COW ELK ECOLOGY, MOVEMENTS AND HABITAT USE IN THE DUCK MOUNTAINS OF MANITOBA

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ABSTRACT

This study conducted baseline research to determine home range, movements and habitat selection of Manitoban elk (*Cervus elaphus manitobensis*) in the Duck Mountain (DM) of west-central Manitoba. Cow elk (n =22) were captured by helicopter net-gun and GPS radio-collared in 2005/06. Data was analyzed with ArcView 3.3 for Windows (ESRI). DM elk show selection for deciduous forest and avoidance of roads. Mean 100% MCP home ranges were 127.85 km^2 with 95% and 50% adaptive kernel home range sizes of 58.24 km^2 and 7.29 km^2, respectively. Home range overlap occurs at all times of the year with many elk using farmland. Elk moved the least in late winter. Movements increased in the spring, declined in June with a gradual increase from July to October. Elk had generalized movement in southerly directions. No cow elk dispersed from the study area. Mean estimated calving date was June 3rd and mean estimated breeding date was September 27th. DM elk were found in mature deciduous/mixed-wood forest and shrub/grassland/prairie savannah ecosites but not found within 200 m of a road or water feature more often than expected by random. Elk were found in areas with <10% and >81% crown closure, on middle slopes and variable aspects. Elk displaced from forestry cut-blocks. Only 149 of 79,284 elk locations were within 100 m of a winter cattle operation. Recommendations to mitigate forestry and BTB impacts focus on riparian areas, road management, farming practices and hunting.

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DEDICATION

I could not have completed this Master's without the love and support of my wife, Mila, my daughter, Deanna and my son, Ryan. I thank you for your understanding, patience and inspiration!

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General Introduction

This study of cow elk is the first baseline research on a population of the Manitoban subspecies (*Cervus elaphus manitobensis*) in the Duck Mountains of west-central Manitoba, Canada using GPS technology. The majority of North American elk research is done on Rocky Mountain elk (*Cervus elaphus nelsoni*) in the USA and Canada (Toweill and Thomas 2002). Therefore, it is interesting to study an elk subspecies from northern latitudes which may exhibit different ecological responses to their surroundings than elk in southern or montane jurisdictions. This baseline research should help to provide basic ecological insight into DM elk populations for Manitoba wildlife managers.

General elk ecology is well documented (Toweill and Thomas 2002). Research on the *C. e. manitobensis* subspecies, however is sparse as only one published reference (Hunt 1979) was found from Saskatchewan (which shares the same subspecies of elk as Manitoba). Manitoba elk research has been limited to home range, movements, food habits and winter distribution. Research that focuses on elk movements and habitat use is lacking in the DM area as it pertains to active forestry operations. From the author's work experience, any new insight into DM elk ecology can help wildlife and forestry managers to plan forest cut-blocks and access roads for wildlife and long term forest sustainability (Frair et al. 2008, Visscher and Merrill 2009). In addition, information on basic elk movement is needed to better understand how DM elk may be associated with bovine TB disease transmission (Pastuck 2002, Manitoba Conservation, unpublished report). For any managed hunted elk populations, baseline data can shed light on aspects of elk demographics and dynamics, not previously documented and this information can assist wildlife managers in future management decisions (Conner et al. 2008).

The Duck Mountain Provincial Forest (DMPF) covers 3,762 km^2 and has high capability to support elk populations (Goulden et al. 1973). The Duck Mountains (DM) are home to 1670 elk (Knudsen 2005, Manitoba Conservation, unpublished report); the second largest population of elk in western Manitoba. The elk in the DM are an important sub-population of the entire Manitoba elk herd. Elk are a high profile wildlife species in Manitoba. They truly inspire many Manitobans as they are a charismatic big game animal. Seeing or hearing a big bull elk "bugle" on a clear September morning along the edge of a boreal lake in the Duck Mountains is the epitome of a wilderness experience. Learning more about elk ecology in Manitoba will be a long-term benefit to wildlife managers when making future wildlife management decisions.

General elk ecology and research

Elk are highly adaptable and are found in a diversity of habitats in their constant search for high quality forage for nutritional needs to achieve reproduction and survival (Skovlin et al. 2002). Elk are known to show strong fidelity to areas having limited human disturbance and/or excellent security cover. Cow elk in non-migratory herds show strong fidelity to seasonal ranges (Shoesmith 1979). Lactating cows have a seasonal dependency on surface water (Thomas et al.1976). In addition, elk can exhibit marked daily (Ager et al. 2003) and seasonal movements, selecting specific habitats. Summer ranges in Montana are frequently in riparian bottoms (Marcum 1976) because of the availability of summer food and water (Pederson et al.1980). In winter, elk prefer upper south and southwest facing slopes as these are areas first to become free of snow (Flook 1962, Blood 1966).

The DM area has had limited scientific research on elk ecology. The Canada Land Inventory project determined that 81% of the DM is rated as having high capability for the production of ungulates with thirty-four (34) percent of the DM being considered Class 1 elk habitat (Bigelow et al. 1973). Schewe (1981) analyzed rumen contents taken from elk in the winter and found grain products in 47.3% of the elk stomachs. Browse species included rose, red-osier dogwood, trembling aspen and paper birch for another 47% with grasses making up the balance (2.5%). Palidwor (1990) documented forest food items for DM elk. She found that grass species such as: redtop (*Agrostis* sp.) and sedges (*Carex* sp.); forbs, such as vetch (*Vicia* sp.) and strawberry (*Fragaria* sp.) and browse species including aspen (*Populus tremuloides*) and willows (*Salix* sp.) were important elk food sources. A Habitat Suitability Index

(HSI) model was developed for Manitoban elk for the DMPF to facilitate integrated resource planning for forest/wildlife activities (TAEM Consultants Inc.1998). The HSI development was designed to assess habitat quality and quantity for elk and represented a comprehensive review of relevant elk research.

Manitoba elk movement research has occurred in the Shilo-Spruce Woods elk herd (Hornbeck 1979, Strong 1981 and Rebizant 1989) and Riding Mountain elk (Rounds 1976, Brook and McLachlan 2004, 2005, 2006). Seasonal home ranges of elk in the Shilo-Spruce Woods area varied from 17 to 64 km^2 in spring; 15 to 28 km^2 in summer and 12 to 48 km^2 in winter (Hornbeck 1979). Strong (1981) determined that winter range of elk was due in part, to proximity of agricultural crops. Maximum distances recorded between any 2 re-locations for adult female were 17 km. Rebizant (1989) determined that male elk had seasonal home ranges of 9-51 km^2. Winter and summer home ranges were smaller than spring or fall home ranges. The maximum distance traveled for male elk was 17.9 km in the spring.

In the RMNP, Rounds (1976) noted that elk movements out of the park were triggered by early deep snow and prolonged cold temperatures. He stated that this exodus was related to weather conditions and population density, with greater numbers of elk leaving the park at higher elk densities. Elk use areas outside the RMNP more during spring and summer than winter months. Cow elk make greater use of areas outside RMNP than bulls (Brook and MacLachlan 2005).

Numerous winter elk population surveys have been conducted (Coulson 1974, Davies 1979, Davies and Whaley 1980, Ball 1987, Storey 1990, Soprovich and Hildebrand 1993, Kitch 1999 and Knudsen 2005, Manitoba Conservation, unpublished reports) in the DM area. Population estimates have ranged from 1506 to 1670 elk. DM elk congregate on the northwest slopes of the DMPF south of Swan River, SW of the DMPF near Boggy Creek, SE of the DMPF north of Grandview and on the east side of the DMPF west of Ethelbert, MB. No additional documentation exists however, for other seasonal movement patterns.

Recent history of bovine TB issues in western Manitoba

Recently, the movements of the Riding Mountain National Park (RMNP) elk population has been intensively studied (Brook 2007) due to concerns associated with bovine tuberculosis (TB) and elk interactions with local cattle herds. RMNP elk herd is considered to be a reservoir for bovine TB (*M.bovis*) by the Canadian Food Inspection Agency, CFIA (Nishi et al. 2006, Koller-Jones et al. 2006). Bovine TB is a federally reportable bacterial disease and is significant due to its potential impacts to international trade, domestic livestock or human health (Lees et al. 2003). Bovine TB is a concern in Michigan where it has been spread among free-ranging white-tailed deer through supplemental feeding and baiting practices in Michigan (Schmidt et al. 1997). Because elk captured in the RMNP have been documented to move to the DM and return to the RMNP (Brook and McLachlan, 2004) cattle and wildlife testing have expanded to the rural municipalities on the south end of the DMPF. Bovine TB has been detected in 14 cattle herds, 40 elk and 10 deer, primarily from areas in and around the RMNP (Kingdon, K., Parks Canada, 2009, pers. comm.). One (1) bull elk of the 40 TB positive elk originally from the RMNP, was blood-test negative in 2002 and 2004. In 2005, when captured and euthanized in the DMPF, this bull elk cultured TB positive. This caused public concern about the potential for TB dispersal by elk from RMNP to the DMPF. The potential for elk to disperse from the SW corner of the DMPF may increase the chance that bovine TB could be transmitted between elk populations of the DMPF and RMNP as noted in other research (Conner et al. 2008). This was the primary reason to study elk movements between the DM and RMNP (Pastuck 2002).

Recent history of forestry in the Duck Mountains

At the turn of the century, portable and fixed sawmills were established at Swan River and Grandview. In the winter, farmers went to the thick forests of the Duck Mountains to work on forestry operations. Logging using horse-drawn sleighs was the area’s first major industry (Manitoba Parks Branch 2001, unpublished report). Quota holders in the Duck Mountains continued to harvest softwoods until the 1990's when demand for hardwoods (aspen) increased.

Large scale modern forestry operations conducted by Louisiana-Pacific Canada Ltd. started in the Duck Mountains in 1995. This company was licenced to harvest wood for an oriented strand board plant at Minitonas, MB (Cable and LeBlanc 2008, unpublished report). The harvest of mature aspen and mixed wood stands in the DMPF caused an increase in roads and access. Over 378 km of new road construction occurred with about 330 km permanently decommissioned. The mill at Minitonas has processed up to 800,000 m^3 of wood annually. Approximately 80 to 200 cut-blocks of hardwood or mixed-wood have been harvested in the Duck Mountains with an average of 5000 ha annually since 1995 (LP Canada Ltd., 2006). Harvest has been concentrated around the periphery of the Duck Mountain landscape (Figure 1.1). Manitoba Conservation works with LP Canada to ensure forestry impacts to wildlife are mitigated but lack of current information on elk ecology has limited efforts to fine tune forestry planning.

Statement of Problem

This study was designed to conduct the first baseline research of Manitoban elk (*Cervus elaphus manitobensis*) in the Duck Mountain (DM) of west-central Manitoba using GPS telemetry. Research on this subspecies is sparse and detailed information on DM elk herd ecology is lacking.

Three important wildlife management issues have converged on the DM area:

1. Bovine TB (BTB) exists in RMNP elk which causes significant economic implications to local cattle producers and there is concern that BTB may spread to the DM by elk movements.
2. Industrial forestry operations harvest timber in elk habitat throughout the DM and wildlife habitat supply needs should be established.
3. The DM elk herd is highly sought after by Manitoba resident and aboriginal hunters and should be maintained at current population levels for future consumptive use.

In order to assist wildlife managers to make informed decisions as it pertains to DM elk populations, bovine TB and forest management, research was conducted on basic DM cow elk ecology (with emphasis in the calving and breeding seasons), movements and habitat use in relation to landscape features and assessing the implications of this baseline information.

Objectives

1. Describe aspects of cow elk ecology in the Duck Mountains including home range, movements and habitat selection, with specific reference to calving and breeding seasons.
2. Assess aspects of cow elk habitat use in relation to specific landscape features such as roads, water, forest cut-blocks and winter cattle operations in the Duck Mountains.
3. Discuss implications of cow elk spatial/temporal patterns to current bovine TB and forest management activities in the Duck Mountains.

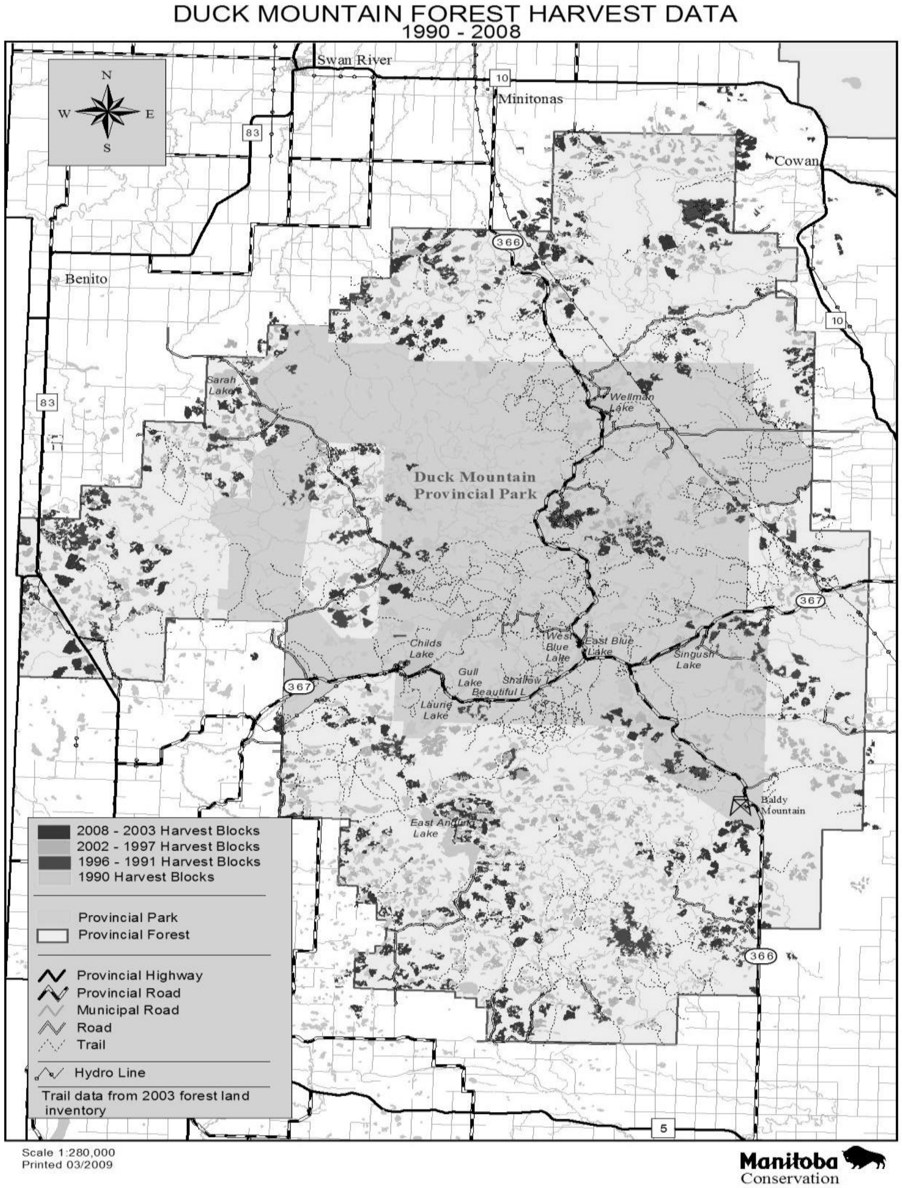

Figure 1.1 Distribution of forest cut-blocks in the Duck Mountains (1990-2008). Printed by permission of Manitoba Conservation.

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Chapter 2:

Study Area

The Duck Mountain Provincial Forest (DMPF) and Park are popular recreational areas for hunters, campers and wild land enthusiasts. The Duck Mountains are also an area of significant cultural value to First Nations. Ojibwa, Dakota and Cree hunters that harvest elk, moose and deer from this area for subsistence use. Local First Nation communities using the Duck Mountain area include Valley River, Pine Creek and Crane River First Nations. Native communities from other parts of Manitoba (e.g. Skownan, Ebb & Flow, Sandy Bay, Rolling River, Sapatoweyak, Wuskwi Sipiuk, Birdtail Sioux and Sioux Valley) also hunt the area for big game animals. Major population centres around the Duck Mountains include Swan River at the north end, Roblin in the SW corner, Grandview on the south end and Dauphin at the SE corner. The town of Ethelbert is found on the east side and Benito is on the west side. Mixed farming is the dominant agricultural activity in the farmland area with forestry, tourism and outfitting occurring throughout the entire study area.

The highest point in Manitoba, Baldy Mountain (841m), is found in the southeast part of the Duck Mountain Provincial Park (DMPP) and is part of the Manitoba Escarpment landform. The DMPF landform rises over 244 m above the surrounding agricultural land from approx.457 m on the flat farmland to approximately 701 m near the interior of the Park. The DMPF is an area of Western Upland mixed-wood forested habitat in west-central Manitoba. It is surrounded by agricultural development on the east, south and north-west. On the west side, a 16 km wide band of forest from the DMPF adjacent to the Saskatchewan border continues west into the Duck Mountain Provincial Park in Saskatchewan. On the north-east corner, forested cover continues north to the Swan-Pelican Lake area.

The study area used for analysis of home range, movements and habitat use by elk consists of Game Hunting Area (GHA) 18, 18A, 18B and 18C. The DMPF is GHA 18. GHA 18A is on the north and NW slopes of the Duck Mountains. GHA 18B covers areas on the east, SE and southern boundaries of the study area. The SW part of the Duck Mountains encompasses GHA 18C. The entire study area is 7,236 km^2 in size. The DMPF landform creates an interface between agriculture and forested areas where elk populations are known to range seasonally (Figure 2.1).

Geology, soils and climate

The Duck Mountains rise over the surrounding lowlands with the greatest relief on the eastern escarpment. The area was under salt water in the Cretaceous period of the Mesozoic era, 100 million years ago. The underlying rocks are grey bentonitic and siliceous shale of the Riding Mountain Formation. The eastern escarpment formed when the harder surface eroded slower than the softer rocks and created the Valley and Swan River valleys separating the three mountains; Porcupine, Duck and Riding. The physiography consists of ground and end moraines covered by glacial till which was laid down in the Pleistocene period of glaciation. After the retreat of the glaciers and the formation and retreat of Lake Agassiz, beaches and plateaus were formed with heavy precipitation from the uplands eroding the underlying shale into smaller steep valleys and canyons on the east side (Manitoba Parks Branch 1971, Barto and Vogel 1978, Manitoba Conservation, unpublished reports).

Soils are primarily medium to moderately fine gray luvisols of orthic grey wooded, gleyed grey wooded, regosolic and undifferentiated associations. There are some calcareous portions over glacial till with well developed A and B horizons. The glacial debris of the parent material has created stones in all horizons with clay gravel in the lower horizons and some acidic properties under the dominant vegetation. The main soil types are the Blackstone (clay), Waitville (loam), Grifton (sandy loam), Meharry (clay loam) Associations, the Duck Mountain (shale clay) and undifferentiated Eroded Slopes Complex (on steep slopes) and organic peat. Soil drainage is well to imperfectly drained in the rolling topography with poorly drained depressions characterized by organic peat soils (Ehrlich et al. 1959, 1962, 1968).

The climate is considered to be in the Sub-Humid Mid-Boreal Ecoclimatic Region (Strong and Zoltai 1989). Temperature and precipitation have wide seasonal fluctuations that vary between the uplands and the lowlands. Mean January temperatures are -18.5^{o}C and mean July temperatures are +17.7^{o}C (Welstad et al. 1996). Mean annual precipitation is 500 mm with precipitation in the uplands being as much as 50% greater than the lowlands and with temperatures 3 to 4 degrees cooler in July and January (Figure 2.2). Plant phenology in the uplands can be delayed in the spring by up to 14 days. The total frost-free period is 114 days. Snowfall is variable but generally from November 1 to April 1, the ground is covered with approximately 10 cm (or more) of snow (Strong and Zoltai 1989).

Plant and animal communities

The DMPP and DMPF are elevated forested areas of deciduous, mixed wood and conifer stands, interspersed with numerous lakes, rivers and wetlands (Manitoba Parks Branch 1980, Department of Natural Resources, unpublished report). Based on Landsat Thematic Mapper Imagery (2002) the entire study area consists of 25% mixed-wood forest, 23% deciduous forest, 8% coniferous forest,19% agricultural cropland, 10% grassland/rangeland, 9% water bodies & wetlands, 3% forage crops, 2% forest cut-blocks and 1% roads & trails. Major tree species present in deciduous forested sections include; trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and white birch (*Betula papyrifera*). Coniferous species present include black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*) and tamarack (*Larix laricana*). Typical under-story shrubs include choke-cherry (*Prunus virginiana*), saskatoon (*Amelanchier alnifolia*), hazelnut (*Cornus connuta*), pin-cherry (*Prunus pennsylvanica*), high bush cranberry (*Viburnum trilobum*), rose (*Rosa spp*.) and willow (*Salix spp*.) Forest cut-blocks are generally areas where timber has been removed with varying degrees of in-block retention, natural regeneration or plantations. Raspberry (*Rubus strigosus*) and fireweed (*Epilobium augustifolium*) are common at these sites as well as, young shoots of trembling aspen and willow. Grass and rangeland areas consist of cool season native grasses (e.g. *Festuca spp., Stipa spp*., *Koeleria spp. and Agropyron spp*.), tame grass species (e.g. *Poa spp, Agropyron spp*. and *Bromus inermus*.) and forbs (e.g. vetchling and peavine, *Lathyrus spp*.; sage, *Artemisia spp*.; vetches, *Vicia americana*;

honeysuckle, *Lonicera spp*. and thistle; *Cirsium arvense* & *Sonchus spp*.) with less than 10% shrub cover. These native grassland areas are usually grazed by local cattle herds outside of the DMPF and may contain shrubs such as western snowberry (*Symphoricarpos occidentalis*) and wolf willow (*Elaeagenus commutate*). Grassland communities in the Duck Mountains are not common but can be found on south west facing slopes dominated by plains rough fescue (*Festuca halli*) (Walker 2001). Water bodies can vary in size from large boreal lakes such as Child's or Singush Lake to smaller shallow wetlands having adjacent wet meadows and bulrush (*Scirpus spp*.) or sedge (*Carex spp*.) vegetation. Also common in these riparian zones are horsetail (*Equisetum spp*.) and red-osier dogwood (*Cornus stolonifera*), a favoured browse species for ungulates. All native plants are described according to Johnson et al. (1995) and Scoggan (1957).

Ungulate species inhabiting the area include elk, moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*). Major predators include wolves (*Canis lupus*), black bears (*Ursus americanus*) and cougars (*Puma concolor*). Meso-predators include coyotes (*Canis latrans*), marten (Martes *americana*) and fisher (*Martes pennanti*) and furbearers including, beaver (*Castor canadensis*), mink (*Mustela vison*) and weasel (*Mustela erminea*) (Manitoba Conservation 2007). All mammals are described according to Duncan (1997). The DMPF also has a rich diversity of avian life including bald eagles (*Haliaeetus leucocephalus*), goshawks (*Accipiter gentilis*), red-tailed hawks (*Buteo jamaicensis*), barred owls (*Strix varia*), ruffed grouse (*Bonasa umbellus*), ravens (*Corvus corax*) and pileated woodpeckers (*Dryocopus pileatus*). There are 208 known bird species recorded in the DMPF. Numerous neo-tropical migrant song-birds breed in the DMPF. The abundant species include, American redstart (*Setophaga ruticilla*), red-eyed vireo (*Vireo olivaceus*), ovenbird (*Seiurus aurocapillus*), Nashville warbler (*Vermivora rufacapilla*) and white-throated sparrow (*Zonotrichia albacollis*) (LP Canada Ltd. 2006). All bird species are described according to Taylor (2003).

Agricultural cropland is dominated by cereals such as, wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*), oilseed and other specialty crops (such as winter wheat and fall rye). Forage crops typical of the area include alfalfa (*Medicago* *sativa*), brome grass and crested wheatgrass. Livestock production is common with over 230 cattle operations around the southern half of the Duck Mountains (Schwaluk, T., CFIA, 2007, pers. comm.). Cattle production does not occur within the DMPF but is found mainly on marginal agricultural lands (private and Crown) adjacent to the DMPF (Welstad et al., 1996).

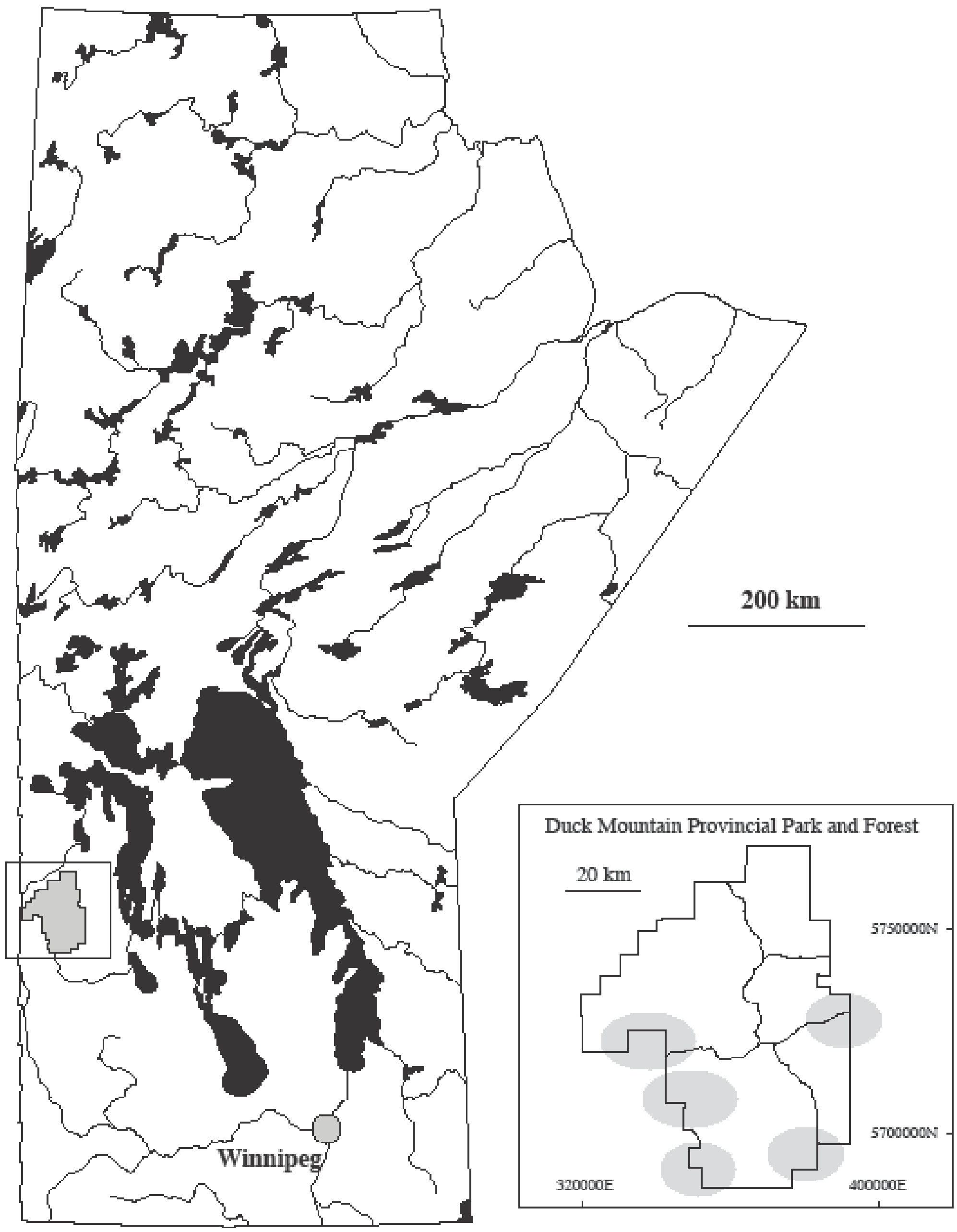

Figure 2.1 Location of the Duck Mountain study area in the Province of Manitoba. Shaded areas are the sites of original elk capture in 2005/2006.

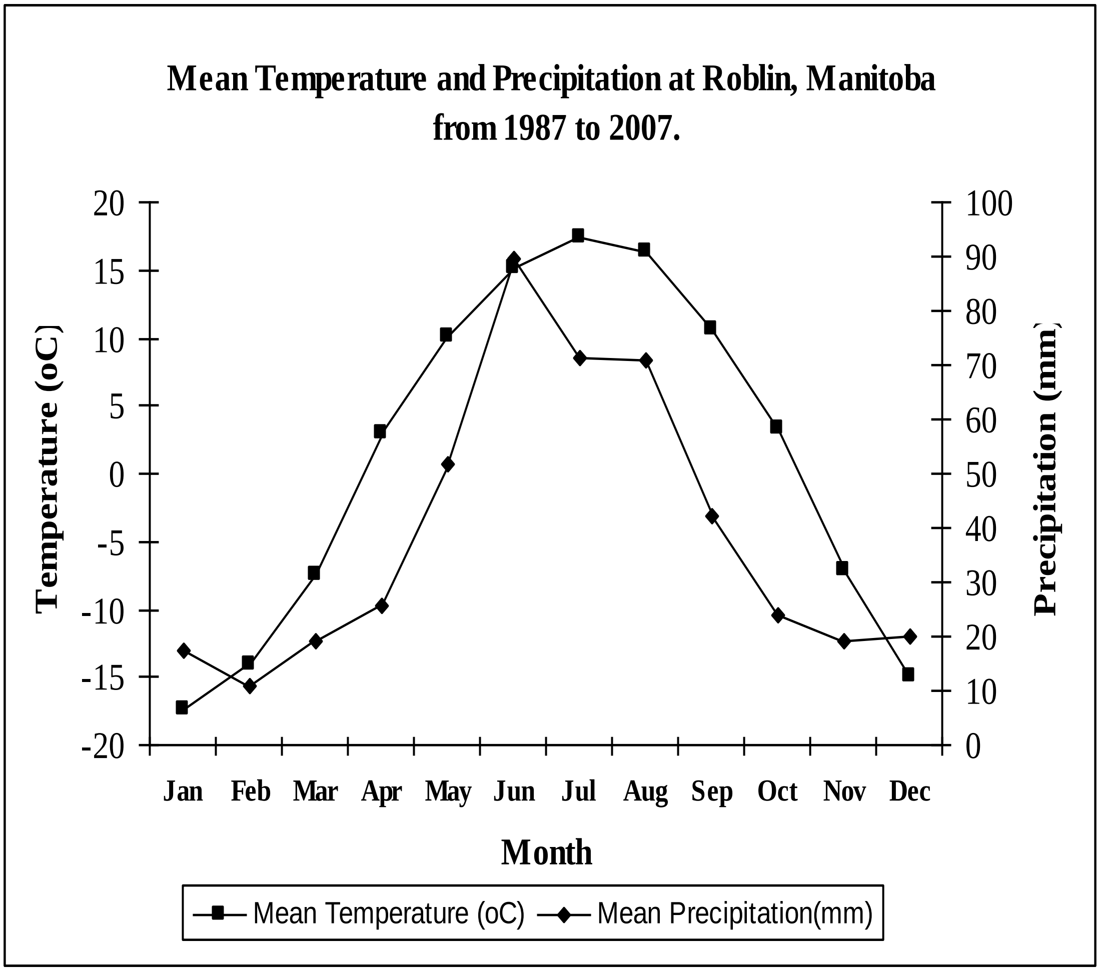

Figure 2.2 Mean monthly temperature and precipitation at Roblin, Manitoba from 1987 to 2007(Environment Canada, 2009).

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Chapter 3:

Aspects of cow elk habitat selection with reference to calving and breeding seasons

Abstract

Baseline research on a herd of 1670 elk in west central Manitoba was initiated in 2005. Cow elk habitat selection was determined with specific reference to calving and breeding seasons. During 2005 and 2006, elk were captured by helicopter net-guns, blood tested for disease, radio-collared with GPS units and released. GPS collars were retrieved in February and April 2007, data downloaded and analyzed with ArcView 3.3 for Windows (ESRI), Spatial Analyst and XTools extensions. Duck Mountain elk show selection at the study area level for one main habitat type; deciduous forest (1.48 $\pm$ 0.45). Marsh/fens (0.45 $\pm$ 0.27), coniferous forest (0.27 $\pm$ 0.40) and roads (0.54 $\pm$ 0.25) were significantly avoided. Habitat selection during the calving period of May to June had selection for deciduous forest (1.22 $\pm$ 0.20) by farm-land elk and marsh habitat (1.90 $\pm$ 0.83) by forest elk and there was clear avoidance of roads (0.16 $\pm$ 0.28). In addition, breeding season habitat selection during September and October had no significant selection, even though deciduous forest had a positive selection ratio (1.23 $\pm$ 0.24) and there was significant avoidance of roads (0.43 $\pm$ 0.30) and open deciduous forest (0.36 $\pm$ 0.53). Duck Mountain cow elk select consistently for deciduous forest year-round. Many cow elk seem to be using farmland habitats as their primary home range. Annual habitat selection by cow elk includes deciduous forest, riparian areas, forage crops and native grassland habitats. These are common landscape features selected by most cow elk. Cow elk also find areas with limited human disturbance with some separation from roads.

Introduction

Elk ecology pertaining to the calving season

Elk are seasonal breeders adapted to seasonal fluctuation in forage quality and quantity and the risk of predation (Raedeke et al. 2002). Captive cow elk have a gestation period of 247 $\pm$ 5 days (Haigh 2001). Wild cow elk generally have a gestation period of 250 to 256 days (Stelfox 1993) and most calves are born between May 15 to June 24 (Paquet and Brook 2004). Late birthing, however does occur annually (Vore and Schmidt 2001). Synchronous calving is conducted by elk to reduce predation (Geist 2002) and late born calves have lower annual survival (Barber-Meyer et al. 2008). Elk herds with high fecundity (i.e. 99% pregnancy rate), such as at Riding Mountain National Park, are considered healthy populations (Brook 2007) but conception dates can be delayed by heavy hunting pressure although not prevented (Squibb et al. 1986). Cow elk are also known to have high annual survival rates of (Ballard et al. 2000). Pregnant elk are known to increase their foraging periods and their intensity of feeding in late lactation to ensure they meet their nutritional requirements (Gedir and Hudson 2001). Cow elk select natality sites that provide security cover for neonates to hide from predators and in close proximity to quality forage to meet the demands of lactation (Brook 2007). Young elk are "hiders" in their first few days of life as this is an anti-predator strategy (Geist 2002). Cow elk in Idaho generally have increased daily movement rates just prior to calving and significantly decreased movement after birth. Cows isolate themselves when they are "with calf" for about 6 days after birth (Vore and Schmidt 2001). Birth weight of calves is closely tied to future survival with calves at 13 kg or greater having a 90 to 100 % chance of surviving their 1^{st} four weeks of life. Female calves have a higher survival rate than males. Calves born to yearling cows can have 38 % mortality with only 27 % mortality if born to cows older than 3.5 years of age (Raedeke et al. 2002). Neonatal mortality can be 27. 5 % on ranges in Wyoming with re-introduced wolves but, wolves only account for 17 % of calf elk mortality, with black bear predation accounting for 60 % of calf elk mortality (Smith et al.2006). Cook et al. (1996) found that growth of calves and over winter calf survival are related to dietary quality of late summer and fall forage. Calf elk survival can also be related to poor spring foraging conditions and lower spring temperatures (Smith et al. 2006). Cow elk survival is positively correlated to January temperatures and negatively to May temperatures and total July precipitation (Sauer and Boyce 1983). Adult cows subject to wolf predation tend to be taken more in late winter (Carbyn 1983). When elk must respond to wolf presence, their behavioural responses may reduce their forage intake and in turn affect nutritional condition, reproduction and survival (White et al. 2009). Since the variation in annual calf survival is closely tied to overall elk population growth (Raithel et al. 2005) and calf survival can be adversely affected by human disturbance (Phillips and Alldredge 2000, Shiveley et al. 2005), learning about the habitat selection of cow elk during calving is vitally important to wildlife managers interested in mitigating calf mortality due to human induced activities. Elk have also been documented using farmland for calving recently (Burcham et al. 1999, Brook 2007). This phenomenon may be occurring because of reduced predation in the farmland areas, in spite of human disturbance on the agricultural landscape. Knowing the habitat and landscape features of elk calving sites in farmland areas can also provide insight to the potential for further elk-cattle interaction. Elk calving in farmland are still calving close to the boundary of Riding Mountain National Park (Brook 2007). It is suspected that elk near the Duck Mountains also weigh the benefits of reduced predators and high quality forage on farmland with the increased chance of human disturbance on a spatial and temporal basis.

Elk ecology pertaining to the breeding season

The breeding season or "the rut" for elk is a busy time of the year. Elk are polygynous breeders and bull elk form large harems of cow elk with which to breed during the fall. Mean harem sizes in Wyoming can vary from 15 to 19 cows with a range from 4 to 32 (Wolff and Van Horn 2003). From my 18 years of archery elk hunting experience in the Duck Mountains, I have observed elk harems ranging from 5 to 22 cow elk in September. The general breeding strategy for bulls is to advertise by being vocal and demonstrating their size by displaying their body size and large antlers. Large bulls scare off subordinates by rushing them, showing their canines and hissing. Mature bulls create wallows to display their presence as well as to dissipate heat. Females chose to be bred by males that display the ability to produce superior progeny. Bull elk conduct loud bugling and its intensity is according to the receptiveness of cows (Geist 2002). Cow elk can be receptive for 12 to 24 hours during which time they will tolerate tending by the bull and possible breeding. Their first estrous cycle lasts for 21 days and can be followed by a second estrous cycle 21 days later depending on the condition of the cow. Mean range of conception of cow elk is September 23 to October 7. Cow elk are bred in the fall after the stress of parturition so they may have a chance to improve their condition before the winter. Mature bulls generally have a rut lasting approximately 41 days with yearling bulls having a rut lasting approximately 71 days (Raedeke et al. 2002). Bull elk rutting behavior can also have some plasticity based on the level of predation risk. Since rutting behavior involves a lot of time and energy, bull elk in predator rich environments spend less time foraging and use more ritualized display behavior to avoid injuries even though the majority of their time was still focused on courting activities (Wolff and Van Horn 2003). Late breeding of cows can occur when late cycling cow elk are bred by younger bulls still in the rut. Having sufficient mature elk in a herd ensures short, synchronous and early calving periods (Bender 2002). Bull elk can suffer from numerous antler wounds over the period of breeding that can contribute to late season infections. Bull elk retain their antlers after the rut however, to provide for defense from predators and reduce strife between bull elk groups in the post-rut period. Bulls tend to travel to secluded areas to avoid cow-calf groups, avoid predators and recover from the physiological rigors of the breeding season (Geist 2002).

The breeding season also tends to coincide with the start of annual hunting seasons across North America and interesting relationships, behaviors and activities develop between elk and hunters. Eighty-six (86) % of elk mortality occurs in September and October. There is a higher probability of mortality with increasing hunter and road densities and a lower probability of mortality for elk in areas of difficult and broken terrain. Cow elk have an annual survival rate of 0. 886 and bull elk survival rate is 0.600 in hunted populations in Idaho (Unsworth et al.1993). In North Dakota, cow elk survival rates are 0.96 in hunted areas and 0.99 in non-hunted areas (Sargent and Oehler Sr. 2007). Bull elk under minimum point hunting restrictions have annual survival rates of 0.57 (Beiderbeck et al. 2001). Also, as hunter numbers and road density increases, hunter success declines (Cooper et al. 2002). Idaho elk hunters that used roaded hunting areas were generally more experienced and hunted closer to home. Researchers found that by managing road access and reducing hunter density hunting quality improved (Gratson and Whitlaw 2000). This type of restrictive control of hunters realizes benefits for bull elk survivorship if bull: cow ratios are sufficient to allow recruitment into the herd. If there were at least 21 bulls per 100 cows, then up to 84% of the harems can be tended by mature bull elk (Bender 2002). In addition, spike bull hunting restrictions can be effective in recruiting bulls to the population, because up to 24% of yearlings can have branched antlers. Controlling cow elk numbers on small ranges through hunting is also important as increasing cow elk numbers can restrict bull access to good forage (Raedeke et al. 2002).

In a detailed study tracking hunters and elk space–use sharing, it was found that elk response to hunters is adaptive and short-lived. These researchers also indicated, similar to Cooper et al. (2002), Gratson and Whitlaw (2000) that, reducing hunter and road density would help to mitigate hunter disturbance to elk in areas with low vegetative cover. Elk prefer to hide and avoid hunters in dense vegetative cover. This pattern also occurs during the rut (Wolff and Van Horn 2003). In these areas there can be high space-use overlap, because hunters find it hard to see elk and elk feel relatively secure. Late season hunting (December) can cause elk to vacate areas and disperse to private lands (Millspaugh et al. 2004). The use of private land refuges is increasing with elk herds and has been noticed in the DM area over the last ten years by the author. Burcham et al. (1999) documented the use by elk herds of private land that had minimal or no hunting. Elk moved to these areas due to increased hunting pressure and a source of high quality forage. Elk would use these private lands in spite of the fact they may be close to roads. Elk on these private land refuges had a sense of security even if the typical secure cover of dense forest was not present. Elk can be repeatedly disturbed during hunting seasons in the rut and generally move after disturbance to areas of security, until they are no longer disturbed. Elk will move to private land refuges about the same time as the start of archery season (Vieira et al. 2003).This is a pattern observed by the author in elk herds around the Duck Mountain area. Burcham et al. (1999) determined that as elk move to private land to calve, increasing elk-landowner conflicts will occur including forage depredation, fence damage and loss of general hunter oppourtunity during the rut. Elk numbers will increase on private land over time (Burcham et al. 1999) if agencies don't address the issue.

Habitat selection research

In management of wildlife populations, managers generally want to assess a species needs and typically characterize 'needs' in relation to habitat use. They use the results to infer resource selection or preference. Selection and preference are sometimes used inter-changeably but are different. Selection implies that an animal is choosing from alternative habitats available. Use is selective if habitats are used disproportionately to their availability (Johnson 1980). Some researchers refer to avoidance of habitats but in reality the habitat is used by virtue of the telemetry locations recorded there. It is best to identify habitats as used less than they are available. Preference can only be determined when there is free access to resources on an equal basis and is rarely done in field conditions (McDonald et al. 2005).

Animals select habitat at various scales. First order selection is that of geographical or physical ranges selected by the entire population. Second order selection is the composition of the home range selected by an individual animal within its geographical range. Third order selection is the relative use of sites within an animal's home range. Generally, habitat use is a measure of proximate variables such as the structural features of the habitat (Johnson 1980). An animal's habitat selection is generally a nested hierarchy in which, choice of habitat type is called macro-habitat selection and the choice of specific patches within habitats is considered micro-habitat selection (Garshelis 2000).The choice of the appropriate spatial and temporal scale of measurement can greatly influence results and interpretation.

While most studies measure discrete levels (i.e. daily, seasonal, home range, etc.) the actual scales of measurement and environmental heterogeneity are continuous. Habitat types must be truly important and not lumped with less important types. Therefore, analysis must take this into consideration and guidelines followed to assist in the design of studies involving second order selection. A study area selected must be larger than most animal's home range (i.e. the Duck Mountain area represented by GHA 18, 18 A, B, C). The number of individuals within the study area must be an adequate sample size for study. In many studies of elk, a minimum of 20 individual elk is required. The individuals captured for study and their home ranges should be randomly selected and be as independent from each other as reasonably possible (this guideline is frequently violated as animals are clumped at various times of the year which makes capture feasible). Lastly, study boundaries should take into consideration the biology of the animal and use physical boundaries vs. geopolitical boundaries, as much as possible (McDonald et al. 2005).

Nevertheless, habitat use is subject to sampling error and error in analytical procedures. Study individuals may not be independent of each other. Study subjects could be gregarious by nature or part of a specific social group (wherein the group leader selects the habitats for the group).The habitats used for analysis must be defined as discrete entities. This can be difficult but, many studies use GIS classified habitats of digital data, readily available from resource agencies. Remote sensing images depict specific habitats that can be quantified and described in a manner useful for resource selection analysis.

Resource selection ratios measure the proportion of habitats used to the proportion of habitats available (Manley et al. 2002). Resource selection ratios are applicable to studies of multiple animals. They allow one to make inferences about the average selection relationship for the large population by averaging individual selection ratios and using the individual animals as the effective sample size, thereby avoiding pseudo-replication (Erickson et al. 2001)

Because researchers truly do not know what level of perception is being used by the study animal it is always best to study use at varying scales in order to pick up any trends. There are two flaws that researchers must be aware in habitat selection studies; (1) it cannot always be assumed that because a resource is more available, it is likely an animal will use it more. This is especially true if availability of a resource varies seasonally. (2) It cannot be definitively inferred that high quality habitats based on habitat selection, can be directly linked to an animal's survival and successful reproduction and/or individual fitness. Habitats used infrequently may be more important than the time spent there (i.e. they may be used infrequently because their value can be extracted in a short period of time). On the other hand, a mixture of habitat types can be more beneficial to a species than a single, highly selected habitat. The time spent in each habitat type may be a poor indicator of the importance of the habitat in the overall habitat mix (Boitani and Fuller 2000). The objective of this Chapter is to determine at various scales, the habitat selection patterns of cow elk during calving and breeding seasons and their relative use of habitat types annually.

Materials and Methods

Elk capture

Elk were captured with a net gun fired from a Hughes 500D helicopter in February and April 2005 and 2006 and radio-collared (Cattet et al. 2004) in and around the DMPF (Figure 3.1). Elk were captured in five main areas (Boggy Creek area, 36 km. north of Roblin, MB; Shell River valley area, 10 km east of San Clara; Merridale area, 14 km. NE of Roblin ; Sulphurspring Creek area, 16 km. north of Grandview, MB. and the Ethelbert area, 40 km. NW of Dauphin, MB., Figure 1.1). Elk were located by observers in 'bird-dog' fixed-wing aircraft that helped direct the helicopter to the elk. A maximum of two animals were captured per group. Capture and handling was conducted by Bighorn Helicopters with the supervision of veterinarians, Dr. Marc Cattet of the Canadian Cooperative Wildlife Health Centre or Dr. Todd Shury of Parks Canada. Ground support was provided by MB Conservation and Parks Canada staff and aerial support by Dauphin Air Service. The elk movement study was approved by Parks Canada environmental screening report # RMNP000567 in November, 2005 and animal care approval was received from the University of Manitoba Fort Garry Campus Protocol Management & Review Committee, Utilization Protocol # F05-026 in January, 2006.

Immediately upon net capture, elk were restrained to prevent escape and excessive kicking. The net was removed, legs hobbled together and a blind-fold was placed over the eyes. Blood samples were taken for assessing animal health and presence of disease. Blood was collected from the jugular vein into serum separator tubes for biochemical analysis and measurement of serum cortisol concentration. Blood was also placed into an EDTA tube for a complete blood count. Blood samples were sent to the Canadian Cooperative Wildlife Health Centre for general health assessment and to the Canadian Food Inspection Agency in Nepean, ON for bovine TB tests. Four different blood tests were used to determine presence of bovine TB (i.e. fluorescent polarization assay (FPA); lymphocyte stimulation test (LST); polymerase chain reaction (PCR) and gamma interferon. Individual elk that tested positive or suspect on any test were re-captured and euthanized for additional confirmatory testing of bovine TB. Each elk received a radio collar or radio ear transmitter and a uniquely numbered ear tag (Figure 3.2). Ear tags were plastic dangle tags, approximately 5 cm^2 in size that fit through the ear.

Habitat selection analysis

Habitat selection by elk was determined at two scales: the study area and the 95% adaptive kernel home range. Relative use was determined at 4 different spatial scales (50, 500, 1000, 2000 m). The study area was not arbitrarily determined using anthropogenic features. It was derived using elk movement data. All 100% MCP home ranges were merged into one polygon using XTools extension ver. 1.1 (De Laune 2003) for ArcView. The greatest distance traveled by any elk in one direction was 18 km. Therefore, the merged MCP polygon was buffered by 18 km. This theme was used to clip out habitat types (i.e. roads, water features, cut-blocks and winter cattle operations) for analysis (Figure 3.3). Analysis to create temporary grids and tabulate areas was done using Spatial Analyst extension for ArcView 3.3 (ERSI, Inc.). Habitat analysis was completed by using digital imagery available from the Manitoba Land

Information Network with the Province of Manitoba. This spectral feature data was originally classified using supervised classification on training areas by the Federal Department of Agriculture Canada, Prairie Farm Rehabilitation Administration (PFRA) in 2002. Shape files were classified into 14 habitat types: Agriculture cropland, deciduous forest, open deciduous forest, mixed-wood forest, coniferous forest, forage crops, grassland/rangeland, water bodies, marsh and fens, bogs, forest cut-over, cultural features, rock, sand and barrens, roads and trails. Resolution of each pixel was 30 m. While habitat types were ground-truthed for accuracy, spectral reflectance for some habitat types (i.e. some forages and native grasslands) caused occasional misclassifications.

Using Spatial Analyst extension, areas of habitat types were calculated for the entire study area as a proportion of total habitat available. The entire area was created into temporary grid cells (250 m^2) to evaluate habitat use based on locations coinciding with each cell. In addition, habitat proportions were tabulated for individual annual MCP home ranges. Locations of elk were buffered (using XTools) with circular radii at 50 metres (to account for location and habitat classification error), 500 metres (to account for maximum mean daily distance traveled by elk), 1000 metres and 2000 metres. Habitat selection was determined at the 500 m scale and annual relative use determined at the 50, 1000 and 2000 m levels. In addition, to ensure auto-correlation was addressed, only 10 elk were used in habitat selection analysis. These were elk that had minimal home range overlap and were representatively distributed throughout the study with 5 elk from the first year and 5 elk from the second year of study.

A selection ratio (SR) for each habitat type was tabulated. The SR was expressed as a ratio of used habitat to available habitat (Manley et al. 2002):

$$Wi = Oi / A\mathit{i}$$

Where Oi is the proportion of ith habitat sampled (used) in a circular radii and Ai is the proportion of the ith habitat type found within the study area or within the home range. In the case of habitat selection by home ranges, 95 % adaptive kernel home ranges were used as clip themes within the study area and proportions of habitat types were tabulated for each home range. SR values above 1 indicate a habitat type is selected relative to its overall availability in the study area or home range. An SR below 1 indicates that the habitat type is underused relative to its availability.

The significance of each SR was evaluated by calculating Bonferroni-corrected confidence intervals derived from Manley et al. (2002) as follows:

$$W_i + Z\alpha / (2l) * SE(W_i)$$

Where l is the number of habitat types (n =14), α = 0.1 and SE is the standard error of Wi. If the confidence interval overlapped with 1, then the habitat type was used in relative proportion to its availability and therefore not significant. If the confidence interval does not overlap 1, habitat selection or avoidance was considered to be significant (i.e. habitat was used or avoided greater than its availability).

Habitat selection analysis was conducted specifically for calving and rut (breeding) seasons. Calving season was deemed to be May 15 to June 24, similar to Paquet and Brook (2004). Approximate calving dates were determined as the shortest movement measured within the calving period (Brook 2007). May/June habitat selection was further analyzed for 6 elk that had ≥90% of their calving season home range in farmland and 4 elk with ≥90 % of their calving season home range in the DM forest. Breeding season was deemed to be September 6 to October 19 to cover the mean rut period of 20 to 41 days for a mature bull elk (Hudson and Haigh 2002).

Monthly relative use of main habitat types (i.e. agriculture cropland, deciduous forest, grassland/rangeland, mixed wood forest, marsh & fens and forage crops) was also tabulated based on percentage of use. Elk centroids were buffered by 500 m to account for location and classification error. In addition, 50 % kernel home ranges were super-imposed over aerial ortho-photos to visually describe general landscape features within the home range. In addition, information on 22 aerial telemetry flights was tabulated for habitat type by elk sighting, elk group size and miscellaneous observations.

Results

Habitat selection

Generally, habitat selection ratios (SR) greater than 1 indicate selection but only those ratios with confidence levels that do not overlap with 1 are significant. Duck Mountain elk show selection at the study area level for one main habitat type: deciduous forest (Figure 3.4). Grassland and forage crops were also preferred but selection was not statistically significantly. Using Bonferroni corrected confidence intervals to determine significance ($Z\alpha = 0.05$), only deciduous forest (1.48 ± 0.45) was selected. Marsh/fens (0.45 ± 0.27), coniferous forest (0.27 ± 0.40), and roads (0.54 ± 0.25) were significantly avoided for those areas within 500 m of elk locations. Habitat selection during the calving period of May to June (Figure 3.5) had no significant selection although, marsh/fen (1.78 ± 0.83) and deciduous forest (1.04 ± 0.34) had positive selection ratios and there was clear avoidance of agriculture cropland (0.57 ± 0.33), coniferous forest (0.31 ± 0.34), open deciduous forest (0.19 ± 0.34) and roads (0.16 ± 0.28). During May and June, elk with home ranges primarily in farm-land (Figure 3.6), selected significantly for deciduous forest (1.22 ± 0.20) with positive selection ratios for grassland/rangeland (1.12 ± 0.39) marsh/fen (1.70 ± 1.20) and significantly avoided open deciduous forest (0.32 ± 0.50). Elk with home ranges primarily in the DM forest during May and June (Figure 3.6) selected significantly for marsh/fen (1.90 ± 0.83) with a positive selection ratio for water (1.59 ± 0.73) and significantly avoided coniferous forest (0.44 ± 0.34). In addition, breeding season habitat selection during September and October had no significant selection (Figure 3.7), even though deciduous forest had a positive selection ratio (1.23 ± 0.24) and there was significant avoidance of roads (0.43 ± 0.30) and open deciduous forest (0.36 ± 0.53). Based on movement path analysis, most elk moved from the farmland to the DMPF during the rut and fall hunting seasons and many elk were in the farmland areas more than the DMPF during calving season.

The entire study area was assessed and relative proportions of use of main habitat types were determined. Elk habitat selection in this analysis showed consistent trends for selection of deciduous forest, grassland/rangeland and forage crops. These habitat types were selected at proportions greater than availablity at all levels of sampling (50m, 500m, 1000m and 2000m). Coniferous forest, mixed-wood forest and agriculture cropland were selected in proportions less than available at all scales. Other habitat types were used less than available but standard errors fell with the range of available habitat (Figure 3.8). At greater distances (i.e.2000m), habitat types that became less available because they were in shorter supply, exhibited stronger selection (e.g. grassland/rangeland and agriculture cropland). Regardless of scale, deciduous forest and forage crops continued to be used in greater proportions than available. In addition, aerial telemetry flights seem to support this observation.

Elk groups ranged in size from 2 to 65 with an average group size of 12 elk. Single elk were observed on 34 of 242 group observations. Groups greater than 10 were generally observed in December to April. Groups less than ten were observed in June to August. In the summer months, some elk (14) were observed near cattle in bush pastures. Over 61% of observations were in deciduous forest and/or deciduous-dominated mixed-wood forest. Nine of 11 cow elk observed in June/July 2005 were seen with calves (Table 3.1).

The previous habitat selection analyses attempted to assess selection assuming the entire study was available for elk. Second order selection occurs when elk select their home ranges within the landscape. In third order selection, elk may use specific habitats in proportion to their availability within the home range. At the 95% home range level (500m buffers) only deciduous forest was significantly selected (1.30 $\pm$ 0.14). Mixed-wood forest showed selection but not significantly. Elk habitat use within their 95% adaptive kernel home ranges showed no other habitat selection and no avoidance was significant (Figure 3.9).

Analysis of each individual elk's MCP home range consisted of different proportions of habitat and therefore habitat selection was quite variable. Any selection ratios greater than 1.5 were considered to be strongly selected habitat types. Most elk (n =11) continued with the trend shown at larger scales by selecting deciduous forest, grassland/rangeland and forage crops while other elk showed selection for : forage crops (n =3), water (n = 4), mixed-wood forest (n =1), open deciduous forest (n =1) and forest cut-blocks (n =2).

Relative use of habitat types by elk on a seasonal basis indicated that deciduous forest was consistently used throughout the year. While generally avoided, agriculture cropland had peak use in April and November with forage crops getting their highest use by elk in March, April and December. Marsh and fen wetlands were used more in the summer months of May, June and August. Grassland/rangeland seemed to have peak use in December and February with mixed-wood forest having peak use during the spring month of May and the fall month of September. Open deciduous forest use peaked in June (Figure 3.10).

Discussion

Habitat selection

Habitat selection by elk can differ markedly between spatial scales and seasonal ranges. Due to this fact, no specific scale is appropriate to determine habitat selection (Boyce et al. 2003). Scale selection depends on the research or management issue. As this study is the first telemetry baseline study of Duck Mountain elk, investigating habitat use at multiple scales was helpful to determine trends even though habitat selection was specific to one habitat type.

Most of the preliminary findings in DMPF elk habitat selection are not surprising. Even though selection significance was not obtained for many habitat types, telemetry error can prevent true selection from being detected if the grain of habitat patch size is smaller than position error (Johnson et al.2000). Selection for deciduous forest at the study area and 95% kernel home range scales was to be expected as this finding was similar to RMNP elk (Blood 1966, Rounds 1981, Trottier et al. 1983, Brook and MacLachlan 2006). Based on other studies indicating that GPS fix success can be biased by heavy canopy cover or rugged topography it is the author’s belief that selection for mature deciduous forest would be even stronger had all radio-collars achieved close to 100% fix success. I speculate that most missed fixes were in mature deciduous forest or in deep valleys that would prevent GPS collars clear view of satellites and consequently bias habitat selection. In addition, the selection (not significant) for deciduous forest in the Sept-Oct breeding season is explained by the need for secure cover during hunting seasons. The fact that forage crops are a favored habitat type of elk is consistent with local farmer observations of elk herds on their alfalfa fields in the spring and autumn months.

In spring, elk respond to greening vegetation and select for open canopies (Unsworth et al.1998). In addition, use of native grassland by DMPF elk is typical as elk are natural grazers (Christianson and Creel 2007, Toweill and Thomas 2002, Hunt 1979). Elk will use cattle pastures previously used by cattle if the pasture is close to good cover and away from visible roads (Grover and Thompson 1986). While Blood (1966) found browse species to be the primary food item in RMNP elk rumens, a significant portion of the elk diet can consist of graminoids on a seasonal basis (Cook 2002). RMNP elk did exhibit the same preferences for forage crops and grasslands. Temporal peak use of grassland habitat types were somewhat similar, with RMNP elk using grassland mainly in April and DMPF elk using grasslands mainly in May. RMNP elk used wetlands a lot in May and throughout the summer while DMPF elk used wetlands in early and late summer but peaked use in June. Association with wetlands for lactating cows has been documented by other researchers (Marcum 1976, Thomas et al. 1976, and Pedersen et al. 1980). This finding is also supported by the MCP home range selection of some elk for riparian areas and the visual ortho-photo observations regarding the consistent presence of creek drainages or wetlands being found within home ranges

The May-June calving period habitat selection analysis indicated selection for deciduous forest and marsh habitats which is consistent with previous researchers. Farm-land elk selected for deciduous forest probably for the security it provides on the open farmland. Forest elk were surrounded by forest and selected for marsh/fen consistent with previous studies indicating the close proximity of lactating cow elk to wetlands. Farmland elk avoided open deciduous forest as it was probably too exposed to human interference and forest elk avoided coniferous forest because it has low forage biomass for elk. My data analysis did not show selection for forage crops even though Brook (2007) was able to show significant selection for forage crops by parturient RMNP elk. This may be related to analysis buffers around elk locations. Brook used 150 m buffers and I used 500m buffers. My analysis may have averaged selection ratios to the point where selection could not be detected. Small diameter buffers around locations tend to mirror the habitat around the actual location (Garshelis 2000). Agriculture crop use rose in April to June with a peak in July around the RMNP while the DMPF elk had high use of agriculture and forage crops in the spring but tapered off in the summer with an increase in use of these habitats in November and December in contrast to the RMNP elk.

Duck Mountain elk seemed to have higher proportional use of mixed-wood forest in the May to August months. Mixed-wood forest was the second most common habitat in which RMNP elk were observed for aerial relocation flights. These observations could be related to the cooler temperatures created by the micro-climate of these denser forests and its associated benefit to lactating cow elk for the cooling effects for the cow and the calf during the hot summer temperatures. Elk are known to select areas with cool micro-climate conditions having high shrub cover and north to east facing slopes (Frair et al. 2005). In late summer, when diversity and abundance of succulent forage species declines elk select sites in more closed canopy areas with high habitat diversity, due to the decreased palatability of forage in open areas (Edge et al. 1988, Sawyer et al. 2007).

In the absence of forest cover (i.e. open areas) elk rely on shrub cover, topography and low human disturbance for thermal and hiding cover (Sawyer et al. 2007). This is similar to Duck Mountain elk that select open deciduous forest in the summer in areas of variable topography. Elk prefer to forage in areas of intermediate forage biomass with low movement costs but tend to move more when close to linear clearings or when moving upslope (Frair et al. 2005). These are consistent with my personal observations of elk activity near forestry cut-blocks. Movements are tied to mean size of cut-blocks as larger open patches create limitations to elk movements within and amongst foraging areas as cut-blocks get larger (Friar et al. 2005). Forest cut-blocks pose trade-off situations for elk as they are potential foraging areas but also pose high risks from wild predators and humans. In the presence of predators, DM elk are likely exhibiting anti-predator behaviours such as increased vigilance, shifts in distribution to lower risk areas (i.e. open deciduous forest) or increases in group size as noted in this study during the winter (White et al. 2009).

Coniferous forest was not commonly used by Duck Mountain elk. Habitat selection by DMPF elk was significant for avoidance of this habitat type. This finding is consistent with other studies (Poole and Mowat 2005, Unsworth et al. 1998).

Conclusions

1. Duck Mountain cow elk significantly select for deciduous forest year-round. Selection for forage crops and grassland/rangeland was biologically significant even though it wasn't statistically significant.
2. Habitat selection by cow elk is specific in the calving season with deciduous forest and marsh being selected. Some cow elk home ranges select for forested areas and other home ranges select for farmland.
3. Forage crops and native grassland habitats were also used by cow elk in the late winter and spring.
4. Cow elk use mature deciduous forest for security during the breeding season in September and October.
5. Elk consistently avoid roads and coniferous forest.
6. Open deciduous forest is generally avoided but used by cow elk during calving season in June.
7. Cow elk also find areas with limited human disturbance with some separation from roads

Table 3.1 Summary of 22 telemetry flights (June 2005 to March 2007) in which 242 different elk groups were classified into habitat types.

Year	*Shrub*	*Forage crop*	*Deciduous forest*	*Mixed wood*	*Cut-block*	*Bush pasture*	*Riparian area*	*Ag crop*	*Grand Total*
2005	0	0	12	2	0	0	0	2	
2006	1	9	46	14	22	8	20	5	
2007	1	6	55	20	5	6	8	0	
Total	2	15	113	36	27	14	28	7	242


Figure 3.1 Duck Mountain elk capture at point of helicopter net-gun discharge, February 2006


Figure 3.2 Duck Mountain elk radio-collar attachment at point of release February, 2006

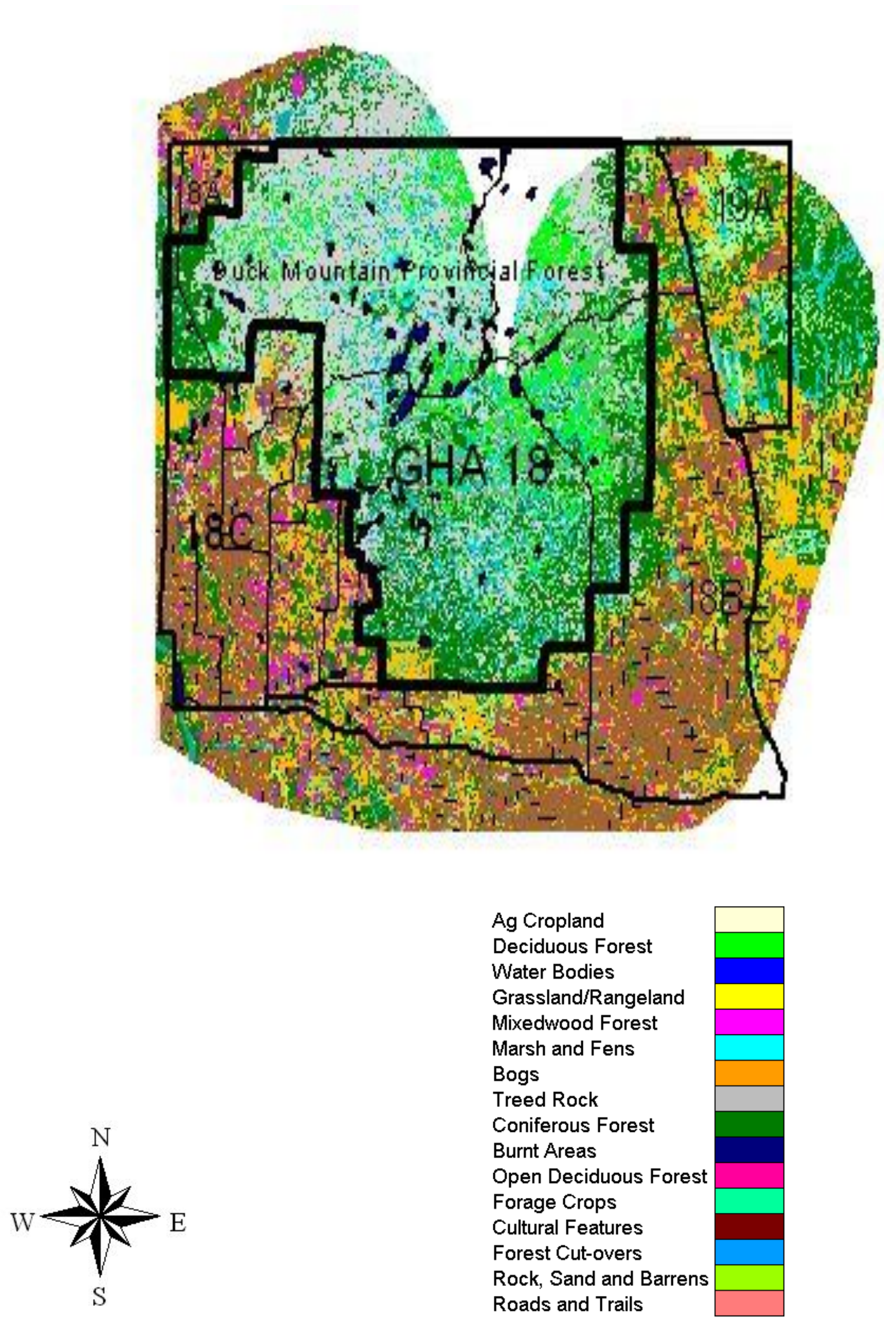

Figure 3.3 Duck Mountain study area layer used for habitat selection analysis

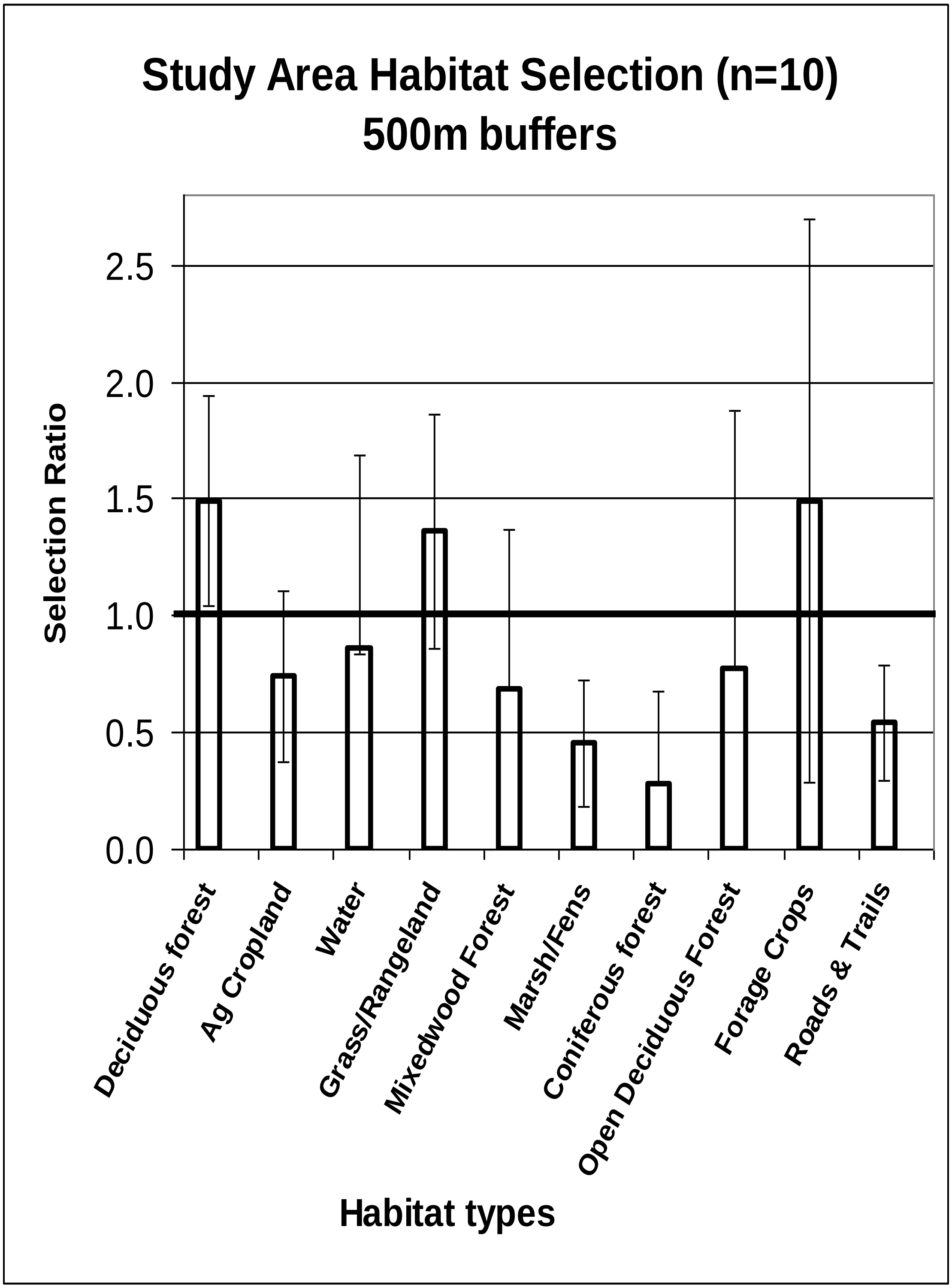

Figure 3.4 Study Area Habitat Selection for 2005 to 2007 (n = 10 elk). Columns with error bars above the dark black line indicate selection and columns with error bars below the dark black line indicate avoidance.

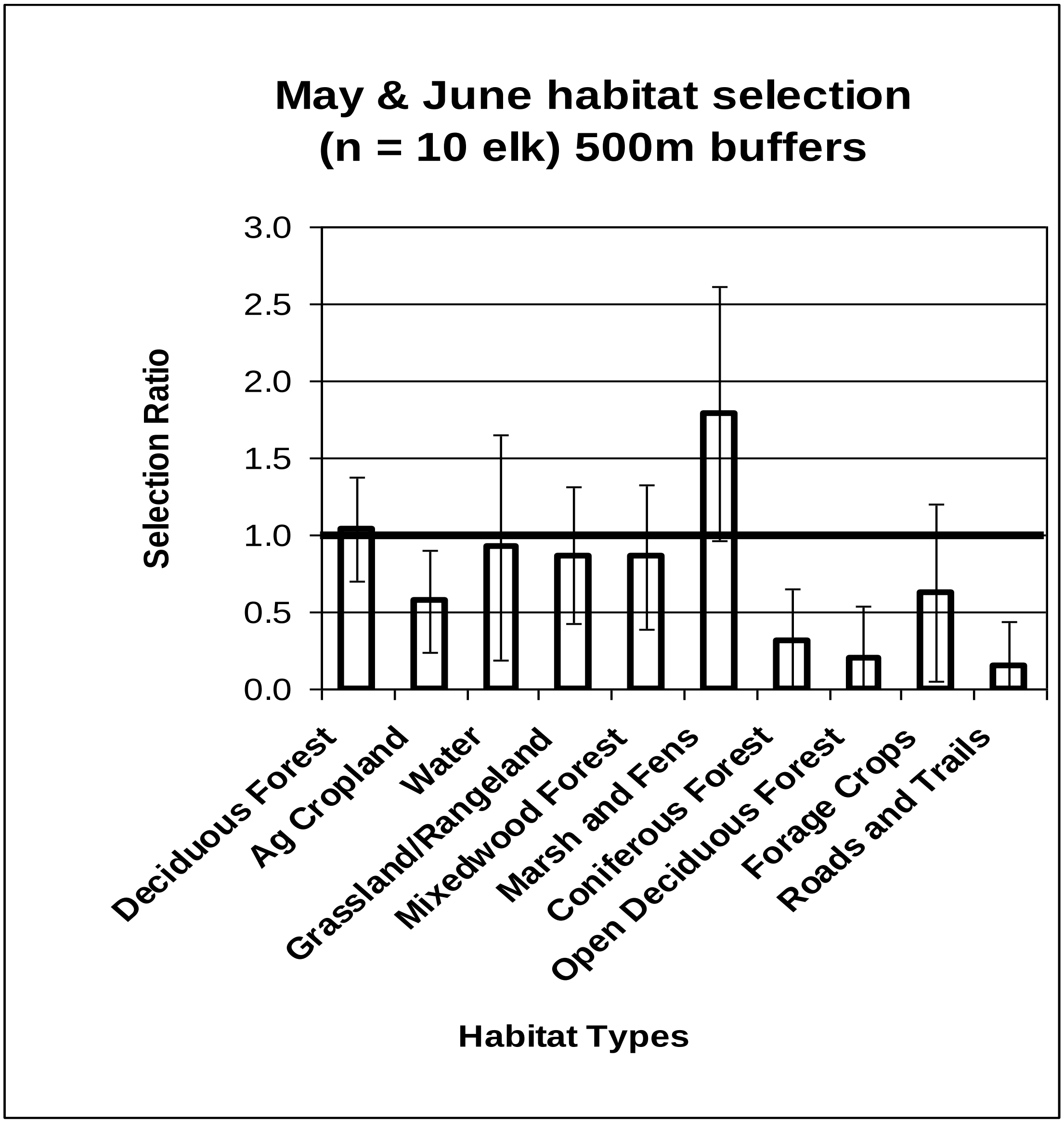

Figure 3.5 Habitat selection in May and June calving period for Duck Mountain cow elk (n = 10 elk). Columns with error bars above the dark black line indicate selection and columns with error bars below the dark black line indicate avoidance.

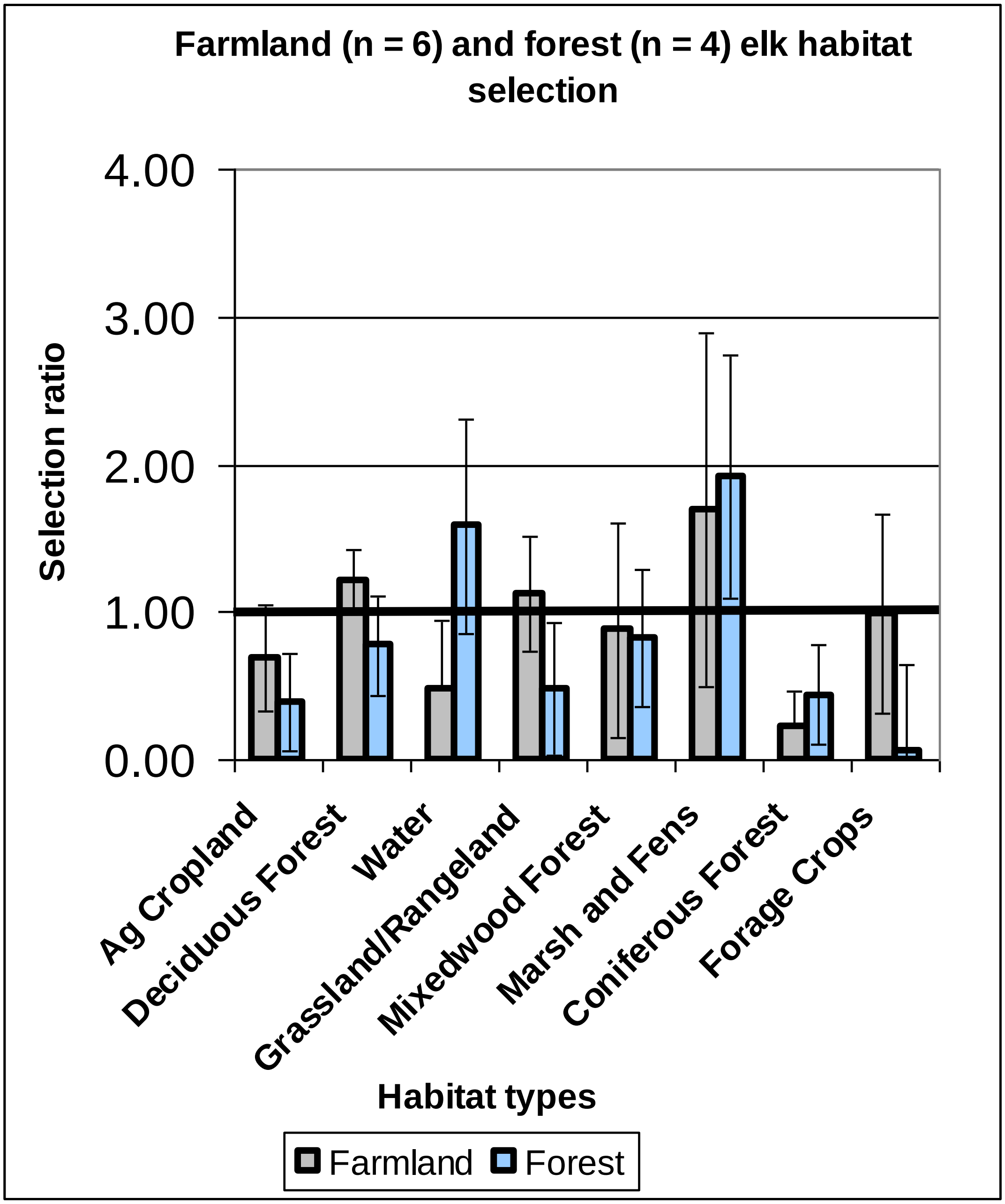

Figure 3.6 Habitat selection by 6 farmland and 4 forest elk each with ≥90% of their home range found within the farmland or forest area respectively, in the DM area.

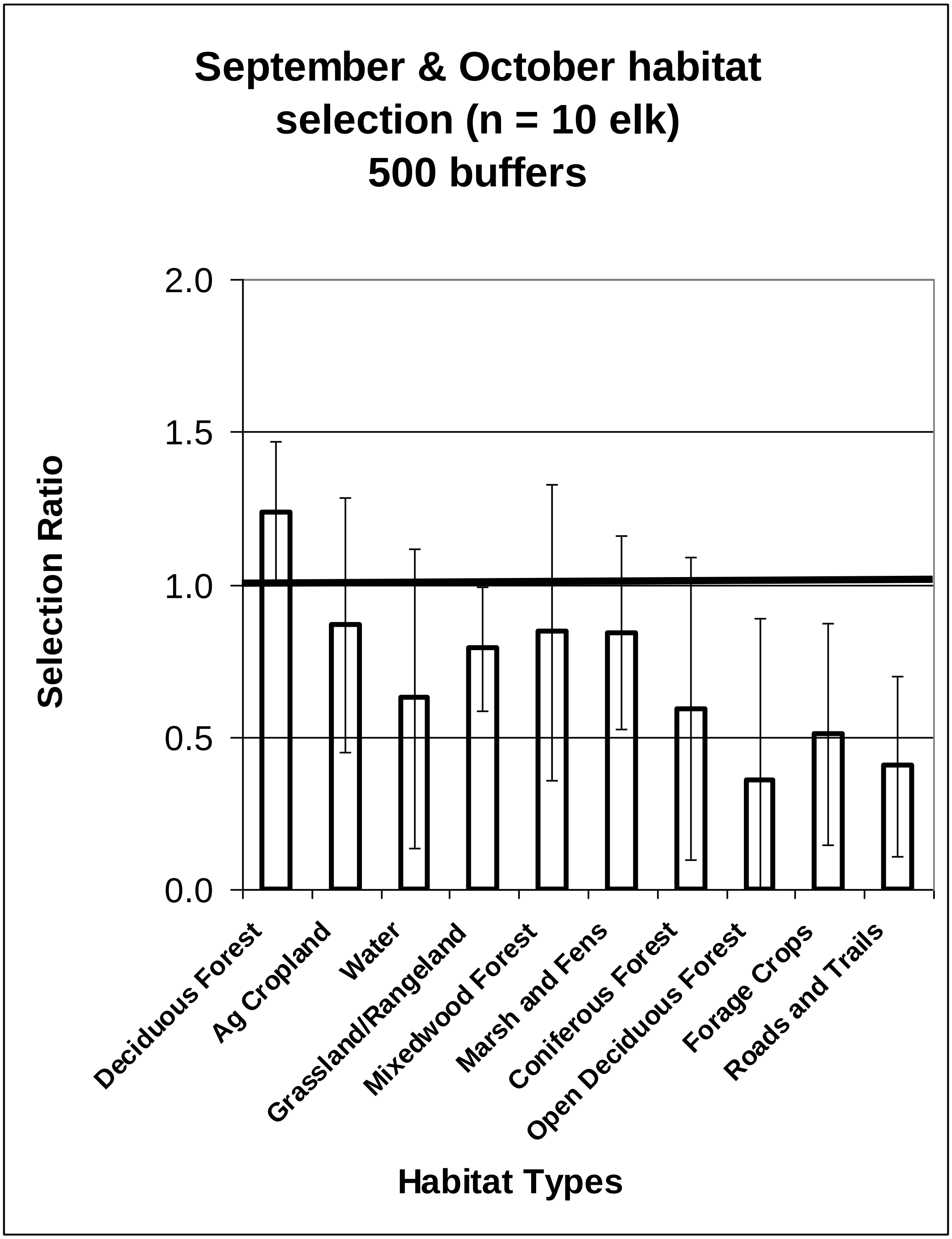

Figure 3.7 Habitat selection in September and October rutting period for DM cow elk (n = 10 elk). Columns with error bars above the dark black line indicate selection and columns with error bars below the dark black line indicate avoidance.

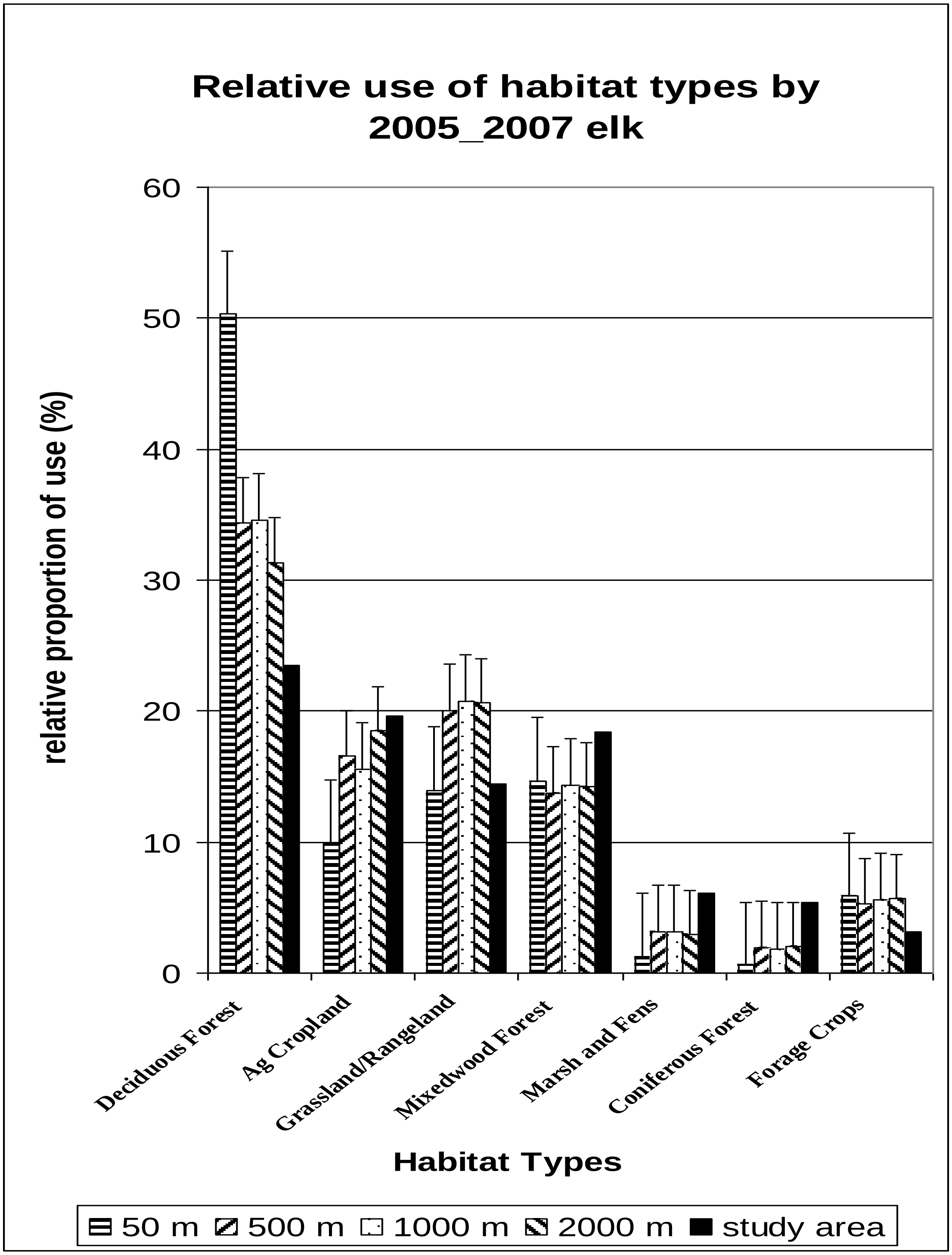

Figure 3.8 Relative annual habitat use (± SE) of habitat types of the Duck Mountain area by cow elk at 4 scales of spatial analysis (i.e. 50m, 500m, 1000m, 2000m).Open deciduous forest, roads & trails and water habitat types not shown

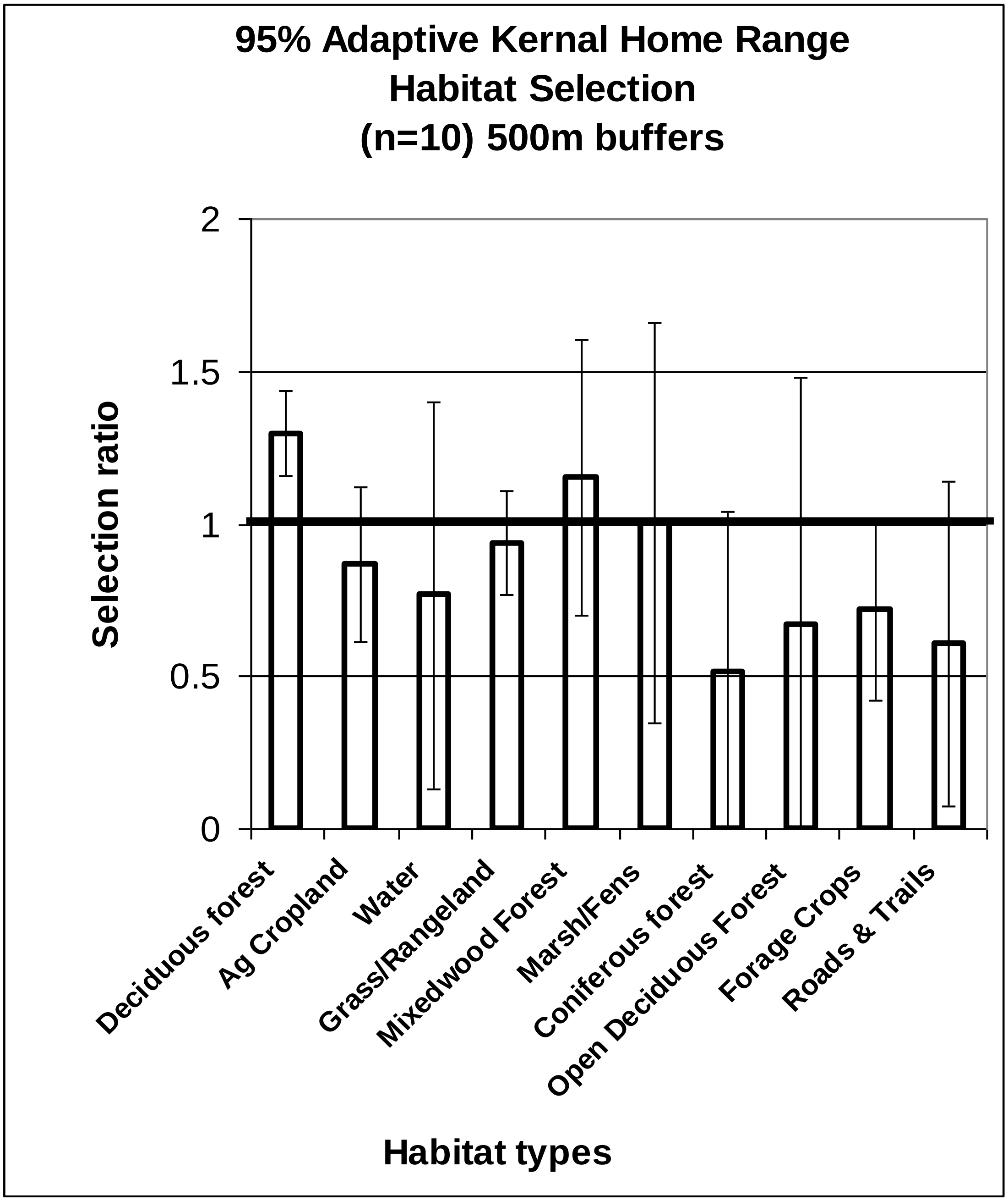

Figure 3.9 Habitat selection within 95% adaptive kernel home ranges for Duck Mountain cow elk (n = 10 elk). Columns with error bars above the dark black line indicate selection and columns with error bars below the dark black line indicate avoidance.

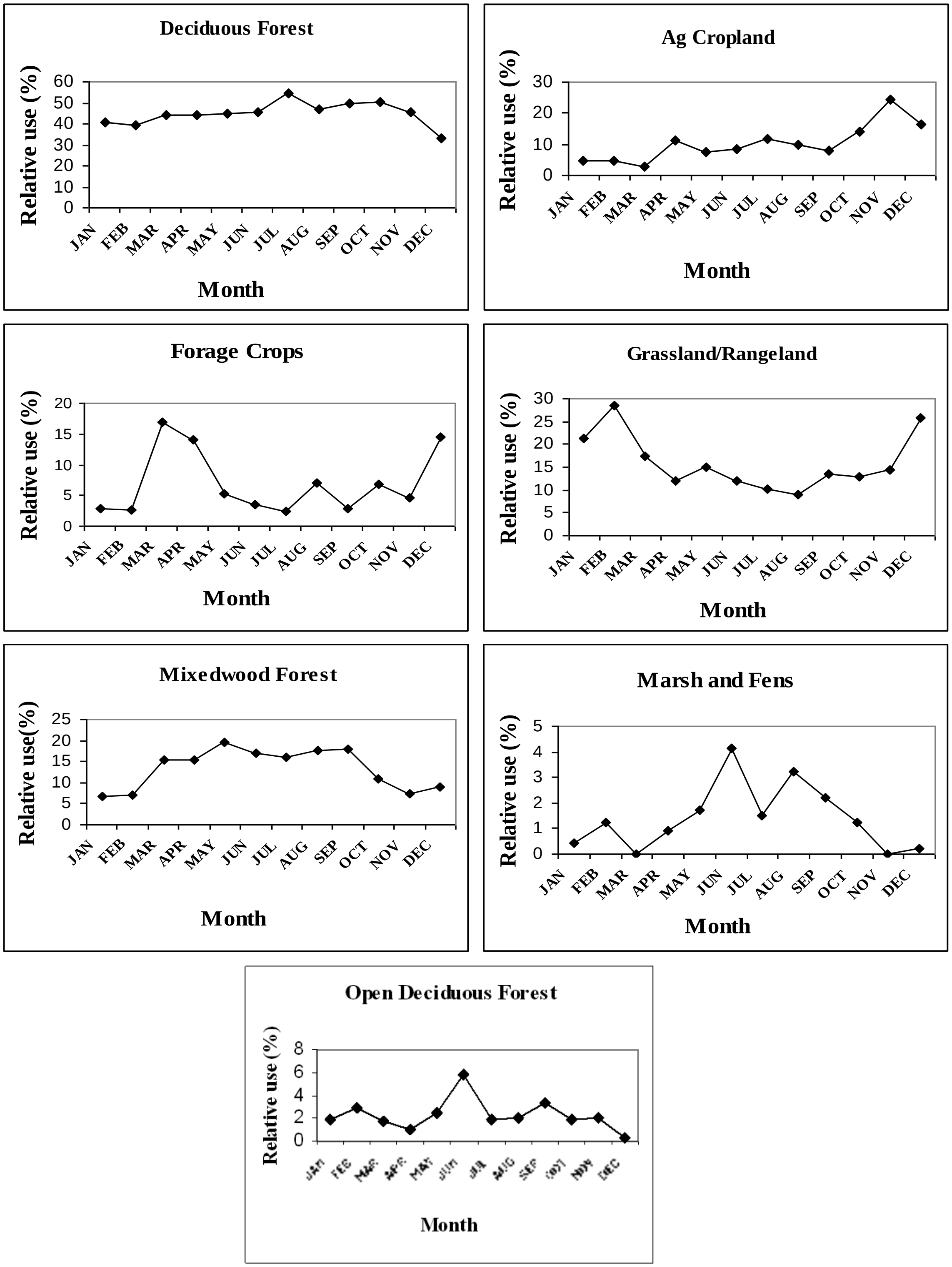

Figure 3.10 Relative use of habitat types within the study area by month for Duck Mountain cow elk (n = 22)

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Chapter 4:

Aspects of cow elk home range and movements with reference to calving and breeding seasons

"The wild things that live on my farm are reluctant to tell me in so many words, how much of my township is included within their daily or nightly beat. I am curious about this, for it gives me the ratio between the size of their universe and the size of mine, and it conveniently begs the much more important question, who is more thoroughly acquainted with the world in which he lives?" (Aldo Leopold 1948).

Abstract

Baseline research on a herd of 1670 elk in west central Manitoba was initiated in 2005. Cow elk home ranges and seasonal movements were determined with specific reference to calving and breeding seasons. Elk were captured by helicopter net-guns, blood tested for disease, radio-collared with GPS units and released in 2005 and 2006. GPS collars were retrieved in February and April 2007, data downloaded and analyzed with ArcView 3.3 for Windows (ESRI), XTools, Animal Movement and Alternate Animal Movement extensions. Average 100% MCP cow elk home ranges were 127.85 km^2 (SE$\pm$ 31.93). The 95% and 50% adaptive kernel home range sizes were 58.24 km^2 (SE $\pm$ 6.20) and 7.29 km^2 (SE $\pm$ 0.79), respectively. Elk moved the least in late winter (February and March) with a mean cumulative distance moved in February of 49.73 km (SE $\pm$ 9.70). Movements increased in the spring then declined in June with a gradual increase from July to September and a peak cumulative monthly movement in October (136.66 km, SE $\pm$ 10.30). Movements gradually declined from November to March. Elk move in all spatial directions with generalized movement in a south, southwest or southeast direction. One elk did show gregarious activity in her monthly movement patterns for the entire year with four other elk exhibiting gregarious movements in specific months only. Mean calving date was estimated to be June 3rd, with 9 elk calving in May and 13 calving in June. Fifty (50) % of cow elk showed reduced daily movements post calving. The mean breeding date

was estimated to be September 27th. There were no significant daily movement differences before, during or after hunting seasons. Elk that were primarily forest dwelling during the rut, moved out of the DMPF to access forage fields frequently under the cover of darkness. No cow elk dispersed from the study area over the duration of the study. There were no specific travel corridors detected. No elk moved between the SW and SE parts of the Duck Mountains. Cow elk showed fidelity to their herd ranges. No specific movement patterns were noted in the calving periods but elk moved into the DMPF or mature deciduous habitat during the rut.

Introduction

GPS radio-collar research

GPS (global positioning system) collars collect data from NavStar satellites over a 24 hour time period and are capable of obtaining location fixes at pre-determined intervals. They are a product that has vast potential in animal habitat use and movement studies. GPS collars are generally superior to VHF radio-collars as they are capable of producing a greater volume of data over a 24 hour period (Hansen and Riggs 2008, O'Neil et al. 2005) but are limited in temporal coverage as batteries typically last only two to three years compared to VHF collars that may last five years or more. Analysis of GPS collar performance indicated bias existed in GPS collars due to increased location error and lower fix success rate under dense conifer canopy cover (Rempel et al. 1996, Moen et al. 1995, D'Eon et al.2002) and mature deciduous cover with lower success rates from June to September (due to leaf interference) and higher fix success rates in March and April (Dussault et al.1999, Hebbelwhite et al.2007). Numerous studies continue to confirm that dense canopy cover can cause bias by increasing type II error in misclassification of habitat use. The missed fixes can bias analysis, as this effect is generally not random (Cain et al. 2005, Hansen and Riggs 2008, Cargnelutti et al. 2007). Researchers suggest that correction should occur to GPS data as this bias under-estimates use of mature canopy cover-dominated habitats (DiOrio et al. 2003). Rugged topography, animal behavior, collar position in relation to vertical and moving collars (at time of fix acquisition) can also reduce fix success rate and increase location error by interacting under field conditions, requiring habitat selection results to be dealt with caution (D'Eon and Delparte, 2005, Sager-Fradkin et al. 2007, Heard et al. 2008). Due to these inherent biases, researchers using GPS collar data should strive for adequate sample sizes, use intermediate fix intervals of 2-4 hours (Mills et al. 2006), attempt to determine specific bias and realize how it may affect data interpretation especially, if complex statistical correction is not incorporated into data analysis.

Home range research

An animal's home range generally includes many of the essential life requirements such as food, cover, water and space in a suitable arrangement. Home range size is generally a result of individual movements and the spatial distribution of a population (Anderson et al. 2005). How animals perceive their environment and why animals confine their activities to home ranges is subject to various opinions. One accepted definition of home range is "an area repeatedly traversed by an animal during a specified time period, with a boundary defined by proportion of occurrence" (Kenward 2001).

Home range delineation depends on the purpose of the study. Location data must be screened to identify unusual movements and a determination made as to include or exclude the data point. Sample size is an important consideration as well as concerns regarding auto-correlation factors. Generally, small sample sizes (i.e. less than 20 locations) are the main concern as home range may be poorly estimated. For kernel estimates, anywhere from 50 to 200 locations per animal are needed to develop reliable home range estimates (Kernohan et al. 2001). Location error is unlikely to affect a fixed kernel density estimate if adequate sample size is obtained (Moser and Garton 2007). Generally, the accurate estimation of home range size should not be constrained by an assumption of independence between location points. In addition, animal movements (and their associated home range) can be associated with con-specifics and to varying degrees can be correlated and not independent. Auto-correlated data results from (1) the animal not having sufficient time to move away, (2) the animal does not move between consecutive observations or (3) the animal returns to the previously used portion of its range. Auto-correlated data yields less information than the same amount of independent observations. Therefore, it underestimates movements and home range size (Swihart and Slade 1985). Some researchers (Otis and White 1999, Reynolds and Laundre 1990) however, have reported that auto-correlated data provided a more accurate estimate of home ranges. If the primary research emphasis is to estimate annual home ranges and movement patterns then accurate spatial distribution estimation is more important than location independence (Kenward 1987, White and Garrott 1990, Millspaugh et al. 2004). Otis and White (1999) stated that sample designs that pre-define a time frame of interest and generate representative samples of animal movement (during that time period) should not be affected by length of sampling interval or auto-correlation. Some data however, have a high degree of auto-correlation based on Schoener's Index of time to statistical independence, in spite of extended fix intervals (Mills et al. 2006). Auto-correlation can also be addressed by using individual animals that have minimal home range overlap especially when all datasets may have high serial auto-correlation. Most home range studies should report on sample sizes, the methods used and core area delineation for future comparative purposes (Laver and Kelly 2008).

The oldest, simplest and most commonly used home range estimator is the minimum convex polygon (MCP). A convex polygon is constructed by drawing a line with minimum sum of linkage distances connecting the outermost locations (Seaman et al.1999). The MCP provides only crude home range outlines. They are sensitive to extreme data points, ignore all information provided by interior data points and can cover large areas that are never used (Powell 2000). Many researchers still use this method, as it is a standard to compare to other studies.

Currently, kernel home range estimators are the standard for probabilistic distribution estimation of use. The kernel estimate generally reports the minimum area that includes a fixed percentage (e.g. 50% or 95%) of the volume in the distribution of use represented by telemetry locations (Kernohan et al. 2001). The bandwidth value or smoothing factor (H) can affect kernel density estimation and can be the major disadvantage in kernel analyses. The bandwidth affects the width of the individual kernels which affects the amount of smoothing. Too much smoothing can hide important aspects of an animal's home range. Currently, the two main methods of choosing bandwidth include least squares cross validation (H lscv) or reference (H ref) bandwidth selection. A third method is the “plug-in” bandwidth selection in which adaptive kernels are plotted with proportions of the smoothing parameter starting at 0.1 x the reference (H ref) and increasing at 0.1 increments to achieve an acceptable fit. This method can be used for large datasets to avoid time consuming analytical problems with least squares cross validation. Researchers are encouraged to try numerous iterations of kernel home ranges for best fit (Fuller et al. 2005, Mills et al. 2006). The two types of kernel estimation are adaptive and fixed. Fixed kernel home ranges have been shown to have lower bias and better surface fit for a given bandwidth (Seaman et al. 1999). Adaptive kernels can over-smooth the outer contours of a home range (Kernohan et al. 2001) but can be very robust to varying fix intervals (Mills et al. 2007).

Home range cores are generally areas of an animal’s home range that are more important than other parts of the range. Since resources are distributed in patches, a core part of a home range would generally contain a greater density of the critical resources. Random use of space can lead to apparent clumps of distribution. In these cases, a uniform random distribution has the mean equaling the variance. For a core part of a home range to be statistically clumped, however, the variance must be significantly greater than the mean (Boitani and Fuller 2000). Core areas can be different between individuals even though they may share a similar home range or the core areas can be very similar. Methodologically, most researchers use telemetry locations to determine an animal’s core home range by either using area-observation curves or the 50% kernel density estimate (Laver and Kelly 2008).

Early elk home range research indicated that cow elk home ranges varied between 9.6 to 18.9 km^2 with late summer and fall home ranges being the largest (Craighead et al. 1973) for non-migratory elk herds. In Arizona, migratory cow elk had large home ranges of 386 km^2 (Wallace and Krausman 1997) and exhibited high degrees of fidelity to seasonal ranges in specific recognizable herd units (Brown 1990). Anderson et al. (2005) analyzed factors affecting cow elk home range sizes and determined that spatial heterogeneity in the landscape was a big factor. Home ranges decrease with increasing availability of forage biomass. Less travel to forage is required and so home range size declines. Home ranges get bigger with increasing percent forest cover because elk are seeking forest cover to reduce predation risk but must travel more to access forage biomass. In order to understand landscape relationships one must conduct analysis at multiple scales (Anderson et al. 2005).

Animal movement research

GPS telemetry technology has greatly enhanced the ability of researchers to track animal movements as the information is almost continuous and can help delineate space-use dynamics (Fuller et al. 2005). Detailed movement analysis at a fine scale however, requires intense sampling at short intervals (Demma et al.2007, Mills et al. 2006). Movement analysis falls into three non-exclusive approaches: (1) descriptive approaches that estimate or describe movement patterns without reference to an underlying model (this study) (2) general movement models (Ager et al. 2003, Frair et al. 2005, Kie et al.2005) and (3) *a priori* mechanistic models based on specific biological attributes of the species under investigation (Morales et al. 2005). In the case of elk, research has shown a great deal of variability in movements in heterogeneous environments. Elk generally move to avoid predators or to forage to increase fat reserves. Predominant movement patterns include moving with directional persistence in well-defined areas with alteration between small localized movements and larger exploratory movements and a tendency to return to previously visited areas (Morales et al. 2005). Elk spring movements depended on topography with elk more likely moving parallel vs. perpendicular to drainages and steep slopes (Kie et al. 2005). Elk had pronounced movements in spring and fall with crepuscular activity having increased movement rates for feeding and slower intra-day movements (Ager et al. 2003). Feeding is the dominant activity for elk in most seasons even though elk had extended rest periods during the winter (Green and Bear 1995). In heterogeneous environments, landscape features and wolves can affect elk movement. Elk will tend to be inactive when in low use areas for wolves, further than 50m from linear features (roads) and in areas with high shrub cover or on northeast slopes. They are likely to be "on the move" when near roads, moving upslope or in areas of high wolf use (Frair et al. 2005). In wolf areas of Yellowstone National Park, elk respond to wolves by shifting habitat selection, which may lead to a change in use of aspen. Elk commonly intensify their use of aspen forested areas in response to wolf pressure and select aspen over conifer sites due to superior browse. When traveling, elk tend to move away from roads (Fortin et al. 2005). The objective of this Chapter is to describe and analyze cow elk home range and movement parameters both seasonally and annually with specific reference to calving and breeding seasons

Materials and Methods

Elk capture

See Chapter 3, pages 28-29 for elk capture protocol.

GPS collar deployment and retrieval

In 2005, a total of 15 GPS collars were deployed on cow elk on the west and south-east portions of the Duck Mountains in February and April. Of the 15 collars deployed, four (4) elk had suspicious blood test results and were taken out of the population for further TB testing, leaving 11 elk for research purposes.

Three (3) of these remaining collars were Global Precision (GP) models. These GPS collars were located monthly and data remotely down-loaded, using a UHF receiver stored in a fixed wing plane. If the receiver was within 30 km of the animal, the signals were picked up and data collected. The remaining eight (8) Telonics GPS collars were "store-on board" models. One (1) collar was retrieved in November 2005. The elk was illegally shot and the collar disposed in a roadside ditch south of San Clara, MB.

The GPS collars were set to collect data about every 2 to 2.5 hours and are capable of recording approximately 600 locations per month or 6460 locations over 11 months. Spatial accuracy of the radio-collars was not measured, although location error is a well recognized factor in GPS telemetry studies of wildlife. In a recent study using the same model of GPS collars as this study, Brook and McLachlan (2006) determined that mean location error varied from 11.1 to 21.3 metres in different habitats of the RMNP. Most GPS locations were found within 50 m of the centroid of each location. Due to the similarity of equipment, habitats and recent timing of Brook's study between the Duck and Riding Mountain areas, it was felt that his results would be comparable to this study. Therefore, minimum location error was assumed to be 50m.

Aerial telemetry flights to locate GPS collared elk began in June 2005 and were conducted monthly to determine if GPS collars are active and collect habitat use data. Five (5) GPS collars (three Telonics and two GP) were re-furbished in December 2005 and were attached to 5 cow elk in February 2006. Seven (7) Telonics GPS collars and three (3) Global Precision GPS collars were retrieved in February 2006 when elk were re-captured, blood tested and the data down-loaded. A total of ten (10) GPS collars (i.e. 8 Telonics and 2 new GP) were attached to ten (10) cow elk in April 2006. At that time, 15 cow elk had GPS collars in the Duck Mountain area.

After initial blood test analysis was completed, one (1) Telonics collared elk was captured and euthanized for additional TB analysis and the collar was not redeployed, leaving nine (9) active Telonics collars. These 9 GPS collars had collar release mechanisms programmed to release on March 15, 2007. Five (5) collared elk were recaptured by helicopter net gun in February, 2007. One elk was illegally shot in November 2006 and the collar retrieved in a roadside ditch in December 2006. In January 2007, one collar was retrieved from an elk that had been wounded during a GHA 18B December hunting season and subsequently died. Another collar was retrieved in a farm field near a rock pile north of Grandview, as the collar release mechanism pre-maturely released. In February 2007 telemetry flight, one collared elk (normally found in the Ethelbert area) was heard in mortality mode and tracked up to Swan River. The elk was illegally shot in January in the Ethelbert area. The collar was removed and transported by the poacher to a roadside ditch east of Swan River and retrieved by the researcher. On March 15, 2007 the telemetry flight indicated that only 2 of 5 collar release mechanisms had dropped collars from their elk. The first two collars were retrieved north of Grandview on March 16, 2007. The remaining 3 elk were ground tracked by the researcher on April 4, 2007 using a hand held ATS VHF "H-antennae" and a portable ICOM radio frequency receiver. All were in mortality mode. These collars were retrieved in the Ethelbert and Shell River valley area on April 4, 2007 and in the Merridale area on April 5, 2007.

Home range analysis

A central database was created in Microsoft Excel to organize data for analysis. Individual elk were identified by frequency and each location fix was given a unique ID number. Greenwich mean times (GMT) were corrected to Central Standard Time (CST). Locations were geo-corrected to UTM NAD83, Zone 14U projection. All fixes were screened for erroneous locations (i.e. high positional or horizontal dilution of precision values). Mean fix interval was calculated for all collars and missing value gaps were manually determined. As a result, some collars were not used in the analysis due to major data gap intervals. All remaining location data was used in analysis, recognizing that location error and habitat types likely affected fix rate success and accuracy.

The author was not involved in the original set-up of collar deployment and collar selection. A mixture of collar types and fix intervals resulted. There were two types of collars and three different fix intervals used. Two collars had fix intervals of 1. 25 hrs, 11 collars had fix intervals of 2 hours and 9 collars had fix intervals of 2.5 hours. This made normalizing data difficult. All data could have been standardized to only use locations every 10 hours but, a significant amount of data would be lost to this process. As average fix interval was similar (2005/06 collars - 2.17 hours and 2.53 hours for 2006/07 collars) it was decided to use all data, as the original purpose of the study was to collect baseline data, in spite of the biases this might create.

Location telemetry data was used to measure step lengths, measure daily and monthly mean movements and direction and create annual/monthly home ranges. Annual and monthly home ranges were calculated using 100% minimum convex polygons for elk with > 20 locations and annual 50% and 95% adaptive kernels (Worton 1989) for elk with > 50 locations using ArcView GIS 3.3 (ESRI Inc.) and the Animal Movement Extension version 1.1 (Hooge and Eichenlaub 1997) for ArcView. Most seasonal MCP and kernel home ranges were calculated with a minimum of 290 locations. Late winter home ranges were not calculated with less than 50 locations.

Annual home ranges were calculated with a minimum of 1,986 locations and a maximum of 6,480 locations. Calculated 50 % and 95 % adaptive kernel home ranges were conducted with a minimum of 3 iterations, until the smoothing factor (i.e. H ref = 900.0) captured most elk locations and core areas. Habitat proportions of 95% adaptive kernel home ranges were compared to study area proportions and 50 % adaptive kernel home ranges were compared to 95% kernel home ranges with the chi-square statistic. Annual, seasonal and monthly home ranges were calculated for 22 elk with locations covering 7 to 12 months of the year. Seasonal home ranges were defined as spring (April, May), early summer (June, July), late summer (August, September), autumn (October, November), early winter (December, January) and late winter (February, March). Statistical calculations were done to determine home range mean area, range, standard deviation and standard error using SPSS Grad Student Pack 16.0 statistical software (SPSS, Chicago, IL, USA). Student's t-tests (two-tailed) were completed to detect differences of home range means between months (Zar 1984). All tests were deemed significant at $P < 0.05$.

Animal movement analysis

Movement paths and cardinal direction were mapped with straight line step lengths between locations calculated. These statistics were calculated by the home range summary statistics produced with the Animal Movement Extension 1.1 home range feature. Circular statistics were calculated by elk by month to determine mean bearing and step length directional persistence. All (225) annual and monthly home range statistics provided angular concentration " r " values and the critical values for Rayleigh's Z statistic for measures of gregariousness. Daily movement rates by elk were determined by summing the distances between all points collected during a 24 hour period and averaged by month. Daily mean and daily maximum movement by month were measured using the Animal Movement Extension 1.1 for ArcView. Monthly cumulative movement rates were tabulated based on mean daily distance traveled in kilometres per month. Movements at night and during the day were calculated for mean and maximum distances traveled (in metres).Only elk with comparable sample sizes were analyzed (i.e. greater than 200 locations per month).

For the calving season analysis, mean daily movements 4 days before and 4 days after approximate parturition was calculated similar to Vore and Schmidt (2001) to determine if movements were different in these time frames. Calving dates for 22 elk was determined by the shortest movements between May 15 to June 24 (Paquet and Brook 2004). Based on the estimated peak calving date and the average gestation period of 250 days (Stelfox 1993), the average date of breeding (conception) was estimated. For breeding season analysis, daily average elk movements were calculated for the weeks before, during and after archery, rifle and landowner hunting seasons in September, October and December to determine possible movement differences in these time periods using the Student's t-test.

Results

A total of 79, 286 location fixes were collected on 22 cow elk from 2005 to 2007 (Figure 4.1). The Global Precision (GP) collars (Winnipeg, MB.) collected 8 to 12, 3-dimensional (3D) fixes per day for a mean 76 % fix location success rate. Four GP collars had malfunctions and were excluded from analysis. Telonics collars (Mesa, Arizona) collected 16 to 20 locations per day and had a mean 96 % fix location success rate with 77.5% being 3-dimensional (3D) fixes. Two Telonics collars had fix location success rates below 75% and were also excluded from analysis. Most collars were on elk for 9 to 12 months duration. Mean fix interval for 2005 collars was 2.17 hours and for 2007 collars, it was 2.53 hours. See Table 4.1 for radio-collar details.

Home range

The mean annual 100 % minimum convex polygon (MCP) home range for 22 Duck Mountain cow elk was 127.85 km^2 (SE$\pm$ 31.93). Individual home ranges varied from 21.78 to 444.64 km^2 (Figure 4.2) Twenty (20) of 22 elk established home ranges that encompassed the original capture location. The 95 % adaptive kernel home ranges were smaller than MCP home ranges by 46 % and averaged 58.24 km^2 (SE $\pm$ 6.20, n = 22) with a range from 26.85 to 103.64 km^2 (Figure 4.3). The mean 50 % adaptive kernel home range was 7.29 km^2 (SE $\pm$ 0.79) with a range from 3.37 to 14.10 km^2 (Figure 4.4 and Table 4.2). The 50 % home range indicates that elk can survive in very small areas, if all life requisites are accessible. For the purposes of this study, the 50 % home ranges were considered to be the core areas for elk (Worton 1989). Monthly annual 100% MCP home ranges were smallest in February and March and largest in May and October. Figure 4.5 shows the trend of home range size gradually increasing from July to October, declining into the winter and spiking again in April and May. The habitat proportions of the 95 % kernel home range were significantly different ($\boldsymbol{X}^2_{0.1, 5} = 10.08$; $0.05 < P < 0.1$) than the study area proportions for the 6 main habitat types (deciduous forest, agriculture cropland, grassland, mixed-wood, marsh and forage crop). The 50 % kernel home range however, was not significantly different ($\boldsymbol{X}^2_{0.1, 5} = 5.92$; $0.05 < P < 0.1$) from the 95% kernel habitat proportions although it was different from the study area habitat type proportions ($\boldsymbol{X}^2_{0.1, 5} = 9.236$; $0.05 < P < 0.1$).

All individual annual home ranges overlapped with the home ranges of other elk at some time during the year. In a few instances, annual elk home ranges were almost identical. Four elk (elk 525 & 631 and elk 635 & 629) north of Grandview had virtually identical 50 % and very similar 95 % home ranges. Overlap of home ranges was exhibited for certain cow elk (i.e. those pairs of elk previously mentioned) throughout the year and did not show general segregation. In fact, MCP home ranges of elk 525 & 631 which normally had separated home ranges from elk 635 & 629, overlapped noticeably in late winter. The overlap in late winter home range for these elk was noted, especially for the 50 % kernel home ranges (Figure 4.6).

There was minimal overlap of home ranges in January, February and March, except in the Grandview area, where 6 home ranges overlapped due to feeding of elk in a specific area. In April and May, 11 elk home ranges overlapped, but the other 11elk had separate ranges. This trend continued in June, July and August. In September, things were similar to August except that 13 elk had overlapping home ranges. In October and November, all elk except one, had overlapping home ranges with other cow elk. A bit of dispersal started in December with only two elk overlapping in Ethelbert and Boggy Creek but 4 elk still overlapped in Grandview and only 2 in the south DMPF. Considerable overlap of some home ranges was also noted in both MCP and kernel home ranges. In particular, elk 633 & elk 638, NW of San Clara, MB had 80 to 90 % overlap of MCP and adaptive kernel home ranges (Figure

4.7 and 4.8). For elk with overlapping home ranges, mean overlap was 70. 03 % with a range of 41.18 to 99.69 % overlap. See Figure 4.9 for comparison of typical minimum convex polygon and 50 % and 95 % kernel home ranges for elk 634 showing elk location distribution.

Seasonal MCP home ranges showed a trend towards larger spring home ranges and smaller summer and winter home ranges (Table 4.3). The late winter data was somewhat limited as few elk had collars on in March. Mean spring MCP home range was 57.26 km^2 (SE $\pm$ 12.19, range 1.27-268.39), early summer was 20.38 km^2 (SE $\pm$ 2.31, range 4.97-46.28) and early winter was 29.68 km^2 (SE $\pm$ 5.47, range 7.39-104.35). Late winter MCP home ranges (8.70 km^2, SE $\pm$ 2.31, range 0.28-36.39) averaged 6.8 % of the mean annual MCP home range for all elk.

All 50 % kernel home ranges were super-imposed over 2002 ortho-photography to conduct a visual assessment of identifiable landscape features for the existence of common attributes. Common landscape features of all 50 % kernel home ranges for Duck Mountain elk (except one elk) include the following:

1. Riparian areas. Either creek or river drainages or the presence of large wetlands (i.e. larger than one hectare) were evident.
2. A mixture of mature deciduous forest, tame forage crops (i.e. alfalfa) and native grassland were present.
3. Crown land with limited access or private land with landowners that restrict access (both provide minimal human disturbance)
4. Few well traveled roads.

Some elk had forest cut-blocks, mixed-wood forest and community pasture within their home range. The 50 % home range was used by elk in every month of the year, with April to September being the most common months occupied.

All elk home ranges (95 % kernel) had the presence of at least one active cattle operation. Some elk spent significant parts of their time in the DMPF having minimal interaction with farmland operations (i.e. elk 630 and elk 631) while other elk spent all (or a significant amount) of their time out on the farmland (i.e. elk 627 and elk 635).

Elk movements

No cow elk dispersed from the study area over the duration of the study. Elk did not interact between the SW and SE parts of the study area. There were no specific movement corridors or predictable travel paths detected. Cow elk showed fidelity to their herd ranges and traveled in all spatial directions. One elk moved 9.6 km west and a second elk moved 16 km south from their original capture locations to establish home ranges.

Elk moved the least in late winter (February and March) with a mean cumulative distance moved in February of 49.73 km (SE ± 9.70). There was an increase in movement in the spring (April and May, 78.6 & 97.5 km, respectively) with a reduction of movements in the summer month of June (78.23 km. ± 7.43) and a gradual increase in distance moved from July through August and September (i.e., 90.81, 92.50 and 121.64 km, respectively) to a sharp increase of cumulative distance moved in October (136.66 km, SE ± 10.30). Cumulative distance moved in November and December was still greater than spring or summer movements and was on a gradual decline from October to March (i.e. from 136.66 km in October to 25.98 km in March). See Table 4.4 and Figure 4.10 for details.

Analysis of daily movement patterns revealed that mean cumulative daily distance traveled was 3460.5 metres (SE ± 271.08). This was relatively consistent for individual elk, with a range from 1647.5 m to 4954.0 metres moved per 24 hour period (Figure 4.11). Most maximum daily movements occurred in the spring and autumn seasons and were consistent with the fact that MCP home ranges for these seasons were larger. There was one large movement exhibited by elk 526 of 18.02 km in a space of 2.5 hours on May 18, 2005. It occurred between 5:30 to 8:00 AM. This elk traversed the distance at an average of 7.2 km/h. On first assessment, I was inclined to remove this location as erroneous but, after reviewing the raw data set the position was retained. For these fixes, the horizontal dilution of precision (HDOP) was lower than 4.2 and any HDOP higher than 5.0 could be considered as poor precision. Since this occurred three months after capture, it could not be attributed to an after-capture movement. The terrain between the two locations is relatively flat (remaining consistent between 1900 and 2000 ft ASL) with no major river valleys to traverse. Any number of reasons could be posited for the short-term long distance movement but given the time of year, predator avoidance or searching for a calving site are the most likely reasons.

In addition, elk 630 traveled into Saskatchewan approximately 2 km on Dec 22-23, 2005 between 11:00 pm and 1:00 am. This excursion was likely unimpeded as snow depths were not deep (i.e. less than 25 cm), although terrain in this area is rugged and intersected with a steep creek drainage. This elk also traversed up into the Shell River valley that was part of the backcountry zone of the Duck Mountain Provincial Park and spent significant amounts of time in this part of the park during June to September. This elk selected relatively remote habitat types not typical of the majority of the GPS collared elk. This elk's behavior could be representative of a portion of the Duck Mountain elk population that uses the DMPF more than the farmland areas. See Figures 4.12 & 4.13 for examples of typical elk movement patterns.

Maximum distances were travelled in the month of May both at night and in the day. This is reflective of the elk which moved in dawn hours between 5:30 AM to 8:00AM. Otherwise, maximum distances were also observed in September and October during the day. Mean distances for nightly and daily movements spiked in March and October for day and night. Daily average distance moved, however, was slightly greater in the day (i.e.360 m) versus the night (i.e. 340 m) in March. In October, daily and nightly distance moved was similar at approximately 380 m but remained higher in the day than nightly movements in November and December (Figure 4.14).

Predominant bearings of elk movements were in south-west and south-east directions although easterly and southerly movements also occurred. Table 4.5 shows main compass bearings and cardinal directions for all twenty-two (22) elk based on measured poly-lines using the Animal Movement Extension for ArcView. These movements give an indication that travel is oriented to the general terrain and somewhat to sun position. From my personal observations, elk tend to move with the sun at their backs; moving west in the mornings as the sun rises in the east and moving east in the evening as the sun sets in the west. Southerly and southeasterly movements can be related to the same general direction of creek valleys as they meander south and southeasterly out of the Duck Mountains to major river systems such as the Shell, Valley and Assiniboine Rivers.

Virtually all elk (except 5) showed generalized movement with no specific directional persistence. For sample sizes between 200 and 300, Rayleigh's $Z_{0.05} = 2.99$ must be exceeded to reject the null hypothesis that all elk movement paths are uniformly distributed around a circle. One elk (# 548) had angular concentration " r " values from 0.29 to 0.33 suggesting gregariousness and Rayleigh's $Z_{0.05} = 19.9$ to 30.8 for all monthly movement paths. This elk was situated in farmland west of Hwy #10 near Garland. In September 2006, it showed strong gregarious movements (r = 0.3322 and Rayleigh's $Z_{0.05} = 30.795$) in mainly north-south and east-west directions (Figure 4.15). This elk moved in a small area near heavy bush, farm fields and marshy areas that was secluded from human disturbance yet, surprisingly close to Hwy #10 and PR 367. Only 4 other elk had gregarious movements in April, June, September, November and December (Appendix 1). See figure 4.16 for gregarious movements by elk 628 in November 2005.

Mean calving date was June 3rd, with 9 elk calving in May and 13 calving in June. Fifteen (15) elk calved in farmland areas and 7 elk calved in the Duck Mountain Provincial Forest area. See Appendix 2 for details on calving habitat descriptions. Most commonly, elk were calving in secluded mature deciduous forest near water features. Elk movements measured (i.e. total metres traveled) 4 days before and 4 days after estimated calving date indicated 11 of 22 elk did not show significantly reduced movements after parturition ($t_{0.05\,(2)}$, 20 = 0.271) and may be indicative of calf loss (Vore and Schmidt 2001).

Duck Mountain cow elk were likely bred between September 13th and October 19th with an average breeding date of September 27th. During the breeding season (rut), elk movements measured (mean daily movement in metres) in relation to hunting season dates showed no significant differences before ($t_{0.05\,(2),}$ 21= 0.43, 0.08, 0.68), or after ($t_{0.05(2)}$,21 = 0.57, 0.75, 0.26) hunting compared to movements during the seasons in the September archery, October and December rifle and landowner seasons. Elk that were primarily forest dwelling elk during the rut, moved out of the DMPF to access forage fields frequently under the cover of darkness. This was observed especially by elk in the Silver Creek area (Figure 4.17). Elk 793 made significantly long (approximately 6 to 7 miles) return movements from thick forest in the DMPF out to a mixed-wood forest ridge near a lake in the farmland area, every 2 to 4 hours from September 12 to 16th (Figure 4.18). This could be related to nursing a late calf or harem movements during the rut.

Discussion

Home range

Cow elk are known for low dispersal rates and strong fidelity to home ranges even in spite of some human disturbance. Cow elk learn their home range from their mothers and other elk in the herd (Edge et al. 1986).

Duck Mountain elk have slightly larger MCP annual home ranges than those of the RMNP. Brook and MacLachlan (2006) indicated that RMNP cow elk had mean MCP home ranges of 78.4 km^2 compared to 127.85 km^2 in the Duck Mountains. Elk in the west park of the RMNP had mean MCP home ranges of 107.7 km^2. While not directly comparable, the 95 % adaptive kernel home range estimates for Duck Mountain elk were closer in similarity to the RMNP elk MCP home ranges (58.24 km^2 in the DMPF compared to 78.4 km^2 in the RMNP). In central Ontario, Ryckman (2006) determined that annual 95 % kernel elk home ranges averaged 51.9 km^2 with a larger range of variation (i.e. 10.7 – 146.8 km^2) than Duck Mountain elk (26.85 – 103.64 km^2). Range of variation in MCP home ranges for the Duck Mountains (21.78 to 444.8 km^2) was similar to the RMNP cow elk MCP home ranges (i.e. 17.3 to 448.1 km^2).

Seasonal home ranges increased in the spring for the DMPF, as well as the RMNP elk. This coincided with increased movement rates. Spring home ranges increased as cow elk dispersed from winter ranges and searched for suitable secluded habitat to drop their calves, similar to other studies (Franklin and Lieb 1979, Waldrip and Shaw 1979, Vore and Schmidt 2001). April home ranges were the largest monthly home ranges at 43.47 km^2. Cow elk probably select sites with hiding cover for the calf and nutritious forage areas in proximity to water for lactation demands (Skovlin et al. 2002). Summer home ranges in the Duck Mountains (i.e. 11.46 to 17.64 km^2) were smaller compared to other jurisdictions such as Alberta (52.9 km^2) and Wisconsin (21.3 km^2), (Anderson et al. 2005). Summer home range selection can be affected by wolf presence and forage availability (Anderson et al. 2006). Small summer home ranges in the Duck Mountains could be explained by abundant forage and abundant secure cover to avoid wolves. As the rut occurs, elk home ranges increased in size in autumn (October, 34.84 km^2) and then declined into the early winter (December, 25.15 km^2) for Duck Mountain elk. This was in slight contrast to RMNP elk which did not exhibit increased home range until the early winter.

Winter home ranges in the DMPF did increase slightly from the summer, as elk moved to winter ranges to concentrate into herds to survive the winter. Winter home ranges for the DMPF were however, much smaller than for Alberta and Yellowstone National Park but larger than home ranges in British Columbia and similar to Wisconsin. Early winter DMPF home ranges were 29.68 km^2 compared to 101.0 km^2 in Alberta and 174.9 km^2 in Yellowstone. Wisconsin winter home ranges averaged 28.4 km^2 (Anderson et al. 2005) and 11.2 km^2 in the interior mountains of BC (Poole and Mowat 2005).

In a comparative study of factors affecting home range size, Anderson et al. (2005) found that larger home range was associated with an increase in forest cover and a reduction of forage biomass and smaller home ranges were associated with resources being available in abundance and in areas with high patch and edge density. Smaller home ranges may also be related to micro-habitat characteristics that are rare in abundance but high in forage value (Norris et al.2002) or the presence of wolves (Winnie et al.2006). In addition, predictive models of summer home range was tied to variables outside of the home range indicating that cow elk make home range decisions based on areas outside their home range. Winter home range, however was tied to variables within that home range, likely because movement is restricted and foraging decisions are based on minimizing energy costs (Anderson et. al. 2005, Fortin et al. 2005). The trend of home range size gradually increasing from summer to late fall, declining in winter and increasing again in spring relates to elk seasonal behavior. In the spring, cow elk leave the winter herds to search for secluded sites to calve. Cow-calf herds begin forming in the summer. The increased activity of the fall rut begins and then elk range widely to feed and gain fat reserves before winter. Restricted winter home ranges are related to the need to conserve energy.

The mean 50 % home ranges of Duck Mountain elk (i.e. 7.29 $\pm$ 0.79 km^2) is comparable to central Ontario elk 50 % kernel home ranges of 9.4 + 0.8 km^2 (Ryckman 2006). The fact that most 50 % kernel home ranges have similar landscape features is also not surprising. Elk need water, deciduous cover and nutritious food sources in areas with limited disturbance for overall survival and these characteristics are found within the core areas of their home range. Some elk use cut-blocks for foraging and bed sites and based on my observations it is purposeful, not necessarily opportunistic. The use of mixed-wood by some elk may be related to security cover and use of community pastures could be related to minimal human disturbance.

Duck Mountain cow elk appear to show fidelity to specific home ranges that can be very small (e.g. 3.37 km^2) and overlap with each other, similar to other studies (Craighead et al. 1973, Edge and Marcum 1985). Home range overlap observed in this study was likely related to herd behaviour and social relatedness as adult cow elk can frequently range with their yearling offspring (Shoesmith 1974). In addition, factors such as feeding elk in the winter or spatially concentrated local food sources (i.e. newly seeded alfalfa or fall rye crops) are also known to bring groups of elk together (Brook and MacLachlan 2006).

Elk movements

No cow elk dispersed from the study area over the duration of the study. No elk moved between the SW and SE parts of the Duck Mountains. Based on the fact that one elk was able to make a one-time movement of 18 km in 2.5 hours indicates the capability of these animals to move from their home ranges in a short time but this study shows it is not the norm for cow elk in the DM.

Cow elk movement rates for the Duck Mountains were fairly similar to those of the RMNP (Brook and McLachlan 2006). Like the RMNP, DMPF elk had the lowest amount of movements in February and March and an increase in movements in the spring. RMNP elk moved more in April and DMPF elk moved more in May. Both elk populations had moderate movements in the summer months with a slight decline in movement for RMNP elk in September but in the DMPF elk herd this was the beginning of a gradual increase of activity to a peak in October. DMPF elk were similar to RMNP elk in that both exhibited higher levels of movements into the early winter as this coincided with increased concentration of elk into larger herd sizes (Brook and McLachlan 2006).

Duck Mountain elk showed marked movement in the spring and autumn and daily versus nightly movements did not show marked differences, this may be a reflection of data analysis and fix intervals. If analysis had focused on activity at crepuscular transitions using shorter fix intervals, similar movements as those found by Ager et al. (2003) may have been noted. Ager et al. (2003) noted increased daily cycles in the spring and autumn (like DMPF elk) and crepuscular movements were accompanied by sharp increases in velocity of movement. Intra-day changes in habitat were done at slower paces, which is similar to DMPF elk that consistently moved a mean of only 318.8 m. per day. Morales et al. (2005) found tremendous variability to elk movement patterns due to heterogeneous landscapes. Properties of elk movement patterns included concentration of activities in well–defined areas, similar to DMPF elk 50 % kernel home ranges and an alteration between small localized movements with larger, exploratory movements. Many DMPF elk exhibited similar patterns, similar to elk 526 (moving 18. 02 km) and elk 630 moving into Saskatchewan and back overnight. This was also evident with four elk in specific months showing a concentration and directional persistence to movements and then a return to no specific movement pattern. Elk movements are generally not random and are characterized by directional persistence, bias to topography and the spatial distribution of food and snow conditions in open habitats (Fortin et al. 2005).

Direction traveled by DMPF elk could be tied to certain landscape features as those found by Kie et al. (2005). Various topographic features such as distance to stream, direction of drainage, elevation, slope and convexity (a measure of ridge top vs. valley bottom) can influence elk movement. Elk are more likely to travel parallel to major river drainages than perpendicular to them and even less likely to cross them when close to the stream in the valley bottom. Some DMPF elk tend to travel in a southeast and southerly direction which can be parallel to the flow of creek drainages in the SW and SE parts of the Duck Mountains.

Most elk did not show specific gregarious movements. One elk had purposeful directional persistence throughout the year. It had a mean bearing of 170^{o} (primarily south). This may be related to her experience with local surroundings that caused her to repeat movement paths to maximize efficiency, reduce disturbance and minimize energy expenditure.

Calving season movements showed some similarity to a study in Idaho (Vore and Schmidt 2001). Eleven of the 22 elk had restricted movement after estimated calving date. The elk that did not have restricted movements after calving may be an artifact of analysis or could have lost their calves soon after birth. Many of these elk were only moving a total 2 to 10 km per day before or after calving and if the estimated calving date (based on the shortest daily movement) incorrectly identified the calving date then, movement analysis may have been biased. The average calving date of June 3rd is similar to Brook (2007) and within the ranges of other studies (Geist 2002). The observation that 15 of 22 elk calved in farmland habitat is similar to Brook (2007) and was expected, based on conversations with local farmers. The visual ortho-photo analysis of these sites indicate that cow elk find secluded areas on private land that had abundant food and minimal predators. The one elk making 6 to 7 mile return trips in September could be related to dropping a late calf in a predator-poor environment and leaving it during the rut to minimize disturbance to the calf from other elk.

The fact that elk movements did not seem to be altered based on hunting season dates is not surprising. My analysis may not have picked up fine-scale movements of elk as detecting change was limited to average daily movement. Proffitt et al. (2009) were able to detect increased elk movements in the early morning of the start of hunting seasons in Wyoming. In their study elk locations were gathered every 30 minutes and averaged over 4 hours, so it would be interesting to see if Manitoba elk show responses to the beginning of hunting seasons when more hunters are present on the landscape than usual. As long as elk find secure cover during hunting seasons, overall movement patterns may not be dramatically altered (Unsworth et al. 1998) There are relatively few hunters (i.e. 50 tags for archery, 130 licences/65 tags for October rifle, 50 licences/25 tags for December rifle and 40 landowner licences) on the landscape in which these cow elk range (i.e. GHA 18C covers 1,001 km^2). Most elk can find areas to hide and may not have even had contact with hunters. Most archery hunters hunt for bull elk in September and may take cow elk opportunistically thereby having little impact on cow elk movement. In the September archery season, if every hunter was hunting on the same day, there would be a maximum of one hunter every 20 km^2 (1001/50).This represents about one (1) hunter per average September 95 % kernel home range of a cow elk. In the October seasons for antler-less elk, it has been my observation that cow elk return to good forage areas even after one cow may have been harvested by hunters. Even if all licenced rifle and landowner hunters were out on the same day hunting with the number of licences allocated, this would represent 1 hunter per 5.9 km^2 or approximately six (6) hunters within the average October 95 % kernel cow elk home range. In Roosevelt elk populations, home ranges, core areas and daily movements can be reduced during hunting access periods (Cole et al.1997). Even though my data did not show significant movement changes in December hunting seasons, other studies have noted elk movement patterns change in December based on hunting pressure (Millspaugh et. al. 2003). In the December rifle and landowner seasons there would be a maximum of one (1) hunter every 11.1 km^2 or two (2) hunters per average December 95 % kernel home range. It does not appear that hunting pressure is high in the Duck Mountain area.

Conclusions

1. Cow elk home ranges in summer & winter are relatively small compared to other studies. Average annual home ranges in km^2 were: 100% MCP – 127.8; 95% kernel – 58.2; 50% kernel – 7.3. Home ranges were smallest in Feb-March and larger in May and October.

2. Home range overlap occurs at all times of the year. The least amount of overlap occurred in January to March.
3. Home range selection of habitat types by cow elk was significantly different from what was available on the landscape. The elk core areas had higher proportions of deciduous forest, grassland/rangeland and forage crop than available in the study area. Many cow elk seem to be using farmland habitats as their primary home range, while others select the DMPF.
4. No cow elk dispersed from the study area over the duration of the study. There were no specific corridors or predictable travel paths detected, although elk movements were predominately in a south, SE or SW direction. Some elk had gregarious movements at certain times of the year. No elk moved between the SW and SE parts of the Duck Mountains.
5. Cow elk showed fidelity to their herd ranges and traveled in all spatial directions. No specific movement patterns were noted in the calving periods, although 50 % of the elk showed restricted movements after birth of their calves. Mean calving date was determined to be June 3rd and mean breeding date was September 27th. Many cow elk moved home ranges into the DMPF or mature deciduous habitat during the rut but did not show significantly altered movement patterns during hunting seasons.

Table 4.1 Duck Mountain cow elk radio collar information (2005-2007)

Elk Identification RE #	***Deploy Date***	***Recapture Date***	***# of days active***	***Fix interval (hours)***	***Potential fixes***	***Actual fixes***	***Fix Success Rate (%)***
525	Feb.3/05	Feb.22/06	384	2	4608	4528	98
526	Feb.3/05	Feb.22/06	384	2.5	4608	3380	73
627	Apr.16/05	Dec.5/05	234	2	2808	2096	75
628	Apr.16/05	Dec.10/05	237	2	2844	1986	70
629	Apr.4/05	Feb.22/06	324	1.25	6480	6416	99
630	Apr.6/05	Feb.21/06	321	1.25	6420	6370	99
631	Apr.4/05	Feb.22/06	324	2	3888	3822	98
633	Apr.6/05	Nov.14/05	222	2	2664	2603	98
634	Apr.6/05	Feb.21/06	321	2	3852	3797	98
635	Apr.4/05	Feb.22/06	324	2	3888	3819	98
638	Apr.12/05	Jan.30/06	294	2	3528	2516	71
548	Apr.8/06	Apr.3/07	360	2.5	3600	3315	92
551	Apr.8/06	Dec 21/06	267	2.5	2670	2494	93
557	Apr.8/06	Jan.9/07	276	2.5	2760	2595	94
560	Apr.8/06	Mar.16/07	342	2.5	3420	3166	93
565	Apr.8/06	Jan.9/07	275	2.5	2750	2600	95
577	Feb.21/06	Dec.8/06	266	2.5	2660	2390	90
659	Apr.8/06	Mar.16/07	342	2.5	3420	3238	95
793	Apr.6/06	Feb.22/07	322	2	4404	3443	89
794	Apr.6/06	Feb.22/07	322	2	3864	3391	88
796	Apr.6/06	Feb.22/07	322	2	3864	2896	75
797	Apr.6/06	Mar.30/07	358	2.5	3580	3370	94

Table 4.2 Mean 100 % MCP, 95 % adaptive kernel and 50 % adaptive kernel home ranges (km^2) for Duck Mountain cow elk (n=22) in 2005/06 and 2006/07

DUCK MOUNTAIN COW ELK HOME RANGES	***100 % Minimum convex polygon MCP (km^2)***	***95 % adaptive kernel (km^2)***	***50 % adaptive kernel (km^2)***
Elk Ear Tag Number			
RE_628	52.68	40.13	4.24
RE_627	55.29	50.89	9.55
RE_638	76.65	45.49	5.90
RE_633	45.30	44.02	7.53
RE_635	88.41	35.96	5.71
RE_629	65.74	37.43	5.51
RE_630	444.84	56.76	3.37
RE_525	176.69	73.04	7.58
RE_526	379.15	103.53	7.76
RE_634	167.58	72.99	14.10
RE_631	176.14	65.38	9.09
RE_548	76.81	47.00	3.63
RE_551	105.17	60.90	11.41
RE_557	93.50	83.66	10.01
RE_560	156.14	68.44	8.11
RE_565	47.34	43.06	7.75
RE_577	21.78	26.85	4.30
RE_659	68.74	42.88	9.19
RE_793	211.05	103.64	6.46
RE_794	153.14	62.19	5.32
RE_796	89.93	69.55	7.98
RE_797	60.57	47.50	5.84
Mean annual MCP (km^2)	(100 %) **127.85**		
Mean annual kernel (km^2)		(95%) **58.24**	(50%) **7.29**
Standard error	31.93	6.20	0.79
Range	21.78 - 444.84	26.85 - 103.64	3.37 - 14.10

Table 4.3 Seasonal 100 % MCP home ranges for Duck Mountain cow elk (n = 22). Home ranges with"0.00" indicate insufficient data available to calculate a home range

Elk Tag ID Number	***spring (apr/may)***	***early summer (jun/jul)***	***late summer (aug/sep)***	***autumn (oct/nov)***	***early winter (dec/jan)***	***late winter (feb/mar)***
635	40.46	46.28	45.63	48.73	34.16	10.29
629	39.44	15.95	41.84	45.57	28.68	12.13
630	156.92	4.97	21.08	93.37	104.35	14.36
525	95.33	17.90	24.49	38.46	60.87	36.39
526	268.39	38.37	66.73	11.45	59.01	36.02
628	21.83	12.92	26.02	45.16	7.39	0.00
627	23.43	29.31	36.53	42.74	11.29	0.00
638	24.76	19.77	26.72	44.50	49.62	0.00
633	24.19	17.70	37.56	31.45	0.00	0.00
634	89.36	29.33	24.45	95.01	42.28	18.21
631	52.99	7.11	20.60	32.64	59.95	16.51
793	41.13	28.73	44.95	108.20	19.85	3.62
796	32.95	9.96	51.51	57.13	34.36	1.92
794	45.38	10.36	26.76	59.56	12.35	4.20
577	1.27	5.28	4.64	3.49	0.00	0.28
551	68.63	12.66	56.06	65.62	40.95	0.00
548	28.75	21.75	18.01	62.37	20.29	4.84
565	42.04	20.67	19.06	0.00	0.00	0.00
557	39.61	24.47	52.66	51.74	26.78	0.00
797	50.20	33.27	22.34	22.94	11.91	11.31
560	35.52	26.80	40.20	81.64	14.63	14.35
659	37.17	24.65	28.17	43.44	14.24	6.99
MEAN	57.26	20.83	33.46	49.33	29.68	8.70
SE	12.19	2.31	3.22	6.00	5.47	2.31
RANGE	1.27 - 268.39	4.97 - 46.28	4.64 - 66.63	3.49 - 108.20	7.39 - 104.35	0.28 - 36.39

Table 4.4 Monthly cumulative distance traveled (in kilometers) by individual elk in the DM from 2005 to 2007 (n = 22)

Month	***MEAN CUMULATIVE DISTANCE (KM)***	***SD***	***SE***	***RANGE (KM)***
JAN	67.7	58.3	12.4	0.8-203.6
FEB	49.7	45.5	9.7	2.3-115.8
MAR	9.4	20.8	4.4	8.9-43.4
APR	78.6	30.5	6.5	14.4-133.6
MAY	97.2	33.8	7.2	40.9-157.2
JUN	78.2	34.9	7.4	14.8-164.3
JUL	90.8	31.0	6.6	17.9-162.0
AUG	92.5	29.8	6.4	11.7-153.5
SEP	121.6	130.3	27.8	14.7-669.3
OCT	136.7	48.3	10.3	17.7-198.8
NOV	130.0	49.7	10.6	9.8-210.2
DEC	93.0	55.2	11.8	11.8-166.1

Table 4.5 Mean bearing (^{0}) and mean cardinal direction for all elk by month for 2005 to 2007 (n = 22)

Month	***Mean bearing (degrees)***	***Mean cardinal direction***	***Cardinal direction abbreviation***	***Main compass bearings and equivalent compass direction for reference***
January	194.26	south-south-west	SSW	45^0 = Northeast
February	190.66	south-south-west	SSW	90^0 = East
March	274.60	west	W	135^0 = Southeast
April	166.58	south-south-east	SSE	180^0 = South
May	154.26	south-south-east	SSE	225^0 = Southwest
June	203.02	south-south-west	SSW	270^0 = West
July	146.78	south-south-east	SSE	315^0 = Northwest
August	202.79	south-south-west	SSW	360^0 = North
September	199.13	south-south-west	SSW	
October	162.33	south-south-east	SSE	
November	172.19	south	S	
December	203.42	south-south-west	SSW	

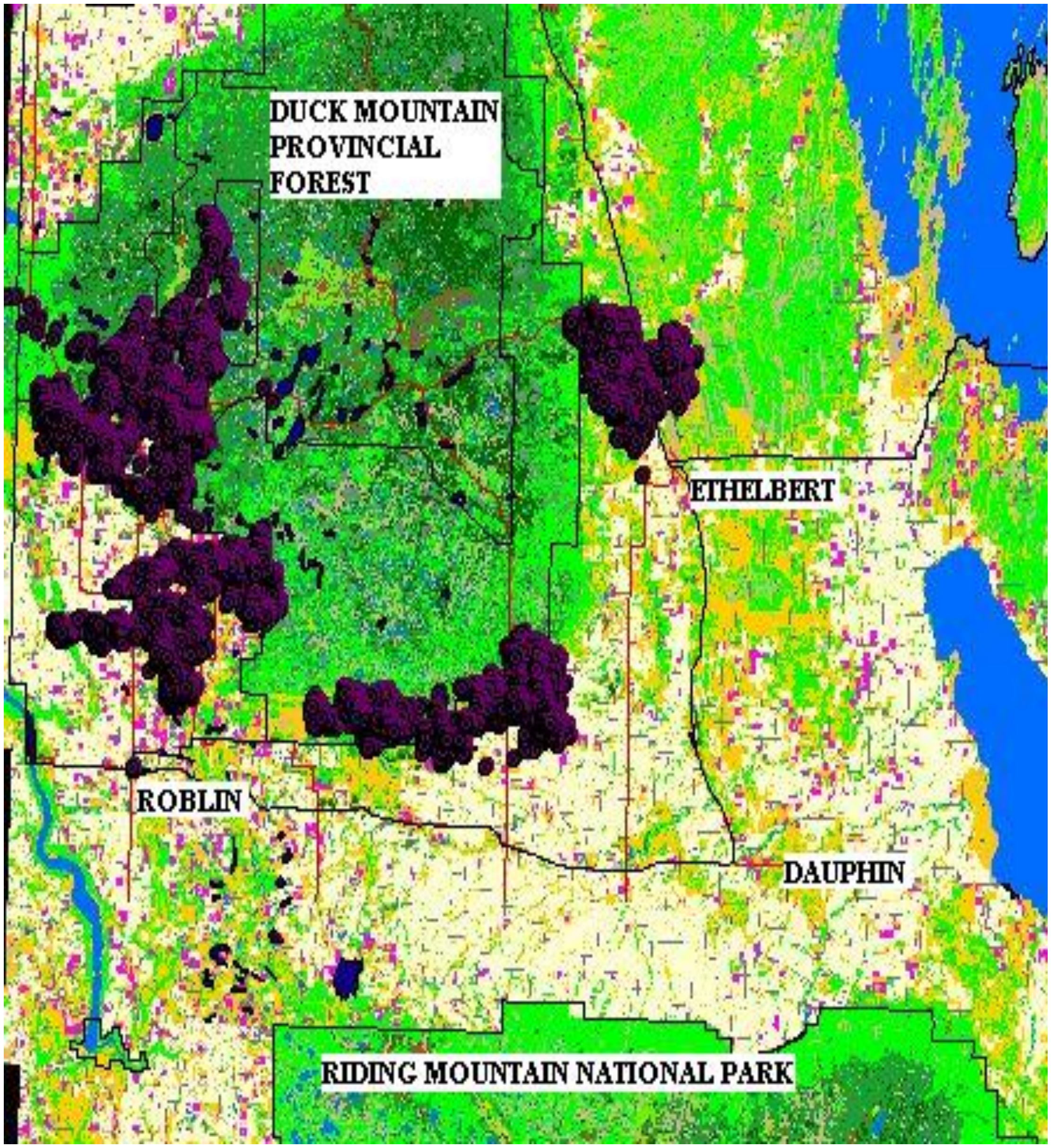

Figure 4.1 All locations of 22 cow elk in the Duck Mountains of Manitoba from 2005 to 2007 (n = 79,286)

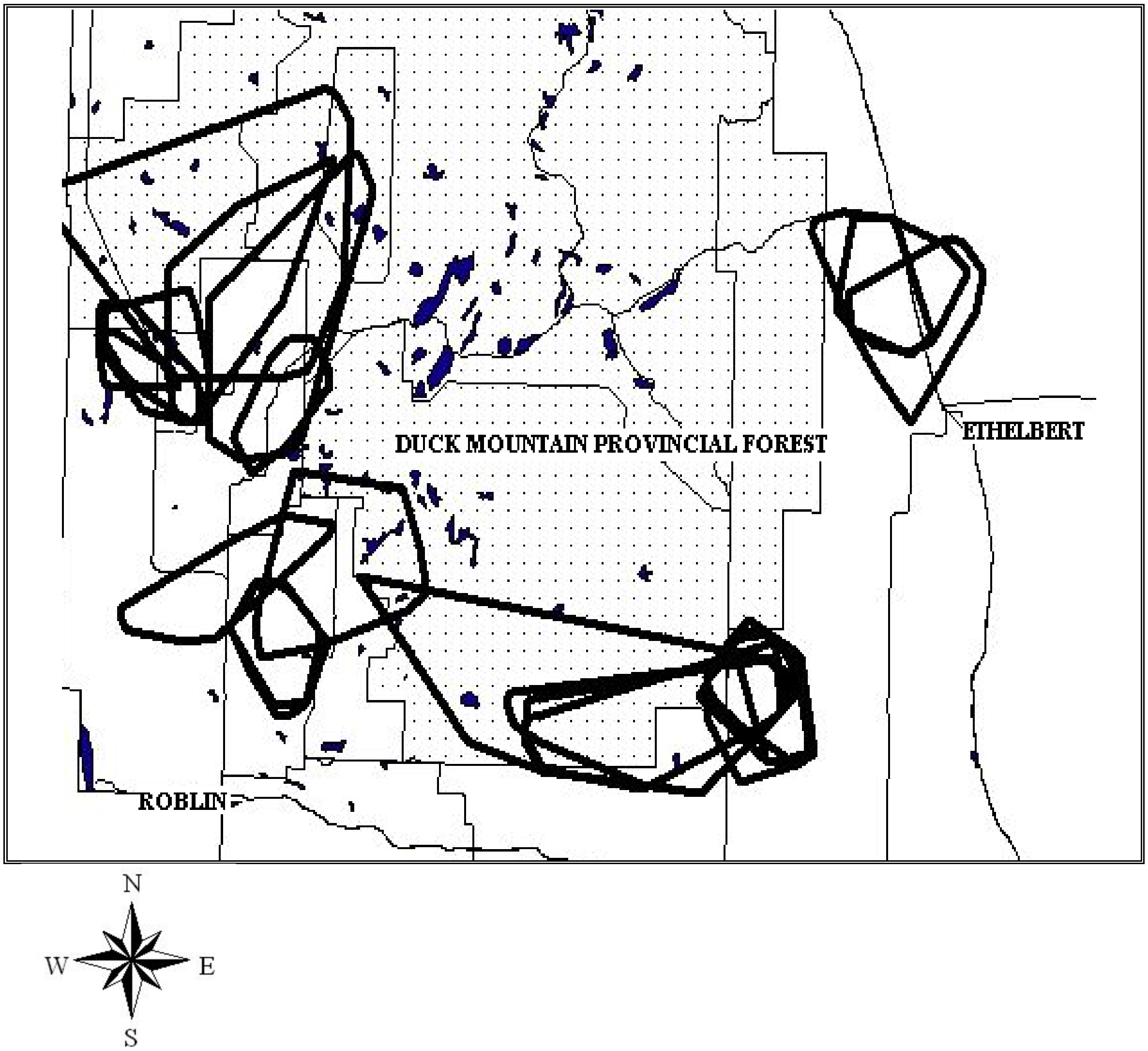

Figure 4.2 Annual 100 % minimum convex polygon (MCP) home ranges from 2005 to 2007 for Duck Mountain cow elk (n = 22)

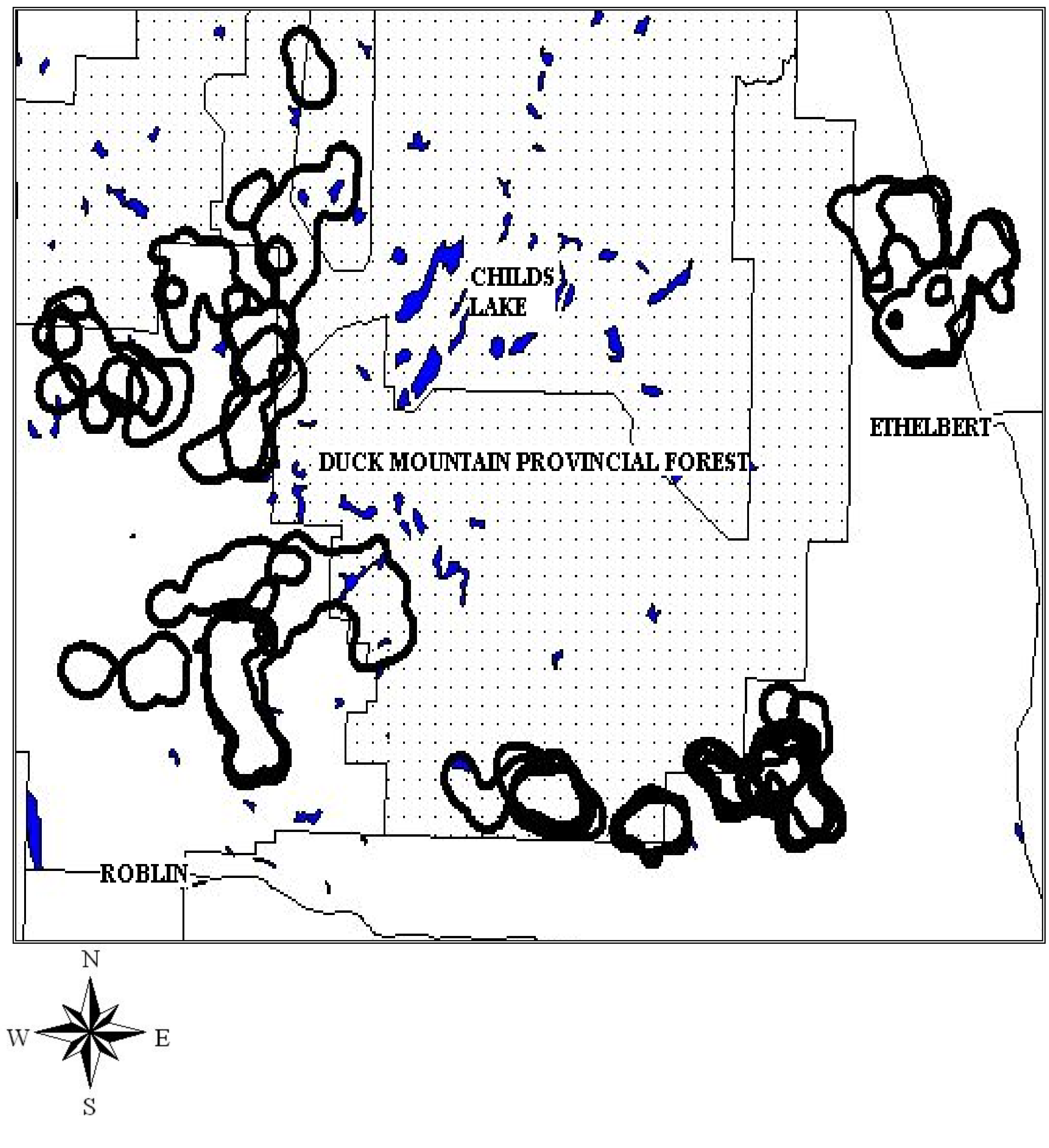

Figure 4.3 All 95 % kernel home ranges for 2005 to 2007 Duck Mountain cow elk (n = 22)

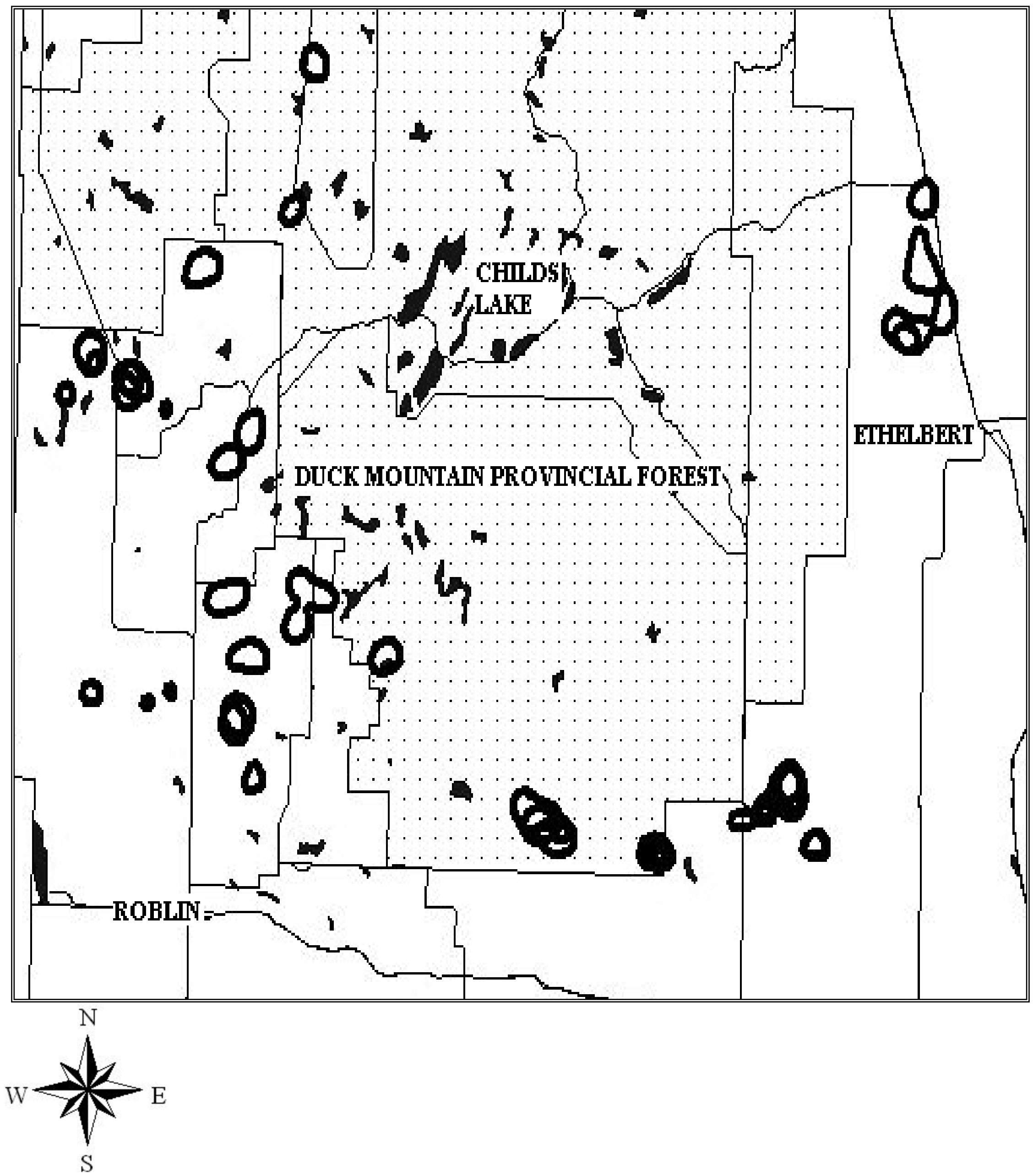

Figure 4.4 All 50 % kernel home ranges for 2005 to 2007 Duck Mountain cow elk (n = 22)

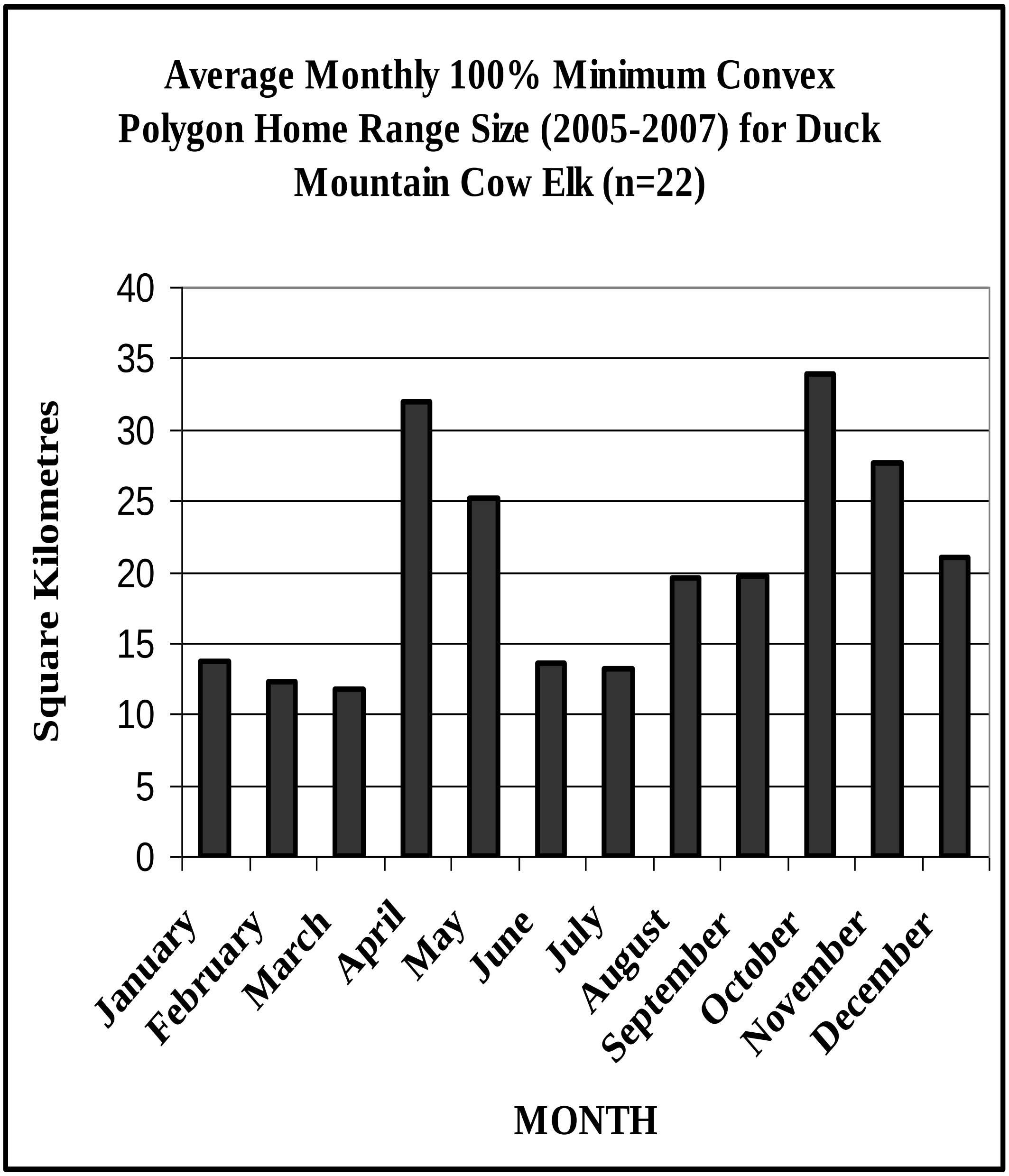

Figure 4.5 Average monthly (100 % MCP) home range size from 2005 to 2007 for Duck Mountain cow elk (n = 22)

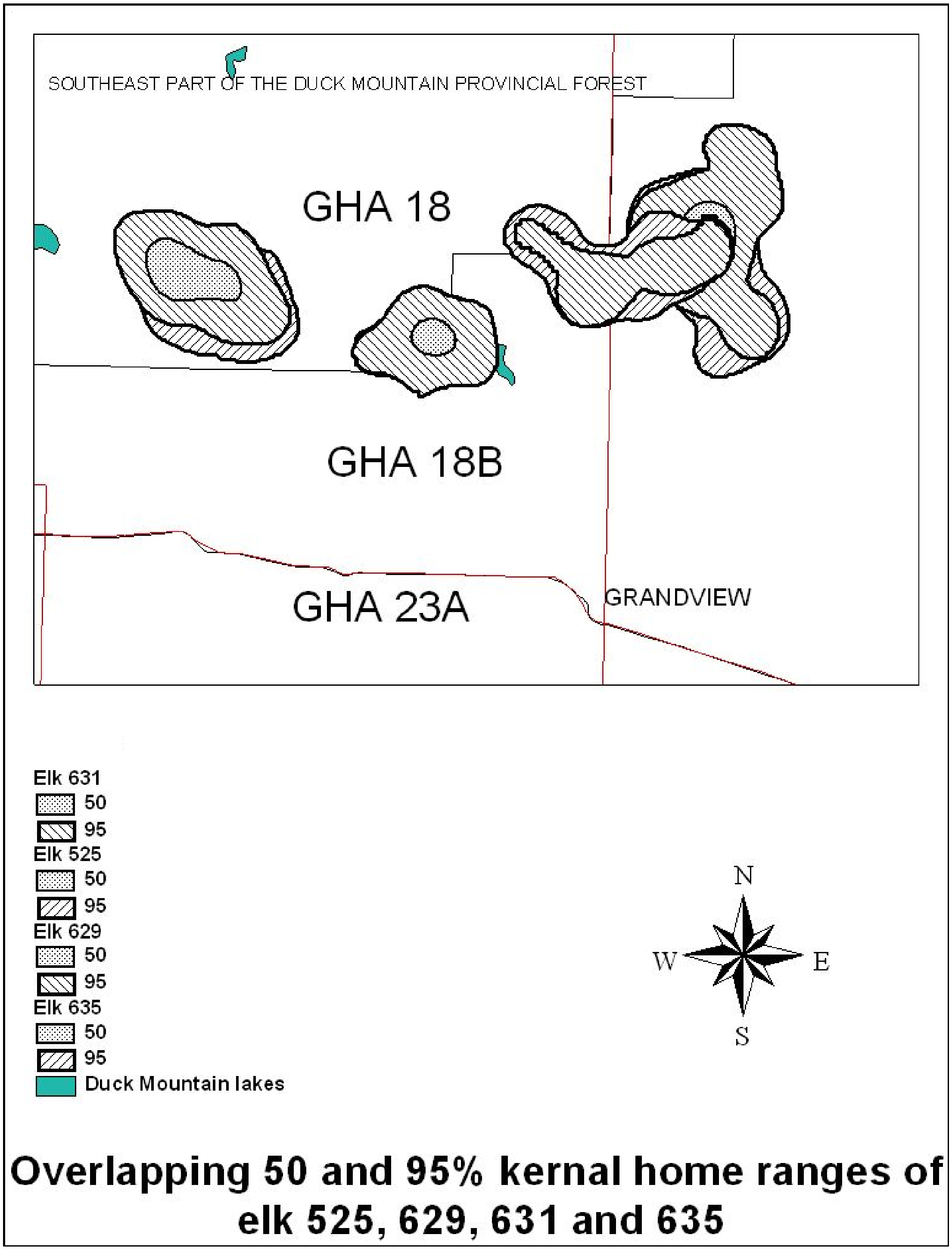

Figure 4.6 Overlapping home ranges of four elk in the SE part of the Duck Mountains, north of Grandview, MB in 2005/06

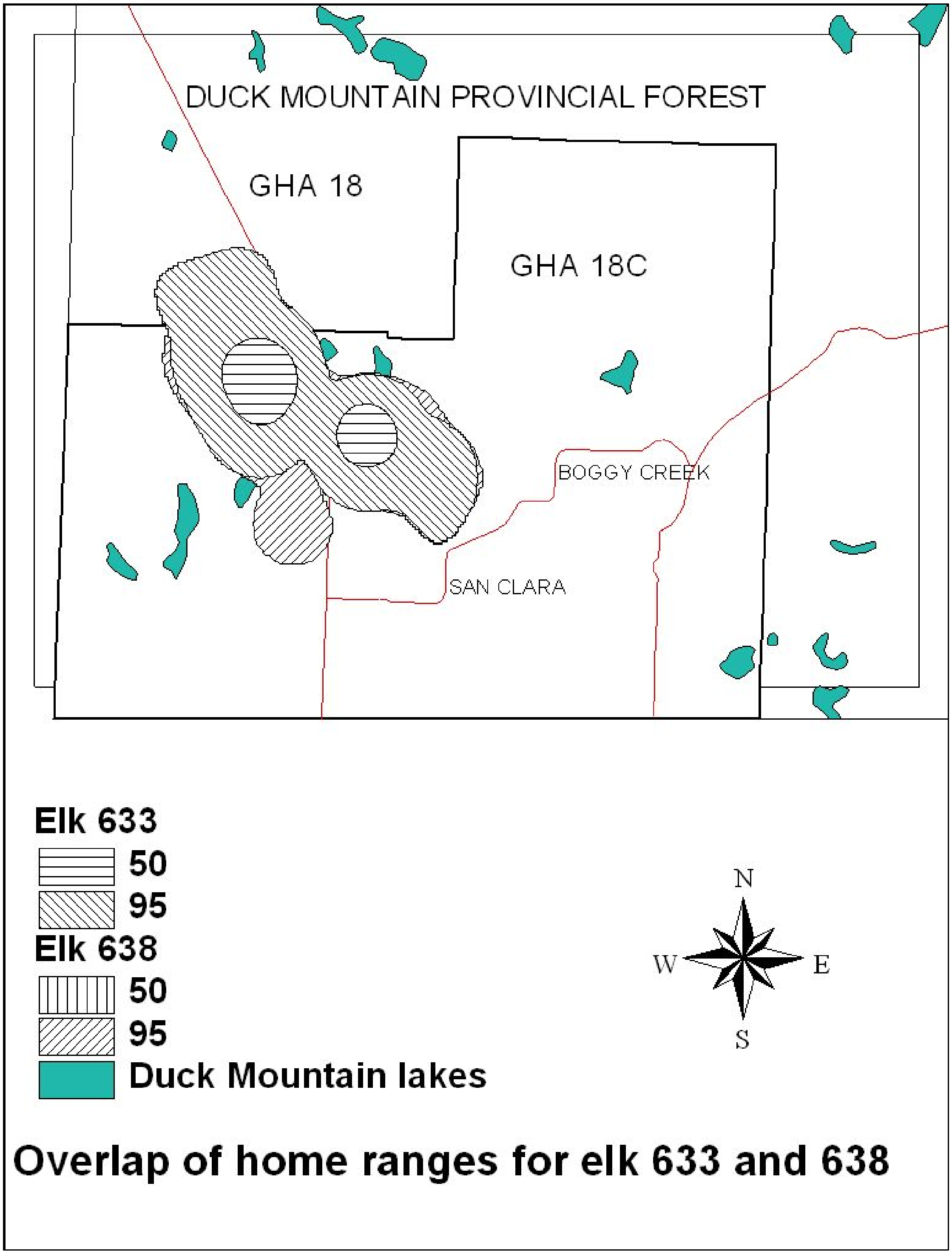

Figure 4.7 Overlap of 50 % and 95 % adaptive kernel home ranges of elk 633 and 638 in the southwestern part of the Duck Mountain Provincial Forest in 2005/06

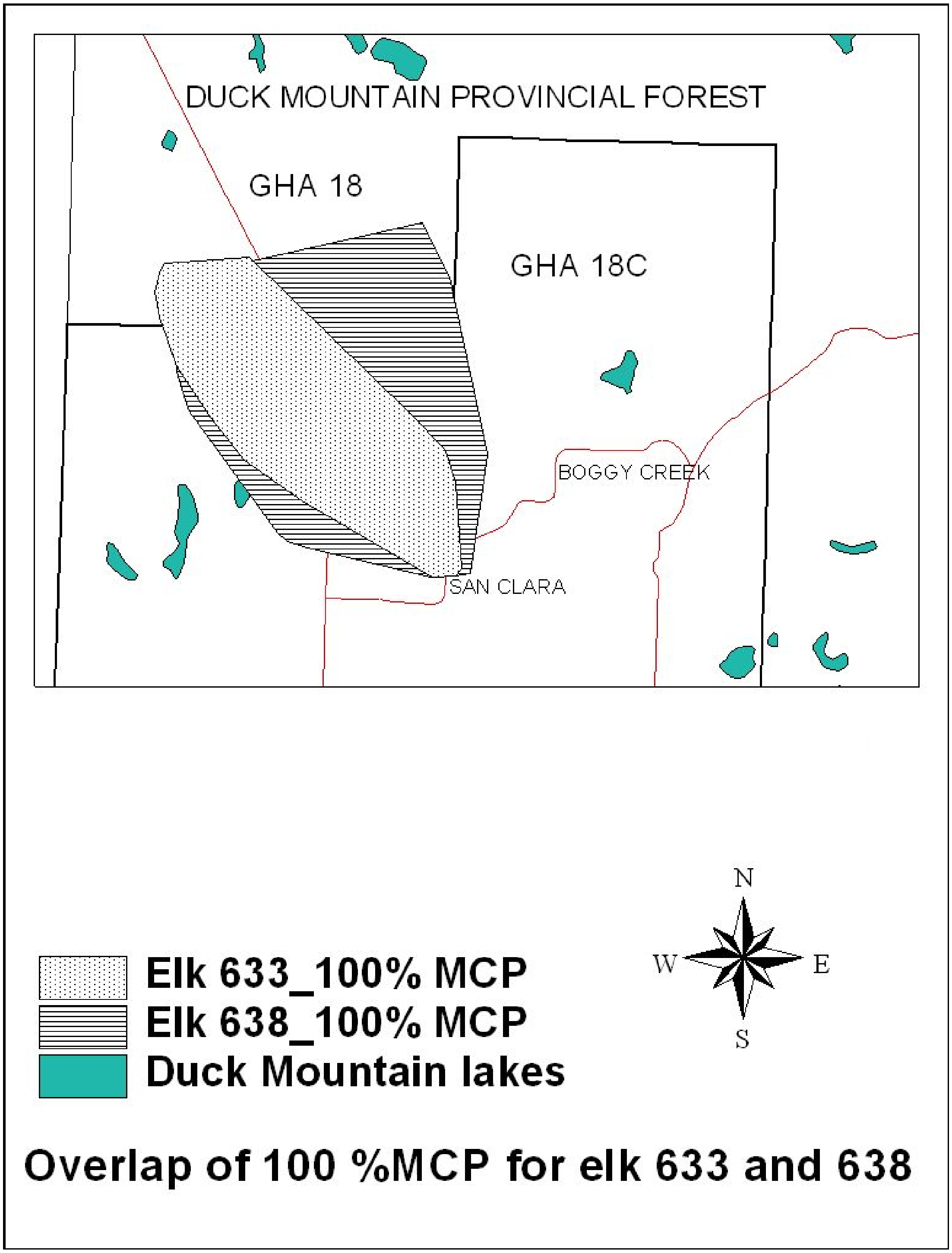

Figure 4.8 Overlap of 100 % minimum convex polygon home ranges for elk 633 and 638 in the southwestern part of the Duck Mountain area in 2005/06

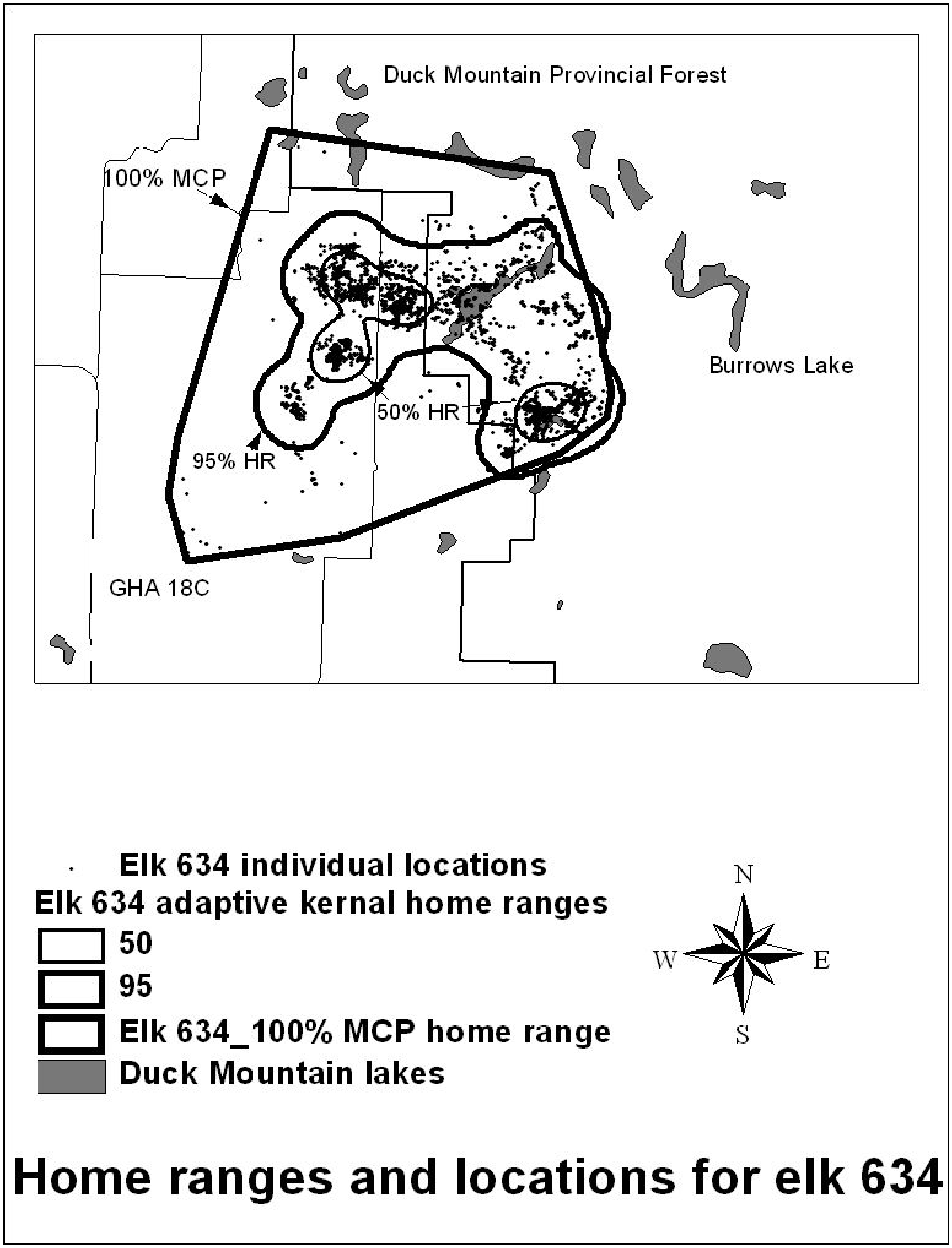

Figure 4.9 Typical 100 % minimum convex polygon, 50 % adaptive kernel and 95 % adaptive kernel home ranges encompassing all locations for elk 634 along the southwestern edge of the Duck Mountain Provincial Forest, northeast of Roblin, MB in 2005/06

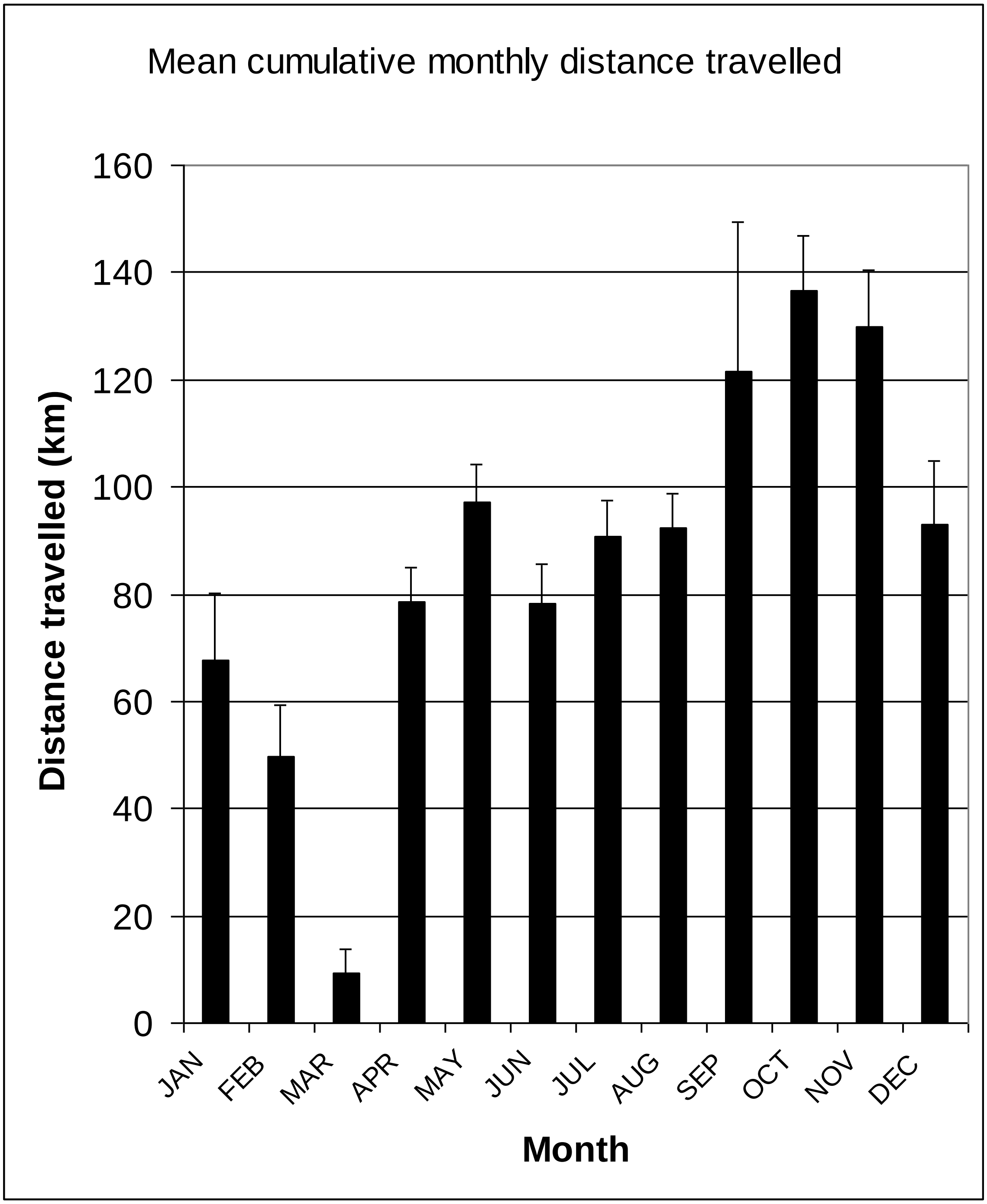

Figure 4.10 Mean monthly cumulative distance traveled by individual elk from 2005 to 2007 (n = 22)

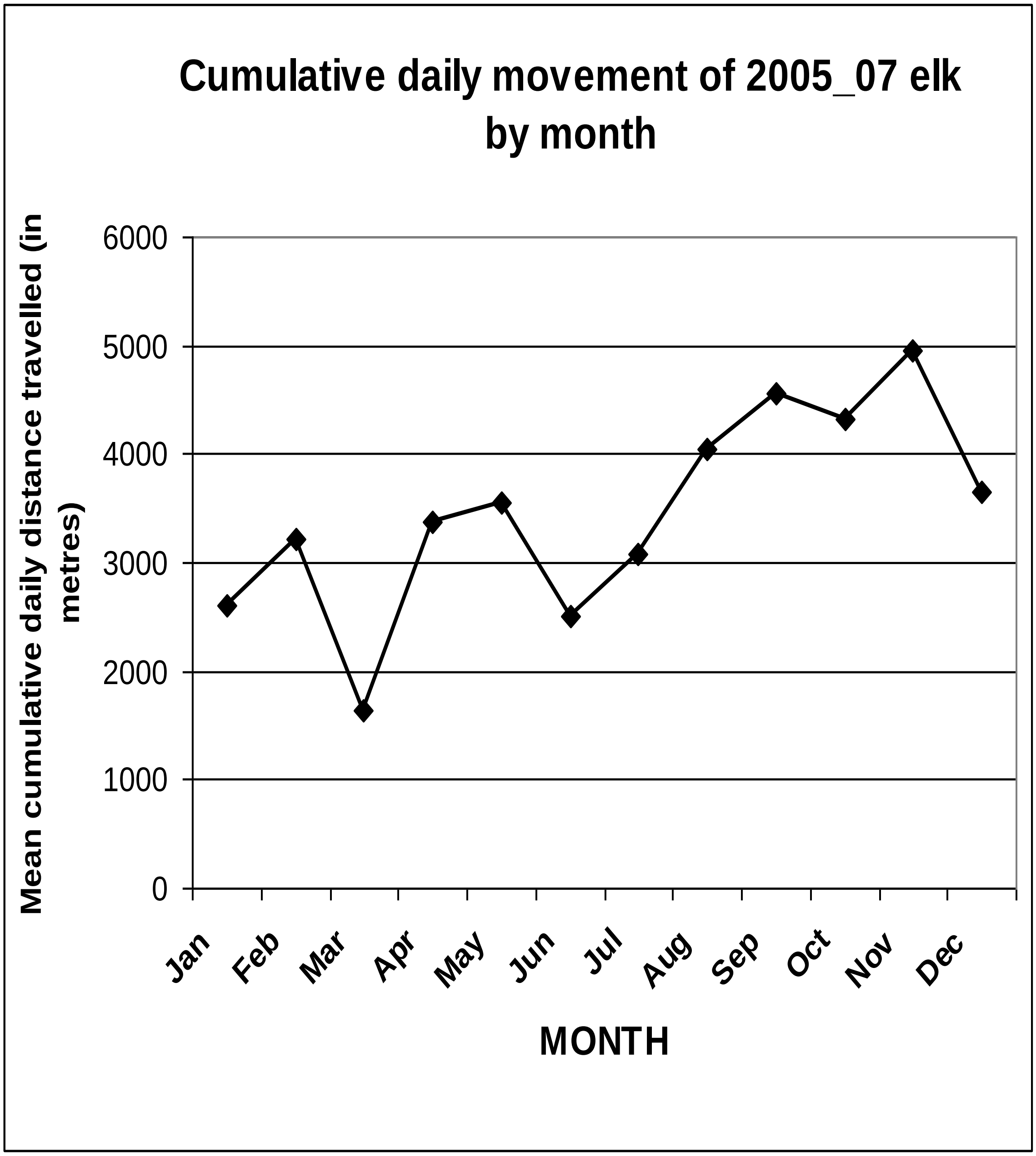

Figure 4.11 Mean cumulative daily distance traveled (m) by cow elk by month from 2005 to 2007

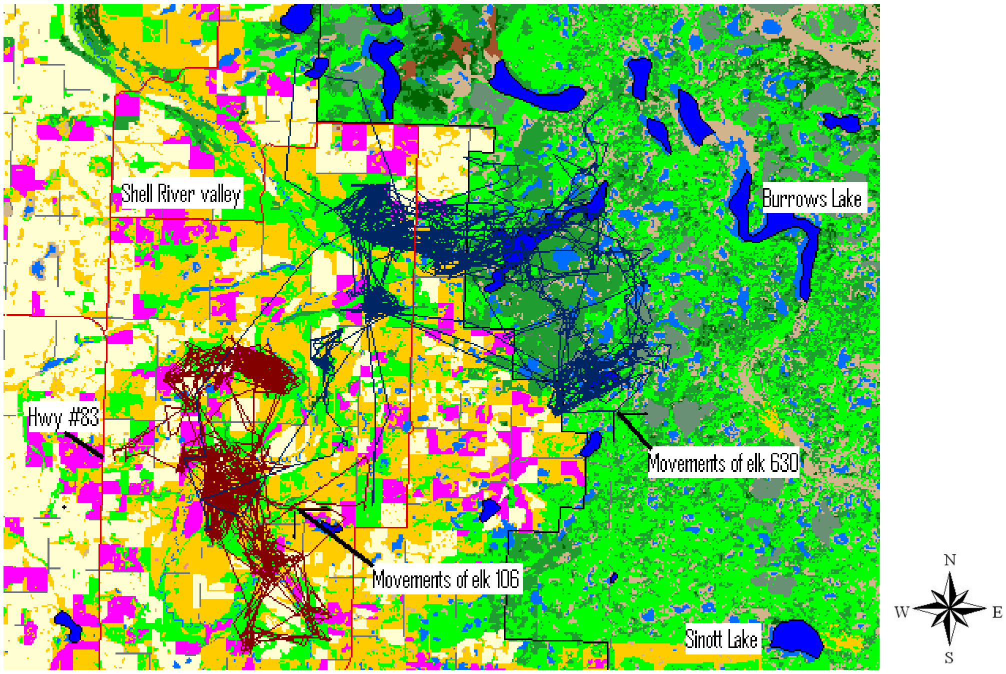

Figure 4.12 Annual movement patterns of elk 630 and 106, NE of Roblin, MB in 2005/06

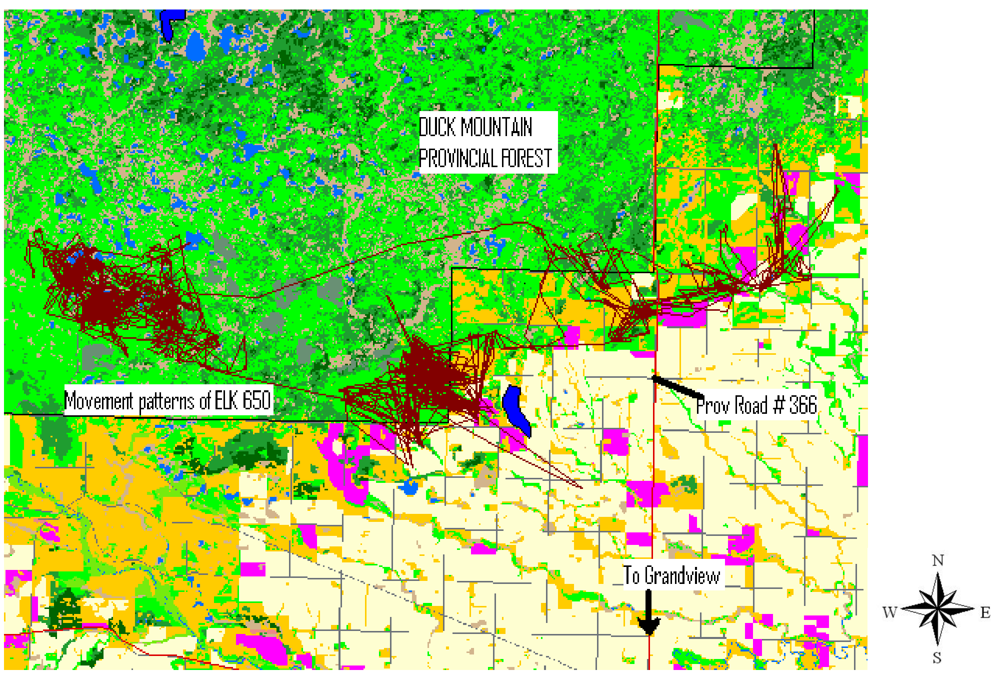

Figure 4.13 Annual movement patterns of elk 650 north of Grandview, MB in 2005/06

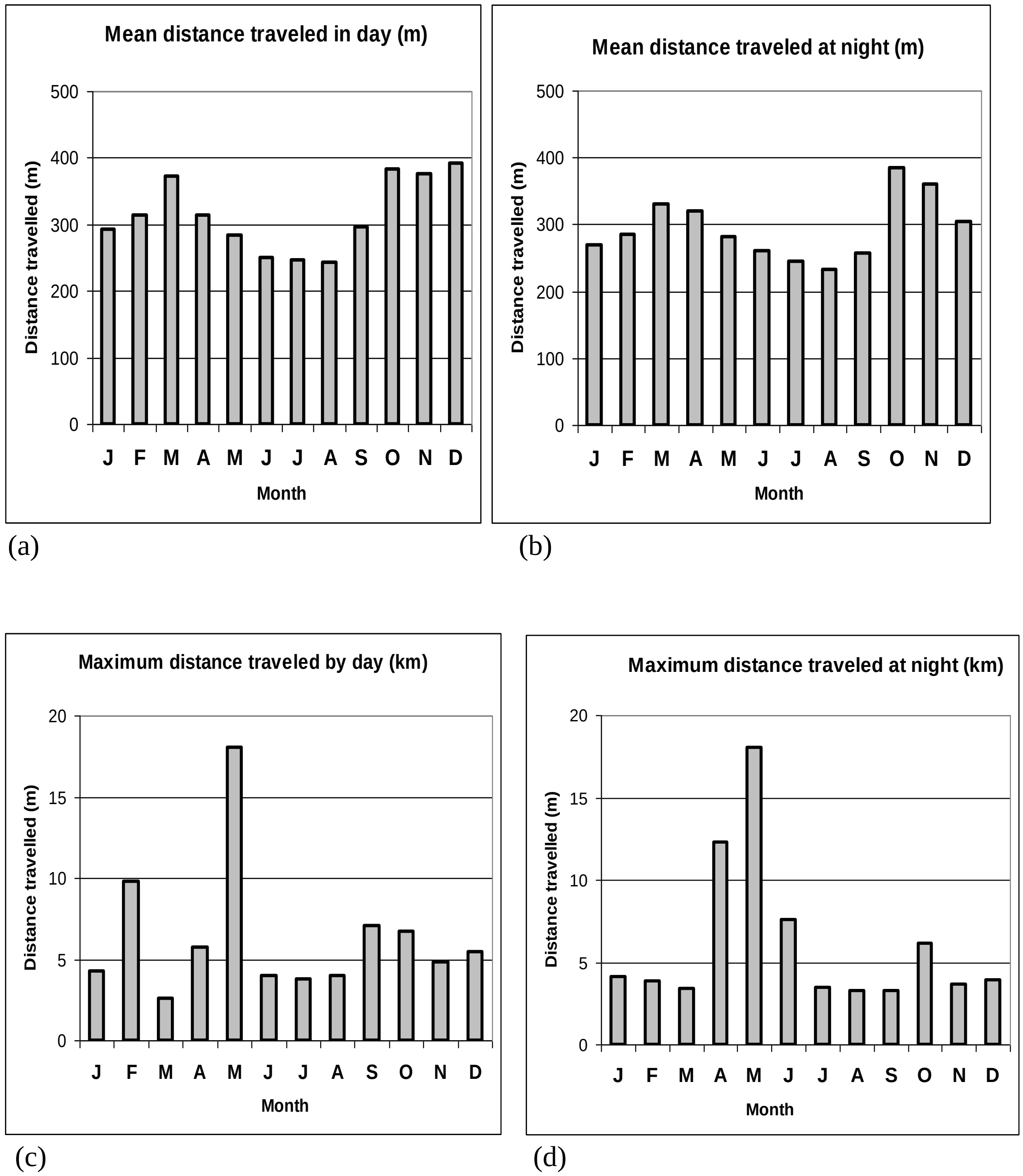

Figure 4.14 Mean distance traveled in the day (a) and at night (b) and maximum distance traveled in the day (c) and at night (d) by month (km).

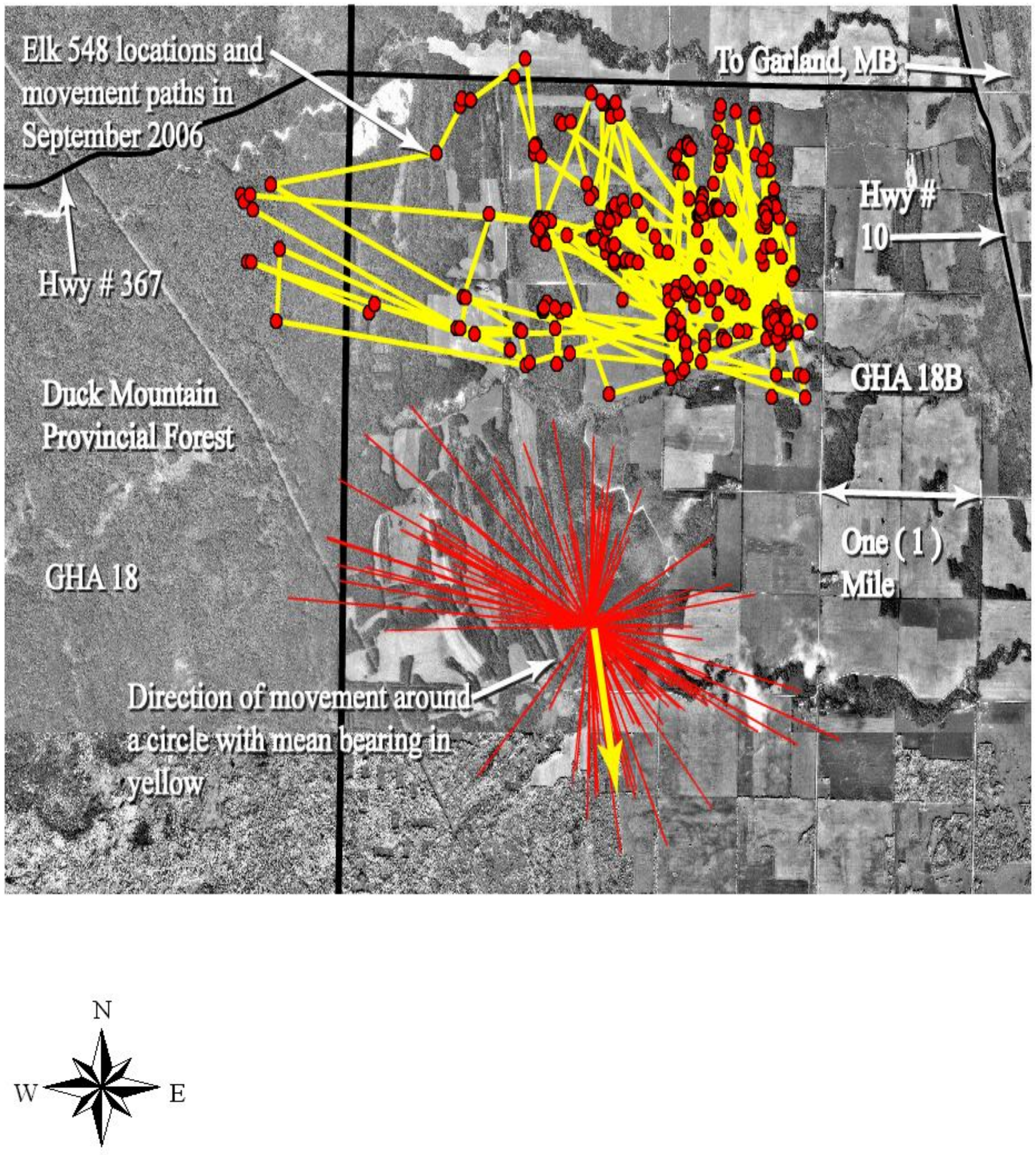

Figure 4.15 Gregarious movements of elk 548 in September 2006 west of Garland, MB on the east side of the Duck Mountain Provincial Forest

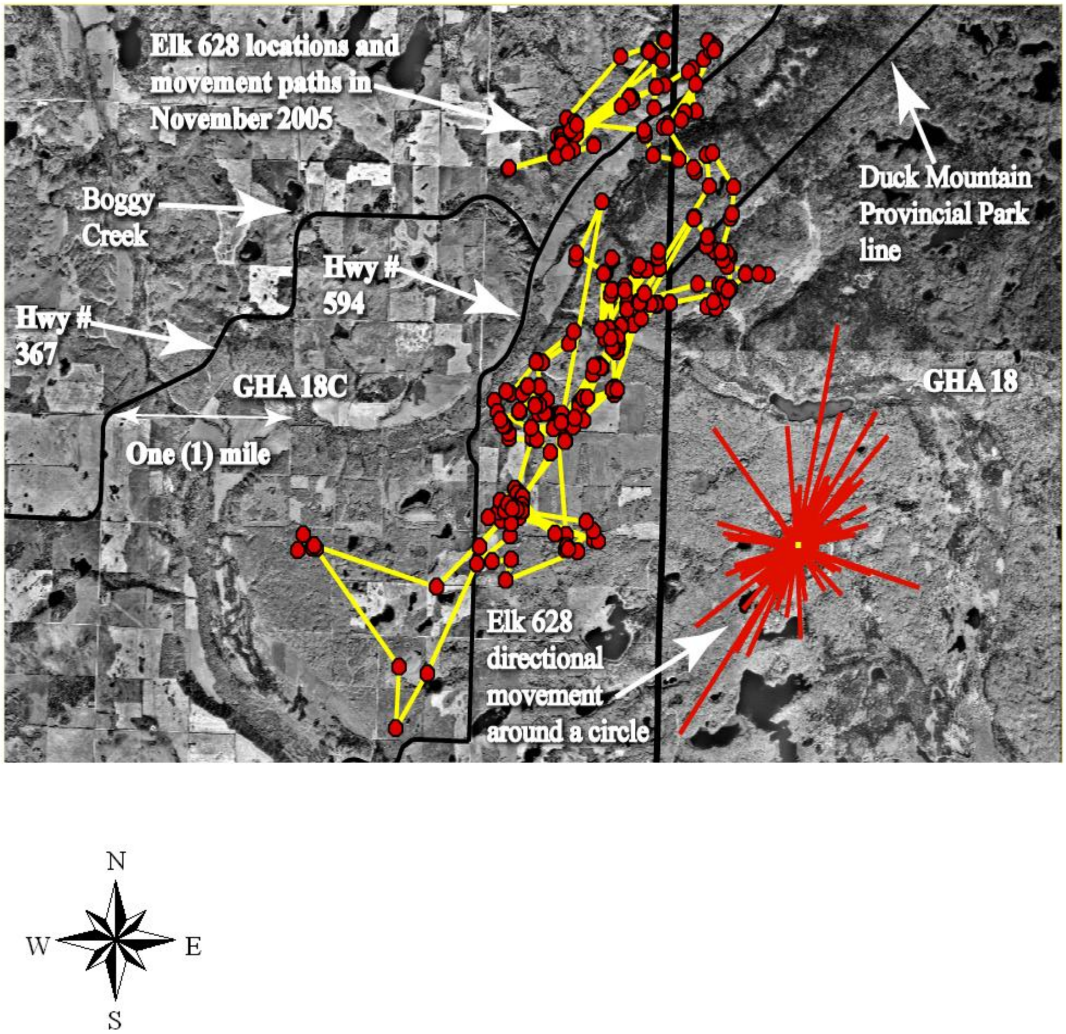

Figure 4.16 Elk 628 locations, movements and directional persistence patterns in November 2005 east of Boggy Creek, MB on the west side of the Duck Mountain area

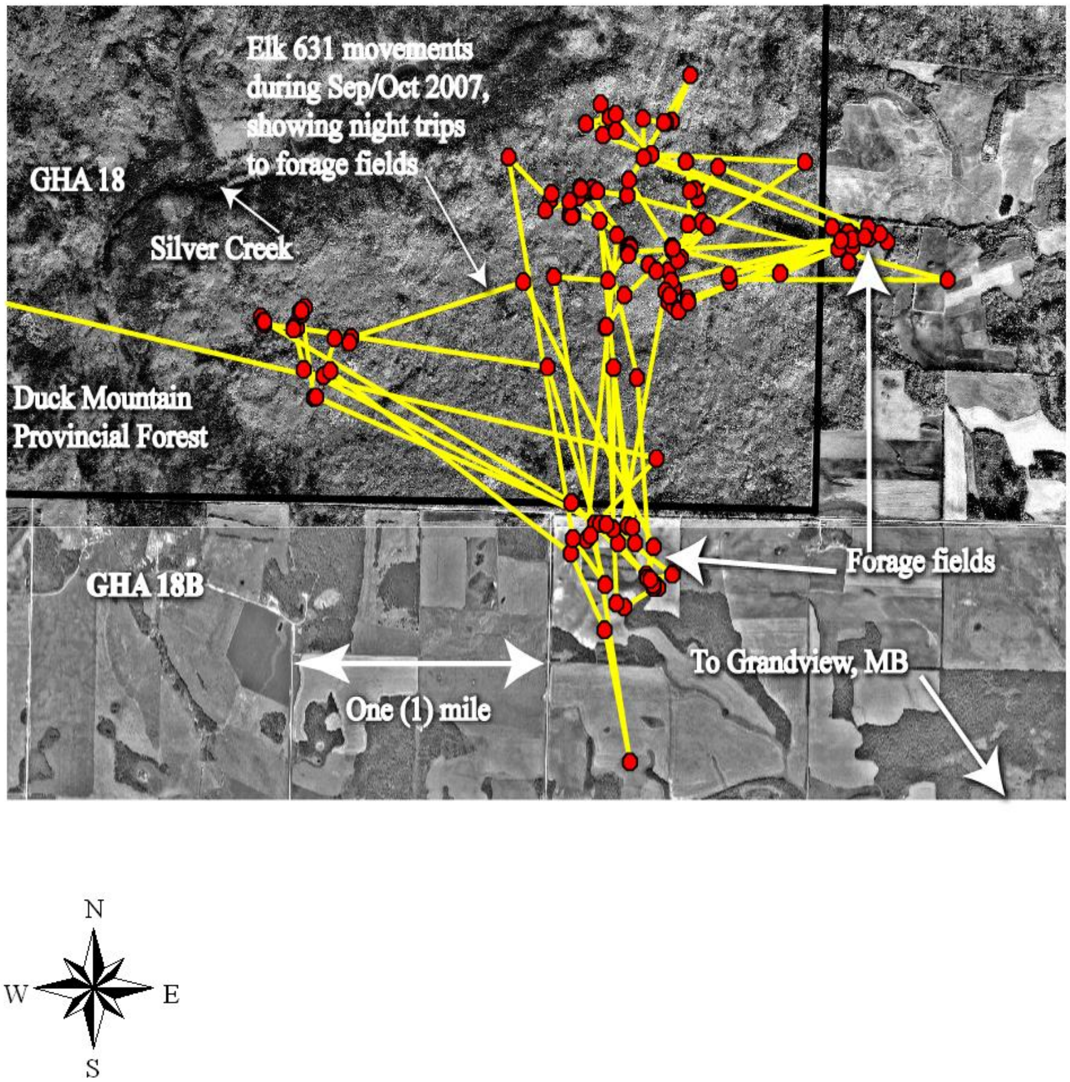

Figure 4.17 Elk 631 movement activity in the rut period (primarily in the Silver Creek area of the DMPF) showing movements to access forage fields in the late night hours

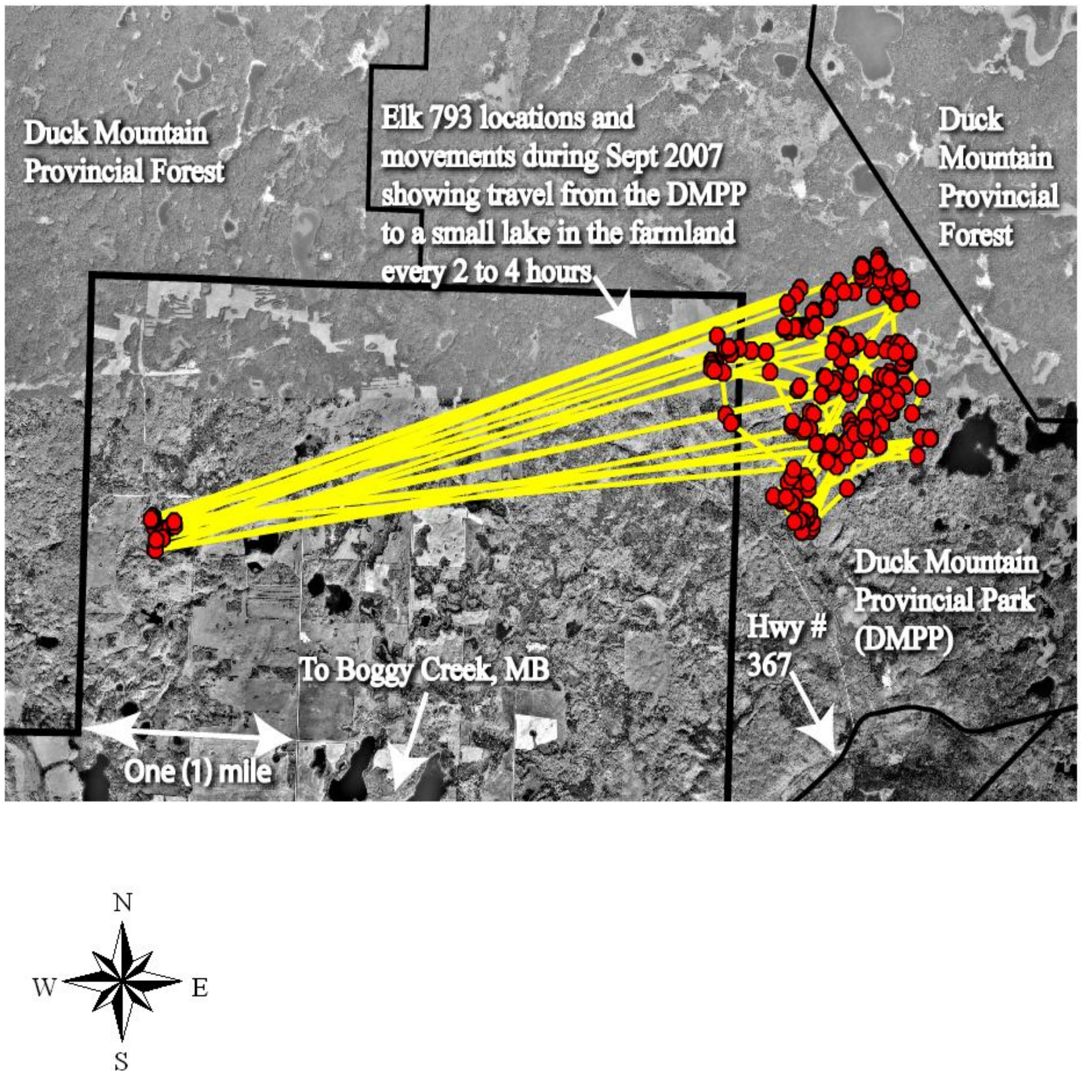

Figure 4.18 Elk 793 showing September, 2007 movements from the DMPF out to a ridge near a small lake in the farmland. Movements were every two to four hours for a distance of 6 to 7 miles, one way

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Chapter 5:

Aspects of cow elk habitat use as it pertains to specific landscape features

Abstract

Baseline research on a herd of 1670 elk in west central Manitoba was initiated in 2005. Relationships between elk habitat use and specific landscape features such as roads, water, forest cut-blocks and winter cattle operations were analyzed. Elk were captured by helicopter net-guns, blood tested for disease, radio-collared with GPS units and released in 2005 and 2006. GPS collars were retrieved in February and April 2007, data downloaded and analyzed with ArcView 3.3 for Windows, XTools and Nearest Feature extensions. Seventy-eight percent (78 %) of all individual elk locations within the DMPF (n = 17,525) were found in eco-sites 31, 32 and 33 (i.e. mature deciduous and mixed-wood forest) which only represent 48% of the DMPF ($0.772 < P_i < 0.789$). Elk were also found in eco-sites 72 and 73 (i.e. shrub, grassland, prairie savannah) more often than expected ($0.035 < P_i > 0.043$). All other eco-sites were selected less than expected. Elk were commonly found in areas between 0 and 10% and 81 to 90% crown closure. Within the DMPF, elk locations were found most frequently (51%) on the middle slopes. Elk seem to prefer variable (~60% of locations) or southerly aspects. There is a general displacement of elk away from forestry cut-blocks at all zones between 100 to 1000 metres. There is not an absolute avoidance of forestry cut-blocks as evidenced by the 3,526 elk locations found within cut-blocks. Elk are less commonly found within 200m of a road than expected by random. When traveling within 100 metres of a road, elk were generally near road types with lower traffic volume. Elk are not found within 200 metres of a water feature more often than random. Elk position themselves more commonly between 400 and 900 metres of water features. Over 38% of all elk travel paths are however, found within 100m of water. Elk are found within 100m of a winter cattle operation more often than random. In total, only 149 elk locations of 79,284 elk locations

were within 100 metres of a winter cattle operation. Only 14% of all elk locations were within 1000 metres of a winter cattle operation. Duck Mountain cow elk exhibit interesting trends with various landscape features and strategies to mitigate forest impacts or bovine TB transmission should focus on riparian areas and mature deciduous forest with implications to road management.

Introduction

Duck Mountain cow elk range across the agricultural/forest interface of the farmland and the DMPF. I chose to determine the general interaction of elk to landscape features that were locally important but also had been studied in other jurisdictions to see if there were any similarities or differences. There are a number of landscape features that are found in the farmland (i.e. yard-sites) or the forest (i.e. coniferous forest) but not both. I chose to analyze two features found both in the farmland and forested area (i.e. road and water features) as well as features that were exclusive to the farmland (i.e. cattle) or the forest (i.e. cut-blocks). The last two features are particularly pertinent to the Duck Mountains due to the bovine TB issue (i.e. elk-cattle interaction) and active forestry operations (i.e. elk-cut block interaction) in the DMPF.

Elk and roads

Elk generally avoid roads. At the Starkey Research Project in Oregon, elk avoided roads and the level of avoidance increased with the increase in traffic volume. Elk reacted more strongly to ATV traffic with some reaction to mountain bikes but reduced reaction to horseback riders or hikers (Rowland et al. 2005). When exposed to ATV traffic, Oregon elk increased their travel time and decreased their feeding time (Naylor et al. 2009). In spring and summer, elk show increasing selection for specific areas as the distance from a road increases. Winter cow elk home ranges generally had lower road densities (McCorquodale 2003).While no other seasonal trends were noted however, the spatial pattern and density of roads can dictate whether elk avoid or select areas (Rowland et al. 2000). When road densities in Alberta were ≤ 0.5 km/km^2, there was a higher probability for hunted elk to occupy their home range in a managed forest landscape. When roads were placed 700 m away from the edge of a cut-block or human access was restricted by road closure, then some elk tolerated intermediate road densities of 1-1.5 km/km^2 but at road densities of ~1.6 km/km^2 no refuge existed for elk to reduce mortality risk from hunting. Roads near cut-blocks reduce habitat accessibility for elk to forage patches and may increase mortality risk for elk that show higher levels of fidelity to a particular area (Frair et al. 2008). In Manitoba, RMNP elk strongly avoided areas less than 200 m from a road (Brook 2007). Elk will use areas near roads when traffic volume is light. Elk will also cross roads with high traffic volume if they are trying to access high quality forage areas such as riparian meadows. Cow elk can cross roads as much as 4 times more frequently than bull elk (Gagnon et al. 2007, Dodd et al. 2007). Elk will use highway underpasses with high traffic volume but disperse when semi trailer trucks are passing over an underpass (Gagnon et al. 2007). These elk observations are similar to moose and bears. Both moose and bears tend to avoid roads and have higher movement rates while crossing roads than immediately preceding or after the crossing (Dussault et al. 2007, Graves et al. 2006).

Elk and water

Elk use of water can vary from area to area and year to year. Elk use habitats near water when surface water is limited. Otherwise, elk can access water in the form of dew, in succulent forage and that produced by metabolic processes to offset the need for water (Skolvin et al. 2002). Cow elk may have a seasonal dependence for water during lactation. In Montana, more than 80% of July elk use was within 0.41 km of a permanent water source (Marcum 1976). When elk move at dawn and dusk crepuscular periods, they tend to travel parallel to water drainages as long as suitable security cover exists adjacent to the drainage. Elk do not like to cross drainages perpendicular to the slope or the flow of the water drainage (Ager et al. 2005). In Manitoba, RMNP cow elk seem to calve away from water features (Brook 2007).

Elk and cattle

Elk and cattle can be found in the general vicinity of each other but tend to use habitats differently and have temporal and spatial separation in most cases. Elk can be displaced from areas used by cattle (Lindzey et al. 1997). On pastures grazed by cattle, elk eat less grass and eat more shrubs. This trend holds during the summer but there can be some overlap of habitat use with cattle by elk in the autumn. Elk however, generally avoid cattle by selecting habitat where cattle are not present and as cattle get rotated through pastures, elk will move into areas when cattle are moved out (Coe et al. 2005). In Manitoba, elk generally avoid cattle and tend to prefer climax grasslands to those grasslands previously grazed by cattle. There is very little competition for habitat between elk and cattle (Blood 1966). I have observed small groups of elk within 500 metres of cattle in bush or shrub pastures during the late summer and fall. I have not observed elk in close proximity (less than 500 m) to grazing cattle in the study during aerial telemetry flights. In the winter, I observed elk in wooded cover no closer than 500 to 1000 m from a winter cattle operation, during aerial telemetry flights.

Elk and forestry

Considerable study has centered on elk and forestry activities. Early studies indicated that elk avoided active logging and road construction (Lyon 1979), but line-of-sight barriers created effective separation from disturbance. Strong home range fidelity was exhibited by cow elk in logged areas. Edge et al. (1985) found no changes in elk home ranges as long as adequate escape cover was available. When foraging habitat was abundant, developing roads away from cut-blocks (forage patches) allowed elk to readily move between forage patches without encountering roads and thereby reducing their mortality risk and increasing their retention in the overall landscape. In addition, restricting human access on logging roads by closure or decommissioning and establishing road-less areas are other effective techniques which retain elk on the landscape (Frair et al. 2008). Lyon and Christiansen (1992) defined escape cover to be a sight distance at which 90% of an elk is hidden from view. Edge and Marcum (1985) did show that elk are generally displaced 500 to 1000m from logging disturbance and only move towards logging areas when they are not active. Eco-tones (areas where different types of vegetation are juxtaposed) and early successional communities are also important elk habitats. Leckenby (1984) found that

80% of summer elk use was within 300 yards of forest/non-forest edges. In the Blue Mountains of Oregon, Leckenby (1984) showed that elk preferred habitats near forage areas (less than 40% canopy cover) and cover (greater than 40% canopy cover). Poole and Mowat (2005) determined that in late winter, elk avoided logged areas due to greater snow depth on these sites and seemed to prefer non-forested or open deciduous vegetation types for the forage and lower snow depths. In the absence of hunting, elk are not negatively affected by timber harvest. Timber harvest roads however, increase elk vulnerability to hunting (Wisdom et al. 2005). The objective of this Chapter is to describe and analyze the habitat use relationships of cow elk with specific landscape features found in the forest, farmland and forest/farmland interface and determine the implications of these patterns to forestry and bovine TB management

Materials and Methods

Elk locations were tallied in buffer zones around various landscape features. The water and road layers were obtained from files extracted from the Manitoba Land Information Network (Government of Manitoba website). The water layer is 1:20,000 scale and was digitized from topographic maps. The road layer was also extracted from topographic maps and Manitoba highways files and digitized by map-sheet. The cut-block layer was obtained by permission from Manitoba Conservation-Forestry Branch and Louisiana Pacific Canada Ltd. The cut-blocks range in date of harvest from 1994 to 2004 and were digitized from maps created by Louisiana-Pacific Canada Ltd and Manitoba Conservation. The winter cattle operation locations for the south half of the Duck Mountains were obtained by permission of the Canadian Food Inspection Agency, Winnipeg. See Figure 5.1 for images of landscape feature analysis layers.

All layers were created into ArcView shape-files. Each feature (i.e. water, roads, cut-block or cattle operation) was buffered using XTools extension for ArcView by 100 to 1000 m in 100 m intervals and areas of the buffers tabulated using Spatial Analyst extension for ArcView. Nearest Features version 3.8b (Jenness 2007) extension for ArcView was used to calculate distances to the nearest landscape feature from each elk location. To address auto-correlation, data was sub-sampled and weighted equally regardless of # of locations (Nations et al. 2006, Land et al. 2008). Locations were tallied into each buffer area and elk per unit area figures were produced for each landscape feature. Then, total actual locations were randomly sub-sampled with 15,000 locations from 2005/06 and 15,000 locations from 2006/07 for each landscape feature. In addition for each of the four landscape features 30,000 random points were generated within the merged 100 % MCP polygon, 10 times to produce 40 separate files. Each file was subjected to Nearest Feature distance measurement and then each file was tallied into the respective landscape buffer to produce random points per unit area (mean, minimum and maximum) and graphed with the actual elk locations to determine if actual elk distribution was significantly different from random.

Elk locations were also tallied and plotted to determine specific feature types when elk locations were within 100 m of a water or road feature. Step lengths (SL) were created for each elk's annual distance traveled. Step length is the straight line displacement between two consecutive 2-hour locations. The Alternate Animal Movement Routes (AAMR) extension version 2.1 (Jenness 2005) for ArcView was used to create 100 m buffers along step lengths (SL) to intersect road and water features. The proportions of SL partially within, entirely within or outside 100 m of the landscape feature were tabulated. The AAMR extension calculates the proportion of the SL between two points that pass through the 100 m landscape line feature buffer. The designation of 100 m buffers for water and road features was used because in Manitoba forest mitigation practice, buffers are often set along water and road features. Determining if this artificial buffer distance was relevant to wildlife use was attempted in this analysis. In addition, elk locations found within cut-block boundaries were tallied by month.

Landscape level habitat use within the Duck Mountain Provincial Forest (DMPF) was assessed with a coarse filter approach using the layer for specific forest ecological attributes from the Manitoba Forest Inventory (2004). The DMPF was re-classified in an updated forest land inventory (FLI) conducted by MB Conservation and Louisiana-Pacific Canada starting in 2000 and documented in a draft user guide document (The Forestry Corp. 2004). The previous forest resource inventory (FRI), was done in 1982. The newer FLI is ecologically based and used an ecosite classification system. Ecosystem sampling plots (both on the ground and from photo interpretation) were measured across the entire area to characterize the forest resource into ecological attributes including live trees, snags, coarse woody debris, soils, vegetation (both canopy and under story), topography and wetlands. Ecosites are landscape descriptors based on a combination of soil moisture, soil texture and vegetation. Photo interpreted stands of forested land were assigned eco-site classes based on the ecological data available for each stand. Ecosites can vary in size from 1 to 100's of hectares and generally incorporate more than one stand of trees.

Elk location theme files found within the DMPF was spatially joined (using Spatial Analyst extension for ArcView) with eco-site classifications and selected ecological attributes. Using the Forest Land Inventory Draft User Guide, a tally was conducted of the number of elk locations found within the following ecological attributes (i.e. % canopy cover, slope position, aspect and eco-site type). Charts were produced of elk locations by eco-site, slope position, aspect and crown closure. Using the summary table for area tabulations of eco-sites for the Duck Mountain Provincial Forest, eco-site proportions were created in MS Excel. Observed and expected proportions of elk locations by eco-site were calculated to produce a chi-square statistic and simultaneous confidence intervals by eco-site groups to determine which eco-sites were being used more or less than expected (Neu et al. 1974; Byers et al. 1984). Primary habitat type descriptions were identified for individual elk by the ecological attribute analysis, to get an indication of relative deciduous forest habitat types used by elk. In addition, elk locations were tallied for each eco-site and percent of locations for selected eco-sites were calculated to indicate relative use.

Results

Relative Forest Use

Elk locations within the Duck Mountain Provincial Forest (DMPF) have shown a distinct trend to the use of specific eco-sites. Seventy-eight (78) % of all individual elk locations within the DMPF (n =17,525) were found in eco-sites 31, 32 and 33, even though these eco-sites (i.e. mature deciduous and mixed forest) only represent

48% of the Duck Mountain Provincial Forest. This finding was significant (0.772 < $\mathbf{P}_i$ < 0.789). Elk were also found in eco-sites 72 and 73 (i.e. shrub, grassland, prairie savannah) more often than expected (0.035< $\mathbf{P}_i$ > 0.043). All other eco-sites were selected less than expected (Table 5.2 and Figure 5.2 for elk locations by eco-site). The eco-site with the most elk locations was eco-site 32. This habitat is described as sites with hardwood stands dominated by trembling aspen and balsam poplar on fresh fine loamy soils. There are a medium number of herbs with abundant tall and low shrubs. The second and third most common eco-sites with elk locations were eco-sites 31 and 33. Eco-site 31 sites have a slight variation, being mixed-wood stands of trembling aspen and some white spruce on fresh clayey soils with a rich herb layer and abundant tall and low shrubs. Eco-site 33 sites are also mixed-wood stands dominated by trembling aspen and some white spruce or jack pine on fresh fine loamy soils with a medium number of herbs and tall shrubs and abundant low shrubs. Two elk showed a distinct use of eco-sites 22 and 23. These eco-sites are similar to eco-sites 32 and 33 but vary mainly by the quality of soil types. Eco-site 22 sites are trembling aspen hardwood dominated stands on fresh coarse loamy to silty soils with a poor herb layer and a medium abundance of graminoids and low shrubs with an abundance of tall shrubs. Eco-site 23 sites are mixed-wood stands of trembling aspen and white spruce on fresh coarse loamy or silty soils with a medium abundance of herbs, tall and low shrubs. In summary, elk were found in eco-sites 31 to 33 and 72 & 73 (shrub/grassland/prairie savannah) significantly more than expected based on availability.

In addition, elk were commonly found in areas between 0 and 10% and 81 to 90% crown closure. About 40 % of elk locations were found in areas with less than 40 % crown closure and about 50 % of elk locations were in areas with greater than 50 % crown closure (Figure 5.3). Within the DMPF, elk locations were found most frequently (51%) on the middle slopes with 24 % found on upper slopes and 11% on level ground. Elk were rarely located at the crest of a hill or in depressions (Figure 5.4). Elk seem to prefer variable (~60 % of locations) or southerly aspects when found on middle or upper slopes. In the Duck Mountains, aspect is difficult to classify due to the hummocky and undulating terrain, which is why variable aspect is so common. In approximately 12 % of the locations however, elk are found on level aspects (Figure 5.5).

In Table 5.1, habitat descriptions were developed for the top ten ecological attributes based on a simple tally of elk locations. In general, however, elk can commonly be located in stands (originating in 1900-1935) with continuous patches of 80-90% trembling aspen and 80% crown closure having inclined & undulating terrain on middle slopes of hummocky or complex topography that have 11-45% slope and level or variable aspect with a fresh moisture regime.

Forest Cut-blocks

When actual elk locations are compared to random locations, elk tend to avoid forestry cut-blocks more often than expected. At 100 m from a cut-block, there are 5.25 random locations per hectare and only 3.5 actual elk locations per hectare (Figure 5.6). There is a general displacement of elk away from forestry cut-blocks at all zones between 100 to 1000 metres. There is not however, an absolute avoidance of forestry cut-blocks as evidenced by the 3,526 elk locations found within cut-blocks. When temporal trends are analyzed for elk locations in cut-blocks, elk are more likely found within a cut-block in December, January, May and August (Figure 5.7). On aerial telemetry flights, I have observed cow elk in recent cut-blocks (i.e. less than 5 years old) during the late summer. Elk like to find a spot near the crest of the knoll within the cut-block to bed down. I also observed elk in cut-blocks foraging in regenerating stands, near the edges of a cut-block.

Roads

Duck Mountain elk avoid roads in most situations evaluated. Elk are less commonly found within 200 m of a road than expected by random. They are located between 300 and 800 m from roads more often than random (Figure 5.8). When traveling within 100 m of a road, elk were generally near road types with lower traffic volume such as, two track machinery roads or municipal gravel roads (Figure 5.9). When close to these lower traffic volume roads, elk were more likely to be within 100m of a road in December, January and February (Figure 5.10). Evaluation of elk

SL reveal that greater than 51 % of elk travel is further than 100 m from a road with only 2.26 % of elk SL found entirely within 100 m of a road (Table 5.3).

Water

Elk are not found within 200 m of a water feature more often than random. Elk position themselves more commonly between 400 and 900 m of water features (Figure 5.11). In spite of these observations, over 42 % of all elk SL are found either partially or entirely within 100 m of water (Table 5.4). When close to water, elk are more likely found near perennial and intermittent lakes and streams (Figure 5.12). Elk SL that are within 100 m of a water feature are more likely occurring in June (i.e. 20%) with May, July and August months showing high travel use also (Figure 5.13).

Winter cattle operations

The location of elk in relation to winter cattle operations around the south half of the Duck Mountain Provincial Forest is interesting. When compared to random, elk are found within 100 m of a winter cattle operation more often than random (i.e. 11 elk locations per hectare vs. 5 random locations per hectare) and less commonly within 400 m of a winter cattle operation. Between 500 m and 1000 m, elk are more commonly found within these distances than expected by random (Figure 5.14). In total, only 149 elk locations of 79,284 elk locations were within 100 m of a winter cattle operation, of which 135 were in August and September. Indeed, only 14 % of all elk locations were within 1000 m of a winter cattle operation. Seven (7) different cattle producers (of 230 total operators) found around the south half of the Duck Mountains have elk within 100 m their winter operation, occasionally. Elk locations between 500 to 1000 m generally represent elk herds that are positioned in wooded cover for bedding sites. They are in close proximity to a winter cattle operation to access the stored hay bales for foraging opportunities during short time intervals.

Discussion

Habitat use in relation to forests and cut-blocks

In the Duck Mountains, cow elk are using eco-site 32 with consistent regularity. Based on the fact this eco-site consists of mature deciduous forest and elk show strong selection for this habitat type, this result is not surprising. This observation also highlights the value that eco-site 32 represents for elk and the forest industry. The majority of cut-blocks in the Duck Mountains have been harvested in eco-site 32. The fact that forestry companies try to maximize their wood supply and wildlife managers try to ensure adequate habitat supply (Rempel and Kaufmann 2003) for elk illustrates the conflicts and challenges related to management of eco-site 32 in the Duck Mountains. When conflicting purposes are difficult to resolve, adaptive management practices based on ecosystem management can help to formalize a structure that can lead to sustainable management which meets the needs of the regulating agencies and the private forest companies in the process (Wall 1999). A landscape–level habitat based planning process linked to a fine filter adaptive management approach should reap the rewards of maintaining biodiversity into the future. In Washington, for example it has been recommended that a balance must be struck between mature forests needed by elk in severe winters and regenerating forests due mild winters. Too many early-seral stage forests will only be beneficial to elk if all winters are mild (Jenkins and Starkey 1993). Wall (1999) recommends setting up management guilds for various life-forms in the managed forest and monitoring these features at two scales: the stand level and landscape level. The key to successful implementation is monitoring for quality control with secure long term funding so that a feedback loop is developed and real corrective measures are implemented when necessary. Further along these lines, Baydack et al. (1999) recommends that future research be directed towards evaluation of habitat management techniques that emulate natural disturbance. This type of adaptive research is in its infancy in Manitoba but should nevertheless be attempted. It is the author's experience that current forest mitigation processes are attempting to meet these laudable goals but still fall short of the target, to some extent.

The data referring to elk selection of specific crown closures is similar to research by Leckenby (1984). Duck Mountain cow elk seem to be found in areas close to the eco-tone between open (less than 40% crown closure) and closed (greater than 50% crown closure) forested habitat. Duck Mountain cow elk selection for more closed canopy is similar to Sawyer et al. (2007) and Unsworth et al. (1998) which found this to occur from summer to fall. Closed canopy forest use can be related to the superior browse available (Fortin et al. 2005) and its ability to provide secure cover at all times of the year (Sawyer et al. 2007, Unsworth et al. 1998, Edge et al. 1988). By maintaining mature forest stands for hiding cover within the average home range of Alberta elk at distances no greater than 600 m from one another, elk use will be promoted (Visscher and Merrill 2009). In the summer, cow elk can be found in sites away from roads with more open deciduous habitat on moderate slopes of variable aspect (Sawyer et al. 2007). These trends are exhibited by Duck Mountain elk in figure 30 for peak relative use of open deciduous forest in June and preference for moderate slopes and variable aspects (figure 33 and 34). In the winter, elk can select moderate slopes with south and west aspects (Unsworth et al. 1998) which is similar to Duck Mountain cow elk. The observation that elk can also select for level aspects (Johnson et al. 2000, Frair et al. 2005) is similar to Duck Mountain elk, as level topography is their third most selected aspect (figure 34). Elk in the Duck Mountains have a diversity of terrain to use throughout their life cycle. The use of open grassland/shrub habitats such as those in eco-sites 72 and 73 by Duck Mountain elk is also corroborated by many researchers (Salter and Hudson 1980, Rounds 1981, Trottier et al.1983, Boyce et al. 2003, and Fortin et al. 2005). The availability of high biomass in grasses (Fortin et al. 2005), fescues in particular (Salter and Hudson 1980) and the adjacent security cover of closed canopy forest are likely reasons why open meadows within the Duck Mountains are preferred by elk.

The general separation of elk from recent forestry cut-blocks by Duck Mountain elk is not unexpected. Elk being found in cut-blocks during spring (i.e. May) is consistent with fuel-reduction studies in Oregon (Long et al. 2009) which showed increased foraging oppourtunities. Elk use is depressed in the presence of open roads or lack of secure cover at the edge of the cut-block (Lyon and Jensen 1980). Edge and

Marcum (1985) found that elk were generally displaced from logged areas by 500 to 1000 m and that is similar to Duck Mountain elk patterns (figure 35). Since elk cumulative movements can be 2500 to 4000 m per day, it is likely that Duck Mountain elk are just spacing themselves at a distance from the cut-blocks but are still within reasonable distance to access the cut-blocks for foraging purposes. Indeed, elk do use cut-blocks as evidenced by the numerous locations in cut-blocks. The use of cut-blocks by elk is determined by factors related to foraging, hiding cover and risk of mortality due to road access In addition, as long as thermal and hiding cover is maintained at >60% for a "even-flow" managed forest within the average home range of an Alberta elk (100 km^2) then forage availability will increase proportionately over 30 years (Visscher and Merrill 2009).Elk peak use of cut-blocks in December in the Duck Mountains (Figure 36) is a bit unusual as Poole and Mowat (2005) found that elk avoided cut-blocks in the winter due to the higher snow depths found in cut-blocks. Snow depths can affect the availability of browse to elk (Visscher et al. 2006) and consequently can be important to winter elk survival. December snow depths in 2005 and 2006 in the Duck Mountains were not deep and may explain this result. The reverse trend may have occurred if heavy snow fall had occurred. Elk use of cut-blocks in May, June and August is also not surprising as recent cut-blocks will have abundant forage near secure forest cover. Elk prefer smaller cut-block openings but will tolerate larger openings if close to natural openings already present in the environment (Lyon and Jensen 1980). My observations of elk bedded down on knolls and ridges in cut-blocks is likely related to the advantage that elevated bed sites acquire good solar exposure and are situated to allow detection of predators approaching. In addition, I have observed elk returning to areas with past logging activity (within 2 years) for calving and rutting activities.

Habitat use in relation to roads

The layer used to evaluate elk habitat use in relation to roads is strongly oriented to the grid road system in the farmland area surrounding the DMPF. Therefore, most areas have a municipal gravel roads spaced 1 mile (i.e. 1600 m) apart. If a section of land is surrounded by grid roads on every mile then the furthest that an elk could be found away from a road would be 800 m, as the elk would then be in the middle of the section of land. The fact that most locations for Duck Mountain cow elk are between 300 and 800 m of a road seems to indicate that elk like to distance themselves from disturbances. Many researchers have documented elk avoidance of roads (Fortin et al. 2005, Rowland et al. 2005, Wisdom et al. 2005, Anderson et al. 2006, Sawyer et al. 2007, Brook 2007, Dodd et al. 2007 and Gagnon et al. 2007). This study has re-affirmed this trend by showing that elk avoid areas within 200 m of roads. Elk will however, use habitats near roads if it is of high forage quality (Gagnon et al. 2007).

In this study we found that when Duck Mountain elk are close to roads, the road is generally a low traffic volume municipal gravel road. This finding coincides with similar results by Gagnon et al. (2007). In addition, lower traffic volumes occur in the winter and this trend is evidenced by Duck Mountain elk being closer to roads in December, January and February. This finding might also coincide with the fact that minimal licenced harvest occurs in these months and elk may sense they are relatively secure during the winter months. I was unable to find differences in movement rates during hunting seasons and this result seems to support this assumption. I did lose 3 of 22 elk to poaching (in November and December) however, and based on aerial photo analysis, the elk were probably shot near roads. This observation indicates that local hunters may have noticed elk being closer to roads in the winter and have tried to take advantage of this trend (in spite of the fact that it is illegal to shoot from a road surface). Even when Duck Mountain elk are close to roads, they tend to minimize their travel within 100 m since only 2.26 % of their SL are found in this zone. This trend may be different by season or individual elk (Rowland et al. 2000) and in some instances elk will be close to roads to access forage (Dodd et al. 2007). I have noted many occasions where elk are along the ditch of a road to feed on alfalfa or other succulent vegetation. In forest management planning, the design of road networks and road density are crucial in determining long term elk retention in a managed forest landscape due to the increased mortality risks from humans due to improved access by roads (Visscher and Merrill 2009). Decommissioning or closing roads to restrict human access should be part of landscape scale forest management (Frair et al. 2008).

Habitat use in relation to water

While the analysis of elk habitat use in relation to water features seems to indicate that elk avoid areas within 200 m of water, I think a biological perspective of this result should be identified. Water is ubiquitous throughout the Duck Mountains even in dry years. Since elk can access their water requirements in many ways and not have to rely on surface water (except during lactation) it is not surprising that elk don't stay in close proximity to water. Water is easily accessible and abundant in the Duck Mountains and therefore it is understandable that elk don't show strong selection for water features, except during the calving season. The Duck Mountain area is intersected with numerous water drainages (i.e. Shell, Valley, Sulphurspring, Fork) and since average elk directional bearing is southerly, it is expected that the streams, creeks and rivers in the Duck Mountain area are used as travel corridors. This travel may not be immediately adjacent to the drainage but elk do have over 42 % of their SL within 100 m of water. This pattern is probably related to the fact that Duck Mountain drainages have abundant wooded cover adjacent to the drainage and this aspect is attractive to elk (Ager et al. 2005) when they travel parallel to drainages. My research does have bias which doesn't reflect the true nature of elk travel next to water. GIS analysis connects locations with straight lines when actually elk would tend to linger next to the stream in good cover to follow the curves and meanders of the stream. Duck Mountain elk also exhibit a trend towards greater use of riparian areas during June (during the peak of calving) and most summer months. This is similar to that found by Marcum (1976) and Thomas et al. (1976) in which cow elk with calves show a seasonal dependency for water due to lactation demands. This study is general in scale and while some trends have emerged, detailed analysis may reveal other relationships with water features on daily intervals, for example.

Habitat use in relation to winter cattle operations

Elk herds near winter cattle operations are a fact, well known to some cattle producers around the south half of the Duck Mountains. Analysis shows that seven (7) producers (of a total of 230 operators) experience close encounters with elk, when elk can be found within 100 m of their operation mainly during August and September. In addition, elk place themselves in secure wooded cover that is within 500 to 1000 m of a winter cattle operation. In this manner, access to stored hay is not far away and yet, it allows elk to separate themselves from cattle for the majority of the time. There are additional 16 cattle producers which can have elk found within 500 m of their operation.

Some specific cattle operations have the right combination of secure wooded cover, a nearby riparian area and minimal human disturbance that attract elk. These are features elk prefer when selecting areas to spend the winter in farmland areas around the Duck Mountains. As elk home ranges can overlap and elk move parallel to drainages with adjacent security cover, the potential for elk to interact with cattle operations in winter can be strong for some operations. This can be especially risky if cattle or elk are infected with bovine TB since disease transmission would be possible at these cattle operations that are within overlapping elk home ranges and movement patterns. Many cattle producers that are farming within traditional elk home ranges are aware of this fact. Some seem to adjust specific farming practices to minimize interaction of their stored hay with elk and others do not take sufficient action (Kaneene et al. 2002).

This study indicates that elk generally avoid cattle throughout the year (Grover and Thompson 1986). In Alberta, however, elk are known to share winter range with horses (Salter and Hudson 1980). My research did not analyze elk interaction with cattle during the summer, as done by Brook (2007). It is the author’s feeling and other researchers (Palmer and Whipple 2006) that the potential for disease transmission between cattle and elk is still greater in the winter at stored hay stacks. From my own personal work experience, elk depredation of hay bales in the winter along the south half of the Duck Mountains varies by year but it can be dramatic in severe winters. In severe winters, there is higher potential for elk to interact with certain cattle operations. This study helps to highlight the sites where specific mitigation strategies could be applied to reduce risk to these cattle operators. It also serves as a reminder that adjusting farming activities such as farm bio-security, feeding practices and feed storage to reduce the risk of cattle-wildlife interaction are necessary by cattle producers to minimize disease transmission (Kaneene et al. 2002).

Conclusions

1. Elk use eco-sites 31 to 33 (mature deciduous and mixed-wood forest) and 72 to 73 (shrub/grassland and prairie savannah) more often than available in the DMPF.
2. Elk select for open and closed canopies on middle to upper slopes having variable, southerly or level aspects.
3. Elk are not commonly found in cut-blocks but they do use them, as there are 3,526 occurrences of elk within cut-blocks.
4. Elk tend to avoid areas within 200 metres of roads and remain 500 to 800m from roads with over 51 % of travel greater than 100 m. from a road.
5. Elk are not found commonly within 200 metres of water but, remain within 400 to 800 metres of water features. Over 42 % of travel paths are within 100 m of water. When elk are found within 100 metres of water it tends to occur in June.
6. Seven of 230 winter cattle operations have had elk within 100 metres of their operation, mainly during August and September. Another 16 operators have had elk within 500 metres of their cattle operation. The majority of elk locations are greater than 1000 m from a winter cattle operation.

Table 5.1 Habitat descriptions of eco-sites with elk locations (n = 17,525) within the DMPF

Eco-site Classification	# of Elk locations and percent	Habitat Type Description
2 to 10	1468(8.3)	Wetlands with continuous open patches of 70 to 90 % graminoids and 10 to 30% shrub ground cover having level topography on variable slope positions.
21 to 24	366(2.1)	Stands with continuous patches of 70 to 90% trembling aspen having 80% crown closure and 10 to 30% graminoids or shrubs in stands originating in 1890 to 1910 having undulating & planar terrain that is complex topography on upper to middle slopes of variable, easterly or southerly aspect on 30-60% slope and very fresh moisture regime.
31 to 33	13677(78.0)	Stands in continuous patches with 70 to 90% trembling aspen and 20% shrub cover with 80 to 90% tree crown closure in stands originating in 1870 to 1901 on undulating & planar terrain on middle slopes having convex or complex topography with variable, S, SE and SW aspects on 21 to 30% slope with fresh & very fresh moisture regime.
34 & 36	535(3.1)	Stands of 70-90% white spruce and 10 to 30% shrubs with trees having only 10 to 40% crown closure originating in 1890 to 1927 on undulating terrain of planar, complex or convex side slope topography on upper to medium slopes having 21-40% slope with variable, south or southeast aspects and very fresh moisture regime.
51 to 53	513(2.9)	Stands originating in 1870-1931 with 70-90% trembling aspen or white spruce and 20% shrub ground cover with trees having 10-50% crown closure in undulating terrain on planar topography in depressional troughs with lower slopes having 11-30% slope on south, southeast or northeast aspects and a moist moisture regime.
72 & 73	677(3.9)	Vegetation with 80-90% grasslands and 10-20% shrubs with 0% crown closure on planar & undulating terrain with concave side slope or complex topography on lower or middle slopes having 11 to 30% slope with south, southeast or southwest aspect and very fresh moisture regime.
88 & 89	208(1.2)	Lakes, ponds and rivers

Table 5.2 Expected vs. observed use of habitat types by cow elk in the Duck Mountain Provincial Forest (2005-2007). Significant use of habitat (either more or less) is indicated. Overall significance ($P < 0.05$, $X^2 = 7921.48$, df = 9) X^2_9, P = 16.92.

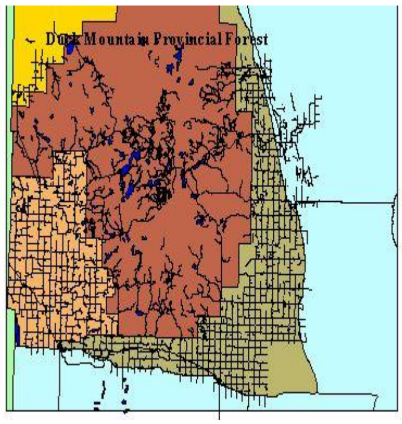
Habitat type (eco-site #)	***Expected proportion of use (Pio)***	***Observed proportion of use(Pi)***	***Bonferroni intervals for Pi***	***Habitat use***
non-forested wetland (2-10)	0.091	0.083	0.078 < Pi > 0.09	less
aspen/birch/spruce/pine mixed-wood (21-24)	0.052	0.021	0.018 < Pi > 0.024	less
aspen hardwood/mixed-wood (31-33)	0.480	0.780	0.772 < Pi > 0.789	more
spruce/fir mixed-wood (34,36)	0.105	0.031	0.027 < Pi > 0.034	less
aspen/spruce hardwood/mixed-wood (41,43)	0.006	0.000	0.000 < Pi > 0.001	less
aspen/spruce/pine mixed-wood (51-53)	0.095	0.029	0.026 < Pi > 0.033	less
spruce/alder/sedge/ sphagnum (61-64)	0.085	0.003	0.002 < Pi > 0.004	less
shrub/grassland/prairie savannah (72,73)	0.015	0.039	0.035 < Pi > 0.043	more
lakes/ponds/rivers (88,89)	0.044	0.012	0.009 < Pi > 0.014	less
transmission lines/roads/cabins (91-93)	0.005	0.002	0.001 < Pi > 0.004	less

Table 5.3 Step lengths of elk that are partially or entirely within or entirely outside 100m of a road feature. Only 11 elk with 2 hour fix intervals used for analysis. Step lengths partially within a feature are 50 to 99% within 100 m of a road.

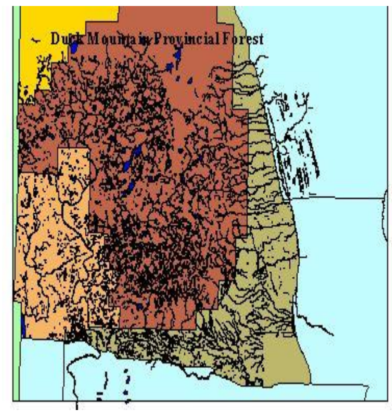
Elk ID #	***Step Lengths (SL): % entirely within 100m***	***Step Lengths (SL): % partially within 100m***	***Step Lengths (SL): % entirely outside 100m***
Elk 525	1.54	8.41	52.59
Elk 626	1.02	47.19	46.29
Elk 628	1.34	33.66	62.43
Elk 627	2.91	36.70	52.73
Elk 638	0.60	29.73	68.14
Elk 633	1.27	27.54	66.33
Elk 634	6.94	41.24	28.78
Elk 631	3.05	40.18	48.95
Elk 793	3.66	61.10	27.93
Elk 796	1.13	49.60	45.33
Elk 794	1.35	32.89	62.49
mean %	2.26	37.11	51.09

Table 5.4 Step lengths of elk that are partially or entirely within or entirely outside 100m of a water feature. Only 11 elk with 2 hour fix intervals used for analysis. Step lengths partially within a feature are 50 to 99% within 100 m of water.

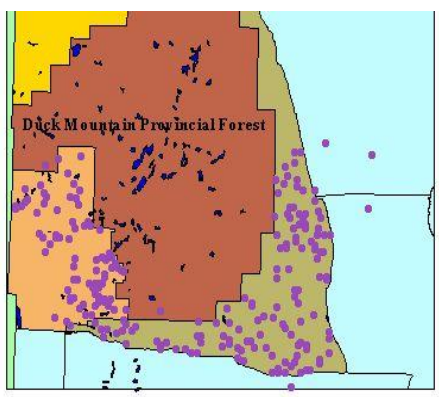
Elk ID #	***Step Length (ISL): % entirely within 100m***	***Step Length (SL): % partially within 100m***	***Step Length (SL): % entirely outside 100m***
Elk 525	0.61	38.80	57.59
Elk 626	0.74	49.15	46.90
Elk 628	1.01	37.62	55.94
Elk 627	1.17	42.40	53.95
Elk 638	0.77	33.59	64.34
Elk 633	0.80	21.47	75.94
Elk 634	1.15	34.89	61.35
Elk 631	0.62	40.16	56.46
Elk 793	1.73	61.62	32.99
Elk 796	1.47	50.27	45.24
Elk 794	2.41	41.21	50.80
mean %	1.13	41.02	54.68



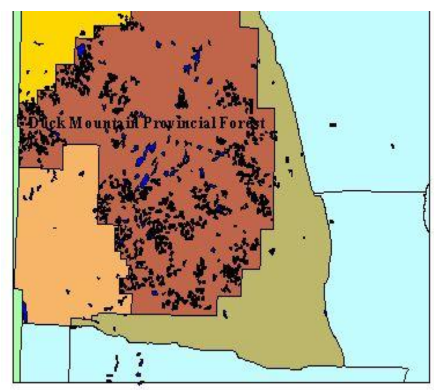
Duck Mountain road layer



Duck Mountain water layer



Duck Mountain winter cattle operation



Duck Mountain forestry cut-block layer

Figure 5.1 Images of analysis layers (roads, water, winter cattle operations and cut-blocks) used for landscape feature analysis in the DM in 2007

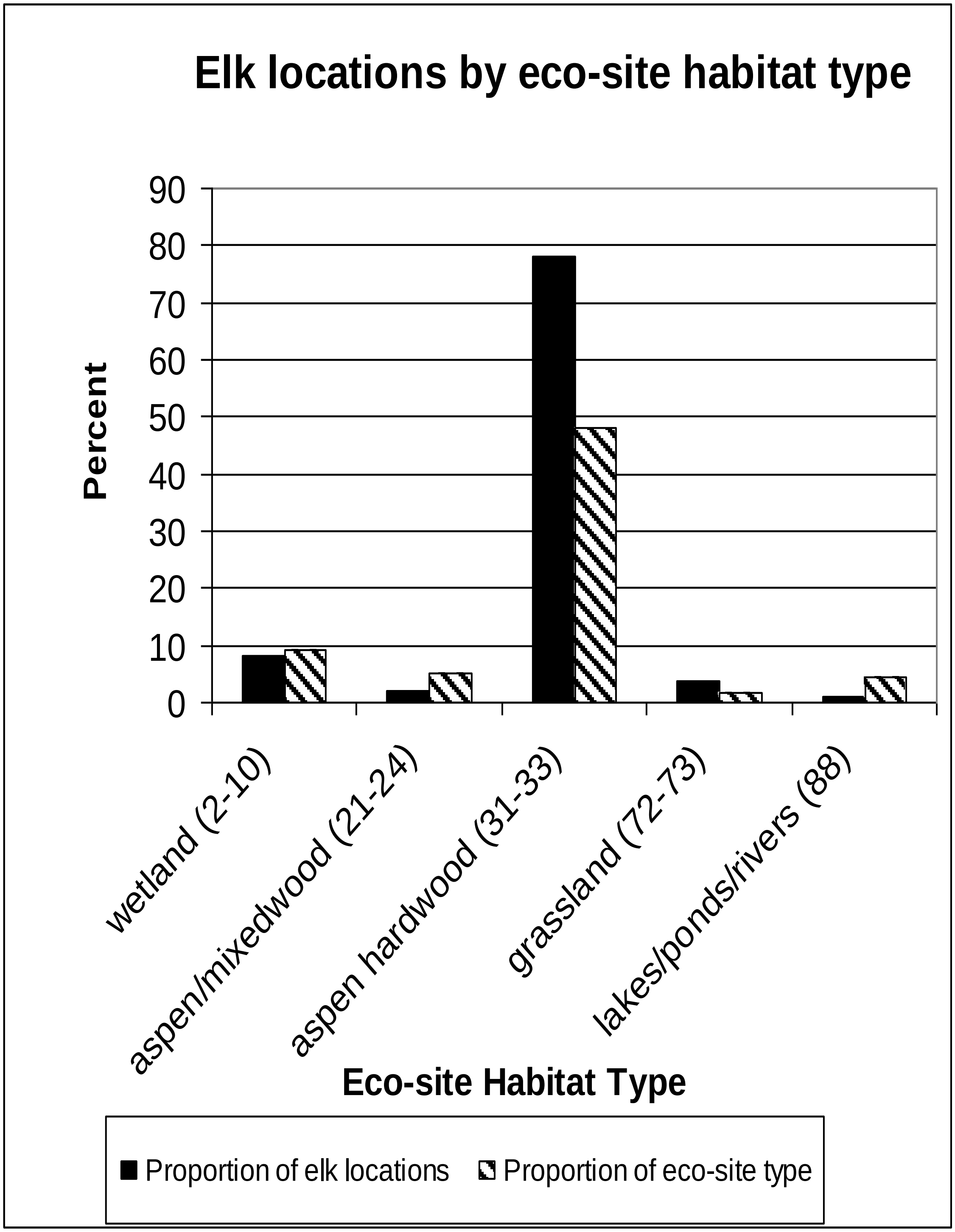


Figure 5.2 Distribution of Duck Mountain cow elk locations by eco-site habitat type in the Duck Mountain Provincial Forest from 2005 to 2007 (n = 17, 525)

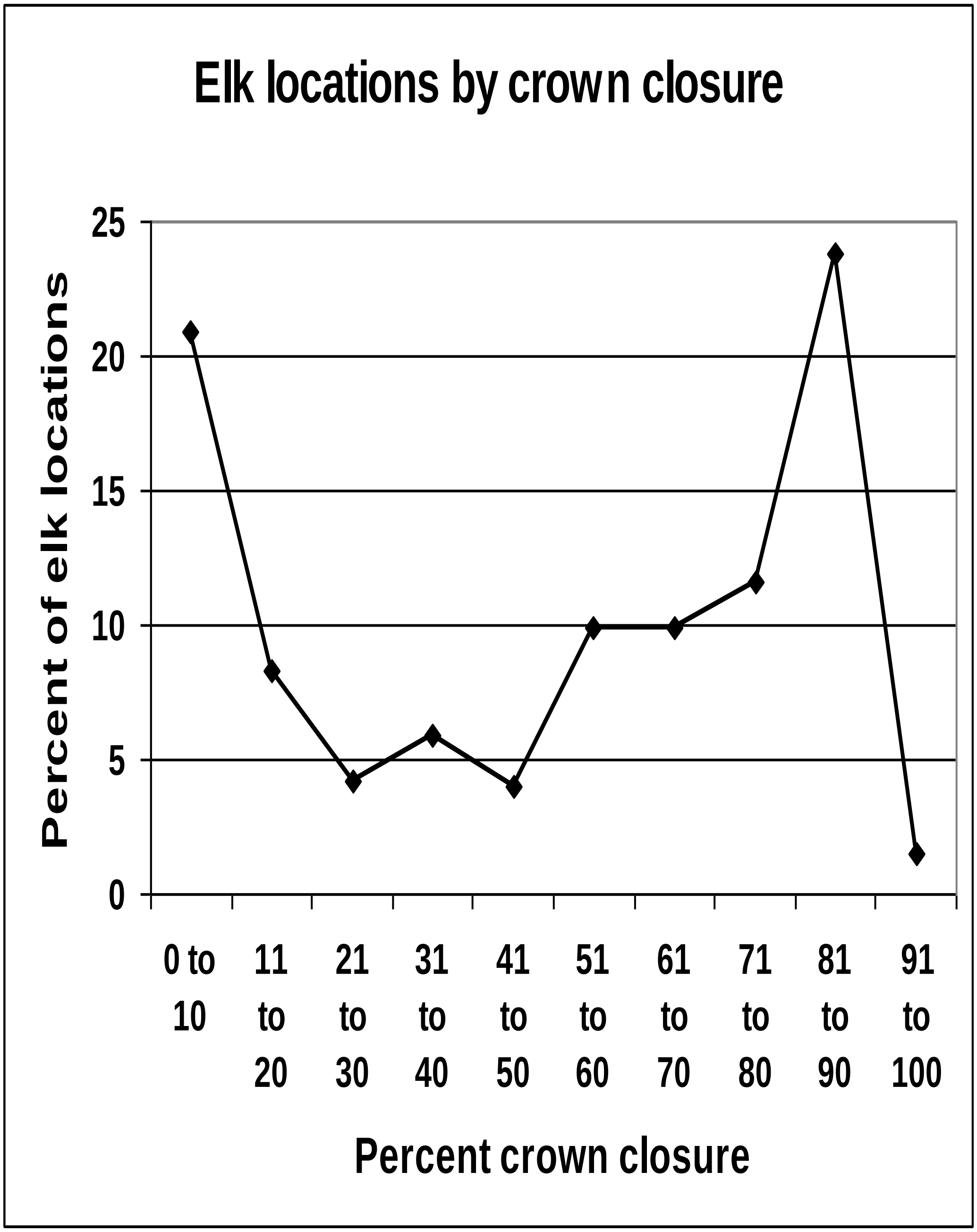


Figure 5.3 Distribution of Duck Mountain cow elk locations by crown closure in the Duck Mountain Provincial Forest from 2005 to 2007 (n = 17, 525)

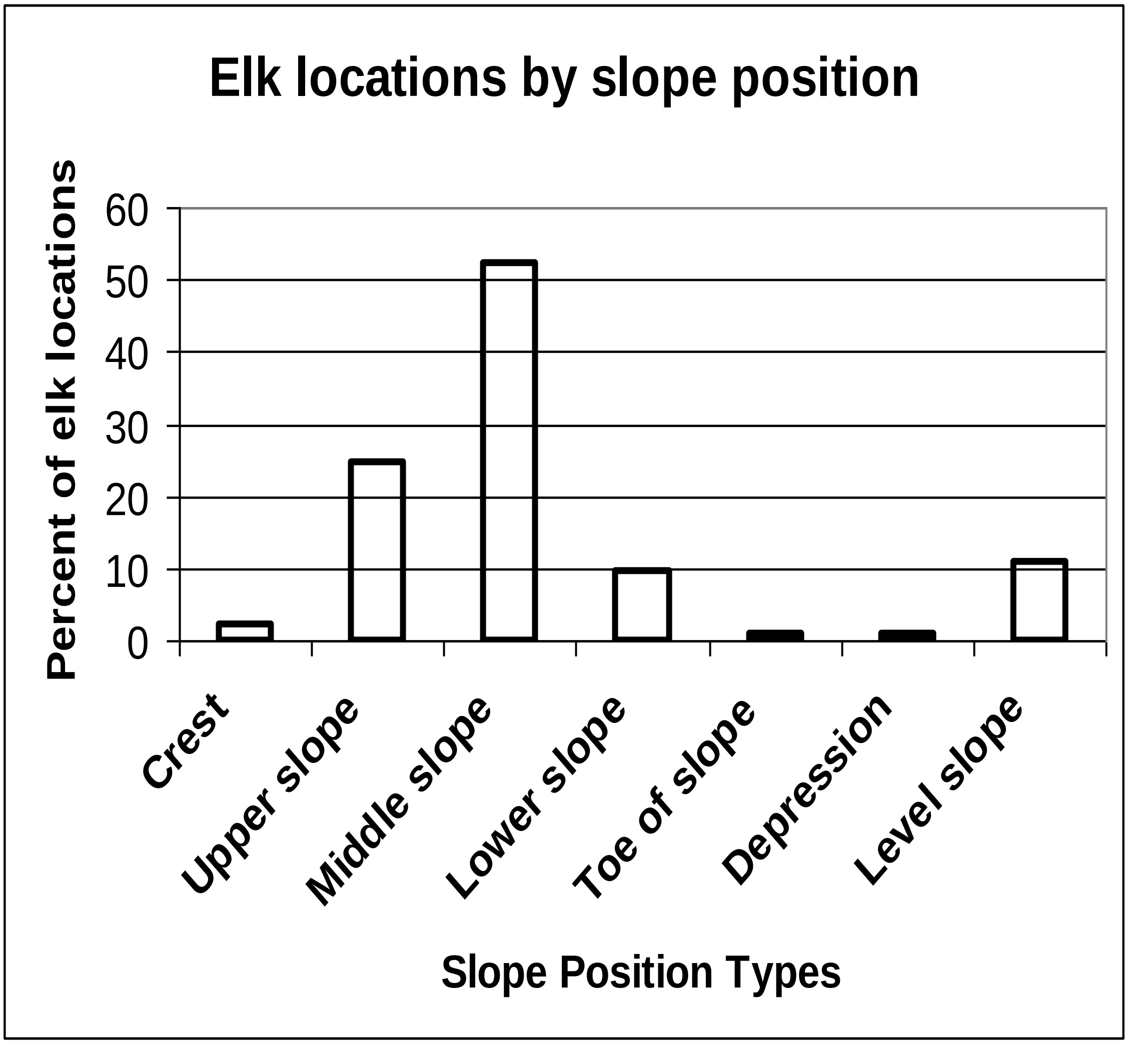


Figure 5.4 Distribution of Duck Mountain cow elk locations by slope position in the Duck Mountain Provincial Forest from 2005 to 2007 (n = 17, 525)

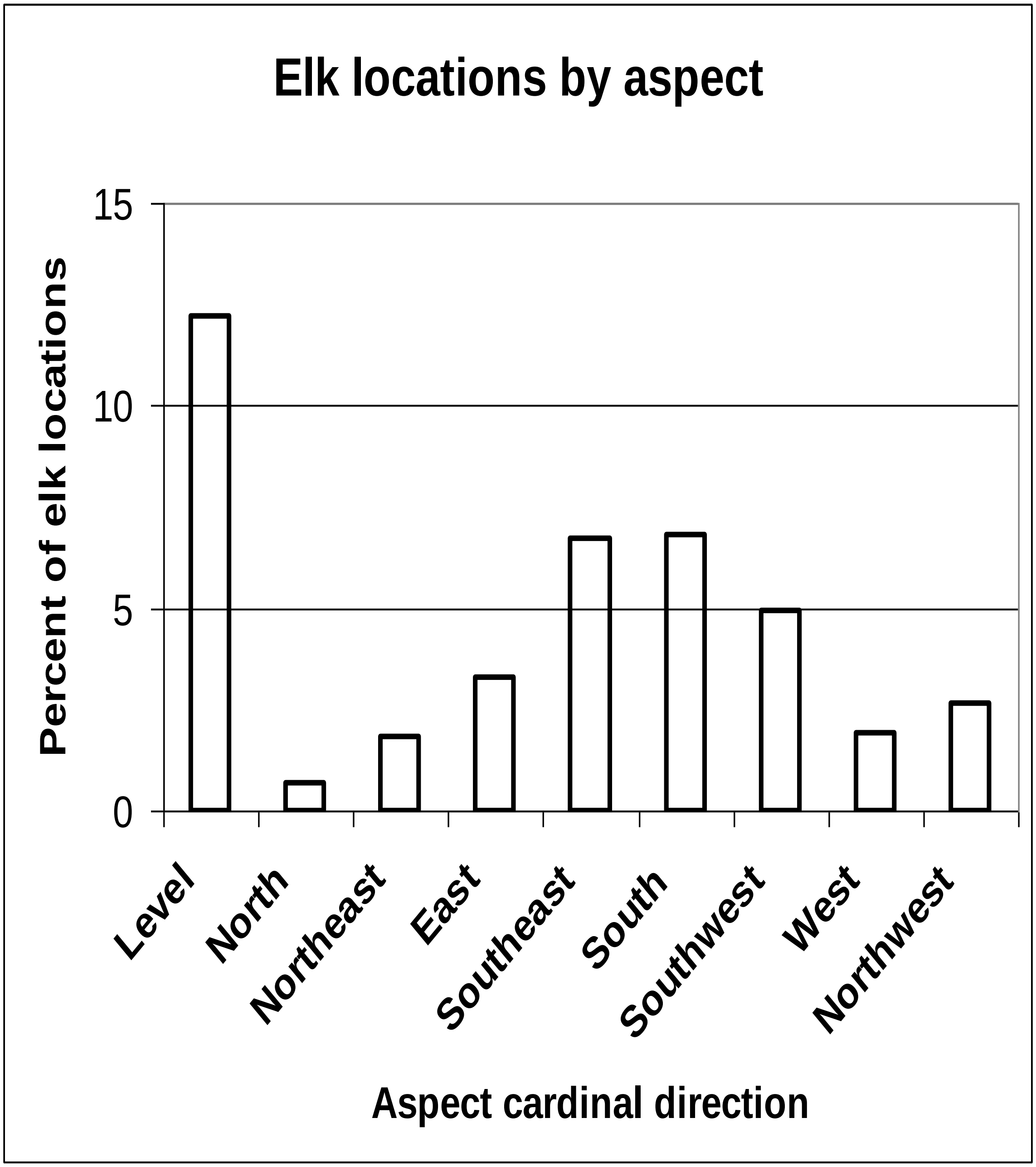


Figure 5.5 Distribution of Duck Mountain cow elk locations by aspect cardinal direction in the Duck Mountain Provincial Forest from 2005 to 2007(n = 17, 525). Fifty-nine (59) percent of locations had a variable aspect.

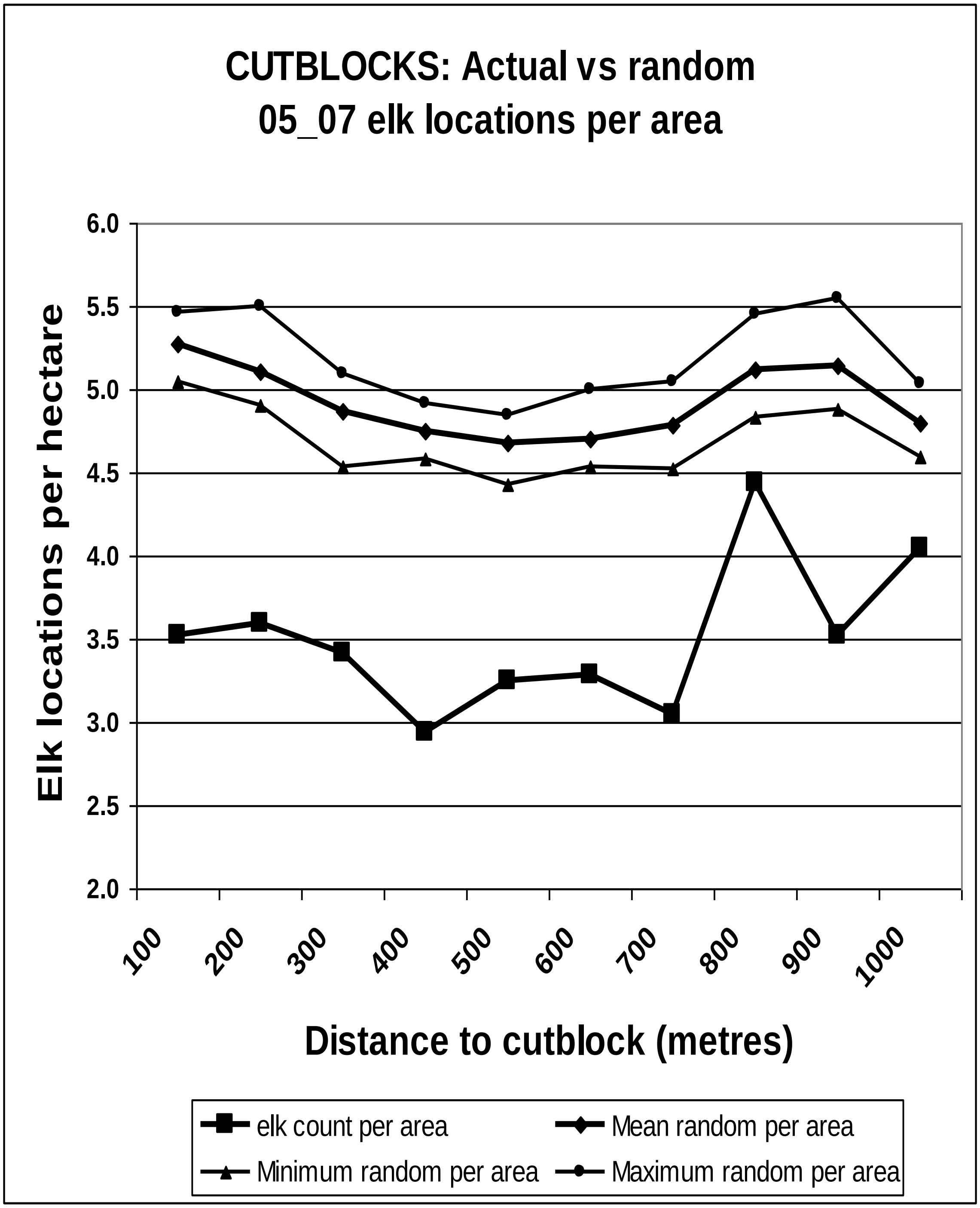


Figure 5.6 Distribution of actual versus random elk locations per unit area (ha) within 100m distance intervals from forestry cut-blocks in the Duck Mountain Provincial Forest area from 2005 to 2007

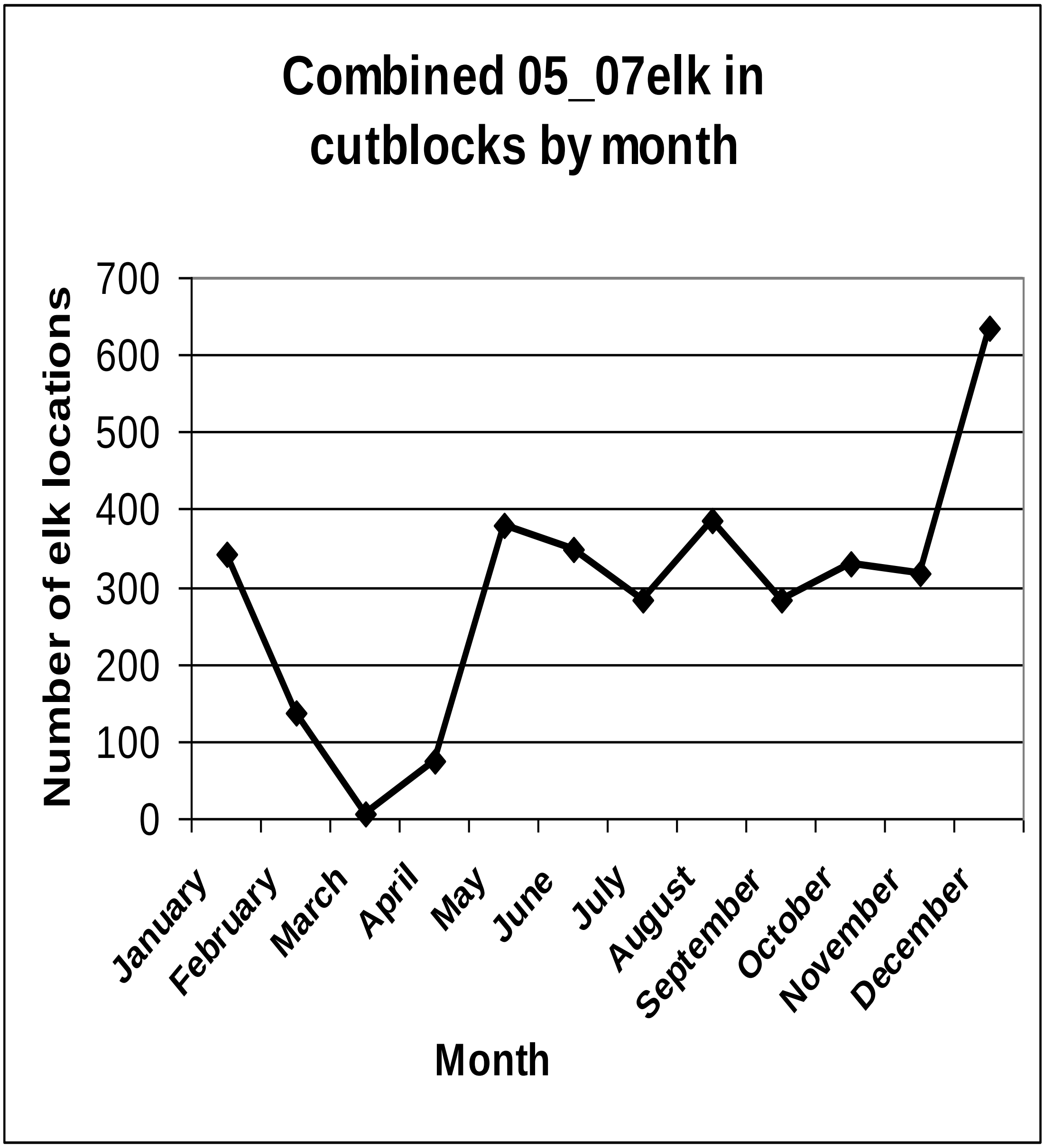


Figure 5.7 Distribution of all Duck Mountain cow elk locations within forestry cut-blocks by month in the DMPF area in 2005 to 2007 (n = 3,526)

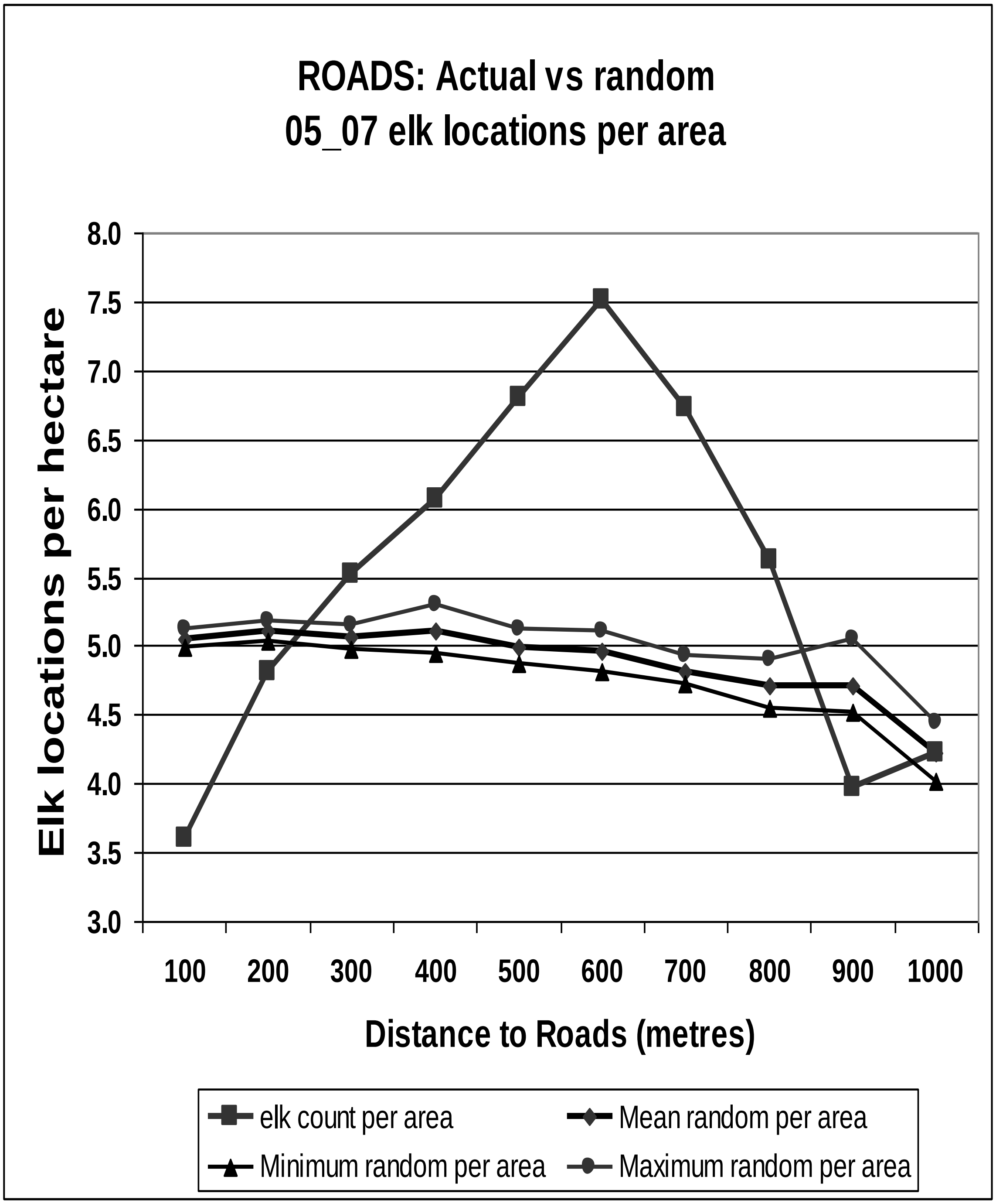


Figure 5.8 Distribution of actual versus random elk locations per unit area (ha) within 100m distance intervals from road features in the Duck Mountain Provincial Forest area from 2005 to 2007

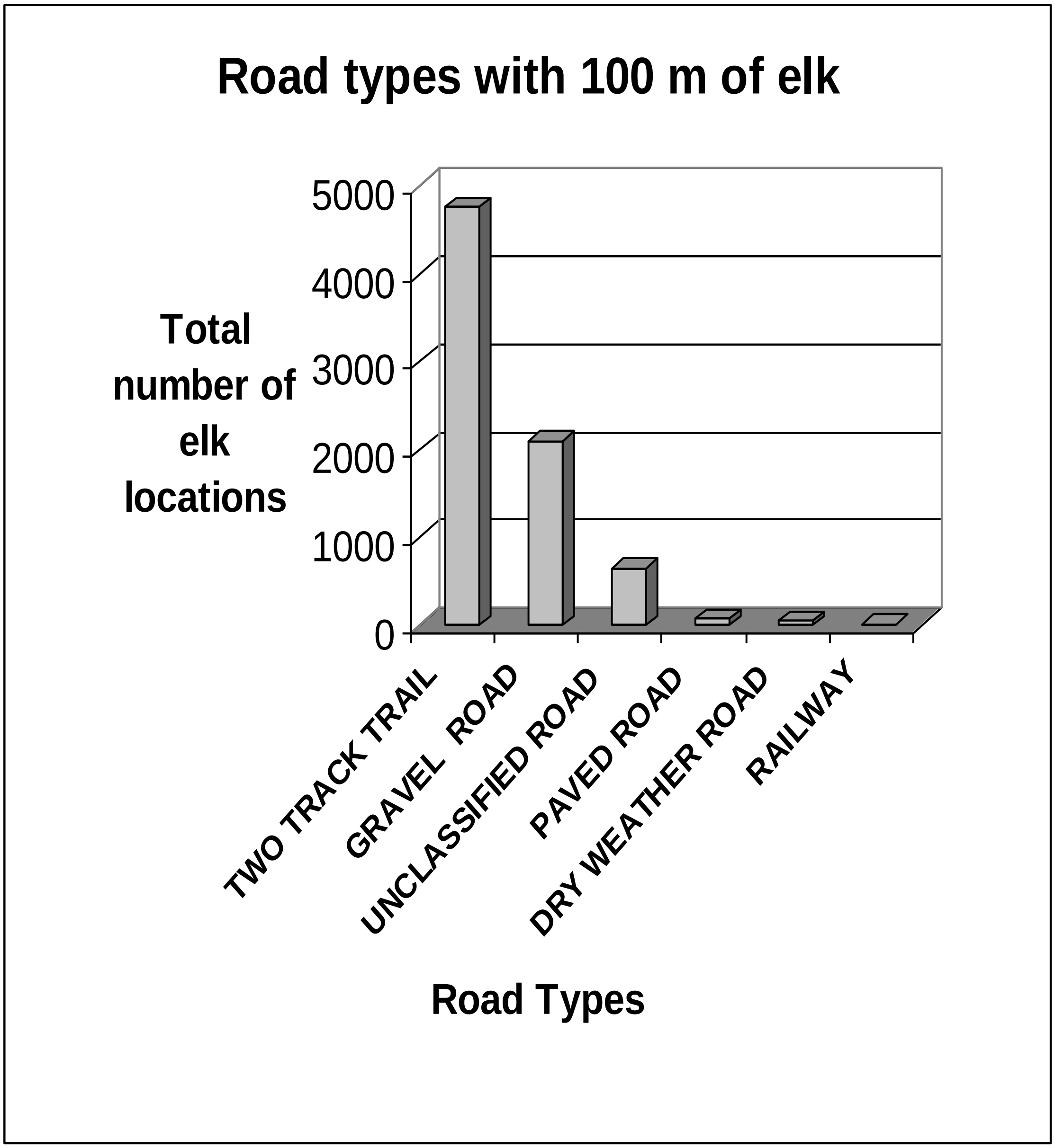


Figure 5.9 Most common road types found near Duck Mountain cow elk locations within 100m of a road (n = 7609)

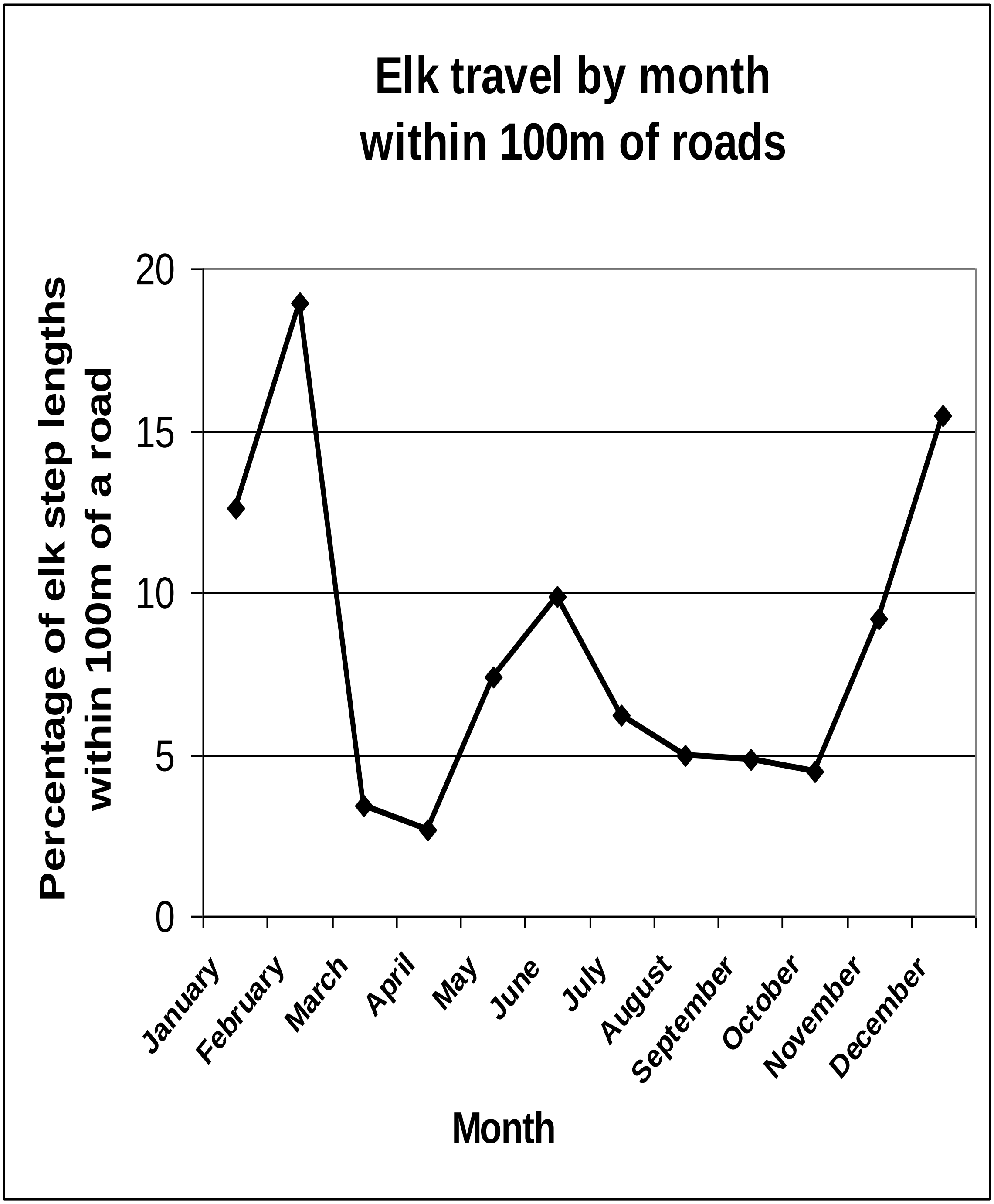


Figure 5.10 Percent of Duck Mountain cow elk step lengths within 100m of a road by month (n = 3,521 step lengths)

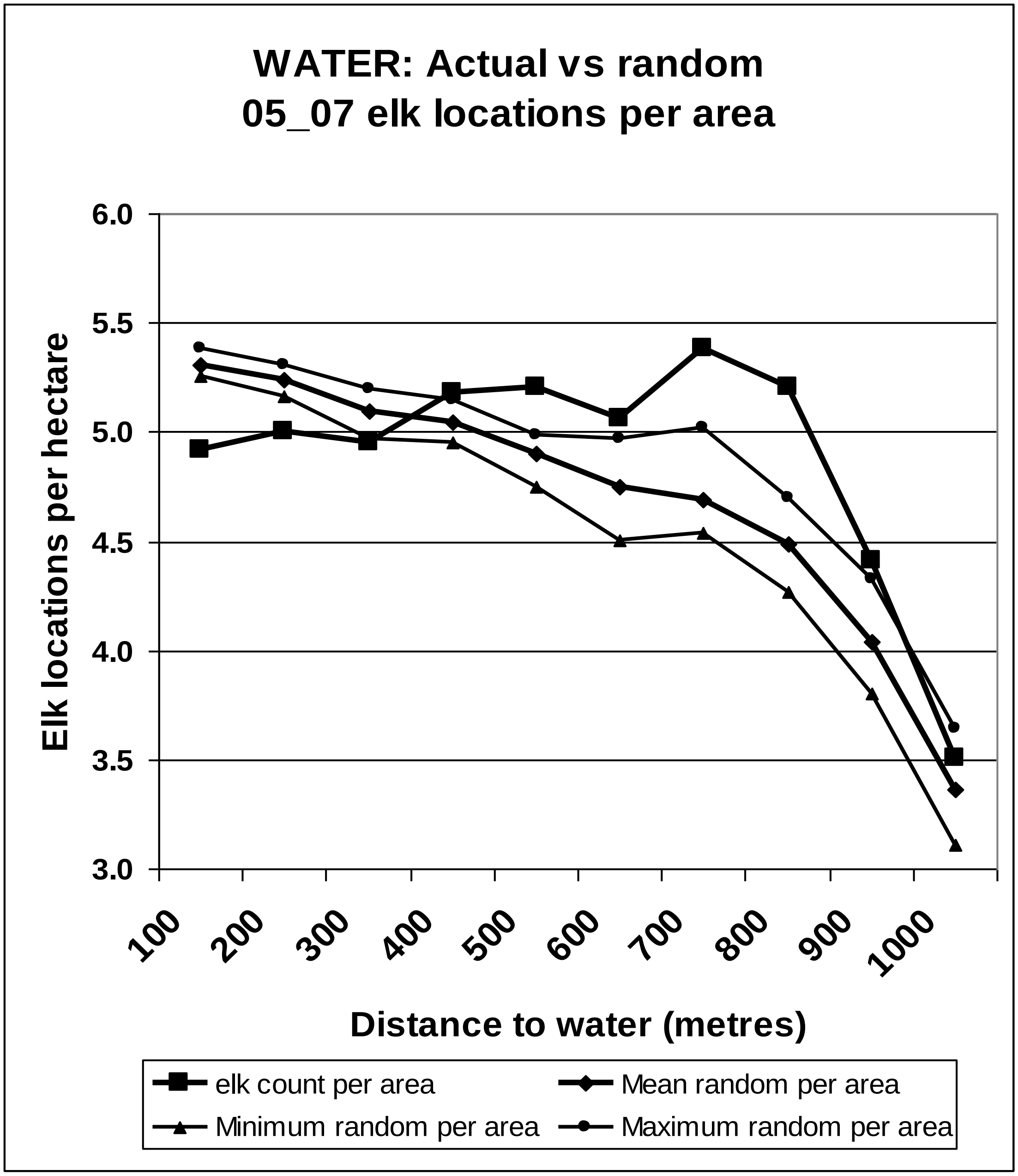


Figure 5.11 Distribution of actual versus random elk locations per unit area (ha) within 100m distance intervals from water features in the Duck Mountain Provincial Forest area from 2005 to 2007

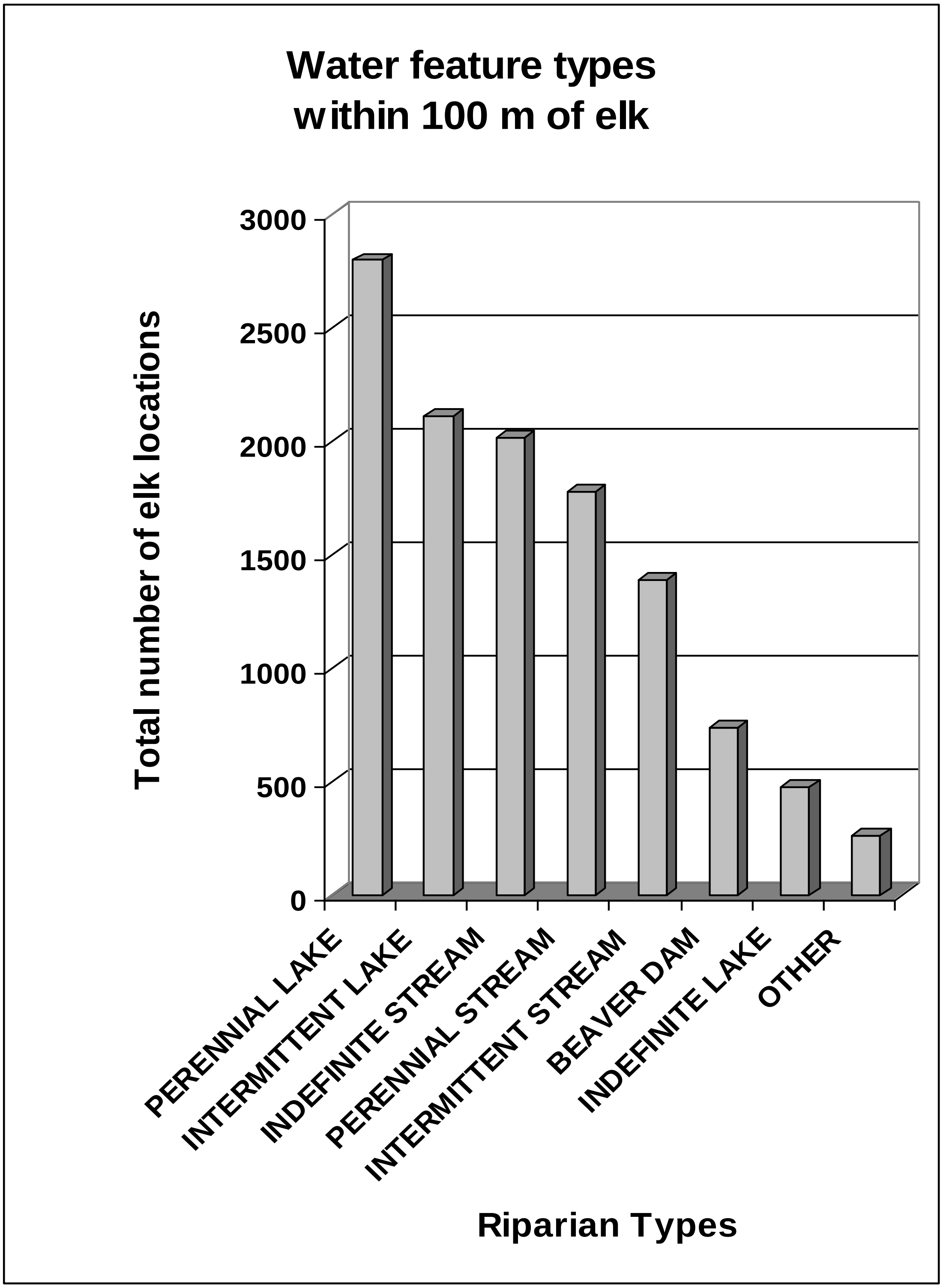


Figure 5.12 Most common riparian water types found near Duck Mountain cow elk for locations within 100m of a water feature (n = 11,571)

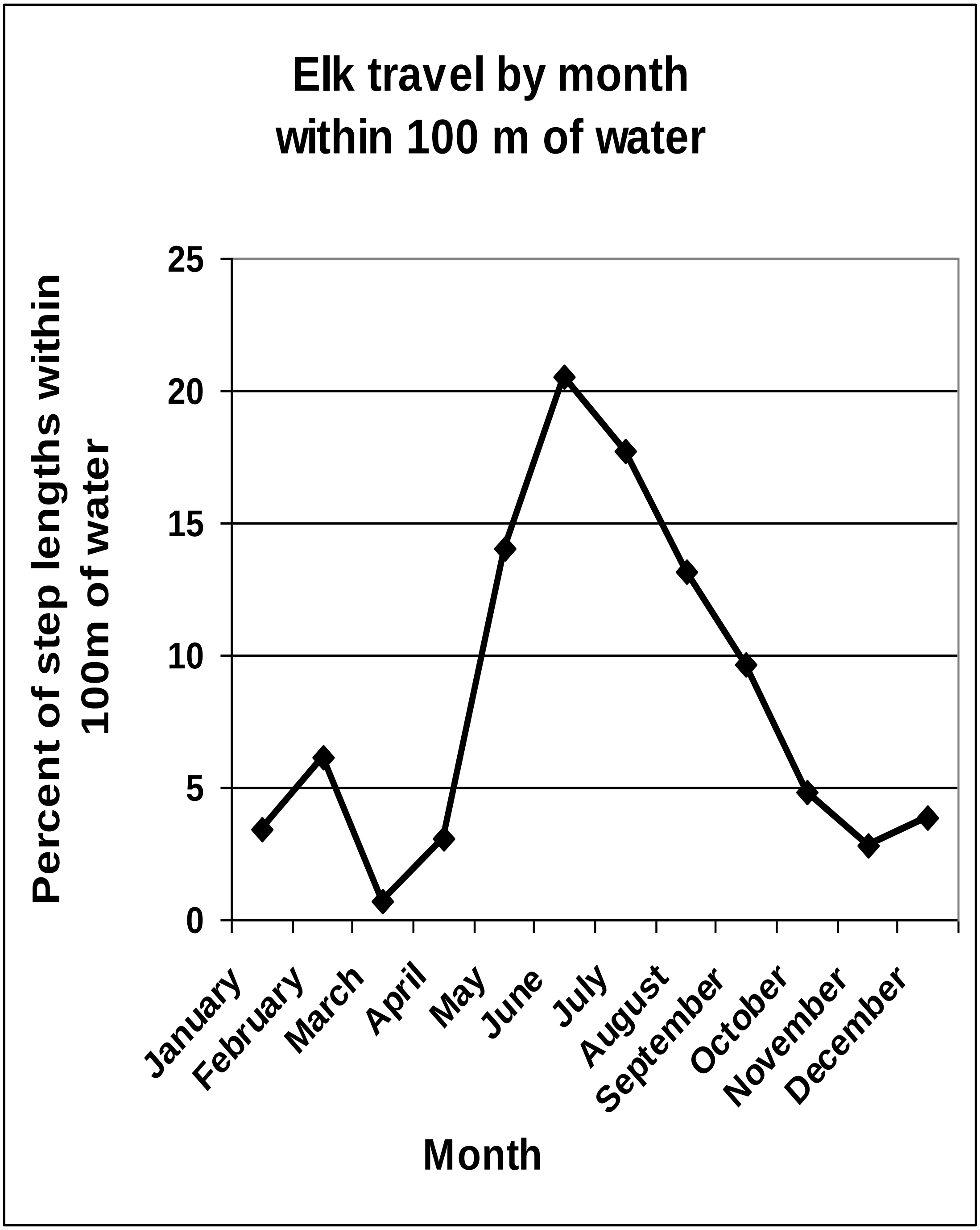


Figure 5.13 Percent of Duck Mountain cow elk step lengths within 100m of a water feature by month (n = 6,714 step lengths

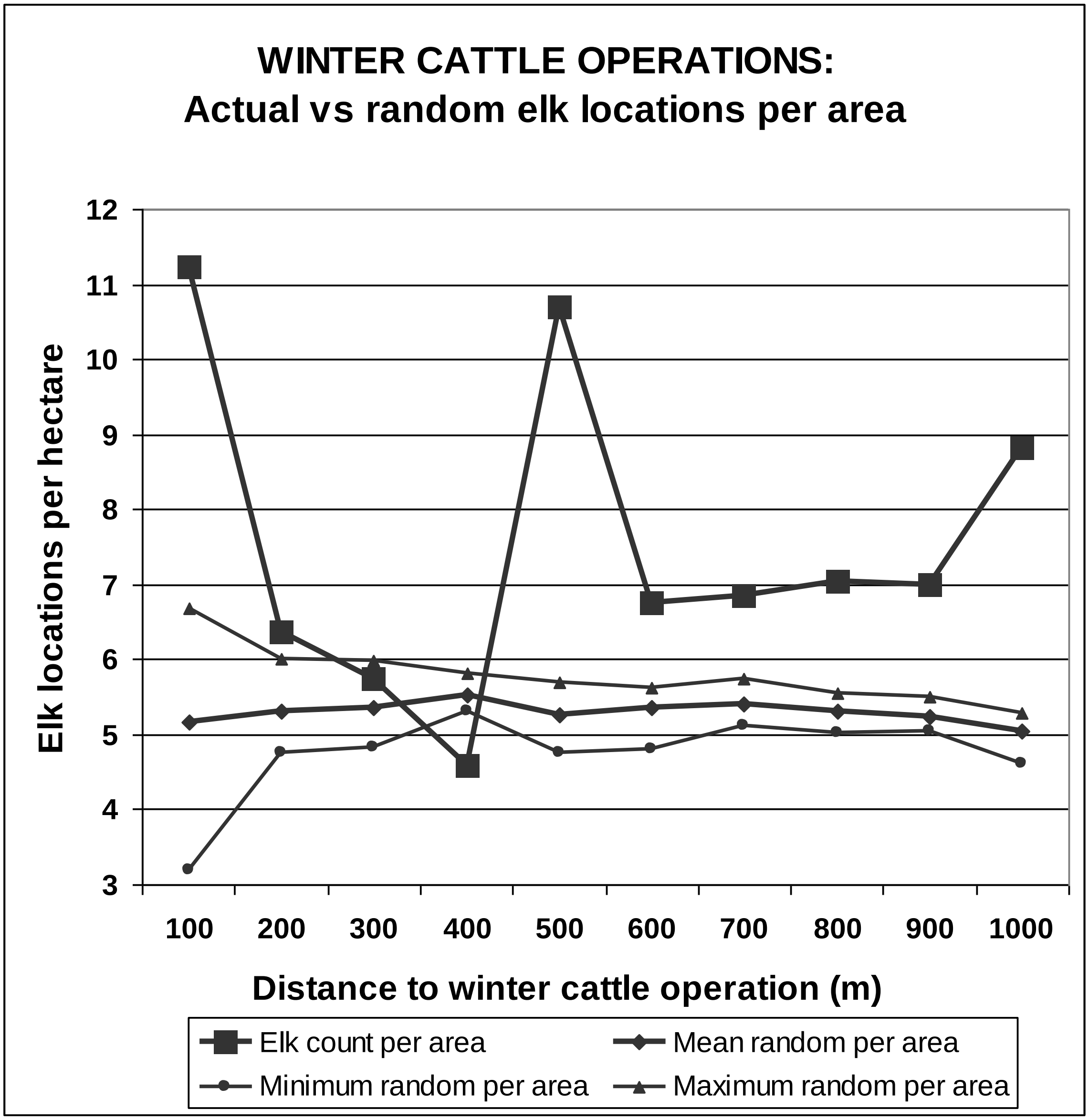


Figure 5.14 Distribution of actual versus random elk locations per unit area (ha) within 100 m intervals from winter cattle operations in the Duck Mountain Provincial Forest from 2005 to 2007

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Chapter 6:

Summary and Conclusions

Baseline ecological research of the *Cervus elaphus manitobensis* elk subspecies in the Duck Mountains has not been conducted in the past. This study helped to shed light onto how elk use habitat in relation to landscape features (i.e. forestry cut-blocks) while providing new information to managers involved in forest management. It also served to provide previously unavailable information on basic elk movement and habitat use and its implications to bovine TB management.

Duck Mountain cow elk strongly select for deciduous forest year-round. Cow elk home ranges are relatively small compared to other studies. Home range overlap occurs at all times of the year. Many cow elk seem to be using farmland habitats as their primary home range. No cow elk dispersed from the study area to the RMNP or other areas over the duration of the study. There were no specific long-distance travel corridors detected. No elk moved between the SW and SE parts of the Duck Mountains. Certain seasonal travel paths however, were observed. Cow elk showed fidelity to their herd ranges and traveled in all spatial directions with predominance to southerly movements. No specific movement patterns were noted in the calving periods. One cow elk did exhibit repeated long-distance movements, during a short time period in September, which may have been related to late calving. Elk moved into the DMPF or mature deciduous habitat during the "rut" breeding season. Habitat selection by cow elk is specific in nature. Deciduous forest, riparian areas, forage crops and native grassland habitats are common landscape features selected by most elk. Cow elk also find areas with limited human disturbance and some separation from roads. Most elk locations were in eco-site 32. Elk use eco-sites 31-33 (mature deciduous and mixed-wood forest) and 72-73 (shrub/grassland and prairie savannah) more often than available in the DMPF. Elk select for open and closed forest canopies on middle or upper slopes having variable, southerly or level aspects. Elk are not commonly found in cut-blocks but, they do use them as there are 3,526 GPS locations of elk within cut-blocks. Elk tend to avoid areas within 200 m of roads and remain 500 to 800m from roads with over 51 % of travel greater than 100 m from a road. Elk are not found commonly within 200 m of water but, remain within 400 to 800 m of water features. About 42 % of elk step lengths are within 100 m of water. When elk are found within 100 m of water it tends to occur in June. Seven of 230 winter cattle farms have had elk within 100 m of their operation, mainly in August and September (i.e. not in the winter). Another 16 farms have had elk within 500 m of their winter cattle operation. The majority of elk locations are greater than 1000 m from a winter cattle operation in the south half of the Duck Mountain area.

Management recommendations as it pertains to bovine TB management

1. It should be noted that most worldwide bovine TB control efforts in free-ranging cervids are motivated by the risk of transmission to domesticated animals. Since there few cases wherein bovine TB has negative affects on cervid survival or growth rates, bovine TB control would not be necessary if proximity of cattle to wildlife was restricted (Conner et al. 2008). For the purposes of bovine TB disease management, it is important to note the proximity of elk herds to some farming operations around the DMPF found in this study. Since DM elk can have overlapping home ranges in specific herds, if disease were to be present, transmission would be easily facilitated. There does not appear to be significant interaction between elk in the SW part of the DM with those elk in the SE, east or north parts of the DM. Since bull elk are known to make large dispersal movements (Brook 2007) it is recommended that new research be initiated on bull elk in the DM. This research would fill in the current information gap and help to clarify bull elk dispersal as it may pertain to disease transmission.
2. Continued long term GPS monitoring of elk herds in the DM is also recommended. Recent research (Brook 2007, Edye and Bayne 2008) indicates that winter ungulate herds can exhibit geographic boundaries with minimal interaction. These elk herds can be viable population units which could be managed differently that other population units (Edge et al. 1986). It was evident from the DM telemetry data that cow elk form about four distinct winter herds in the southern half of the DM. These

sub-populations can be identified by local place names such as the Boggy Creek, Merridale, Grandview and Ethelbert elk herds. While no GPS collared elk were followed on the north side it is felt that the NW side of the DM is another sub-population of wintering cow elk. Management at a sub-population level can be beneficial if sub-populations exhibit different demographic features. Different management regimes (i.e. hunting seasons) could be tailored to these management unit herds. This type of detailed management can be a luxury (which is unlikely to be attained) unless significant dollars are assigned to management activities. Then, significant benefits will be accrued to elk and the hunting public.

3. As elk home ranges tend to have water features commonly present within their boundaries, mitigation strategies such as barrier fences for hay bale yards might be strategically placed near these riparian corridors. These farm operations may be at higher risk for interaction with elk than other farm operations. In addition, the use of livestock protection dogs should be employed at these specific farm operations to help reduce elk-cattle interaction at all times of the year.
4. Hunting can be a tool to reduce wildlife-cattle interaction at certain times of the year. Government agencies should continue to search for innovative ways to enhance hunting oppourtunity and still address specific issues as it pertains to elk depredation on private land. With a potentially increasing trend of elk taking residence on private farmland, hunting season options that address resident hunter and landowner concerns would be beneficial. Possibly, resident hunters could financially assist farmers to install barrier fences or contribute to the purchase of a livestock protection dog and receive a free hunting licence on the farmer's property. Non-resident hunters could also be valuable allies to resident farmers. Non-resident draw elk licences could stipulate that a non-resident must contribute (a specified fee) to a bovine TB management program managed by local cattle producers. The program would institute farm practice changes that reduce wildlife-cattle interactions. In the final analysis, increasing elk licence availability in farmland areas, especially in early winter, may serve to reduce elk densities in this area and overall reduce elk-cattle interaction risk.

5. One other option to assist farmers with elk depredation and interaction with their cattle in the winter is to establish working relationships with First Nation hunters. As long as permission is granted by the landowner on private land and strict shooting protocols are defined, First Nation hunters could be responsive to farmers on fairly short notice if depredating elk herds become too much of a nuisance to the farmers stored hay bales. No licences are necessary. This can be a potentially positive situation for both parties. The farmer receives a service free of charge that alleviates depredation and the First Nation hunter obtains a valuable meat source for his subsistence use. Obviously, there must be a level of trust established. My experience with First Nations people is that they can be trustworthy. They are part of the local fabric and community. Farmers should take a serious look at all options. It is possible that governments could play a role in facilitating this process but as with most relationships, face-to-face meetings used to forge personal relationships will be the best way to achieve this level of cooperation.
6. Cattle producers, with the assistance of government and their member associations, must work towards methods that reduce elk-cattle interaction. Elk and cattle will continue to co-exist in farmland Manitoba. Under the present scenario, it is impossible to completely separate wild ungulates from all aspects of current farm practice. I believe the ultimate challenge and final solution rests with individual cattle producers. Farmers must take accountability for their farm operation and begin initiating farm practices that reduce cattle-ungulate interaction if they truly are concerned about disease risk. There are many producers that do not have a strong level of concern about their cattle's interaction with elk. Another group of producers seem to want zero risk to their operation. A "happy medium" or a level of tolerance must be found and the people living on the land have it within their power to make the most significant changes. Government incentives can assist cattle producers working towards minimizing disease risk but that won't completely solve the problem. Based on this study, some specific winter cattle operations are at higher risk for elk-cattle interaction. These operations should receive a steady level of support from their associations and government agencies especially if these operators have

Crown land cattle grazing leases, so that efforts can be focused at risk management assessment and mitigation to solve their specific issues. I would recommend that cattle grazing be excluded from these leases to reduce elk-cattle interaction. Flexibility in approach, based on science and common sense will likely achieve long term success.

7. Current wildlife surveillance activities (i.e. collection of hunter harvested elk) should continue until no TB positives are found in wildlife for a specified period. In addition, continual focus needs to be placed on the ban on feeding and baiting of wildlife in and around RMNP as feeding wildlife is so central to why TB still cycles within wildlife and cattle. There should be zero tolerance for this activity until TB is eliminated or reduced to undetectable levels.
8. The farming practice of bale shredding or unrolling bales to feed cattle must be addressed by agricultural groups and governments agencies. One cannot turn a "blind eye" to this practice as it clearly allows interaction between cattle and wildlife. While it is an accepted farm practice, it is not the fault of wildlife that they feed on these same bales used by cattle. MAFRI must either exclude the farm practice under the Animal Disease Control Act or provide financial incentives to farmers for total exclusion of wildlife where this practice occurs on a farm by farm basis.
9. I would also call on MAFRI to investigate the idea used in Minnesota to buy-out cattle farms in the TB core areas in the RM of Grandview and Rossburn to reduce overall cattle densities. While expensive, I believe it will be one of the best long term solutions to the eradication of TB in this area.
10. Finally, I would recommend that CFIA begin research into cattle and cervid vaccines for TB. Again, while the research would be costly and take a long time, the benefits to all of Canada would be worth it. All avenues must be pursued if the goal is to eradicate bovine TB from the RMNP area. Just reducing wildlife populations will not by itself, achieve that goal.

Management recommendations as it pertains to forest management

1. For the purposes of forestry management, detailed analysis of use by elk of specific ecological attributes is still required. In this regard, I would recommend that research

be directed to ground-truthing of sites used by elk compared to random sites. One could take all elk locations in deciduous forest outside the DMPF and randomly pick 100 sites for detailed documentation of the ecological attributes at these sites according to the eco-site classification field guide. Then, one could randomly pick another 100 deciduous forest sites inside the DMPF and compare the actual ecological attribute measurements between the two sites. This type of study could help to verify the eco-site classification as well as providing some information on forested sites outside the boundaries of the DMPF.

2. It appears obvious that specific eco-sites (i.e. eco-site 32) and certain ecological features (riparian zones, middle slopes, open and closed canopies and level or south facing aspects) will continue to be important to DM elk and consequently play an integral role in forestry mitigation planning. Perhaps, with long term planning and tracking exercises of cut-block design, the management of eco-site 32 to meet wildlife habitat supply objectives and wood supply objectives will be met in 80% of the scenarios. From my personal work experience, the adaptive management process used in Louisiana-Pacific cut-block mitigation is a practical application of ecosystem based management (Baydack et al. 1999). Line–of- sight (LOS) and distance –to-cover (DTC) guidelines are grounded in early wildlife research indicating cut-clocks should provide hiding cover for ungulates from poaching and bedding cover in and adjacent to cut-blocks. These guidelines have been altered at times to attempt new approaches in some cut-blocks with follow-up evaluation to determine how ungulates and birds respond (i.e. either positively or negatively) on a coarse scale. The maintenance of mature forest stands adjacent to cut-blocks however is crucial to retaining elk on the landscape. Landscape –level forest planning that incorporates cut-block placement, adjacency of mature cover and in-block cover as well as well-designed road networks that incorporate aggressive road closures and decommissioning to reduce human access, will be needed in the future to ensure sustainable ungulate populations in the DM.

3. The retention of wooded cover along riparian areas should be encouraged in the farmland areas to allow for travel corridors for elk. These areas of security cover adjacent to forage areas help elk maintain high survival rates due to the close proximity of cover, water and forage. In the forested zone, DM elk do not generally reside in riparian areas except during calving but they travel within these areas year-round. Mitigation strategies should help to retain safe areas for elk calving near riparian areas. Forest activity is minimal during calving but may impact prime calving areas indirectly. There can be opportunities to harvest adjacent to riparian areas as long as secure segments of riparian corridor are set aside in the normal course of forest cut-block mitigation. In order to assess long term harvest impact to riparian areas, stretches of key riparian forest (i.e. 5 miles) should be identified and harvest in these areas be tracked to ensure a pre-determined amount of the riparian zone receives minimal harvest. These riparian areas may be harvested in the future as long as previously harvested areas had met regeneration standards.
4. More detailed analysis of elk use of cut-blocks (and cut-block size) should be attempted to determine specific seasonal use patterns. While it appears that elk are not found in cut-blocks commonly, their existence on the landscape does not appear to cause elk to incorporate major changes to their annual life cycle. Snow depth measurements should be incorporated into cut-block studies to determine the interaction of snow with browse availability as recommended by Visscher et al. (2006). Clearly, abundant secure cover within and adjacent to cut-blocks in the Duck Mountains will allow elk to use the areas opportunistically. Some jurisdictions suggest that in logged forests, the size of shrub and mature forest communities must remain similar to the stands of these communities found within the average summer or winter home ranges of ungulates in order to maintain species presence (Yeo and Peek 1992).While the direct impacts from forestry that affect elk may be neutral or minor, the secondary impacts of hunting from access roads must be managed. This is specifically important when it comes to road management plans.
5. Elk can be particularly vulnerable to hunting when road densities increase in forest operations. The need to restrict access using innovative approaches should continue

to challenge forest companies and government officials as the risk from road hunting to elk is always high. Currently, forest companies try to get in and out of areas relatively quickly. In some circumstances however, access is open for extended periods and these situations need better management. The use of gates and other direct access restrictions should continue to be options for road management to reduce secondary hunting impacts to elk (and other ungulates). While gates are costly and time consuming to maintain they don't have to exclude poachers 100% of time to be successful in reducing impacts over the long term.

Future research

1. This study was restricted to cow elk in the south half of the DM. Future wildlife studies should place radio-collars on male elk and focus on the north half of the DM area. This type of research will fill in the gaps remaining about elk ecology in the DM and also help to determine if male elk have higher rates of dispersal as has been found in other studies.
2. The existing data should receive additional analysis that could develop models to help map habitat types and landscape features that predict important areas which may need conservation as it pertains to forestry and farming activities.
3. Determine if other ecological attributes in the DM forest land inventory (FLI) are predictive of elk movements or habitat selection. This study looked at 4 ecological attributes known to be predictive of elk habitat use. The DM FLI however has over 20 ecological attributes. Further analysis could turn up some interesting trends.
4. Similar to the RMNP, studies should be initiated in the DMPF to determine elk response to prescribed fire, as fire can significantly increase forage availability in the summer (Sachro et al. 2005). Prescribed fire was studied by Palidwor (1990) in the DM but future research should emphasize the maintenance of natural grassland openings by prescribed fire. This research would be able to compare elk responses to fire in the DM to those in the RMNP and help to preserve native grasslands within the DMPF.

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APPENDICES

Appendix 1 Elk with seasonal directional persistence showing angular concentration values, Rayleigh's *Z* values and mean bearing during the month. For sample sizes from 200 to 300 locations, Rayleigh's *Z* values need to exceed 2.99 to reject the null hypothesis that movements are uniformly distributed around a circle.

Elk ID	***Month***	***Angular Concentration "r"***	***Rayleigh's Z value***	***Mean Bearing (in degrees)***	***Cardinal Direction***
548	September	0.3322	30.795	170	SSE
551	April	0.1329	3.728	40	NE
551	December	0.1249	4.450	240	SW
634	June	0.1009	3.615	199	SSW
525	September	0.1035	3.721	245	SW
628	November	0.1218	4.508	290	WNW

Appendix 2 All Duck Mountain cow elk calving habitat types, estimated date of parturition and calving site landscape descriptions for 2005 to 2007 (n = 22)

Elk ID	***Calving site habitat***	***Est. date of parturition***	***Calving habitat description***
633	forest	15-May	In heavy deciduous bush on San Clara pasture near creek.
634	forest	19-May	In DMPF, heavy deciduous bush, on peninsula near small lake
548	farmland	21-May	west of hwy #10 and Garland, in deciduous bush near creek
638	farmland	23-May	On Crown land south of Tee Lake, near wetlands and farm field
526	forest	24-May	within south DMPF, heavy deciduous bush, near creek
630	forest	24-May	In DMPP, marsh, mixed-wood and grassland.
557	farmland	25-May	West of hwy #10 and Garland, along Fork River drainage.
565	farmland	26-May	Same as 635, secluded bush on private land near creek and field.
560	farmland	30-May	On edge of DMPF, in deciduous bush near farm field and Silver Creek.
627	farmland	02-Jun	Secluded bush on private land along Shell River
796	farmland	02-Jun	Along Shell River in secluded deciduous bush & willows on private land
797	farmland	03-Jun	Similar to 627, near wetlands and in heavy deciduous bush near grassland field.
551	farmland	10-Jun	West of hwy #10 and Garland, in secluded marshy area
659	farmland	11-Jun	Same as 565, 635 & 629, secluded bush on private land near creek
525	forest	12-Jun	Within south DMPF, heavy deciduous bush, near lake
628	farmland	12-Jun	Boggy creek area farm, in heavy willow along Shell River
577	farmland	13-Jun	Same as 638,near Crown land SW of Tee Lake, near wetlands and farm field
635	farmland	15-Jun	Same as 629, secluded bush on private land near creek.
794	farmland	16-Jun	Edge of DMPF on crown land in heavy deciduous bush near lake.
631	forest	20-Jun	In DMPF near 630, mixed-wood, near lake
793	forest	23-Jun	Same as 630, in DMPF near marsh and lake in heavy deciduous bush
629	farmland	26-Jun	Secluded bush on private land near creek.