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Original Research

The Behaviour and Dynamics of a Restored Elk (*Cervus canadensis manitobensis*) Population in Southern Ontario, Canada: 5-12 Years Post Restoration

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Abstract

Elk *(Cervus canadensis*) were extirpated from Ontario, Canada, during the late 1800s. As part of a provincial restoration effort, 120 Elk acquired from Elk Island National Park (EINP) Alberta, Canada, were released during 2000 and 2001 near the town of Bancroft, Ontario. The majority of this study focused on the dynamics of six social units of Elk in an approximate 2,500 km² area near Bancroft, Ontario, from 2006 to 2013, 5 to 12 years post restoration. Most Elk had above average body mass and post mortem examinations revealed that 61% (25 of 41) were in good condition. Sixteen of those 41 Elk were in an emaciated condition and succumbed during the initial years of the restoration project (2000-2006). Four of those initial years had a winter severity index of moderately severe or severe. Productivity of cow Elk was 24% to 65% (percentage of cows with calves during late winter). Elk finite survival rate was 0.79 (Standard Error = 0.13) in 2006-2010, prior to the initiation of hunting, and 0.76 (SE = 0.07) in 2011 and 2012, after a hunt was initiated. From 2006 to 2013, Elk were found in several small- to large- sized social units within the 2,500 km² Bancroft Area Core Elk Zone. The mean size of social units ranged from 11 to 47 Elk. Mean bull:cow and calf:cow ratios in the Bancroft area during 2002-2013 were 25:100 and 39:100, respectively. However, the mean bull:cow ratio in areas where winter feeding by residents occurred was 48:100 during late-winter surveys. By comparison, bull:cow ratios in areas where winter feeding did not occur averaged 13:100. The estimated mean Elk population size in the Bancroft Area Core Elk Zone increased from 107 in 2002 to 499 in 2013. The annual rate of increase during most years ranged from 23% to 34%. These rates were achieved most likely due to a lack of significant predation; however, population declines were experienced during some years due to a variety of

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mortality factors. Elk density in the Bancroft Area Core Elk Zone in 2013 was about 0.2/km², which is likely far below the biological carrying capacity of the habitat.

Key Words: Behaviour, *Cervus canadensis*, Elk, Population Dynamics, Restoration, Survival.

INTRODUCTION

Based on skeletal and fossil evidence, Elk (*Cervus canadensis*) have been present in Ontario, Canada, for at least 3,000 to 8,000 years (Bosveld 1996; Boyer 1996; O'Gara and Dundas 2002). However, Elk were extirpated from Ontario, as well as the remainder of eastern North America, during the late 1800s, due to demands for meat and resultant unregulated harvesting, as well as the clearing of forests to meet the demand for agricultural lands (Murie 1979; Bryant and Maser 1982). During the early to mid -20th century, attempts to restore Elk to Ontario were generally unsuccessful due to a variety of reasons (see Rosatte *et al.* 2007a).

The most recent attempt to restore Elk to Ontario occurred in 1998-2001 when 443 Elk were transported from Elk Island National Park (EINP) in Alberta, and released in four areas of Ontario (Rosatte *et al.* 2007a; Rosatte 2013). Part of those shipments included 120 Elk that were released near Bancroft, Ontario in 2000 and 2001 (Rosatte *et al.* 2007a). From 2000 to 2005, these Elk were intensely studied by graduate and post-graduate students, and Ontario Ministry of Natural Resources (OMNR) staff (Rosatte *et al.* 2007a), and the majority of that research has been published (Bellhouse and Rosatte 2005; Jenkins *et al.* 2007; McIntosh *et al.* 2007; Rosatte *et al.* 2007a; Fryxell *et al.* 2008; Haydon *et al.* 2008; Ryckman *et al.* 2010; Yott *et al.* 2011). From 2006 to 2012, 56 of the Bancroft area Elk were captured and fitted with global positioning system (GPS) collars to study their dynamics and behaviours 5 to 12 years post restoration. This paper focuses on the information collected during this program but also reports on the natural history of the Elk population during the initial years of the overall restoration project (2000-2005).

STUDY AREA

This study was conducted in an approximate 2,500 km² area of southeastern Ontario, Canada, during 2000-2013. The study area was centered at 44º 58' N, 77º 33' W near Bancroft, Ontario, which is located about 250 km northeast of Toronto. The region is influenced by a temperate continental climate with cold winters and warm summers and the elevation of the land is about 200-400 m above sea level. Summer and winter temperatures average about 7ºC and -9ºC, respectively. Rainfall during summer averages about 75-85mm/month, and snowfall during winter averages about 30-50 cm/month. The study area lies within the Great Lakes-St. Lawrence Forest Region with dominant forest cover species (hardwood and conifer) that include Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), Yellow Birch (*Betula alleghaniensis*), Eastern Hemlock (*Tsuga canadensis*), and Eastern White Pine (*Pinus strobus*) (Chambers *et al.* 1997). The more common landforms are associated with glacial till and soils varying from sandy to loamy in texture.

The habitat east of the town of Bancroft is mainly forested with small pockets of arable farmed lands near the hamlets of Boulter, New Carlow, and Little Ireland (Figure 1). The landscape included large blocks of mixed-wood forest interspersed with fields. The Hartsmere area, also east of the town of Bancroft (Figure 1), primarily consisted of coniferous and deciduous forest blocks, with some low lying swampy areas, and many streams, small lakes, and ponds. Extensive winter feeding of Elk and White-tailed Deer (*Odocoileus virginianus*) by residents occurred in this area during the period of the study. The Turriff area, south of the town of Bancroft, consisted of mixed-wood forest blocks, primarily hardwoods with some open field areas. Winter feeding of White-tailed Deer and Elk by residents occurred in this area but it was not as intensive as in Hartsmere. The Mephisto area consisted of mixed conifers and a number of lakes, ponds, and streams with some rocky outcropping areas. The Lingham area primarily consisted of coniferous and deciduous forests with many lakes, ponds, and barren areas. The barren areas were rugged and composed of exposed rock and grasses with Red Oak (*Quercus rubra*) scattered on the ridges, and Red Maple along the waterways.

METHODS

History of the restoration project

In 2000 and 2001, 120 Elk (56 cows, 27 bulls, 37 calves) were acquired from EINP, Alberta, for release near Bancroft, Ontario. This was part of a larger provincial restoration project in which 443 Elk were released in four different areas of Ontario in 1998-2001 (Rosatte *et al.* 2002, 2007a). Elk were captured in corral traps in EINP and transported to a processing facility on site where they were sexed and aged, weighed, ear-tagged and radio-collared, tested for diseases such as bovine tuberculosis and brucellosis, and treated for parasites. Elk were transported to Ontario (40-58 h trip) via commercial trailers (provided hay and water during the trip) and placed in a holding pen located near Hartsmere, Ontario (about 30 km east of Bancroft). The plan was to hold the Elk in the pen for a period of time to allow them to recover from the trip and to acclimate to the release area. Some of the 70 Elk that were acquired during 2000 escaped from the holding pen almost immediately so the remaining Elk were released on day 0 (January

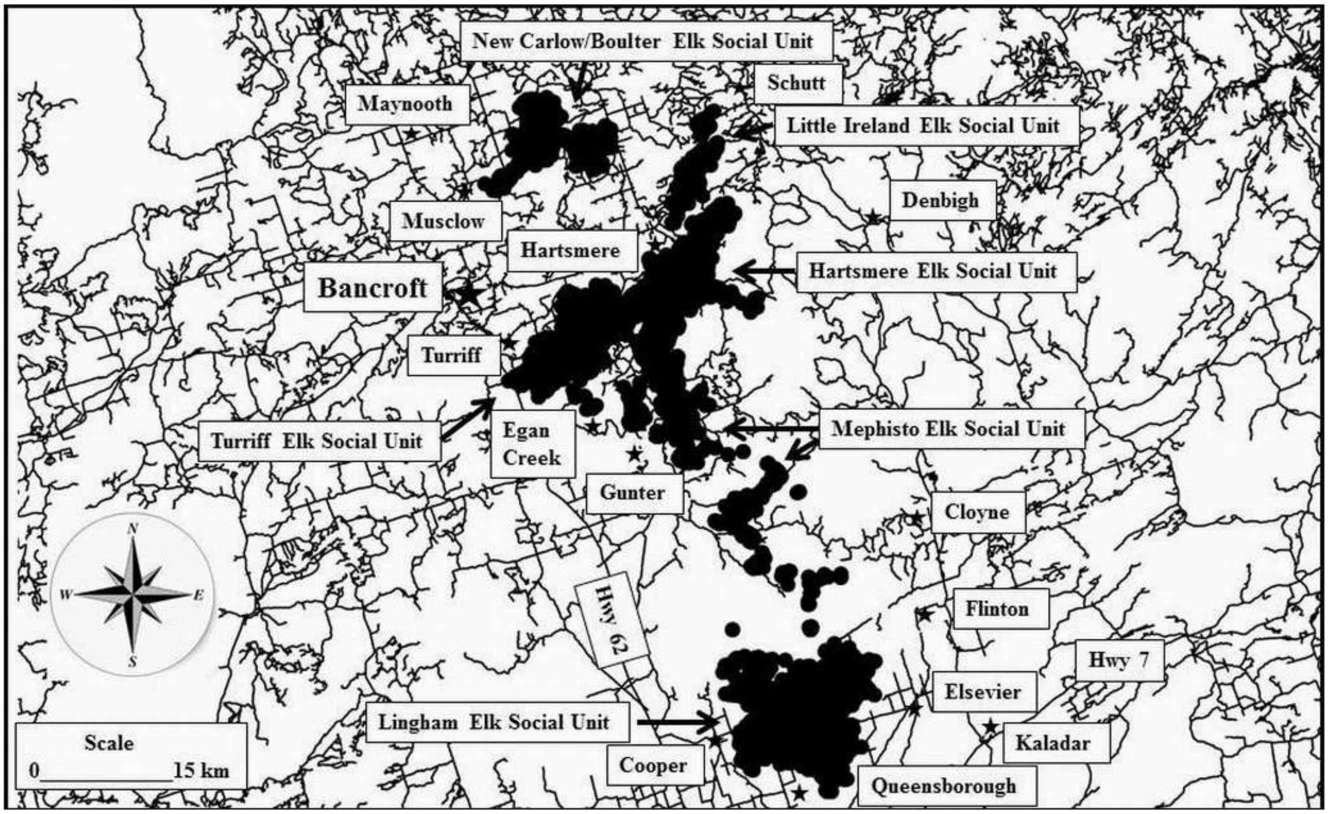

Figure 1. Location of Elk social units within the Bancroft Area Core Elk Zone, Ontario, 2006-2013. Locations of towns/villages are approximate.

9, 2000) of the holding period. In 2001, Elk were held in the pen for 90 days and released on April 14, 2001 (Rosatte *et al.* 2007a). Elk that were released near Bancroft during the restoration phase of the project in 2000 and 2001 had been fitted with VHF collars prior to shipment from Alberta. These Elk were monitored by radio-telemetry (receivers and yagi antennae) either aerially (using helicopters or fixed winged aircrafts and hand-held GPS units) or on the ground (using triangulation, compasses, and GPS units) until the collars malfunctioned or the animals died.

Post-restoration animal capture and data collection

From 2006 to 2012, 56 adult Elk (40 cows, 16 bulls that were offspring of the restored Elk released in 2000-2001) in the Bancroft area were captured via helicopter and net gun, or via immobilization on the ground with a dart gun (see Rosatte 2007 for methods). The captured Elk were fitted with GPS collars (Lotek 3300, Lotek Engineering, Newmarket, Ontario, Canada) or Random Access Satellite Sensor Link (RASSL) GPS/Satellite collars (North Star Science and Technology, King George, Virginia, USA) to study the dynamics of the Elk herds in the Bancroft area, 5 to 12 years post restoration. The locational data acquired (4-8 times/day) by the Lotek GPS collars were stored on-board the collars. Elk were recaptured at a later date at which time the data were retrieved from the collars by downloading to a laptop computer. The Northstar GPS/Satellite collars transmitted the data to a satellite (2-4 times/day) while the collars were on the Elk, and the data were later retrieved by accessing a website via computer. The telemetry data provided information on home range, movements, and survival of the Elk.

Elk Social Units and Groups

Individuals that were collared during the post restoration phase of the program were acquired from Elk social units in the Bancroft area. Those Elk social units were monitored and studied in an approximate 2,500 km² area that was termed the Bancroft Area Core Elk Zone. The units were named for the nearest town, lake, or township and included: Hartsmere, Little Ireland, New Carlow/Boulter, Turriff, Mephisto, and Lingham (Figure 1). The approximate size of each of the Elk social units during the study period was 4-53 individuals. Due to small sample sizes for some social units, winter feeding of Elk and White-tailed Deer in the Bancroft area (which tended to keep Elk in small areas during winter), and habitat differences, the data were pooled for purposes of analysis into two groups of Elk: Lingham and Bancroft. However, some analyses were also conducted on individual social units (Figure 1). The Lingham group included the Mephisto and Lingham Elk social units that occupied the southern part of the Elk range in the Bancroft Area Core Elk Zone (Figure1). The

Bancroft group included the Hartsmere, Little Ireland, New Carlow/Boulter and Turriff Elk social units and occupied the northern part of the Bancroft Area Core Elk Zone (Figure 1).

Health assessments

Elk that died (i.e., road-kills, illegal shooting, natural mortality, euthanized, harvested) during 2000-2013 were collected opportunistically depending on the location of the animals. The whole carcass was retrieved if it was easily accessible; otherwise, only the head and vital organs were collected. Carcasses or samples were submitted to the Canadian Cooperative Wildlife Heath Center (CCWHC) in Guelph, Ontario, for post mortem. Morphological (e.g., weight, neck circumference), age (tooth sectioning. see Rosatte *et al.* 2007b), and condition (fat reserves and condition of bone marrow) information on Elk were collected during post-mortem.

Annual surveys

Elk were surveyed annually (using a Bell Long-ranger or EC 130 helicopter) in January-March 2002 to 2013 (surveys were not conducted in January 2007) to obtain a count of Elk (to estimate population size using radio-collared and uncollared animals), an estimate of productivity (number of cows with calves), and an indication of Elk group composition in winter. As some Elk in each social group had been fitted with VHF and GPS collars prior to release during the restoration phase as well as during post-restoration years of the project, Elk social units were located during annual aerial surveys using a telemetry receiver and antennae system (Lotek Engineering, Newmarket, Ontario) attached to the helicopter. Once located, the total number of visible Elk in each social unit was counted, sex and age noted (adult, sub-adult, calves), and the number of radio-collared Elk tabulated. A digital photo was also taken of the Elk social unit to later confirm the aerial count and the number of collared Elk. Transects of variable width and length were also flown annually to attempt to locate Elk groups which did not have animals with radio-collars. In 2011, transects (each transect was 25 km² in area with flight line spacing of 500 meters) were also flown in a helicopter to locate Elk within the 2,500 km² study area.

Data presentation and analysis

A modified Petersen model was used to estimate Elk population size in the Bancroft Area Core Elk Zone (Krebs 1989). Population estimates for 2002-2008 included data from the six Elk social units previously mentioned, while estimates for 2009-2013 included data from one or two additional units located near Kaladar and Madoc, Ontario. As a result of this, and the fact that no survey was conducted during January 2007, the annual rate of increase (using the percent population increase from one year to the next) was not calculated for 2008-2009. The OMNR Bancroft District staff conducted a second Elk survey in February 2011 with a helicopter and flight lines spaced 500 m apart. One of the goals of this transect survey was to determine the precision of the annual method of estimating population size within the core Elk range. The resulting estimate data was determined to be within 6% of the author's Elk population estimate of 2011.

Prior to analysis, data were screened using Statistica 6.0 to verify the normality assumption and to test for heterogeneity of variances (Levene's test). If assumptions were not met, data were transformed using a Box-Cox power transformation. A Students *t* test for independent variables was used to determine if there were differences in bull:cow and calf:cow ratios in social groups that were fed or not by residents during winter (Zar 1999). A *t* test was also used to compare mean movements of cows and bulls during the parturition period, the mean duration of the rut for immature and mature bull Elk, and differences in bull and cow survival. Survival (finite) of radio-collared Elk was estimated using a Kaplan-Meier model and Ecological Methodology software (Krebs 1989). This model allowed entry of deceased animal as well as newly collared Elk data for each year. The finite survival rate was the rate for the time period in question, e.g., 2006-2010. A correlation analysis was conducted to examine the relationship between Elk population size and winter severity (Zar 1999). All data were analyzed using Statistica 6.0.

The severity of winters in the Bancroft area was determined using a Snow Depth Index (SDI) (based on impacts on White-tailed Deer) where cumulative weekly average snow depth measurements (cm) were taken at one snow station – Bancroft 45° 4' N, 77° 51' W, during 2001-2013. A mild winter has an SDI of < 590 at the end of the winter. A moderately severe winter and a severe winter have SDI indices of 591-760 and >760, respectively (OMNR 1997).

RESULTS

Elk morphology

Elk in the Bancroft area are classed as the Manitoban subspecies (*Cervus canadensis manitobensis*) with initial re-introduction stock being acquired from EINP, Alberta, Canada during 2000 and 2001 (Polziehn *et al.* 1998; Rosatte *et al.* 2002, 2007a) (Figure 2). Mean live-weight (body mass) of mature bulls and mature cows prior to shipment to Ontario was 216 kg and 227 kg, respectively (Table 1). Twenty-four of 46 Elk that died in the Bancroft area between 2000 and 2013 had a complete carcass and were weighed. The mean weight (non-dressed) of three healthy mature bulls and six healthy mature cows was 300 kg and 247 kg, respectively (Table 1). The largest bull (7 years old) from Bancroft that was necropsied in November 2006, weighed 351 kg. Eight mature bulls (>5x5 rack) were examined at a check station during the September 2011 Elk hunt near Bancroft; mean dressed weight was 263 kg with the largest bull being 301 kg (Table 1). Mean dressed weight of two cows taken during the hunt was 148 kg (Table 1). Considering that dressed weights of Elk in Manitoba were, on average, 75% of whole weights (range

Table 1. Body mass (kg) of healthy Elk at Elk Island National Park, Alberta, during January 2000/2001, and healthy as well as emaciated Elk from Bancroft, Ontario during 2000-2001 (dressed weight of Manitoban Elk is, on average, 75% of whole body weight with a range of 67% and 82% - Blood and Loas 1966).

	Adult male $\bar{x}$ (SD) (*n*)	**Yearling male $\bar{x}$ (SD) (*n*)**	**Juvenile male $\bar{x}$ (SD) (*n*)**	**Adult female $\bar{x}$ (SD) (*n*)**	**Yearling female $\bar{x}$ (SD) (*n*)**	**Juvenile female $\bar{x}$ (SD) (*n*)**
EINP healthy Elk	216 (29) (21)	188 (14) (4)	118 (13) (15)	227 (27) (44)	153 (10) (6)	107 (11) (19)
Bancroft healthy Elk	300 (44) (3)	182 (6) (3)	92 (na) (1)	247 (7) (6)	173 (8) (4)	na
Bancroft emaciated Elk	na	88 (na) (1)	70 (13) (2)	124 (33) (2)	na	76 (13) (2)
Bancroft Elk dressed weight	263 (35) (8)	na	na	148 (22) (2)	na	na

Figure 2. Photograph of Elk in the Bancroft area showing darker colored extremities, rump patch, and the lighter body color and darker legs of bulls. Photo: R. Rosatte.

of 67% to 82% depending on body condition and the amount of food in the stomach; Blood and Lovaas 1966), actual weights of the Bancroft dressed bulls and cows would have been, on average, 25% higher.

The mean age of 8 cow Elk harvested from the Bancroft area during the 2011 hunt was 7.3 years (SD = 5.6 years, range = 1-15 years). Five bulls harvested during that hunt averaged 5.8 years (SD = 2.8 years, range = 3-10 years). One radio-collared bull that was released in Ontario in 2000 was killed by a collision with a vehicle in 2013 at the age of 16 years. In addition, 2 cows from the Bancroft herd (non-harvested) were aged at 13 and 17 yrs post mortem by annual growth lines in incisor teeth.

Bull Elk in the Bancroft area sport majestic antlers during the fall and winter. On numerous occasions bulls with 6x6 and 7x7 antlers were photographed (Figure 2). The mean beam diameter of the right antlers (5x6 to 7x8 antlers) of 8 mature bull Elk harvested during the September 2011 Elk hunt was 8.0 cm (Standard Deviation: 1.1 cm; range: 6.3 to 9.6 cm). The mean length of the right antlers (along the curvature of the antler) of harvested bulls was 110 cm (SD: 14.6; range: 90.0 to 131.5 cm). A 7.5-yr-old bull Elk that died in the Lingham Lake area had antlers that weighed 7.7 kg and had 7 points on each antler (7x7) in November. The distance from the pedicle at the base to the tip of each antler was 100 cm (112 cm along the curvature of the antler) and the base of each antler was 9 cm in diameter (Figure 3). The brow (1^{st}) and bez (2^{nd}) tines were 36 to 38 cm in length, respectively. The royal tines were 37 cm in length (Figure 3).

Elk were observed shedding their antlers in late March-April, namely on March 21, 2006 (mature bull), April 7, 2005 (mature bull), April 27, 2006 (spike bull), and April 30, 2006 (mature bull).

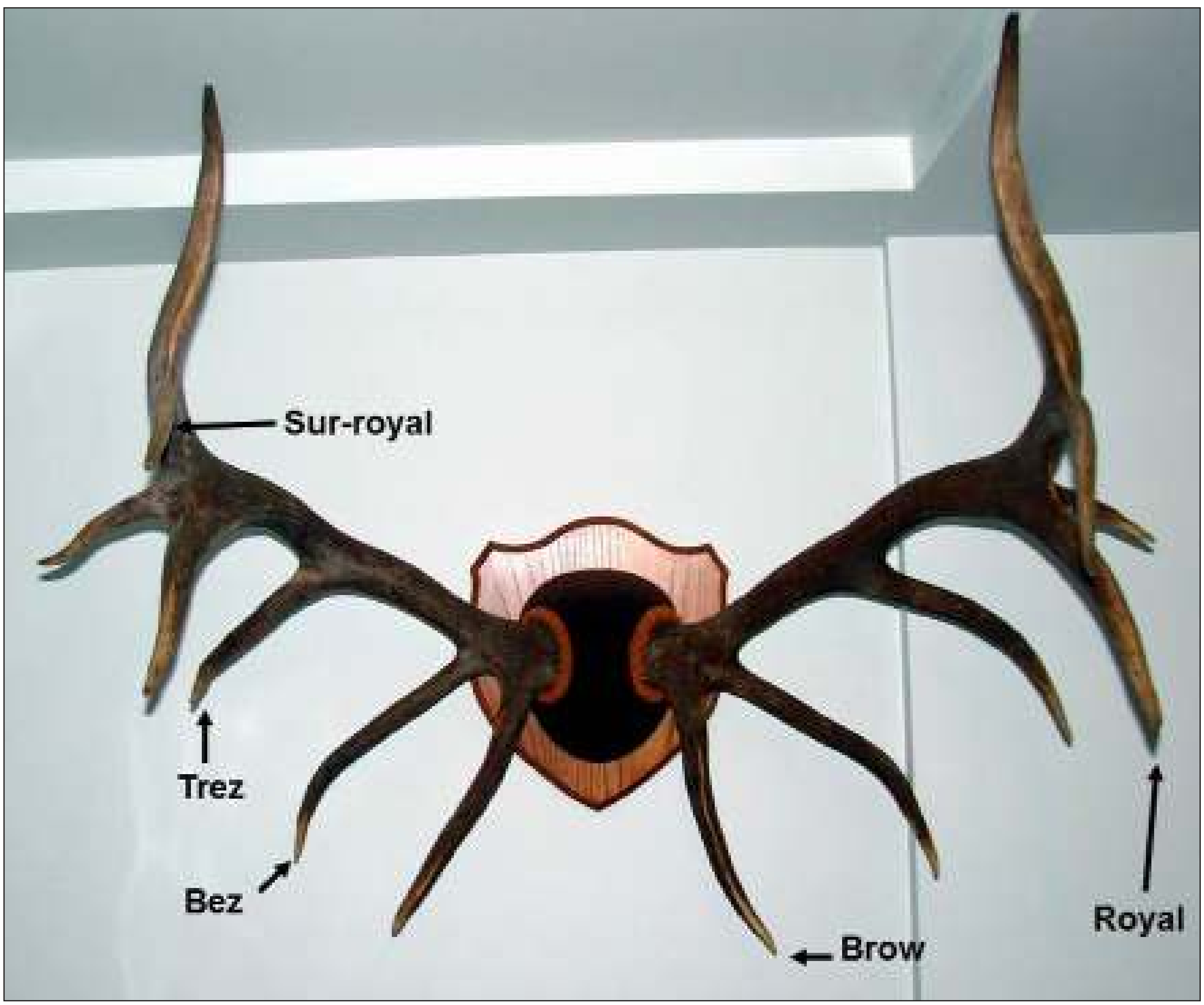

Figure 3. Photograph of antlers from a bull Elk that resided in the Lingham Lake, Ontario, area. Configuration of tines as per O'Gara (2002). Photo: R. Rosatte.

Bull Elk (yearling as well as mature) still had their antlers during an aerial survey on April 1-2, 2011. Re-growth of antlers began by May with antlers being fully developed by August of any given year.

Elk condition

Of the 46 Elk that were collected in the Bancroft area and necropsied between 2000 and 2013, body condition was assessed for 41 (10 AM, 4YM, 4 JM, 18 AF, 1 YF, 4 JF) of them. Twenty-five (8 AM, 2 YM, 2 JM, 10 AF, 1 YF, 2 JF) (61%) were determined to be in good condition and they had significant reserves of subcutaneous, pericardial, perirenal, and omental fat, and fatty bone marrow. Sixteen (2 AM, 2 YM, 2 JM, 8 AF, 2 JF) of the 41 Elk (39%) were considered to be emaciated as they had little or no fat reserves, reduced muscle mass, and their bone marrow was red, watery, and gelatinous.

Elk from the Bancroft area that were considered to be emaciated were well below average weights of healthy Elk (Table 1). Ten of the emaciated Elk died during 2000 and 2002, 5 during 2003-2006, and one during 2006-2013. Winters during 2000-2001, 2002-2003, 2004-2005, and 2005-2006 were classed as moderately severe to severe when the majority of the Elk died (Figure 4). The emaciated Elk died between late November and early May of any given year, with 75% of the deaths occurring in late winter, i.e., January-March.

Elk behaviour

Elk Behaviour on a Seasonal Basis – The GPS locations of collared Elk as well as aerial and ground observations during the 2006-2013 period were used to document the behaviour and herd dynamics of Elk on a seasonal basis. In winter, adult female Elk, their calves, and some yearlings remained as a social unit (4 to 53 Elk in size). Bull Elk (raghorn to mature) were usually solitary during the winter or formed small bachelor groups (2 to 6 in size

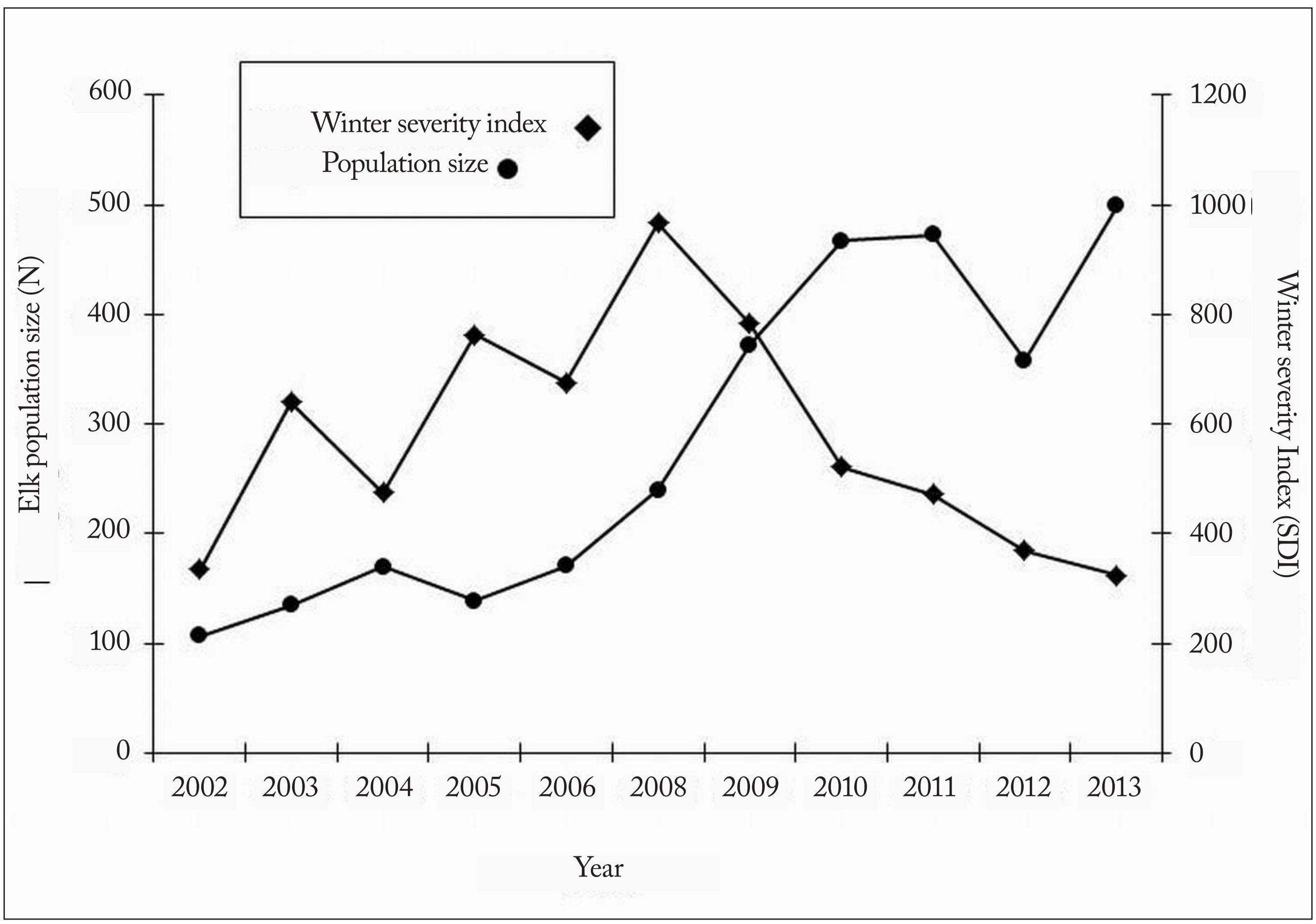

Figure 4. Mean Elk population size and winter severity in the Bancroft Area Core Elk Zone from 2002 to 2013[a].
[a] SDI = snow depth index; N = estimated number of Elk; an Elk population survey and estimate was not done for January-March 2001 and 2007, and the Elk survey for 2009-2013 included data on one or two additional Elk social groups, so the annual rate of increase could not be calculated for 2007-2009. Elk population estimates were calculated for January-March of any given year, and the winter severity index (SDI) was calculated at the end of the winter of any given year, e.g., SDI for 2002 is the value for the winter that occurred in late 2001 and early 2002. The SDI for 1999-2000 was 167 (mild) and for 2000-2001, 864 (severe).

based on 10 sightings) that remained within a few kilometers of the larger social unit containing cows and calves. Bulls (1 to 4 Elk in total; yearling to mature) were occasionally observed in winter with social units of cows and calves (group size of 16 to 49 Elk) in areas where supplemental feeding by residents did not occur. However, in areas where winter feeding by residents occurred, 8-14 bulls were observed with social units of cows and calves (37 to 53 Elk/unit in total) (Table 2).

Pregnant cow Elk in the Bancroft area usually left the social unit in May to bear their calves in solitude (based on telemetry movements). Prior to calving, cow Elk (n = 10) moved an average of 8.3 km (SD = 5.6 km) to calving sites in 2007-2010. Based on a cessation of movements ($\bar{x}$ = 0.2 km/day; SD = 0.1), 10 cow Elk had their calves between May 26 and June 14 during 2007-2010. During this same time period, bulls (n = 10) moved an average of 2.0 km/day (SD = 0.47, t=11.07, df: 17, P=0.001). Cows and calves returned to the social unit during July-September. Solitary bulls not living with the social unit during the summer re-joined the unit in early September in preparation for the breeding season (rut) which occurred in September-October in the Bancroft area.

Collared bull Elk (n =11) traveled to cow units for the rut in the Bancroft/Lingham Lake area during September 4-19, 2012. Generally, collared bulls were just associated with one cow social unit during the rut (in the Lingham area). In fact, four collared bulls (two 5x5s, one 2x2 and one spike bull) remained with one social unit of cows in Lingham during the September 2012 rut. Based on telemetry and Elk movements, three mature bull Elk in the Lingham area remained with collared cow Elk for an average of 34 days (SD = 13.5) from early to mid-September to mid- to late October 2012. Those bulls left the cow units and traveled 6 km north of the cows in one day. This suggests the rut may have lasted about five weeks for these mature bulls. However, two immature bulls (2x2) remained with collared cow Elk for an average of 53.5 days (SD = 5.0 days) during mid-September to the last week of October, 2012. This suggests that the rut for these immature Elk lasted about 7 weeks, longer than mature bulls although not significantly (t = 1.87, df: 3, P=0.16). Rut duration could not be determined for Bancroft area bull Elk as they remained with the cows during the fall-early winter due to winter feeding by the public.

The cycle commenced again in late fall-early winter as Elk moved to their winter range and bulls broke away from social units of Elk following the rut. Sixty-eight percent (19/28) of Elk that had separate fall-winter ranges moved to their winter range during December 2-21 of any given year (2007-2012). Fourteen per cent (3/28) moved to winter ranges during October, and 14% (3/28) during November of those years.

Impact of winter feeding on Elk behavior – Normally, following the rut, bull Elk left the harem or social unit and formed small bachelor groups in the Bancroft area. This occurred in all areas except Hartsmere and Turriff where winter feeding of Elk by residents occurred. In Hartsmere, bulls remained in the vicinity

Table 2. Late winter Elk social unit composition in areas where winter feeding by residents did, or did not occur, in the Bancroft area, 2006-2013, Ontario, Canada[a].

Year	Elk social unit	Winter feeding by residents	Number of bulls observed	Number of calves observed	Number of cows observed	Bull:calf:cow ratio/100 cows
2006	Hartsmere	Yes	14	8	15	93:53:100
2006	Lingham	No	3	7	20	15:35:100
2008	Hartsmere	Yes	10	7	27	37:26:100
2008	Lingham	No	0	9	17	0:53:100
2009	Hartsmere	Yes	14	11	25	56:44:100
2009	Lingham	No	4	6	16	25:38:100
2010	Hartsmere	Yes	13	12	25	52:48:100
2010	Lingham	No	4	8	27	15:30:100
2011	Hartsmere	Yes	10	11	32	31:34:100
2011	Lingham	No	2	10	32	6:31:100
2012	Hartsmere	Yes	8	8	28	29:29:100
2012	Lingham	No	6	14	45	13:31:100
2013	Hartsmere	Yes	8	10	23	35:44:100
2013	Lingham	No	6	13	33	18:39:100

[a] Elk were observed during aerial surveys and through observations on the ground; no survey was done during January-March 2007.

of the feeding location with the cows and calves during the entire winter. This resulted in unusually high bull:cow ratios (up to 93:100) (Tables 2 and 3) during winter. Direct observations of the Hartsmere Elk social unit during winter revealed constant sparring by bull Elk. Constant sparring yielded injuries to bulls at a time when their fat reserves were low. In addition, breeding during winter (January) was noted with calves being born in September. Calf mortality (n = 6) in the Hartsmere Elk social unit was also noted due to bull aggression (spearing with antler tines) towards calves when bull ratios were high during the winter. High bull:cow ratios were not observed in the Lingham area where winter feeding did not occur (Tables 2 and 3).

Elk population dynamics in the Bancroft Area Core Elk Zone

Size and location of Elk social units – During the study, Elk group size was the greatest during 2010-2011. Elk social unit size (primarily cows and calves) averaged 47 Elk (SD = 6.2, range = 43 to 53) in the Hartsmere and Lingham areas during the winters of 2010 and 2011 when the estimated mean population size in the Bancroft Area Core Elk Zone was >450 animals. Moderate group size ($\bar{x}$ = 25 Elk, SD = 4.6; range = 19-30) was observed in the Turriff and New Carlow areas for that time period. Smaller groups were found in areas such as Mephisto, Kaladar, Madoc, and Little Ireland, where average Elk unit size was 11 Elk (SD = 5.3, range = 4-16) during the winters of 2010 and 2011. These are minimal social unit size estimates as some Elk were not detected during aerial surveys due to visibility bias created by the forest cover. This was confirmed by locating collared animals (using a telemetry receiver) that were not visible during the aerial count.

Sex, age, and ratio of Elk in winter surveys – The mean ratio of bulls:cows (based on aerial surveys) in the Bancroft Area Core Elk Zone during late winters of 2002 to 2013 was 25:100 (SD = 8.2) (Table 3). The mean ratio of calves to cows was 39:100 (SD = 10.2) during this period of time (Table 3). The mean ratio of bulls:cows and calves:cows in the Hartsmere Elk social unit, which was fed by residents during the winters of 2002 to 2013, was 48:100 and 40:100, respectively (Table 2). The mean ratio in the Lingham Elk social unit where supplemental winter feeding did not occur was 13:100 (bulls:cows) and 37:100 (calves to cows) (Table 2). The mean bull:cow ratio was significantly greater in the Hartsmere winter fed Elk social unit than in the Lingham unfed social unit (t = 3.81,

Table 3. Number, age/sex, observed bull, cow, calf ratio, and estimated population size for Elk observed during late winter aerial surveys in the Bancroft Area Core Elk Zone, 2002-2013. No survey was done during January-March 2007

Year	Total Elk (n)	Bulls (n)	Cows (n)	Calves (n)	Bull:Cow ratio[a]	Calf:Cow ratio	Population estimate $\bar{x}$ (95% CI)[f]
2002	63	6	43	14	14:100	38:100[b]	107 (95-128)
2003	64	7	48	9	15:100	24:100[c]	135 (110-182)
2004	88	9	48	31	19:100	65:100	170 (134-237)
2005	56	9	33	14	27:100	42:100	139 (119-177)
2006	118	25	67	26	37:100	46:100[d]	171 (150-207)
2008	113	21	68	24	31:100	35:100	240 (183-354)
2009	132	28	80	24	35:100	34:100[e]	372 (260-630)[g]
2010	150	24	93	33	26:10	36:100	467 (330-766)
2011	187	37	111	39	33:100	35:100	466 (330-758)[h]
2012	173	19	113	41	17:100[i]	36:100	358 (293-476)
2013	174	26	104	44	25:100[j]	42:100	499 (394-633)

[a] The initial bull:cow ratio due to the reintroduction in 2000-2001 was 48:100.
[b] Calf:cow ratio was calculated using 37 mature cows (5 cows were immature).
[c] Calf:cow ratio was calculated using 37 mature cows.
[d] Calf:cow ratio was calculated using 56 mature cows.
[e] Calf:cow ratio was calculated using 70 mature cows.
[f] 95% CI = 95% confidence interval.
[g] Population estimate included two new social groups that formed on the southern periphery of the Bancroft Area Core Elk Zone.
[h] OMNR Bancroft District staff estimate for 2011 was 500 (380 to 660 95% CI).
[i] 19 bull Elk were removed during 2011 by harvest and agricultural authorizations.
[j] 14 of 26 bulls were yearlings (spike horns).

P = 0.003). However, the number of bulls counted in the Lingham unit may have been underestimated due to the winter dispersion of bull Elk away from cow groups in non-fed areas. No difference was detected in the calf:cow ratios between the two social units (t = 0.61, P = 0.55).

Elk population size and rate of increase – Following the release of 120 Elk in 2000-2001, the Elk population in the Bancroft Area Core Elk Zone increased from a mean of 107 in 2002 to 499 Elk in 2013 (Table 3), which equates to an overall density of 0.04 to 0.2 Elk/km². The annual rate of increase was 26% from 2002 to 2004. This was followed by an 18% population decline during 2004 to 2005 due to a variety of factors including emaciation, collisions with vehicles, illegal shooting, drowning, injuries, and the effects of meningeal worm infection. However, the population recovered and increased by 23% during 2005-2006 (Figure 4). No survey was done during 2007, and the 2009 population estimate was derived using two additional Elk social units; therefore, a rate of increase estimate was not calculated for 2007 and 2008. The population increased by 26% during 2009 and 2010, was stable to decreasing during 2010-2012, and then increased by an estimated 34% during 2012-2013 (Figure 4). The above estimates for 2009-2013 are crude estimates as Elk units in the Kaladar and Madoc areas were not located during all years.

Winter severity and population increase/decrease – The winters in the Bancroft study area were generally classed as mild with the SDI ranging between 324 and 590 during 2001-2002, 2003-2004, 2006-2007, and 2009-2010 to 2012-2013. However, the winters of 2000-2001, 2004-2005, 2007-2008 and 2008-2009 were classed as severe based on data from the Bancroft snow station. Snow Depth Indices were 864, 763, 967, and 784 for those years, respectively (Figure 4). Winters were moderate during 2002-2003, 2005-2006 in Bancroft with SDI of 641 and 676, respectively. A significant correlation between winter severity and Elk population size was not detected (r = -0.30, P=0.37) (Figure 4). It should be emphasized that the SDI was derived for White-tailed Deer and may not be relevant for Elk.

Productivity – During 2002-2013 late-winter aerial surveys, the number of mature cows with calves was counted. The percentage of cows with calves was used as an indication of productivity and calf survival and ranged between 24% and 65% during those years (Figure 5).

Elk Survival – Survival estimates for GPS collared bulls and cows

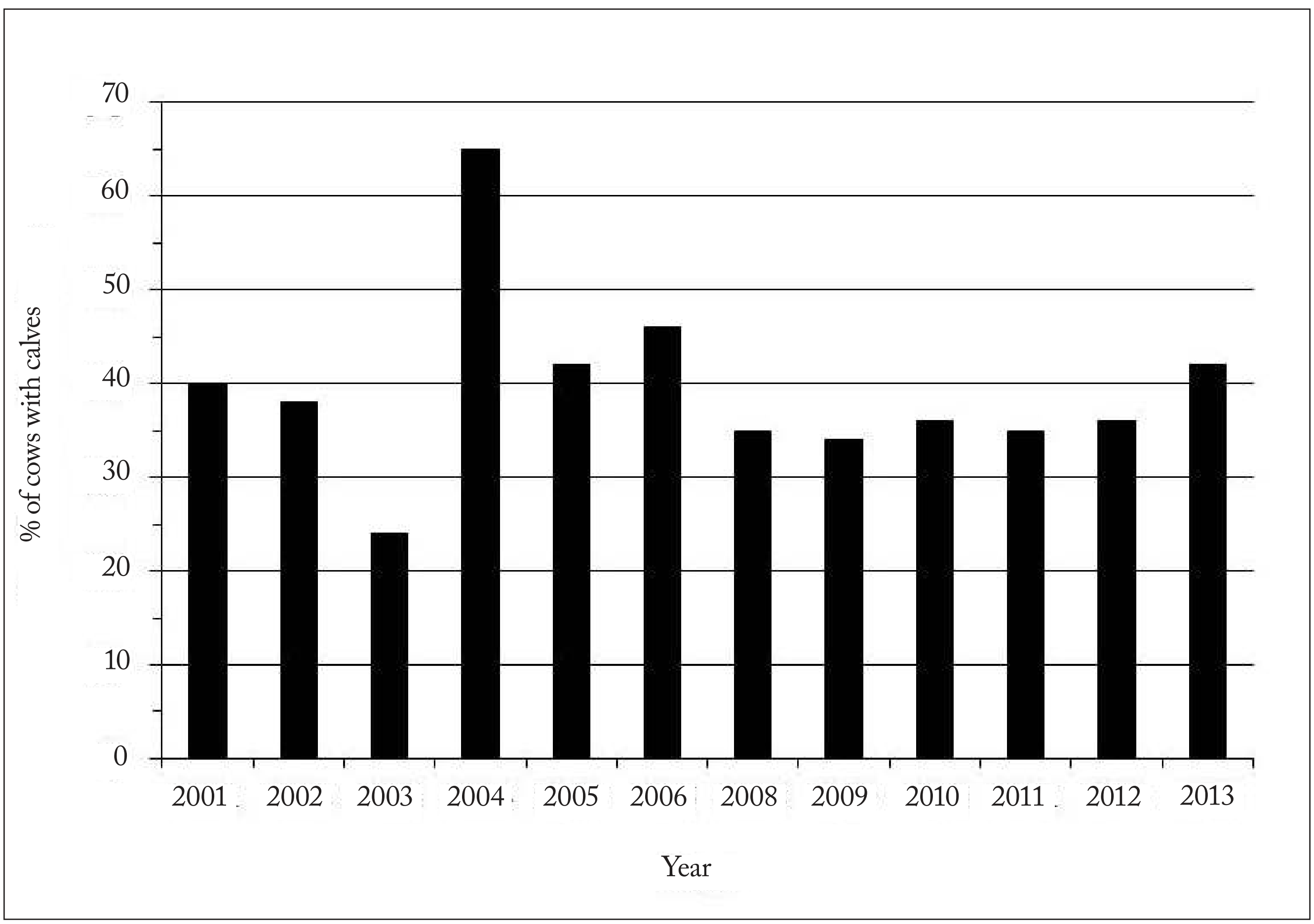

Figure 5. Percent of cow Elk observed with calves during late winter surveys in the Bancroft Area Core Elk Zone during 2001-2013.

were calculated separately as bulls are more prone to injury and mortality due to activities during the rut. Using a Kaplan Meirer model, the finite survival rate for Bancroft Elk group bulls (n = 7) that were monitored (prior to hunting) during 2006-2011, was determined to be 0.75 (SE = 0.21, 95% CI = 0.33-1.0). For the Lingham group bulls (n = 7) that were only monitored during 2012 (hunting allowed), the finite (annual) survival rate was 0.86 (SE = 0.13, 95% CI = 0.6-1.0). For Lingham and Bancroft group bulls (n = 9) that were monitored during the 2011 and 2012 hunts, the finite survival rate was 0.67 (SE = 0.16, 95% CI = 0.36-0.98).

The finite survival rate for cow Elk in the Bancroft area during 2007-2010 (prior to hunting) was 0.86 (SE = 0.13, 95% CI = 0.6-1.0, n = 14). During hunting years (2011-2012), survival was 0.71 (SE = 0.11, 95% CI = 0.49-0.92, n = 17). In the Lingham area, survival (prior to hunting) was 1.0 for six cows in 2010. After hunting, the survival rate was 0.88 (SE = 0.08, 95% CI = 0.71-1.0) in 2011-2012. The finite survival rate for Lingham and Bancroft cow Elk in 2011-2012 was 0.79 (SE = 0.07, 95% CI = 0.65-0.93, n = 33) when hunting was allowed.

No differences in bull and cow Elk survival rates were found before (t = 0.38, df: 8, P = 0.71) or after (t = 0.48, df: 5, P = 0.65) the hunt was initiated; therefore, the data were pooled. The Elk (bull and cow) finite survival rate during 2006-2010, prior to the initiation of the hunting season, was 0.79 (SE = 0.13, 95% CI = 0.53 – 1.0, n = 27). After the hunting season in 2011-2012, it was 0.76 (SE = 0.07, 95% CI = 0.63 – 0.89, n = 42).

DISCUSSION

Elk morphology and longevity

Elk in the Bancroft area were generally comparable in size to Elk (Manitoban) found in central and western North America where bulls and cows weighed from 300 to 450 kg, and 250 to 275 kg, respectively (Blood and Lovaas 1966; Peek 1982, 2003). Elk body size, weight, condition, and fitness (based on survival, productivity, post mortems, and population increase) did not appear to be affected by a change in habitat (due to Elk relocation) from the Aspen (*Populus tremuloides*) Parklands of Elk Island National Park, Alberta, to the mixed coniferous-deciduous forests of the Bancroft area (Rosatte *et al.* 2007a). In fact, mean weights of adult bulls and cows in Bancroft following restoration were greater than those of animals shipped from Elk Island National Park.

Antler size in bull Elk is a function of body size, age, condition, genetics, as well as forage nutritional value (Smith 1998). The higher the forage protein and mineral content (e.g., calcium and phosphorus), the larger the antlers (O'Gara 2002). The weighed and measured antlers from the Elk herds of the Bancroft area were not record size, but they were comparable to Elk antlers in western North America (Smith 1998). This suggests that habitat in the Bancroft area provides Elk with adequate forage that is high in protein and mineral content required for good antler growth (Peek 1982; Smith 1998).

Elk are generally a long-lived animal and have been known to live in excess of 20 years. However, their life span is generally much shorter (Peek 1982). Three cow Elk from the current study were 13 to 17 years old at post mortem, and one bull Elk was 16 years old when it was road-killed. Rosatte *et al.* (2007b) found Elk in Ontario that were up to 20 years old in 1999-2004. The habitat of the Bancroft area, and a lack of significant predation and other mortality factors, may explain the longevity and health of Elk.

Elk condition during late winter

During severe winters, body fat reserves are depleted and there is an increased use of body protein which results in emaciated conditions in Elk (Delgiudice *et al.* 1991). High mortality, especially in young animals, can occur when snow depths reach the point where Elk starve to death (Cook 2002). Most of the Elk (61%) necropsied in 2000-2013 were in good condition, thus indicating that the habitat was sufficient to meet their energy demands. However, 39% of the animals were emaciated and in poor condition. This may have been a function of winter severity in conjunction with other factors during the early stages of the restoration program. Other factors such as parasite load may have contributed to the poor condition of Elk, especially during severe winters. Some Elk also died from emaciation during the restoration phase of the program. Elk originating from the Aspen Parklands of Alberta may not have had time to adjust to their new habitat (mixed coniferous-deciduous forests), and a severe winter in 2001-2002 in unfamiliar habitat may have resulted in emaciation-related mortalities. In some jurisdictions such as Manitoba, significant Elk mortality (up to 20%) has been attributed to severe winters (Banfield 1949). Although moderate to severe winters were noted during some years in the Bancroft study area, a significant correlation between winter severity and population change was not detected. However, severe winters in combination with other mortality factors such as collisions with vehicles, drowning, illegal shooting, and disease/parasites may have limited population growth during some years.

Elk behavior and life cycle

Elk in the Bancroft area generally followed the life cycle of Elk in western North America. The rut normally lasted from early September to late October as evidenced by movement of bulls to cow groups, bugling of bulls, harem formation by dominant bulls, dominant bulls sparring with other bulls to maintain their harem, and breeding of cows by the dominant bull. In the Lingham area, bulls moved to cow groups during early September with most leaving the cow groups during the last week of October. Based on bull Elk movements to and from cow groups, the rut lasted a mean of 34 days for mature (5x5 or greater) and 54 days for immature Elk (2x2's). This is similar to the findings of Noyes *et al.* (1996) who found that the rut for yearling bulls was about 71 days, and 41 days for five-year-old Elk in Oregon.

During the winter, large groups of Elk in the Bancroft study area primarily consisted of mature cows, immature cows and bulls, and calves. Mature bulls usually formed small groups (or were solitary) that existed outside of the large winter groups of Elk. However, in areas where Elk were fed by residents during the winter, mature bull Elk were often observed in the larger groups of Elk (cows, calves and yearlings). Elk social unit size during the winter of 2010-2011, when the Elk population was near its maximum size (mean of 470 individuals), ranged between 19 and 53 Elk for the primary herds in the Bancroft Area Core Elk Zone. In southwest Manitoba, Hornbeck (1985) noted Elk group size to be about 14 Elk in a population of about 650 Elk during the late 1970s. Rounds (1980) reported that Elk groups were smallest during the warmest months and largest during the fall breeding period in a study in Manitoba where group size was as large as 35 during the fall and winter. Elk group size was smaller and more scattered during severe winters, while Wichrowski *et al.* (2005) noted that Elk were more gregarious during fall and winter in southeastern Kentucky. In Montana, Elk group size was smaller in spring than winter, and Elk density was greatest in grassland habitats (Proffitt *et al.* 2012). It appears that Elk group size in Ontario, as well as in some other North American jurisdictions where supplemental winter feeding does not occur, reaches a maximum size of about 50 to 60 Elk, and is possibly maintained at this size by mortality, social mechanisms, and possibly dispersion movements.

Prior to calving, cow Elk move away from the social unit (Hudson and Haigh 2002). In this study, cow Elk had their calves during late May and early June in the Bancroft area which is similar to other studies in western North America (Hudson and Haigh 2002). However, late breeding (January) was observed near Bancroft, in areas where winter feeding of Elk by residents occurred, and several calves were born in September (Rosatte and Neuhold 2006). Cows with newborn calves stayed away from the herd for about a month before rejoining the social group during the summer. This is similar to cow Elk behavior in other studies in southern Ontario and in western North America (Peek 1982; Hudson and Haigh 2002; Allan 2013).

Population dynamics

A modified Petersen model using the number of collared and uncollared Elk observed during aerial winter surveys was utilized to estimate Elk population size in the Bancroft area (Krebs 1989). Given the large sample sizes, the model should have been fairly precise, however, during some years, wide confidence limits occurred. There may have also been some visibility or detection bias due to Elk in heavy forest cover. In Manitoba, Elk sightability was influenced by forest type and habitat openness (VanderWal *et al.* 2011). However, in the current study, population estimates using the Petersen method as well as a sightability model (developed by McIntosh *et al.* 2009) which accounted for visibility bias, were similar. In addition, estimates for the Bancroft Elk population size derived during 2011 using two different survey methods and different staff differed by only 6% (Rosatte, unpublished data). Cogan and Diefenbach (1998) and Eberhardt *et al.* (2007) suggested that most aerial surveys result in undercounting Elk groups due to visibility bias and canopy cover. It was suggested that estimates may be negatively biased by up to 20% (Cogan and Diefenbach 1998). If this is true for the Bancroft area, then in all likelihood, the Bancroft Elk estimates are minimum population estimates. This is an advantage as it provides a cushion in case over-harvesting or significant mortality due to severe winters, predation, and other factors occurs during future years.

The years 2001-2006 were a period of slow population growth for Elk in the Bancroft area due to a combination of factors including dispersion of Elk away from the release area, resource restrictions due to deep snow during some winters, high mortality, and illegal shooting (Jenkins *et al.* 2007; Rosatte *et al.* 2007a; Yott *et al.* 2011). However, during 2009-2010, Elk experienced a period of good population growth due to less dispersion, high productivity, medium to large-sized social unit formation, and low mortality. In addition, during the early to mid-2000s, following introduction to a new environment, Elk switched from a dispersive phase to a settling down or home-ranging phase (Fryxell *et al.* 2008; Haydon *et al.* 2008). In 2011, the population seemed to have stabilized. At this time, two different estimator models and two different survey teams, during two different time periods, derived very similar population estimates; therefore, estimation error is unlikely to be the cause for the stabilization.

Elk population size in the Bancroft Area Core Elk Zone increased during 2000-2003, declined during 2004-2005, increased from 2006 to 2010, and then stabilized in 2011 prior to the first harvest. Good population growth from 2006 to 2011 was likely due to a lack of significant predation, high productivity, and mild winters with little snow during some years. Rounds (1977) also noted that Elk populations fluctuated over time in Manitoba during 1950-1976. Gogan and Barrett (1987) noted that as populations of Tule Elk (*Cervus elaphus nannodes*) increased in California, calf:cow ratios were high. However, as the herd increased to a certain size, calf:cow ratios began to decline. This also occurred in the Bancroft study area where calf:cow ratios were high during 2001-2005, and then decreased during 2008-2011. Stabilization of the population size during 2011 may also have been a function of Elk dispersion away from the core zone. Proffitt *et al.* (2012) noted that Elk group size decreased as Elk population size increased in a study during 1987-2000 in Montana. In the Bancroft study, as Elk group size reached the units apparent socially tolerable limit, Elk likely dispersed outside of the core zone as indicated by sightings in eastern Ontario.

Lower calf production and survival may have partially contributed (along with other causes of mortality) to the population stabilizing in 2011. Murrow *et al.* (2009) suggested that poor Elk calf recruitment (survival ranged from 0.3 to 1.0) in a restored herd in the Great Smokey Mountains resulted in poor population growth. Yarkovich *et al.* (2011) noted that American Black Bear (*Ursus americanus*) predation was the primary calf mortality factor in that population. As calves were not collared in the Bancroft study area during 2006-2013, it is unknown whether Black Bear predation had any impact on calf survival and Elk population growth. However, Black Bears are common (40-60 bears/100 km²) in the Bancroft area (http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/ @fw/documents/document/274503.pdf). In fact, Black Bears were documented predating on Moose (*Alces alces*) calves in Algonquin Provincial Park (Patterson *et al.* 2013), which is the northern limit of the Bancroft area Elk range.

In the past, Wolf (*Canis lupus*) predation on Elk in the Burwash/French River area of Ontario has been significant (Kittle *et al.* 2008; Rosatte *et al.* 2007a). During 2000-2013, Wolf predation on adult Elk in the Bancroft Core Elk Area was practically non-existent. This may be a function of the fact that most wild canids in the Bancroft area are Eastern Wolves (*Canis lycaon*), Eastern Coyotes (*Canis latrans*) or hybrids (*Canis* spp.) (Benson *et al.* 2012) that are considerably smaller than a pure Gray Wolf. A smaller canid such as an Eastern Wolf, Coyote or hybrid would likely be an ineffective predator of adult Elk. However, these wild canids could easily prey on Elk calves as a study by Patterson *et al.* (2013) documented Wolf (*Canis* sp.) predation on Moose calves in Algonquin Provincial Park, just north of Bancroft, Ontario. In view of this, annual monitoring of Elk populations in the Bancroft area would be prudent so that impacts due to potential predation of Elk calves can be ascertained and wildlife management strategies altered to maintain the Elk population objective.

Caughley (1970) noted that when ungulates are introduced to an area, they generally experience an increase in population size followed by a decline to lower densities. The cause of the decline is often related to disease, predation, competition, over-browsing of vegetation, and dispersion. Rosatte *et al.* (2007a) and Yott *et al.* (2011) noted that emaciation resulted in Elk mortality up to 13% in the Bancroft area during the early 2000s. Other mortality factors in the Bancroft area included illegal hunting, collisions with automobiles, and meningeal worm infection (Bellhouse and Rosatte 2005; Jenkins *et al.* 2007; McIntosh *et al.* 2007; Rosatte *et al.* 2007a). In Alberta, Elk population growth was limited by snow depth and Wolf predation in 1985-2000 (Hebblewhite *et al.* 2002). However, to date, it appears that predation and winter severity have not limited Elk population growth in the Bancroft area.

During most years, Elk population size in the Bancroft Area Core Elk Zone increased at a rate of 23% to 26% annually, i.e., a four-fold increase during 2002-2010. Other jurisdictions have experienced similar rates of population growth. An introduced Elk herd in Michigan increased at a rate of about 20%/yr (Moran 1973) as did a naturally colonizing herd in Washington 2 to 13 years post colonization (McCorquodale *et al.* 1988). An Elk herd in North Dakota experienced a 7-fold increase during 1985-1993 and had to be culled to meet population objectives (Sargeant and Oehler 2007). In Alaska, the annual rate of increase was 0.4, six years after the Elk introduction program was initiated (Burris and McKnight 1973). High rate of increase in Washington during the 1970s and 1980s was attributed to high yearling survival as well as high reproductive output in two-year-old Elk (McCorquodale *et al.* 1988). Nelson and Peek (1982) noted that reduced mortality rates in Elk had a greater impact on population growth than did an increase in the reproductive rate. However, despite high reproductive rates in the above areas, and in some parts of Ontario (e.g., French River area), Elk mortality can be quite high due to severe winters and high levels of predation.

Population increases will be much higher in restored Elk populations in more southerly climates such as Kentucky where winters are mild and predation low. Larkin *et al.* (2002a,b; 2003a,b) found Elk calving rates between 66% and 92%, and annual survival of all sex and age classes between 0.90 and 0.97 in 1998-2000. The rate of increase in a hunted Elk herd in New Mexico was 11-12% during 2003-2007, and 26% in North Dakota (Sargeant and Oehler 2007; Halbritter and Bender 2011). It is anticipated that the future annual rates of increase may decrease in Ontario with the initiation of Elk hunting in the province since 2011. However, currently (2013) hunting has had a negligible impact on the Elk population in the Bancroft area, at least at a level that can be detected by the precision of our winter survey methods.

Supporting the evidence of longevity for Elk near Bancroft, the finite survival rate for adult Elk (bulls and cows) in this study prior the implementation of a hunting season in the Bancroft area was 0.79 in 2006-2010 (5 to 10 years post restoration). This is considerably higher than the survival rate of 0.54 (0.45 – 0.63) for the Bancroft Elk herds immediately following restoration (2000-2005) (McIntosh 2012). In Washington, survival of cow and bull Elk was 0.8 and 0.80-0.85, respectively, where harvest was limited to spike bulls only (McCorquodale *et al.* 2011). In a study in Colorado and New Mexico, survival of cow Elk over four years was 0.8 and 0.91 when harvest mortality was included and excluded, respectively (Webb *et al.* 2011). This is comparable to the survival rate (0.76) of cow and bull Elk in this study when hunting was allowed in the Bancroft area in 2011 and 2012.

In view of the fairly high survival rates of adult Elk in the Bancroft area once the herds were established, mortality of calves must have been significant otherwise the herds would have increased dramatically following restoration. Using an assay for progestagen concentration in fecal samples, McIntosh (2012) estimated that the minimum pregnancy rate for cow Elk in the Bancroft area during 2004-2005 was 63%. An additional 13% to 18% of the samples were inconclusive so pregnancy rates may have been much higher. In Washington and Oregon, Cook *et al.* (2013)

documented Elk pregnancy rates ranging from 68% to 100%. Late winter annual Elk surveys in Bancroft, showed that 24% to 65% (most years were <40%) of the cow Elk had 7 to 10 month-old calves with them. Minimal mortality rates for calves during most years likely ranged between 20% to 40%. The difference between minimal pregnancy rates and the above calf mortality rates suggests that during some years, calf mortality would account for the majority of Elk mortalities in the Bancroft area.

Bull:cow ratios in 2002-2004 were low (<20:100) despite a high initial release ratio during the first two years of restoration (48:100). Low ratios were probably related to a high rate of dispersion by bull Elk during the initial release years (dispersive phase following restoration) as well as small social unit size, or detectability during surveys (Fryxell *et al.* 2008; Haydon *et al.* 2008; Yott *et al.* 2011). Annual mortality for the population was 19% and 11% during the initial two years of the restoration effort (Haydon *et al.* 2008). However, as Elk entered into settling down, encamped, or ranging phases (Fryxell *et al.* 2008), mortality decreased (8% during year 3 of the restoration – Haydon *et al.* 2008), social unit size increased, and as noted in this study, bull:cow ratios increased (27:100 to 33:100) during 2005-2011. Bull:cow Elk ratios in western North America averaged 27:100 to 45:100 (Peek 1982; Raedeke *et al.* 2002). In Washington, mature bulls tended >84% of the harems where bull:cow ratios exceeded 21:100, and as bull age increased, conception dates occurred earlier and pregnancy rates were higher (Bender 2002). In Oregon, productivity of cow Elk decreased due to a decline in mature bulls (Noyes *et al.* 1996). Therefore, in Ontario, it would be prudent from a management perspective to maintain mature bull:cow ratios above a 20:100 ratio to ensure high productivity and herd health.

In heavily harvested areas such as Colorado, bull:cow ratios have been low (10:100) during some years (Peek 1982). In a small herd (650 Elk) in southwestern Manitoba, bull:cow ratios were about 17:100 during the late 1970s (Hornbeck 1985). During March 2012 the bull:cow ratio in the Bancroft core Elk area appeared to have dropped to 17:100. This may have been a function of 19 bulls being removed from the herds during the 2011 harvest and via agricultural authorizations. It may have also been a function of bull dispersal or the fact that bull Elk often remain in small bachelor groups during the winter where they may have been missed by aerial surveys. In areas where feeding by residents occurred, many bulls remained with the cow-calf group throughout the winter. In areas without winter feeding, bulls broke off into small bachelor groups (2-5) for the winter, similar to other studies such as in Manitoba where mean bull group size was 3.3 (Hornbeck 1985). Regardless, monitoring of the bull:cow ratio is important in the Bancroft area especially with hunter harvest.

Elk density and carrying capacity

As Elk have not existed in Ontario at appreciable densities for many decades, density information on them is scarce. Elk density in neighboring Michigan, 20 years after an introduction effort, was about 1.2 to 1.5 animals/km² during the 1950s and 1960s (Moran 1973). In neighboring Manitoba (Riding Mountain National Park), Elk density was about 1.2/km² during the 1960s (Blood 1966; Moran 1973) and between 0.6 and 0.9/km² during the late 1970s (Hornbeck 1985). Elk density in Wisconsin and Alberta during the early 2000s was 0.4/km² and 0.2/km², respectively (Anderson *et al.* 2005). In the Burwash area of Ontario, Elk density during the mid-1990s prior to the recent restoration program was about 0.06/km² (Hamr and Filion 1996). One year after (2001) the initial Bancroft restoration release, Elk density was 0.003/km² as Elk were in a dispersive phase with a population range of 27,000 km² (Yott *et al.* 2011). However, after Elk settled down and entered an encamped or home range phase, Elk density in the Bancroft Area Core Elk Zone was about 0.2 Elk/km² in 2012-2013. This is likely far below the biological carrying capacity of the habitat in the Bancroft area given that the carrying capacity in other jurisdictions has been noted as having been much higher (Blood 1966).

The carrying capacity of a geographical area to support a given density of Elk is related to the quality of habitat. In Colorado, the carrying capacity of winter habitat was greatest in willow (Salix spp.)-dominated habitats and lowest in landscapes dominated by pine forest (Hobbs *et al.* 1982). The biological carrying capacity of Elk in Riding Mountain National Park, Manitoba, was considered to be about 2 Elk/km² (Blood 1966). However, Moran (1973) thought that Elk browsing would negatively impact Aspen regeneration, crop depredation would occur, and there would also be over-browsing of vegetation by Elk at that density. The carrying capacity for Elk in Nevada and Colorado studies was also thought to be between 1 and 2 Elk/km², for summer and winter range, respectively (Hobbs *et al.* 1982; Beck and Peek 2000). Assuming the biological carrying capacity of Elk habitat in southern Ontario is somewhere around 1 to 2 Elk/km², Elk are currently (2013) far below the biological carrying capacity of the landscape in the Bancroft area. Studies need to be initiated to determine Elk nutrient requirements and habitat quality in southern Ontario (Hobbs *et al.* 1982). Regardless of the biological carrying capacity, the socially acceptable carrying capacity for Elk in this area of Ontario will be important. Currently (2013), OMNR's Elk population objective for the Bancroft Area Core Elk Zone is 400 to 600 Elk. This population objective for a 2,500 km² area takes into account the provision of hunting and viewing opportunities as well as preventing and managing human-Elk conflicts.

Also of importance with respect to Elk density is the potential for competition between Elk and other ungulates such as White-tailed Deer and Moose (Bellhouse and Rosatte 2005; Patterson *et al.* 2013). Although Elk currently exist well below the biological carrying capacity of the land, they could compete with White-tailed Deer during winter. This is especially true in deer yarding areas of Bancroft when Elk switch to a diet of browse similar to

White-tailed Deer (Bellhouse and Rosatte 2005; Jenkins *et al.* 2007). Ballard *et al.* (2001) suggested that declines in Mule Deer (*Odocoileus hemionus*) populations in western North America could be due to competition with Elk. In fact, dietary overlap between Elk and Mule Deer in Wyoming, Nevada, and New Mexico was 45%, 45% to 59%, and 64%, respectively (Beck and Peek 2005; Sandoval *et al.* 2005; Tortenson *et al.* 2006). Dietary overlap between White-tailed Deer and Elk near Bancroft was 50 to 57% during two winters (2001/2002) (Jenkins *et al.* 2007) when Elk population size was low (95 to 128 Elk) during the initial stages of the restoration program. However, now (2013) that the herd has increased to about 500 Elk, the potential for competition with other ungulates such as White-tailed Deer may be greater and needs to be carefully monitored with the Elk population size being managed through hunting.

MANAGEMENT IMPLICATIONS

Elk were successfully restored to southern Ontario in 2000-2001, and had quadrupled in numbers by 2013. Populations flourished due to low mortality and high productivity. The density of Elk in the Bancroft area will need to be closely monitored to ensure that there is minimal competition between Elk and White-tailed Deer in wintering areas. As Elk populations increase, the probability of competition for resources between Elk and White-tailed Deer will likely increase especially in deer wintering areas in the Bancroft area (Bellhouse and Rosatte 2005). As a result of the potential for competition, Elk population density in the Bancroft area should continue to be monitored.

Bull:cow and calf:cow ratios should be monitored in the Bancroft area to ensure good productivity and herd health. Managers will need to remain vigilant as Elk numbers increase and range expansion occurs in the Bancroft area. Research and monitoring programs should be expanded beyond the Bancroft Area Core Elk Zone and include social groups of Elk that have become established in other regions of southern Ontario.

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