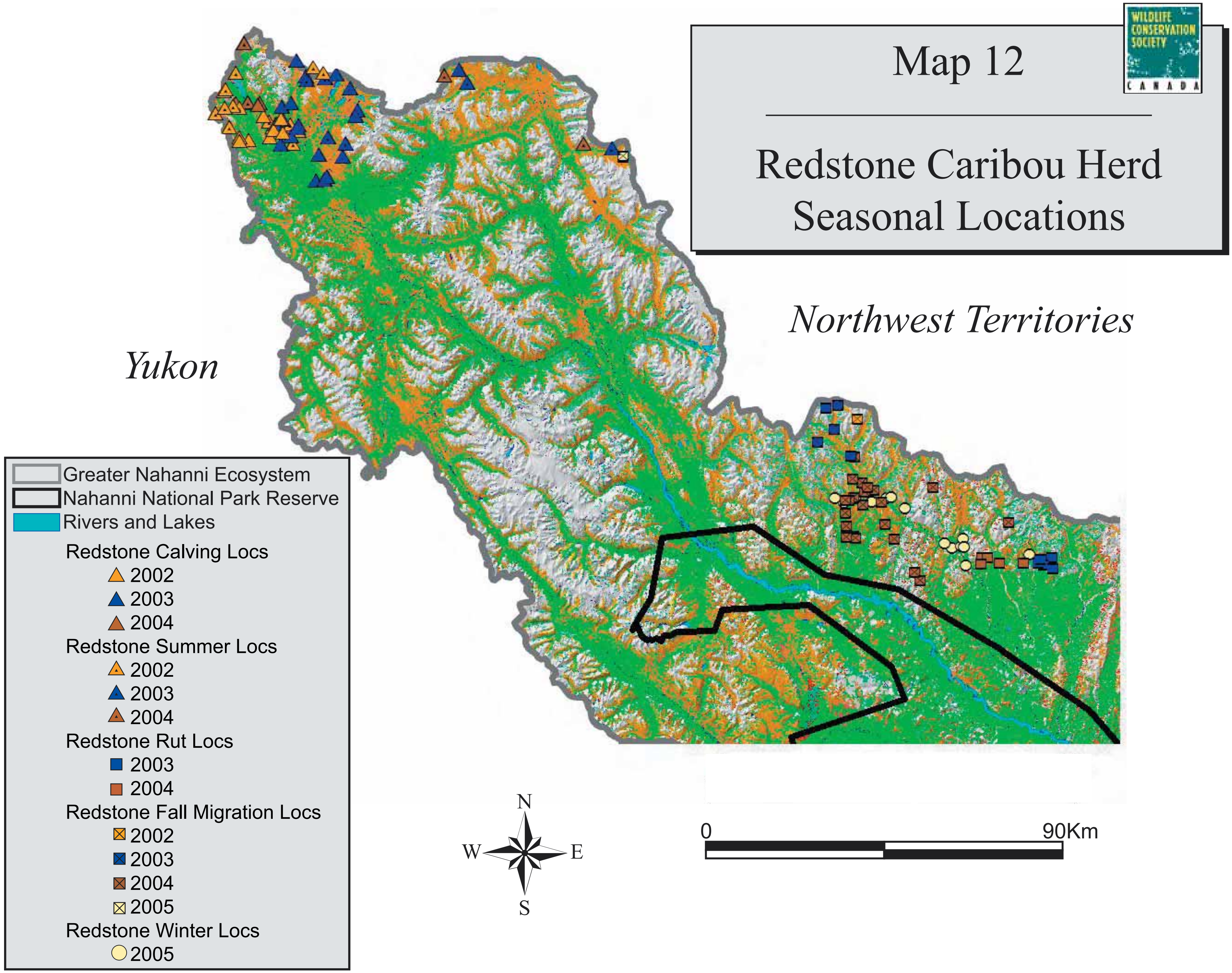
Rut. —One of the collared caribou (#25617) spent the rut period in 2003 in the mountains between upper Cathedral and upper Wrigley Creeks (Map 12). She occurred in the spruce-lichen and subalpine open woodlands at elevations between 1000 and 1400 m. She also returned to this area for the rut in 2004.

Fall Migration. — Another one of the collared caribou (#25443) favored the upper Clearwater and upper Flood Creek area during November-December (Map 12). She occurred in association with the subalpine open woodland, montane spruce-lichen woodland, and closed spruce forest types at 1000-1300 m elevation. She spent the fall in the upper Clearwater in 3 successive years (2002-2004). At the same time, other collared animals occurred just across the divide in the headwaters of Thundercloud Creek and the North Nahanni River.

Winter. — During winter 2005, this female caribou (#25443) stayed in the upper and middle sections of Clearwater Creek between 1000 and 1300 m (Map 12). She occurred mostly in the spruce-lichen woodland and closed spruce forest types. In other years, she and the other collared animals have wintered just over the divide in the headwaters of Thundercloud Creek and the North Nahanni River.

Spring Migration. — In spring 2002, the collared members of the Redstone herd moved west up the Moose Horn River, continued to the headwaters of the Keele River, and came into the headwaters of the South Nahanni River west of O'Grady Lake for the calving period. The straight-line distance was approximately 165 km. They followed most of this same migration route again in spring 2003.

To summarize: Two areas within the Greater Nahanni Ecosystem provided important seasonal habitat for members of the Redstone caribou herd. The headwaters of the South Nahanni River served as a traditional calving area whereas the upper reaches of Clearwater/Cathedral/Wrigley Creeks served as a traditional area during rut and late fall. There is an important landscape linkage between the upper Clearwater and the adjoining headwaters of the North Nahanni River and Thundercloud Creek.


Map 12
Redstone Caribou Herd
Seasonal Locations
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Rivers and Lakes
Redstone Calving Locs
2002
2003
2004
Redstone Summer Locs
2002
2003
2004
Redstone Rut Locs
2003
2004
Redstone Fall Migration Locs
2002
2003
2004
2005
Redstone Winter Locs
2005
N
W
E
S
0
90Km

Upper Nahanni Herd: Seasonal Distribution and Movements

The Upper Nahanni caribou herd occupied a range of 17,500 km^2 (MCP) across the northern portion of the South Nahanni River watershed. In fall 2001, biologists counted 781 caribou in the rutting area and observed 9.9 calves per 100 adult females (Gunn et al. 2002). They estimated that size of the herd could vary from 940 caribou (based upon an assumed correction for sightability of 1.2) to 1140 animals (based upon an empirical correction for sightability of 1.46). Computed density estimates varied accordingly from 54 to 65 caribou/ 1000 km^2.

During 1995-2001, wardens and biologists located the VHF-collared caribou a total of 377 instances during 18 seasonal periods (Table 4-3a). Approximately 75% were 'visual' or rated as 'very good'.

The transmitter on #22120 remained active for 2.4 years and provided 163 locations, while the other transmitter on #10804 lasted 1 year and provided 68 locations within the Greater Nahanni Ecosystem (Table 4-3b). For all locations obtained during 1998-2001 (n = 231), 27 % were Class 3, 28% Class 2, and 45% Class 1. Locations from the 2 types of radio-transmitter are depicted separately on the seasonal maps.

Table 4-3a. Chronology of VHF locations for 43 adult female caribou of the Upper Nahanni caribou herd within the Greater Nahanni Ecosystem, Northwest Territories, 1995-2001. Data for 1995-1998 extracted from Gullickson and Manseau 2000 and for 1998-2001 from Gunn et al. 2002.

Flight Date	No. Active Collars	No. Animals Located
Mar 18-22, 1995	25	25
Jun 1-17, 1995	24	24
Jul 18, 1995	22	21
Oct 12-16, 1995	21	20
Feb 10, 1996	21	17
Jun 1, 1996	20	19
Jul 27, 1996	20	19
Oct 1-9, 1996	19	14
Feb 3, 1997	18	15
Jun 3-6, 1997	17	14
Jul 20 – Aug 5, 1997	17	16
Oct 7-8, 1997	16	14
Feb 2, 1998	15	14
Oct 7 , 1998	20	20
Mar 24, 1999	4	4
Oct 3, 1999		13
Oct 3-6, 2000	20	12
Sep 25-30, 2001	18	8

Table 4-3b. Chronology of satellite (PTT) locations for 2 adult female caribou of the Upper Nahanni caribou herd, Greater Nahanni Ecosystem, Northwest Territories, 1998-2001. Data courtesy of Environment and Natural Resources/GNWT and Yukon Wildlife/ Yukon Territory.

Collar Numbers	Start Date	End Date	Duration (years)	n Locs
22120 (29)	Oct 8, 1998	Mar 11, 2001	2.4	163
10804 (28)	Mar 3, 2000	Mar 18, 2001	1.0	68
Totals			3.4	231

Summer. — During the calving period, most of the radio-collared caribou moved into the upper (northwest sector) part of the South Nahanni River watershed in the Little Nahanni River basin (Map 13) (Gullickson and Manseau 2000). They scattered across an area west of the South Nahanni River to the Yukon border and from Tungsten north past Howard's Pass and nearly to the Moose Ponds. They occurred at elevations ranging from 1000 m to 1600 m in a diverse landscape of subalpine open woodland, spruce-lichen woodland, subalpine shrubland, and tundra types. During the post-calving period of the summer, these caribou appeared to concentrate more in the subalpine and alpine areas in the upper reaches of the Little Nahanni River and Steel Creek. The more frequent data from the animals with satellite collars confirmed that they were relatively stationary during the post-calving period.

A few of the radio-collared caribou did not move very far from winter range and summered closer to the Park Reserve (Map 13). They were scattered through the southern part of the Ragged Range (Hole-in-the-Wall/Pass Creek), south end of Mount Hamilton Gault, and the Swan Lakes area.

Rut. — During the rut, the collared caribou remained in the same area as during summer (Map 14). The data spanning 1995-2001 shows that these caribou exhibited remarkable fidelity to the subalpine/alpine plateaus around the Little Nahanni River. During fall surveys 1995-1997, biologists observed that most groups (84% of 229) of caribou contained fewer than 15 animals but some ranged in size up to 102 animals (Gullickson and Manseau 2000).

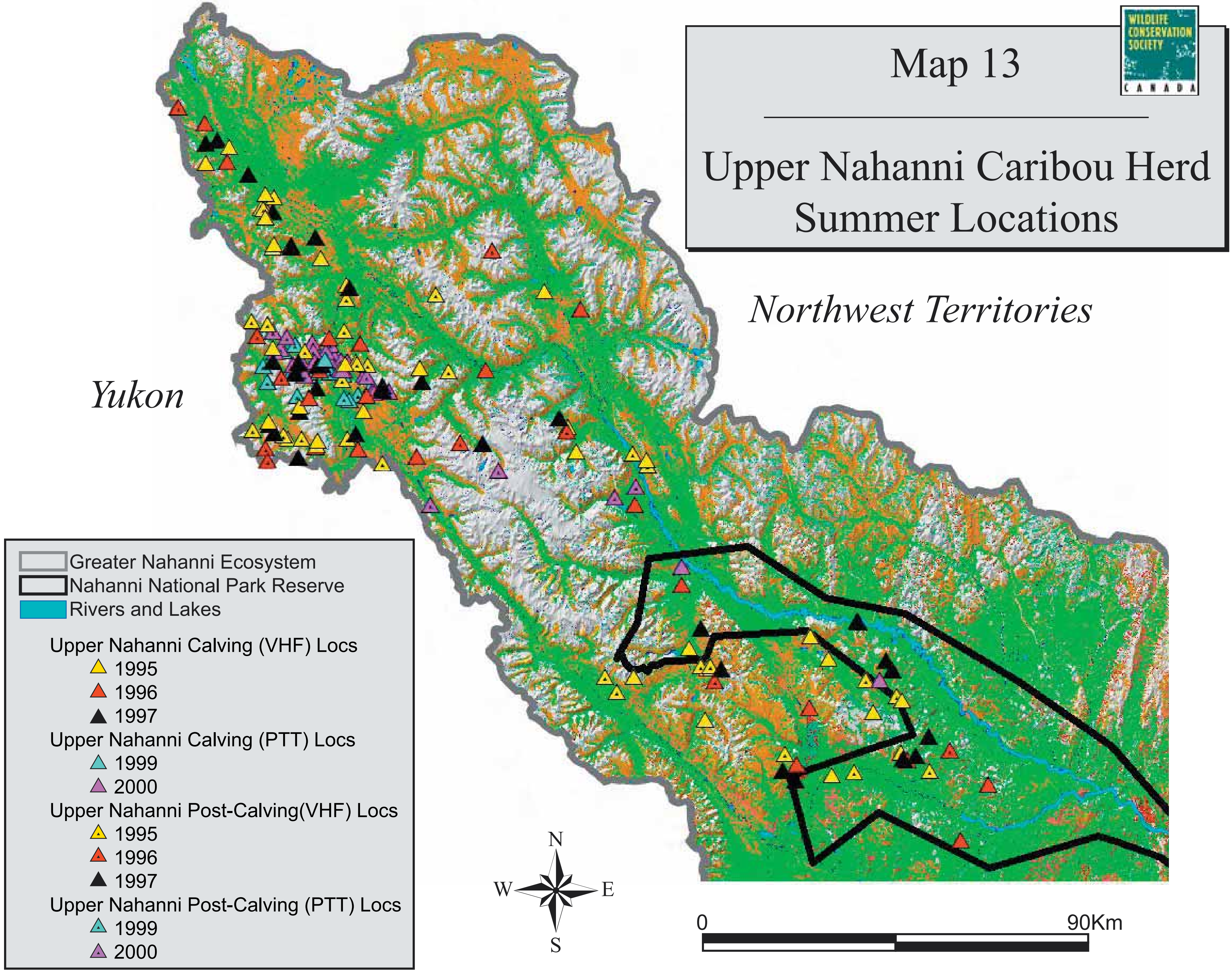
The more stationary animals closer to the Park Reserve also remained close to their respective summer areas during the rut and displayed fidelity to the same areas over time (Map 14).

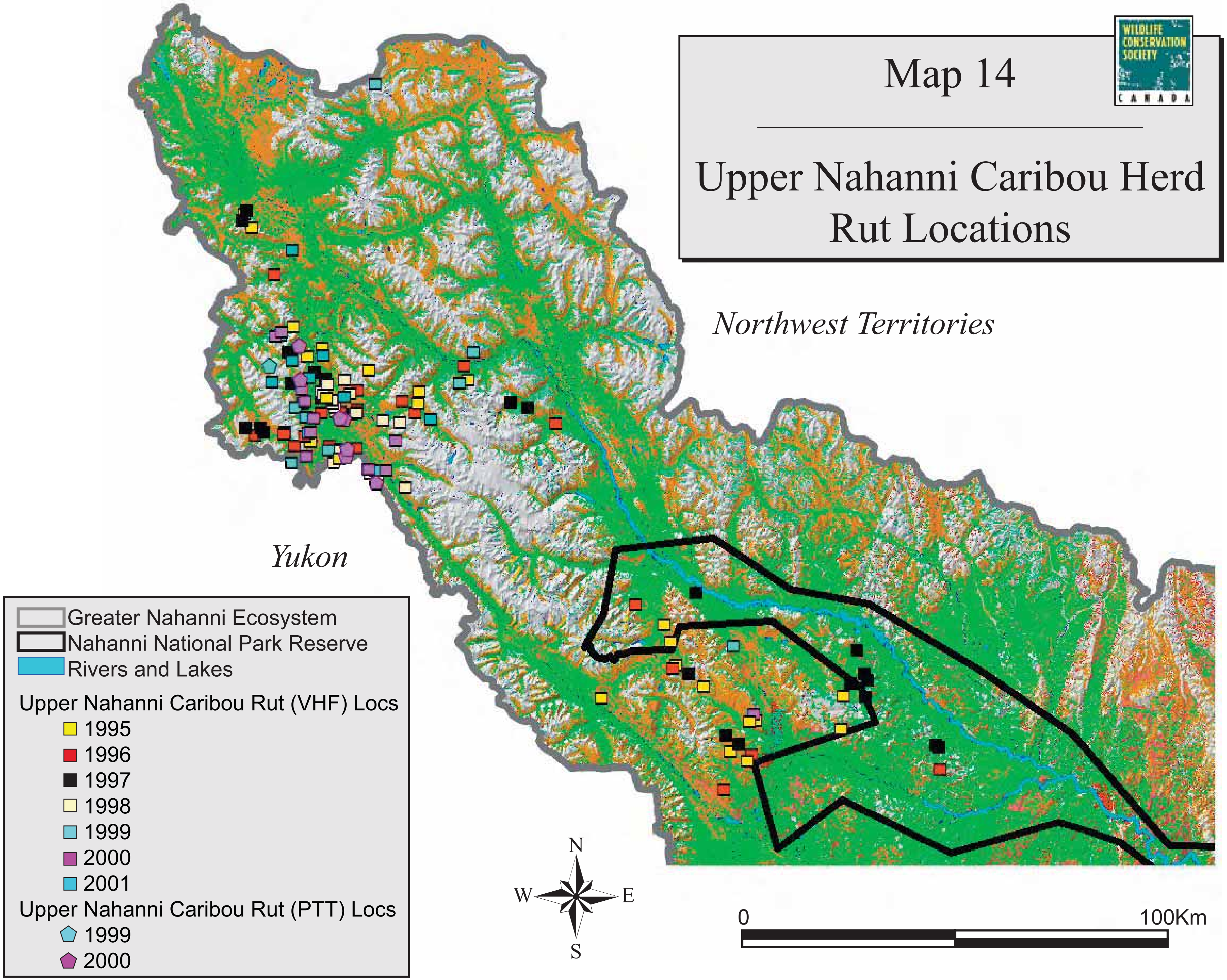
Fall Migration. — Data for this period was provided only by the 2 animals with satellite collars during 1998-2000 and the reconnaissance flights made by wardens near the Park Reserve during 1977-1980 (Map 15). Between mid-October and early November, the collared animals migrated approximately 160-170 km from the high plateaus around the Little Nahanni River to a winter area in the Park Reserve in 10-15 days. This rapid migration limited the number of locations obtained because the collars transmitted every 5 days. Nonetheless, based upon the available data, the following route seems to be the mostly likely migration pathway. Caribou likely moved down (northeast) tributary valleys past Bologna Ridge to the main valley of the South Nahanni River. They proceeded east, then south along the main valley, passing on either side of Dolf Mountain, and entered the Park Reserve near Rabbitkettle Lake. At this point, some animals may have moved south up Hole-in-the-Wall Creek and through the pass to Pass Creek before turning eastward to the wintering area (based on Park warden observations November-December 1977-1980). Other animals likely continued to move directly down the main valley to the wintering area.

Winter. — In most years, the Upper Nahanni caribou herd wintered primarily along the South Nahanni River valley between Hellroaring Creek and Swan Lakes down to Virginia Falls (Map 16). Another key wintering area was the Clearwater-Cathedral Creek basin (north of the Falls). Some caribou in some years also wintered further up the main valley near Dolf Mountain where Gullickson observed 'large numbers' of caribou in March of 1997 and 1998 (Gullickson and Manseau 2000) and collared caribou spent time there in 1999. Some caribou occasionally moved as far down the main valley as the confluence with the Flat River. The south boundary of winter range for this herd did appear to be the Flat River. Caribou wintered at elevations ranging from 550 to 1000 m in association with the montane spruce-lichen woodland. They showed strong fidelity to these winter ranges between years.

Spring Migration. — During spring migration, members of the Upper Nahanni caribou herd essentially re-traced their fall migration routes (Map 17). Based upon telemetry information supplemented by reconnaissance flights, it appeared that most animals migrated northwest out of Nahanni National Park Reserve up the main South Nahanni River valley. Past the Island Lakes area, some animals turned southwest to follow Bologna Creek up to the headwaters of Little Nahanni River while others continued up the main South Nahanni River to their calving range (Map 17). Overall, they traversed approximately 140-240 km, depending upon location of their calving area. Other caribou migrated shorter distances of 10-40 km to calving sites in the southern Ragged Range and Mount Hamilton Gault areas (Gullickson and Manseau 2000).

The 2 caribou with satellite radio-collars had annual home ranges of 5870 km^2 and 7143 km^2 (MCP). Base upon locations of all the collared animals, the Upper Nahanni caribou herd had a range (MCP) of approximately 17,461 km^2. This included, however, some area in the Yukon outside the Greater Nahanni Ecosystem as well as some area in the Ragged Range that did not appear to be used. Excluding those areas, I calculated that the Upper Nahanni caribou herd used a range of 10,077 km^2 within the GNE.

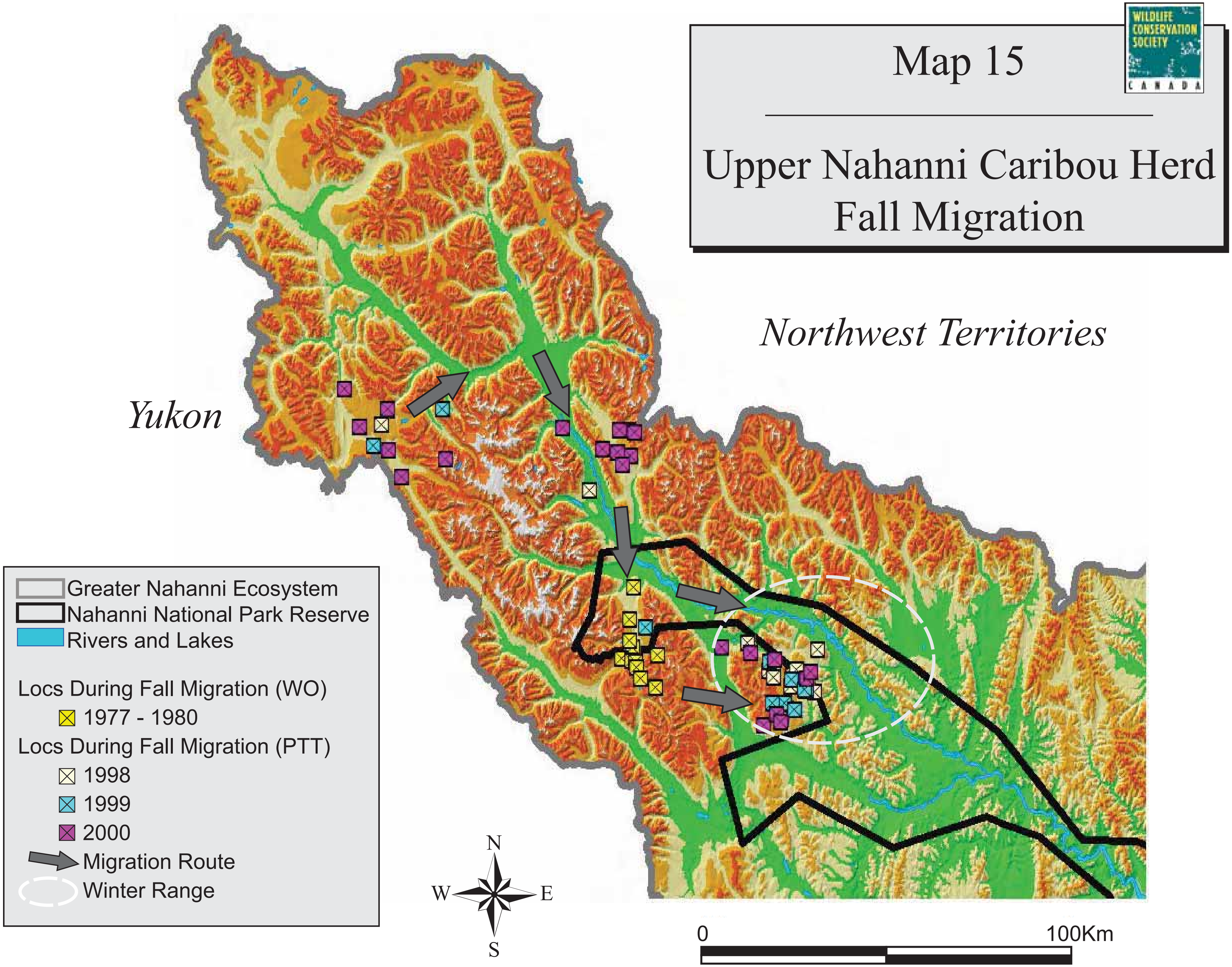

Map 13
Upper Nahanni Caribou Herd Summer Locations
WILDLIFE CONSERVATION SOCIETY CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Rivers and Lakes
Upper Nahanni Calving (VHF) Locs
1995
1996
1997
Upper Nahanni Calving (PTT) Locs
1999
2000
Upper Nahanni Post-Calving(VHF) Locs
1995
1996
1997
Upper Nahanni Post-Calving (PTT) Locs
1999
2000
N
W
E
S
0
90Km



Map 14
WILDLIFE CONSERVATION SOCIETY CANADA
Upper Nahanni Caribou Herd Rut Locations
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Rivers and Lakes
Upper Nahanni Caribou Rut (VHF) Locs
1995
1996
1997
1998
1999
2000
2001
Upper Nahanni Caribou Rut (PTT) Locs
1999
2000
N
W
E
S
0
100Km

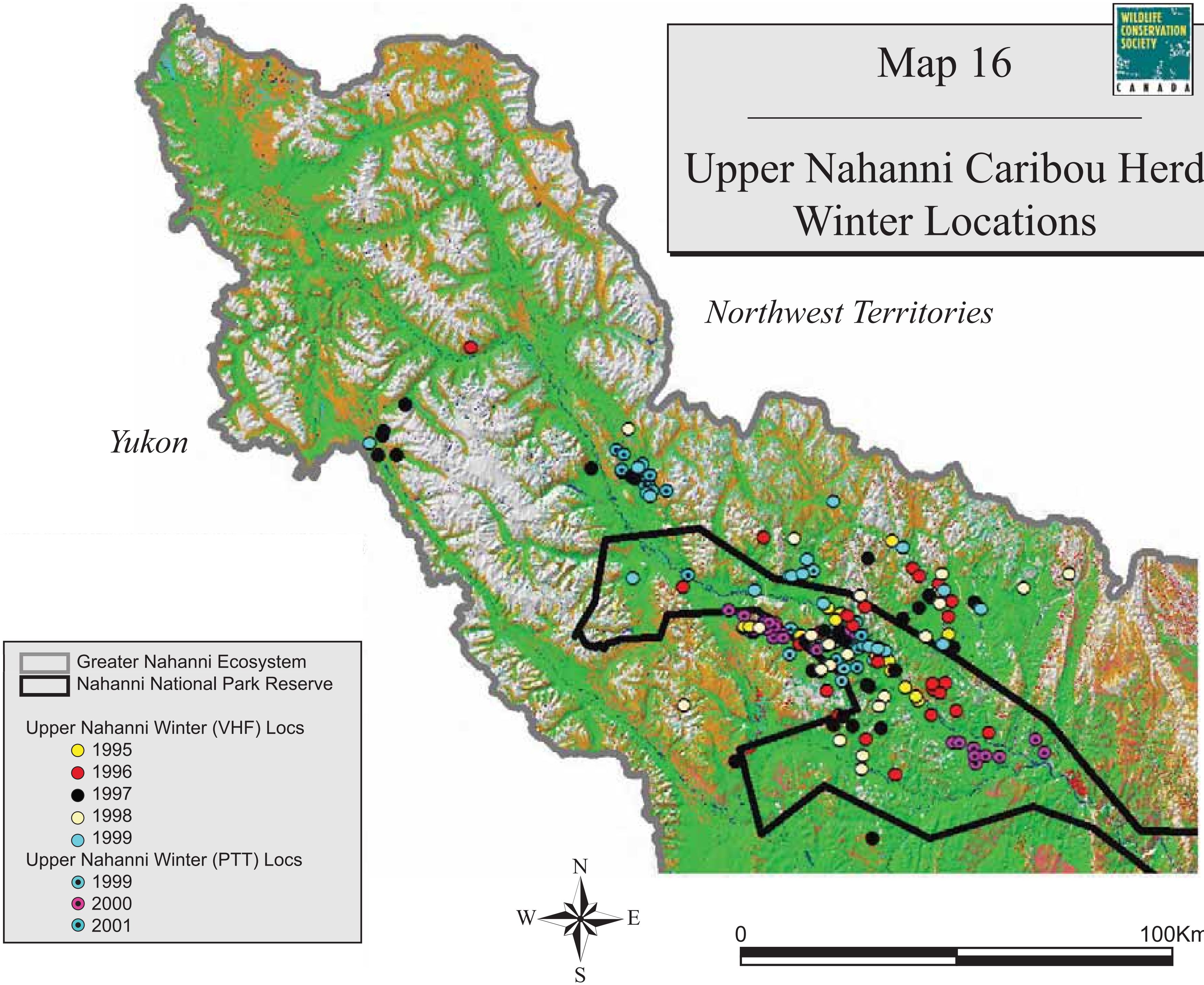
Map 15

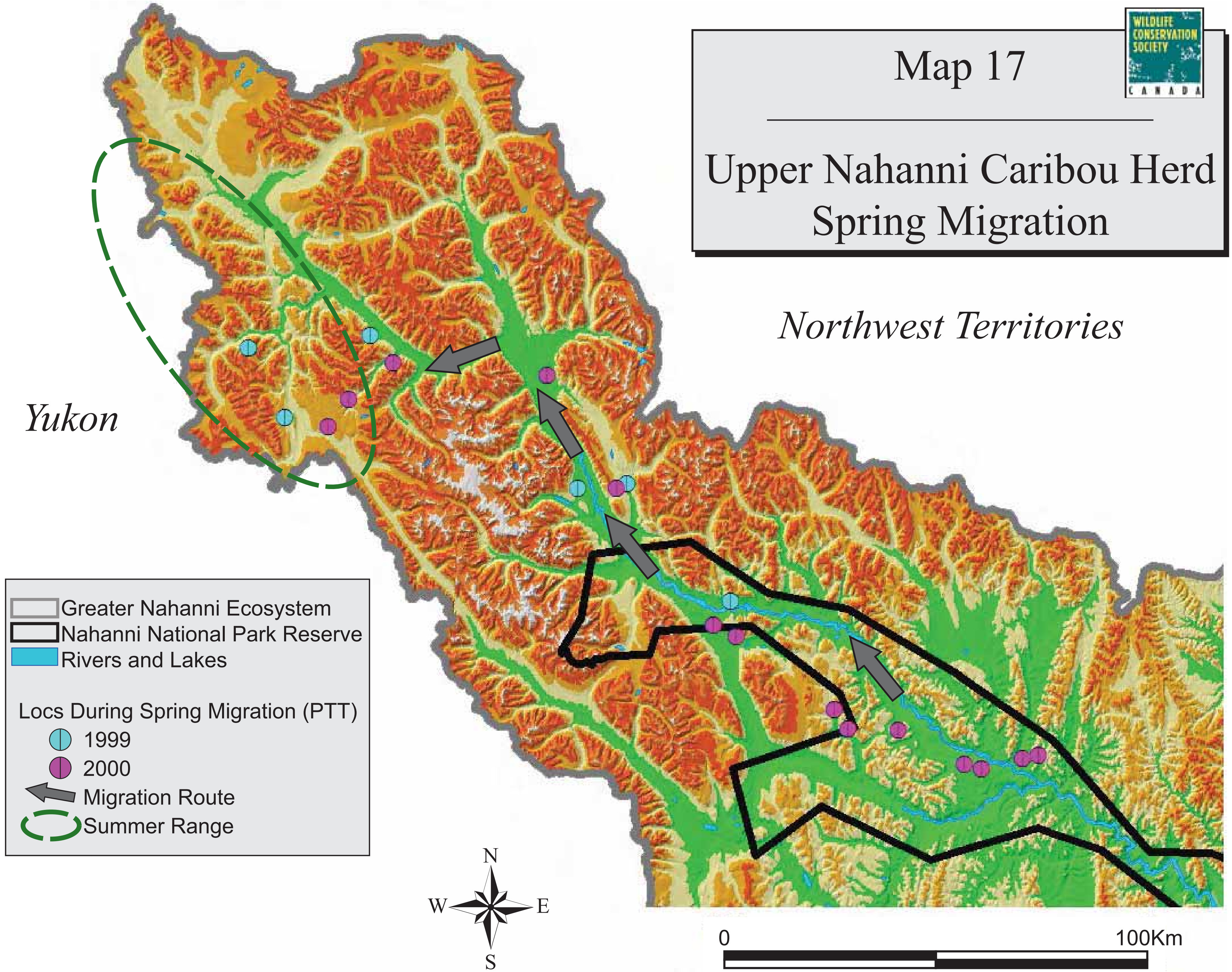
Upper Nahanni Caribou Herd Fall Migration



Map 16

Upper Nahanni Caribou Herd Winter Locations




Map 17
Upper Nahanni Caribou Herd
Spring Migration
WILDLIFE CONSERVATION SOCIETY
CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Rivers and Lakes
Locs During Spring Migration (PTT)
1999
2000
Migration Route
Summer Range
N
S
W
E
0
100Km

Lower Nahanni Herd: Seasonal Distribution and Movements

The Lower Nahanni herd had a range of 31,874 km^2 (MCP), with approximately 55% in the Yukon (Map 11). This herd typically spent the summer and fall rut on alpine plateaus scattered across a wide arc in southeast Yukon, then wintered on the Northwest Territories side (Nahanni). Previously, Yukon biologists had recognized 2 'herds' of caribou ('Coal River' and 'LaBiche'), but data was lacking about where the animals spent the winter. Telemetry data presented here indicated that these 2 'herds' arguably could be viewed as groups of the same herd because they occupied the same winter range. I have plotted locations of animals from these 2 groups separately on pertinent seasonal maps here to illustrate their coalescence during fall and winter.

There are no valid estimates of population size for these groups or the herd in total. In fall 1993, a Yukon biologist counted 348 caribou in the LaBiche group, with a ratio of 22.5 calves per 100 adult females (Florkiewicz 1993). In fall 1997, the same biologist counted 383 caribou in areas occupied by the Coal River group, with a ratio of 20.3 calves per 100 adult females (Florkiewicz 1997). He reported that they were not able to survey approximately 50% of this group's range due to deteriorating weather conditions. Applying the 1.2 sightability factor that Gunn et al. (2002) used for the Upper Nahanni herd would yield a corrected estimate of 418 animals in the LaBiche group and 460 animals -- for the area surveyed --in the Coal River group. Thus, it's reasonable to assume that this herd numbered 731-878 animals in the mid 1990s, with a crude density 23 to 27 caribou per 1000 km^2.

The 9 satellite transmitters deployed 2000-2001 remained active for an average of 2.9 years (range 0.1-5.4 years), whereas 10 of the 15 satellite transmitters deployed in October 2004 were still active at the end of 2005. A total of 2294 locations accrued for these 24 animals, with 53% (1209) occurring within the Greater Nahanni Ecosystem. The estimated accuracy of satellite locations for caribou was relatively good. For all locations obtained during 2000-2005 (n = 1209), 58% were Class 3, 26% Class 2, and 16% Class 1. The number of locations within the GNE averaged 50 per animal (range 3-187) whereas the percentage averaged 57 (range 13-97) (Table 4-4). I continue to monitor animals with active collars and will prepare a complete report on this trans-Territory herd.

Summer. — The Lower Nahanni herd summered along a 240-km axis of alpine plateaus and subalpine basins scattered across southeast Yukon from east of Francis Lake to the LaBiche Range (Map 11). A few collared animals, however, did spend summer (primarily post-calving) on the Northwest Territories side right along the divide (Map 18). Some members of the Coal River group traditionally spent the summer in the mountains north of the headwaters of the Caribou River and also north of Bear Pass Creek further up the Flat River, in the alpine at elevations ranging from 1600 m to 2000 m. Some of the LaBiche group summered in the alpine at the head of the Meilleur River just west of Tlogotsho Plateau at 1600 m elevation.

Rut. — Most of the rutting activity by collared caribou of the Lower Nahanni herd occurred on alpine plateaus scattered across southeast Yukon, but some members of the Coal River group did breed on the Northwest Territories side (Map 19). One of the more

Table 4-4. Chronology of satellite (PTT) locations for 24 adult female caribou of the Lower Nahanni caribou herd within the Greater Nahanni Ecosystem, Northwest Territories, 2000-2005.

Collar Number	Start Date	End Date	Duration (years)	n Locs total	n Locs w/in GNE	% Locs w/in GNE
10802	Mar 3, 2000	Jul 25, 2005	5.4	304	187	62
10803	Mar 3, 2000	Jun 20, 2004	4.3	162	36	22
10805	Mar 3, 2000	Aug 20, 2002	2.5	69	45	65
12190	Mar 3, 2000	Jun 21, 2000	0.3	22	14	64
15037	Oct 19, 2001	Nov 27, 2005	4.1	98	68	69
15040	Oct 24, 2001	Nov 23, 2001	0.1	7	3	43
15042	Oct 19, 2001	Aug 29, 2005	3.9	239	146	61
15043	Oct 19, 2001	May 21, 2004	2.6	166	69	42
15044	Oct 19, 2001	Jun 20, 2004	2.7	156	39	25
53585	Oct 16, 2004	Dec 31, 2005	1.2	89	60	67
53587	Oct 16, 2004	Dec 31, 2005	1.2	89	42	47
53588	Oct 16, 2004	Dec 31, 2005	1.2	88	52	59
53589	Oct 16, 2004	Mar 5, 2005	0.4	29	28	97
53590	Oct 16, 2004	Dec 31, 2005	1.2	85	45	53
53591	Oct 16, 2004	Nov 20, 2004	0.1	8	7	88
53592	Oct 16, 2004	Dec 31, 2005	1.2	89	43	48
53593	Oct 16, 2004	Jun 13, 2005	0.7	47	31	66
53594	Oct 16, 2004	Dec 31, 2005	1.2	88	59	67
53595	Oct 16, 2004	Dec 31, 2005	1.2	87	39	45
53596	Oct 16, 2004	Dec 31, 2005	1.2	89	57	64
53597	Oct 16, 2004	Dec 31, 2005	1.2	89	57	64
53599	Oct 16, 2004	Oct 1, 2005	1.0	67	37	55
53600	Oct 16, 2004	Dec 31, 2005	1.2	88	11	13
53601	Oct 16, 2004	Apr 24, 2005	0.5	39	34	87
Totals			40.6	2294	1209	53

consistent sites was on the isolated alpine plateau north of the 'L' bend in the upper Caribou River.

Fall Migration. — After the rut, caribou from both the Coal River and LaBiche groups migrated eastward from the southeast Yukon over the divide and into the Greater Nahanni Ecosystem (Map 20). The Coal River group crossed the Territorial divide along a 50-km front essentially at the head of the Rock River and upper Coal River on the Yukon side and the headwaters of the Caribou River on the Northwest Territories side. Here, they skirted around the south end of the rugged Selwyn Mountains. Animals crossing at the northern end moved across the forested Liard Plateau past Skinboat Lakes and McMillan Lake on their way to wintering sites along the lower Flat River in Nahanni National Park Reserve. Others moved through Caribou Pass (headwaters of Caribou River) and then eastward over to the forested headwaters of Marten Creek and Meilleur River. From there, they moved northward along the eastern flank of the Caribou Range to wintering sites in the lower Mary River in the Park Reserve. By selecting these migration routes, caribou avoided rugged terrain. The Coal River group migrated upwards of 240 km from summer sites in southeast Yukon to wintering sites in Nahanni National Park Reserve.

Members of the LaBiche group crossed the low Territorial divide along a 30-km front between the headwaters of LaBiche and Whitefish Rivers on the Yukon side and the southeast headwaters of the Meilleur River on the Northwest Territories side (Map 20). From there, they moved northwest and merged with the Coal River group in a migration route through the upper Mary River to wintering sites in the Park Reserve. This group migrated upwards of 90 km to reach the winter range.

Both groups of the Lower Nahanni caribou herd moved rather quickly from rut sites in southeast Yukon to the territorial divide. Then, the rate of movement appeared to be in response to the buildup of the snow pack. In years of milder conditions in late fall, caribou may not reach the core wintering area in Nahanni National Park Reserve until late December. In those years, some members of the LaBiche group stayed high in alpine sites along the divide and/or in subalpine forests on the Yukon side and did not make the long migration. In harsher winters, animals moved earlier and further east to a core winter range in Nahanni National Park Reserve (Map 20). This influence of snowfall was evident in winter 2004-05, following capture and collaring of the new sample of caribou in October 2004. Snow fall at Watson Lake, Yukon (nearest site with weather data) during winter 2004-05 was 156 % greater than the average for the previous 10 years (268 cm *vs*. 171 cm: Environment Canada 2005).

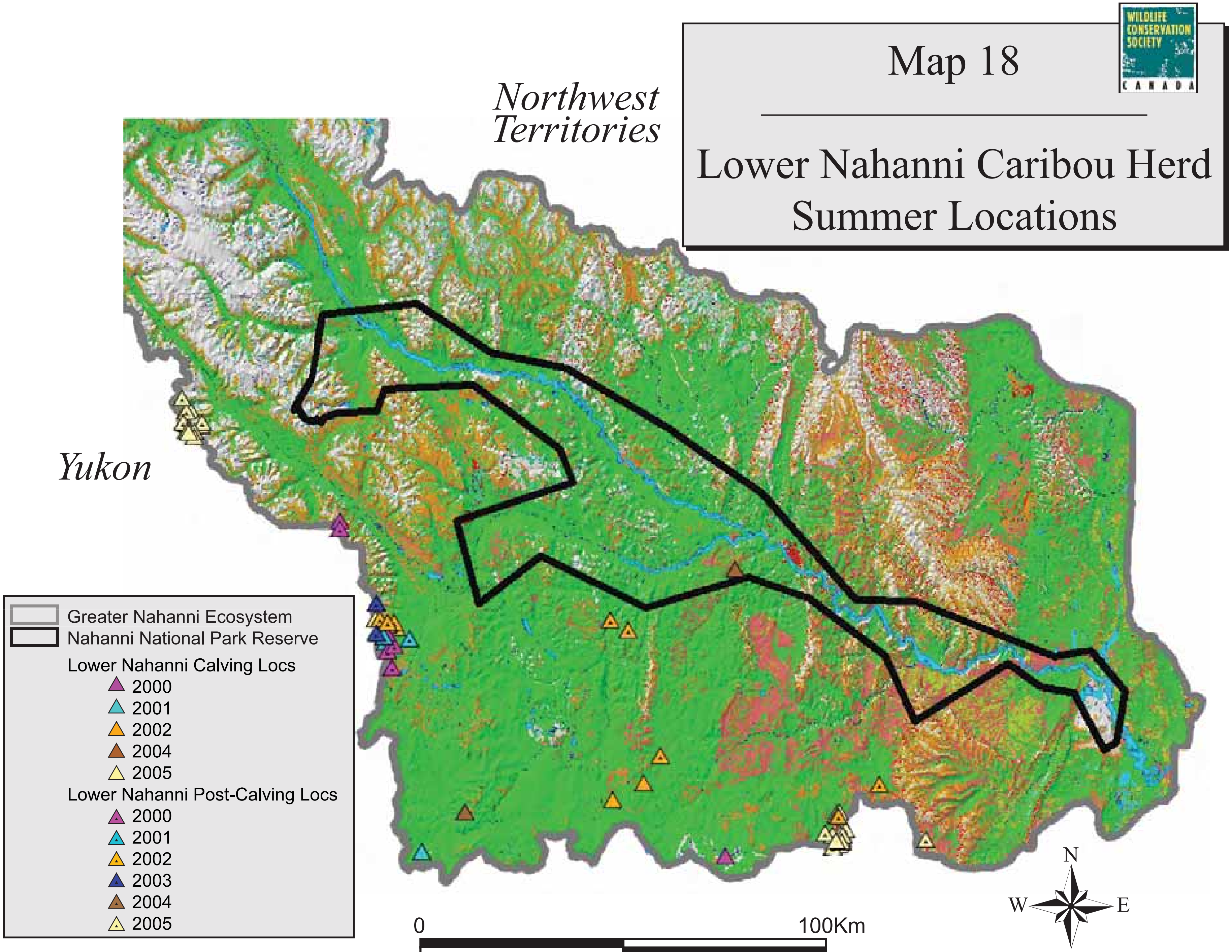
Winter. — The core wintering area for both groups of the Lower Nahanni caribou herd was centered on the confluence of the Flat River and the South Nahanni River in Nahanni National Park Reserve (Map 21). It extended from the Funeral Range on the east to Clark Lake and up to the Flat River on the west; and from Virginia Falls on the north to the headwaters of May Creek and the Mary River on the south. The LaBiche group tended to occur more on the eastern side of this winter range whereas the Coal group tended to spread out more on the western side. Nonetheless, both groups intermingled in the central core and exhibited a strong fidelity to the core wintering area, especially during late winter (March). Elevations ranged from 400-500 m along the Flat and South Nahanni

Rivers to 700-900 m on slopes and benches. The large majority of caribou locations at this season were in the Montane Spruce – Lichen Woodland type, and caribou clearly avoided the Pine – Aspen Woodland type prevalent in May Creek and middle section of the Meilleur River basin (Map 21).

Spring Migration. — During spring migration, collared members of the Lower Nahanni caribou essentially re-traced their fall migration routes (Map 22). Some members of the Coal River group moved up the Flat River, then turned southwest and moved along the north side of the Caribou River up to the headwaters. One animal continued further up the Flat River before turning west to cross the divide. Others moved from the lower Mary River-May Creek winter area south up May Creek and Meilleur River, then turned west around the lower end of the Caribou Range and crossed the divide near Caribou Pass. Members of the LaBiche group tended to migrate directly south up May Creek and the Meilleur River to the divide.

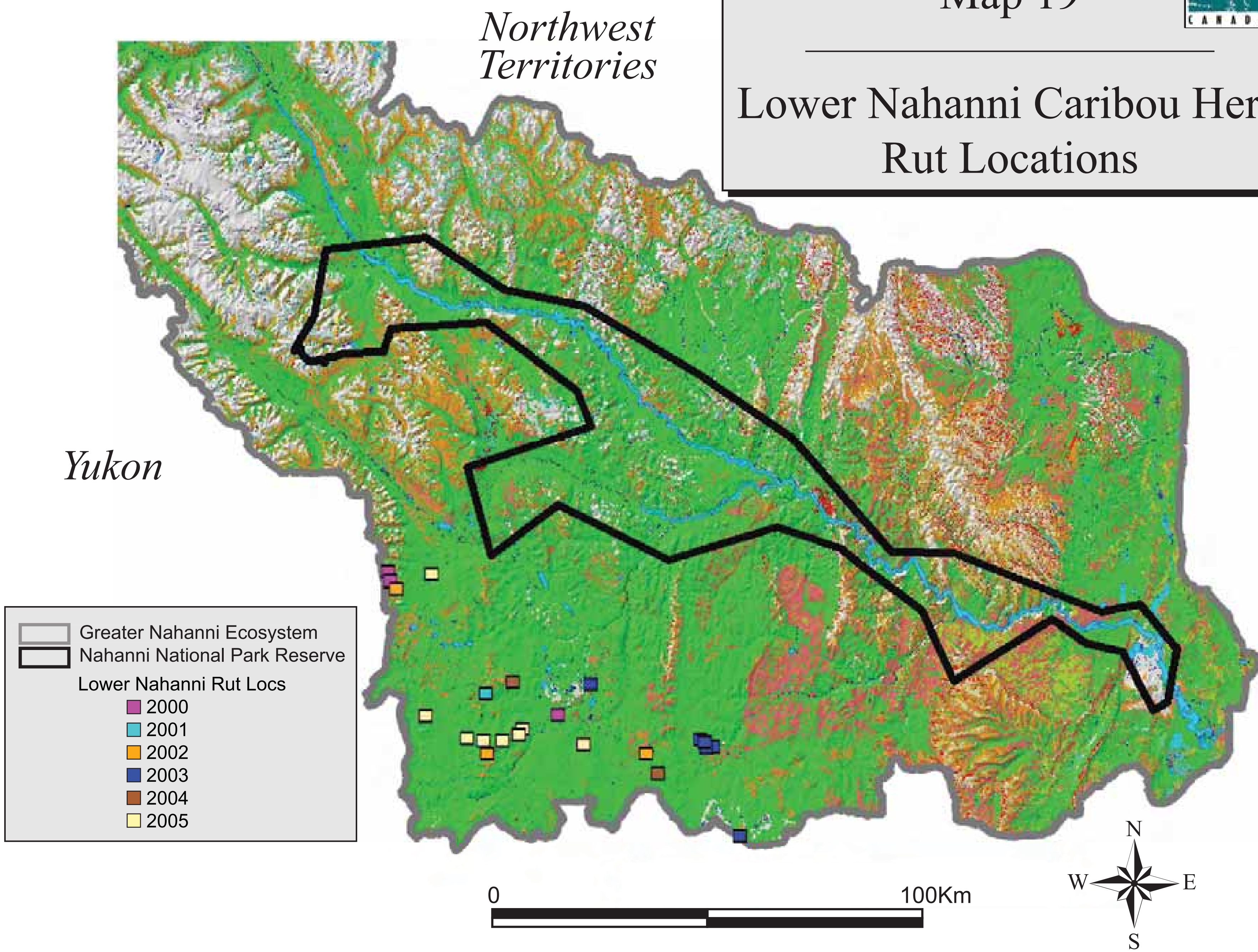
In contrast to the rather slow movements during fall migration, the caribou seemed to gallop during the spring migration. Several animals made the trek of 175-225 km back to their traditional calving sites in 15-20 days during the first 3 weeks of May.

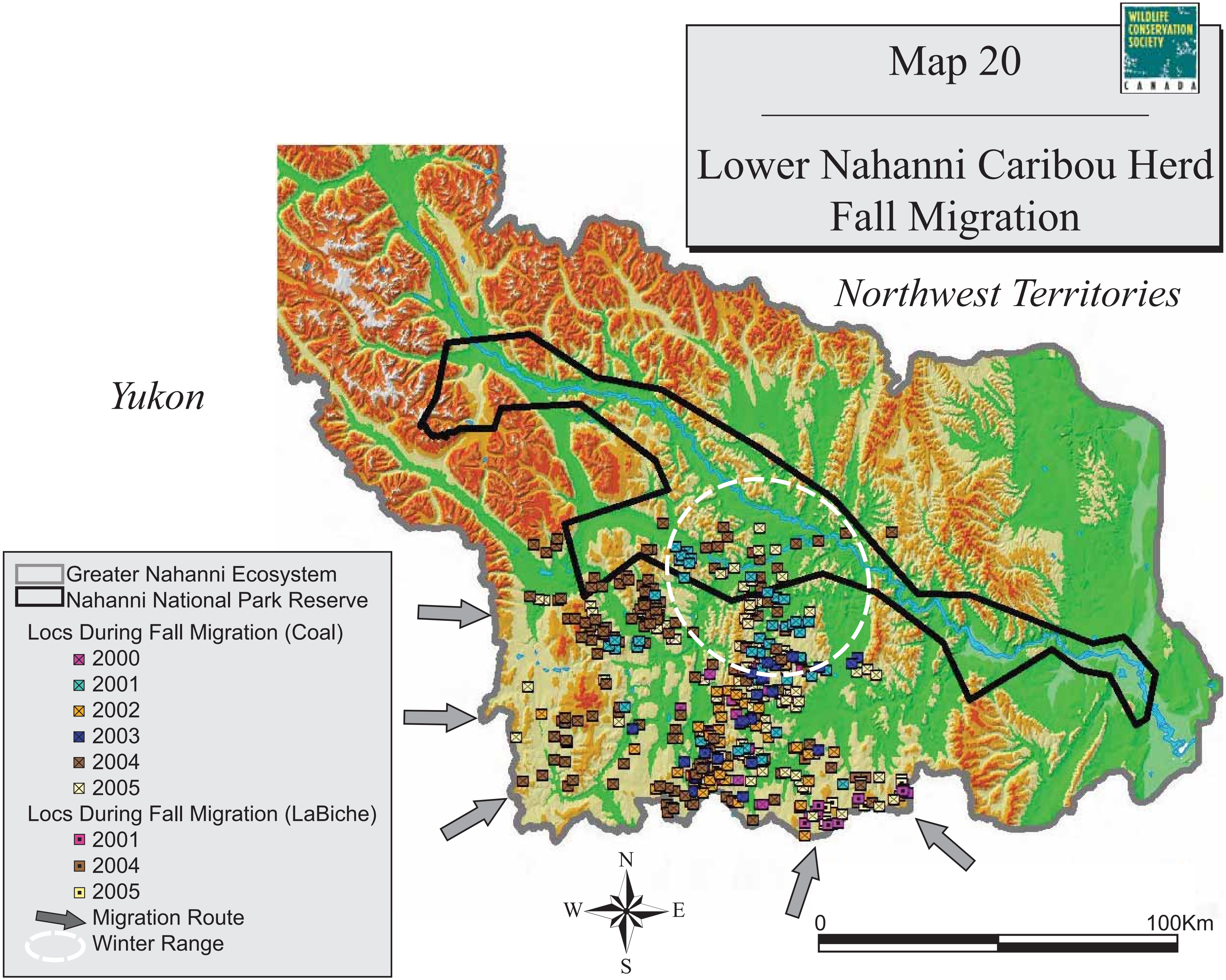
To summarize: the Lower Nahanni caribou herd is a trans-Territory herd with approximately 45% of its annual range (post-rut, fall migration, and winter) in the Greater Nahanni Ecosystem. Home ranges for individual caribou with >1 year data averaged 6524 km^2 (± 1292 km^2 SE, range 2626 km^2 -10,248 km^2) for the Coal River group (n=6) and 2218 km^2 (± 720 km^2 SE, range 1498 km^2 - 2937 km^2) for the LaBiche group (n=2). The expansive boreal forest in the adjacent (southwest) sector of the Greater Nahanni Ecosystem provided crucial habitat for this herd from November to May. This area lies in a ‘snow shadow’ in the lee of prevailing winter storms from the southwest. As winter progressed, caribou moved north into Nahanni National Park Reserve for their core winter range.


Map 18
Lower Nahanni Caribou Herd
Summer Locations
WILDLIFE CONSERVATION SOCIETY
CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Lower Nahanni Calving Locs
2000
2001
2002
2004
2005
Lower Nahanni Post-Calving Locs
2000
2001
2002
2003
2004
2005
0
100Km
N
W
E
S

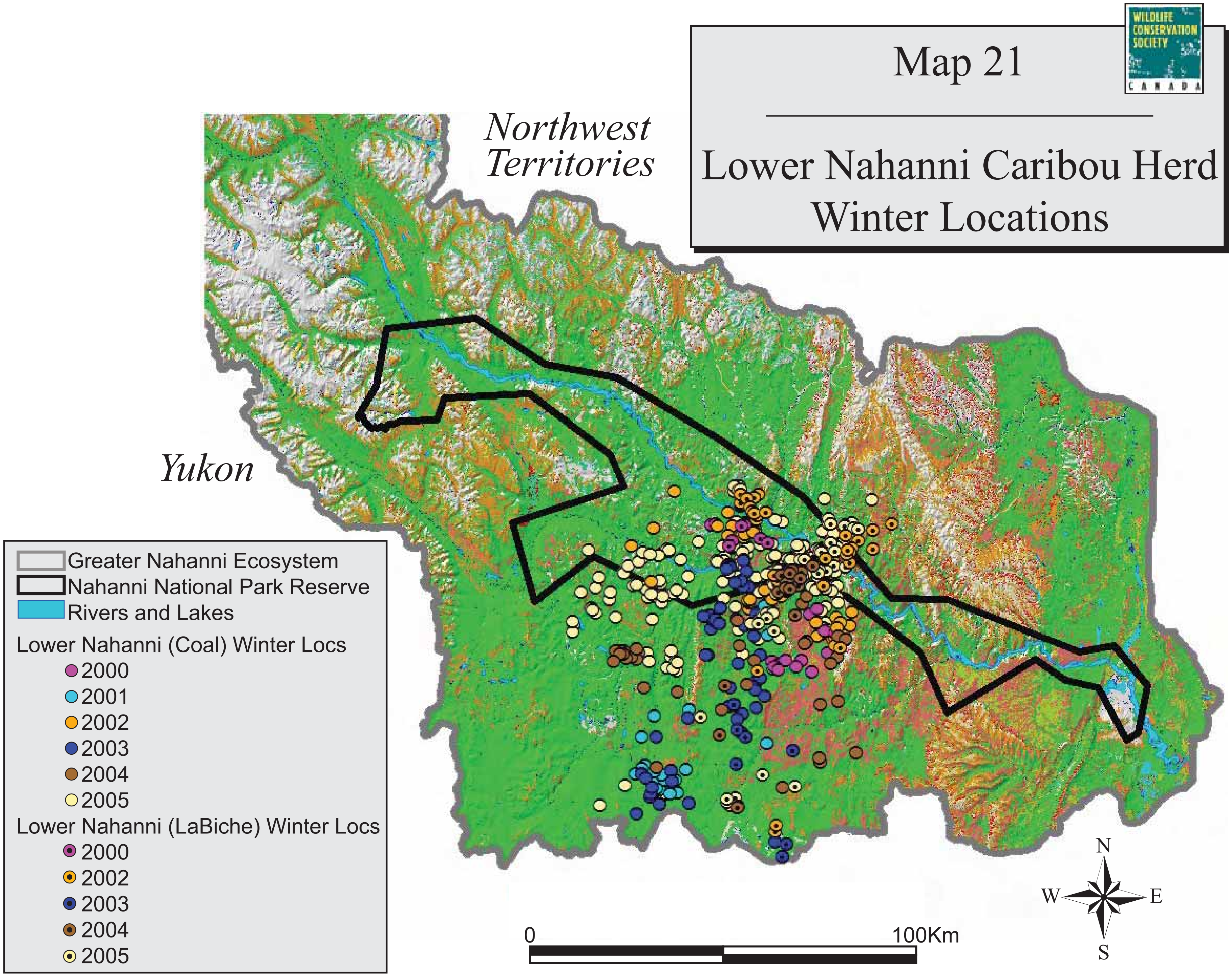
Map 19

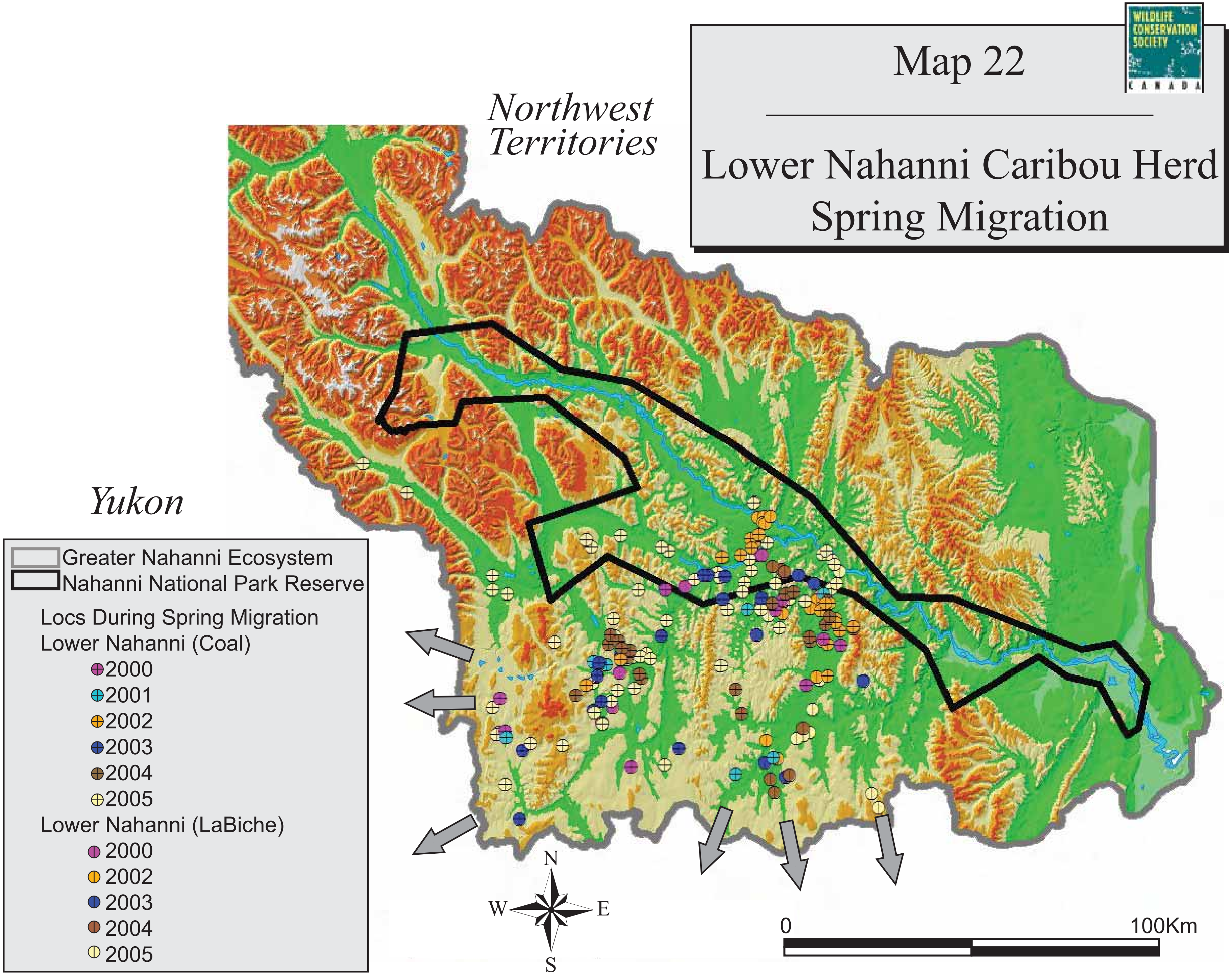
Lower Nahanni Caribou Herd Rut Locations





Map 20
WILDLIFE CONSERVATION SOCIETY CANADA
Lower Nahanni Caribou Herd Fall Migration
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Locs During Fall Migration (Coal)
2000
2001
2002
2003
2004
2005
Locs During Fall Migration (LaBiche)
2001
2004
2005
Migration Route
Winter Range
N
W
E
S
0
100Km


Map 21
Lower Nahanni Caribou Herd
Winter Locations
WILDLIFE CONSERVATION SOCIETY
CANADA
Northwest
Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Rivers and Lakes
Lower Nahanni (Coal) Winter Locs
2000
2001
2002
2003
2004
2005
Lower Nahanni (LaBiche) Winter Locs
2000
2002
2003
2004
2005
0
100Km
N
W
E
S


Map 22
Lower Nahanni Caribou Herd
Spring Migration
WILDLIFE CONSERVATION SOCIETY
CANADA
Northwest Territories
Yukon
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Locs During Spring Migration
Lower Nahanni (Coal)
2000
2001
2002
2003
2004
2005
Lower Nahanni (LaBiche)
2000
2002
2003
2004
2005
N
W
E
S
0
100Km

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CHAPTER 5 – WILDLIFE CONSERVATION: IMPLICATIONS for EXPANSION of NAHANNI NATIONAL PARK RESERVE

INTRODUCTION

Proposed expansion of Nahanni National Park Reserve raises several questions. How much is enough? How large should a population be to persist over 100 years? … 500 years? What proportion of the ecosystem should be protected to ensure that the ecological processes that drive the system remain intact?

These are some of the most challenging and discomforting questions for biologists and conservation planners (Groves 2003). They are challenging because our understanding of many species and ecosystem functioning is rudimentary, and our ability to forecast far into the future is shadowed by scientific uncertainty. For scientists, such questions may be discomforting because they reflect social values…what do people really care about? how much risk will they accept to the things they value? The role of science is to give guidance in how to achieve conservation goals that reflect social values, not to insert those values (Maguire 1994).

People clearly care about Nahanni. Native Dene have expressed their respect for the land and waters of Nahʔą Dehé through stories and traditional practices. More recently, they have signaled their intent to protect the entire South Nahanni River watershed through conservation zoning in their land use plans (Sahtu Land Use Planning Board 2002, Dehcho Land Use Planning Committee 2006). The original designation of some of the area as a National Park (Reserve) was – of itself – a national statement of value. Finally, designation of Nahanni National Park Reserve as a World Heritage Site underscored its value to the world community.

Another way of understanding people's values about the land is to listen to their statements about the condition or quality they desire. The Nahʔą Dehé Consensus Team, with representatives appointed by Parks Canada and the Dehcho First Nations, developed the following vision statement (Parks Canada Agency 2004):

> Nahʔą Dehé will protect a wilderness watershed in the Mackenzie Mountains where natural processes such as fires and floods will remain the dominant forces shaping the park's ecosystems. Special features of the park, including waterfalls, hotsprings, glaciers, plateaux, canyons, karst landscapes and cultural/spiritual sites will be preserved. Naturally-occurring plant communities will thrive and native animal species, including woodland caribou and grizzly bears, will be sustained at viable population levels.

This vision establishes a very high conservation standard that embodies values of naturalness and ecological integrity sustained for the long term. It calls for a place where natural processes continue to mold the land and the life therein. Such a vision will not be served by aiming for only minimal levels of wildlife populations that are too small to enact their ecological function, it will not be served by providing only part of the area needed by wildlife in their yearly round, nor will it be served by limiting the room and connectivity necessary for plants and animals to respond to climate change.

In the past, boundaries of most National Parks in North America (including Nahanni) and elsewhere in the world have been established on an *ad hoc* basis. Often, this resulted in parks that were too small to achieve conservation goals, including the long-term persistence of vulnerable wildlife species (Newmark 1985, Newmark 1995). In recent years, a more systematic approach to assessing and planning conservations areas on a regional basis has emerged (Pressey et al. 1993, Margules and Pressey 2000, see Noss et al. 2002 for a cogent application in the Greater Yellowstone Ecosystem and Groves 2003 for excellent overview).

Where ecological inventory data is limited (such as Nahanni), a practical approach for designing a better blueprint for a conservation reserve or park is to consider the area, critical seasonal habitats, and security needed by wide-ranging species such as large carnivores or migratory ungulates (Soulé and Terborgh 1999, Groves 2003).

In this chapter, I summarize and synthesize pertinent information we collected for grizzly bears, Dall's sheep, and woodland caribou. Then, bearing the salient concepts of conservation planning in mind, I recommend new boundaries for Nahanni National Park (Reserve).

SYNTHESIS OF KEY WILDLIFE RANGES

Grizzly Bear

Our field surveys and ecological modeling indicated that grizzly bears occurred most often and in greater numbers in the mountains and tributary valleys of the northern portion of the Greater Nahanni Ecosystem. Grizzlies were less common in the boreal forests of the southwest and southeast sectors. Limited surveys during the berry season suggested that distribution of grizzly bears in Nahanni did not change dramatically later in the summer. Nonetheless, grizzly bears probably do move to key berry patches (e.g., Rabbitkettle Lake area) during years of favorable berry production. Through supplemental collection of hair at natural rub trees, we documented that grizzlies used the main South Nahanni River corridor, primarily above Náìlîcho or Virginia Falls. In addition, grizzly bears ranged widely across the Greater Nahanni Ecosystem. Finally, genetic analyses revealed that Nahanni grizzlies exhibit the highest level of genetic diversity (along with grizzlies in Kluane) found in grizzly bears across their North American range. The picture that emerges, then, is a grizzly population characterized by variable but moderate density, wide-ranging movements, and intact connectivity (genetic) to grizzly populations in the larger region of northwest Canada.

Because grizzly bear populations have low resiliency and are highly vulnerable to human impacts and persecution, their long-term persistence or viability becomes an issue. Shaffer (1981) pioneered the conceptual basis for assessing the viability of an animal population (known as Population Viability Analysis or PVA). PVAs quantify the risk to small populations due to random demographic changes, environmental variation, loss of genetic diversity, and catastrophic events (Gilpin and Soulé 1986). Over time, however, it has become clear that such assessments require a rich set of data to be accurate (Beissinger and McCullough 2002) and that factors such as human destruction of habitat or direct human persecution have figured prominently in many case histories of wildlife extirpation (Caughley and Gunn 1996).

In the absence of demographic data for grizzly bears in the Nahanni area, we can turn to other information that might bracket a conservation goal. Genetic considerations would suggest that populations need to number in the many 100s and perhaps 1000s of animals for long-term persistence and evolutionary adaptation (Allendorf et al. 1991, Allendorf and Ryman 2002). On a strictly empirical basis, the historical record reveals that -- of 37 'islands' of grizzly populations scattered across the western United States in 1922 -- 32 were extirpated by 1975 (Servheen 1999). The only areas where major grizzly bear populations survived were contiguous areas >20,000 km^2 that had large national parks (Yellowstone and Glacier) at their core (Mattson and Merrill 2002). In the Greater Yellowstone Ecosystem, where an estimated 600 grizzlies occur across nearly 24,000 km^2, the U.S. Fish and Wildlife Service has proposed that the grizzly population there be taken off the 'Threatened' species list. In the region containing Glacier National Park, several large Wilderness areas, and substantial tribal lands, a grizzly population estimated >500 bears occurs across nearly 25,000 km^2. This population has a tenuous link with bears on the Canadian side of the border. State and federal agencies are reviewing the status of this population for possible de-listing from 'Threatened' status.

Based upon this information, I suggest a population objective of 500 grizzly bears toward the conservation goal of a viable population for Nahʔą Dehé. Our modeling of grizzly bear density and the distribution of density classes in Nahanni National Park Reserve indicates that the Park Reserve can support about 80 grizzly bears, far below that needed to meet the conservation goal. Moreover, it's likely that many bears – particularly males – range beyond the narrow confines of the present boundaries of the Park Reserve.

In order to secure a larger number of grizzly bears that would approach a viable population, Nahanni National Park Reserve should be expanded. Although the block of boreal forest in the broadest portion of the Greater Nahanni Ecosystem is extensive, it has a comparatively low density of grizzly bears. By combining areas across the Greater Nahanni Ecosystem that have moderate to very high densities of grizzly bears (see Map 6), an estimated population of approximately 500 grizzly bears (75% of the population) could be achieved on 23,481 km^2 (59%) of the Ecosystem land base (Map 23). Such an area would include fragments of low-density grizzly habitat embedded in landscapes of higher density areas, and disjunct areas of high grizzly density in a landscape of low-density habitat. Because grizzly bears survive best in large, contiguous areas secure from human disturbance, I discuss and resolve these issues in a planning context later in this chapter.

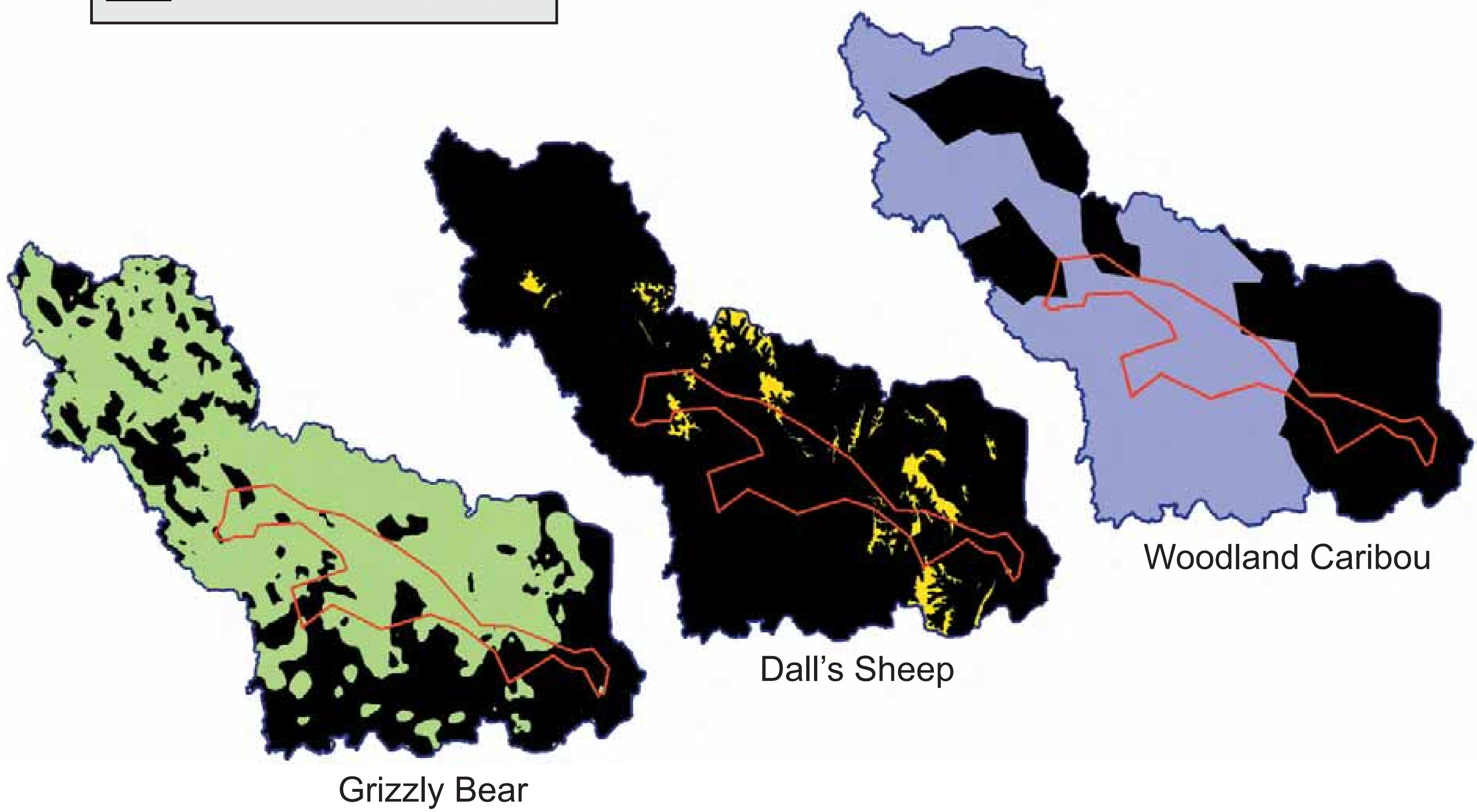
Dall's Sheep

Dall's sheep have low resiliency if natural or human impacts extirpate them from a local area. Dall's sheep occurred in suitable patches of alpine habitat across the Greater Nahanni Ecosystem -- mostly in the northern and eastern sectors of the ecosystem where winter snow pack was usually shallow and/or windblown. Important areas harboring some of the larger populations included: Liard Range, Tlogotsho Plateau, Headless and Funeral Ranges, and Nahanni Plateau. The mountainous divide at the head of Clearwater and Flood Creeks may serve as a landscape-level linkage for sheep in Nahanni to other sheep bands further north in the Mackenzie

Map 23

Key Wildlife Ranges
Greater Nahanni Ecosystem

- Greater Nahanni Ecosystem
- Nahanni National Park Reserve
- Key Grizzly Bear Range
- Key Dall's Sheep Range
- Key Woodland Caribou Range
- Area of low or no occurrence



Mountains. Sheep on the Tlogotsho and Nahanni Plateaus (and possibly the Ram Plateau) exhibited a distinct genetic structure. Importantly, all of these principal ranges lie either mostly or entirely outside the present boundary of Nahanni National Park Reserve.

During sheep surveys in 2005, we discovered a concentration of caves used by sheep on the Nahanni Plateau and others on the Ram Plateau. Ewe-lamb pairs occupied several of these caves which appear to provide both security and forage. Discovery of sheep using the numerous karst caves on the Nahanni Plateau was notable in two respects. It extended (by 20 km) the known occurrence of the Nahanni karst features which are considered the finest in the arctic and sub-arctic regions of the world (Derek Ford, personal communication). Moreover, it represented the greatest concentration of wild sheep using caves documented anywhere in North America.

Mountain sheep typically occur in separate herds on discrete patches of suitable habitat across a landscape. Both the size of individual herds and the number and distribution of different herds across the landscape will influence the likelihood of long-term persistence or viability. For bighorn sheep (*O. canadensis*) in the deserts of southwest United States, Berger (1990) reported that populations with <50 individuals went extinct within 50 years, whereas populations with >100 animals lasted at least 70 years. If populations are small, more of them are required to reach an overall objective for persistence. General modeling of viability indicates, for example, that if each population has a likelihood >0.6 of persistence (and their population dynamics are not correlated), then 6-10 separate populations will result in <0.1 chance of extinction (Morris and Doak 2002).

Based upon this information, I suggest an objective of 8 populations each >100 animals (or some combination that yields similar probability) toward the conservation goal of a viable population of Dall's sheep for Nahʔą Dehé. Comin et al. (1981) estimated that only 50-55 sheep resided within the narrow confines of the Park Reserve.

To secure a greater number of Dall's sheep herds that would approach a viable population, Nahanni National Park Reserve should be expanded. It's essential that revised boundaries include Tlogotsho Plateau and the Liard Range, as they harbor the largest populations of sheep (>300 each). In addition, sheep on Tlogotsho (and perhaps the Liard Range) have a unique genetic structure. It's important to include all of the Headless and Funeral Ranges (a portion of each is within present boundary) because they have modest number of sheep (>50) and may serve as 'stepping stones' to sheep ranges north of the Park Reserve. Sheep density on the Nahanni Plateau is quite low but would sum to nearly 200 animals for the occupied ranges. Sheep ranges in the Sunblood Mountain and upper Clearwater areas could contribute >100 sheep each to the overall population if one assumes those areas support average sheep densities (0.37 sheep/ km^2). These areas may serve as a landscape-level linkage for sheep in Nahanni to sheep bands further north in the Mackenzie Mountains, too.

In order to protect the complete ranges of the larger populations of Dall's sheep as well as the continentally-unique occurrence of sheep using karst caves, the boundary of Nahanni National Park Reserve should be expanded to include all of the principal sheep ranges north and south of the present Park (Maps 23). This comprises approximately 8% of the Greater Nahanni Ecosystem.

Woodland Caribou

Woodland caribou have low resiliency and are vulnerable to human impacts. Three distinct herds of woodland caribou relied upon portions of the Greater Nahanni Ecosystem for key seasonal ranges: (1) Redstone herd, (2) Upper Nahanni herd, and (3) Lower Nahanni herd. Part of the Redstone herd used an area at the headwaters of the South Nahanni watershed for calving/post-calving and a separate area during fall and winter. The total area was approximately 4170 km^2, all of which is outside the present park boundary. The Upper Nahanni herd concentrated most of its activity within the South Nahanni River watershed, ranging from a winter area centered around Virginia Falls to summer and fall areas in the upper reaches west of the main river. The range of this herd was approximately 10,077 km^2, which excluded the central part of the Ragged Range that did not appear to be used. The Lower Nahanni herd had about 45% of its range within the South Nahanni River watershed, primarily areas used during fall, winter, and spring. The extent of its range within the watershed was approximately 10,134 km^2. Importantly, radio-collared caribou in each of these three herds exhibited strong fidelity to seasonal areas and migration routes which form a cohesive network for that particular herd. Finally, woodland caribou throughout the Mackenzie Mountains and Selwyn Mountains of the Yukon-Northwest Territories region exhibited a high level of genetic diversity and shared a common genetic structure.

Caribou scientists have expressed increasing concern over the declining status of many populations of woodland caribou across Canada (COSEWIC 2002). Some experts have recommended that the entire range of all herds should be designated as critical habitat (CBI/WCS Canada 2006). Thus far, caribou in the Mackenzie Mountains have not been subjected to the same pressures of industrial activities as elsewhere. The caribou herds using Nahanni may provide a vital benchmark for caribou conservation in Canada.

Based upon these concerns, I suggest an objective of maintaining the ecological and spatial integrity of ranges used by each caribou herd within the Greater Nahanni Ecosystem. Two of these herds (Upper and Lower Nahanni) have traditional core winter ranges within the Park Reserve but move outside for other critical activities (calving, rutting). Animals from the other herd (Redstone) move into the watershed for these same activities.

In order to conserve the integrity of these traditional ranges for these caribou herds, Nahanni National Park Reserve should be expanded. Altogether, the ranges of these three caribou herds within the Greater Nahanni Ecosystem sum to 24, 381 km^2. There is, however, some slight overlap in their ranges. Thus, the combined range for the three herds is approximately 23, 695 km^2 or about 59% of the Greater Nahanni Ecosystem (Map 23).

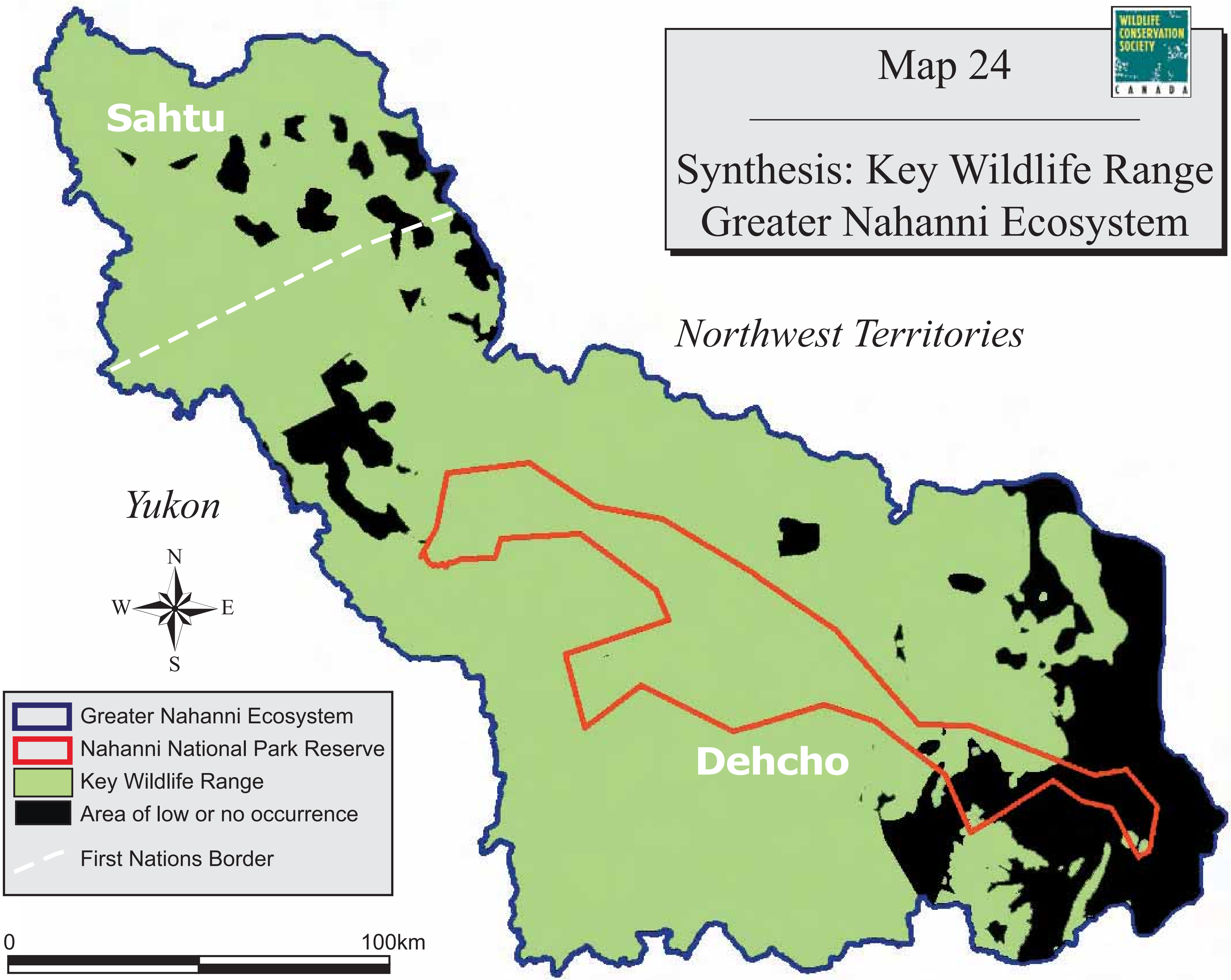
Synthesis

This suite of wildlife species – grizzly bear, Dall's sheep, and woodland caribou – is quite vulnerable to human activities and thrives best in large, intact, and secure landscapes. Due to the low productivity of northern mountain and boreal ecosystems, each of these species occurs at relatively low densities and ranges widely across the Greater Nahanni Ecosystem. Consequently, they require large protected areas to persist at levels approaching viability. Each species has its unique ecological requirements and distribution, but there is some overlap in their occurrence. I combined the key ranges used by each species into a single map of their collective range (Map 24). Altogether, the suite of species occupies an area of about 34,108 km^2, or 85.6% of the Greater Nahanni Ecosystem.

There are several areas that do not appear to provide habitat directly for these 3 focal species (Map 24). These areas (outside the present Park Reserve) sum to approximately 5761 km^2 or 14.4% of the Greater Nahanni Ecosystem. What is their value to conservation goals for these species?

There are 2 complexes in the upper part of the South Nahanni River watershed: (1) small blocks totaling 395 km^2 (1.0%) that are scattered through the upper Broken Skull River area, and (2) a strip of land containing 313 km^2 (0.8%) along the watershed boundary above Black Wolf Creek. Although these sites ranked as 'low' density of grizzly bears (Map 6), they are embedded in a landscape that has 'high' and 'very high' density of grizzly bears. Another area in the upper reaches of Wrigley Creek contained 95 km^2 (0.2%). Although it was not mapped as seasonal range for woodland caribou, it does lay immediately adjacent to areas used by both the Redstone and Upper Nahanni caribou herds; tracks of caribou have been observed in the vicinity, too (Norman Simmons, unpublished data). In addition, it is surrounded by lands ranked as 'high' and 'very high' density of grizzly bears (Map 6). Because both grizzly bears and caribou are exposed to detrimental impacts at edges of conservation areas, it does not make any sense to retain such 'holes' in the fabric of a conservation area. The same logic applies to edges of the primary sheep ranges on Tlogotsho Plateau and the Liard Range.

It must be noted, of course, that areas not important for these 3 prominent wildlife species may be quite important for other wildlife or ecosystem values. Higher elevations of the Ragged Range, for example, where patches of alpine tundra occur in a landscape of igneous rock outcrops and large ice fields, provide some of the best habitat in the Greater Nahanni Ecosystem for mountain goats (*Oreamnos americanus*), hoary marmots (*Marmota caligata*), and other species limited by suitable habitat.


Map 24
WILDLIFE CONSERVATION SOCIETY CANADA
Synthesis: Key Wildlife Range
Greater Nahanni Ecosystem
Sahtu
Northwest Territories
Yukon
N
W
E
S
Dehcho
Greater Nahanni Ecosystem
Nahanni National Park Reserve
Key Wildlife Range
Area of low or no occurrence
First Nations Border
0
100km

NEW BOUNDARIES FOR NAHANNI NATIONAL PARK

One of the most robust messages emerging from conservation science in recent years is that populations of large animals need large spaces, and most national parks around the world are simply too small and too narrow to protect them adequately (Newmark 1995, Woodroffe and Ginsburg 1998, Schwartz 1999, Groves 2003). Indeed, one of the leading causes of contemporary declines in wildlife populations has been fragmentation of habitat and diminished security for vulnerable populations.

Clearly, our research findings revealed that Nahanni National Park Reserve is too narrow and too small to protect these wide-ranging wildlife that represent a prime conservation goal. Hence, it is necessary to expand the park to protect critical seasonal ranges from loss and fragmentation of habitat, contribute substantially toward sustaining viable populations, and safeguard unique phenomena for these wide-ranging, vulnerable species of wildlife.

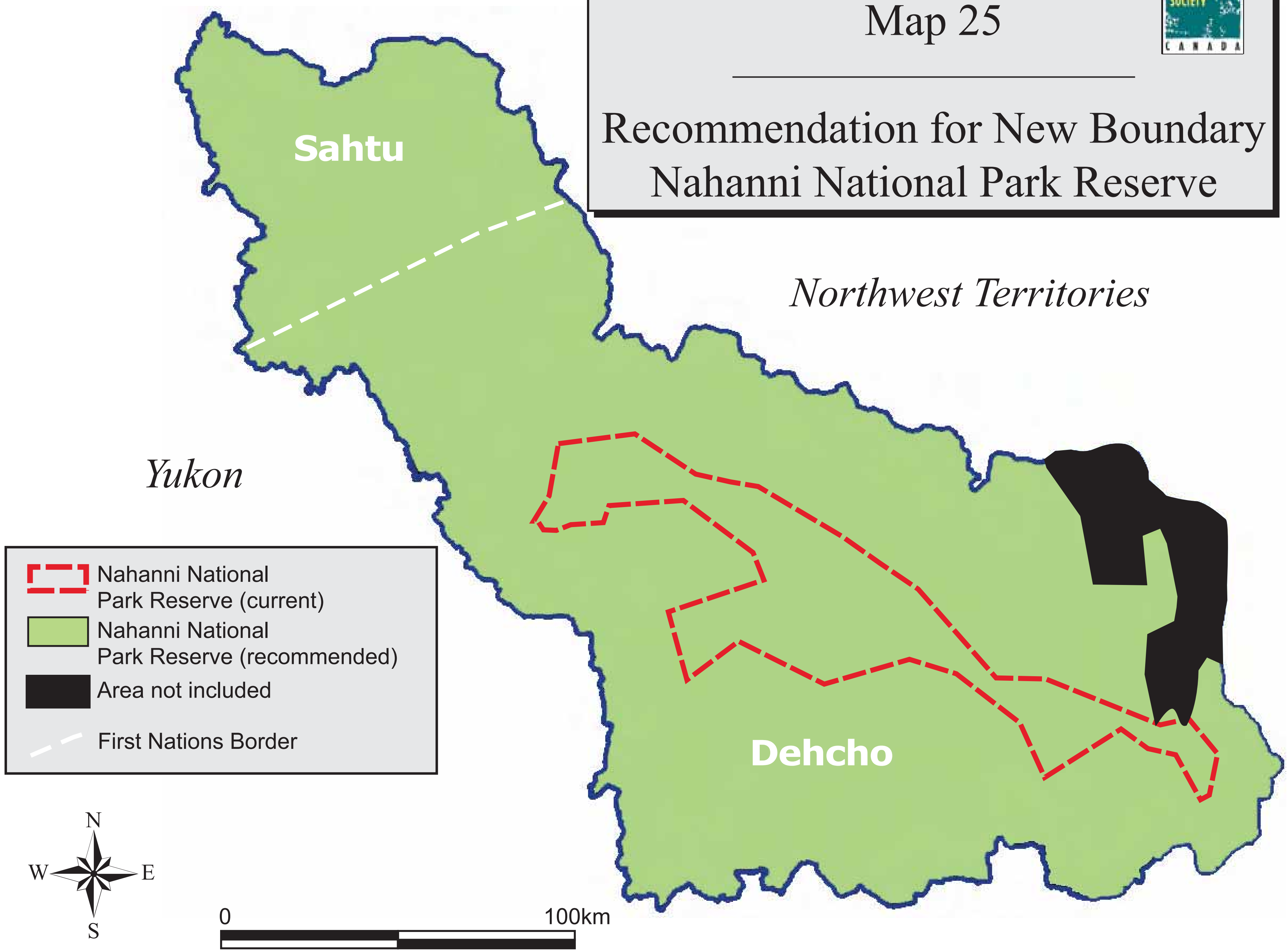
Based upon the data presented in the previous chapters, sound principles of conservation science, and my own extensive field experience across the Greater Nahanni Ecosystem, I recommend that Nahanni National Park Reserve be expanded to include the entire South Nahanni River watershed and the adjacent Nahanni Karstlands (Map 25). This recommendation does not include some of the northeast sector of the ecosystem (Tetcela River drainage and portions of Sundog Creek), which does not appear to be critical for conservation of these particular wildlife species (though it may be for other species). The recommended area comprises about 38,000 km^2, approximately 95% of the Greater Nahanni Ecosystem.

Such an expansion would embody many of the foundation principles of ecological integrity because it would:

- ✓ Protect important ranges and habitat for several wide-ranging wildlife species that are vulnerable to human impacts due to their low resiliency (grizzly bears and woodland caribou) and/or their reliance on special landscapes (Dall’s sheep).
- ✓ Safeguard the high level of genetic diversity present in these wildlife populations.
- ✓ Encompass the variety of land cover types and landscape features that are representative of the Mackenzie Mountains.
- ✓ Protect the unique assemblage of caves used by Dall’s sheep as well as other world-class karst features.
- ✓ Safeguard the natural integrity of the entire South Nahanni River watershed which is one of the most spectacular and intact wild landscapes in North America.
- ✓ Provide room for plants and animals to move and shift northward and higher in elevation in response to warming climatic changes.

Map 25

Recommendation for New Boundary Nahanni National Park Reserve



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About the Author

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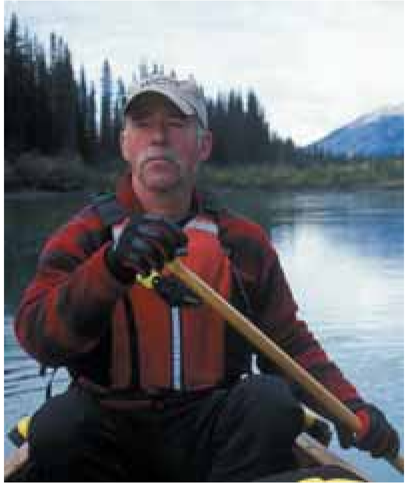
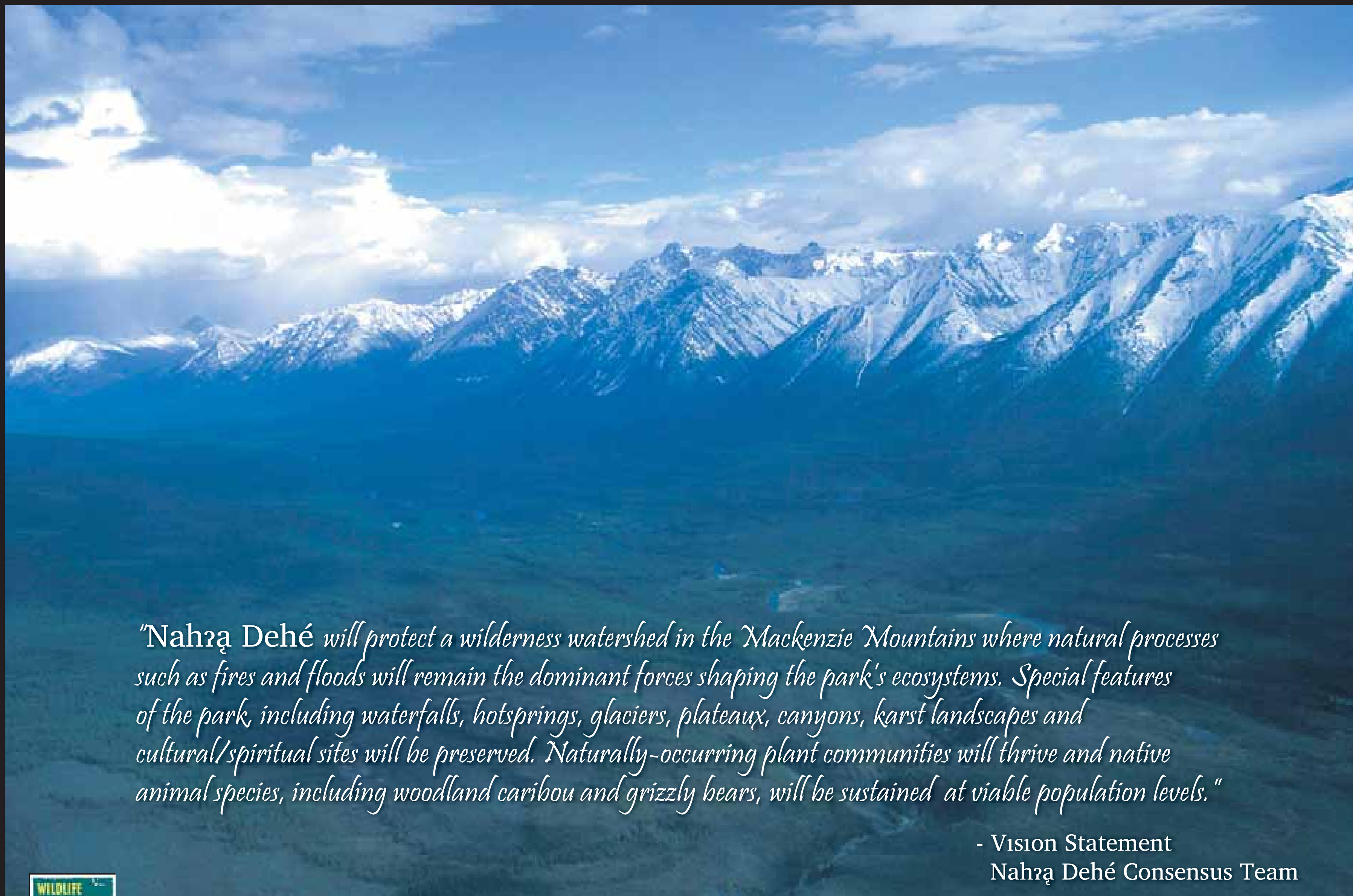
John L. Weaver graduated from the honors program at Utah State University and earned a Ph.D. in wildlife biology from the University of Montana for his field research on wolves in Jasper National Park. For the past 30 years, John has conducted research on a wide variety of carnivores in North America and served in several leadership positions in government for grizzly bear management in the United States. Currently, he is a conservation biologist with the Wildlife Conservation Society conducting field research on grizzly bears, caribou and other wildlife in western Canada. He lives on a small ranch in Montana where he raises and trains horses.





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