ASSESSMENT OF METHODS FOR REDISTRIBUTING ELK TO BENEFIT VEGETATION IN ROCKY MOUNTAIN NATIONAL PARK

Final Report

Submitted to Rocky Mountain National Park

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INTRODUCTION

Abundant populations of Rocky Mountain elk (hereafter elk) have caused substantial challenges for resource management agencies. Crop depredation (Wilson et al. 2009, Hegel et al. 2009), lack of regeneration of native aspen and willow stands (White et al. 1998, Brookshire et al. 2002), spread of disease (Brook and McLachlan 2006, Hamir et al. 2006), vehicle collisions with elk, and direct attacks by elk can affect human interests and entire ecosystems. Management of elk damage can be difficult, given that elk home ranges and/or migration routes may overlay a variety of land holdings (e.g., national parks, national forest, private), especially when a variety of entities (e.g., National Park Service, U.S. Forest Service, state wildlife agencies, private landowners) have different goals and objectives. The resulting challenges and impacts on adjacent private lands further complicate elk management. In recent history, these factors have changed the physical and social landscape for managing elk and the resources they impact, constantly providing new and evolving challenges to elk-human conflict resolution.

Elk were reintroduced into the Estes Valley in 1913–1914 and flourished with no natural (e.g., wolf, grizzly bear) or human population control within Rocky Mountain National Park (ROMO) until the early 1940s. As early as 1931, there was concern for elk becoming overabundant as the herd's toll on vegetation became apparent (McLaughlin 1931, Wright et al. 1933). By 1940, the herd size within ROMO had reached an estimated 1,100 elk (Ratcliff 1941), potentially approaching ecological carrying capacity (Wright et al. 1933). Forage reduction due to grazing by domestic livestock on privately owned land within the winter range of elk was proposed as the root for the herd's negative effect on vegetation within ROMO (Wright et al. 1933). Subsequently, ROMO purchased privately owned land (e.g., Beaver Meadows) adjacent to the park as it was thought this particular property was the most important winter range of elk in the area (Ratcliff 1941). Due to increases in elk numbers and continued degradation of vegetation within ROMO an elk management plan was developed in 1943 (Guse 1966). An initial reduction (i.e., lethal removal) of elk occurred within ROMO in the mid-1940s with periodic removals occurring until 1962. During the 1960s, management of the ROMO's elk herd consisted of hunting outside and adjacent to park boundaries and trap-and-transfer of individuals. However, by the end of the 1960s all direct reductions of the elk herd within ROMO ceased with the adoption of a hands off approach, coined "natural regulation" (Huff and Varley 1999).

Elk and their habitat relationships within ROMO have been monitored since the inception of natural regulation. The number of elk that winter in the Estes Valley inside the park has grown since natural regulation, with recent population estimates ranging from 700–1,100 individuals from 1995–2005 (Lubow et al. 2002). Of more notable occurrence however, was the growth in number of elk that winter in the adjacent town of Estes Park which ranged from 1,000 to 2,500 individuals from 1997 to 2005 (Lubow et al. 2002). During 2001, annual survival rates for adult males within ROMO and Estes Park were estimated at 79% and 42%, respectively (Lubow et al. 2002) while annual survival rates of adult females were similar between ROMO and Estes Park at an estimated 91%. Although hunting is the primary source of mortality for elk in Colorado, elk that occupy ROMO and Estes Park must leave the town and park boundaries to be available for harvest by hunters (Lubow et al. 2002). The growth of the ROMO and Estes Park populations of elk with relatively high survival rates have led to vegetation degradation (Baker et al. 1997). Elk have prevented aspen suckers from maturing at heights >8 ft in occupied regions of ROMO since approximately 1970 (Suzuki et al. 1999, Kaye et al. 2005). The current number of elk within ROMO may be the primary factor controlling aspen regeneration within winter range (Olmsted 1979, Baker et al. 1997). Elk have the potential to directly decrease willow growth and size (Peinetti et al. 2002, Singer et al. 2002). Furthermore, elk have been observed to limit willow reproduction within their winter range in ROMO demonstrated by the lack of seed production and limited seedling survival (Cooper et al. 2003).

Elk herbivory is a concern in ROMO because of focused feeding patterns and relatively high densities within specific areas of the park (e.g., Moraine Park; Baker et al. 1997). The relatively high numbers of elk and levels of herbivory have degraded the vegetation within ROMO, limiting flora and other fauna (Mueggler 1985, Connor 1993, Turchi et al. 1994, Simonson et al. 2001). Furthermore, chronic wasting disease (CWD), a lethal disease of cervids, has been detected in ROMO (Spraker et al. 1997). The relatively high aggregation of elk within ROMO may promote transmission of CWD (Miller and Williams 2004). As ROMO is obligated by law and policy to attempt to maintain and restore natural conditions and processes within the park, personnel recently developed an elk and vegetation management plan and environmental impact statement (plan/EIS, Rocky Mountain National Park 2007). The plan/EIS focuses on the population of elk inhabiting the eastern-side of the park during winter (Figure 1).

Elk that occupy remote landscapes that are free of routine human presence or disturbance, except during hunting seasons, typically flee when they are encountered by humans (Edge and Marcum 1985, Vieira et al. 2003, Storlie 2006). Additionally, elk can become accustomed or habituated to human presence when humans are routinely in proximity and seldom harass or pose any threat. Elk frequently adapt to non-threatening routine human disturbance (e.g., feeding livestock, recreational activity; Cassirer et al. 1992, Thompson and Henderson 1998) and become difficult to manage with most nonlethal techniques. Habituated elk have been identified in residential communities (Thompson and Henderson 1998), national parks and refuges (Schultz and Bailey 1978, White et al. 1998), and near developed areas (e.g., ski-areas, wind turbines;

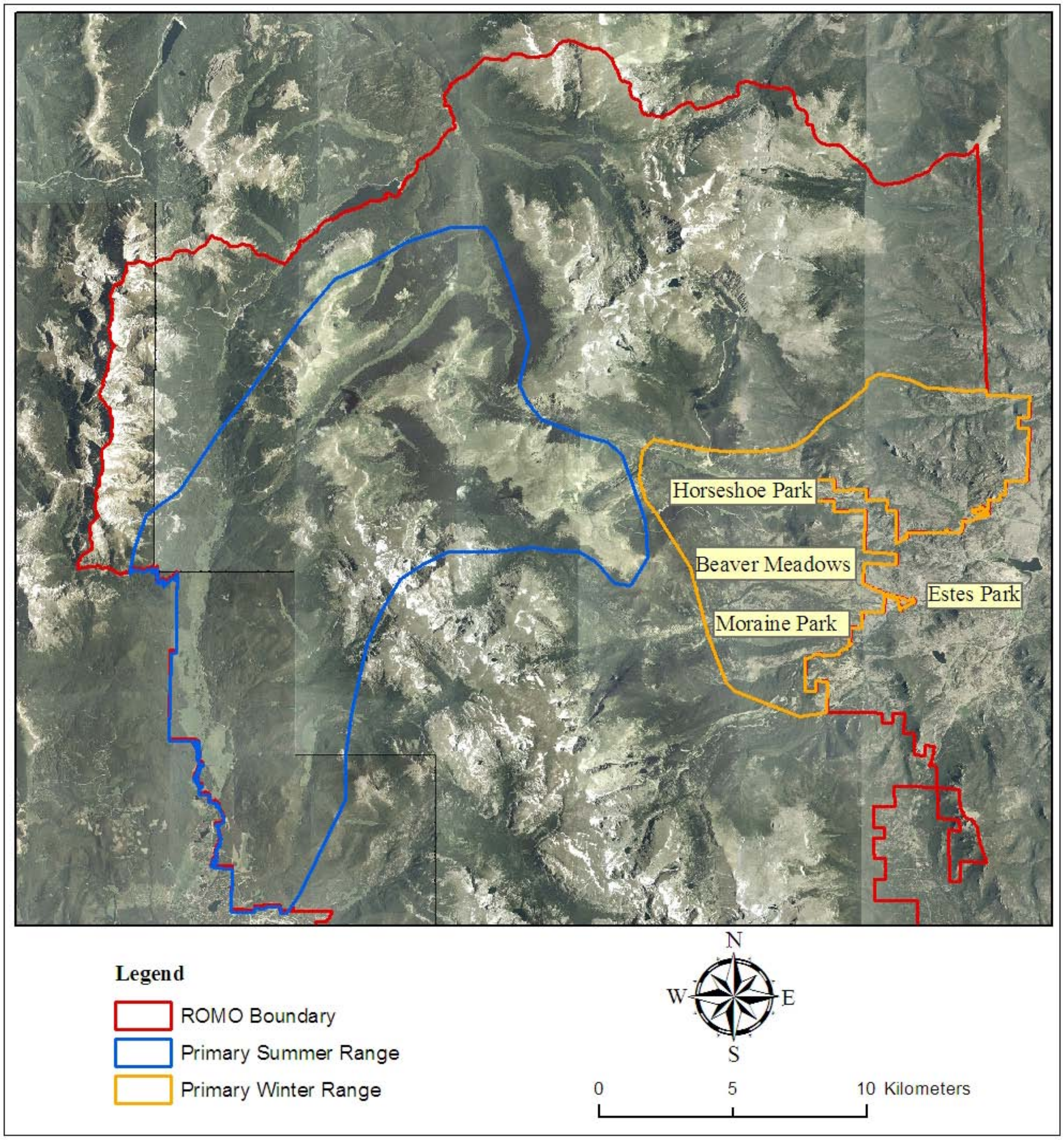

Figure 1. Locations of Horseshoe Park, Beaver Meadows, Moraine Park, Estes Park, and the primary winter and summer range of elk within ROMO.

Morrison et al. 1995, Walter et al. 2006). Habituation of elk to human presence and disturbance has been considered the driving force behind many elk-human conflicts in recent years (Thompson and Henderson 1998). Elk-vehicle collisions often result when elk habituate to human activities in residential communities, parks and refuges, or high-use travel corridors (Clevenger et al. 2001, Biggs et al. 2004, St.Clair and Forrest 2009). Habituation of elk can also lead to increased health and survival in urban/suburban landscapes (McKenzie 2001, Rubin et al. 2002, Hebblewhite and Merrill 2009) and will continue as long as human encroachment into wildlife habitat occurs combined with a lack of concerted efforts, including both lethal and nonlethal, to encourage elk to regard humans as a threat. Elk that frequent roadsides and developed areas (e.g. residences) in ROMO are habituated to humans, typically not reacting to human presence. However, further from roads, elk in the park do react to people, often fleeing when approached. Additionally, the lack of large carnivores (i.e., wolf , grizzly bear) within ROMO may contribute to sedentary behavior of elk, similar to Yellowstone National Park (YNP) when no wolves were present (Laundre et al. 2001). Fortin et al. (2005) documented that wolves influenced elk movements in YNP and wolves have been documented as having a direct influence on cervid abundance and foraging behavior (Kunkel and Pletscher 1999, Peterson 1999, Hebblewhite et al. 2002). Wolves can affect populations of elk directly (i.e., killing of individuals), but the presence of wolves may have indirect impacts, such as increasing vigilance (Brown 1999). Fortin et al. (2005) reported elk preference for aspen stands decreased with increased wolf presence, perhaps due to an increased perceived risk of predation in such habitat.

Recreational hunting is the primary tool used by wildlife agencies to control and, if needed, reduce the size of elk populations (Boyce 1989, Bunnell et al. 2002, Hegel et al. 2009) and is the preferred method of many agencies for controlling nuisance elk (Table 1). Regulated harvest has been successfully used to control populations of white-tailed deer, mule deer, elk, and moose by numerous agencies in open landscapes and fenced parks or preserves (Conner et al. 2001, Bunnell et al. 2002, Walter and Leslie 2002, Hams and B. Trindle 2008). Hunting occurs outside ROMO and is managed by the Colorado Division of Wildlife. Hunting is prohibited in ROMO, however, by law and long standing National Park Service policy, so the plan/EIS considered a variety of other conservation tools for reducing elk numbers and redistributing the population. The selected alternative within the plan/EIS focuses on management through population reduction (e.g., culling), vegetation management (e.g., fencing), and redistribution (e.g., forced dispersion). Culling elk via shooting, in addition to some capture/euthanasia for research purposes, is the management strategy currently being used to reduce elk numbers. Objectives of culling were to maintain a population of elk ranging from 1,600 to 2,100 individuals in the ROMO/Estes Valley population, including 600–800 elk wintering inside the park. The strategy involves removing a maximum of 200 elk annually, with the actual number of elk culled modified annually by an updated estimate of the elk population. Culling currently occurs in mid-winter to minimize visitor impacts, however the plan/EIS identifies the potential to cull any time of year to meet specific objectives. A culling operation consists of 10–15 agency personnel that travel ROMO roadways until appropriately located elk are observed then one to several are killed using firearms.

Fencing for vegetation management (i.e., protection of aspen and willow) within ROMO has been another strategy implemented in accordance with the plan/EIS. Options for fence construction include the use of wooden and/or wire fence in a rail or woven-wire fence design with a gap in the bottom, similar to those developed by VerCauteren et al. (2007). Up to 160 acres of aspen could be fenced on primary elk range. Fences to protect willows on winter and summer range could total up to 260 and 180 acres, respectively. This is in addition to the 12 acres of research exclosure fencing already in place within the primary winter (i.e., Beaver Meadows, Horseshoe Park, Tuxedo Park, Moraine Park, and Buck Creek) and primary summer range (i.e., Kawuneeche Valley). To date approximately 46 acres of aspen and 145 acres of willow have been fenced on the winter range using a woven wire design with a gap in the bottom to avoid impeding other wildlife. These fences are temporary, but will be in place until vegetation restoration is deemed adequate, potentially 10–20 years.

Adaptive management of abundant elk is necessary in ROMO to reduce impacts of elk on vegetation and restore, to the extent possible, the natural range of variability in the elk population and affected plant and animal communities. Our objectives were to build upon the plan/EIS management practices within ROMO by presenting nonlethal techniques that are available within the constraints of ROMO’s policies to redistribute elk to minimze damage to sensitive habitats or conflicts with human interests. Specific objectives were to: (1) review the present state of knowledge of management methods and create a database on literature to reduce the impacts of elk and potential for use in ROMO, (2) review research needs to develop preliminary protocols that may provide feasible options for managing or redistributing elk within ROMO, and (3) provide a publishable manuscript in regard to the aforementioned review of management methods (Appendix 1).

STUDY AREA

The primary winter range of elk within ROMO includes Moraine Park, Beaver Meadows, and Horseshoe Park (Figure 1). Rocky Mountain National Park encompasses 265,638 acres and is located in Larimer County, Colorado. The town of Estes Park lies on the eastern border of ROMO.

METHODS

We used several databases (e.g., WorldCat, JSTOR, DigiTop, Web of Knowledge) in our review of published literature on methods for redistribution of elk and/or other cervids and preventing or alleviating damage (e.g., herbivory). Additionally, we examined gray literature (e.g., state, federal) and interviewed agency biologists to determine any and all methods they have used for elk dispersion and damage control. We interviewed agency personnel throughout the range of elk within North America, a summary of agency personnel can be found in Table 1. We provide a review of elk dispersion and damage abatement techniques acquired from the aforementioned literature and interviews. We also consulted with ROMO personnel for details pertaining to on-going ROMO-specific management methods and protocols. We then considered this knowledge relative to ROMO’s specific circumstances and needs and discuss how different techniques and tools could be applied in ROMO. Finally, we provide protocol ideas for strategies we determined to have the most potential to achieve ROMO’s goals.

RESULTS

Nonlethal tools such as fencing and frightening devices (e.g., scarecrows, noise makers) have been used for centuries. Recently, society has placed greater emphasis on use of nonlethal techniques, thus demonstrating need for development and rigorous evaluation. Limited effectiveness and high cost of nonlethal techniques can make them economically impractical, even when used in conjunction with lethal techniques (DeNicola et al. 2000). Cost-benefit analyses of nonlethal actions should be conducted to ensure costs will not exceed benefits received (DeNicola et al. 2000). Unfortunately, absent of annual regulated hunting, most nonlethal approaches provide only temporary protection of resources and safeguard areas of relatively limited size (Witmer 1998, DeNicola et al. 2000). Due to limitations of nonlethal techniques to maximize benefits, they should often be part of an overall integrated management approach that includes lethal practices. The focus of nonlethal control techniques, with no lethal component, should be on reducing damage to tolerable levels, as elimination of damage is unlikely (Gilsdorf et al. 2002). In the case of elk at ROMO, nonlethal management strategies could help achieve objectives of reducing elk presence in sensitive habitats in a manner acceptable to the public.

Exclusion Fences

Fences are an effective, potentially long-term, nonlethal technique for protecting and minimizing cervid damage to sensitive resources. Fences for elk and deer have been rigorously tested and a substantial amount of research has been conducted and collated in a review by VerCauteren et al. (2006a). Broad classes of fence designs with potential for use in ROMO include: woven-wire mesh, modified woven-wire mesh, high-tensile electric, slanted, poly mesh, and electrified poly tape and poly rope (VerCauteren et al. 2006a, Lavelle et al. 2010; Table 2). Variables to be considered when selecting an appropriate fence design include: value of resources to be protected, level of protection desired, seasonality of the resource being protected, physical ability of the target species, motivation to breach, behavioral characteristics, costs associated with constructing and maintaining the fence, longevity of the fence, and possible negative effects of erecting a fence (VerCauteren et al. 2006b).

A commonly used fence for deer and elk, an 8-ft-woven-wire fence, is a physical barrier that greatly reduces the possibility of an animal passing over, under, or through. Reviewing various fencing methods (e.g., woven wire, remesh), Schneidmiller (1987) stated that a 6 to 7-ft high fence constructed of 50% woven-wire mesh and 50% multiple strands of barbed wire spaced at 6-in intervals provided the best long-term protection of stored crops. Karhu and Anderson (2006) found that a 2.5-ft, 2-wire fence did not deter crossings by elk, while a 4.3 ft, 4-wire fence deterred crossings by 41% of approaching elk. VerCauteren et al. (2007) designed and evaluated a fence intended to exclude elk while allowing passage by other wildlife species that is currently being used and evaluated further in ROMO (Gage and Cooper 2009). Buck-and-pole fences (6-ft in height), made of wood or steel, along the northern boundary of YNP, Montana, appeared to be a substantial barrier to animals that rely on jumping to breach such fences (Scott 1992). Buck-and-pole fence design provides a seemingly effective barrier with an aesthetically pleasing appearance offering an option for applications where public perception is a concern.

Electric fences act as psychological barriers based on learned avoidance conditioning (McKillop and Sibly 1988). Polytape, polyrope, and other electrified wire fencing can be effective for deterring cervids seasonally (dry snow can reduce conductivity and decrease effectiveness) provided the proper height and number of strands are used. Avoidance conditioning effects success of these fence types, thus animals must first experience these fences under low motivation to build respect. Avoidance conditioning occurs when an animal contacts the fence, often with the nose or tongue, and receives a powerful electric shock. Training can be expedited by baiting with peanut butter or molasses applied directly to the fence to create a negative stimuli when contact is needed with the fence (Porter 1983, Hygnstrom and Craven 1988, Byrne 1989; J.W. Fischer, USDA APHIS WS NWRC, unpublished data).

Proposals for fencing installations to provide protection for vegetation from elk in ROMO resulted in split acceptance by survey respondents (Stewart et al. 2004). The degree of movement across fences would depend on motivation to breach, which would likely be related to availability of alternative forage. Though fencing could permit regeneration of tree species and elk-specific exclusion is possible, cost, aesthetics, and maintenance requirements need to be considered.

Hazing

Hazing is defined as the continued disturbance and disruption of behavioral patterns of problem individuals by the persistent use of a variety of techniques including: dogs, humans on foot, horseback, or in vehicles, and use of rubber bullets and shot, or paintballs. Human-induced disturbance of elk has recently received increased attention from researchers and wildlife managers (Kloppers et al. 2005). Hazing techniques induce an escape response to avoid potential negative consequences (i.e., perceived predation) by approaching humans or dogs (Kloppers et al. 2005). Reduction of habituation through hazing has not been evaluated in elk and deer to a great extent (Frid and Dill 2002, Kloppers et al. 2005), yet should be rigorously evaluated. Where hunting occurs, human disturbance appears to be perceived as a risk of predation by elk (Plumb et al. 2009, Kilpatrick et al. 2009), demonstrating a vulnerability that may enable hazing to be an effective tool for redistribution of elk from sensitive habitats. Managers routinely haze bison (Plumb et al. 2009, Kilpatrick et al. 2009) and elk away from sensitive areas in the west (Neff 2007, Washington Department of Fish and Wildlife 2009). Personnel within Yellowstone National Park have used a combination of ATVs, snowmobiles, helicopters, employees on horseback and on foot in combination with cracker shells and rubber bullets to haze bison back into the park (National Park Service 2009). Bison are notoriously difficult to herd and will only go where they want to go (Meagher 1989), sometimes resulting in park personnel reverting to culling when hazing becomes ineffective (Keiter 1997). Elk seem more susceptible to hazing, but as with bison, tend to only go where they are willing to go (Colorado Division of Wildlife, personal communication; National Elk Refuge, personal communication; Table 1). Hazing could be used to reverse habituation in human-dominated landscapes to redistribute elk away from sensitive habitats (i.e., regenerating aspen stands). Hazing of elk can target a specific habitat in need of protection from elk, focus on particular offending animals, and be implemented in various habitats.

Interviews with agency personnel revealed that hazing is a commonly used technique to redistribute elk (Table 1). Common tools for hazing used by agency personnel were ATVs, vehicles, helicopters, humans on foot, bird shot, cracker shells, screamer shells, and propane cannons. In South Dakota, agency personnel often use ATVs and cracker shells to haze elk. In Nevada, agency personnel have used several method combinations, such as a helicopter, birdshot, propane cannons, vehicles, and ATVs. According to agency personnel, hazing can work but some elk can return either at night or within days. A commonality for failure of hazing seems to be tied with timing or convenience. More specifically, hazing may be conducted when convenient (i.e., in daylight when elk are visible), may not extend beyond the boundary of the zone of protection, may not begin immediately after elk appear, or may not be conducted for a long enough duration. If hazing does not occur upon the first detection of elk it may be difficult to keep them out of the area; especially if resources (e.g., forage) are greater within an area than beyond its boundaries. Elk can be most active during nocturnal periods to avoid hazing efforts or hunters. Agency personnel for the state of Washington sometimes operate hazing efforts at night to improve efficacy. Furthermore, agency personnel combine tools when elk become habituated, such as by changing from cracker shells to a screamer round to improve effect of hazing. A combination of auditory (e.g., cracker shells) and physical (e.g., rubber bullets) stimulus seems to have the best effect. Private landowners near Jackson, Wyoming haze usually only on their own property, resulting in landowners often pushing elk back and forth among their properties. In addition, by landowners stopping at the boundaries of their property (depending on size of the property) a hazing event may not occur for a long enough time to be effective.

Hazing elk in ROMO to alleviate habitat damage appeared to be acceptable to some visitors and hazing with dogs was preferred over hazing with rubber bullets or noise (Stewart et al. 2004). Furthermore, hazing or targeted disturbances reduced reproductive success of elk in Colorado (Phillips and Alldregde 2000, Shively et al. 2005) and could have considerable population demographic consequences on elk populations to further achieve ROMO objectives. Strategically scheduled hazing during various times of year may be effective in inducing dispersals through disturbance of behavior during critical times of year (Phillips and Alldregde 2000). When capsaicin paintballs are approved for use on animals, paintball technology could be evaluated by comparing the effectiveness (e.g., elk deterrence) between traditional paintball rounds (i.e., paint filled) and rounds filled with capsaicin. Furthermore, oil-based paintballs would enable researchers to mark offending elk to document the duration elk remained away from sensitive habitats after hazing. Long-range paintball rifles using heavy-paint rounds may be more effective at marking elk (Washington Fish and Wildlife Department, personal communication), especially if elk have learned short-range avoidance of personnel using short-range hazing equipment (Olympic National Park, personal communication). However, there may be high costs of labor, equipment, and vehicles and nocturnal work may be necessary if elk alter use of sensitive areas in response to hazing during daylight hours. Hazing costs would depend upon the size and the number of crews utilized. A minimum crew size should be 2 individuals. Hazing would need to be dynamic and occur continual until elk do not return to an area.

Recreational activities, hunting, roads, and vehicular travel all influence elk activity (Schultz and Bailey 1978, Trombulak and Frissell 2000, Rowland et al. 2000, Conner et al. 2001, Vieira et al. 2003). Logging has long been considered a negative disturbance factor for populations of elk (Edge and Marcum 1985) and habitat improvements may contribute to landscape alterations providing additional habitats for elk (Storlie 2006). Elk in YNP, where lethal methods of managing the population were abandoned in 1969, demonstrated sensitivity to human activity and fled when cross-country skiers approached within 2,133 ft (Cassirer et al. 1992). Conversely, Schultz and Bailey (1978) found that elk in ROMO were reluctant to flee when approached by humans on foot (mean distance approached to induce flight = 282 ft) and often required 3 to 4 approaches before they would retreat into escape cover. Flight response of elk may be related to their habituation level and the spatial nature of human activity (e.g., snowmobiles, cross-country skiing), such that elk disturbed in areas of low human activity may have a greater flight response than elk with a higher habituation level and/or located in an area with greater amounts of human activity (Borkowski et al. 2006). Elk may habituate to repetitive actions, such as riding a snowmobile or hiking along the same trail, but when humans do something out of the ordinary, like snowmobile off trail, there will be a greater flee response.

Disturbances, such as hunting, frequently influence elk to move to areas of refugia such as private lands and national parks (Conner et al. 2001). As a result, these elk are no longer available for hunter harvest, which wildlife agencies rely on for population control (Conner et al. 2001).

Lethal methods of population control in ROMO ceased in 1962, followed by a noted decrease in sensitivity to human activity by elk (D. Stevens, ROMO Biologist; personal communication in Schultz and Bailey 1978). Researchers observed an influx of elk coincident with opening of hunting season on public lands adjacent to ROMO (Schultz and Bailey 1978), demonstrating elk use of ROMO as refugia. Similarly, elk vacated public lands in northwestern Colorado during archery season and moved to adjacent private lands with less hunting activity (Conner et al. 2001, Vieira et al. 2003). Select activities, such as those simulating hunting behavior, at strategically scheduled times in established refugia may enable agencies to counteract the effects that the annual beginning of hunting season causes (i.e., movement to refugia), thereby bolstering hunter success and enabling managers to achieve population goals more effectively. Altering behavior of elk in sensitive habitats could be practical at ROMO and could be aided by normal human activity of visitors, especially if they are encouraged to use areas off established trails within the park. Furthermore, ROMO personnel or local volunteers could disturb elk using rubber bullets or paintballs to simulate the activity associated with hunting. Simulating the activity associated with hunting could be performed at any time by actively seeking out elk rather than just waiting until detection of elk in sensitive areas. Thereby, potentially decreasing sedentary behavior of elk by actively seeking them out and disturbing them.

Herding

Herding, also known as driving, is the act of pushing (e.g., human on horse-back) an animal away and/or towards a specific area or pre-determined destination. Spaedtke (2009) documented herding as a technique capable of changing distribution patterns of elk and time they spent on a specific area (e.g., grasslands) within days, within seasons, and among years. Spaedtke et al. (2009) applied conditioning treatments by herding (i.e., 2–15 humans on horseback) elk daily over 3 summers in the direction of their historic migratory route and monitored changes in elk distribution and grassland biomass each year. After herding, the summer elk presence on the study area had declined substantially and grassland biomass had increased. Elk habitat use shifted in the desired direction, but an increase in migration distance for targeted elk was not detected. However, changes in the distribution of elk had limits (i.e., study area boundary), and sometimes the elk doubled-back to the point of initial contact made during the herding effort (Spaedtke 2009). Perhaps these observed limits of distribution and double-back behavior were related to a perceived predation risk given that wolves were present on the study area. Prior to 1953, herding (i.e., aircraft, vehicles, and humans on horseback) was a technique used to move an overly abundant population of elk from within Wind Cave National Park (Lovaas 1973). However, herding was deemed an unsuccessful technique for the park, although no reason was given (Lovaas 1973). In 1959, herding was used as a wildlife damage technique in 3 states, and herding is currently used by state (e.g., Wyoming Game and Fish Department), federal (e.g., U.S. Fish and Wildlife Service), and private entities (McDowell and Pillsbury 1959,Table 1).

Humans on horseback with or without herding dogs (e.g., border collies) could be used to drive or herd elk away from sensitive areas within ROMO. Herding using humans on foot would likely prove an inefficient method when compared to humans on horseback as humans lack the speed, mobility, and stamina required to persistently herd stubborn elk and move them a substantial distance. Herding elk out of the park would likely be more effective on the west side of ROMO than the east side because elk could be more readily herded to U.S. Forest Service land and there is less private property on the west side of ROMO compared to the east side. Furthermore, the city of Estes Park on the east side and private lands may provide refugia to elk that are herded out of ROMO. Benefits of this technique are that it is primarily needed during autumn hunting seasons and could target specific sensitive areas or problem herds of elk. Herding in late-summer and early-autumn may redistribute elk to adjacent lands and decrease reliance of elk on resources within ROMO over time. The drawbacks are the distance needed to herd elk may be prohibitive, duration of effectiveness is unknown, hunting pressure could drive elk back into ROMO, and herding may not work well in forested cover. During summer, Spaedtke (2009) herded elk within open grasslands and ravines a mean distance of 1.7 miles with a minimum distance of 0.2 miles and a maximum distance of 4.0 miles. Agency personnel often just herd animals a distance far enough to push them across property boundaries (Table 1). Spaedtke (2009) observed the number of humans on horseback and temperature had a significant influence on the herding distance, such that for every unit increase in the number of riders and temperature there was a 3.5% increase and 1.4% decrease, respectfully, in herding distance. Herding elk within ROMO westward off the eastern winter range toward the alpine and Kawuneechee Valley summer range may be possible during summer. However, resources (e.g., forage) need to be great enough in the summer range to reduce the likelihood of elk returning to winter range during summer. Herding paths within ROMO will need to be examined for barriers to travel, size of herd, final destination, and safety of personnel.

Predetermined paths for herding may be problematic given tendencies for elk going only where they want to go during herding (Table 1). As an example, agency personnel with the National Elk Refuge have to wait until the wind is out of the north, the intended direction of herding, before elk will respond appropriately (i.e., leaving boundaries of the refuge) to herding.

Dogs

Resource protection dogs (RPDs) have been used to protect diverse resources such as forest plantations (Beringer et al. 1994), golf courses (Castelli and Sleggs 2000), office complexes (Curtis and Rieckenberg 2005), orchards (VerCauteren et al. 2005a), and vegetable farms (Rigg 2001, Curtis and Rieckenberg 2005) from a variety of wildlife. Dogs can be used to either herd animals for dispersal means or be used to protect a specific area. Hansen and Bakken (1999) reported that on occasion RPDs chased reindeer (*Rangifer tarandus*); an observation that provided merit for the potential of RPDs repelling white-tailed deer (VerCauteren et al. 2008). Dogs within the perimeter of invisible fencing systems that surround agricultural crops reduced damage by deer (Curtis and Rieckenberg 2005, VerCauteren et al. 2005a) and several producers used dogs to protect orchards and annual crops (Beringer et al. 1994). Selection, training, and care of dogs are important components to success of this strategy. The particular management strategy (e.g., herding, specific site protection) will determine the dog behavior needed and ultimately the specific breed to be used. VerCauteren et al. (2005a) recommended breeds that are territorial and demonstrate a patrolling behavior for effective protection of space and inanimate objects such as crop fields. Working dog breeds such as Siberian husky and Alaskan malamute performed well in protecting a specific area (VerCauteren et al. 2005a), and they are also hardy dogs that adapt well to harsh winter conditions and have a wolf-like appearance so may be perceived by elk as threatening predators.

Great Pyrenees readily pursued deer but needed encouragement from handlers (VerCauteren et al. 2008). Alaskan malamutes and Siberian huskies used to protect crops naturally pursued deer without encouragement (VerCauteren et al. 2005a). Kloppers et al. (2005) used border collies near Banff National Park, Alberta, Canada to disperse habituated elk that were a nuisance in the town of Banff. The border collies acted in a silent and controlled manner when directed by handlers to herd elk in a desired direction. Kloppers et al. (2005) found hazing with dogs was effective for dispersing elk and no signs of habituation to hazing were observed. Using 10 15-min trials (i.e., conditioning) per elk during a 5-month period (November–March), Kloppers et al. (2005) reported dog and human (2 individuals on foot) treatments moved elk an average 0.8 miles and 0.7 miles, respectively. Furthermore, both humans on foot and dog trials were observed to have a positive relationship with average daily distance of elk from the town boundary. Hazing with dogs did not provide additional motivation, however, beyond the level provided by humans on foot alone. Lavelle et al. (2010) reported 7 of 11 deer successfully jumped over a 7.5 foot enclosure fence during census drive utilizing humans on foot; perhaps providing further evidence that humans on foot may be just as effective deterrent as humans with dogs. The effects of true predation by adjacent packs of wolves counteracted the desired effects achieved by hazing with humans on foot because elk would return to the area of conflict in response to harassment by wolf packs in areas to which elk were hazed (i.e., Banff National Park; Kloppers et al. 2005).

Resource protection dogs would be a viable option for redistribution of elk within ROMO via hazing for protection of sensitive areas or use in herding operations. However, management conflicts may arise since dogs are not allowed off leash within the park boundaries. Dogs may be an added attraction to park visitors, learned behavior may have long-term effects for elk herds, multiple areas can be protected by multiple dog pairs, and they could be quickly deployed to sensitive areas being used by elk. The downside for RPDs is that they may predate small mammals entering the protected area, dogs would need to be fed daily and require periodic veterinary care. VerCauteren et al. (2005a) estimated an RPD cost at $767/animal/year across a 25-year period.

Frightening

Unlike hazing, which is a persistent use of a stimuli, frightening options rely on conditioning of target animals by delivering a stimulus (e.g., loud sound, scary image) to induce a sensation (e.g., anxiety, fear, pain) followed by a desired response (e.g., dispersal, flight) in target animals. Furthermore, frightening is the use of devices, intended as a 1 time occurrence per redistribution event with no persistence in use (i.e., no pursuit or continual use per redistribution event). Frightening is focused upon an area (e.g., un-fenced aspen stand) needing protection, the device or person using a device is essentially stationary, such that, hazing is an active and persistent pursuit of an animal. Although predator calls seem intuitively appropriate to use as frightening sounds, they may invoke a curiosity response rather than a flee reaction (New Mexico Game and Fish Department, personal communication). Frightening devices are generally not effective for extended periods (Koehler et al. 1990, Bomford and O'Brien 1990, Gilsdorf et al. 2002, Gilsdorf et al. 2004b), but may alleviate damage long enough to achieve a goal, such as while migrating elk pass through an area (Nolte 1999). Most research on frightening devices for cervids has focused on white-tailed deer (e.g., Belant et al. 1996, 1998, Beringer et al. 2003); limited research results have been published regarding efficacy of frightening devices for elk and mule deer (VerCauteren et al. 2005b). Elk seem to habituate rapidly to sound-emitting frightening devices, rendering them ineffective in alleviating damage (Henigman et al. 2005, Table 1).

Propane cannons, flashing lights, shell crackers, lasers, and other sonic devices used near at-risk resources can provide short-term relief from cervid damage, but these and similar frightening tools are generally ineffective even for short time periods (i.e., hours to days; Koehler et al. 1990, Belant et al. 1998, VerCauteren et al. 2003, Gilsdorf et al. 2004a). Efficacy may be improved by simultaneously incorporating a variety of stimuli (Nolte 1999, Shivik and Martin 2000, Gilsdorf et al. 2002, Beringer et al. 2003), frequent movement (Koehler et al. 1990), and activation by offending animals (Belant et al. 1996, Beringer et al. 2003). Although some multi-stimuli devices have proven ineffective (Roper and Hill 1985, Koehler et al. 1990, Belant et al. 1998), Roper and Hill (1985) developed a strobe light and sound (i.e., blackbird distress call) frightening device that was deemed ineffective at deterring blackbirds. Belant et al. (1998) evaluated an animal-activated device that emitted an ultrasound and strobe light that was observed to deter white-tailed deer but only for <1 week before habituation. Beringer et al. (2003) developed and evaluated a device with acoustic and visual stimuli that repelled white-tailed deer from soybean plots for 6 weeks. This device incorporated sounds likely to frighten deer (i.e., aggressive dogs, gunshot barrages, cervid distress calls), incorporated activation by deer, and included a rapidly moving illuminated human effigy. Supplementing pyrotechnic use (i.e., auditory cue) with an occasional impact by a rubber ball (i.e., physical cue) might provide sufficient negative stimuli and improve dispersal of elk and should be the focus of future research on frightening devices for deterring cervids from sensitive resources (Nolte 1999, Gilsdorf et al. 2002, 2004b, Seward et al. 2007). Seward et al. (2007) combined animal activation and physical contact to create an effective device to deter deer from cattle feed. Research is limited on the use of frightening devices to deter elk from sensitive habitats and may be applicable to ROMO objectives where short-term measures of elk dispersal are warranted.

The most effective frightening devices developed to date target multiple senses, including touch. The focus of future research on frightening devices for deterring cervids from sensitive resources should take this into consideration (Gilsdorf et al. 2002, 2004b). Although most research has been on deer, use of frightening devices on elk likely would only be effective for short durations, require multiple stimuli (i.e., auditory and physical cues) and regular maintenance, and be animal activated. Frightening devices are easily moved and may be deployed quickly. However, continual use of frightening devices can be labor intensive (New Mexico Fish and Game Department, personal communication). Elk can habituate to frightening devices quickly, especially when the protected area provides a high value resource (e.g., crop field; California Department of Fish and Game, personal communication). So employing them in backcountry or remote areas may not be an option. Further, dependent on the device (e.g., propane canon), frightening may not be visually or auditorally acceptable to park visitors.

Individual Plant Protection

A variety of devices are available to protect individual plants or parts of plants in situations where fencing areas are impractical or only short-term protection is needed (e.g., Campbell et al. 1988). Protection is provided by limiting access to roots, stems, foliage, and growing points until plants are less vulnerable to serious damage. One benefit of protecting individual plant parts is that animals are not completely excluded from portions of their habitat.

The number of plants (usually tree seedlings) and size of area being protected must be considered, because cost of protecting individual plants may approach or exceed the expense of fencing entire areas (Campbell et al. 1988, Taylor et al. 2006). Chicken-wire cylinders, photodegradable polypropylene cylinders (i.e., Tubex), and a variety of flexible mesh sleeves (i.e., Vexar) can effectively protect seedlings from cervids (i.e., Taylor et al. 2006, Kimball et al. 2008). Cylinders and sleeves provide protection only until the terminal bud protrudes from the top of the cylinder, when it is then advantageous to apply bud caps (i.e., protective cover on the terminal bud).

Individual plant protection fencing may be applicable to ROMO for protecting regenerating trees and shrubs if deemed cost-effective to achieve objectives. Protecting individual plants may be costly over large areas, maintenance is needed periodically, may be aesthetically displeasing and it may not apply well to clonal colony species like aspen that can send a root sucker outside the zone of protection.

Lure crops

Lure crops (Nolte 1999, Smith 2001) or strategic provisioning of desirable foods (Doenier et al. 1997) has been used to divert cervids from more valuable crops. However, providing additional forage leads to higher reproductive and survival rates, and congregates animals (Hines et al. 2007), which may lead to additional damage (e.g., Long 1989) and potential for transmission of disease among wildlife (Miller et al. 2003, Dean et al. 2004). Lure crops have the potential to redistribute elk to alternate habitats, may decrease group size in specific areas, and have been shown to be successful on small strategic areas. However, lure crops may increase survival and reproduction of elk and require taking habitat out of its natural state. Furthermore, lure crops may be expensive to create and maintain.

Improvement of habitat or forage conditions adjacent to areas where damage is occurring (e.g., croplands, orchards) has potential to alleviate damage situations. Herbicide application followed by fertilization and seeding has been used successfully to mitigate crop damage in several instances (Bayoumi and Smith 1976, Skovlin et al. 1983, Ramsey and Krueger 1986, Witmer and Cogan 1989). Basic application of fertilizer to rangeland was suggested to alleviate damage on adjacent cropland by improving nutritional quality and quantity of forage (Craven and Hygnstrom 1994). Lure crops have been used successfully in South Dakota to lessen damage by elk, but they are expensive or plots must be small and strategically located to be effective (South Dakota Game, Fish, and Parks, personal communication).

Mineral supplements

Use of mineral supplements (e.g., salt blocks) was a common management technique for manipulating range use by wild cervids during the first half of the last century (Case 1938, Stockstad et al. 1953, Williams 1962, Dalke et al. 1965). Today, domestic livestock producers strategically locate mineral supplements and other desired resources (i.e., water, supplemental feed) to disperse or target use of specific areas within pastures. Wildlife managers created artificial salt licks by strategically placing 50–300 lbs crude rock salt to reduce numbers of animals using natural licks, disperse use of available forage, prevent crop damage, and increase hunter harvest (Case 1938, Cooney 1952, Stockstad et al. 1953, Dalke et al. 1965). However, during interviews with 17 agency personnel, none stated any current use of artificial salt licks to detour cervid damage (Table 1).

Supplements may redistribute elk to alternate habitats and may increase health of the elk population. However, increased health may have the draw-back of increased elk survival and reproduction, which may result in increased damage. By supplying supplements there is the potential of increased elk congregation, thereby increasing risk of disease transmission and damage to the vegetation surrounding the supplement location. Also, use of supplements would only be a seasonal (i.e., spring-summer) means of redistribution as elk may use during spring/summer for antlergenesis and lactation..

Repellents

Repellents are nonlethal chemicals that theoretically decrease a plant's desirability and therefore deter foraging by cervids. Among repellents, 3 different modes of action reduce herbivory: odor, contact, and systemic. Active ingredients of odor repellents commonly contain ammonium soaps (Hygnstrom and Craven 1988, Andelt et al. 1994), putrescent whole egg solids (Swihart and Conover 1990, Andelt et al. 1991, 1992), predator odors (Swihart et al. 1991, Andelt et al. 1992, Nolte et al. 2001), and human food products (Andelt et al. 1994, Nolte et al. 1995, Seamans et al. 2002). A plethora of research has been conducted on odor repellents used to reduce browse damage to plant resources by deer (Palmer et al. 1983, Harris et al. 1983, Conover 1984, Sayre and Richmond 1992) and to a lesser extent, elk (Andelt et al. 1992, Baker et al. 1999). Harris et al. (1983) found moth balls, human hair, and creosote ineffective at deterring white-tailed deer from eating shell corn, but suggested further work in using meat and feather meals were worth further examination. Andelt et al. (1992) observed a reduction in consumption of cubed alfalfa by captive elk, but this reduction diminished from day 1–5 of the trial. However, further examination of Deer-Away® Big Game Repellent (BGR, putrescent egg) for efficacy of deterring captive elk from eating feed pellets and twigs revealed no reduction in browsing when elk were hungry (Andelt et al. 1992). Baker et al. (1999) documented a 27% reduction in elk browsing on aspen sprouts treated with BGR, with a suggested efficacy for protection of 5-weeks. Conover (1984) observed ≤27% reduction in browsing by deer using human hair and Magic Circle® (bone tar oil), but was only significant from the control in ≤2 of 7 trials. Furthermore, he observed that applications on yews (*Taxus cuspidata*) in small scale fields (~ 328 feet) reduced browsing while in larger fields (~ 2.5 acres) it was ineffective, presumably due to the distance a deer would have to travel to encounter untreated forage.

Contact repellents are topically applied to targeted resources and immediately decrease plant palatability or induce negative post-ingestion consequences causing illness (aversive conditioning). Browse damage to plant resources by deer and elk has been alleviated with contact repellents that include capsaicin, which creates a "hot" sensation when it contacts mucous membranes (Palmer et al. 1983, Harris et al. 1983, Andelt et al. 1994, Baker et al. 1999). The capsaicin reacts via a chemical interaction with sensory neurons by binding with the vanilloid receptor, which permits cations to pass through the cell membrane and into the cell when activated. The resulting depolarization of the neuron stimulates them to signal the brain with the same sensation that excessive heat or abrasive damage would cause. Andelt et al. (1994) observed that mean daily consumption (cm) by captive mule deer of twigs treated with hot sauce increased daily. Others have demonstrated that bittering agents (e.g., denatonium benzoate; Harris et al. 1983, Swihart and Conover 1990, Andelt et al. 1991, Andelt et al. 1992) and certain proteins (e.g. hydrolyzed casein; Kimbell et al. 2005, Kimball and Nolte 2006) reduce browsing of preferred forage. Conover (1984) observed only a slight reduction in browsing by deer using Hinder® (ammonium soaps). Similar to the human hair and Magic Circle trials, applications on yews in small scale fields reduced browsing while in larger fields it was ineffective (Conover 1984). Sayre and Richmond (1992) documented that Hinder and Jersey® were effective at reducing deer browse on yews within 4 and 6 plant plots near homesteads. However, they mentioned as a caveat that the study was not conducted during the peak period of damage (i.e., winter). With most cervids, the efficacy of repellents for reducing browsing is based largely on the hunger of the animal and the availability and distance of other resources (Conover 1984, Andelt et al. 1992).

Systemic repellents are absorbed into plants by their roots and translocated to foliage either by supplementation (e.g., selenium; Angradi and Tzilkowski 1987), genetic manipulation of morphology (e.g., pubescence, barbs, spines), or naturally occurring plant defense compounds (i.e., alkaloids, phenolics, turpenes; Conover 2002). The repellent absorption by the plant may circumvent the problem of being washed away by rainfall (El Hani and Conover 1997). However, a relatively high absorption of the repellent may be toxic to a plant (Allan et al. 1984).

Many interacting factors determine efficacy of repellents and all repellents have a limited duration of success. Contact repellents may wash off or decompose, thus repeated applications are necessary. As plants continue to grow, repellents need to be re-applied to new leaves or shoots. Andelt et al. (1992) speculated that food stress plays a major role in effectiveness of repellents. Thus, repellents are most effective when motivation (i.e., food stress) is low and alternative food sources are available. Regardless of repellents used, some damage to agricultural and forestry resources should be expected, even when conditions are optimal. Furthermore, the cost and practicality of using repellents, considering their limitations (e.g., duration of efficacy, size of area to be treated,) may require they be used in conjunction with other methods (e.g., short-term fencing) to increase efficacy. Application rate depends on the product and vegetation, Conover (1984) applied contact repellents at the rate of 9.63–13.69 gallon/acre with a cost of $10.64–400.81/acre. Andelt et al. (1994) reported a cost of $0.27–$143.85/gallon for contact repellents applied to forage given to captive mule deer to examine avoidance induced by the repellent.

Repellents can be applied to small tracts (~1,076 ft^2, Conover 1984) of land or specific regenerating trees. Success is of limited duration (≤5-weeks, Baker et al. 1999), with needs for reapplication to new vegetative growth (e.g., leaves, shoots) and after substantial rainfall (Andelt et al. 1991). Systematic repellents do not need as frequent reapplication, but could pose a toxic risk to the vegetation being protected. Overall some damage should still be expected when using any repellent due to factors such as inadequate coverage or elk enduring the repellent. Large scale (≥2.5 acres, Conover 1984) applications of repellents are expensive and impractical on large tracts of land.

Repellents would not likely be an efficient method within ROMO for discouraging elk browsing in large sensitive areas (i.e., ≥2.5 acres) because reapplication is needed and would be difficult. Considering that efficacy of repellents depends on the availability of alternate forages to elk, and elk appetite, repellents may not be the best technique to deter elk from browsing in large sensitive areas. Repellents could be used within ROMO to protect individual plants, small sensitive areas (~1,076 ft^2), or near residences/offices. However, other techniques (i.e., hazing) may be effective, given the need for reapplication and no guarantee for them to work.

Summary of Techniques

Exclusion fences are sturdy barriers with the intent of barring entry of elk into a sensitive area. Exclusion fences can be either short-term or with proper maintenance can be used temporarily or long-term. Types of exclusion fences include buck-and-pole, woven-wire mesh, modified woven-wire mesh, high-tensile electric, slanted, poly mesh, and electrified poly tape and poly rope. Hazing is the persistent use of stimuli using human disturbance, dogs, or human disturbance and dogs. Human disturbance can include vehicles or humans on foot or horseback in combination with rubber bullets and shot, or paintballs. Human disturbance could be used in conjunction with dogs or RPDs could be a stand-alone tool stationed in sensitive areas. Herding is the act of pushing an animal away and/or towards a specific area or to a pre-determined destination. Herding requires the use of humans on horseback with optional tools of frightening devices (e.g., screamer shells) and/or dogs. Resource protection dogs enclosed behind an invisible fence can be used to protect sensitive areas from elk. Dogs can also be implemented as tools for herding and hazing. Frightening is a technique that utilizes sonic and/or visual devices. Frightening devices (e.g., propane cannons) are usually stand alone with either a timer or animal activated trigger, however, humans can use frightening devices (e.g., screamer shells) during hazing and/or herding. Individual plant protection is a short-term technique for excluding elk from roots, bark, stems, and foliage of a plant. Individual plant protection tools include chicken-wire cylinders, photodegradable polypropylene cylinders, and a variety of flexible mesh sleeves. Lure crops are the strategic planting of a crop preferred by cervids, used to lure elk from sensitive areas. Providing mineral supplements is also a technique used to lure elk from sensitive areas. Artificial salt licks are often used as mineral supplements to divert elk from sensitive areas. Repellents are nonlethal chemicals that theoretically decrease a plant’s desirability and therefore deter foraging by cervids. Three types of repellents are available, including odor, contact, and systemic.

DISCUSSION

Elk management is a complex process of understanding distribution and ecology of populations of elk along with land-ownership and public desire for particular management strategies. Specific lethal (e.g., hunting, sharpshooting) options are not legal or publically acceptable in many national parks. Nonlethal (e.g., contraception, relocation) options for managing free-ranging populations of elk often are not proven, practical, or economically feasible, and should be used in conjunction with other methods to optimize effectiveness. Frightening techniques are only effective for short durations, require regular maintenance to work properly, and could be disturbing to park visitors. Although fences can be effective in many situations, installation of fences around large tracts of habitat could be cost-prohibitive and aesthetically unappealing to visitors of national parks and preserves. Recently, hazing and herding by humans with dogs or on horseback has been successful at temporarily preventing use of urban and sensitive areas by elk near Banff National Park, Alberta (Kloppers et al. 2005). Use of avoidance conditioning with dogs to mimic presence of and disturbance by predators appeared to be a relatively publicly acceptable method for relocating habituated elk (Stewart et al. 2004). Hazing with rubber bullets or loud noises were less acceptable to visitors and nearby residents of ROMO and Banff National Park (Stewart et al. 2004, Kloppers et al. 2005), but have potential to provide positive results. Although aversive conditioning (e.g., hazing) has been effective at dispersing elk from urban areas over the short-term, no long-term data are available to determine the cost or practicality of displacing elk from urban areas or sensitive habitats and further research is needed.

Management Needs of ROMO

The selected alternative in the plan/EIS addressed the effects of redistribution methods on elk movements and concluded redistribution methods should be applied in a way that would avoid moving elk into the Town of Estes Park, thereby exacerbating human-elk conflicts. Some detail was provided within the plan/EIS on the methods of redistribution considered but several other methods (e.g., RPDs) are applicable to ROMO's objectives of an integrated approach to elk management and should be explored. Several nonlethal methods could reduce use of an area by elk while others should not be used or be more a component of an integrated approach. Repellents, habitat modification, lure crops, mineral supplements, and individual plant protection are less suited for elk redistribution or are very expensive. Frightening devices and short-term fencing could be used as needed or for immediate response to elk damage but would only be effective for short durations and could be integrated with one another to temporarily protect sensitive areas. Various forms of hazing and herding could be the most favorable methods to redistribute elk, could be site- or season-specific, and may be the next logical step building on the ideas set forth in the Alternatives of the plan/EIS.

Discussions with ROMO personnel during preparation of this report identified several season-specific needs for elk redistribution. Specifically, the 3 management needs of ROMO are: (1) seasonally return elk to summer range, (2) redistribute elk from sensitive areas of vegetation to reduce sedentariness on winter range, and (3) discourage elk from using the Kawuneeche Valley as a refuge during autumn. The return of elk to their summer range is required to permit regeneration of sensitive habitats during the growing season as some elk tend to be year-round residents on sensitive habitats on the winter range (Figure 2). Redistribution of elk on winter range in Beaver Meadows/Horseshoe Park/Moraine Park (Figure 2) to reduce sedentariness and protect sensitive areas is needed to facilitate vegetation restoration, and may contribute to reducing the need for or duration of fencing. Discouraging elk from using the Kawuneeche Valley as a refuge during autumn would potentially redistribute elk to surrounding public lands that are hunted (Figure 2).

Return elk to summer range

Supplementation of the current culling practices with human disturbance (i.e., hazing) using rubber bullets and/or paintballs could be used during late-spring or early summer may cause elk to abandon winter range (e.g., Moraine Park) and move to summer range (e.g., subalpine regions) at higher elevations in ROMO (Figure 2). This supplementation would entail, when a elk is culled the remaining elk in the herd are immediately hazed. During late-spring or early summer, implementation of hazing by simulation of activities associated with hunting (e.g., rubber bullets, paintballs) entailing humans moving through locals where elk congregate may cause elk to abandon winter range (e.g., Moraine Park) and move to summer range (e.g., subalpine regions). Using a simulation of activities associated with hunting would be used separately from culling operations. Protecting sensitive areas may have the potential to redistribute elk off sensitive areas, and induce movement of elk to summer range at higher elevations. Sensitive areas could also be protected using hazing (e.g., human disturbance with rubber bullets) upon detection of elk within the area. Use of herding with humans on horseback or dogs may be the best choice for herding elk with a destination in mind. The herding technique

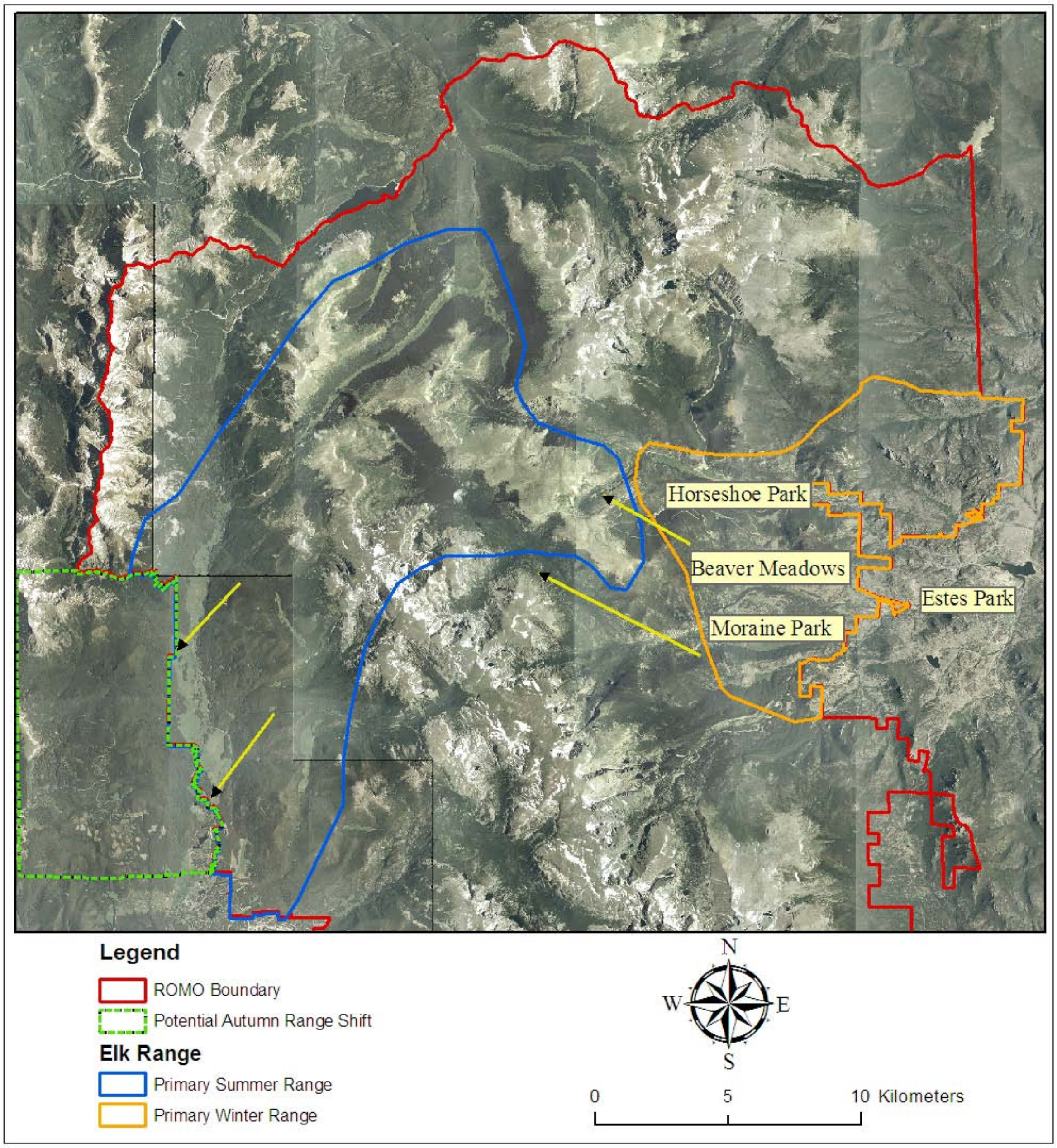

Figure 2. Locations of Horseshoe Park, Beaver Meadows, Moraine Park, Estes Park, the primary winter and summer range of elk, potential autumn range shift, and potential redistribution paths within ROMO. Property located within the autumn range shift may include both private and public lands, requiring comments from landowners prior to any management action.

provides a means for directionality whereas hazing is only used to prevent offending animals from using a defined area. Use of herding of elk from winter to summer range may be difficult, because elk may only go in a direction they want or are willing to go (Colorado Department of Wildlife, personal communication; National Elk Refuge, personal communication). Furthermore, the herding path needs to be examined and reviewed to properly prepare and determine feasibility of herding. The addition of hazing (e.g., cracker shells) may make elk more responsive to herding activities by integrating auditory stimulus to the visual disturbance. Areas such as Moraine Park and West Horseshoe Park may be too large of an area for frightening devices to be effective. Resource protection dogs could be equipped with electronic collars contained behind an electric fence placed in strategic areas to stimulate elk to abandon winter range.

Protocol #1.—Employment of hazing crews to keep elk from sensitive areas.

Strategically scheduled hazing during various times of year and nocturnal activity may be effective in inducing dispersals through disturbance of behavior (Phillips and Alldredge 2000). Rubber bullets or paintballs could be deployed by researchers, ROMO personnel, or trained volunteers to expose populations of elk to a perceived threat. The inclusion of physical pain (e.g., rubber bullets) in the disturbance effort may be critical to instilling a long-term desired behavior (e.g., area avoidance) in elk to avoid the area hazed (California Department of Fish and Game, personal communication). Use of hazing should be initiated upon detection of elk in sensitive areas because any delays will increase the fidelity of elk to the area, thus increasing the level of effort required to disperse elk from the area (Table 1).

A hazing crew could be stationed in or near a protection zone to provide a 24-hr service to the area. An elk-activated alert system should be deployed to increase response time. These systems include strategically placed sensors to alert crews to the presence of elk. Upon detection of an elk, a hazing crew would be deployed to the area to persistently haze elk using rubber bullets or paintball technology. Avoidance of an area would be deemed the best measure of success when using a hazing crew as a tool for dispersing elk. A hazing crew may be successful if initiated quickly (i.e., first sign of an animal within a sensitive area), carried out for a proper duration with the appropriate number of individuals. Motivation provided by the HC must outweigh the attraction of the area being protected. Placement of GPS collars on elk could be used to monitor the success of hazing crew. The duration of hazing effort would need to be very dynamic, such that it would last until elk stop trying to use an area (e.g., week) then occasionally some may try to use the area again and would require additional hazing. Would need to react to the elk, over time they would establish elsewhere and not try as hard to use areas where they were hazed. A minimum hazing crew of 2 should be used.

Redistribute elk on winter range

The use of elk- or human-activated frightening devices as a short-term (i.e., days to weeks) method may protect small sensitive areas (i.e., few acres) during winter. Use of frightening equipment may be more of an acceptable management tool in areas with lower amounts of human activity. Although frightening within areas of low public access may be used, other methods with greater potential for effectiveness (i.e., hazing) may be more applicable. A frightening device may be used to supplement other techniques, such as positioning a device in a sensitive area after a hazing operation. Under the plan/EIS, up to 440 acres of aspen and willow could be fenced. To date, approximately 190 acres of aspen and willow have been fenced with elk proof fencing expected to be in place for 10 to 20 years. In addition, short term fences could be deployed seasonally and may be used to protect sensitive areas from elk on the winter range. When a sensitive area has been designated with the need for protection (e.g., heavy browsing) a short-term fence (e.g., baited electric fence; J. W. Fischer, USDA APHIS WS NWRC, unpublished data; G. E. Phillips, USDA APHIS WS NWRC, unpublished data) could be deployed to exclude elk until they establish elsewhere. The use of hazing (e.g., human disturbance, hazing dogs) to protect sensitive areas can be used during winter. Once notified of elk near or within a sensitive area designated for protection (e.g., unfenced aspen stand with high browsing damage), hazing crew could be deployed to initiate human disturbance (e.g., paintballs, rubber bullets). Alternatively, RPDs could be confined by invisible electronic containment system (Off Limits Crop Protection System, Green Bay, WI, USA) surrounding sensitive areas to provide defense of vegetation from elk. Unlike human disturbance that would rely on close monitoring or an alert system, an RPD would provide 24-hr protection and the fastest reaction time to elk venturing into a protected sensitive area. Herding would not be needed if only protection of a sensitive area or decrease in sedentary behavior is desired. Although not significant, Spaedtke (2009) observed a 20% difference in vigilance between conditioning using humans or dogs and controls. This suggests that hazing may be effective at reducing sedentary behavior of elk. However, the effectiveness of hazing for decreasing sedentariness of elk may be less during winter than summer because nutritional demands may outweigh security (Spaedtke 2009).

Protocol #2.—Resource protection dogs within invisible fences to keep elk from entering sensitive habitats.

Kloppers et al. (2005) found hazing with dogs was effective for dispersing elk and no signs of habituation to hazing were observed. Although large predators (i.e., grizzly bear, wolf) are absent in ROMO, innate behavior to predation would likely cause elk to perceive RPDs as predators and act accordingly to avoid use of areas occupied by RPDs. Areas could be protected with an invisible fence that would confine 2 RPDs by use of an electronic collar activated by radio waves transmitted along a 14-gauge insulated copper wire. The copper wire would be around the perimeter of the treatment habitat and electronic collars will be activated when RPDs get within 6–10 ft of the buried wire. Resource protection dogs would be spayed or neutered, vaccinated for diseases and parasites, checked daily, and provided food, water, and shelter at all times. Animal-activated cameras and direct observations could be used to assess the number and duration of elk visits, as well as nontarget species, to treatment and control areas.

Ultimately RPDs may be an added attraction to park visitors, protect areas overnight without need for human presence, learned behavior may have long-term effects for the elk herd, multiple areas could be protected by multiple RPD pairs, and they could be quickly deployed to sensitive areas being used by elk. Of course, RPDs may predate small mammals entering areas, they would need daily food and water, and require periodic veterinary care. To our knowledge, predation of RPDs is not likely and has not been observed in past research. To monitor success GPS collars could be used to assess changes in space-use of elk.

Discourage elk from using the Kawuneeche Valley as a refuge during autumn

Use of culling practices outside the season (November–February) described in the plan/EIS when most culling would be carried out, coupled with hazing of elk (e.g., human disturbance, hazing dogs) may decrease sedentariness of elk during any season (e.g., summer, winter) and region (e.g., Kawuneeche Valley, Moraine Park). Increasing the overall number of culling teams conducting the culling coupled with hazing could decrease sedentariness. Millspaugh et al. (2000) reported a negative effect of hunter density on the space-use overlap between elk and hunters in Custer State park. Simulation of culling practices with human disturbance (e.g., humans on horseback) using rubber bullets and/or paintballs could be used to decrease sedentariness of elk during any season and location. All hazing of elk using human disturbance with rubber bullets, paintball, or hazing dogs, or RPDs equipped with electronic collars contained behind an electric fence would likely cause decreased sedentariness. Short-term fencing could deny access to desired resources and potentially change elk behavior. The herding technique could be used to decrease sedentariness, but elk may only go in a direction they are willing to go and the herding path needs to be reviewed to properly determine feasibility. Again, frightening devices could be used but only for the purpose of short duration abatement.

Protocol #3.— Movement and range use of elk on western range of ROMO to determine pre-treatment effects (i.e., prior to application of redistribution techniques) on sensitive habitats.

Critical to success of any management strategy is a method to determine the outcome of practices to redistribute elk. Using GPS technology to monitor elk before and after treatments (i.e., hazing, herding) is imperative to determining overall success of integrated management to redistribute elk from sensitive habitats within ROMO. Limited information is available on elk movements, migration, and range use on the west side of ROMO in the Kawuneeche Valley (Stevens 1980). Information on space-use by elk is imperative to successfully implementing redistribution methods of elk in ROMO west of the continental divide.

We propose capturing 30–40 elk from the Kawuneeche Valley and North Fork areas to equip them with GPS collars. Elk will be captured with chemical immobilization drugs by project personnel on winter range, aged by tooth wear and replacement, and released. Distances and routes of travel from winter to summer range will be determined from GPS data collected daily from collared elk. After several management strategies are implemented by ROMO, an additional 30–40 elk will be captured and equipped with GPS collars to determine reactions to management strategies occurring in ROMO west of the continental divide.

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TABLES

Table 1. Methods used to disperse nuisance Rocky Mountain elk (*Cervus elaphus nelson*) or negate their damage and comments from interviews of agency personnel, 2010.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
Department of Fish and Game	California	Yes	Frightening	Initially, frightening using cracker shells works but elk can come back quickly (e.g., hours). Nothing physically happens to elk so food resource (i.e., crop field) keeps drawing them back.
			Herding	Herding using vehicles and all-terrain-vehicles works initially, but they come back. Time for them to come back depends on the resource (types of crops) they are being pushed out of.
			Fencing	Fencing seems to work.
			General	Dogs have had limited use by the public (not used by the agency) with better success than frightening. Hunting works the best.
City of Estes Park (Colorado Department of Wildlife)	Colorado	Yes	Frightening	Initially, frightening works but elk come back. Have used firearm cracker shells, rubber bullets, pepper-spray, and a garden-hose.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
			Herding	Tried herding with vehicles and ATVs, but elk will only go in the direction they want to go.
Department of Fish and Wildlife Resources	Kentucky	Yes	Frightening	Frightening works okay if it is done soon after elk show up, may take some time if they have been there a while. Need to continue to frighten for it to be effective. Have used firearm cracker shells and firecrackers.
			Trap-and-transfer	Transferred 47 elk to a location 25-miles away and have stayed put thus far.
			Fence	Electric fence seems to work well. Woven fence did not work, either went over or through.
			General	Placing hunters in nuisance complaint areas works the best.
Glacier National Park	Montana	No	……….	……….

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
Department of Game and Fish	New Mexico	Yes	Frightening	Propane canons have limited success in keeping elk from areas, they become habituated. Cracker shells and rubber bullets are used as a short term methods and are very labor intensive. Tested a military grade sound system with random sounds, sirens, and predator sounds. Random sounds and sirens worked extremely well, but the system was too expensive to implement. A turret system to rotate device by animal-activated trigger and the gas and generator to power system was too costly. The use of predator sounds brought elk closer to investigate the sound origin rather than move away. The "elk-out' sonic device seemed to work well in small areas, such as gardens. However, the system only deterred elk for a few days.
			General	Interested in the use of dogs to haze nuisance elk, but to date have not employed this tactic.
Custer State Park	South Dakota	No	……….	Relatively low number of elk in the park.
Game, Fish, and Parks	South Dakota	Yes	Frightening	Frightening works but elk come back within 2-weeks. Have used firearm cracker shells, rubber bullets, and propane canons.
			Hazing	Hazing using ATV and cracker shells seems to work, but they come back quickly.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
			Lure crop	Lure crops work very well, but expensive and only on small areas.
			General	Hunting is the best management strategy. Have a program that puts hunters in contact with landowners with cervid nuisance complaints.
Wind Cave National Park	South Dakota	Yes	Fencing	Fence them out of areas with aspen and hardwoods.
Division of Wildlife Resources	Utah	Yes	Frightening	Initially, frightening works using firearm cracker shells, rubber bullets, and firecrackers but elk come back quickly. Usually can't get close enough for rubber bullets.
			Fencing	Fencing works the better than frightening.
			General	Hunting is the best management tool.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
Department of Wildlife	Nevada	Yes	Frightening	I have pretty much tried all of the frightening techniques, including firearm cracker shells, rubber bullets, firecrackers, propane cannon, and screamer shells. Propane cannons do not work except for the first day, then elk feed nearby once they realize the cannons have no other negative impact other than noise.
			Hazing	We have tried chasing a small group of elk out of the area with a helicopter, birdshot, propane cannons, and various vehicles. Hazing usually doesn't work because the elk are addicted to the crop they are using. It is like free candy to a kid. Once they get a taste of it they keep coming back. In addition, elk are often using the crop or haystack during the summer when native vegetation has dried up and is not as palatable or in the winter when food resources are scarce, so they are difficult to discourage. Hazing will work for as long as you are willing to keep a person there to conduct the hazing. Normally, once you leave, the elk come back. If you chase them away at sunset, they will probably be back by 10 p.m.
			Fencing	Eight foot high wildlife fences work.
			General	Harvesting the animals usually works by physically removing the persistent elk and scaring away those that have less tolerance for being hazed.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
Mt. Rainer National Park	Washington	No	……….	Elk are in the high country most of the year, then migrate out of the park in winter.
Olympic National Park	Washington	Yes	Frightening	Initially, frightening works with rubber bullets but elk come back quickly. Have learned to avoid rangers but not visitors.
			General	May develop a plan to put radio-collars on elk and monitor if they get close to a sensitive area, then they can haze them.
Department of Fish and Wildlife	Washington	Yes	Frightening	Use cracker shells, but if elk get habituated then add screamer rounds. Have used paintball pepper spray but poor accuracy. Use longer range paintball rifles with heavy paint (100-m). Often use cracker shells in hazing effort.
			Fencing	Fencing can work, but if elk don't see it at night then they can go through them. Experimenting with a technique (i.e., top vinyl) to make fence more visible.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
			Hazing	Often do hazing at night because public hunting makes elk more nocturnal. Use cracker shells, but if elk get habituated then add screamer rounds.
			Repellents	Have used repellents in and near crop fields, but only on limited areas and only with drip irrigation.
			General	Have master hunter program to send hunters out in nuisance areas, helps even by pushing them around (i.e., hazing).
City of Jackson (Wyoming Game and Fish Department)	Wyoming	Yes	Frightening	Shell crackers and propane cannons work, but they get use to them.
			Fencing	Fencing works best for nonlethal methods.
			Herding	Farmers herd them off the fields with tractors and trucks, but put them on other ranchers property, so, it is like ping-pong with elk.
			General	Hunting is the best method for nuisance control.

Table 1. Continued.

Agency	State	Nuisance elk present	Methods used to disperse or abate damage	Personnel comments
Grand Teton National Park	Wyoming	No	General	Have a managed hunt in the park every year. Wyoming Game and Fish Department has permit lottery for the park every year.
National Elk Refuge (U.S. Fish and Wildlife Service)	Wyoming	Yes	Herding	Herd elk off the refuge during summer using all-terrain-vehicles, but only if there is a north wind because elk will not go in the direction (north) biologists want them to go unless the wind is in their face. Regulated hunting works to limit elk disturbance.
Yellowstone National Park	Wyoming	No	……….	Just have personnel monitor elk during the breeding season.

Table 2. Fence types, cost per meter, height (m), percent efficacy at excluding deer, the expected longevity of efficacy (years), and amount of maintenance needed (low, medium, high) for a fence to remain effective, and relative ease of initial fence installation.

Fence type	Cost	Height (m)	Efficacy (%)	Longevity (Maintenance)	Ease of installation
High-strength black polypropylene mesh (Lavelle et al. 2010)	7.69/m	2.30	80-90	10-20 (Medium)	Moderate
Woven wire (VerCauteren et al. 2006a)	10.00–15.00/m	2.40	90–99	30–40 (Low)	Difficult
Welded wire (VerCauteren et al. 2006a)	10.00–15.00/m	2.40	90–99	20–30 (Low)	Difficult
Chain link (VerCauteren et al. 2006a)	>20.00/m	2.40	90–99	30–40 (Low)	Difficult
Poly. rope 9 (VerCauteren et al. 2006a)	5.00–10.00/m	1.82	70–80	15–25 (High)	Easy

Mod. WW 3 HT[a] (VerCauteren et al. 2006a)	5.00–10.00/m	2.40	80–90	20–30 (Medium)	Difficult
Poly. snow[b] (VerCauteren et al. 2006a)	5.00–10.00/m	2.12	80–90	15–25 (Medium)	Easy
Offset HT (VerCauteren et al. 2006a)	2.00–5.00/m	1.05	60–70	20–30 (High)	Difficult
Slanted 7 HT[c] (VerCauteren et al. 2006a)	2.00–5.00/m	1.50	70–80	20–30 (High)	Difficult
Penn St. 5 HT (VerCauteren et al. 2006)	2.00–5.00/m	1.12	70–80	20–30 (High)	Difficult
Poly. tape 2[d] (VerCauteren et al. 2006a)	2.00 /m	0.90	60–70	5–15 (High)	Easy
Baited electric (VerCauteren et al. 2006a)	2.00 /m	1.12	80−90	10-20 (High)	Easy

[a] Modified woven-wire fence with 3 strands of high-tensile wire above.
[b] Polypropylene snow fence.

[c] Slanted 7-strand high-tensile wire.
[d] Two-strand poly-tape.

APPENDIX

Appendix 1. Reprint of manuscript submitted for publication in Wildlife Research titled "Management of damage by elk (*Cervus elaphus*) in North America: a review."

Final approved manuscript will be submitted upon final approval by journal.