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ELK CALF SURVIVAL, MORTALITY, AND NEONATAL HABITAT USE IN EASTERN KENTUCKY

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ABSTRACT OF THESIS

ELK CALF SURVIVAL, MORTALITY, AND NEONATAL HABITAT USE IN EASTERN KENTUCKY

I estimated survival, cause-specific mortality, and neonatal habitat use of elk (*Cervus elaphus nelsoni*) calves in eastern Kentucky. I also measured habitat characteristics of elk parturition sites and annual calf production . Radio-collared females were fitted with vaginal-implant transmitters and monitored for parturition behavior to locate, capture, and radio-collar calves during the springs of 2001 and 2002. Thirty-seven adult females with implant transmitters were translocated from Logan, Utah, to Addington Wildlife Management Area (WMA) in eastern Kentucky. Additional females from previous releases during 1997 and 1998 were monitored for parturition behavior. Mean calf production for all females monitored (n=77) was 66.2%. Parturition sites (n=10) were typically in closed-canopy hardwood forest within 152 m of a forest/grassland interface. Female selected sites with more boulders, < 20° slope, a higher percentage of woody saplings, and thicker vegetation between 1.0 – 2.25 m in height compared to random sites. Twenty-seven calves were radio-collared and intensively monitored by ground and aerial telemetry. Mean annual survival was 0.766 (± 0.103). Coyote (*Canis latrans*) predation, meningeal worm (*Parelaphostongylus tenuis*), and human-caused mortality may slow population growth. Retention of implant transmitters for 40 cows ranged from 1 to 276 days (61.6 ± 3.0). Only 2 implant transmitters worked as designed and led to calf captures. I had better success (n=25) capturing calves by monitoring parturition behavior and searching areas where pregnant cows were suspected to have given birth.

KEYWORDS: Calf survival, *Cervus elaphus*, elk, habitat, mortality, vaginal-implant transmitter, wapiti

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in Forestry
in the College of Agriculture at the University of Kentucky.

By
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2003

To my parents, Bill and Lynn Seward,
who’s land ethic and passion for nature
helped me decide to dedicate my life to wildlife conservation.

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INTRODUCTION

The Cervidae has one of the most widespread distributions of mammalian vertebrate families in the world with representative species inhabiting North America, South America, Europe, Asia, and North Africa (Bryant and Maser 1982). The Wisconsin glaciation of the late Pleistocene created environmental conditions favorable for migration of Old World species into North America (Geist 1998). Many of these species lived on Beringia, the land bridge that connected today's Siberian Chuckchi peninsula with Alaska's Seward peninsula, before the bridge was breached creating the Bering Strait ~ 15,500 years B.P. Some of the species present during the Pleistocene and extant in North America are elk (*Cervus elaphus*), moose (*Alces alces*), bison (*Bison bison*), muskox (*Ovibos moschatus*), deer (*Odocoileus spp*.), pronghorn (*Antilocarpa americana*), bighorn sheep (*Ovis canadensis*), caribou (*Rangifer spp*.), and mountain goat (*Oreamnus americanus*) - all of which migrated from Asia, except pronghorn (Pielou 1991). Many predators also crossed Beringia invading North America following the populations of ungulates. These include the gray wolf *(Canis lupus*), brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), and humans (*Homo sapiens*). This period was also notable for the extinction of 35 - 40 species of large mammals, several of which were mega-fauna (Pielou 1991) and potential competitors and predators of elk. The North American elk radiated into 6 subspecies and may have numbered as many as 10 million prior to European settlement (Seton 1927, Murie 1956, Lyon and Ward 1982).

By the early 1900s, Merriam's elk (*C. e. merriami*) and eastern elk (*C. e. canadensis*) were driven to extinction due to unregulated hunting and habitat destruction (Taber et al. 1982, Lyon and Thomas 1987). The eastern elk lived in boreal and hardwood forests, open savannas in the Midwest, and throughout the interior Piedmont of the southeast. It inhabited all of the eastern states, except Florida and northern New England (Boyd 1978, Bryant and Maser 1982). The last known specimen was shot and killed in November of 1867, along the headwaters of the Clarion River in eastern Elk County, Pennsylvania (Gerstell 1936, Bryant and Maser 1982). The eastern elk's extinction represented a 33% reduction in the species' North American range.

The extirpation of the eastern elk in Kentucky coincided with the disappearance of the gray wolf, red wolf (*C. rufus*), mountain lion (*Puma concolor*), bison, swallow-tailed kite (*Elanoides forficatus*), ivory-billed woodpecker (*Campephilus principalis*), Carolina parakeet (*Conuropis carolinensis*), and passenger pigeon (*Ectopistes migratoris*) (Funkhouser 1925, Maehr et al. 1999). Even the abundant white-tailed deer (*Odocoileus virginianus*) was scarce in Kentucky at the beginning of the 20th century (Gassett 2001). Thus, Kentucky has been without most of its large mammalian fauna for more than 150 years. The loss of large mammals can have negative effects on ecosystems, so their restoration should be a conservation priority (Terborgh 1988, Owen-Smith 1988, Dinerstein 1992, Wikramanayake et al. 1998, Maehr et al. 1999).

Elk in the western United States persisted in remote mountainous areas, private reserves, and in the Greater Yellowstone Ecosystem (GYE) during the late 19th century (Robbins et al. 1982). By the early 20th century, the elk population was < 60,000 (Jackson 1944, Wisdom and Cook 2000). Yellowstone National Park (YNP) was created to protect the unique hydrology and scenic landscape, but it also provided a refugium for elk. The Yellowstone Park Protection Act of 1894 addressed unregulated hunting of resident wildlife populations (Bolen and Robinson 1999) and the Lacey Act of 1900 prohibited interstate transport of illegally taken game. These protective laws, establishment of hunting regulations, and enforcement of state game laws allowed dwindling elk populations to recover to sustainable levels.

Throughout recorded history, humans have moved free-ranging wild animals from one location to another (Franzmann 1997). Burris and McKnight (1973) listed 6 translocation objectives: increased recreational hunting, additional food supply, economic gain, population reestablishment, preservation of endangered species, and enhancement of wildlife viewing opportunity. Leopold (1918) discussed the feasibility of elk restoration and warned that crop depredation depended on: 1) the configuration of the country; 2) the extent and distribution of agriculture; and 3) the manner in which elk were liberated. Between 1892-1967, 15,745 Rocky Mountain elk (*C. e. nelsoni*) were translocated from YNP to various locations (Franzmann 1997) including 12 eastern states such as Pennsylvania, Virginia, West Virginia, Michigan, and Wisconsin (Robbins et al. 1982). Witmer (1990) reported that 8 out of 10 elk introductions in the eastern U.S. prior to 1990 were unsuccessful. Documentation of these restoration attempts is sparse, however several factors may have influenced population establishment (or lack there of) such as founder population size, poaching, disease (Byrant and Maser 1982, Kistner et al. 1982, Witmer 1990, Layne 1993), availability of adequate habitat, and highway mortality (Eveland et al. 1979, Cogan 1996, Witmer 1990). The exact limiting factors are largely unknown because of limited post-release monitoring, unknown fates of released animals, insufficient understanding of elk restoration ecology, and a resistance by managers to modify restoration protocols (Larkin 2001). Michigan and Pennsylvania were the only states that successfully established and maintained free-ranging elk populations in the eastern U.S. The success of these introductions was nominally recorded (Eveland et al. 1979) in agency reports and other “gray” literature (Bryant and Maser 1982).

Today, Michigan, Pennsylvania, Wisconsin, and Arkansas support elk populations. Elk restoration throughout the U.S. and Canada has been possible largely because of the financial support from the Rocky Mountain Elk Foundation (RMEF). RMEF is a member-based, international, nonprofit, wildlife conservation organization that targets elk restoration and the management of other wildlife and their habitat. Several state natural resource agencies in the eastern U.S. have recently explored the feasibility of elk restoration. New York, Illinois, Virginia, and North Carolina considered elk restoration, but decided against it due to poor habitat, insufficient space, extensive agricultural lands, too many highways, and human resistance (Van Deelen et al. 1997, Didier and Porter 1999, McClafferty and Parkhurst 2001). West Virginia is currently studying the feasibility of reintroduction (T. Brown, Cornell University, pers. comm). In 1997, the Kentucky Department of Fish and Wildlife Resources (KDFWR) conducted a literature review (Phillips 1997) and held public forums to educate and poll citizen’s attitudes toward elk restoration. Larkin et al. (2001) described in detail the establishment of public support and the evolution of the elk restoration protocol. With the collaboration among RMEF, KDFWR, the University of Kentucky, and private landowners, 168 elk were released during the winter of 1997-98 in Perry County (Maehr et al. 1999). These were the first of 1800 elk scheduled for release over 9 years (Phillips 1997). Today, Kentucky has released 1,541 elk and supports the largest free-ranging elk herd in the eastern U.S. (J. Day, KDFWR, pers. comm). Additional stocking efforts will not occur because of the concern of possibly introducing chronic wasting disease (CWD) (Spraker et al. 1997). To date, all shipments of elk have come from populations free of CWD.

Success of translocation depends on a number of factors such as condition and health of the individuals, habitat quality at the release site, and time of year (Mosillo et al. 1999). The ability of a species to adapt to a new landscape and successfully reproduce facilitates establishment of a permanent population. Elk are tolerant of a range of environmental variables (Skovlin 1982) and can habituate to human disturbances if they are predictable and nonthreatening (Thompson et al. 1998). Potential disturbances associated with the eastern Kentucky landscape include strip mining, logging, forest fires, vehicular traffic, off-road vehicles (Orvs), poaching, dogs, wildlife viewing, and other recreational uses. These disturbances can displace elk from optimal habitat (Johnson 1985, Kuck et al. 1985, Wichrowski 2001), which may negatively affect energy budgets, reproduction, calf recruitment, and population growth.

Female elk generally carry a single fetus during gestation, twinning occurs in < 1% of births (Haigh and Hudson 1993), and may be an indicator of optimal habitat (Wisdom and Cook 2000). Gestation averages 255 days (range = 247-262) (Haigh and Hudson 1993, Haigh 2001). Parturition usually occurs from mid-May to mid-June in North America (Bubenik 1982, Skovlin 1982). Birth date, birth mass, nutrition, diseases, and parasites influence calf size and vigor (Taber et al. 1982). Winter weight loss in females that exceeds 14% may cause prenatal calf loss, low birth mass, and low calf survival (Thorne et al. 1976). Extreme weather conditions or associated stress can cause re-absorption of fetuses and increase neonatal mortality (Banfield 1949). Stress associated with translocation caused re-absorption of fetuses during the reintroduction of elk at Land Between the Lakes (LBL) – Elk and Bison Prairie Range in western Kentucky (Steve Bloemer, USDA Forest Service, pers. comm). Severe winter stress is unlikely to be an important mortality factor in Kentucky because of the relatively mild winter temperatures and minimal snow accumulation compared to the western U.S.

Female elk leave the herd a few days before giving birth (Graf 1943, Craighead et al. 1972) and use ecotones with various forms of hiding cover and nutritious forage (Skovlin 1982). Calving sites have been described as a specialized kind of habitat, although this concept is not universally accepted (Johnson 1951, Roberts 1974, Thomas et al. 1979, Lyon and Ward 1982). In western populations parturition is synchronized (McLean 1972, Skovlin 1982) with migration to higher elevations in summer (Kuck et al. 1985). Some individuals repeatedly use the same calving areas (Zahn 1974, Stillings 1999, Vore and Schmidt 2001). Moran (1973) stated Rocky Mountain elk introduced to portions of the original eastern elk range do not display migratory behavior. However, Kentucky females appear to move before parturition to isolate themselves from the herd (C. Logsdon, KDFWR, pers. comm). This behavior likely reduces scent in the calving area and may lessen the probability of predation.

Newborn calves anti-predator defense is to remain motionless when threatened and let their cryptic coloration and white spotted coats camouflage them. High quality calving habitat may reduce predation and promote colonization and growth of the population. Characteristics of calving habitat in eastern elk populations are poorly understood. Beyer (Michigan DNR, pers. comm) suggested that pregnant cows did not shift habitat use in response to parturition in Michigan. In the western United States, females appeared to select areas with gradient ecotones (Roberts 1974), downed logs, or other woody cover (Phillips 1966). Stillings (1999) found that cattle, slope, forest type, distance from roads, and cover type were important factors in calving site selection. Calving sites were further from roads, on steeper slopes (12-29°), had greater hiding cover (denser vegetation), and were located in ponderosa pine or riparian forest habitat. Black et al. (1976) suggested that pregnant cows in the Pacific Northwest need escape and thermal cover in the form of forests, whereas calves need hiding cover in the form of shrubs or fallen timber. Lactating females need succulent forage and were located on average within 305 m of water and on gentle terrain (Black et al. 1976). Idaho elk calved in conifer stands mixed with aspen (*Populus tremuloides*) and adjacent to open sagebrush (*Artemesia spp*.) shrub lands and meadows (Phillips 1974).

Hiding cover appears to be an important component of calving habitat (Stillings 1999) because it contributes to human and predator avoidance. Human activity, mining, coyotes, and free-ranging dogs may influence parturition site selection in Kentucky elk. Feral horses (*Equus spp*.) and cattle (*Bos taurus*) may displace pre-parturition elk. Stillings (1999) documented that pre-parturition females in Nebraska were more likely to calve in pastures when cattle were absent. Elk avoided pastures with cattle with a stock density was 0.33 cattle/ha. Road distribution and subsequent human activity may also influence Kentucky calving sites. However, the rugged topography, limited access, and limited human activities on some reclaimed mines may ameliorate the effect of roads and human disturbances elsewhere (Edge and Marcum 1991).

Elk are susceptible to a variety of diseases and physical anomalies (Kistner et al. 1982), but the meningeal worm (*Parelaphostrongylus tenius*) is the cause of the most common disease among re-established eastern elk populations (Severinghaus and Darrow 1976, Eveland et al. 1979, Raskevitz et al. 1991). This macroscopic nematode inhabits the central nervous system of its host and causes neurological damage. Where sympatric with white-tailed deer (with which it coevolved), elk can be negatively affected by *P. tenuis* (Eveland et al. 1979). The meningeal worm has been implicated in the failure of several elk reintroductions (Carpenter et al. 1973, Severinghaus and Darrow 1976, Raskevitz et al. 1991), however no cause-and-effect has been demonstrated. Samuel et al. (1992) suggested that self-sustaining elk populations in the eastern U.S. might depend on the ability of some individuals to survive with low parasite infestation.

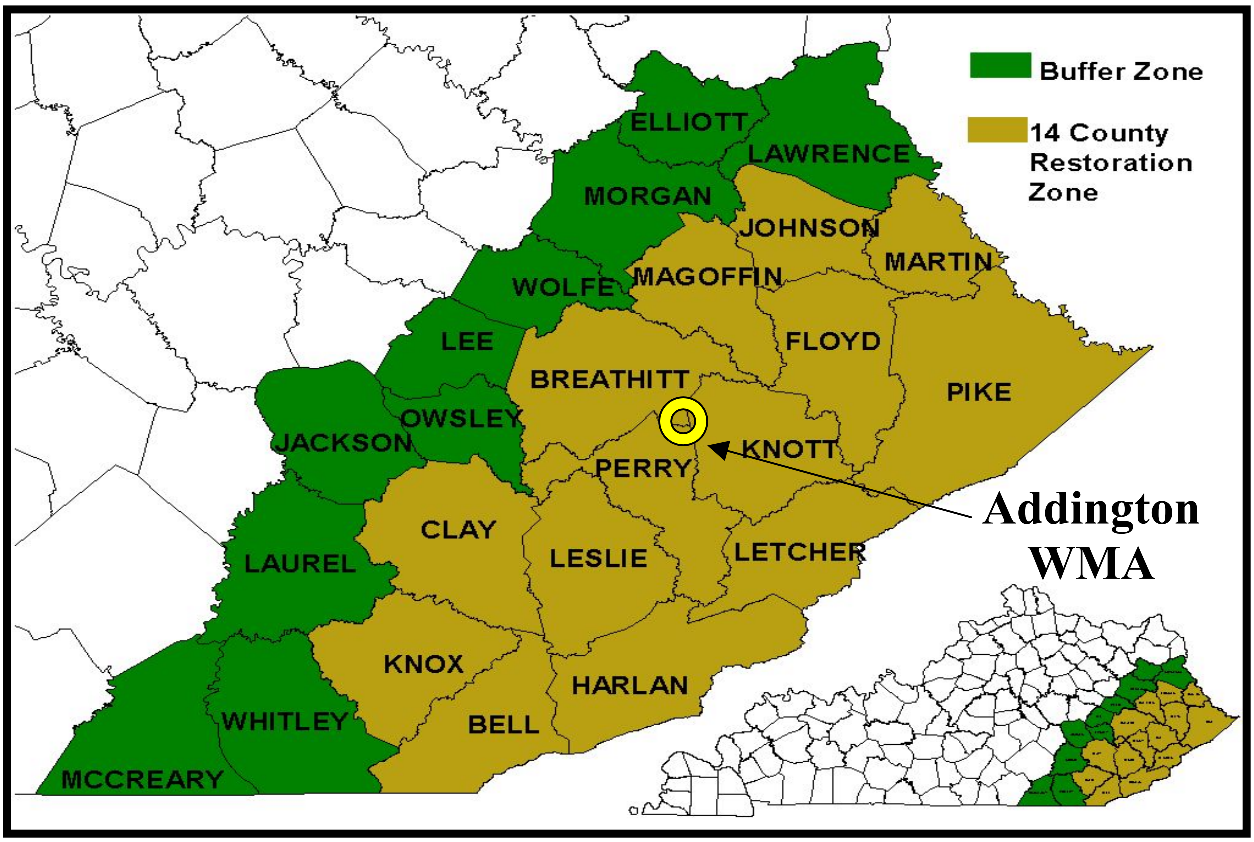
Recreational hunting is the main cause of mortality in western elk populations (Bunnell 1987, Wisdom and Cook 2000). Disease, poaching, and removal of nuisance animals appear to be the leading causes of mortality among re-introduced elk in eastern North America (Severinghaus and Darrow 1976, Witmer 1990, Cogan 1996). Mortality affects recruitment, population growth, age structure, and sex ratios (Bolen and Robinson 1999). Especially high mortality rates can have negative effects on isolated populations (Bolen and Robinson 1999). Juvenile survival to recruitment age is an important consideration for Kentucky managers because it directly affects population growth and colonization (Taber et al. 1982). Kentucky elk densities are likely low compared to western herds. Colonizing populations, which typically are not limited by habitat or density constraints, may exhibit higher mean fecundity (Raedeke et al. 2002). Without resource competition, females should be healthier, bear heavier calves, and produce ample milk (Oldemeyer et al. 1993). Evidence of adequate habitat for elk in Kentucky includes twinning, consecutive year pregnancies, (Larkin 2001) and reproduction by yearling females (C. Logsdon, KDFWR, pers. comm.).

Kentucky elk restoration has been well documented because of research conducted since 1997 (Larkin et al. 2001). Initial studies examined demographic and spatial characteristics (Larkin et al. 2002), effects of elk on amphibian populations (Secrist 2000), activity, movements, and habitat use (Wichrowski 2001), and the effects of elk on shrub-nesting birds (Ciuzio 2002). Although initial survival estimates were high in the adult and yearling age-classes, little was known about Kentucky-born calves. The objectives of my research was to document calf survival, cause-specific mortality, habitat characteristics of parturition sites, and neonatal habitat use. An accurate understanding of juvenile survival and how it affects population dynamics is critical to managing recovery and restoration. Documentation of parturition sites and neonatal habitat can be incorporated in management plans to enhance calf survival and overall population growth.

STUDY AREA

The restoration zone covers more than $1.05x10^6$ ha in 14 counties of the Cumberland Plateau region in southeastern Kentucky (Figure 1). This area supports a sparse human population (30-60 people per km^2) (Watkins 1998), limited agriculture (1%), and large areas of reclaimed strip mines (8%) (Phillips 1997). The southeastern Kentucky landscape is a mosaic of second growth mixed mesophytic forest and reclaimed surface mines. Addington Wildlife Management Area (WMA) (formerly Cyprus-Amax WMA) is a 7,400 ha coal mine with approximately 4,400 ha of forest, 2,000 ha of reclaimed grassland and 1,000 ha of active mining (Larkin et al. 2002). Undisturbed topography consists of narrow, winding ridges, steep side slopes, deep dendritic drainages, and narrow valleys (McFarland 1943). Elevations range from 244 – 488 m above mean sea level (Overstreet 1984). The highest point in the restoration zone is 1,261.5 m above mean seal level on Black mountain (Miller 1919).

Figure 1 Fourteen county elk restoration zone, 10 county buffer zone, and Addington WMA in southeastern Kentucky.



Reclaimed grasslands are a mixture of exotic grasses and other herbaceous plants, but are dominated by Kentucky-31 fescue (*Festuca arundinacea*), perennial ryegrass (*Lolium perenne*), orchardgrass (*Dactylis glomerata*), sericea lespedeza (*Lespedeza cuneata*), crown vetch (*Coronilla varia*), common bird's-foot-trefoil (*Lotus corniculatus*) white sweet clover (*Melilotus alba*), yellow sweet clover (*Melilotus officianalis*), and red clover (*Trifolium pratense*) (Hamner 1998). Woody vegetation includes black locust (*Robinia pseudoacacia*), autumn-olive (*Elaeagnus umbellata*), American sycamore (*Platanus occidentalis*), white pine (*Pinus strobus*), Virginia pine (*Pinus virginiana*), eastern redbud (*Cercis canadensis*), and hazel alder (*Alnus serrulata*).

Approximately 30 dominant canopy tree species make up the mixed mesophytic forest including American beech (*Fagus grandiflora*), yellow-poplar (*Liriodendron tulipifera*), basswood (*Tilia* spp.), sugar maple (*Acer saccharum*), northern red oak (*Quercus rubra*), white oak (*Quercus alba*), eastern hemlock *(Tsuga canadensis*), and yellow buckeye (*Aesculus octandra*) (Braun 1950). Common mid-story trees include eastern redbud, flowering dogwood (*Cornus florida*), spicebush (*Lindera benzion*), magnolias (*Magnolia spp.*), sourwood (*Oxydendrum arboreum*), American hornbeam (*Carpinus caroliniana*), eastern hophornbeam (*Ostrya virginiana*), downy serviceberry (*Amelanchier arborea*), and paw paw (*Asimona triloba*). Elk use scattered forest patches for resting and ruminating (Wichrowski 2001).

The climate of the study area is temperate humid continental with warm summers and cool winters (Overstreet 1984). Average annual temperature is 13°C (Hill 1976), with mean winter temperature of 4°C, and mean summer temperature of 24°C (McDonald and Blevins 1965). Annual precipitation averages 117 cm and is evenly distributed throughout the year (Hill 1976, Overstreet 1984). Snowfall averages 50.8 cm annually with accumulation usually lasting no more than a few days (McDonald and Blevins 1965).

Disturbances such as automobiles, mine equipment, all-terrain vehicles (ATVs), and free-ranging dogs (*Canis familiaris*), occur throughout the WMA. Potential elk predators include black bear (*Ursus americanus*), coyote (*Canis latrans*), and free-ranging dog (Scott and Causey 1973). Canids may target newborn elk, however predation will likely be minimal because of the abundance of various other prey and the ability of adult females to fend off single coyotes (Gese 1999). As of the winter of 2002-03, the current elk population in eastern Kentucky is estimated at 2,000 – 2,400 animals (J. Day, KDFWR, pers. comm.).

MATERIALS & METHODS

Translocation. In 2001, adult female elk (≥ 2.5-years-old) were captured by net-gun from a helicopter (Barrett et al. 1982, DeYoung 1988, Schemnitz 1994) and transported to Hardware Ranch WMA operated by the Utah Department of Wildlife Resources (UDW) in Logan, Utah. Pregnancy was indicated if blood serum progesterone levels were > 1 ng/ml (Schmitt et al. 1986, Willard et al. 1994, Bender et al. 2002). Pregnant females were ear-tagged with a Duflex® plastic tag (Destron Fearing Corp., South Saint Paul, MN., USA), fitted with a collar-mounted VHF radio transmitter (Telemetry Solutions, Concord, CA., USA, Telonics Inc., Mesa, AZ., USA, and Lotek Engineering, Newmarket, Ontario, Canada), and a vaginal-implant transmitter (Advanced Telemetry Systems, Inc., Isanti, MN., USA) (Appendix A, Figure 11). Instrumented elk were transported non-stop to Kentucky and released at Addington WMA (Figure 2) following established protocol (Larkin et al. 2001).

Parturition Monitoring. In April 2001 and 2002, adult females with radio collars previously released at Addington WMA were chemically immobilized using a DanInject delivery system and carfentanil citrate (Wildnil®, Wildlife Pharmaceuticals, Inc., Fort Collins, CO., USA). Pregnancy was determined by rectal palpation (Greer and Hawkins 1967). Pregnant females were then fitted with a vaginal-implant transmitter. I continued to monitor female elk for parturition behavior if they prematurely expelled the vaginal-implant transmitter. In addition, I randomly selected a group of radio-collared adult females translocated to Addington WMA from previous years for parturition behavior monitoring. I monitored this group strictly by their radio collars, without the use of implant transmitters. Movements from the herd, dispersal to new areas, restricted movement patterns (Langley and Pletscher 1994, Vore et al. 1996, Kastler 1998, Vore and Schmidt 2001), reluctance to leave an area when approached by researchers, and bark vocalizations were behavioral cues that suggested parturition. I initiated a calf search when these behaviors were detected during the calving season (1 May – 30 June).

Figure 2 Adult females released at Addington WMA on February 25, 2001.

All radio-instrumented elk were located once per week, weather permitting, using aerial and ground telemetry (Mech 1983) until the calving season. During the calving season, all radio-collared elk were located 2-3 times per week. Females with implant transmitters were monitored daily. Aerial telemetry was performed in a Cessna 182, using a Lotek GRX receiver with scanner and 2 wing-strut mounted “H” antennae (Telonics, Inc., Mesa, AZ). Locations were recorded as Universal Transverse Mercator (UTM) coordinates (Grubb and Eakie 1988) with a Magellan ColorTRAK global positioning system (GPS) unit (Magellan Systems Corp., San Dimas, CA) in 2001 and a GARMIN GPS 3+ unit (GARMIN International, Inc., Olathe, KS) in 2002. I recorded locations during aerial telemetry flights on a datasheet and later plotted the locations in ESRI ArcView on digitalized U.S. Geological Survey (USGS) topographical maps (DRT, 1:24,000).

Radio-telemetry error was estimated by comparing aerial locations of dropped collars and animal mortalities to the “true” ground location measured with a GPS unit when the collar or animal was retrieved. Distance error (D) was calculated between aerial and ground UTM locations by using the formula: $D=sb\{(X_1-X_2)^2 + (Y_1-Y_2)^2\}$, where X_1 = Aerial UTM northing coordinate, X_2 = Ground UTM northing coordinate, Y_1 = Aerial UTM easting coordinate, and Y_2 = Ground UTM easting coordinate (White and Garrott 1990). I summed the differences of all locations and divided by the number of pairs (n=25) for the mean distance error between aerial and ground locations.

Calf Production. I documented calf production through direct observation and by approaching females that displayed parturition behavior. Searches were conducted on all radio-collared females at least 3 times during the calving season or until a calf was observed. With the help of Earthwatch volunteers, cow and calf pairs were flushed and observed from a distance using binoculars or a spotting scope. Females without a calf by 1 August were considered solitary or reproductively fallow for the year. Females that dispersed to new areas during the calving season and that displayed parturition behavior, but were not observed with a calf were also considered “fallow”. Thus, annual calf production ratios should be somewhat conservative. Reproductive success in this study is presented as the number of calves / 100 females.

Calf Capture. Field searches were conducted during the calving season in 2001 and 2002. Increased pulse rates or stronger radio signals of implant transmitters initiated calf searches. Searches began at sites where implants were found or, in the case of females without implant transmitters, at the location where the female was last observed. Groups of 1-3 researchers systematically searched the area by expanding outward from the center of the site. Elk calves were captured by hand as described by White et al. (1972), ear-tagged, and fitted with a 200-g Vhf transmitter mounted on an expandable collar (Advanced Telemetry Systems, Inc., Isanti, MN) (Keister et al. 1988, Smith et al. 1998) (Figure 3 and 4). Collars expanded from 25 – 80 cm to prevent asphyxia as calves matured and were equipped with a 4-hour mortality delay switch. Transmitter battery life was 24 months. I recorded sex, age, capture location, body weight, length, chest girth, radio frequency, and body condition (Appendix B). Age was estimated by size and condition of the umbilicus, degree of umbilicus healing, hardening of the hooves, hoof wear, and the mobility and coordination of the animal (Johnson 1951). Capture weight was determined by placing the neonate in a large cotton bag and suspending them with a 25 kg Homs (Douglas Homs Corp., Belmont, CA.) spring scale. The weight of the bag was then subtracted from the total weight.

Survival. Radio-collared calves were monitored daily by aerial and ground telemetry for calf mortality signals. Volunteers searched for and observed calves every 3 days for 60 days post-capture to document survival and habitat use. The GPS location, group size, behavior, and distances to various landscape features such as water or a road was recorded (Appendix C). Calves were monitored once weekly starting mid-August 2001 through December 2002. Cause of death was determined in the field from physical evidence, including carcass condition (i.e., trauma, tissue consumed, buried, puncture wounds) and presence of sign (tracks, scat) of other species (O'Gara 1978, Wade and Bowns1985) (Appendix E). If the carcass was fresh or cause of death could not be determined in the field, it was transported to the University of Kentucky Livestock Disease Diagnostic Center (LDDC) for a complete necropsy. I estimated date of mortality as the midpoint between the calf's last observation or normal telemetry signal and when the carcass was found. I used the Kaplan-Meier product-limit estimator (Kaplan and Meier 1958) modified for staggered entry (Pollock et al. 1989) to estimate survival of calves during the neonatal (birth-15 July) and fall (1 Oct-31 Dec) periods, and on an annual basis. Calves were censored from the data set as radio-collars were shed. A time interval of 1 day was used for survival rate calculations and all means are presented ± standard error (SE). The moderately conservative log-rank test was used to compare survival estimates between the 2 periods and between years (Pollock et al. 1989). I assumed each calf captured was an independent experimental unit, had equal probability of survival, being captured, and that radio transmitters did not influence survival or behavior. Elk calf studies that reported capture weights (Johnson 1951, Schlegel 1976, Smith et al. 1997) typically have not indicated the portion of the calf crop with low birth weights (Cook 2002). I estimated the predicted birth weights by multiplying the age (days-old) by 0.635 kg per 100 kcal daily growth rates to determine the portion of calves with low birth weight and greater susceptibility for mortality (Cook et al. 1996).

Characteristics of Parturition Sites. Locations of parturition sites were recorded with a GPS unit and marked with pink flourescent flagging. Center points of calving sites were recorded as the location where the implant transmitter was found (n=2) or where field sign suggested otherwise. Female elk usually consume the after-birth and all vegetation exposed to amniotic fluids to reduce scent and calf susceptibility to predation (Geist 1982). Areas where all vegetation was consumed in the vicinity of the calf capture location was recorded as the parturition site.

Figure 3 Expandable radio-collar on Kentucky elk calf.

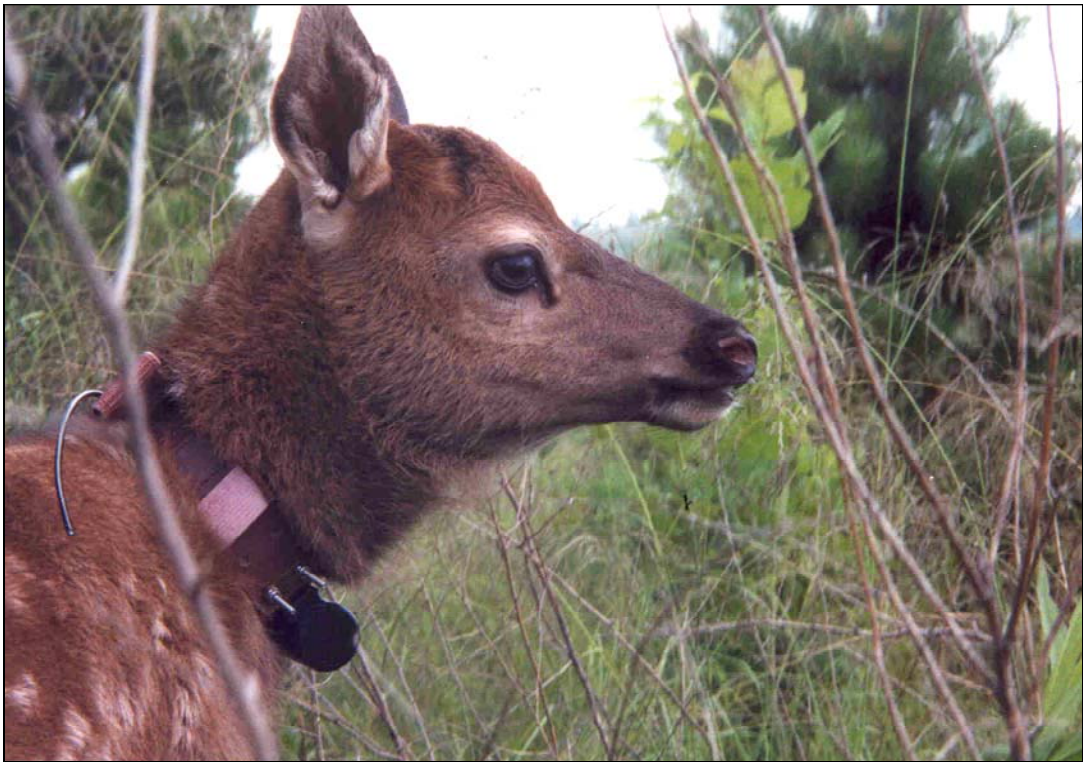


Figure 4 Expandable radio-collar and identification ear-tag applied to elk calves.

Vegetation at parturition sites was measured within a 0.04 ha circular plot (James and Shugart 1970) after radio telemetry indicated the cow and calf pair had abandoned the area. Sampling began 1 July, concluding the calving season, and continued until 20 August. I recorded slope, slope position (bottom, mid, top, or ridge-top), number of downed logs > 10 cm and boulders > 50 cm diameter, ground cover, litter depth, tree basal area, horizontal vegetation density, over-story canopy coverage, shrub and canopy height, and distance to nearest water, edge, active mine, and main and secondary roads. I used a Geographic Information System (GIS; ArcView, Redlands, CA.) to measure the distance to nearest water source, forest edge, active mine, and main and secondary roads, using ArcView's Nearest Features extension tool (ESRI 1999) unless the distance was < 100 m and could be accurately measured in the field. Main roads had higher traffic volume and were typically highways or state routes. Paved dead-end roads, cul-de-sacs, and gravel and mining roads normally characterize secondary roads. Slope and aspect were determined using a compass. Ground cover was measured using a 1-m2 plot (Bonham 1989) positioned in each quadrant (NW, NE, SE, SW) approximately 3 m away from the center point. Percent coverage of grass, forbs, woody sapling, vine, dead woody debris, bare ground/rock, and litter were estimated within the 1 m^2 plot. Litter depth was measured with a ruler (mm). Tree basal area was calculated by counting the number of stems with a #10 cm prism (Higgins et al. 1996). I counted boulders > 50 cm because this is the approximate size of a newborn elk calf and could provide additional cover. I included downed logs > 10 cm in diameter as another form of hiding cover. Dead woody debris < 10 cm was randomly measured in the 1 m^2 plot. The number of tree stems 2.5-5.1, 5.1-10.2, and 10.2-15.2 cm in diameter was counted as a measure of horizontal cover. Over-story canopy coverage was estimated using a spherical densiometer (Lemmon 1957). Percent coverage of horizontal vegetation was estimated using a 2.25 m checkered density pole 11.3 m from the center point in the four cardinal directions (north, south, east, and west). The percentage of the pole visibly obstructed from the center point at 4 levels (0-0.2, 0.2-0.6, 0.6-1.0, and 1.0-2.25 m) was recorded and a mean value for each level calculated among the 4 directions. I also generated a mean value for litter depth and the percent coverage of grass, forbs, woody sapling, vine, dead woody debris, bare ground/rock, and litter in the 1-m^2 plot. Dominant woody and herbaceous species were identified and recorded. A total of 28 variables were measured for each vegetation site.

Logistical regression would be an appropriate technique to model characteristics of parturition sites. Unfortunately, parturition site sample size was low (n=10) compared to the number of variables measured (n=28). The use of logistic regression in this case could result in models that tailor to the data, i.e., are over-fitted. Over-fitting can result in unrealistically large estimates of precision and can diminish the validity of inferences about the data (Burnham and Anderson 1998). I constructed box-and-whisker plots to identify variables with central tendencies that varied between parturition and random sites (Johnson 1999). I selected a subset of variables that showed differences in central tendency between random and used sites, statistical integrity (normal distribution, low multicollinearity), and biological integrity (relevance to elk ecology). For each variable in the chosen subset, I performed analysis of variance (ANOVA, PROC GLM; SAS Institute 1990) to compare differences among the parturition, random, and neonatal habitat sites. Before performing ANOVAs, all percentage data were arcsine transformed to comply with the assumption of normality. Results were considered significant if P #0.05.

Neonatal habitat. Earthwatch volunteers assisted me with homing in on collared calves approximately every 3 days to document survival. Volunteers recorded the location of the calf with a GPS unit (Appendix C). Habitat characteristics of these sites were sampled as described for parturition sites during the same time frame after the cow and calf abandoned the area.

RESULTS

Translocation. Thirty-seven adult female elk were net-gunned from a helicopter at Hardware Ranch, fitted with radio-collars and vaginal implant-transmitters and released at Addington WMA. Fourteen females with implant transmitters died from capture related injuries within 6 weeks post-release. Due to this high mortality, 20 and 24 adult females with radio-collars from previous releases were randomly selected for parturition monitoring during 2001 and 2002, respectively. All translocated females except one, stayed within ~35 km of the release site (Figure 5).

Parturition Monitoring. In 2001, 2 implant transmitters were expelled during the ~3,000 km transport to Kentucky. Sixteen implants were expelled pre-partum. In 4 instances, transmitter pulse rate did not change after exposure to ambient conditions and reduced temperature. In addition, 3 adult females previously released at Addington WMA were chemically immobilized and equipped with implant transmitters. All 3 implants in these anesthetized females prematurely expelled within 14 days. I continued to monitor females that prematurely expelled implants for parturition behavior and movement patterns. Overall, implant transmitters were unsuccessful. I had better success locating and capturing calves by patterning females' movements and behavioral cues. Three behavioral cues that divulged the presence of a calf for all calf captures was dispersal to a new area (63%), reluctance to leave when approached by researchers (85%), and bark vocalizations (30%). All females displayed at least 1 or more of these behaviors before the calf was captured. Further description on the efficacy of vaginal-implant transmitters is in Appendix A.

Figure 5 Locations of translocated female elk relative to the release site between February of 2001 and December of 2002.

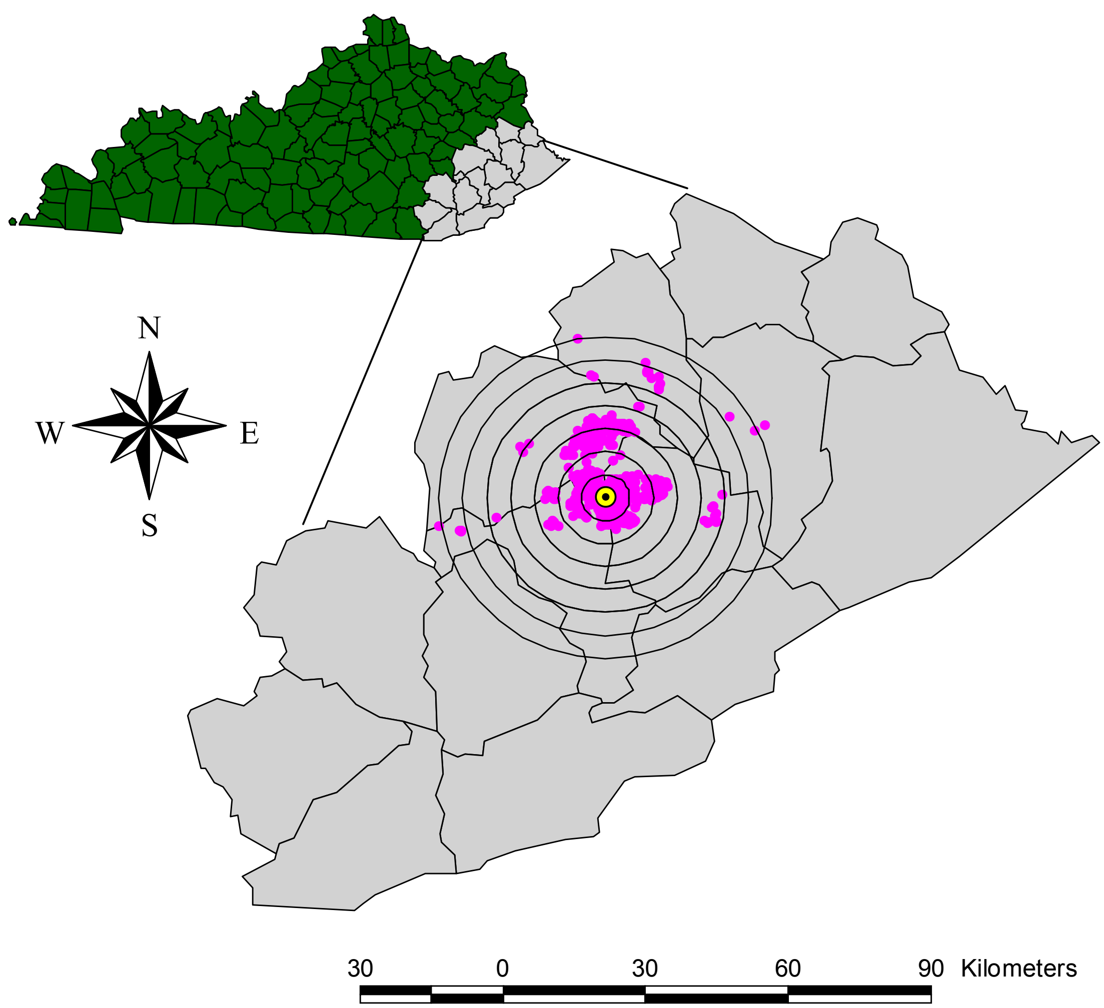
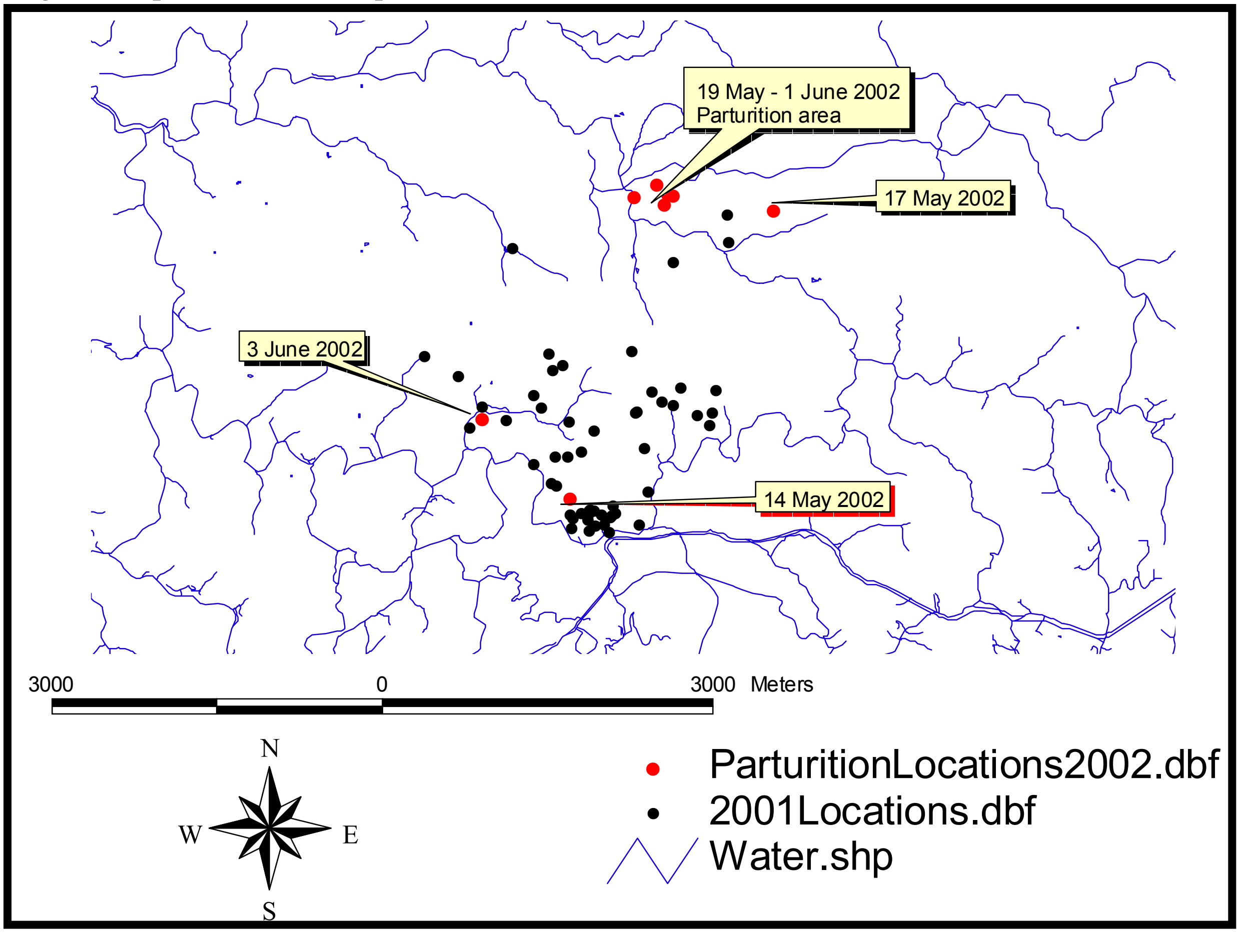


Figure 6 Spatial movement pattern of adult female #255.



During 2001, telemetry error between aerial and ground locations was 387.94 ± 48.61 m (n=9) using the Magellan GPS unit. During 2002, telemetry error was reduced to 202.40 ± 24.21 m (n=16) for the Garmin GPS 3+. Accuracy of telemetry locations was enhanced by direct observation and use of a 12-channel GARMIN GPS 3+ unit, which received more satellite signals. Mean aerial telemetry error between years was 269.20 ± 24.07 m (n=25). Accuracy of aerial locations was inhibited by weather, rugged topography, and pilot experience. Typical estimated percentage error (EPE) with ground locations using the GARMIN GPS unit was < 23 m. Accuracy of ground locations with the GPS unit was dependent upon canopy cover, topography, and weather.

Calf Production. Peak calving occurred on 26 May and 1 June during 2001 and 2002, respectively (Figure 7). Calf production for females translocated with vaginal-implant transmitters and sired by bulls in Utah (n=19) was 37:100 during 2001 (Table 1 and 2). Calf production for these females (n=14) increased to 64:100 during 2002. Calf production was higher for females with more than 1 calving season in Kentucky. Previously released females that I selected for parturition monitoring (n=20, n=24) exhibited calving rates of 70:100 and 87:100 during 2001 and 2002, respectively. Mean calf production for all females monitored (n=77) was 66:100 (Table 2).

Figure 7 Parturition dates and peak activity for 2001 and 2002 calving seasons.

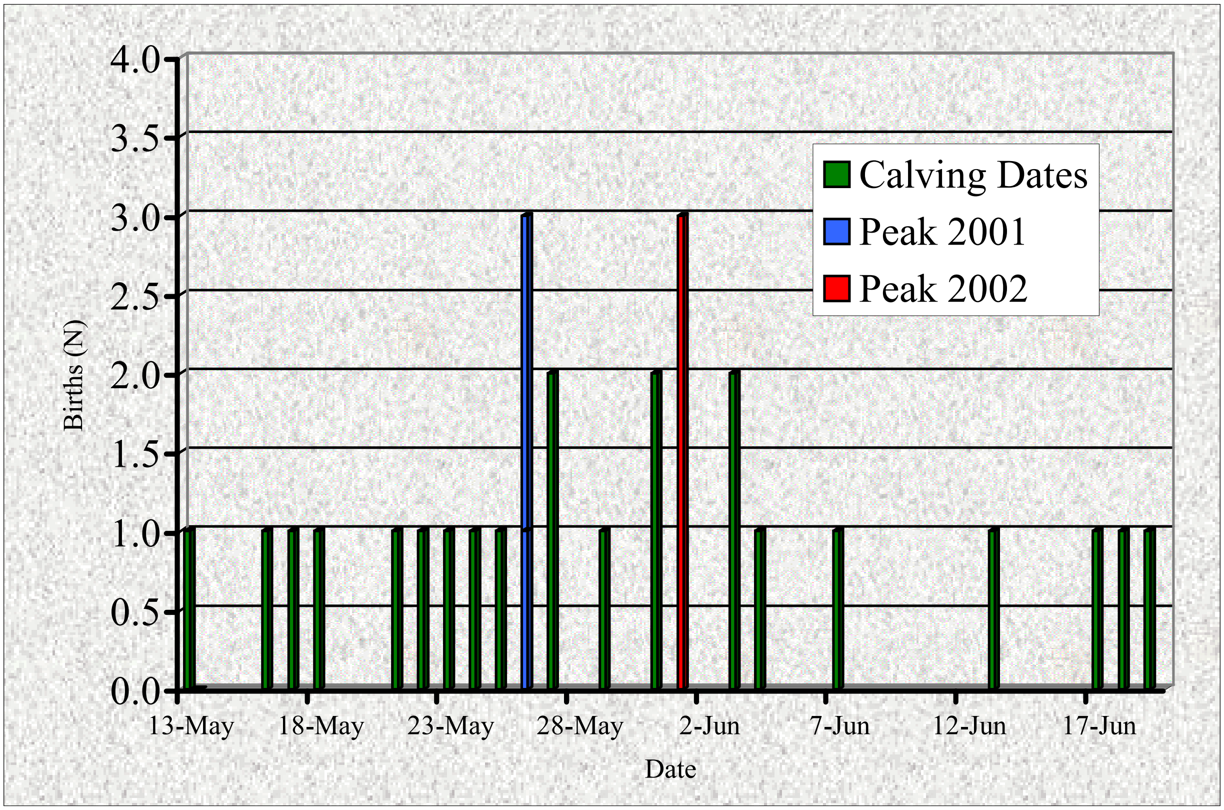


Table 1 Calving history of adult female elk translocated and randomly selected for parturition monitoring at Addington WMA.

#	I.D.#	Ear tags	2001	2002
1	C3	W#91	Calf	Not monitored
2	521	None	Calf	Calf
3	L18	P#9/10	No	Not monitored
4	L11	P#3/4	Cow died	Cow died
5	L12	P#1/2	No	MIA
6	L16	P#11/12	Cow died	Cow died
7	L14	P#13/14	Cow died	Cow died
8	None	P#23/24	No	MIA
9	L15	P#7/8	Cow died	Cow died
10	524	W#363	Not monitored	Calf
11	402	P#15/16	Calf	Cow died
12	222	P#73/74	No	Calf
13	522	W#327	No	Calf
14	97	W#244	Unknown	Calf
15	528	W#367	Calf	Calf
16	59	W#82	No	Calf
17	404	None	Not monitored	No
18	511	W#398	Not monitored	Calf
19	70	W#107	Calf	Calf
20	52	W#98	Unknown	Calf
21	58	P#27/28	No	No
22	512	W#395	Not monitored	No
23	2	P#61/62	Calf	Not monitored
24	2	P#21/22	No	Calf
25	E2	P#5/6	MIA	Not monitored
26	230	P#43/44	Cow died	Cow died
27	230	W133	Not monitored	Calf
28	526	P#31/32	Cow died	Cow died
29	531	P#65/66	Cow died	Cow died
30	262	Y#80	Not monitored	No
31	532	P#59/60	Calf	No
32	360	P#39/40	Cow died	Cow died
33	373	P#41/42	No	Calf
34	None	P#17/18	Cow died	Cow died
35	154	P#25/26	Calf	No

Table 1 (Cont.)

#	I.D.#	Ear tags	2001	2002
36	64	W#93	Calf	Not monitored
37	429	B#34	Calf	Calf
38	509	P#33/34	MIA	Cow died
39	156	W#234	Calf	Not monitored
40	255	P#53/54	Calf	Unknown
41	443	P#35/36	Cow died	Cow died
42	48	W#85	Calf	Not monitored
43	294	P#49/50	Cow died	Cow died
44	158	W#235	No	Not monitored
45	50	W#109	Calf	Calf
46	86	W#163	No	Calf
47	335	P#45/46	No	Calf
48	331	P#29/30	Cow died	Cow died
49	105*	W#125	No	Calf
50	56	W#95	Calf	Calf
51	332	P#51/52	MIA	MIA
52	67	W#111	Calf	Not monitored
53	53	W#118	Calf died	Calf died
54	284	P#47/48	No	Calf
55	77	W#121	Calf	Not monitored
56	282	P#55/56	Cow died	Cow died
57	535	P#71/72	No	Calf
58	74	W#117	Calf	Not monitored
59	534	P#63/64	No	Calf
60	250	P#37/38	No	Calf
61	281	P#57/58	Calf	No
62	285	W#396	Not monitored	Calf
63	529	P#67/68	Cow died	Cow died
64	288	W#381	Not monitored	Calf
65	536	P#69/70	Calf	No
66	117	W#160	Calf	Cow died
67	Uncollared	Unknown	Not monitored	Calf
68	Uncollared	Unknown	Not monitored	Calf
69	Uncollared	Unknown	Not monitored	Calf
70	Uncollared	Unknown	Not monitored	Calf

Table 2 Calf production between translocated and previously released adult females during 2001 and 2002.

Year	Translocated	Established	All Females
2001	37/100	70/100	54/100
2002	64/100	88/100	80/100
Mean	48/100	80/100	66/100

Calf Capture. I captured and radio-collared 27 calves that ranged in age from < 1 to 10-days (0=4.18 ± 0.51 days) (Table 3). Twenty-five of these were captured without use of implant transmitters. I confirmed another 32 calves by monitoring cow parturition behavior, but these calves were too old to capture. Most captured calves (24; 89%) were located within 40 m of the dam. An average of 34.5 hours was invested for each calf captured. Premature expulsion and malfunction were prevalent problems with vaginal-implant technology in free-ranging elk and resulted in only 2 captured calves out of 40-instrumented cows (Appendix A).

Figure 8 Elk calf age versus weight between sexes for 2001 and 2002.

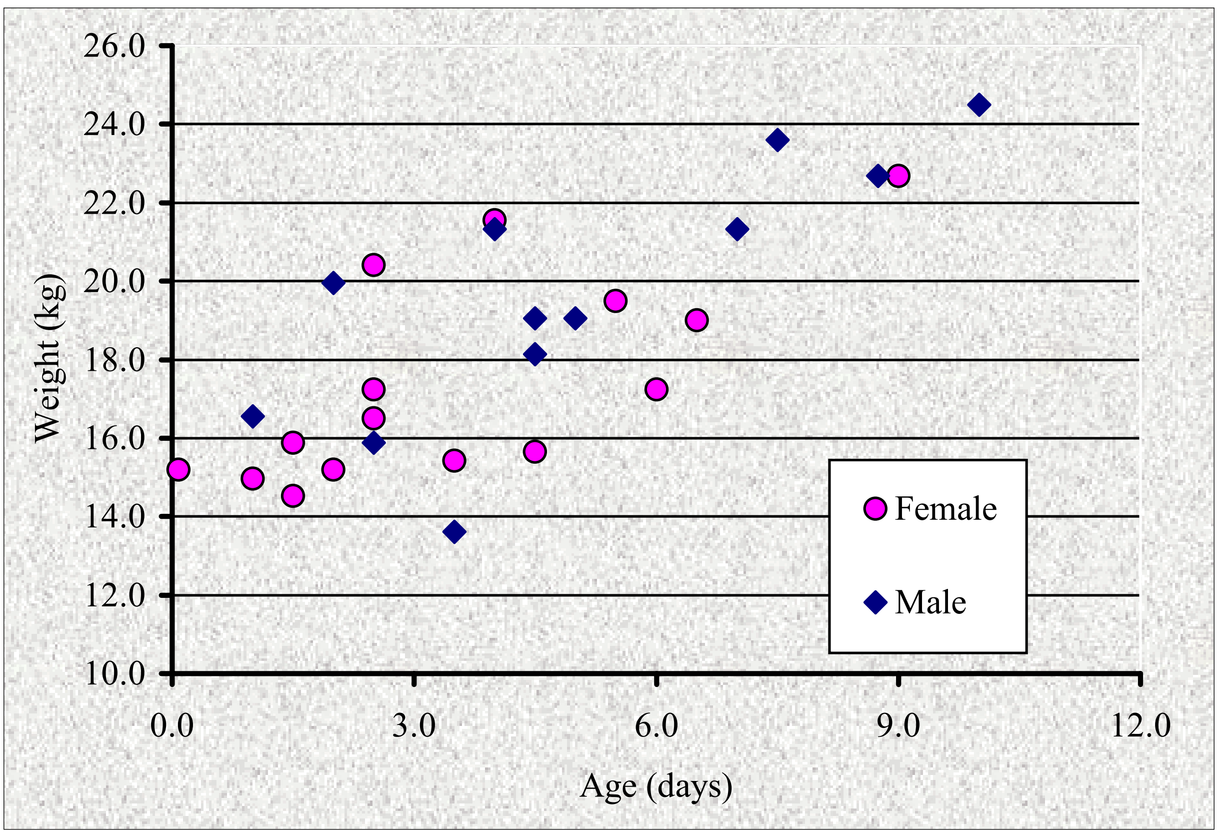
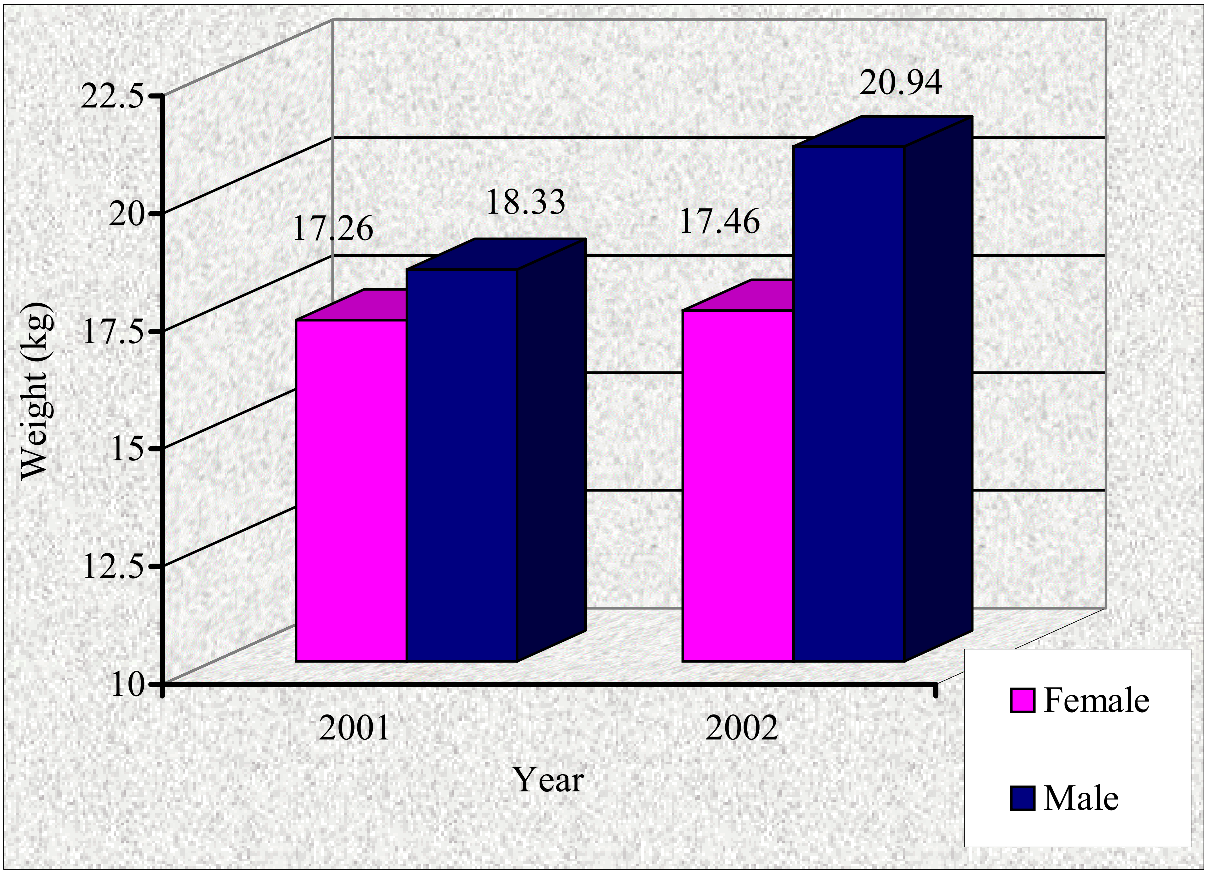


Table 3 Elk calf sex, weight, and age at time of capture (n=27).

#	ID#	Sex	Weight (kg)	Age (days)
1	90	Female	15.42	3.50
2	W413	Female	16.50	2.50
3	94	Female	14.97	1.00
4	101	Female	19.00	6.50
5	96	Female	20.41	2.50
6	100	Female	15.65	4.50
7	104	Female	17.24	2.50
8	112	Female	15.20	0.08
9	106	Female	21.55	4.00
10	107	Female	22.68	9.00
11	108	Female	15.20	2.00
12	121	Female	15.88	1.50
13	110	Female	19.50	5.50
14	99	Female	14.52	1.50
15	98	Female	17.24	6.00
16	91	Male	13.61	3.50
17	92	Male	24.49	10.00
18	None	Male	18.14	4.50
19	95	Male	15.88	2.50
20	93	Male	21.32	4.00
21	97	Male	16.56	1.00
22	105	Male	23.59	7.50
23	111	Male	19.05	4.50
24	109	Male	22.68	9.00
25	122	Male	19.96	2.00
26	115	Male	19.05	5.00
27	114	Male	21.32	7.00

Survival. Male calves were heavier than females ($t= 1.99$, $p=0.029$, $df=25$) (Figure 9). Three calves born to adult females with symptoms of meningeal worm died, but cause of death was not determined. These mortalities were likely either stillborns or cases of coyote predation. Insufficient evidence was available to determine if these calves were cases of low birth weight such as < 11.39 kg (Thorne et al. 1976). None of the radio-collared calves predicted birth weight was < 11.39 kg (Table 2). No calf with > 14.0 kg birth weight was killed by natural causes.

Figure 9 Mean elk calf weight between sex and year for 2001 and 2002.



Five (42%) males and 6 (40%) females shed their collars prior to 1 December 2002 and were censored from mortality estimates. Seven calf deaths were documented during the 2-year study including 3 that were uncollared. One male was harvested during the limited cow hunt in December of 2001. In 2002, 3 female radio-collared calves were killed. Causes of natural mortality were dog predation, coyote predation, and drowning (Figure 10).

During 2001, survival during the neonatal period (birth – 15 July) was 1.00. Fall survival was 0.833 ± 0.152 because of the hunter harvested calf. During the neonatal period of 2002, all mortality occurred within 30 days of capture. Neonatal survival was estimated at 0.726 (±0.105). No calves > 30 days-of-age died during the fall. No difference (alpha=0.05) between gender, period, and year was detected (Table 4). Mean annual survival was 0.766 (±0.103). The 95% confidence interval (CI) for annual survival ranges from 0.56 – 0.97.

Table 4 Predicted birth weights of elk calves to determine high mortality vulnerability.

ID#	Sex	Capture Weight (kg)	Age (days)	Weight Gain (kg)	Predicted Birth Weight (kg)
91	Male	13.61	3.50	2.22	11.39
100*	Female	15.65	4.50	2.86	12.79
90	Female	15.42	3.50	2.22	13.20
98*	Female	17.24	6.00	3.81	13.43
99	Female	14.52	1.50	0.95	13.57
108*	Female	15.20	2.00	1.27	13.93
95	Male	15.88	2.50	1.59	14.29
94	Female	14.97	1.00	0.64	14.34
101	Female	19.00	6.50	4.13	14.87
413	Female	16.50	2.50	1.59	14.91
121	Female	15.88	1.50	0.95	14.93
112	Female	15.20	0.08	0.05	15.15
102	Male	18.14	4.50	2.86	15.28
104	Female	17.24	2.50	1.59	15.65
115	Male	19.05	5.00	3.18	15.88
97	Male	16.56	1.00	0.64	15.93
110	Female	19.50	5.50	3.49	16.01
111	Male	19.05	4.50	2.86	16.19
114	Male	21.32	7.00	4.45	16.88
107	Female	22.68	9.00	5.72	16.97
109	Male	22.68	9.00	5.72	16.97
92	Male	24.49	10.00	6.35	18.14
122	Male	19.96	2.00	1.27	18.69
93	Male	21.32	4.00	2.54	18.78
96	Female	20.41	2.50	1.59	18.82
105	Male	23.59	7.50	4.76	18.83
106	Female	21.55	4.00	2.54	19.01

* Natural calf mortality

Figure 10 Age and weight of elk calves (n=27) with mortalities.

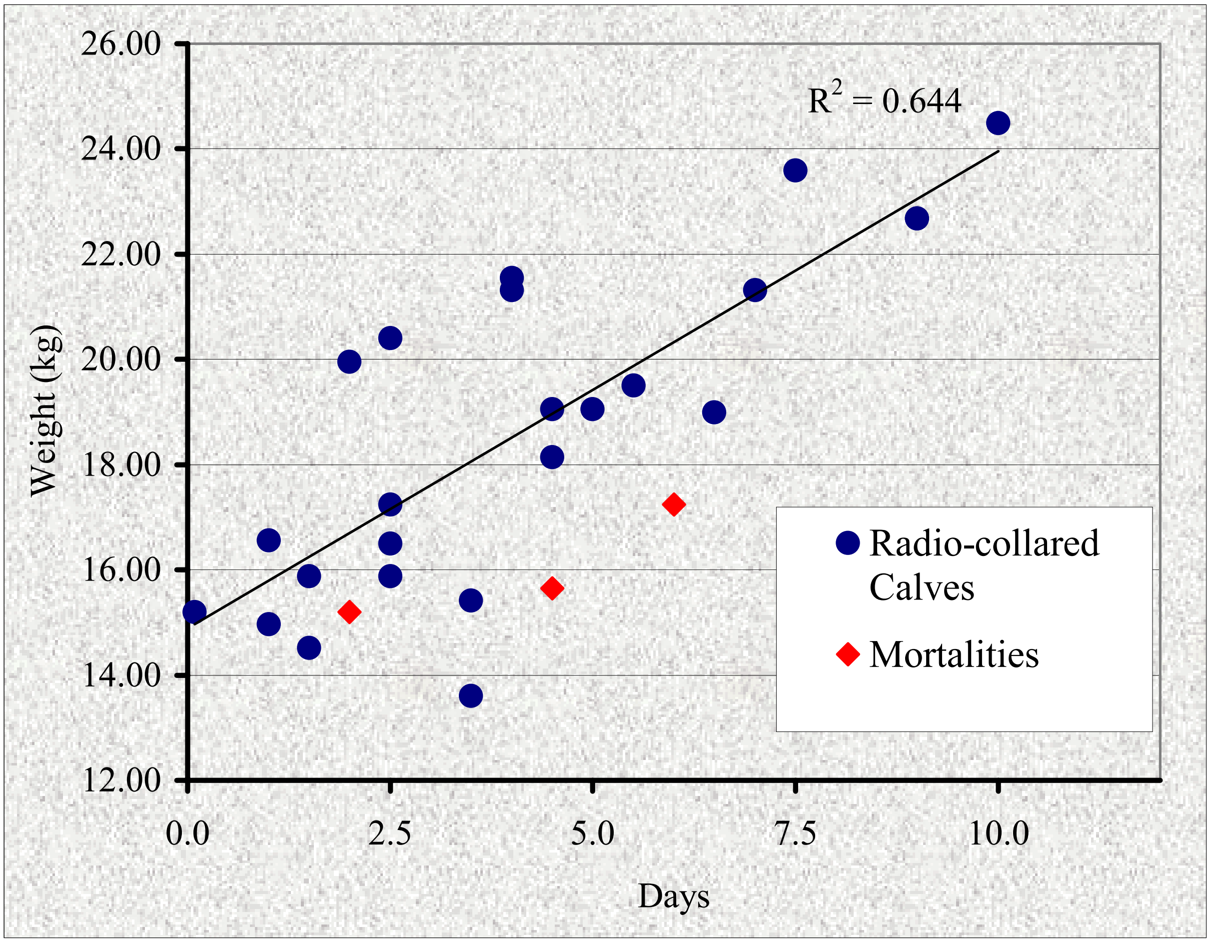


Table 5 Estimates of periodical and annual calf survival between sex, year, and combined.

					Survival		95% C.I.		
Year	Period	Sex	# Collared	# Deaths	Rate	SE	Lower	Upper	P-Value
2001	Neonatal	M	6	0	1.000	0.000			
2001	Neonatal	F	5	0	1.000	0.000			
2001	Fall	M	6	1	0.833	0.152	0.535	1.132	
2001	Fall	F	5	0	1.000	0.000			0.361
2002	Neonatal	M	6	0	1.000	0.000			
2002	Neonatal	F	10	3	0.726	0.105	0.407	0.976	0.141
2002	Fall	M	6	0	1.000	0.000			
2002	Fall	F	7	0	1.000	0.000			
2001	Annual	All	11	1	0.909	0.087	0.739	1.079	
2002	Annual	All	16	3	0.726	0.105	0.520	0.932	0.462
2001-2002	Combined	F	15	3	0.720	0.156	0.415	1.025	
2001-2002	Combined	M	12	1	0.833	0.139	0.561	1.106	0.374
2001-2002	Annual	All	27	4	0.766	0.103	0.564	0.967	

Characteristics of Parturition Sites. Ten parturition sites were located, sampled, and compared to 56 random sites. Based on box-and-whisker plots, variables with differences in central tendency included: horizontal vegetative cover between 0.2 – 2.25 m, number of boulders > 50 cm in diameter, distance to water and forest/grassland interface, slope, canopy coverage and height, shrub canopy height, and percentage of woody saplings, forbs, and grass in the ground cover (Figures 11 and 12).

Differences in habitat characteristics among calving and random sites during the ANOVA analysis were determined by least significant differences (LSD) tests for percent canopy coverage, slope, number of boulders > 50 cm in diameter, number of trees 10.2 – 15.2 cm in diameter, shrub height, percent woody saplings, and horizontal vegetation cover between 1.0 – 2.25 m in height. Variables that were not significant included: distance to water, edge, active mine, main road, and secondary road, number of woody logs and boulders, basal area, vegetative cover < 1.0 m, understory height, number of trees 2.5 – 10.2 cm in diameter, and percent ground cover (except percent woody sapling) (Table 6).

Neonatal Habitat. I compared 186 neonatal habitat locations, capture to 60 days post capture, and 56 random locations using ANOVA for the same 28 habitat variables that were used for parturition sites. Significant variables included: distance to secondary roads, slope, shrub height, and horizontal vegetation cover between 0 and 1.0 m in height (Table 7).

Figure 11 Box-and-whisker plots of central tendencies (0 " SE) for each landscape habitat variable between parturition and random sites.

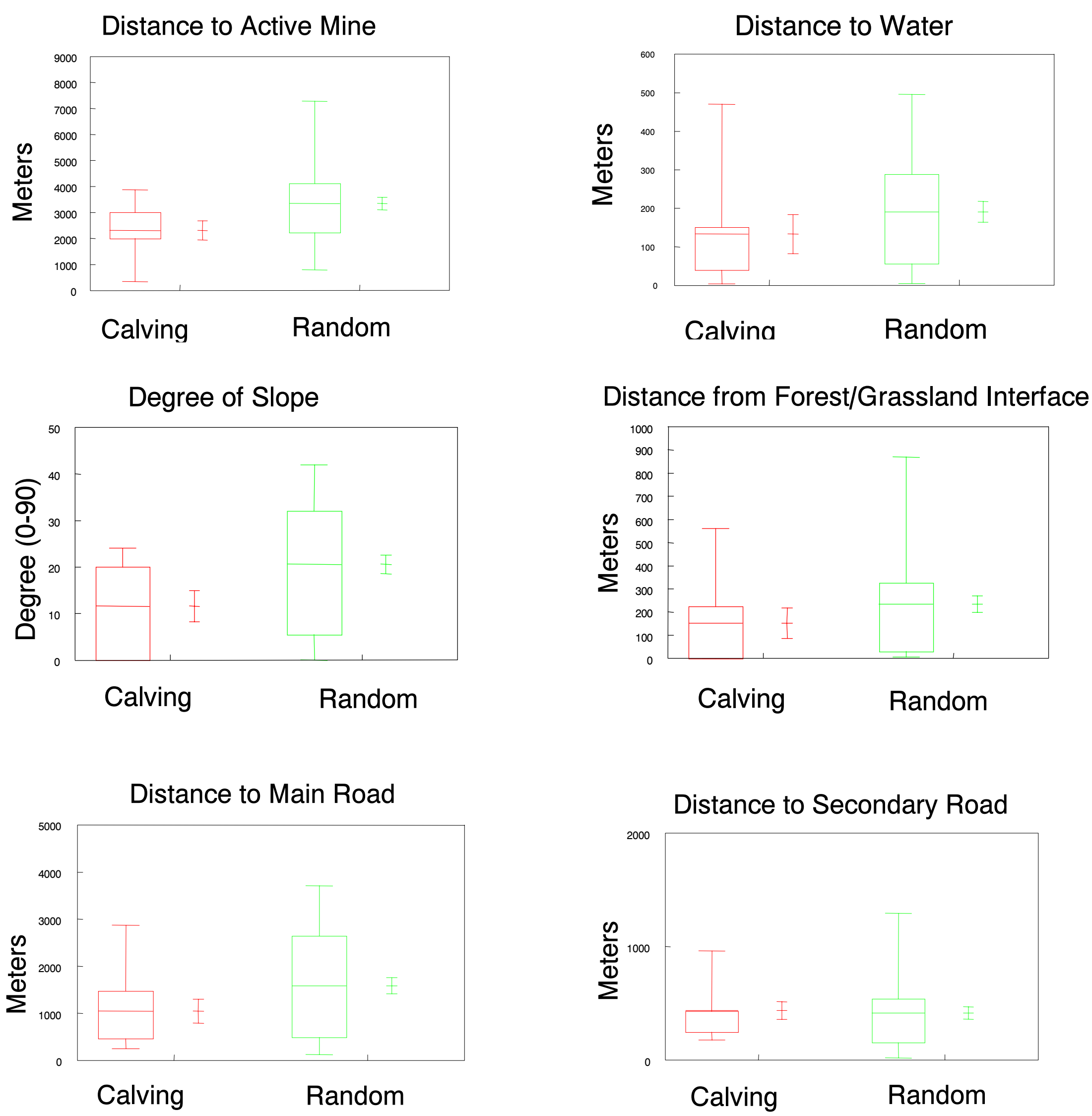


Figure 12 Box-and-whisker plots of central tendencies (0 " SE) for each site-specific habitat variable between parturition and random sites.

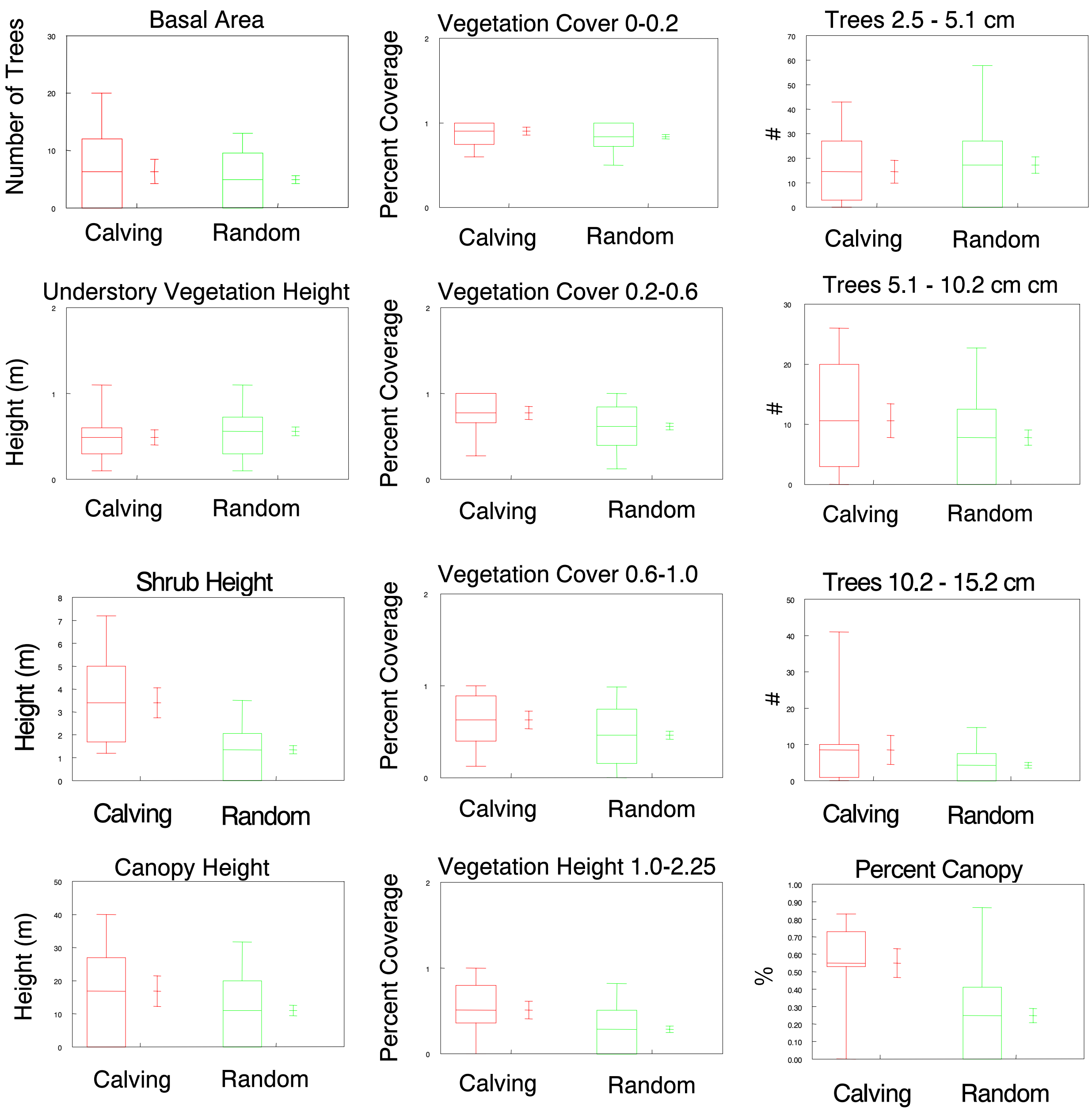


Figure 12 Continued

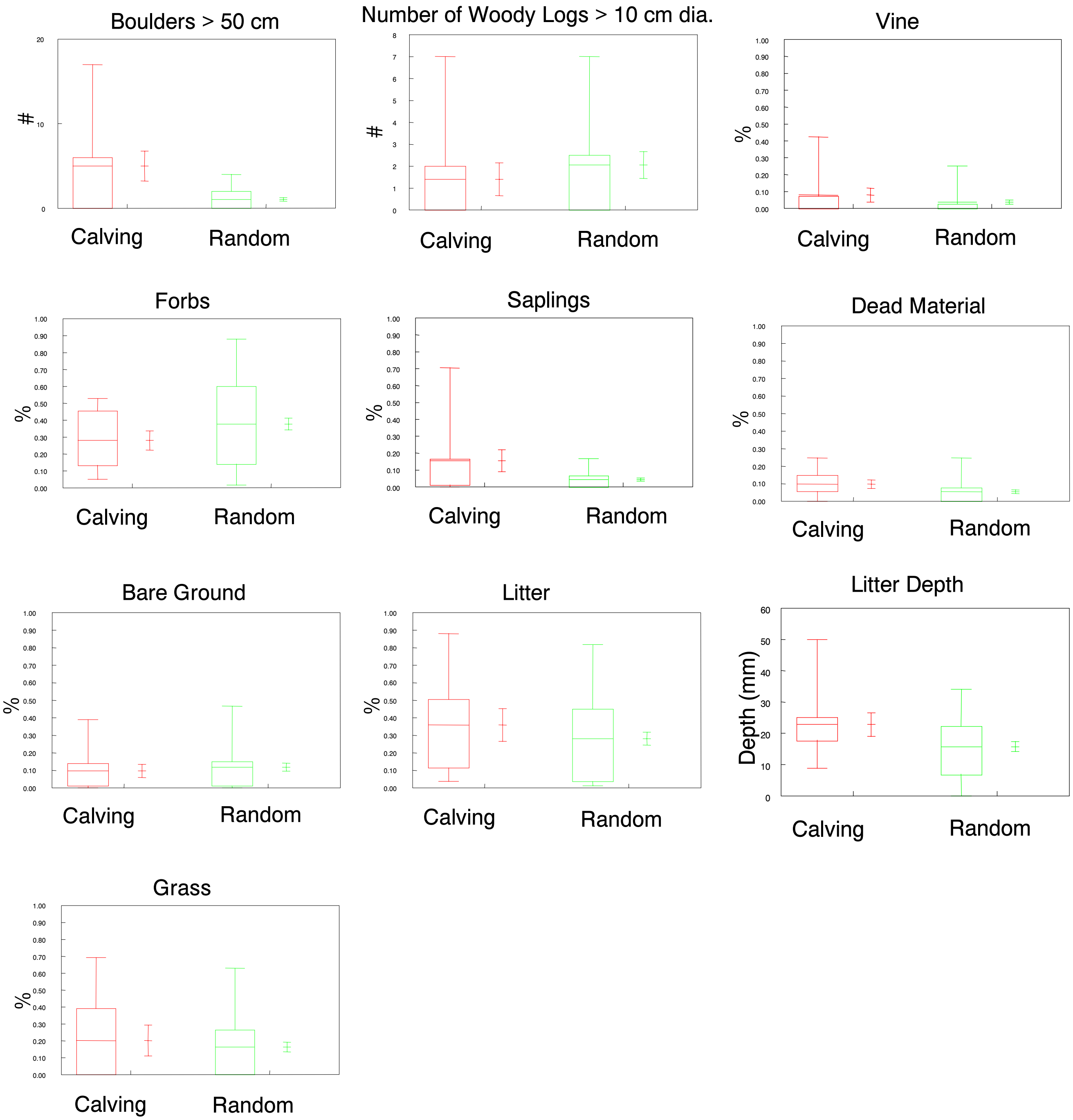


Table 6 Characteristics of calving sites compared to random habitat sites.

	Habitat Sites					
	Calving			Random		
Variable	Mean	SE	95% CI	Mean	SE	95% CI
Distance to water (m)	133.10	50.88	17.99 - 248.21	190.86	26.88	136.98 - 244.73
Distance to forest interface (m)	151.90	64.77	5.37 - 298.43	234.11	35.70	162.56 - 305.65
Distance to active mine (m)	2309.60	368.28	1476.50 - 3142.70	3340.64	243.05	2853.56 - 3827.72
Distance to main road (m)	1048.20	253.93	473.77 - 1622.63	1586.38	172.71	1240.25 - 1932.50
Distance to secondary road (m)	436.90	77.55	261.48 - 612.32	414.29	54.29	305.49 - 523.08
Slope (0-90°)	11.60	3.33	4.07 - 19.13	20.57	2.02	16.53 - 24.62
Percent canopy coverage	0.60	0.09	0.39 - 0.82	0.28	0.05	0.18 - 0.37
Basal area	7.00	2.24	1.83 - 12.17	4.89	0.71	3.47 - 6.32
Number of woody logs	1.40	0.75	-0.29 - 3.09	2.05	0.61	0.84 - 3.27
Number of boulders	5.00	1.77	1.00 - 9.00	1.04	0.20	0.63 - 1.44
Number of trees 2.5-5.1 cm ϕ	14.50	4.63	4.03 - 24.97	17.21	3.34	10.53 - 23.90
Number of trees 5.1-10.2 cm ϕ	10.60	2.81	4.24 - 16.96	7.79	1.26	5.25 - 10.32
Number of trees 10.2-15.2 cm ϕ	8.50	4.01	-0.56 - 17.56	4.29	0.78	2.71 - 5.86
Understory height (m)	0.49	0.09	0.29 - 0.69	0.56	0.05	0.46 - 0.67
Shrub height (m)	3.40	0.66	1.91 - 4.89	1.34	0.18	0.99 - 1.70
Overstory canopy height (m)	16.90	4.60	6.50 - 27.30	10.98	1.60	7.78 - 14.19
Horizontal cover 0-0.2 (m)	1.30	0.12	1.03 - 1.57	1.14	0.06	1.03 - 1.25
Horizontal cover 0.2-0.6 (m)	1.02	0.15	0.69 - 1.35	0.77	0.06	0.64 - 0.90
Horizontal cover 0.6-1.0 (m)	0.77	0.14	0.44 - 1.09	0.55	0.06	0.43 - 0.66
Horizontal cover 1.0-2.25 (m)	0.63	0.16	0.27 - 0.99	0.32	0.05	0.22 - 0.41
Percent grass	0.22	0.10	0.01 - 0.44	0.17	0.03	0.11 - 0.24
Percent forbs	0.29	0.06	0.15 - 0.43	0.41	0.04	0.33 - 0.49
Percent woody sapling	0.16	0.07	0.00 - 0.33	0.05	0.01	0.03 - 0.06
Percent vine	0.08	0.04	-0.01 - 0.18	0.04	0.01	0.01 - 0.06
Percent dead woody debris	0.10	0.02	0.04 - 0.16	0.06	0.01	0.03 - 0.08
Percent bare ground/rock	0.10	0.04	0.01 - 0.18	0.13	0.03	0.07 - 0.18
Percent litter	0.40	0.11	0.14 - 0.66	0.31	0.04	0.22 - 0.39
Litter depth (mm)	22.78	3.82	14.13 - 31.42	15.73	1.59	12.54 - 18.92

Table 7 Characteristics of neonatal sites compared to random habitat sites.

	Habitat Sites					
	Neonatal			Random		
Variable	Mean	SE	95% CI	Mean	SE	95% CI
Distance to water (m)	156.14	9.63	137.14 - 175.15	190.86	26.88	136.98 - 244.73
Distance to edge (m)	188.15	24.25	140.32 - 235.99	234.11	35.70	162.56 - 305.65
Distance to active mine (m)	2961.85	138.15	2689.30 - 3234.40	3340.64	243.05	2853.56 - 3827.72
Distance to main road (m)	1613.99	103.27	1410.27 - 1817.72	1586.38	172.71	1240.25 - 1932.50
Distance to secondary road (m)	566.56	28.93	509.49 - 623.63	414.29	54.29	305.49 - 523.08
Slope (0-90°)	16.20	0.88	14.45 - 17.94	20.57	2.02	16.53 - 24.62
Percent canopy coverage	0.26	0.03	0.21 - 0.32	0.28	0.05	0.18 - 0.37
Basal area	3.53	0.35	2.83 - 4.22	4.89	0.71	3.47 - 6.32
Number of woody logs	1.92	0.27	1.38 - 2.47	2.05	0.61	0.84 - 3.27
Number of boulders	1.19	0.16	0.88 - 1.51	1.04	0.20	0.63 - 1.44
Number of trees 2.5-5.1 cm ϕ	18.54	1.86	14.87 - 22.22	17.21	3.34	10.53 - 23.90
Number of trees 5.1-10.2 cm ϕ	6.66	0.51	5.66 - 7.66	7.79	1.26	5.25 - 10.32
Number of trees 10.2-15.2 cm ϕ	4.08	0.37	3.36 - 4.80	4.29	0.78	2.71 - 5.86
Understory height (m)	0.62	0.03	0.57 - 0.68	0.56	0.05	0.46 - 0.67
Shrub height (m)	2.08	0.13	1.82 - 2.34	1.34	0.18	0.99 - 1.70
Overstory canopy height (m)	8.87	0.85	7.18 - 10.56	10.98	1.60	7.78 - 14.19
Horizontal cover 0-0.2 (m)	1.34	0.03	1.28 - 1.39	1.14	0.06	1.03 - 1.25
Horizontal cover 0.2-0.6 (m)	0.98	0.03	0.91 - 1.05	0.77	0.06	0.64 - 0.90
Horizontal cover 0.6-1.0 (m)	0.73	0.04	0.66 - 0.80	0.55	0.06	0.43 - 0.66
Horizontal cover 1.0-2.25 (m)	0.36	0.03	0.31 - 0.41	0.32	0.05	0.22 - 0.41
Percent grass	0.21	0.02	0.18 - 0.25	0.17	0.03	0.11 - 0.24
Percent forbs	0.42	0.02	0.37 - 0.46	0.41	0.04	0.33 - 0.49
Percent woody sapling	0.05	0.01	0.04 - 0.07	0.05	0.01	0.03 - 0.06
Percent vine	0.04	0.01	0.02 - 0.05	0.04	0.01	0.01 - 0.06
Percent dead woody debris	0.07	0.01	0.06 - 0.09	0.06	0.01	0.03 - 0.08
Percent bare ground/rock	0.11	0.01	0.09 - 0.12	0.13	0.03	0.07 - 0.18
Percent litter	0.31	0.02	0.27 - 0.36	0.31	0.04	0.22 - 0.39
Litter depth (mm)	18.24	0.76	16.75 - 19.73	15.73	1.59	12.54 - 18.92

DISCUSSION

Annual elk calf survival in Kentucky (0.76) is similar to estimates in Pennsylvania, Michigan, Wisconsin, and other populations in the western United States. Survival in Pennsylvania was 0.71 (95% CI 54.3 – 91.9) for 30 radio-collared calves (Cogan 1999). In Wisconsin, Lizotte (1998) observed 0.86 annual survival in an area occupied by black bear and gray wolf. Annual survival of calves in Michigan (0.87) appears to be the highest survival rate in the eastern U.S. (Bender et al. 2002), although black bear and coyote are abundant. In western elk populations that are sympatric with coyote, black bear, mountain lion, and in some areas with grizzly bear and gray wolf, calf survival ranged from 0.58 in the Jackson, Wyoming, (Smith and Anderson 1998) to 0.69 in YNP (Singer et al. 1997). Houston (1982) reported that even with the diversity and abundance of predators in YNP, predation was insufficient to prevent elk herd dynamics from being resource limited. Houston concluded that predation would likely dampen the fluctuations observed in the elk population by reducing parasitism and epizootic disease. With or without the presence of large carnivores, all of these populations exhibit positive population growth and may be tolerant of additional mortality associated with recreational hunting.

Calf survival is influenced by several factors including cow health and nutrition, birth weight, birth date, maternal care, abundance of predators, and adequate neonatal habitat or hiding cover (Schlegel 1976, Guinness et al. 1978, Sauer and Boyce 1983, Singer et al. 1997, Smith and Anderson 1998). Reproduction by yearling females, consecutive year pregnancies, and twinning suggest Kentucky elk experience a high nutritional plane (Larkin 2001). In addition, heavy birth weight suggests that adequate nutrition is available for both cow and calf. Birth weights of healthy calves typically range from 15 – 22 kg (Hudson et al. 1991) and may be a good indicator of survival (Guinness et al. 1978, Singer et al. 1997, Bender et al. 2002, Hudson and Haigh 2002), especially during winter in areas lacking large predators (Clutton-Brock et al. 1982, Cederlund et al. 1991). However, Smith and Anderson (1998) found that calf survival on the National Elk Refuge, Wyoming was not related to a calf's individual birth weight, but correlated to mean cohort birth mass, which is a function of environmental conditions when calves were in utero (Smith et al. 1997). Contrary to other research, birth weight was not important to calf survival, but weather severity and birth date were important.

Male calves are usually heavier than females at birth (Cook 2002) and may be less susceptible to mortality (Raedeke et al. 2002). Sexual dimorphism in neonatal weight has been previously reported for white-tailed deer (Verme 1989), mule deer (Kucera 1991), red deer (Clutton-Brock et al. 1981), and recently for moose in Alaska (Boertje et al. 1998). Captive elk calves that weighed > 16 kg at birth had a 0.90 probability of surviving 28 days, whereas calves <11.4 kg had < 0.50 probability of survival over the same time interval (Thorne et al. 1976). Even in areas where grizzly bear, black bear, and other predation was common, calf survival was mostly influenced by birth weight (Singer et al. 1997, Keech et al. 1999; however see Smith and Anderson 1998), and thus, by local environmental conditions. Heavy capture weights of Kentucky elk calves are likely correlated with high daily growth rates and adequate milk production. In Kentucky, calves with predicted birth weights < 14.0 kg (n=6) had a 0.50 probability of survival. However, low birth weight does not appear to be problematic for Kentucky calves born to healthy adult females. Differences between Thorne et al. (1976) and this study were likely due to different diets, energy intake, presence of meningeal worm, and captive versus free-ranging environments. Kentucky calves may have a higher daily growth rate due to quality and quantity of forage associated with reclaimed mines. In addition, Kentucky's population is still growing and approaching western herd density. Thus, in the absence of conspecific competition, females should maintain adequate health and fecundity. Carrying capacity of the restoration zone is more likely to be determined by social limits, i.e., human tolerance for crop depredation and automobile collisions, than biological constraints – at least in the near future.

In a review of neonatal mortality patterns of northern temperate ungulates, mean survival rates in areas where predators occurred averaged 0.53 versus 0.81 in areas that were predator-free (Linnell et al. 1995). Along with malnutrition, predation was the most commonly reported proximate cause of mortality for elk calves in North America (McCullough 1969, Schlegel 1976, Singer et al. 1997, Bender et al. 2002). Black bear and coyote are the most common predators and cause of mortality at the National Elk Refuge (Smith and Anderson 1996). In the eastern U.S., black bear predation has been observed in Wisconsin (Lizotte 1998), Pennsylvania (Cogan 1999), and in the Great Smoky Mountain National Park (Dobey 2003). In Michigan, despite abundant populations of black bear and coyote, survival in all age-classes have been high enough that predation does not appear to be limiting (D. Beyer, Michigan DNR, pers. comm). In contrast, wolf predation is the primary cause of mortality (50%) for the French River/Nipissing elk population in Ontario where survival of calves is estimated at 30-40% during the first 6 months (Hamr 2002). Mortality rates of elk calves in eastern North America appear to fluctuate with environmental conditions and stochasticity, diversity and abundance of predators, and possibly by the extent of meningeal worm infestation.

Survival on Addington WMA will likely remain high because of the absence of large predators. Coyote predation is unlikely to significantly reduce recruitment because of the abundance of other prey, (i.e., white-tailed deer, rabbits, rodents, and hard mast). Where gray wolf, coyote, elk, and white-tailed deer are sympatric, Mech (1970) and Kunkel et al. (1999) found that wolves preyed on white-tailed deer more than elk. Deer produce 1-2 fawns (Rhodes et al. 1985) versus elk, which normally produce a singleton. If Kentucky predators target a prey species, it will likely be white-tailed deer fawns more than elk calves because of difference in body size, number of offspring, and the fact that elk are more protective of their young than deer (Cogan 1999). Cow elk can deter medium-sized predators such as coyotes (Altmann 1952, Gese 1999) and can lure larger predators away from their calves (Altmann 1963, McCullough 1969). Coyote predation will likely continue opportunistically (Blanton and Hill 1989), depending on coyote and calf abundance and times when the dam is away from the calf, but predation is unlikely to limit population growth and affect demographics in Kentucky.

Larkin et al. (2002) documented temporary Allee effects during the first 2 years of the Kentucky elk restoration with males skewed towards yearlings, thus calving seasons were longer (67 and 37 days in 1999 and 2000, respectively). Without mature bulls siring adult cows, timing and synchrony of the calving season was extended. Peak calving during 2001 and 2002 occurred on 26 May and 1 June, respectively. Peak calving activity during 2002 was synchronous with Rocky Mountain elk herds in Pennsylvania (Everland et al. 1979), Michigan (Moran 1973), and western North America (Rust 1946, Johnson 1951, Flook 1970). Calving season length in Kentucky was 35 and 37 days during 2001 and 2002. This shorter calving season is the result of mature bulls efficiently breeding the majority of females (Bubenik 1982, Noyes et al. 1996). A shorter calving season may enhance calf survival in a predator-rich environment because it causes a "swamping" of births, which reduces the ratio of predators to juveniles (Cook 2002). Higher calf mortality documented by Larkin (2001) during the first 2 years of Kentucky's elk restoration may be attributed to the longer calving season. This may have allowed coyotes and free-ranging dogs a longer window to kill calves. In addition, late born calves are more susceptible to winter mortality because of lack of sufficient body size and energy reserves (Smith 1994, Gese and Grothe 1995, Smith and Anderson 1998).

Meningeal worm has been estimated to kill 1% of the population each year in Pennsylvania and Michigan (Witmer and Cogan 1989, Pils 2000). The affect of meningeal worm on fetal development, calf survival, and population growth needs further study. Elk with chronic signs of meningeal worm may be deprived or even killed by the restriction of energy and nutrient intake caused by neurological altered behavior. Females with high parasite infestations may not be capable of carrying a fetus through gestation, effectively nursing their calf, and defending their offspring from predators. Thus, calves may be negatively affected by lack of adequate nutrition and maternal care. For example, two 6-month old male calves harvested during the 2001 and 2002 cow hunt weighed 136.08-kg (300#) and 95.26-kg (210#), respectively. The lighter dam was infected with meningeal worm and probably unable to sustain high yields of milk, which impaired the calf's growth and body mass. In addition, 3 uncollared calves born to infected cows were found dead. These calves were either stillbirths or killed by coyotes. Calves with inadequate nutrition during early development take longer to become sexually mature (Raedeke et al. 2002), which may limit the individual's fecundity.

Calving cover has been described as a specialized kind of habitat, although this concept is not universally accepted (Johnson 1951, Roberts 1974, Thomas et al. 1979, Lyon and Ward 1982). In the western U.S., elevation of calving habitat may vary inversely with latitude (Sweeney 1975) because parturition occurs during migration. Calving habitat depends largely on succulent vegetation availability, which is also related to receding snowline and plant phenology (Skovlin et al. 2002). Several calving site characteristics have been reported in the western U.S. more often than might be suggested by chance (Skovlin 1982) (Table 8). However, most of these studies are more descriptive of neonatal habitat use than parturition sites because researchers assumed that where the calf was first observed or captured was also the parturition site. Many of these studies documented calves that were several days old, which are more mobile and had likely dispersed from the calving site. Wallace and Krausman (1985) reported that cows remain within 200 m of their newborn calf, which may reduce the distance traveled away from the calving site. However, I observed on 4 different occasions dams > 400 m (n=3) and > 800 m (n=1) away from their calves that were < 7 days-old.

Table 8 Elk parturition site and neonatal habitat characteristics in the U.S.

Habitat Features **Source**	Sample size	Distance to water (m)	Distance to edge/ecotone (m)	Distance to active mine (m)	Distance to main road (m)	Distance to secondary road (m)	Percent canopy coverage	Basal area	Slope	Aspect[c]	Hiding cover	Number of woody logs/cover	Number of boulders	Number of trees 2.5-5.1 ϕ	Number of trees 5.1-10.2 ϕ	Number of trees 10.2-15.2 ϕ	Understory height (m)	Shrub height (m)	Overstory canopy height (m)	Horizontal veg cover 0-0.2 (m)	Horizontal veg cover 0.2-0.6 (m)	Horizontal veg cover 0.6-1.0 (m)	Horizontal veg cover 1.0-2.25 (m)	Percent grass	Percent forbs	Percent woody sapling	Slight depressions
Johnson (1951)[b]			X				X																				X
Altmann (1952)[ab]		X	X						X	S	X																
Phillips (1966)[b]			X									X						X						X	X		
Harper (1971)[b]			X						X																		
Reichelt (1973)									X	S	X																
Phillips (1974)[b]			X				X[d]		X	NW																	
Roberts (1974)[b]							X[d]		X	NW										X	X						X
Waldrip and Shaw (1979)[ab]	2/52						X		X	S	X		X													X	
Wallace and Krausman (1985)[b]	26	X					X			SW	X						X				X	X	X			X	
Koshowski (1998)[a]	12	X	X	U	U	U	X																				
Stillings (1999)[b]	22				X	X			X				X	U	U	U				X	X	X	X				
This study (2003)[a]	10	X					X		X				X			X		X					X			X	X

X = Important feature

U = Importance unclear

[a] = Descriptive of parturition site

[b] = Descriptive of neonatal habitat/calving area/calf bed sites

[c] = Aspect direction

[d] = Shrub layer coverage

[e] = Distance from feature

Elk calving habitat that reduces vulnerability of calves is critical to the growth of a population, therefore these areas should be identified and protected (Roberts 1974, Bian and West 1997). Adult females in Kentucky isolated themselves from the herd and appeared to select areas with adequate forage and thermal and security cover. They did not congregate to a specific area to calve as was found in some western states (Phillips 1966, Roberts 1974). This may suggest that suitable calving habitat is not limiting in Kentucky. In Kentucky, healthy cows calved in hardwood forest or reclaimed mine shrub lands with dense canopy closure (0=0.60 ±0.09) within 152 m of the forest/grassland or forest/shrub interface. Parturition sites in Kentucky were found on gentle slopes <11.6° and an average of 135 m (±50.9) from a water source. Cows selected areas with a greater number of boulders >50 cm in diameter and areas with a thicker (visually obstructed) horizontal shrub and vegetation layers between 0.2 - 2.25 m in height.

Several measurements of parturition sites were not selected. Distance from the nearest active-mine, main road, and secondary road, did not appear to influence site selection. In addition, slope position, basal area, canopy height, and number of trees 2.5 – 15.2 cm in diameter were not influential. Ground cover in the forms of grass, forbs, vine, dead woody debris, bare ground, litter, and litter depth were not selected more than random. Roberts (1974) reported that cow and calf pairs used wet meadows and grassy areas with herbaceous forbs between parturition and formation with a nursery group. In Kentucky, percent grass and forbs may not have been significant because dense overstory canopy closure and woody saplings in the ground cover layer may have inhibited such growth. Millspaugh et al. (1998) found that overstory canopy closure, number and basal area of trees, percent litter, and bare ground were greater at elk bed sites and provided thermal cover. Thus, the low percentage of grass and forbs at parturition sites may be attributed to thermal cover selection.

Parturition site fidelity could not be adequately determined because radio-collars failed due to battery exhaustion, therefore most females were not monitored both years. However, a group of 5 females dispersed from Addington WMA to an adjacent reclaimed mine (Redstar) during the calving season for parturition during both years. One of these females calved within ~ 100 m of the same grassland/hardwood forest interface at the end of a ridge point for 3 consecutive years (C. Logsdon, KDFWR, pers. comm). Protection or restriction of access to traditional calving areas may be beneficial to calf survival and population growth by reducing energy expenditure associated with disturbances.

Johnson (1951), Phillips (1974), Reichelt (1973), and Koshowski (1998), reported that distance from the forest edge was important, and that newborn calves were often found a short distance into the forest (Phillips 1966). Skovlin et al. (2002) reported that ecotones appear to be selected by females for calving sites because calves were typically found in proximity of the transition zone. I determined characteristics of parturition sites in Kentucky by physically locating the birth site - not by assuming that it was the same location where the calf was captured. Females may actually prefer forested areas adjacent to open areas such as grassland, wet meadow, sagebrush, or scrub-shrub for parturition because it provides solar and thermal cover, as well as forage and security. Beall (1976) concluded that elk selected bedding sites according to the "comfort range" needed. This comfort range is influenced by solar radiation and thermal conditions at each bedding site. Solar and thermal conditions vary considerably with habitat type and percentage of canopy closure. Waldrip and Shaw (1979) documented calf bed sites were significantly cooler than ambient temperature because boulders and woody vegetation provided shade. In Arizona, Wallace and Krausman (1985) found 94.4% of calf bed sites were in forest. Thomas et al. (1979) found that forest stands greater than 150 m in width with at least 70% canopy closure provided satisfactory cover for elk. Thus, management of thermal cover can be advantageous for elk during the summer months when adverse weather can complicate thermoregulation (Millspaugh et al. 1998). Ecotones probably provide a range of solar and thermal conditions allowing cows and calves to select their own "comfort range". This may explain why all healthy cows in Kentucky calved in forested areas within 135 m of grassland or shrub land edge, and calves were later located closer to the edge or in the open habitat a few days after birth. This supports Altmann's (1952) observation that after a calf had developed muscle strength and coordination, it followed the dam away from the parturition site into open areas such as sagebrush or grassland communities or gradient areas. Roberts (1974) also suggested that younger calves were located inside the forest edge and older more mobile calves were found in the more open sagebrush-grass community adjacent to the quaking aspen and timber-grass ecotone.

In general, neonatal elk habitat in North America is related to gradient vegetation types (ecotones) on gentle slopes <20° that provide adequate forage for the cow and hiding cover for the calf. In Kentucky, neonatal habitat appears to be associated with reclaimed strip mine shrub land that is re-contoured to #20° and commonly consists of autumn-olive and black locust with broad crowns. These areas normally consist of dense horizontal vegetative coverage from 0 - 1 m in height and had taller shrub height. The mean distance from the forest/grassland or forest/shrub land interface was 188 m (±38.3), thus neonatal habitat use may be associated with the daytime bedding/ruminating bed site of the dam. The calf may also select a bed site where hiding cover in the form of boulders, slight depressions, and dense vegetation exists. Calves were commonly captured in slight depressions at the base of a blow-down where the root mass was exposed (n=3) and in small erosion channels (n=10) on gentle slopes. Calf use of areas farther from secondary roads may have been related to unpredictable disturbances such as vehicular traffic, such activities likely cause more of a flight response than a predictable event (Stillings 1999) such as traffic on a regularly used paved road (Hwy 80). Bian and West's (1997) model for calving areas in Kansas corroborates my finding that calves used areas farther from secondary roads. The explanation may be associated with the use of secondary roads by coyotes. Coyotes commonly travel secondary roads because they are easy to travel and may provide carcasses from vehicular collisions. Thus, it may be advantageous for newborn calves to select neonatal habitat with hiding cover farther away from secondary roads and their related disturbances.

MANAGEMENT IMPLICATIONS

Calf survival in Kentucky appears to be adequate for positive population growth, but it may not be as high as managers and the general public had anticipated. Feral and free-ranging dogs and coyotes will likely continue to kill calves opportunistically. Managers may want to address the abundance of free-ranging dogs on WMAs within the elk restoration zone.

High survival and calf: cow ratios are indicative of an expanding elk population in mild climate with little or no predation (Ballard et al. 2000). This study provides baseline information of an expanding elk population in an area denuded of most large predators. However, calf mortality should continue to be monitored as the black bear continues re-colonization of eastern Kentucky.

Another calf survival study that addresses landscape variation among release sites should be conducted. This study did not address landscape variation because of its site-specificity. Calf production, survival, and recruitment will likely differ geographically because of differences in vegetation and predator abundance. Statistical inferences derived from this study are limited due to small sample size (n=27). The 95% CI for annual survival range from 0.56 to 0.97 and do not allow managers to accurately model population growth. However, White and Burnham (1999) state that telemetry studies usually estimate survival probabilities with high precision even in the case of small sample size because each animal's status is well documented at each sampling occasion. This may be true because each animal's fate is typically known, however for statistical purposes a larger sample size is required to reduce the standard error and 95% CI if an accurate population model is desired.

Calving and neonatal habitat are important components of population growth, therefore these areas should be identified and protected (Roberts 1974, Bian and West 1997). I identified 2 areas that cows regularly used during the calving season. These areas, Redstar and Laurelfork, are reclaimed coal mines, which are adjacent to Addington WMA. For 3 consecutive years, several adult females moved to these areas to calve. They may have been selected because of the lack of mining activity, vehicular traffic, and disturbances associated with wildlife viewing. Further restriction of human access in these two areas may enhance calf survival by reducing energy expenditure and travel distance to circumvent disturbance. This may enhance population growth in the greater Addington WMA study area.

An important feature of elk habitat is the juxtaposition or interspersion of vegetative types (West 1993). Habitats with high interspersion of vegetative types provide large amounts of edge per area, which increases elk forage (Skovlin et al. 2002). In Oregon, Leckenby (1984) found that at least 80% of elk use in summer forage areas occurred within 275 m of an ecotone. Edge and ecotones do not appear to be limiting at Addington WMA. Disturbances caused from mountain-top removal (MTR) coal mining, arson, and timber harvest have created a matrix of forest, shrub, and herbaceous openings with extensive edge. Coal mine reclamation creates large grass and herbaceous openings that elk use to forage. Arson may reduce woody debris, which can inhibit movement, and provide lush new-growth in the understory. However in Kentucky, approximately 93% of the restoration zone is forested (Phillips 1997). Therefore, areas where elk might be a target for management, opening the overstory canopy through timber harvest

(Reynolds 1964) or prescribe fire (Peck and Peek 1991) can enhance elk use of grass and herbaceous forbs in the understory in areas predominantly forested. These management options can be used to ameliorate crop depredation and other conflicts by luring nuisance animals away. These disturbances benefit elk by providing forage and escape cover in the form of early-successional forest. Disturbances may temporarily displace elk, but will likely be used after initial threats cease (Edge and Marcum 1985).

Finally, elk managers may wish to reduce the number of free-ranging dogs on WMAs in the elk restoration zone, protect isolated reclaimed mines with high juxtaposition of vegetative types for calving areas, and continue studying yearling age-class survival, effects of meningeal worm on reproduction and survival, and calf survival across the landscapes. Until this research is performed or a survey demonstrates a minimum viable population has been established, I recommended that KDFWR not significantly increase the harvest. This may allow elk time to occupy vacant habitat between release sites and facilitate the establishment of a single contiguous population.

Appendix A

EFFICACY OF VAGINAL-IMPLANT TRANSMITTERS FOR LOCATING ELK CALVES

Synopsis: We assessed the utility of vaginal-implant transmitters for locating newborn elk (*Cervus elaphus nelsoni*) calves in eastern Kentucky during the springs 2001-2002. Retention of implants among all 40 cows ranged from 1 to 276 days (0 = 61.6 ± 3.0 days). Only two implant transmitters performed as designed by the manufacturer and led to calf captures. Implant transmitters prematurely expelled and malfunctioned. In comparison, we captured more calves (n=25) by monitoring parturition behavior and systematically searching areas where cows were suspected to have given birth. Approximately 34.5 hours were invested for each calf captured by behavior monitoring. Implants may provide a tool for researchers to better document cervid neonate survival, however our experience suggests current design needs further refinement.
Keywords: *Cervus elaphus*, elk, neonate, parturition, radio-telemetry, translocation, vaginal-implant transmitter, wapiti

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Accurate juvenile survival estimates can be difficult to obtain from ungulates because they remain hidden after parturition to avoid predators (Darling 1937, Geist 1982, Garrott and Bartmann 1984, Bowman and Jacobson 1998). Neonates are vulnerable to a variety of mortality factors such as predation (Schlegel 1976), abandonment, disease, malnourishment, and various physical anomalies (Kistner et al. 1982). In the western United States, researchers commonly use helicopters to capture elk calves (Kuck et al. 1985, Smith and Anderson 1996, Singer et al. 1997), where high densities and open landscapes may facilitate large sample sizes. The use of helicopters in eastern Kentucky is impractical due to a sparse elk population (~2000), the lack of traditional calving areas, steep slopes, and dense forest cover. For these reasons, we used vaginal-implant transmitters as cues to parturition sites and relatively immobile calves (< 10 days-of-age) (Wallace and Krausman 1985). Further, vaginal-implant transmitters may reduce sampling bias by helping researchers target very young animals and increase the likelihood that the most vulnerable animals are included for study. Our objective was to evaluate the efficacy of vaginal-implant transmitters for locating free-ranging elk calves in Kentucky where other methods are not currently feasible.

METHODS

In February 2001, female elk were captured by net gun from a helicopter (Schemnitz 1994) and transported to a holding facility operated by the Utah Department of Wildlife Resources (UDW) in Logan, UT. We determined pregnancy by a serum progesterone test and considered cow elk pregnant if serum progesterone levels were > 1ng/ml (Schmitt et al. 1986, Willard et al. 1994, Bender et al. 2002). Pregnant cow elk were tagged with a Duflex® ear tag (Destron Fearing Corp., South Saint Paul, MN, USA), fitted with a collar-mounted Vhf radio-transmitter (Telemetry Solutions, Concord, CA., USA, Telonics Inc., Mesa, AZ., USA, and Lotek Engineering, Newmarket, Ontario, Canada), and fitted with a vaginal-implant transmitter (Advanced Telemetry Systems, Inc., Isanti, MN, USA). Instrumented elk were translocated non-stop to Kentucky and released at Addington WMA. Larkin et al. (2001) described in detail the trapping and handling protocol of translocated elk. In April 2001 and 2002, previously released cow elk in Kentucky were chemically immobilized using carfentanil citrate (Wildnil®, Wildlife Pharmaceuticals, Inc., Fort Collins, CO., USA). These female elk were tested for pregnancy by rectal palpation (Greer and Hawkins 1967) and fitted with a vaginal-implant transmitter if determined pregnant. In addition, cow elk with radio-collars previously released to Addington WMA were selected for parturition behavior monitoring. All radio-instrumented elk were located once a week using aerial and ground telemetry (Mech 1983) until the calving season (1 May – 30 June). During the calving season, all instrumented elk were located 2-3 times per week and cows with vaginal-implants were monitored daily. Locations were recorded with a GPS unit (GARMIN International, Inc., Olathe, KS, USA) as Universal Transverse Mercator (UTM) coordinates (Grubb and Eakie 1988). We continued to monitor female elk for parturition behavior if they prematurely expelled the vaginal-implant transmitter.

Field searches were conducted during the calving season in 2001 and 2002. Increased pulse rates or stronger implant radio signals initiated calf searches. In addition, behavior that suggested parturition such as social isolation from other elk, dispersal to new areas, restricted movement patterns (Langley and Pletscher 1994, Vore et al. 1996, Kastler 1998, Vore and Schmidt 2001), reluctance to leave an area when approached, and bark vocalizations instigated calf searches. Searches began at the location where the implant was found or at the last site where the cow elk was observed. Searches were performed in an expanding outward grid. Calves were captured by hand as described by White et al. (1972) and fitted with a Vhf transmitter mounted on an expandable collar (Advanced Telemetry Systems, Inc., Isanti, MN.). Collars expanded from 25 – 80 cm to prevent asphyxia as calves matured. Measurements including weight, length, and chest girth were recorded following Johnson (1951). Radio-signals were monitored daily for calf mortality, whereas visual observations, habitat use, and group size were recorded approximately every 3 days.

We estimated the financial cost per calf captured in 2001 by their corresponding technique. We estimated the total cost for using vaginal-implant technology at $5,175, by multiplying the number of vaginal-implants that could have been retained until parturition (n=23) by the cost for each implant transmitter ($225.00). We estimated the financial cost of parturition behavior monitoring by aerial telemetry at $8,000. This assumes that we located female elk 8 times during the month of April and 24 times during May and June with an average cost per flight of $250.00. We then divided the total cost by the number of elk calves captured by technique (n=2, n=9). We assumed that the researcher salary was the same amount of money and the price of a radio-collar for each study animal was equal in both techniques.

Vaginal-implant transmitters were equipped with a temperature sensor that doubled the pulse rate from 40 to 80 beats per minute below 34.4°C. The vaginal-implant transmitter weighed 26 grams and had a life expectancy of 160 days. The dimensions of the implant were: overall length including antennae-246 mm; body-86 mm; antennae-160 mm; wing-length-57 mm; wing width-9 mm; and diameter-14 mm (Figure 12).

Figure 13 Vaginal-implant transmitter fitted in pregnant female elk.

RESULTS

Vaginal-implants transmitters were inserted in 40 pregnant adult cow elk. Two vaginal-implants were immediately expelled during the ~3000 km transport to Kentucky. Fourteen cows died from capture related injuries during the first 6 weeks after release. Thirty-six percent of these implant transmitters were recovered in the carcass, while most were recovered an average of 135 meters from the carcass. Retention of vaginal-implants in capture-related deaths was (0= 42.5 ± 2.4) days. Sixteen implants were expelled pre-partum. Seven of these were lost 7 days prior to the calving season. Only 2 cows that expelled implants pre-partum were subsequently observed with a calf. All vaginal-implant transmitters in anesthetized elk during their 3rd trimester were prematurely expelled within 14 days. In 4 instances, the transmitter pulse rate did not change after exposure to ambient conditions and reduced temperature. In these cases, expulsion was detected by increased signal strength and locations that were different than the radio-collared cows. Battery failure was suspected in one transmitter because the signal was lost after 14 days of monitoring the radio-collared cow. Our mean retention for 18 cows that survived until the calving season was (0 = 78.0 ± 3.4) days. We captured 2 calves as a result of homing in on expelled transmitters. These were found 8 and 30 meters from hidden calves. Mean retention for the 2 successful vaginal-implants was (0 = 95) days. Two cows retained implants after the calving season for 154 days and at least 276 days. Both cows were bred and successfully calved in 2002. Sixty-four percent of cows that had vaginal-implant transmitters in 2001 produced a calf in 2002. Vaginal-implants do not appear to cause future reproductive complications when retained for long periods.

We captured 25 calves by monitoring pre-parturition movements and behavior of pregnant female elk during the calving season. Due to the mortality of 14 translocated female elk, an additional 20 and 24 cow elk with radio-collars were monitored during the springs of 2001 and 2002. Cow elk behaviors that consistently identified calf presence were dispersal to a new area, reluctance to leave when approached by researchers, and bark vocalizations. An average of 34.5 hours was invested per calf captured during the calving season. We identified 57 female elk with calves by monitoring parturition behavior, however 32 of these calves were too old and mobile to be captured. The estimated cost per calf captured by parturition monitoring was $890.00. The estimated cost per elk calf captured by vaginal-implant technology was $2,588.00.

DISCUSSION

There is a paucity of literature on the use of vaginal-implant transmitters to locate neonatal ungulates. Garrott and Bartmann (1984) described reproduction complication in mule deer (*Odocoileus hemionus*) when a purse-string suture in the vulva was used to retain vaginal-implants. Trauma associated with the technique may have deterred further research. However, Bowman and Jacobson (1998) developed an inert vaginal-implant for white-tailed deer (*Odocoileus virginianus*) that retained without sutures and that did not complicate reproduction. Vore modified the improved Bowman and Jacobson vaginal-implant for use in free-ranging elk (Kastler 1998). Thus, we were not concerned about reproductive complication in our study.

We found the efficacy of vaginal-implants for locating free-ranging neonate elk to be limited. In Kentucky, early expulsion and stress-related mortality limited the efficacy of this technology. Kastler (1998) reported that 8 vaginal-implant transmitters inserted in free-ranging elk in Montana were “marginally useful”. Kastler captured and collared 4 elk calves, however it is unclear whether capture efforts were enhanced by vaginal-implant technology. Poor retention and battery malfunction have been prevalent problems with implant studies (Garrott and

Bartmann 1984, Nelson 1984, Bowman and Jacobson 1998, Kastler 1998). Kastler (1998) observed battery failure in 38% of vaginal-implants. In our study, female elk that retained vaginal-implants until the calving season was 45% (n=18), compared to Kastler (1998) rate of 100% (n=5). Causes of premature expulsion were likely caused by early contractions, stillborn passage, or were pulled out by the elk. Two vaginal-implants expelled during transport may not have been properly installed because of researcher inexperience or reproductive tract physiology.

We believe vaginal-implants should be inserted early during gestation for proper placement and to allow the transmitter to shift with the changing physiology of the reproductive tract. In female elk, the distance from posterior end of the cervix to the vulva is 200-250 mm with a cervix diameter of approximately 12–16 mm in 2.5-year-old animals (Greer and Hawkins 1967). We suggest that future researchers use vaginal-implants that are > 25 mm in diameter because an adult multiparous elk cervix is approximately 52 mm in diameter (Greer and Hawkins 1967) and the vaginal canal increases with age. A larger diameter implant would prevent excessive displacement and reduce the likelihood of cervix puncture and premature expulsion. Because vaginal canal length increases with age, the antennae should be capable of being trimmed in the field. An extension of wing length and wing width may also aid retention. With a larger vaginal-implant, we recommend use only in female elk ≥ 3.5-years-of-age that have likely produced at least one calf (Wisdom and Cook 2000). Kastler (1998) estimated vaginal-implant transmitter range while internally retained as 0.4 km by ground telemetry and 0.8 km by aerial telemetry. We concur that transmitter range is limited. With increased implant size, a larger battery may be used and emit a stronger signal to facilitate the detection of parturition. Future vaginal-implant testing should occur in a somewhat restricted environment, for example Davis Island, as attempted by Bowman and Jacobson (1998). The study site should allow easy access so animals may be monitored every few hours throughout implant retention and the calving season.

We believe that current vaginal-implant transmitter design for elk is unreliable and more expensive on a per calf basis. A more dependable and retainable vaginal-implant transmitter design must be established before vaginal-implant technology can make a superior contribution to wildlife research on free-ranging populations than traditional parturition monitoring and field searches.

Appendix B

Eastern Kentucky Calf Study - 2001 Field Season

Calf Capture

Frequency (cow): **ID#/Eartag(cow):** **No. Calves Produced:** 0 *1* *2*

Age (cow): *Adult* *Yearling* **Date Last Stalked:** ____________

Frequency (calf): **ID#/Eartag(calf):** **Sex (calf):** *MALE* *FEMALE* *UNKNOWN*

Date: ________________ **Time:** ______________

Weather: ____

Visual: Cow: *Yes* *No* Calf #1: *Yes* *No* Calf #2: *Yes* *No*

Observer(s): _________________ ____________________ __________________

GPS Coordinates: EAST: ____________(UTM) NORTH: ____________(UTM)

Map Datum: __________ **DOP:** __________ **EPE:** __________ **Elev:** _______

Cover Type: ____

Plant Spp: _______________, _______________, _______________, __________

_______________, ____________________, ____________________, ____________

Calf Weight: _______ **(#'s)** **Days/Hours Old:** _________ **After Birth?** (circle) Yes No

Slope Location: **(check)** _____ **Bottom** _____ **Middle** _____ **Top;** Aspect: _________

Inclination: (circle) 0-10% 10-20% 20-30% 30-40% 40-50%, Other _______

Distance from (m's): __________Water, __________ Edge, __________ Road,

Physical Condition : *Cow:* ______________________________________

*Calf #1:*______________________________________

Behavior: *Cow:* ______________________________________

*Calf #1:*______________________________________

*** FLAG CALVING SITE LOCATION ***

Notes:

Length= **Chest girth=**

Appendix C

Eastern Kentucky Calf Study - 2001 Field Season

Calf Survival

Frequency (cow): **ID # (cow):** **No. Calves Produced:** 0 *1* *2*

Age (cow): *Adult* *Yearling* **Date Last Stalked:** ________________

Frequency (calf): **ID # (calf):** **Sex (calf):** *MALE* *FEMALE* *UNKNOWN*

Date: ________________ **Time:** ______________

Weather: ____

Visual: Cow: *Yes* *No* Calf #1: *Yes* *No* Calf #2: *Yes* *No*

Observer(s): _____________________ ________________ ____________________

GPS Coordinates: EAST: ______________(UTM) NORTH: ____________(UTM)

Map Datum: __________ **DOP:** __________ **EPE:** __________ **Elev:** _________

Cover Type: ____,

Plant Spp: _______________, _______________, ______________, _____________,

_______________, ____________________, _______________, __________________

Items Collected: HAIR FECAL OTHER: _______________

Physical Condition : *Cow:* ____

*Calf #1:*____

Behavior: *Cow:* ____

*Calf #1:*____

Notes:

____

____

____

____

____

Appendix D

Eastern Kentucky Elk Study - 2001 Field Season

Mortality Report

Frequency: ______________ **ID # :** ________ **Age:** ADULT YEARLING CALF

Date Last Normal Signal: _____________ **Date Mortality Signal:** ______________

Sex: *MALE* *FEMALE* *UNKNOWN* **Ear Tags** __________ **Metal Tag #** __________

Date Collected: _____________ **Time:** ___________ **Vaginal Implant Freq** _________

Weather: ____

Collector(s): ___________________ ___________________ _________________

Cause of Mortality: ____

GPS Coordinates: EAST: _____________(UTM) NORTH: _____________(UTM)

Map Datum: ___________ **DOP:** ___________ **EPE:** ___________ **Elev:** ___________

Cover Type: ____

Plant Spp: ________________, ________________, ________________, _____________

________________, _____________________, _____________________, _________________

Slope Location: **(check)** _____ **Bottom** _____ **Middle** _____ **Top; Aspect**: ___________

Inclination: (circle) 0-10% 10-20% 20-30% 30-40% 40-50%, Other _________

Distance from (m's): __________Water, __________ Edge, __________ Road,

Photographs #'s ______________________ **Fetus**: ____________________________

Fate of Animal and/or Parts: **Taken to LLDDC: Yes No**

Whole carcass:	Collected	Not Collected	Comments: ____________________________
Collar:	Collected	Not Collected	Comments: ____________________________
Head:	Collected	Not Collected	Comments: ____________________________
Femur:	Collected	Not Collected	Comments: ____________________________
Blood Sample:	Collected	Not Collected	Comments: ____________________________

Description of Carcass/Notes: ____

____

Appendix E

Eastern Kentucky Elk Study

Vegetation Sampling Form

Calf Frequency: _______________ **Date:** ____________ **Weather:** ______________
Type of Habitat (circle)**:** **HU** **HL** **RSM** **SMS** **CHM** **WA** **Other:** _________
GPS Coordinates: (E) ______________ (UTM) (N) ______________ (UTM)
Site: _______ *CALVING* _______ *HABITAT*

Observers: _____________, _______________, _____________, __________________

Distance from (m): _________ **Water** ___________ **Edge** _________ **Active Mine**

_________ **2-Track Rd** ________ **Gravel Rd** ________ **Paved Rd**

Densiometer: ____________
Slope: ____________
Position: bot ss mid ss top ss rt
Presence of (circle): Cattle or Horses

Basal Area: _________
Downed Logs/Boulders: ____/____
Aspect: _________

Under-story Vegetation Ranking:
1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________

Over-story Woody Vegetation Ranking:
1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________

Sapling DBH(>1”): 1-2” ________ 2-4” ________ 4-6” ________

Under-story Ht: __________ Shrub Ht: ____________ Canopy Ht: ___________

% Density	North	East	South	West
0.0-0.2				
0.2-0.6				
0.6-1.0				
1.0-2.5				

Nearest Neighbor (m)	NE -Type	SE - Type	SW - Type	NW - Type
Shrubs				
Trees				

Appendix E continued.

Percent Sample Plot (1-m^2)

NE	0	1-10	11-25	26-50	51-75	76-100
Grass						
Forbs						
Woody						
Vine						
Dead						
Bare						
Litter						

SE	0	1-10	11-25	26-50	51-75	76-100
Grass						
Forbs						
Woody						
Vine						
Dead						
Bare						
Litter						

SW	0	1-10	11-25	26-50	51-75	76-100
Grass						
Forbs						
Woody						
Vine						
Dead						
Bare						
Litter						

NW	0	1-10	11-25	26-50	51-75	76-100
Grass						
Forbs						
Woody						
Vine						
Dead						
Bare						
Litter						

Litter Depth (mm): NE: _______ SE: _______ SW: _______ NW: _______

37’ = 1/10 acre

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