TALES OF A REPATRIATED MEGAHERBIVORE: CHALLENGES AND OPPORTUNITIES IN THE MANAGEMENT OF REINTRODUCED ELK IN APPALACHIA

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Abstract.—Reintroductions of large mammals are challenging and often controversial endeavors. Elk (*Cervus elaphus canadensis*) were successfully reintroduced to southeastern Kentucky beginning in 1997. Since then, elk have exhibited a decade-long irruptive growth pattern in the absence of mortality factors that commonly limit its abundance in more western portions of North America. As a result, elk impacts on local vegetation in this area are increasingly apparent and concomitant with population growth of the species, particularly on or near reclaimed surface mines. Despite 8 continuous years of hunting, state wildlife officials estimate the current elk population has grown to 10,000-11,000. This paper examines some of the current and future challenges that local wildlife managers and land stewards increasingly face in managing elk numbers within social and ecological carrying capacities in an area with little public land.

INTRODUCTION

The early-mid Pleistocene epoch was characterized by the evolution of an abundant diversity of large mammalian fauna (Kurtén and Anderson 1980). Fifteen Pleistocene predators larger than 15 kilograms hunted the North American landscape, and their prey consisted of approximately 56 herbivores larger than 30 kilograms (Van Valkenburgh and Hertel 1993). Twenty-nine of these herbivores exceeded 300 kilograms and are often referred to as "megaherbivores" (Van Valkenburgh and Hertel 1993). These long since disappeared giants had profound influences on the continent's ecosystems during this period, yet the majority of plants they coevolved with (e.g., Kentucky coffeetree, *Gymnocladus dioca*) have persisted into modern times.

Rapid ecosystem change (Pielou 1991) and over-exploitation by humans (Martin 1984) during the late Pleistocene are thought to have caused the extinction of many habitat specialists, including many megaherbivores. Evolutionarily older, less specialized habitat generalists prevailed to colonize vacated niches in the landscape (Guthrie 1984). Archaeological data suggest that at least 18 species of large mammals in the Appalachians were extirpated during the Pleistocene and the range of dozens more was reduced (Guilday 1984). Geist (1992) refers to the remaining biota as "species-poor megafauna based on Siberian generalists and Rancholabrean survivors…poorly adapted to North America and to one another."

Global reductions in megaherbivore diversity and abundance have especially characterized the past two millenia. Today, there remain 11 North American herbivores larger than 30 kilograms and only three that can exceed 300 kilograms (elk, *Cervus elaphus*; bison, *Bison bison*; and moose, *Alces alces*). "Ubiquitous and abundant to the point of dominating mammalian biomass over most of the globe for millions of years, megaherbivores have been so systematically persecuted that they have become almost irrelevant to today's

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ecosystem and conservation concerns, except in dwindling portions of Africa and Asia" (Terborgh and others 1999). Despite this gloomy prognostication concerning these faunal giants, we must not ignore the realized nor potentially undiscovered influences remaining megaherbivores can exert on the landscape and ecosystem processes.

A "keystone species" has been defined as having a disproportionately great ecological effect on ecosystems relative to their biomass (Power and others 1996). A number of apex predators have been observed to exert keystone influences on ecosystems through top-down regulatory effects on species at lower trophic levels (*sensu* Smith and others 2003). Megaherbivores have been suggested as keystone species because they act as habitat modifiers through grazing, trampling, wallowing, and uprooting of existing vegetation. Ungulates are important modifiers of ecosystem structure and function because they can trigger trophic cascades (McNaughton 1979, Mattson 1997), increase spatial heterogeneity, accelerate successional processes (Hobbs 1996), and influence nutrient cycling and primary productivity (Augustine and McNaughton 1998). For example, elephants have converted entire woodlands to grasslands, which in turn become susceptible to invasion by ungulate grazers and fire; both agents suppress woody growth, thus maintaining grassland regimes (Laws 1970). In pre-European North America, herds of migratory bison numbering in the hundreds of thousands may have exerted similar keystone influences on the ecosystem (Knapp and others 1999). Through acts of grazing, trampling, and wallowing, bison probably maintained existing, and perhaps often created, large tracts of prairie. In more closed-canopy systems, bison activity may have been responsible for creating natural glades (Collins and Uno 1987).

Historically, herbivores were spatially and temporally dynamic modifiers of the bluegrass savanna-woodland of Kentucky (Wharton and Barbour 1991) and other areas within the Central Hardwoods Region. Species that persist precariously in only a few isolated areas of Kentucky, such as the federally endangered running buffalo clover (*Trifolium stoloniferum*) and Short's goldenrod (*Solidago shortii*), apparently depended on the conditions created by the physical disturbances of large herbivores (Baskin and Baskin 1984, Campbell 1988). Whether the elk and bison historically functioned as keystones in this region or as ecological dominants (Odum 1971) is unknown.

ELK RETURN TO KENTUCKY

Measuring between 225 and 450 kilograms, the elk is the smallest extant megaherbivore in North America. Elk had a pre-European settlement distribution that encompassed southern Canada and much of the contiguous United States (Murie 1951), but it has experienced a drastic range reduction since. Two subspecies—the eastern elk (*C. e. canadensis*), which occurred in Kentucky, and the Merriam elk (*C. e. merriami*)—were extirpated due to habitat loss and overharvest (Bryant and Maser 1982). The eastern elk was extirpated by the mid-1800s (Murie 1951) and little information exists on its morphological distinctiveness or its ecological function in the landscapes of the east. Although early explorers of the Commonwealth provide accounts of elk, this information has been insufficient to infer its historic statewide abundance or relative distribution. The abundance and distribution of elk place names in Kentucky suggest a statewide distribution (Cox and others 2002). Because large generalist herbivores such as elk and white-tailed deer evolved in disturbed ecotonal landscapes where edge provides both food and cover (Geist 1982, 1998), eastern elk distribution and relative abundance may have coincided with areas of disturbance. As such, elk in Appalachia may have foraged primarily in or near river floodplains and glades, and seasonally within the forest for its herbaceous understory and mast. The relative importance the eastern elk played in shaping the biodiverse ecosystem of this region remains largely speculative.

Cervids are highly valued for consumptive and nonconsumptive reasons (Potter 1982, Conover 1997) and have been the subject of extensive and intensive restoration efforts in North America (Bergerud and Mercer 1989, Witmer 1990). Although attempts to reintroduce woodland caribou (*Rangifer tarandus*) largely failed (Bergerud and Mercer 1989), those involving elk and white-tailed deer have been more successful. Since 1900, restoration efforts in North America have facilitated population increases of white-tailed deer (*Odocoileus virginianus*) from approximately 500,000 (Downing 1987) to 26 million (Demarais and others 2000), and elk from less than 100,000 (Seton 1953) to over 1 million (Bunnell 1997). Limited post-release monitoring and scant documentation frequently hindered insight into factors responsible for elk reintroduction failures, although insufficient habitat, crop depredation, disease, poaching, and lack of sufficient funding for adequate management were often blamed (Witmer 1990).

In 1997, the Kentucky Department of Fish and Wildlife Resources (KDFWR) established an elk reintroduction program aimed at translocating approximately 1,800 elk from the western United States to Kentucky over 9 years. Initial public support for elk reintroduction was strong, although some expressed concerns that elk would depredate crops, cause automobile accidents, outcompete and cause population declines of white-tailed deer, and place additional herbivory pressure on plant communities beyond that caused by white-tailed deer (Maehr and others 1999). To address some of these concerns, KDFWR selected a 1.06 million-ha, 14-county area in the southeastern portion of the State for elk release and population establishment characterized by low densities of roads, row crops, and humans (Phillips 1997). The long-range population objective was initially 7,500, or 2.6 elk per square kilometer within the elk restoration zone (Phillips 1997). A few years later, the target population goal was increased to 10,000 and the elk zone expanded to include an additional two counties that bordered Tennessee's newly created elk reintroduction zone.

Management plans for reintroduced species should account for spatial and temporal variation in habitat use and availability at geographical scales appropriate to the species to enhance the likelihood of successful establishment. Griffith and others (1989) stated, "Without high habitat quality, translocations have low chances of success regardless of how many organisms are released or how well they are prepared for the release." Although less than 1 million people lived in the elk restoration zone, human settlement patterns closely mirrored the dendritic patterns of watersheds that were likely important historical foraging grounds of ungulates such as elk. With these areas occupied, alternative habitat of sufficient size, quality, and distribution through the restoration zone was a prerequisite for reintroduction.

Surface coal mining and subsequent reclamation have changed the physical and biotic character of the landscape in eastern Kentucky and other portions of Appalachia. Rugged, forested terrain has been converted into gently sloping mesas and plateaus that have been revegetated with grass and forb species that are typically exotic, yet provide an inexpensive means to bind soils and minimize erosion. Reclaimed mine lands are novel landscapes that sometimes harbor a bizarre combination of grassland and forest species not found in more intact lands surrounding them. Surface mines can exceed 5,000 ha in size, and uncannily resemble the rolling plains that elk inhabit in portions of its range in the western United States. As such, reclaimed coal surface mines were thought to provide a suitable habitat alternative for reintroduced elk. By March 2002, more than 1,500 elk had been released at eight sites in Kentucky, including seven on active or reclaimed coal surface mines.

DO DENATURED MOUNTAINS LIVE IN FEAR OF ELK?

Habitat selection by large herbivores can occur at multiple ecological scales as dictated by the morphophysiological adaptations of the species (Senft and others 1987). A number of North American ungulates, including elk, have foraging patterns that can operate at the landscape scale and can influence both single species and community dynamics in profound ways. Elk modify ecosystems directly through alteration of plant composition, diversity, and structure, and by serving as a nutrient and propagule carrier (Frank and others 1994, Singer and others 1994, Stewart and others 2009). These effects in turn can cause habitat changes at several spatial and temporal scales that have equally profound indirect impacts on other species, and sometimes lead to trophic cascades and alternative stable states within an ecosystem, particularly where elk predators are absent (Ripple and others 2001, Smith and others 2003). In the absence of wolves, elk in Yellowstone National Park (located in portions of Wyoming, Idaho, and Montana) exerted top-down herbivory influences that caused declines in willow (*Salix* spp.) and aspen (*Populus* spp.), which in turn influenced a host of other species dependent on these plant communities (*sensu* Smith and others 2003). Arguably, elk in Yellowstone functioned as ecological dominants in relation to their biomass rather than as ecological keystones before wolf reintroduction.

The release of elk onto minescapes posed several management questions, including whether these areas would retain elk at or near release sites, and whether habitat was of sufficient quality to foster population growth. Reintroduced elk in Kentucky quickly settled into these novel habitats and were found to select mine lands over others at all release sites at landscape and home range scales (Cox 2003). Although surface-mined areas represented only 10 percent of the elk restoration area, composite elk home ranges at each release site contained a minimum of 30 percent of this cover type. Reintroduced elk in Pennsylvania have also been found to extensively use reclaimed mine lands (Cogan 1996).

Elk in the western United States can exhibit migratory movements largely in response to the availability and quality of foods and winter severity (Craighead and others 1973, Irwin 2002). Murie (1951) suggested that the eastern elk subspecies was nonmigratory. Most elk populations that currently inhabit the eastern United States live in more temperate climates with longer growing seasons than their western counterparts. Therefore, assuming an adequate supply of food is available, eastern elk should show little to no tendency to migrate and have greater fidelity to local ranges, a pattern exhibited by elk in Pennsylvania (Cogan 1996) and Kentucky (Larkin and others 2003). In an area with little public land, fidelity to mine lands has thus far likely reduced both the number of elk-vehicle collisions and depredation of crops on smaller private parcels. Despite high fidelity to reclaimed mines, complaints about elk as nuisances persist in Kentucky, and primarily include use of cemeteries, gardens, golf courses, and orchards (KDFWR, data available on file, Frankfort, KY).

Although surface mines have severely impacted forest ecosystems in Appalachia (Hamel 2000, Holl and others 2001), these denatured lands have thus far proved ideal habitat for elk in Kentucky. Reclaimed mines have reduced topographic gradients, which allow elk to maximize forage intake, minimize energy expenditure, and remain close to forest edges and thermal cover (Coop 1973, Grace and Easterbee 1979). In addition, reclaimed mines have created vast viewscapes favorable to the gregarious elk. This herbivore is morphologically and behaviorally adapted to open areas, where it coevolved with cursorial predators such as the gray wolf (*Canis lupus*) (Geist 1998). Despite having been hunted for nearly a decade, many elk freely roam active and long-abandoned surface mines during diurnal times, conspicuously bed in open areas, exhibit little fear of humans, and thus appear to be operating as optimal foragers (MacArthur and Pianka 1966). In fact, many elk monitored using global positioning system collars move only a few hundred meters per day as they travel from bedding to feeding areas (J. Cox, unpubl. data). Areas with a high concentration of elk activity have been humorously place-named "elk nirvana" by elk researchers.

The availability of thousands of hectares of reclaimed mineland, coupled with mild winters and the absence of large predators, appears to have provided ideal conditions for elk in Kentucky, as demonstrated by the their irruptive population growth in the past decade. Despite being hunted since 2001, elk have grown in population by an estimated average of nearly 25 percent since 1997, although population growth has slowed from an estimated high of 57.6 percent in 1998 to around 4.7 percent in 2009 (KDFWR, data available on file, Frankfort, KY).

Researchers (including the author) at the University of Kentucky have studied the habitat use, space use and movement patterns, and demographics of reintroduced elk in Kentucky for more than a decade (e.g., Larkin and others 2003). However, the initially rosy prognostication for elk population growth, viability, and compatibility with local systems belies disturbing new ecological patterns that have emerged in recent years as elk have dramatically increased in abundance and density. Concomitant with elk population growth have been more frequent observations of their impact on local plant communities and soils, particularly on mine lands and adjacent forests. These effects are perhaps most noticeable in forest-grassland edge that elk frequently traverse in large herds containing as many as 150 individuals, in forest remnant islands surrounded by mine lands, and in areas of reclaimed mines where reforestation has been initiated.

On the edge of surface mines, elk have created wide movement paths as they enter and exit forests during their daily activities. In these areas, erosion is readily visible, where soils have been excavated by trampling hooves, particularly on steeper slopes. Piles of elk feces frequently dot these trails and form concentrated pools of nutrients and plant propagules that are carried into surrounding forests where erosion channels have become sufficiently deep and furrowed. Additionally, elk browse lines in edge areas have become apparent, and tree saplings in mined areas frequently exhibit arrested growth patterns from having been repeatedly browsed. Elk have also been repeatedly observed browsing invasive exotic species, such as multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellate*), and crown vetch (*Coronilla varia*) in mined areas (Schneider and others 2006). Transport of propagules of these and other invasive, exotic plant species by elk into nearby forests has increased the likelihood that neighboring forests will become invaded and native species eventually displaced by these prolific and difficult-to-eradicate aliens. This threat is particularly serious from shade-tolerant invaders, such as multiflora rose.

Forest remnant islands and peninsulas adjacent to reclaimed mines are favorite day bed areas for elk. As early as 2 years post-reintroduction, the impacts of elk were readily apparent and manifested in overbrowsed vegetation. Most noticeable were the larger group beds characterized by hundreds of square meters of ground stripped of topsoil and vegetation and littered with prolific piles of elk feces and widespread urine deposition. Smaller forest remnants near favorite feeding grounds in particular were highly fragmented by both day beds and numerous trails that radiated from them.

Elk impacts on individual trees and shrubs also became evident early on during active restoration efforts. Elk were observed to impact entire hillsides of tree plantings to the point these areas were place-named by field researchers to demarcate elk impacts (e.g., "Rubout Ridge"). In particular, elk browsing of the nitrogen-fixing black locust (*Robinia psuedoacacia*) has been high, constituting as much as 27 percent of woody browse in their seasonal diet (Schneider and others 2006). Much to the dismay of some of my fellow forestry researchers, entire experimental plantations of black locust have been browsed to extinction on these mines (J. Lhotka, University of Kentucky, pers. comm.). Additionally, black locust is frequently antler-rubbed and subsequently top-killed by bull elk during the rut. Repeated browsing and rubbing by elk in some areas have left thousands of black locust saplings deformed and in an arrested state of growth. Silver maple (*Acer saccharinum*) and yellow-poplar (*Liriodendron tulipifera*) are also commonly browsed by elk on reclaimed mines (Schneider and others 2006), while others such as American sycamore (*Plantanus occidentalis*) are virtually untouched.

These observations collectively suggest that elk in Kentucky are at minimum exerting direct local effects on plant composition and abundance, and perhaps are emerging as ecologically dominant species with landscape-level impacts concurrent with rapid population growth. Given the difficulty of natural vegetative succession and successful reforestation on compacted mine lands, and the unique species assemblage that occurs there, it may be possible that elk will exert ecological influence in these areas in ways that exceed what their numbers alone would suggest. Such keystone effects may alter ecological trajectories of these novel systems in ways that favor grassland and frustrate managers and reclamation bond holders alike. These potential impacts are only now stimulating interest in long-term ecological studies of elk in the region on both natural areas and reclaimed mines.

THE CHALLENGE OF REGIONAL ELK MANAGEMENT

The Kentucky elk restoration program was one of the most successful single-species reintroductions in history. Elk have at least partially filled an ecological niche vacated for nearly two centuries. However, the use of a surrogate elk subspecies coupled with its repatriation into a landscape altered by forest fragmentation, establishment of high-elevation exotic grasslands, and absence of important players such as large predators and American chestnut (*Castanea dentata*), has created an entirely new ecological dynamic vastly different from what existed immediately prior to pre-European settlement.

As of early fall 2009, it is estimated that between 10,000 and 11,000 elk roam the 16-county elk zone (T. Brunjes, KDFWR, pers. comm.), a number approaching wintering elk numbers in Yellowstone National Park. Given the scarcity of natural openings in the pre-European forests of eastern Kentucky, it is likely that elk numbers in this area were historically much lower than today, and that the regional carrying capacity for the species has been substantially increased as a result of surface mining. Widespread forest fragmentation caused by mining and timber harvest could act synergistically with high densities of elk and white-tailed deer to dramatically alter regional biodiversity, community composition, and ecosystem services as they have elsewhere (Coté and others 2004) .

The return of elk poses a conservation and management dilemma for many. Elk are a charismatic species that is popular with the general public and hunters, and thus a focal species that generates management income and tourism dollars that can ultimately benefit many other wildlife species. Concurrently, coal mining interests herald the elk as a symbol of the benefits surface mining has provided to wildlife and its users, while those opposed to surface mining often view the elk as the industry poster child associated with the ecological ills caused by mountain-top removal (J. Hardt and others, Kentuckians for the Commonwealth, pers. comm.).

Depending on the management goal of post-mined land, elk persistence and mine reclamation may be at odds. Remedies to control deer and elk overbrowsing are typically costly measures implemented at the local scale (e.g.,fencing, tree guards) and not at landscape scales, where effects can be equally pervasive yet harder to detect unless carefully measured and monitored over longer time intervals. Mine managers that implement reforestation of post-mined lands will, if successful, ultimately create conditions less favorable to elk and more likely to encourage depredation of private yards, pastures, gardens, and fields of landowners with small parcels of land. In contrast, elk would likely fare much better and cause less depredation if mines were managed as grasslands, as improved pasture, or as a shrub-grassland mosaic with limited forest cover in all cases. If elk continue to increase and persist at high densities, surface mine managers will be increasingly challenged to maintain viable populations of common plant species used in reclamation. It is possible that elk depredation could lead to instances of delayed release of reclamation bonds if their impacts increased soil erosion or prevented revegetation of bare ground.

Despite the successful repatriation of several wildlife species to Appalachia during the past century, the region still contains 8 of the top 15 states with species most vulnerable to extinction (Kentucky Environmental Quality Commission 1997). Habitat loss and fragmentation, pollution, and exotic species now represent the major threats to regional biodiversity (Kentucky Environmental Quality Commission 1997). Managers of protected areas and public lands may also find the additional burden of elk management challenging, particularly in those areas that border large mines and are more likely to harbor high densities of elk. Overabundant elk could increase fragmentation and accelerate species loss, particularly along edge, but also in the interior of these lands if palatable grasses and other forbs sewn on reclaimed mines become scarce and/or as elk approach local ecological carrying capacity.

Knowledge of the abundance and distribution of elk is paramount for successful management. These data allow managers to best allocate hunting and other elk management efforts to maintain population viability and minimize conflicts with humans and other species. For wildlife managers, just knowing how many elk are out there is challenging enough. Elk are particularly difficult to survey in Kentucky because they occur in relatively remote places in an area over twice the size of Yellowstone National Park. Areas occupied by elk are difficult to access from the ground, thus making population estimates based on these types of surveys unreliable. Further, elk in Kentucky typically bed in forests during the day which makes expensive aerial surveys unreliable given the gregarious nature and clustered distribution of elk.

As of 2009, six reintroduced elk populations had been successfully established east of the Mississippi River (PA, TN, KY, WI, MI, Great Smoky Mountains National Park). Kentucky's elk population remains 10 times the size of others and individuals have already moved into the neighboring states of Virginia, Tennessee, North Carolina, and West Virginia. Thus, it's likely that elk will continue to influence the region's ecosystems and land management for the foreseeable future. In particular, it appears that elk have much potential to influence policymakers and land stewards in how and why we manage surface mined lands. To better understand the role of elk in this highly altered landscape, it is recommended that long-term ecological studies be established to monitor the changes this megaherbivore will continue to bring to this biologically diverse, yet ecologically threatened area.

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