

REDUCING RELIANCE ON SUPPLEMENTAL WINTER FEEDING IN ELK
(*CERVUS CANADENSIS*): AN APPLIED MANAGEMENT EXPERIMENT
AT DESERET LAND AND LIVESTOCK RANCH, UTAH

by

Dax L. Mangus

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Biology

Approved:

Frederick D. Provenza, PhD
Major Professor

Mary M. Conner, PhD
Committee Member

Carl D. Cheney, PhD
Committee Member

Byron R. Burnham, EdD
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2011

ABSTRACT

Reducing Reliance on Supplemental Winter Feeding in Elk
(*Cervus canadensis*): An Applied Management Experiment
at Deseret Land and Livestock Ranch, Utah

by

Dax L. Mangus, Master of Science

Utah State University, 2011

Major Professor: Dr. Frederick D. Provenza
Department: Wildland Resources

Wildlife managers have fed elk in North America for nearly 100 years. Giving winter feed to elk can compensate for a shortage of natural winter range and may boost elk populations while also helping prevent commingling with livestock and depredation of winter feed intended for livestock. In contrast to these benefits of supplemental feeding, there are economic and environmental costs associated with feeding, and elk herds that winter on feeding grounds have a higher risk of contracting and transmitting disease. Brucellosis is of primary concern now, and Chronic Wasting Disease may be in the future. Many see the discontinuation of winter-feeding programs as a necessary step for decreasing the risk of disease spread due to high animal densities associated with feeding during winter.

My research evaluated the use of behavioral training to reduce reliance on supplemental winter feeding of elk, while minimizing population reductions and human-

wildlife conflicts. My study was conducted at Deseret Land & Livestock (DLL) in Rich County, UT, where managers at DLL have over 20 years of data on elk feeding during winters of varying intensities. I tested the effectiveness of range improvements, strategic cattle grazing, dispersed supplemental feeding, hunting, and herding to distribute and hold elk in desired areas during winter. I compared elk numbers on the feed ground during this study with historic data on DLL, and also contrasted elk responses with other comparable feed sites in Wyoming that served as controls. In 2 mild winters we completely eliminated elk feeding without incident and were able to reduce the quantity and duration of feeding during 1 severe winter. Since the conclusion of my study, DLL has further reduced quantity and duration of feeding during severe winters, and has completely eliminated feeding in light winters. Based on a Before After Control Impact (BACI) analysis, the reduction in the proportion of the elk population fed at the study site was significantly less than the proportion of the elk populations fed at the control sites in Wyoming ($P = 0.057$). Based on these results, I anticipate wildlife managers can decrease dependence on costly supplemental winter feeding and reduce the risks of disease while keeping human-wildlife conflicts at a minimum. This research illustrates an adaptive method that can enable wildlife managers to keep elk populations in northern Utah at or near their current size, while constraining disease outbreak and transmission risks within “acceptable” levels.

ACKNOWLEDGMENTS

I wish to acknowledge those individuals and/or organizations that helped make this project possible. At the Utah Division of Wildlife Resources I wish to thank Scott McFarlane, Alan Clark, Darren Debloois, and Clair Schaffer. At Deseret Land and Livestock I couldn't have completed this project without the cooperation of Todd Cornia, the ranch staff, and the cowboys. I wish to thank the Rocky Mountain Elk Foundation and Sportsmen for Fish and Wildlife for their generous financial support. I also must recognize the BEHAVE organization for their great ideas and support during this project. I want to thank Bob Welling and Ridley Block. I owe special thanks to Jared Rogerson at the Wyoming Fish and Game for taking the time to dig up the data I needed.

I must recognize my committee members for their contributions. Dr. Conner's assistance with the analysis combined with thoughtful suggestions and thorough reviews was extremely helpful and greatly appreciated. Dr. Cheney's ideas and perspective not only provided the foundation for the basic premise of our experiment, but also changed my entire world view.

Special thanks go to Fred Provenza and Rick Danvir who not only helped me through every step of this project, but who also displayed great patience and went the extra mile taking time to mentor me. They invested much more into helping me develop as a person and a professional than was merited by this project, and I will always be grateful.

Dax Mangus

CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGMENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
INTRODUCTION	11
General Focus and Motivation for Project.....	2
The Manager’s Dilemma, to Feed or Not to Feed	4
Background	10
Behavioral Principles	14
Thesis Objectives	16
STUDY AREAS	18
Deseret Land and Livestock.....	18
Big Piney Elk Herd Unit (BPEHU)	19
Afton Elk Herd Unit (AEHU).....	20
METHODS	22
Positive Reinforcement (Carrots)	22
Punishment (Sticks)	27
DATA ANALYSIS.....	32
RESULTS	36
Historic Data Results	37
BACI Results	37
DISCUSSION.....	40
Behavior by Consequences	42
Providing Hay in Severe Winters	46
Use of Supplements	47
Reducing Disease Transmission	49

	vi
Creating Locally Non-Adapted Animals	49
Creating Locally Adapted Animals	51
MANAGEMENT IMPLICATIONS	56
LITERATURE CITED	61
APPENDICES	74
A Narrative of Elk Response	74
B Elk Use of Molasses-Based Low-Moisture Supplement in Northern Utah	81

LIST OF TABLES

Table	Page
1 Winter severity and elk feeding at Deseret Land and Livestock ranch, Utah 1983-84 – 2006-07	36
2 Winter severity and elk feeding on Big Piney and Afton elk herd units, Wyoming 1983-84 – 2006-07	37
3 Winter Severity and Elk Feeding at Deseret Land and Livestock ranch, Utah 1983-84 to 2009-10	42
B-1 Color-coding for summer supplement tubs at Deseret Land and Livestock ranch, Utah, summer 2005	86
B-2 Classification of winter supplement use at Deseret Land and Livestock ranch, Utah, winter 2005/2006	87
B-3 Summer supplement consumption by elk on Deseret Land and Livestock ranch, Utah , July 1, 2005 – Aug. 18, 2005	89
B-4 Winter supplement use by elk at Deseret Land and Livestock ranch, Utah, winter 2005/2006	90
B-5 Summary of winter use of low moisture block and alfalfa hay by elk on Deseret Land and Livestock ranch, Utah, winter 2005/2006	92
B-6 Contents of mineral supplement and low moisture block supplements tested at Deseret Land and Livestock ranch, Utah, 2005-2006	92

LIST OF FIGURES

Figure	Page
1 Proportion of elk population fed vs. average winter snow depth winter 1983-84 to winter 2004-05 at Deseret Land and Livestock ranch, Utah	12
2 Late cow elk harvest by date 2003-04 to 2006-07 on Deseret Land and Livestock ranch, Utah	29
3 Map of strategic cow elk hunt zone boundaries on Deseret Land and Livestock ranch, Utah	30
4 Pre- and Post-treatment proportions of elk herd fed vs. winter snow depths, winter of 1983-84 to winter 2005-06 at Deseret Land and Livestock ranch, Utah	38
5 Proportion of elk populations fed at Piney and Afton Wyoming and Deseret Land and Livestock ranch, Utah winter feeding grounds from winter 1989-90 to winter 2006-07	39
B-1 Granular salt and liquid molasses mix at Deseret Land and Livestock ranch, Utah, summer 2005	95
B-2 Elk and supplement tubs at Site 2, (Blue Ridge) at Deseret Land and Livestock ranch, Utah, summer 2005	95
B-3 Motion-activated camera damaged by elk at Site 3 (Monument) on Deseret Land and Livestock ranch, Utah, summer 2005.	96
B-4 Granular salt with dry molasses after a thunderstorm on Deseret Land and Livestock ranch, Utah, summer 2005	97
B-5 Alfalfa hay placed at winter elk supplement site on Deseret Land and Livestock ranch, Utah, winter 2005/2006	97

B-6 Cut sanfoin placed atop low-moisture block tub at winter elk supplement site 1 (Alkali) on Deseret Land and Livestock ranch, Utah, winter 2005/2006.....98

B-7 Highest observed level of elk use of low-moisture block on Deseret Land and Livestock ranch, Utah, winter 2005/200698

INTRODUCTION

Darwin articulated the notion of the evolution of species through natural selection. Individuals that produce the most viable offspring have a controlling influence on the evolution of genetic traits in a species or population. Genetically-based variable reproductive success of individuals leads to evolution of a species as the proportion of individuals with genes that enhance survival, at the time, do the bulk of the breeding.

The evolution of behavior in organisms follows a similar path. Rather than multiple karyotypes of a gene, there are multiple behaviors, and selection for behaviors based on the consequences they generate. Behaviors that result in positive consequences are more likely to reoccur than behaviors that result in a negative experience. In general, behaviors that contribute favorably to the survival and reproduction of a species are more likely to occur than behaviors that do not improve an organism's fitness (Skinner 1981).

Behavior is a result of ongoing interactions among genes, organism, and environment (Lewontin 2000). While genes certainly influence the expression of behaviors, it is just as true that behaviors influence the expression of genes. In that sense, genes "learn" from the environment. Genes need not be expressed if biophysical and social landscapes were static. However, the ever-changing nature of nature requires genes to converse with the environment, and much of this important discussion occurs during development in utero and early in life (Provenza et al. 2011). The emerging field of epigenetics is highlighting this dynamic as none before.

Changes in behavior alter animals neurologically, morphologically and physiologically. In that sense, just as the body influences the structure of experience, experience influences the structure of the body (Provenza 1995a). Historically, scientists

believed that the only way the brain/body changes its structure is through evolution of the species, which in most cases takes many thousands of years. According to modern Darwinian evolutionary theory, new biological brain structures develop in a species when genetic mutations arise, creating variation in the gene pool. If these variations have survival value, they are more likely to be passed on to the next generation. But neural plasticity creates another way – beyond genetic mutation and variation – of introducing new biological brain structures in individuals by non-Darwinian means (Doidge 2007). Through these processes the behavioral evolution of a species or population is shaped neurologically, morphologically, and physiologically by the consequences of their actions. Consequently, when managers desire to change the behavior of a group of organisms, changing the consequences of the undesired behavior may be the most effective method.

My objective was to apply behavioral principles as an adaptive approach to a typically difficult wildlife management dilemma. Using various forms of positive reinforcement and punishment, I set out to change the winter-feeding behavior of elk or wapiti (*Cervus canadensis*). My intent was to reduce disease risks as well as economic and environmental costs associated with winter-feeding programs, elk damage to agricultural crops and other human wildlife conflicts, while maintaining elk population numbers.

General Focus and Motivation for Project

Wildlife species have been supplemented throughout the world to increase survival, body condition, reproduction, and to reduce levels of damage caused to

agriculture and forestry. For generations, people fed red deer (*Cervus elaphus*) in the winter in Europe (Putman and Staines 2004), and for a century people fed elk in the winter in North America. The state of Wyoming began feeding hay to elk north of Jackson in the winter of 1910. As cattle (*Bos taurus*) operations grew in western Wyoming so did competition for limited range suitable for wintering both elk and cattle. To alleviate the situation the state began a winter-feeding program, and in 1912 the federal government purchased 800 ha of land in the Jackson Hole area to serve as a winter refuge for elk, thus initiating the National Elk Refuge (NER) and government support for supplemental winter feeding of elk in North America (Smith 2001).

In Wyoming and Utah, agricultural development of areas traditionally used by wildlife during winter created conflicts when elk ate crops, including stored hay farmers and ranchers intended for livestock. Many ranchers in the West feed hay to cattle each winter, and are intolerant of elk usurping this forage. People in several western states began feeding elk during winter to reduce competition, including two major elk feeding operations in Utah.

In the 1940's elk were fed in several locations in Utah "rather than let them become a nuisance" (Kimball and Wolfe 1985). To alleviate depredation conflicts in Cache County, Utah, the Utah Division of Wildlife Resources (UDWR) purchased 7,500 acres at the top of Blacksmith Fork Canyon in 1945; elk are still fed there to minimize depredation on crops in Cache Valley. This property, the Hardware Ranch Wildlife Management Area, is now about 19,000 acres and winters 500 - 600 elk annually (Smith 2001). During the hard winter of 1983/84 a second elk feeding program was initiated on Deseret Land & Livestock Ranch (DLL), approximately 40 miles southeast of Hardware

Ranch in Rich County, Utah on the Wyoming border, to address concerns over elk use of winter feed intended for livestock. Until the initiation of my research, DLL had fed approximately 1,000 elk per year for 20 years (Rick Danvir, Wildlife Manager DLL, personal communication).

The Manager's Dilemma, to Feed or Not to Feed

Biological and Social Reasons for Feeding Elk. — Feeding wildlife in the winter has benefits and drawbacks. Feeding can reduce depredation of crops and stored feed. By influencing distribution feeding can also keep wildlife off busy roadways reducing wildlife-vehicle collisions responsible for an estimated \$2 billion a year in repair costs for deer alone (Conover 1997). Providing wildlife with feed can also reduce competition with livestock for forage, which is important to ranchers as the availability of economically valuable winter forage is often limited in western states. Finally, reducing contact between wildlife and livestock may be especially significant if disease is present in either population and contact could lead to transmission.

On some winter ranges, competition for forage by elk and mule deer may be alleviated by feeding elk. In the West, elk populations continue to grow as mule deer populations decline. Elk respond favorably to feeding, while deer do not always respond so well to winter feeding (Peterson and Messmer 2007). Although elk are primarily grazers, and mule deer browsers, there is some diet overlap, especially in severe winters when browse begins to make up a greater proportion of elk diets (Hansen and Reid 1975). Winter feeding of elk can reduce competition for winter forage and potentially benefit struggling mule deer populations.

Economic Reasons for Feeding Elk. — In temperate climates, the availability of winter forage typically limits the number of wildlife a landscape can accommodate. Providing winter feed to wildlife can compensate for the shortage of natural winter range allowing “artificially” high wildlife populations (Putman and Staines 2004). High numbers of wildlife benefit the human population through viewing and hunting opportunities, which contribute to the economic bottom line of landowners, local businesses, and state wildlife agencies.

Discontinuation of winter feeding programs could significantly affect wildlife populations. Some estimate that if elk were no longer fed on the NER the Jackson elk herd in western Wyoming would have to be reduced by 62% to 86% (Ron Dean, Wyoming Game and Fish Department ret., personal communication). The hospitality sector of rural economies as well as all guiding and outfitting related businesses would be dealt a sharp financial blow if elk numbers and, in turn, hunting opportunity were to decrease so dramatically. In addition, displaced elk would likely deplete both stored and standing crops intended for livestock creating new costs to be born.

Drawbacks to Feeding Elk. — The benefits of feeding elk must be considered in light of the drawbacks. Winter-feeding programs cost thousand of dollars, and many man-hours are required to produce, transport, and distribute winter feed. Private landowners and state wildlife agencies operate with limited budgets and would like to allocate the resources currently attached to winter elk feeding to other programs.

Winter elk feeding programs can also degrade natural winter ranges. The prolonged presence of unnaturally high elk densities in the vicinity of winter feeding operations can damage habitat through over utilization of native forage. Sagebrush ranges

provide winter browse for significant populations of mule deer, pronghorn (*Antilocapra americana*), and Greater Sage-Grouse (*Centrocercus urophasianus*). Thus, there is concern about possible inter-specific competition for forage and habitat with elk as well as over browsing of sagebrush by elk in habitats critical for deer and Greater Sage-Grouse (Hansen and Reid 1975, Kasworm et al. 1984, Kinuthia et al. 1992, Wambolt 1996, Kirchoff et al. 1998).

Although feeding programs at Hardware Ranch and DLL have solved some problems, new and pressing issues have arisen related to diseases and predators. Feed grounds may foster the spread of Chronic Wasting Disease (CWD) in elk and deer. Less is known about the risks of CWD infection in elk related to feeding grounds, but states such as Michigan, Minnesota and Wisconsin have restricted or outlawed deer bating and feeding in response to increased CWD rates (Dunkley and Cattet 2003).

Feeding grounds may also increase transmission of brucellosis between elk and cattle (Williams et al. 2002, Miller et al. 2004, Galey 2005). Brucellosis, a bacterial infection caused by the bacterium *Brucella abortus*, affects ungulates and has been tied to populations of wild bison and elk in the Greater Yellowstone Ecosystem. Brucellosis can also be contracted by domestic livestock and often causes infected females to abort their calves with economic losses due to lost revenues and increased testing costs (Galey 2005). Brucellosis-induced abortions typically occur at the end of the second or beginning of the third trimester of pregnancy, at a time of the year when elk are typically congregated on winter feeding grounds. The prevalence of brucellosis has been linked to the timing and duration of elk feeding operations that congregate elk when brucellosis induced abortions occur (Cross et al. 2007). In Wyoming, brucellosis seroprevalence, a

measure of disease exposure rather than infection, was detected in 13% to 32% of elk on 13 feed grounds (average 24.2%), compared to 2.3% in elk that did not winter on a feed ground (Dean et al. 2004a). The high infection rate among fed elk has fueled concern regarding the transmission of brucellosis from elk to cattle (Meagher and Meyer 1994, Thorne et al. 1997, Ferrari and Garrot 2002). While brucellosis has not yet been detected in Utah, a strain of brucellosis found in cattle in Lincoln County (WY) in 2003 may also occur in the local elk herd (Smith 2001). Based on the proximity of infected elk in Wyoming, and studies of elk movement and dispersal, it seems inevitable that elk in Utah may already, or will eventually, be exposed to brucellosis.

In Wyoming the reintroduction of gray wolves (*Canis lupus*) appears to have affected the operation of feed grounds. Wolves can chase elk off winter feeding grounds and complicate the ability of managers to predict wintering areas, herd movement, and migration patterns. Wildlife managers stage winter elk feed at feeding grounds based on historic elk behaviors and numbers, but some feeding grounds have been completely abandoned after wolf disturbances, and in other feeding areas much larger numbers of elk than expected have showed up, quickly exhausting the supply of feed. For example, in 2003 elk were displaced 50 km from the Black Butte feed ground to the Soda Lake feed ground (Dean et al. 2004b). Wolves are thought to be the cause of this kind of unpredictable elk movement (Mech et al. 2001, Dean et al. 2004b). Gray wolves periodically migrate into the Bear River valley which encompasses the lower elevations of DLL. Although pack formation has not occurred in Utah, future wolf-pack presence and activities could influence elk behavior and movements at DLL.

Elk that are fed become accustomed and even tolerant of human presence (Kozak et al. 1994). Decreased fear of humans, and increased association of humans with food, can increase depredation of stored hay should a feeding program be discontinued. Feeding can also facilitate other problems such as wildlife-vehicle collisions if elk are attracted to areas with higher human populations and vehicle traffic volumes. Locating feeding grounds in areas convenient to humans can draw animals away from preferred wintering habitats into areas with lower forage quality (Putman and Stains 2004).

Winter Feeding and Lack of Local Adaptation of Elk. — Finally, there is the issue, not often considered, of what happens to populations of large herbivores and the landscapes they inhabit when the animals have been “on welfare” during winter within and across generations. The effects of supplemental feeding on wildlife can include altered survival, reproduction, space-use patterns, and densities (Boutin 1990). Winter feeding thus could have undesired behavioral, physiological, and even epigenetic impacts on wild ungulate populations and their habitats causing welfare elk, subsidized on ever more costly fossil fuel inputs, not to be locally adapted to the landscapes they inhabit (Provenza et al. 2011).

Feeding necessitates more feeding by inhibiting in-season physiological adaptations that occur in response to natural winter diets. Some ruminants, including red deer (*Cervus elaphus*), have physiological adaptations to winter which result in decreased body temperature and decreased heart rate (Schmidt 2005). These adaptations reduce caloric intake requirements and make animals more adapted to harsh winter conditions. Should feeding stop mid-winter, animals being fed can be at greater risk of starving than

animals wintering on natural forage because subsidized animals may lose their physiological adaptations to cold.

In addition, pregnant elk or young calves fed in winter may be less well adapted to foraging on naturally occurring winter feed. Wiedmeier et al. (2002, 2011) found exposure in utero or as calves to high fiber, low quality diets positively affected the ability of beef calves to effectively use high fiber, low quality diets later in life. Cattle exposed to high-fiber, low-quality diets as young calves were able to ingest more, maintain a higher body condition, produce more milk, and reduce the postpartum interval to rebreeding. Animals exposed to high-fiber diets in utero better use high-fiber diets and gain more weight than individuals not exposed in utero. This research illustrates the potential importance of early life experience in both the behavioral and physiological adaptations of elk, as occurs in a broad range of creatures (Provenza et al. 2011). Accordingly, pregnant cows and young elk calves that winter out are more likely to foster new generations of elk that are better adapted to wintering out on lower quality naturally available forages.

Typically in temperate climates a severe winter will cause some animals to die of starvation, and reduce the body condition of surviving animals thus reducing their capacity to produce/raise viable offspring (Peterson and Messmer 2007). In that capacity, winter removes animals physiologically or behaviorally less well adapted to extreme environmental conditions, and over time, favors animals genetically and behaviorally better adapted to surviving during periods of extreme cold and/or deep snow. Winter-feeding programs enable animals that would starve or winter poorly to survive winter in favorable condition to reproduce (Robbins 1993, Kozak et al. 1995). Fed animals thus

have a fossil-fuel subsidized short-term evolutionary fitness advantage over animals that winter on rangelands unassisted by winter-feeding operations. Winter-feeding programs may thus contribute to human-induced selection for animals less well adapted to use native rangelands during winter. Over generations, winter feeding programs could produce ungulate herds composed of animals ill suited to local conditions and climates. This could lead to large die-offs if feeding programs are discontinued due to increasing costs for fossil fuels that are predicted to peak during the first half of this century (Kunstler 2005).

Finally, welfare animals may arrive on wintering grounds earlier and stay later than animals not fed in winter. This prolonged and concentrated use can adversely impact vegetation on wintering grounds ultimately reducing carrying capacity (Doman and Rasmussen 1944). These less well adapted animals effectively reduce the carrying capacity of available winter range, often severely over-use browse on winter ranges, and provide an even greater challenge to managers desiring to eliminate winter feeding programs.

Background

Prior to 2004, DLL fed approximately 1,000 elk per year for more than 20 years. The feeding program was implemented in 1983 following a meeting at which DLL, UDWR, Rich County Commission, and Wyoming Game and Fish Department (WGFD) representatives determined DLL should feed elk on their property to stop elk depredate hay on adjoining ranches in the Bear River valley. DLL benefits most from elk through hunting, an activity that generates significant revenue, so the neighbors felt that DLL

should shoulder the financial burden of feeding elk during winter. Feeding reduced elk depredation of hay on DLL and neighboring ranches, and lessened competition for shrubs used during winter by deer and Greater Sage-Grouse in Utah and Wyoming.

Nonetheless, feeding programs are costly. DLL spent on average \$70,000 per year on hay for elk (Rick Danvir, Wildlife Manager DLL, personal communication).

Winter feeding behavior in elk is a function of bioenergetics, energy requirement vs. availability of energy in available the forages. When historic feeding data from DLL are examined for correlations with environmental variables, several relationships stand out. The proportion of the elk population that was fed in winter from 1983-2005 is positively correlated with the average winter snow depth ($R^2 = 0.505$), calculated by measuring the snow depth on the elk winter range 3 times per month from November through March, and taking the average of those measurements (Fig. 1). The average snow depth is an index of forage availability, as snow depths increase more potential winter forage is covered and thus less accessible to elk.

Anecdotal accounts of problem elk behavior are correlated with cold temperatures. Unwanted elk behavior was often observed after multiple days with temperatures at or below -29°C . Elk require significantly more energy to maintain body temperatures during periods of extreme cold, and the increased demand for calories may cause elk to seek more abundant and higher quality food sources, such as stored hay and other feed intended for livestock.

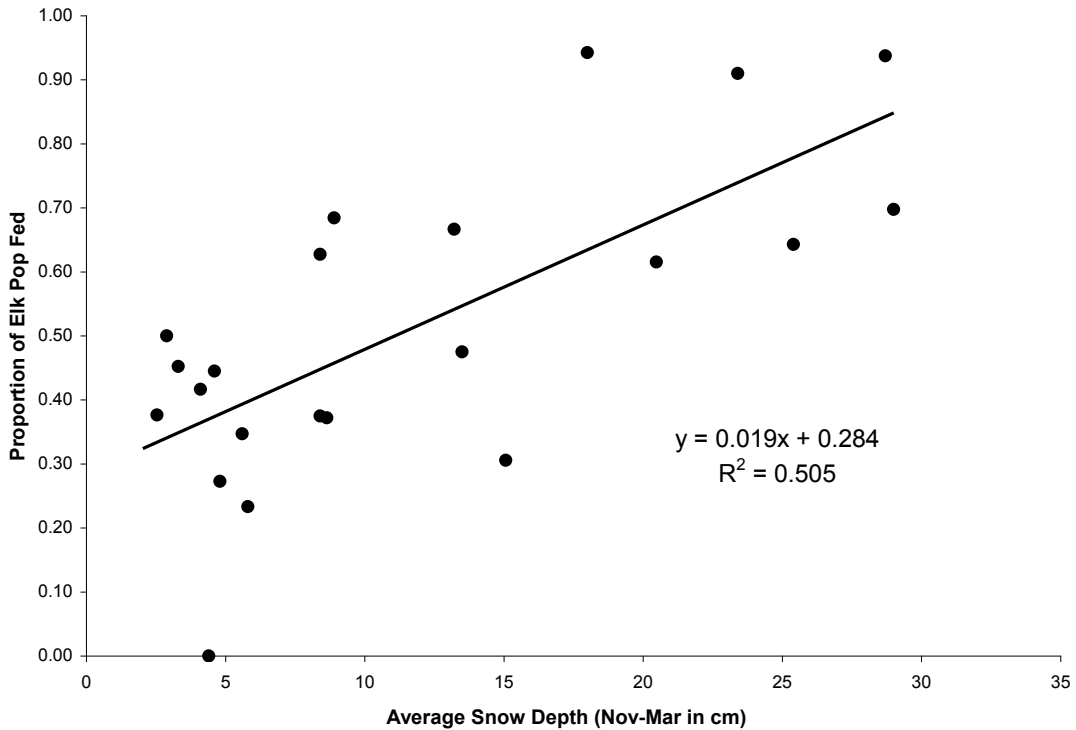


Fig. 1. *Proportion of elk population fed vs. average winter snow depth winter 1983-84 to winter 2004-05 at Deseret Land and Livestock ranch, Utah.*

Disease transmission among wildlife and livestock, competition for forage with mule deer and sage grouse, depredation of agricultural crops, and management of large predators are all politically sensitive and socially charged issues for the Utah Department of Agriculture, the National Cattlemen's Association, the Farm Bureau, UDWR, numerous sportsmen and environmental groups, and the Utah legislature. Wildlife managers must appropriately and proactively understand and respond to these potentially volatile situations. In light of these concerns, the UDWR and DLL must gain the knowledge and management experience necessary to significantly reduce or end the need to feed elk during winter at DLL. This must be balanced with the equally important goals

of maintaining productive ranges, healthy big game herds, and successful agricultural operations.

I realized the successful elimination of a winter elk feeding program would be a complex process that would have to take many factors into consideration. To stop feeding “cold turkey” presents unacceptable risks. In 1970 when Yellowstone National Park stopped feeding grizzly bears in park garbage dumps the number of human-bear conflicts increased dramatically, and park officials were forced to kill numerous bears that simply did not learn how to survive without handouts. This outcome was predicted by Frank and John Craighead, but their research and predictions were largely ignored by park officials (Craighead 1979). If winter elk feeding on DLL were stopped cold turkey, most elk would likely leave the ranch to depredate stored hay on neighboring ranches. This outcome was not desirable to DLL nor neighboring landowners. Thus our efforts needed to focus on changing elk behavior in a manner that was aggressive, yet still allowed wildlife managers to anticipate results and maintain influence as the situation evolved. That required adaptation to ever-changing environmental conditions and elk behaviors within and among years.

I evaluated a combination of techniques to train elk to use new foods and habitats during winter, including range improvements, strategic grazing by cattle to enhance habitat for elk, dispersed supplemental feeding, hunting, and herding. I monitored elk winter feeding behavior and distribution with respect to these treatments to gauge our success. I used multiple treatment methods simultaneously, I did not distinguish the effectiveness of individual methods, but I did quantify the cumulative effect on elk behavior.

Our work followed the model of adaptive management, an integrated ongoing cycle of planning, implementing, monitoring, evaluating, and adjusting to facilitate continued success throughout the project (Lancia et al. 1996). Prior to the initiation of this project I met with DLL wildlife and livestock managers, behavior analysts, and academics to jointly formulate the basic methodology, structure and criteria for applying the methods discussed, and more importantly, the underlying principles of teaching elk by rewarding desired behaviors and punishing undesired behaviors. In the style of adaptive management, both positive reinforcement and punishment were used as appropriate opportunities presented themselves.

This project was ideal for applying the adaptive management concept. We set goals, made a plan to accomplish those goals using a variety of methods, implemented our methods, monitored the outcome, and made adjustments along the way when there was the opportunity to improve. As a case in point, after the first winter of the project we realized that if we increased the proportion of the cow elk harvest that occurred later in the year we could extend the hunting-related influence on elk distribution later into the winter when it was most critical. Therefore, in the 2 following winters, we scheduled more hunters later in the hunting season. Ongoing adaptation to ever-changing conditions is essential for changing behavior.

Behavioral Principles

Positive reinforcement is defined as feedback stimulus that increases the frequency of a behavior (Pierce and Cheney 2004). I attempted to provide stimuli to elk that would increase the frequency of the desired behavior -- foraging on rangelands and

spending time away from the traditional winter feeding grounds. The positive stimuli provided included various sources of nutrition and security.

Punishment is defined as feedback stimulus that decreases the frequency of a behavior (Pierce and Cheney 2004). When elk displayed undesired behaviors, such as showing up at traditional feeding grounds, or moving towards haystacks, I provided stimuli that would dissuade them from repeating those behaviors. Punishment included hunting pressure, hazing or harassment, and herding.

It is noteworthy that a combination of positive reinforcement and punishment were used to modify elk behavior. Wildlife managers often use only punishment to remedy human-wildlife conflicts. Punishment, by definition, is effective, and therefore is often overemphasized as a way to modify undesired behaviors. However, the over-reliance on punishment has drawbacks as animals can become confused, aggressive, afraid, and apathetic and they do not learn well under stress (Pierce and Cheney 2004). A combination of positive reinforcement and punishment thus can be more effective in the long term, with punishment used to motivate a behavioral change and positive reinforcement used to reward the modified, desired behaviors. This “carrot” and “stick” approach uses positive reinforcers as carrots, and punishers as sticks. I attempted to provide winter feeding alternatives acceptable to elk, rather than just punishing undesired winter feeding behaviors. Because elk were accustomed over many generations to being fed in the winter, rather than foraging on their own, they needed some motivation to jumpstart the learning process which over generations I hypothesized would change elk culture from one that expects to be fed during winter to one that mostly forages during winter.

Thesis Objectives

This 3-year study tested the effectiveness of applying behavioral principles to solve a complex wildlife-management problem. I used positive reinforcement and punishment in an attempt to change undesirable winter feeding behaviors in elk to reduce disease risks and costs. This had to be accomplished without large reductions in the elk population, and without causing an increase in human-wildlife conflicts.

This project was conceived and executed as an applied management experiment, a science-based and analytical, yet adaptable approach to solving a wildlife-management problem. In the style of adaptive management, we set goals for reducing elk reliance on winter feeding, outlined strategies to achieve those goals, implemented our strategies, monitored the outcome, and throughout the process made modifications to improve the likelihood of accomplishing our goals based on observations and learning.

Prior to the initiation of this project, I met with DLL wildlife and livestock managers, behavior analysts, and academics and we jointly formulated the basic methodology, structure and criteria for applying the methods discussed, and more importantly the underlying principle of teaching elk through the rewarding of desired behaviors and punishment of undesired behaviors. Throughout the project we used both positive reinforcement and punishment whenever appropriate opportunities were presented in an adaptive/opportunistic manner. This project is based on the application of behavioral principles rather than any individual specific method per se, to influence distribution of elk. In this thesis I hope to convey the context of our specific problem, the thinking behind our approach to solving it, the rationale and principles of our

methodology, and finally the results of our efforts and what they could mean to others facing complex wildlife management problems.

STUDY AREAS

To assess the impact of the various behavior modifications, I compared elk numbers on the feed ground at DLL during this study with historic data on DLL. I also contrasted elk responses with two comparable feed sites in Wyoming that served as controls.

Deseret Land and Livestock

Deseret Land and Livestock, a working cattle ranch, is located in Northeastern Utah. It straddles Rich, Weber, and Morgan counties in Utah, and a small portion of the Ranch is located in Uintah county Wyoming. DLL is comprised of approximately 82,963 ha of private land, and contains 6,070 ha of Bureau of Land Management (BLM) land within its boundaries. Elevations range from 1,920 m on the northeastern portion of the ranch to 2,650 m in the more rugged western mountainous regions.

The ranch can be divided into three regions based on elevation and vegetation type. The lower elevations in the north/northeast portion of the ranch are dominated by grasses such as crested wheatgrass (*Agropyron cristatum*) and western wheatgrass (*Pascopyrum smithii*). The mid elevations in the southeast are primarily sagebrush steppe habitat consisting primarily of Wyoming big sage (*Artemisia tridentata spp. wyomingensis*), which transition into aspen (*Populus tremuloides*) and pines such as the douglas fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*) at the higher elevations on the western portion of the ranch. The sagebrush steppe and grassland portions of the ranch constitute potential elk winter range, while the higher elevations on the western portion of the ranch are primarily elk summer range. Average annual

precipitation is 23 cm (9 inches) in the lower elevations, 28 cm (11 inches) in the middle elevations, and 38+ cm (15+ inches) in the western foothills and mountains. The mean temperature for lower elevations recorded at nearby Woodruff is 4.4°C (40° F), summer temperatures exceeding 32°C (90° F) and winter temperatures below -29° C (-20° F) are not uncommon.

Big Piney Elk Herd Unit (BPEHU)

Approximately 107 kilometers northeast of DLL the BPEHU lies on the east slope of the Wyoming Range in western Sublette and eastern Lincoln Counties, WY. The area is bound on the north by the Hoback Rim, on the northeast by Highway 189, on the east and southeast by the Green River, on the southwest by LaBarge Creek, and on the west by the hydrographic divide between the Green River and Grey's River drainages. The BLM is responsible for managing 157,212 ha (38%) of the surface area in this herd unit. The U. S. Forest Service (USFS) manages 98,420 ha (24%) of the area. Private and state lands account for the remaining 152,032 ha (38%) of the area along: North and South Horse Creek; North and South Cottonwood Creek; North, Middle, and South Piney Creek; and LaBarge Creek.

Currently, five feed grounds are located within the BPEHU: Franz, Jewett, Bench Corral, North Piney, and Finnegan. All feed grounds in this Herd Unit (excluding Bench Corral) are located along the border of BLM or private lands and USFS lands and were established "uphill" from livestock operations primarily to prevent damage to stored hay and later, prevent commingling of elk and livestock.

The total area of the BPEHU is approximately 407,664 ha, of which 403,261 ha have been delineated by the WGFD as occupied elk habitat. Approximately 336,698 ha (83%) are delineated as Spring/Summer/Fall range, 32,116 ha (8%) as Crucial Winter/Yearlong range, 2,072 ha (<1%) as Crucial Winter range, 18,389 ha (5%) as Winter range, and 14,245 ha (3%) as Winter/Yearlong range.

Afton Elk Herd Unit (AEHU)

Approximately 111 kilometers north-northeast of DLL the Afton Elk Herd Unit (AEHU) covers the western slope of the Wyoming Range to Tri-basin Divide, the Salt River Range, and west to the Wyoming-Idaho state border including Star Valley. The Salt River and the Greys River are the major drainages in the herd unit. The AEHU lies within Lincoln County and covers 250,711 ha. The USFS, which manages 79% of the surface area, is the major land management agency for this herd unit. Private property, restricted primarily to Star Valley, makes up most of the remaining area (19%).

The major uses of the USFS lands include domestic livestock grazing and year-round recreation. Summer uses include fishing, camping, horseback riding and motorized all-terrain vehicle use. In the fall, hunting is the predominant use. During winter, both private and outfitted snow machine use is common along the Greys River road, and in some of the tributaries of the Salt River Range and Wyoming Range. Livestock grazing also occurs throughout the Greys River watershed in the summer. Grazing allotments are predominantly cattle along the riparian bottomlands and domestic sheep on the uplands.

Approximately 205,904 ha (82%) of the AEHU is considered occupied elk habitat. Of the total occupied elk habitat, there are approximately 171,457 ha (83%)

designated as spring, summer, and fall range. There are 1,165 ha (<1%) designated crucial winter range, and 29,526 ha (14%) are considered winter-yearlong range.

There are two feed grounds: Forest Park feed ground is located in the upper Greys River, and the Greys River feed ground is located near the town of Alpine. The Greys River feed ground serves to prevent damage to stored crops, co-mingling of elk and domestic livestock, elk from getting on Highway 89, and winter starvation. Forest Park serves only to prevent winter starvation of elk in the upper Greys River.

METHODS

To affect a change in elk winter feeding behavior, we applied a combination of positive reinforcement for desired behaviors and punishment for undesired behaviors. The positive reinforcement served to reward elk that exhibited desired behaviors while punishment served to decrease undesirable behaviors. Positive reinforcement for being in various locations came in the forms of refuge from hunting pressure and harassment and increased forage availability, while punishment for being in particular locations came in the forms of hunting pressure and harassment.

I evaluated winter feeding behaviors based primarily on the location of elk. A priori, we defined wintering areas where elk presence was desired based on the absence of stored agricultural crops, potential to reduce or eliminate competition with mule deer and/or livestock for forage, and proximity to highways to prevent wildlife vehicle collisions. I wanted to train elk to stay in desired areas during the winter. I defined as undesirable behavior when elk entered the historic feeding grounds, ranges where they could potentially compete with mule deer or livestock, areas near stored agricultural crops, or the borders of the ranch near roads and towns.

Positive Reinforcement (Carrots)

Range Improvements.— In the desired elk wintering areas we attempted to reward elk by providing enhanced nutrition through range improvements, strategic livestock grazing, and dispersed supplementation. DLL uses a variety of range improvement techniques to benefit both livestock and wildlife by increasing the amount of digestible protein and energy available on rangelands (Aoude 2002, Summers 2005). Mechanical

range improvement methods include disking and seeding with a seed mix containing plants high in protein and energy, or pulling a large double drum aerator behind a tractor to remove older age class sagebrush plants to increase understory grasses and forbs. Over 12,000 acres of rangelands likely suitable for wintering elk have been improved since 2001: 6,931 acres have been disked and seeded, 4,196 acres have been aerated and seeded, and approximately 1,000 acres have been burned (Craig Kennedy, Range Manager DLL, personal communication). Fire and grazing by sheep are also used to remove older age class plants to allow for more diverse and younger plants (Rick Danvir, Wildlife Manager DLL, personal communication). These range treatments typically increase quality and quantity of forage available to elk, cattle, and other wildlife species through the reduction of sagebrush biomass and increase of more palatable grasses, forbs and shrubs including *Kochia prostrata* (Aoude 2002).

Strategic Livestock Grazing.— Cattle grazing on DLL, which is management-intensive, high-intensity short-duration grazing, similar to that described by McNaughton (1976) and Savory (1988), has positively contributed to overall range land health at DLL. Multiple studies have assessed the use of domestic livestock grazing to improve habitat as winter range for elk (Anderson and Scherzinger 1975, Frisina and Morin 1991, Wambolt et al. 1997, Clark et al. 2000, Short and Knight 2003). Livestock grazing on DLL is planned in detail and closely managed and monitored such that cattle graze at high densities for short periods of time on only a small proportion of the 126 separate pastures in any given year. After grazing, the pastures are then rested for extended periods (often greater than one year) before cattle are again introduced into the pasture. The timing and season of use are also varied each year.

In addition to the overall benefit to plant communities on DLL, I also used strategic livestock grazing specifically related to the objectives of my study. Based on historic winter elk distribution data and proximity to problems areas, I identified sites where increased use by elk would be desirable. I coordinated with DLL livestock managers to alter the grazing schedule to maximize winter forage in these areas, while still allowing livestock use. Desirable areas for elk to winter were grazed by livestock earlier in the year to allow time for plants to regrow. If pastures are grazed in the early spring, they have the remainder of the growing season to recover, thus leaving more standing forage during winter and increasing the ability of elk to winter in those areas. If elk have adequate forage to meet their needs for nutrition, they are more likely to remain in a particular area. Importantly, elk are typically attracted to the nutritious re-growth where cattle have grazed previously.

Dispersed Supplemental Feed.— Dispersed supplemental feed, or spot feeding, is another way to increase the ability of elk to use forage in an area (Provenza et al. 2003). Dispersed supplemental feed may be used to move and settle smaller groups of elk in desired areas and to keep elk out of problem areas. I used dispersed supplemental feed in the form(s) of limited amounts of hay, pellets, and or mineral blocks in an attempt to lure elk to desired areas, to intercept moving/migrating elk, and to hold elk in desired areas. These foods were intended to supplement and complement their natural diet, rather than replace it as with previous feeding. Supplements provide additional nutrients, and may also allow elk more access to the nutrition potential of naturally occurring rangeland vegetation. Some nutritional supplements can counteract secondary compounds such as

terpenes in sagebrush thereby enabling animals to ingest more of the vegetation naturally available to them without adverse effects (Provenza et al. 2003, 2011).

Using a concentrated low-moisture supplement block or tub was desired due to the logistical ease of placing the supplement in the environment. During the winter of 2005-2006, I offered elk a molasses-based 25% protein block supplement while they were congregated at the feeding grounds. This also served as a training period for elk to learn about and become familiar with the supplement. I continued offering various forms of nutrition supplements on summer range to continue the familiarization and learning processes. During the winter of 2006-2007, I used the preferred forms of supplement in an attempt to lure elk into desired wintering areas, intercept elk along natural movement/migration corridors, and hold lured and intercepted elk in these areas. I also conducted several supplement pen trials with captive elk at Hardware Ranch (see appendix B Elk Use of Molasses Based Low Moisture Supplement Blocks in Northern Utah). All these methods were designed to reward elk nutritionally for being in desired wintering areas.

Sanctuary or "Safe" Zones.— Food and security are the two critical factors influencing elk distribution (Wertz et al. 2001). In addition to providing elk with the necessary nutrition to keep them away from winter feeding grounds and out of problem areas, I provided elk with a security incentive to keep them in desired areas.

DLL has an active wildlife management program, and hunting is a large component of that program. On average DLL harvests over 300 elk from Sept. 1 to Jan 31. In September approximately 60 bull elk are harvested in the higher elevations of the western portion of the ranch, and approximately 250 cow elk are harvested throughout

the ranch from September through mid December. All elk hunts on DLL are guided, and success rates approach 100%.

Designating safe areas where elk have refuge from hunters was a complicated process involving many factors. I worked cooperatively with DLL staff to designate varying types of “safe” zones to provide sanctuary to elk while still allowing the necessary harvest to manage the population. I identified safe zones that corresponded with historic winter range for elk. I choose areas that had minimal human activity in winter and that were isolated from potential human-wildlife conflict areas such as highways and haystacks. Safe areas also had to correspond with treated rangelands and livestock pastures where we could implement strategic livestock grazing. I used the boundaries of livestock grazing pastures to define hunt zones with differing hunt strategies as those boundaries were well known by ranch staff and hunting guides and corresponded with different livestock grazing strategies.

After considering these criteria, I divided the ranch into 4 zones, each with a different elk-hunting strategy (Fig. 3). The first zone was designated the “shoot zone” where elk would be hunted during the entire hunting season. This zone included the northern portions of the ranch and the summer range where fall hunts would occur. It also included the northeast corner of the ranch where the traditional feeding grounds were located and where elk have the highest potential to get on the highway and into haystacks. At any time during the hunts, elk found in this zone were targeted by hunters, especially elk in the northeast corner of the ranch. Hunting elk in this area reduced numbers of animals we did not want to be in the area and provided incentive for surviving elk not to return to this area.

The second zone was designated as “shoot through November.” This zone extended across the southern end of the ranch, and typically held some elk in the winter. The shoot through November designation was a compromise between achieving the necessary harvest and still providing some sanctuary in conflict-free wintering areas. Hunters were free to harvest elk in this area through the month of November, but they had to stop hunting December 1st to allow elk to settle in for winter.

The third zone was designated as the “last resort” zone. This zone was located in the southeast corner of the ranch in the area that is primarily grassland. This was a highly desirable location to winter elk. However, in the interest of achieving the necessary harvest, people were allowed to hunt in this area as a last resort if elk could not be found in other parts of the ranch after extensive searching.

The fourth zone was a designated “safe” area. This area was located in the central western portion of the ranch and was chosen due to isolation from problem areas, historic observations of where elk wintered, recent rangeland improvement projects and available winter forage, and ability to manipulate the grazing season of use to earlier periods. No elk hunting was allowed in this zone and ranch personnel were asked to completely avoid entering the area unless absolutely necessary.

Punishment (Sticks)

Punishment is defined as feedback stimulus that decreases the frequency of a behavior (Pierce and Cheney 2004). I used punishment in the forms of hunting and herding to discourage elk from relying on winter feeding, and depredating haystacks.

Hunting.— While adequate nutrition is critical, sanctuary from hunting pressure is perhaps even more important, as elk select habitats of lower quality in exchange for increased security (Wertz et al. 2001, Conner 2002, Viera et al. 2003). Hunting pressure can have significant and lasting impacts on the movement and distribution of game animals (Conner 2002, Viera et al. 2003). An incident at DLL illustrates the powerful influence of hunting on elk. Prior to 1986 both bull and cow elk at DLL migrated to lower elevations on the eastern portion of the ranch in mid-October. In the fall of 1986, 100 hunters were simultaneously allowed access to the ranch to hunt cow elk. In prior years only a few hunters were allowed to hunt at any one time, but in 1986 hunting pressure was intense, and hunters harvested 86 cows in one morning; since that date cow elk have not migrated to lower elevations until snow pushes them down later in November or December. Obviously, most of the cows that survived have since died, so the behavior has been maintained culturally by offspring trained by their mothers when and where to migrate. Bull elk, not hunted in the lower elevations of the ranch, have continued to migrate to lower elevations by mid October.

Given these observations, we attempted to use strategic hunting pressure to influence elk culture and distribution in an attempt to move and settle elk in areas that would reduce disease risk and depredation incidents. While dead elk obviously don't learn, hunting is an effective way to make a lasting impression on the elk that survive. On DLL using noise making devices that simulate gunfire has not been as effective as hunting at dissuading problem elk, as elk quickly habituate to simulated gunfire (Rick Danvir, Wildlife Manager DLL, personal communication).

In addition to the 4 different hunt zones previously described, we also made a strategic shift in the dates of the harvest. Historically the bulk of cow elk harvest occurred Nov. 1 – Dec. 15, but in an effort to have a more lasting impact on winter elk distribution, we extended the hunting season through January (see Fig. 2).

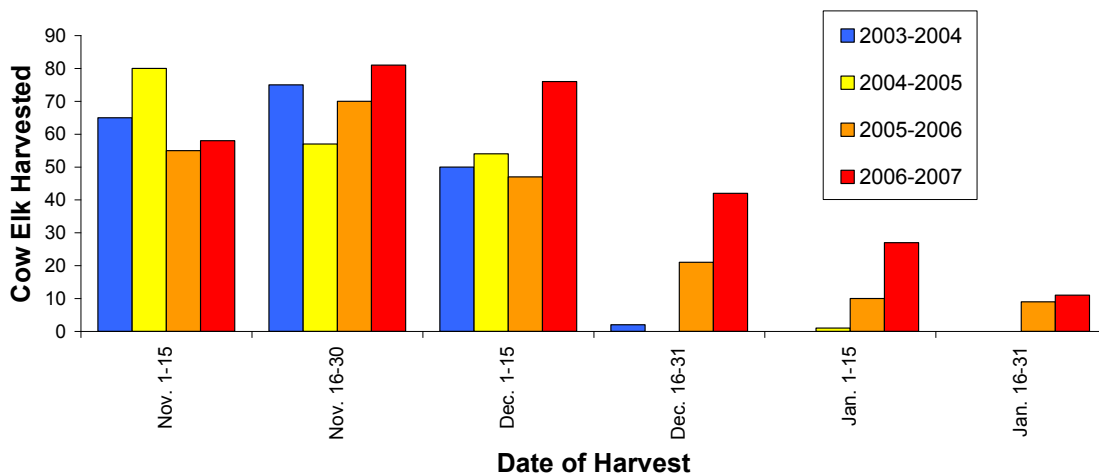


Fig. 2. Late cow elk harvest by date 2003-04 to 2006-07 on Deseret Land and Livestock ranch, Utah.

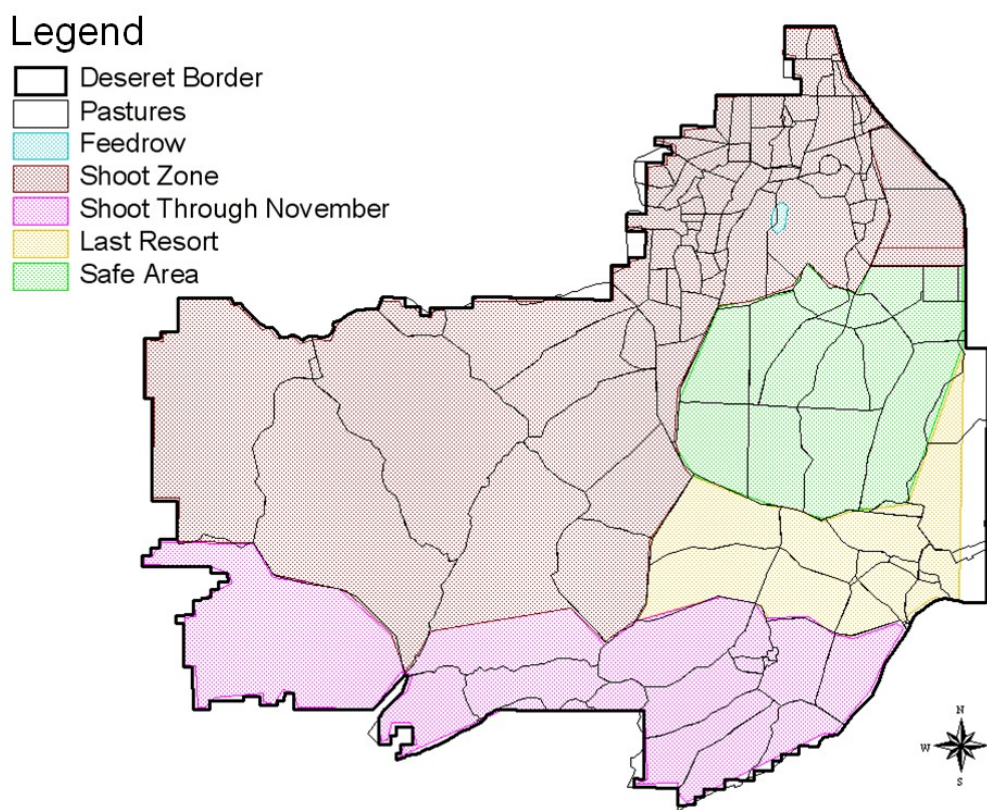


Fig. 3. *Map of strategic cow elk hunt zone boundaries on Deseret Land and Livestock ranch, Utah.*

Herding and Hazing.— We also used herding and hazing to train elk. Elk were herded from undesired locations when hunters were not available, when the location made hunting unsafe, or when hunting season had ended. Herding was conducted in on foot, in vehicles, and snowmobiles depending on circumstances. We typically attempted to use low-stress herding techniques to keep animals calm and to maintain more control of movements (Cote 2004). A herder would approach the elk in plain sight from a distance and move in slowly occasionally stopping and waiting. The elk would notice the presence of the herder and as they approached the elk would become uncomfortable and begin to move away from the herder. If herding was done slowly, often the elk moved

calmly, and did not move a great distance. In some instances hazing was also used to move elk from undesired wintering locations. In these cases elk were approached rapidly typically in a truck, atv, or snowmobile. Typically elk fled from the approaching vehicle and their flight distances were greater, and less predictable, than if they had been herded. Hazing had a more powerful impact on elk distribution than herding, but was also harder to control. If herding efforts were initiated and elk began moving into an undesirable area, herding could be curtailed and elk often settled and stopped moving. However, once a hazing effort had been initiated it was practically impossible to stop elk movements (see Appendix A Narrative of Elk Response).

DATA ANALYSIS

To gauge the success of our efforts to decrease the reliance on supplemental winter feeding, I compared pre- and post-treatment elk numbers at the DLL feeding ground using winter snow depth as a covariate. Preliminary data from DLL and research from Wyoming suggest that snow depth affects elk feed ground attendance and feeding duration (Cross et al. 2007). DLL has snow depth and elk feeding data from 1983 to present providing 20+ years of baseline data for historical comparison.

For an additional comparison, feed ground data from DLL together with Wyoming Fish Game Department (WFGD) feed grounds were used in a Before-After Control-Impact or BACI study design (Stewart-Oaten et al. 1986, Underwood 1994, Smith 2002). A BACI study design provides a “control” or reference area to allow evaluation of trends in two independent sites before and after treatment. A significant change in the average difference between the sites infers treatment effect.

For this analysis, I compared the proportion of the elk population fed on DLL with the proportion of the elk populations fed on the Big Piney and Afton elk herd units in Wyoming. I used data provided by DLL and WFGD from 1983 to 2006. Both DLL and WFGD estimate elk population numbers using modeling. WFGD estimates numbers of elk in their herd units during winter using a combination of aerial observations and production, harvest and classification data. DLL estimates their elk population in the spring based on production, harvest, and classification data, and ground counts in sample areas distributed through different habitat types on the ranch. The specific computer models used by each organization to estimate numbers differ, and have changed over the

years as modeling techniques and technologies improved. Both organizations also conducted regular aerial trend counts to verify/validate estimates, and are constantly seeking to improve the accuracy of their estimates. The values used in this analysis represent the best available estimation of elk populations in these respective units.

On both DLL and WGFD feeding grounds, the number of elk is counted and recorded multiple times each year. I calculated the proportion of the elk population being fed each winter by dividing the peak count of elk on feed grounds by the total estimated population for the elk herd unit. I used proportion of the elk population being fed rather than the actual number of elk fed because elk population numbers have fluctuated over time.

Because data from DLL and Wyoming suggest climatological factors such as snow depths and winter temperatures influence the number of elk that come to winter feeding grounds, I wanted to incorporate a measure of winter severity as a covariate to account for some of the variability between sites for the BACI analysis. In my preliminary analysis, I correlated average winter snow depth on DLL, calculated by measuring snow depth on the elk winter range 3 times per month from November through March, with the proportion of the elk population being fed. This analysis resulted in a positive correlation ($y = 0.019x + 0.316$) and r^2 value of 0.534.

While I wanted to use this same measure of average winter snow depth from the weather station closest to a feeding ground in the Wyoming elk herd units, the Wyoming weather stations did not have historic daily snow depth data. Data included total monthly precipitation in inches, average monthly temperatures, temperature extremes and freeze data, monthly and seasonal cooling degree days, soil temperatures, and evaporation and

wind movement. I first attempted to use total winter precipitation as a substitute for average winter snow depth, assuming a strong correlation. When I compared total precipitation from Nov – March in cm vs. average winter snow depth on DLL, the results did not indicate a strong correlation, $r^2 = 0.287$, $y = 0.187x + 5.646$.

I subsequently used DLL elk feeding data to perform additional regression analyses of the proportion of elk on the DLL feed ground compared with other climatological data available at weather stations on all study sites. I compared average winter maximum snow depth, calculated by taking the average of the maximum snow depth recorded each month Dec. – Feb. vs. proportion of DLL elk fed. The results of the correlation were: $r^2 = 0.314$, $y = 31.564x + 3.360$. I also compared the average monthly minimum temp from Dec. – Feb. vs. proportion of DLL elk fed with the following results: $r^2 = 0.373$, $y = -0.047x - 0.214$. I then compared average winter temperature, an average of monthly average temperatures from Dec. – Feb. vs. proportion of DLL elk fed with a resulting $r^2 = 0.391$, $y = -7x - 5.054$. Based on these analyses and resulting r^2 values, I decided to use average winter temperature as a covariate in the BACI comparison between DLL and the Wyoming study sites.

For my analysis I used archived average winter temperature data from National Oceanic and Atmospheric Administration (NOAA) weather station closest to DLL which was in Woodruff, UT. I used the Bedford SE, WY weather station near the Alpine feeding ground on the Afton elk herd unit, and the Daniels Fish Hatchery, WY weather station near the Bench Corral feeding ground on the Big Piney elk herd unit to get Wyoming temperature data. These weather stations were selected based on proximity to feeding grounds and availability of long-term data sets.

My analysis compared elk feeding on DLL with the 2 similar elk herd units in WY, using average winter temperature as a covariate. Data were analyzed in SAS using Proc MIXED. I modeled treatment period (before and after treatment), area (treatment and control), and average winter temperature (awt) as a fixed effect (model: $\text{proportionelkfed} = \text{treatperiod} + \text{treatarea} + \text{treatperiod} * \text{treatarea} + \text{awt}$). The treatment area model grouped the 2 control areas, and compared them against the treatment area. The null hypothesis was that there was no treatment effect, the alternative hypothesis was that treatment reduced the proportion of the elk population fed on DLL. I used a 1-sided test.

RESULTS

Winter severity has varied greatly in the 20+ year history of elk feeding at DLL, but on average DLL has fed approximately 53% of the elk population, 7 days a week, for 90-100 days. During the winter of 2004-05, the first winter of this study, after above average snow depth in January, DLL fed approximately 64% of the elk herd, 7 days a week, for 65 days. During the winters of 2005-06 and 2006-07, both mild winters, DLL did not feed any elk (Table 1).

Table 1. *Winter severity and elk feeding at Deseret Land and Livestock ranch, Utah 1983-84 – 2006-07.*

Year	AWT in C	Description	% Fed	Feeding Days	Feeding Frequency
20 Year Historical Average	-8.57	average	53%	90-100	7 days a week
2004-05	-9.78	colder	64%	65	7 days a week
2005-06	-8.00	warmer	0%	0	0
2006-07	-7.35	warmer	0%	0	0

Historically, 62% of the Big Piney and Afton elk herds were fed 7 days a week for 137 days. Elk were fed until managers determined adequate natural forage was available and deemed feeding operations could be terminated for the year without risk of elk depredation. The winter of 2004-05 was warmer than average and 65% of the elk herd was fed for 124 days. During the winter of 2005-06 temperatures were colder than average and 73% of the elk herd was fed for 135 days. In the winter of 2006-07 temperatures were again colder than average and 76% of the Big Piney and Afton elk herd was fed for 127 days (Table 2).

Table 2. *Winter severity and elk feeding on Big Piney and Afton elk herd units, Wyoming 1983-84 – 2006-07.*

Year	AWT in C	Description	% Fed	Feeding Days	Feeding Frequency
20 Year Historical Average	-9.4	average	62%	137*	7 days a week
2004-05	-8.45	warmer	65%	124*	7 days a week
2005-06	-9.95	colder	73%	135*	7 days a week
2006-07	-10.2	colder	76%	127*	7 days a week

*average of all feed grounds in these elk herd units

Historic Data Results

Winter severity has a large impact on winter elk distribution and feeding behavior at DLL. The 3-winter treatment period that I analyzed included 2 mild winters with warmer than average temperatures, and 1 severe winter with colder than average temperatures. During the 2 mild winters DLL completely eliminated winter feeding. In the severe winter we still fed elk on DLL, but we fed for a shorter period time (see Fig. 4 and Table 1).

BACI Results

At the treated area (DLL), the proportion of elk fed dropped from an average of 0.519 before treatment to 0.186 after treatment, while at the WY control sites, the proportion of elk fed increased from 0.639 prior to treatment to 0.716 after treatment. The average difference between the proportions of the elk populations fed at the treatment site at DLL and Wyoming control sites changed significantly after the implementation of the treatment ($P = 0.057$, $df = 43$, 1-sided) (Fig. 5).

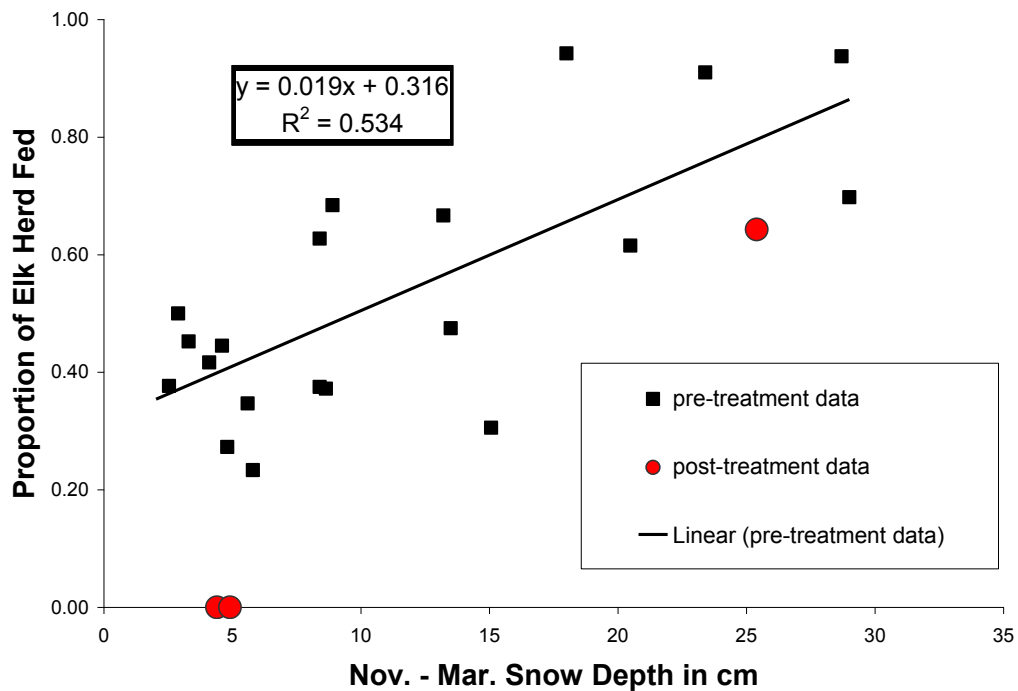


Fig. 4. Pre- and post-treatment proportions of elk herd fed vs. winter snow depths winter of 1983-84 to winter 2005-06 at Deseret Land and Livestock ranch, Utah.

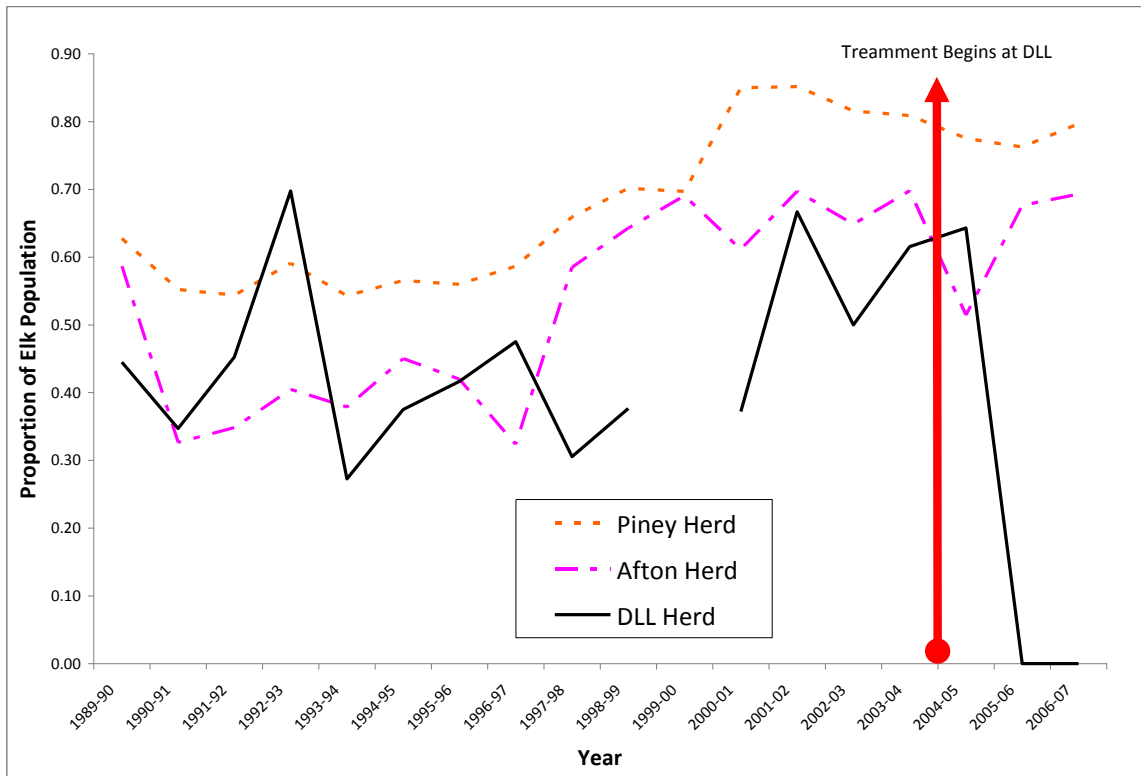


Fig. 5. Proportion of elk populations fed at Piney and Afton Wyoming and Deseret Land and Livestock ranch, Utah winter feeding grounds from winter 1989-90 to winter 2006-07.

DISCUSSION

My objective was to test the application of behavioral principles as a management tool to teach/train elk to winter on rangelands rather than depending on a winter feeding program at DLL. I hoped to accomplish this without large elk population reductions, and while minimizing human-wildlife conflicts on neighboring roads and ranches. The null hypothesis was that management efforts or treatment would not produce a significant response in elk winter feeding behavior and that DLL would have to continue to feed large numbers of elk for long periods of time in winter. Results from historic data comparisons and the BACI comparisons both suggest rejection of the null hypothesis. In all three winters we eliminated or reduced feeding and elk wintered on rangelands without causing depredation problems for neighboring landowners.

BACI analysis also showed that our management efforts reduced the proportion of the elk population fed in the winter when compared to comparable WY feeding grounds not engaged in an active effort to reduce winter feeding reliance at that time. Due to the treatment, fewer elk were congregated on the DLL feeding ground, thereby reducing the risk of disease exposure and transmission.

For the BACI analysis I attempted to choose elk herd units in Wyoming that were similar to DLL based on conversations with WYGF personnel, but due to the inevitable environmental and biological uniqueness of large study sites, it was not possible to find an exact match. While the Utah and Wyoming study sites are similar in many ways, because the Wyoming elk herd units are larger and contain more than one feeding ground, there is more variation in topography, elevation, vegetation, and winter weather

in the Wyoming study areas and in the areas immediately adjacent the Wyoming feeding grounds. Historically at the Wyoming study sites elk were fed an average of 137 days/year compared to 90-100 days at DLL. On average Wyoming fed 3,443 elk or 62% of their estimated elk population each winter on 7 different feeding grounds. DLL fed an average of 981 elk or 53% of their estimated elk population on 1 feeding ground. Nonetheless, because a BACI analysis compares the average difference between sites, it is not critical that the sites are exactly alike.

The success of this project prompted DLL to integrate our treatment methods into their management scheme. They have experienced continued success in their efforts to reduce reliance on winter feeding in elk while keeping human wildlife conflicts at a minimum. In the winter of 2007-08 they experienced deep snow and cold temperatures. Under the old management strategy this would have been considered a severe winter and would have led to intensive and expensive feeding efforts. Instead, DLL fed for only 65 days, rather than 90-100 days, and only fed 4 times opposed to 7 times per week. Their feeding expenses were \$35,000 rather than \$70,000. DLL still fed a peak count of 1200 elk, but overall fed 40-60% less than in years past under the old management strategy, and did it without wandering, depredating elk. The winters of 2008-09 and 2009-10 were relatively mild, and with the continued application of the new management strategy, no elk were fed (Table 3).

Table 3. *Winter severity and elk feeding at Deseret Land and Livestock Ranch, Utah 1983-84 to 2009-10.*

Year	AWT in C	Description	% Fed	Feeding Days	Feeding Frequency
20 Year Historical Average	-8.57	average	53%	90-100	7 days a week
2004-05*	-9.78	colder	64%	65	7 days a week
2005-06*	-8	warmer	0%	0	0
2006-07*	-7.35	warmer	0%	0	0
2007-08	-10.83	colder	54%	65	4 days a week
2008-09	-6.11	warmer	0%	0	0
2009-10	-7.83	warmer	0%	0	0

* years included in analysis

Behavior by Consequences

Rather than test individual methods separately, I applied multiple methods simultaneously and adapted their usage as I learned how elk responded. Based on the concurrent use of multiple methods to change elk winter feeding behavior, I cannot determine the effectiveness of individual methods. The successful reduction of proportion of elk fed is likely due to the panoply of treatments.

Training that uses punishment of undesired behaviors in combination with reinforcing desired behaviors is typically more successful than training efforts that use only punishment or reward singly (Frank et al. 2004, McGreevy and Boakes 2008). There is little in the scientific literature regarding the simultaneous use of multiple methods of punishment in conjunction with positive reinforcement to change behavior of wild or domesticated animals on landscapes. However, there have been multiple studies examining the effectiveness of individual treatment methods similar to those I used.

Punishment to Decrease Undesired Behaviors.— I used hunting and hazing to dissuade elk from entering problem areas, to selectively remove individuals exhibiting

undesired behaviors, and to encourage elk to seek refuge in desired wintering areas where they were not hunted or disturbed. Hunting is an effective way to reduce/prevent depredation and human-wildlife conflicts (Conover 2001). Hunting can also increase the effectiveness of hazing and harassment to prevent damage as animals learn the threat is real. When hunting is used to reinforce hazing, animals tend not to habituate (Conover 1981). Conversely, animals routinely hazed or harassed eventually learn the threat is benign and these methods quickly lose effectiveness (Espmark and Langvatn 1985, Ujvari et al. 2004, VerCauteren et al. 2005).

In areas where they are not hunted, elk do not show the same response to vehicles and roads. In Rocky Mountain National Park, traffic volume has little effect on elk behavior, and elk do not avoid roads in winter (Schultz and Bailey 1978). Conversely, in Roosevelt National Forest, adjacent to Rocky Mountain National Park, hunted elk avoid roads in winter (Rost 1975). Indeed, the mean distance of radio-collared elk from jeep trails more than doubles from 800 to 2,100 M with the opening of hunting season (Wright 1983). At DLL, elk hunting was conducted in 4 wheel drive trucks. These same trucks were used to haze elk from undesired areas later in the winter when hunters were not available or when the hunting season was over. Elk strongly avoided 4 wheel drive trucks, which made their use to haze elk from undesired areas very effective.

While hunting and hazing influence elk behavior, elk depredation will likely continue if there are no acceptable alternative sources of winter food. Consequently, we emphasized providing acceptable alternative sources of winter forage to reinforce desired forage and habitat selection behaviors in addition to the punishment that provided elk the motivation to change behavior.

Positive Reinforcement to Increase Desired Behaviors.— Past efforts to provide elk with alternative sources of winter forage to prevent depredation and conflicts have been met with mixed results. Increasing forage quality on winter range is possible, as levels of protein and energy increased after habitat improvement efforts on DLL (Aoude 2002). Moreover, elk prefer to forage in wintering areas with less dead or coarse plant material as result of strategic livestock grazing or prescribed burning (Jourdonnais and Bedunah 1990). However, improved range conditions alone may not be enough to alter winter elk distribution and feeding behaviors. Strategic livestock grazing, fertilization, and burning did not increase use of winter range by elk in Washington, perhaps because disturbance on those lands limited elk use, or because elk already had adequate nutrition elsewhere and thus did not seek new food sources (Skovlin et al. 1983). Range improvement projects on DLL increase forage for both wildlife and livestock. In some cases, at middle and lower elevations, habitat projects were done specifically with elk in mind, such as the introduction of forage kochia into old crested wheatgrass seedings.

On DLL, strategic livestock grazing was used to increase the available forage in desired wintering areas through manipulation of the season of use, and by resting some important pastures from livestock grazing each year. Manipulation of the season-of-use for livestock grazing can positively affect the quantity of available forage. On DLL we grazed desired wintering areas in early spring to allow more time for vegetation to recover before winter. In Idaho, late-spring sheep grazing results in fall regrowth that is high in protein and energy (Clark et al. 2000). Fall livestock grazing removes coarse

unpalatable plant material thus creating better access by elk to more desirable regrowth of forages on winter range (Short and Knight 2003).

Elk select rested pastures in rest-rotation grazing systems because they typically have either actively growing forage or dormant forage not used by cattle (Anderson and Scherzinger 1975, Frisina 1992, Yeo et al. 1993, Werner and Urness 1998). In Montana, strategic early season and rest-rest rotation grazing increased carrying capacity for livestock and elk by providing nutritious re-growth. That, in turn, increased landowner tolerance of elk (Frisina and Morin 1991). Both early season livestock grazing and rest-rotation grazing were used on DLL to increase winter forage for elk.

Anderson and Scherzinger (1975) attracted elk to desired wintering areas through strategic livestock grazing, but when the public learned of the wintering elk and began visiting the site to observe wildlife, the elk left. After managers closed the area to motorized access, the elk returned. Wambolt et al. (1997) and Halstead et al. (2002) found that elk subjected to hunting pressure ignored areas managed to provide additional forage, and instead preferred areas with lower quality forage that had more protective topography and cover. Thus, elk must feel secure to use treated/improved winter ranges.

On DLL, safe zones where elk were not hunted corresponded with rangelands that held adequate forage and/or that had been improved via strategic livestock grazing or by other range improvement methods. Again, the combination of multiple methods, based on principles of behavior, undoubtedly contributed to our success.

Providing Hay in Severe Winters

Feeding has successfully prevented elk damage to agricultural crops in many circumstances (Kimball and Wolfe 1985, Smith 2001, Putman and Stains 2004). The feeding operation on DLL we attempted to eliminate was the result of a successful effort to keep elk from raiding stored hay in winter.

Historically, DLL fed elk continuously during winter. We reduced the duration of feeding in an attempt to train elk 1) to use the alternative sources of forage, and 2) to be fed only during extremes of snow depth and temperature. In essence, we were retraining elk to forage for themselves except when conditions were at their worst. Feeding elk continuously all winter without regard to conditions reinforced a pattern of behavior that resulted in elk showing up to be fed, even when there was plenty of forage available on natural winter ranges. If DLL had fed elk intermittently or on a variable schedule it may have been more difficult to retrain elk to new winter foraging behaviors. Continuous winter feeding provided elk a schedule of continuous reinforcement. When continuous reinforcement is eliminated (feeding every day is stopped), behaviors typically extinguish rapidly (expecting to be fed) (Pierce and Cheney 2004). On the other hand, intermittent and variable schedules of reinforcement (fed only on occasion) extinguish very slowly as animals never know for sure when they will be fed (Pierce and Cheney 2004). That's why behaviors such as gambling, fishing, hunting and many others that are reinforced only occasionally are so "addicting".

Use of Supplements

I hoped to supplement elk diets on winter ranges to optimize their ability to utilize available natural forage. By enhancing nutritional status and detoxification processes, nutritional supplements can partially counteract the negative effects of plant secondary compounds, thus allowing animals to ingest more of the vegetation naturally available to them without adverse effects (Provenza et al. 2003). For instance, providing a protein-energy supplemental nearly doubles intake of sagebrush by sheep and goats that have learned of the complementary consequences due to eating the supplement along with the sagebrush (Villalba et al. 2002).

On elk feeding grounds at DLL and Wyoming, elk are fed a complete diet replacement in the form of hay, which concentrates animals as they no longer need to move to seek additional forage. An ideal supplement partially meets nutritional needs and complements other forages available to elk (Provenza et al. 2003).

I attempted to use a dispersed supplement in the form of mineral blocks, and low-moisture molasses-based energy blocks spread across desired wintering areas. I placed supplement blocks on winter feeding ground where elk were fed hay in the winter of 2004-2005. However, elk did not ingest any of the supplement block; rather, they ate only the hay. I hypothesized that the familiarity of the hay as a source of nourishment, along with the novelty of the molasses, both in block form (hardness) and flavor, may have dissuaded elk. As elk use of blocks was so low, they were never reinforced nutritionally for using the blocks nor did they learn that the blocks could potentially complement the other forages growing on those sites (Provenza 1995a).

In the spring and summer of 2005, I added both granular and liquid molasses to granular salt and mineral supplements and placed them on summer range hoping to accustom elk to the flavor of molasses. Elk consumption of these summer supplements was high, and I increased the concentration of molasses throughout the summer.

In the fall of 2005 I once again placed mineral blocks and several formulations of molasses-based low-moisture blocks in desirable wintering areas. I also initially baited these sites with hay to attract elk. Although elk came and consumed the hay, their consumption of low-moisture supplement was negligible and these sites did not hold elk through the winter. I was thus unable to find a nutrition supplement to disperse and hold elk on desired winter ranges, though this is a potentially fruitful area for further research (see Appendix B Elk Use of Molasses Based Low Moisture Supplement Blocks In Northern Utah, for a full account of nutrition supplement experimentation).

Increased training and/or different supplement formulations may boost nutritional availability on winter ranges thereby reducing elk feeding operations and associated disease risks. I observed high elk consumption of granular and liquid molasses in the summer at DLL, and in a winter pen trial with captive elk at Hardware ranch I also observed elk eating granular molasses. Perhaps the texture and physical properties of a low-moisture block, which is very hard, discouraged consumption by elk. However, the high density of low-moisture block is a large part of its value as a supplement. A relatively large amount of supplement can be placed in one trip and will last a long time. From a logistical standpoint, a highly concentrated supplement like low moisture blocks would be ideal.

Reducing Disease Transmission

This project also demonstrated the potential for reducing risk of brucellosis transmission. While brucellosis has not been detected in elk in Utah, it is still desirable to reduce potential for transmission should the disease infect elk. I was not able to completely eliminate feeding in years with severe winter conditions. However, the epidemiology of brucellosis indicates that abortion events typically begin to occur in late Feb. and can continue into early June (Barbknecht et al. 2007). Even in years when elk must be fed, by reducing the length of feeding, especially by ceasing feeding operations earlier in the spring, managers could reduce the likelihood of disease exposure and transmission. I accomplished that objective in this study.

Creating Locally Non-Adapted Animals

One issue, not often considered when we embark on feeding programs, is what happens to populations of large herbivores and the landscapes they inhabit when the animals have been “on welfare” during winter within and across generations. The effects of supplemental feeding on wildlife can include increased survival and reproduction, reduced space-use patterns, and greatly increased densities (Boutin 1990), with the result that over many generations animals may lose behavioral knowledge and physiological adaptations related to how and where to forage during winter (Provenza et al. 2003, 2011). Winter feeding could thus have undesired behavioral, physiological, and even epigenetic impacts on wild ungulate populations and their habitats.

Elk fed often become accustomed and even tolerant of human presence (Kozak et al. 1994). Decreased fear of humans, and increased association of humans with food, can

lead to increased depredation of stored hay when feeding programs are discontinued. Feeding can also facilitate other problems such as wildlife vehicle collisions if elk are attracted to areas with higher human populations and vehicle traffic volumes. Locating feeding grounds in areas convenient to humans can draw animals away from preferred wintering habitats into areas with lower forage quality (Putman and Stains 2004).

Feeding necessitates more feeding and can inhibit in-season physiological adaptations that occur in response to natural winter diets. Some ruminants, including red deer (*Cervus elaphus*), have physiological adaptations to winter including decreased body temperature and decreased heart rate as ways to reduce energy expenditure during winter when food supplies are limited. These adaptations, which reduce caloric intake requirements and make animals more adapted to harsh winter conditions, do not occur to the same degree when animals are fed during winter (Schmidt 2005). Should feeding stop mid-winter, animals being fed can be at greater risk of starving than animals that have been wintering on natural forage.

Typically in temperate climates a severe winter causes some animals to die of starvation, and reduces the body condition of surviving animals thus reducing their capacity to produce/raise viable offspring. In that capacity, winter removes animals physiologically or behaviorally less well adapted to extreme environmental conditions, and over time, favors animals better adapted to survive periods of extreme cold and deep snow. Intensive winter feeding programs reduce natural selection in juvenile red deer (Schmidt and Hoi 2002). Feeding enables animals that would have starved or wintered poorly to survive and reproduce (Kozak et al. 1995, Robbins 1993), giving them a fossil-fuel induced evolutionary or fitness advantage over animals that must winter on

rangelands unassisted by winter-feeding operations. After a severe winter, animals that winter out are often in poorer condition and consequently have lower reproductive capabilities (Peterson and Messmer 2007). Therefore winter-feeding programs may contribute to human-induced selection for animals less well adapted to winter utilization of native rangelands and climates. Over generations, winter-feeding programs could produce welfare animals ill suited to local conditions and climates. These less well adapted animals effectively reduce the carrying capacity of available winter range, and provide an even greater challenge to managers desiring to eliminate winter feeding programs. Ironically, a growing number of ranchers throughout the U.S. realize these costs and are selecting for livestock that live on what nature provides.

Animals fed in winter also may arrive on wintering grounds earlier and stay later than animals not given winter feed. This prolonged and concentrated use can adversely impact vegetation and reduce carrying capacity (Doman and Rasmussen 1944). Severe winters and ensuing die-offs provide time for winter ranges to recover from heavy use by herbivores.

Creating Locally Adapted Animals

Future behaviors of unborn calves and young elk may be influenced by early life exposure to winter feeding. Calves of cows given winter feed may be less prepared to feed on naturally available winter forage. Early exposure to winter feeding behaviors such as pawing through snow to access feed, and exposure to the specific plants and their chemical compositions could be very important in helping break the winter feeding cycle and creating an elk herd capable of finding its own food in winter.

Herbivores acquire preferences for foods as a result of experiences early in life, and these preferences are passed transgenerationally (sheep - Nolte and Provenza. 1992a, b, Squibb et al. 1990; goats - Biquand and Biquand-Guyot 1992; cattle - Wiedmeier et al. 2002). Experiences in utero and early in life cause a suite of neurological (Coppersmith and Leon 1984, LeDoux 2002, Doidge 2007), morphological (Schlichting and Pigliucci 1998), and physiological (Dufty et al. 2002) changes that in turn affect behavior (Provenza and Villalba 2006). Thus, while the body influences the structure and function of experience, it is just as true that experience influences the structure and function of the body.

The fetal taste system is fully functional during the last trimester of gestation, and flavors in mother's diet influence food preference of her offspring (Simitzis et al. 2008), thus preparing the developing fetus for forages it will encounter after birth. In many winters cow elk on DLL and Wyoming feedgrounds are given supplemental feed during part of the last trimester. Flavors of plants such as onion and garlic are transferred in utero and in milk, which increases the likelihood young animals will eat onion and garlic when they begin to forage (Nolte et al. 1992, Nolte and Provenza 1992a,b). Thus elk calves whose mothers were given supplemental winter feed may not have exposure to the tastes of naturally occurring winter forages and may not be as well adapted to eating those foods in the future.

As offspring begin to forage, they further learn what to eat and where to go from mother (Mirza and Provenza 1990, 1992; Thorhallsdottir et al. 1990; Howery et al. 1998). Lambs fed wheat with their mothers for as little as 1 hour/day for 5 days eat more wheat than lambs exposed to wheat without their mothers. Even 3 years later, with no additional

exposure to wheat, intake of wheat is nearly 10 times higher if lambs are exposed to wheat with their mothers than if inexperienced lambs are exposed alone or not exposed at all (Green et al. 1984). Following similar brief exposure, lambs that ate grain had ruminal papillae with 38% more surface area than did lambs that did not eat grain even after lambs and their dams grazed on summer range for 2 months before the lambs were placed in drylot (Ortega Reyes et al. 1992). Elk calves that winter away from feeding grounds with their mothers could be more likely to learn palatable winter plant species and foraging strategies such as pawing through deep snow to find buried food, enabling them to successfully “winter out” as adults.

Experience influences intake of plants high in secondary compounds. Cross-fostering studies show young goats from two different breeds, one that prefers and the other that does not prefer high-tannin browse, eat markedly more high-tannin browse if their foster mother eats high-tannin browse (Tzack et al. 2009). Goats reared from 1 to 4 months of age with their mothers on blackbrush-dominated rangeland ate over 2.5 times more blackbrush than did goats naive to blackbrush, a shrub which is low in quality and high in tannins. Experienced goats consumed 30% more blackbrush than inexperienced goats even when allowed to choose between the poorly nutritious blackbrush and alfalfa pellets (Distel and Provenza 1991). Rumen volume and ability to detoxify tannins were markedly higher for goats reared on blackbrush than for goats reared on a higher-quality diet.

Experience also influences intake of plants high in fiber. Food intake and animal performance also differed substantially during a 3-year study which began when cows 5 years of age were fed straw as a major part of their diet from December to May

(Wiedmeier et al. 2002). Half of the cows ate straw for 2 months as calves, whereas the other half had never seen straw. Throughout the 3-year study, experienced cows ate more straw, lost less weight, maintained better body condition, produced more milk, and bred back sooner than cows not exposed to straw. Experience with high-fiber diets in utero enables cattle to better use high-fiber diets by enhancing intake and digestibility of fiber (Wiedmeier et al. 2011). Preference for poor-quality grass diets and ability to recycle nitrogen are both enhanced by exposure to low-quality grass diets early in life (Distel et al. 1994, 1996).

Finally, experiences of lambs in utero and early in life influence intake of saltbrush plants after birth. Lambs exposed to saltbush *in utero* grow faster and handle a salt load better than lambs from mothers on pasture. Fetal experiences thus enable lambs to excrete salt more rapidly, drink less water, and maintain higher intake when eating saltbush (Chadwick et al. 2009*a, b, c*; Digby et al. 2009). While available winter forages are typically of lower palatability and nutritional content than other times of the year, early life exposure in elk calves could lead to adaptations that make animals better suited to wintering without supplemental feeding.

Collectively, the aforementioned findings highlight the important role of mother as a transgenerational link to the foods and habitats her offspring are likely to eat and inhabit, and they raise questions regarding the kinds and durations of epigenetic changes that may occur due to experiences in utero and early in life that induce changes neurologically, morphologically, physiologically, and behaviorally (Provenza 1995*a, b*). With few exceptions (food intake – Green et al. 1984, Wiedmeier et al. 2002), the aforementioned studies were conservative estimates of the degree to which experience

early in life affects performance of adults as exposure and testing occurred when animals were young and still learning, not as adults years later (Provenza et al. 2003). These processes, which enable animals to adapt to diets and habitats available locally and to changes in those diets and habitats over time, imply that what constitutes a “high quality diet or habitat” will differ for herbivores reared in different environments.

Based on this ungulate research highlighting the importance of early life exposure to foods and foraging behaviors, having cow elk winter on naturally available forages should increase the likelihood that subsequent generations of elk will successfully winter out with increasingly reduced effort on the part of wildlife managers.

MANAGEMENT IMPLICATIONS

The application of behavioral principles has promise as a management tool for solving complex wildlife problems. The consequences of animal behaviors influence the frequency of those behaviors. When managers wish to reduce the occurrence of undesired behaviors and/or increase desired behaviors, the most effective method is to modify the consequences of those behaviors through management. Unfortunately, managers have not been trained to think in terms of behavior principles and their application in management. We simply assume animals behave by “instinct” without appreciating the roles of learning in culture in everything they do. Critically, we must come to realize animals are not machines and genes are not destiny.

While we were not able to completely eliminate winter feeding on DLL, there may still be potential for complete elimination as the collective learning and behaviors of the elk herd progress, especially if we can recreate locally adapted animals. Elk are a relatively long lived wildlife species, and for an entire elk herd to learn new behaviors – to change the culture of the group -- takes time. At the conclusion of this study there were 2 cohorts of elk that had no experience with a feed ground. As 5 years have passed since the inception of this project, there are now 5 cohorts with limited to no experience with a feeding ground. As these management efforts are continued, and the memory of regular winter feeding regardless of winter conditions fades from the collective memory of the population, complete elimination of winter feeding may be feasible. At the very least, elk do not need to be fed as they were historically.

Over time elk accustomed to being fed every winter regardless of conditions will be replaced by young animals that have only been fed intermittently in severe winters or not at all. The elk population will have more knowledge of winter foraging areas and behaviors that enabled them to survive without supplemental feeding. As DLL transitions from continuous feeding (continuous reinforcement) to occasional winter feeding (intermittent reinforcement) there are potential complications. As mentioned previously, it is easier to eliminate an undesired behavior if that behavior is based on continuous reinforcement vs. intermittent reinforcement (Pierce and Cheney 2004). Therefore, it is important elk learn that feed will be delivered only when conditions are severe, and not just when they “show up” at the historic feeding grounds. Importantly, managers must take care to train the elk, not vice-versa.

In the context of historic elk feeding data kept by DLL, the 2 years of this project when elk were not fed were the first times since the inception of the feeding program in 1983 that DLL did not feed. For the ranch, this represented a significant cost savings. On average DLL spent approximately \$70,000 annually on hay for elk feeding. Since the inception of this project 5 years ago, DLL has avoided feeding entirely during 3 winters, and fed only half the usual amount one winter, for a total cost savings of approximately \$245,000. Some additional labor is required each year by DLL to continue to herd/haze elk, but the daily winter feeding labor has been eliminated, resulting in a net savings in labor costs as well.

The methodology we used for changing winter elk feeding behavior in relation to a winter feeding program showed that understanding and using behavior principles was effective. The results saved DLL a considerable sum of money, and reduced disease risks

associated with winter feeding programs while allowing DLL to maintain elk numbers and keep depredation at a minimum. The application of behavioral principles, specifically in the forms of rewarding elk with security and nutrition and punishing elk with hunting pressure and hazing/harassment, was successful on DLL.

Based on my results, I anticipate the application of these principles in other settings and situations would yield similar results. This research can serve as an impetus for discussing the application of behavioral principles for managers desiring to reduce or eliminate winter feeding programs, or modify other wildlife behaviors. However, the successful application of these principles in other similar situations will likely require adaptation and modifications of procedures unique to each situation.

Large-scale range improvement projects are typically expensive and can be time consuming due to National Environmental Policy Act (NEPA) regulations on federal lands or when federal monies are involved. Range improvements often require time to increase vegetation. However, multi-year savings in feed costs may cover the costs of treatments and incidental depredation. In addition to the challenges posed by range improvement work, modifying livestock grazing strategies can be challenging. Often public lands grazing permit holders have no incentive to change their grazing practices to benefit elk, which are often viewed as competitors for forage. Where policies such as NEPA are applicable, it can be difficult to make any changes to existing grazing regimes. Cooperation with federal land management agencies, state wildlife agencies and grazing permit holders may be fostered through communication and education. Many state wildlife agencies have programs with financial incentives for landowners that provide habitat to wildlife and/or access to hunters (Messmer et al. 1998, Torstenson et al. 2002).

These and other incentives should be used for grazing permit holders willing to modify livestock grazing programs to benefit livestock and wildlife.

The use of strategic hunting pressure to influence elk distribution will also require cooperation between sportsmen and state wildlife agencies. It may take “outside the box” thinking for state wildlife agencies to find ways to use hunters to strategically apply hunting pressure on elk while still achieving a level of harvest necessary to manage population levels. That requires a higher level of communication, diligence and cooperation between state wildlife agencies and hunters to adapt to changing season dates and hunt boundaries as locations and conditions warrant different hunting strategies.

Based on the findings of this project, a successful effort to reduce or eliminate a winter elk feeding operation should: 1) ensure adequate naturally available winter forage for elk, which may include improvements to existing rangelands and changes to current livestock grazing strategies; 2) take potential human-wildlife conflicts into consideration to minimize the risk of wildlife vehicle collisions and/or depredation; 3) use strategic hunting pressure in combination with herding and hazing to influence movements into desired wintering areas; and 4) involve people willing to change and make changes.

Finally, all parties must be willing to work together to continually adapt to ever-changing conditions. That means not only planning and implementing ideas, but also monitoring and learning based on feedback. In the case with DLL, we continually modified our behavior over the past 5 years as conditions dictated. When elk raided neighboring haystacks we fenced those haystacks. After the first year of the project we lengthened our hunting season to give us the ability to use that tool for influencing elk distribution later into the winter. When we anticipated difficulty achieving the necessary

cow elk harvest, we adjusted the boundaries and designations of our safe and shoot zones in a way that allowed for more flexibility for hunters and that still provided refuge for elk in desired wintering areas. When cattle managers expressed concern at leaving standing forage in some of the safe area pastures, we adjusted season of use so that cattle could still benefit for those pastures and allow ample time for regrowth so there would be late-season feed for elk. We were able to find ways to balance the use of the resource between multiple users and interests. We focused on applying the best information we had along with continual monitoring of the situation to make necessary adjustments that increased the likelihood of success. This approach required diligent monitoring, communication, cooperation, and the ability to quickly adapt to changing conditions. This type of management experiment gives managers a valuable example for addressing and solving complex challenges by modifying our behavior and that of the animals in our care. It allows for research and learning while at the same time providing a framework where solutions to real-world problems are the priority.

LITERATURE CITED

- Aoude, A. 2002. The effects of four rangeland manipulations on plant and animal richness and abundance. Thesis, Utah State University, Logan, USA.
- Anderson, E. W., and R. J. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. *Journal of Range Management* 28(2):120-125.
- Barbknecht, A., J. Rogerson, E. Maichak, L. Linn, W. S. Fairbanks, B. Scurlock, K. Belinda, H. Edwards, T. Cornish. 2007. Ecology of Elk Abortion and Parturition in the Brucellosis Endemic Area of Wyoming. State of Wyoming, Cheyenne, USA.
- Biquand, S., and V. Biquand-Guyot. 1992. The influence of peers, lineage and environment on feed selection on the criollo goat. *Applied Animals Behavioral Science* 43:231-245.
- Boutin, S. 1990. Food supplementation experiments with terrestrial vertebrates: patterns, problems, and the future. *Canadian Journal of Zoology* 68:203-220.
- Chadwick M.A., P. V. Vercoe, I. H. Williams, and D. K. Revell. 2009a. Programming sheep production on saltbrush: adaptations of offspring from ewes that consumed high amounts of salt during pregnancy and early lactation. *Animal Production Science* 49:311-317.
- Chadwick M.A., P. V. Vercoe, I. H. Williams, and D. K. Revell. 2009b. Dietary exposure of pregnant ewes to salt dictates how their offspring respond to salt. *Physiology and Behavior* 97:437-445.

- Chadwick M.A., P. V. Vercoe, I. H. Williams, and D. K. Revell. 2009c. Feeding pregnant ewes a high-salt diet or saltbrush suppresses their offspring's postnatal rennin activity. *Animal* 3:972-979.
- Clark, P. E., W. C. Krueger, L. D. Bryant, and D. R. Thomas. 2000. Livestock grazing effects on forage quality of elk winter range. *Journal of Range Management* 53:97-105.
- Conner, M. M. 2002. Movements of mule deer and elk in response to human disturbance: a literature review. Colorado Division of Wildlife, Mammals Research. Fort Collins, USA.
- Conover, M. R. 1981. Evaluation of behavioral techniques to reduce wildlife damage. Pages 332-344 *in* Proceedings of the wildlife-livestock relationships symposium. L. Nelson, Jr. and J. M. Peek, editors. University of Idaho, Moscow, USA.
- Conover, M. R. 1997. Monetary and tangible valuation of deer in the United States. *Wildlife Society Bulletin* 25:407-414.
- Conover, M. R. 2001. Effect of hunting and trapping on wildlife damage. *Wildlife Society Bulletin* 29:521-532.
- Coppersmith, R., and M. Leon. 1984. Enhanced neural response to familiar olfactory cues. *Science* 225:849-851.
- Cote, S. 2004. Stockmanship: a powerful tool for grazing land management. USDA-NRCS. Boise, Idaho and Butte Soil and Water Conservation District. Arco, Idaho, USA.
- Craighead, F. C. Jr. 1979. Track of the grizzly. Sierra Club Books, San Francisco, California, USA.

- Cross, P. C., W. H. Edward, B. M. Scurlock, E. J. Maichak, and J. D. Rogerson. 2007. Effects of management and climate on elk brucellosis in the Greater Yellowstone Ecosystem. *Ecological Applications* 17:957-964.
- Dean, R. S., M. Gocke, B. Holz, S. Kilpatrick, T. Kreeger, B. Scurlock, S. Smith, E. T. Thorne, and S. Werbelow. 2004a. Elk feedgrounds in Wyoming. *Wyoming Game and Fish*, Cheyenne, USA.
- Dean, R. S., S. Werbelow, and B. Holz. 2004b. A note about the effects of introduced wolves on the operations of elk feedgrounds in Western Wyoming. *Western States and Provinces Deer and Elk Workshop* 5:23-29.
- Digby, S. N., D. G. Masters, D. Blache, P. I. Hynd, and D. K. Revell. 2009. Offspring born to ewes fed high salt during pregnancy have altered responses to oral salt loads. *Animal* 4:81-88.
- Distel R. A., and F. D. Provenza. 1991. Experience early in life affects voluntary intake of blackbrush by goats. *Journal of Chemical Ecology* 17:431-450.
- Distel, R. A., J. J. Villalba, and H. E. Laborde. 1994. Effects of early experience on voluntary intake of low-quality roughage by sheep. *Journal of Animals Science* 72:1191-1195.
- Distel, R. A., J. J. Villalba, H. E. Laborde, and M. A. Burgos. 1996. Persistence of the effects of early experience on consumption of low-quality roughage by sheep. *Journal of Animal Science* 74:964-968.
- Doidge, N. 2007. *The brain that changes itself: stories of personal triumph from the frontiers of brain science*. Viking Press, New York, USA.

- Doman, E. R., and D. I. Rasmussen. 1944. Supplemental feeding of mule deer in northern Utah. *Journal of Wildlife Management* 8:317–338.
- Dufty, A. M. Jr., J. Clobert, and A. P. Moller. 2002. Hormones, developmental plasticity and applications. *Trends in Ecology and Evolution* 17:190-196.
- Dunckley, L., and M. R. L. Cattet. 2003. A comprehensive review of the ecological and human social effects of artificial feeding and baiting of wildlife. Canadian Cooperative Wildlife Health Centre. Saskatoon, Saskatchewan, Canada.
- Espmark, Y., and R. Langvatn. 1985. Development and habituation of cardiac and behavioral responses in young red deer calves (*Cervus elaphus*) exposed to alarm stimuli. *Journal of Mammalogy* 66:702-711.
- Etter, R., and M. L. Drew. 2006. Brucellosis in elk of eastern Idaho. *Journal of Wildlife Diseases* 42:271–278.
- Ferrari, M. J., and R. A. Garrott. 2002. Bison and elk: brucellosis seroprevalence on a shared winter range. *Journal of Wildlife Management* 66:1246-1254.
- Frank, M. J., L. C. Seeberger, and R. C. O'Reilly. 2004. By carrot or by stick: cognitive reinforcement learning in parkinsonism. *Science* 306:1940-1943
- Frisina, M. R. 1992. Elk habitat use with a rest-rotation grazing system. *Rangelands* 14:93-96.
- Frisina, M. R., and F. G. Morin. 1991. Grazing private and public land to improve the Fleece elk winter range. *Rangelands* 13:291-294.
- Galey, F. 2005. Wyoming Brucellosis Coordination Team report and recommendations, Jan. 11, 2005. State of Wyoming, Cheyenne, USA.

- Green, G. C. R. L. Elwin, B. E. Mottershead, and J. J. Lynch. 1984. Long-term effects of early experience to supplementary feeding in sheep. *Proceedings of the Australian Society of Animal Production* 15:373-375.
- Godfroid, J. 2002. Brucellosis in wildlife. *Revue Scientifique et Technique Office International des Epizooties* 21:277-286.
- Halstead, L. E., L. D. Howery, G. B. Ruyle, P. R. Krausman, and R. J. Steidl. 2002. Elk and cattle use under a specialized grazing system. *Journal of Range Management* 55:360-366.
- Hansen, R. M., and L. D. Reid. 1975. Diet overlap of deer, elk, and cattle in southern Colorado. *Journal of Range Management* 28:43-47.
- Howery, L. D., F. D. Provenza, R. E. Banner, and C. B. Scott. 1998. Social and environmental factors influence cattle distribution on rangelands. *Applied Animal Behavior Science* 55:231-244.
- Jourdonnais, C. S., and D. J. Bedunah. 1990. Prescribed fire and cattle grazing on an elk winter range in Montana. *Wildlife Society Bulletin* 18:232-240.
- Kasworm, W. F., L. R. Irby, and H. B. Ihsle Pac. 1984. Diets of ungulates using winter ranges in north central Montana. *Journal of Range Management* 37:67-71.
- Kimball, J. F., and Wolfe, M. L. 1985. Elk management opportunities in northern Utah: to feed or not to feed. Pages 191-197 in G. W. Workman, editor. *Western elk management: a symposium*. Utah State University, Logan, USA.
- Kinuthia, R. N., J. Powell, F. C. Hinds, and R. A. Olson. 1992. Range animal diet composition in southcentral Wyoming. *Journal of Range Management* 45:543-545.

- Kirchoff, M. D., and D. N. Larsen. 1998. Dietary overlap between native sitka black-tailed deer and introduced elk in southeast Alaska. *Journal of Wildlife Management* 62:236-242.
- Kozak, H. M., R. J. Hudson, N. French, and L. A. Reneker. 1995. Winter feeding lactation and calf growth in farmed wapiti. *Rangelands* 17:116-120
- Kozak, H. M., R. J. Hudson, and L. A. Reneker. 1994. Supplemental winter feeding. *Rangelands* 16:153-156.
- Kunstler J.H. 2005. *The long emergency: surviving the end of oil, climate change, and other converging catastrophes of the twenty-first century.* Grove Press, New York, USA.
- LeDoux, J. 2002. *Synaptic self: how our brains become who we are.* Viking Penguin, New York, USA.
- Lewontin, R. 2000. *The triple helix: gene, organism, and environment.* Harvard University Press, Cambridge, Massachusetts, USA.
- Lancia, R. A., C. E. Braun, M. W. Collopy, R. D. Deuser, J. G. Kie, C. J. Martinka, J. D. Nichols, T. D. Nudds, W. R. Porath, and N. G. Tilghman. 1996. ARM! For the future: adaptive resource management in the wildlife profession. *Wildlife Society Bulletin* 24:436-442.
- McGreevy, P., and R. Boakes. 2008. *Carrots and sticks: principles of animals training.* Cambridge University Press, New York, USA.
- McNaughton, S. J. 1976. Serengeti migratory wildebeast: facilitation of energy flow by grazing. *Science* 191:92-94.

- Meagher, M., and M. E. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. *Conservation Biology* 8:645-653.
- Mech, L. D., D. W. Smith, K. M. Murphy, and D. R. McNulty. 2001. Winter severity and wolf predation on a formerly wolf-free elk herd. *Journal of Wildlife Management* 65:998-1003.
- Messmer, T. A., C. E. Dixon, W. Shields, S. C. Barras, and S. A. Schroeder. 1998. Cooperative wildlife management units: achieving hunter, landowner, and wildlife management agency objectives. *Wildlife Society Bulletin* 26:325-332.
- Miller, M. W., E. S. Williams, N. T. Hobbs, and L. L. Wolfe. 2004. Environmental sources of prion transmission in mule deer. *Emerging Infectious Diseases* 10:1003-1006.
- Mirza, S. N., and F. D. Provenza. 1990. Preference of the mother affects selection and avoidance of foods by lambs differing in age. *Applied Animal Behaviour Science* 28:255-263
- Mirza, S. N., and F. D. Provenza. 1992. Effects of age and conditions of exposure on maternally mediated food selection in lambs. *Applied Animal Behaviour Science* 33:35-42.
- Nolte, D. L., F. D. Provenza, R. Callan, and K. E. Panter. 1992. Garlic in the ovine fetal environment. *Physiology & Behavior* 52:1091-1093.
- Nolte, D. L., and F. D. Provenza. 1992a. Food preferences in lambs after exposure to flavors in milk. *Applied Animal Behaviour Science* 32:381-389.
- Nolte, D. L., and F. D. Provenza. 1992b. Food preferences in lambs after exposure to flavors in solid foods. *Applied Animal Behaviour Science* 32:337-347.

- Ortega Reyes, L., F. D. Provenza, C. F. Parker, and P. G. Hatfield. 1992. Drylot performance and ruminal papillae development of lambs exposed to a high concentrate diet while nursing. *Small Ruminant Research* 7:101-112.
- Peterson, C. and T. A. Messmer. 2007. Effects of winter feeding on mule deer in northern Utah. *Journal of Wildlife Management* 71:1440-1445.
- Pierce, W. D., and C. D. Cheney. 2004. *Behavior analysis and learning*. Third edition. Lawrence Erlbaum Associates, Mahwah, New Jersey, USA.
- Provenza, F. D. 1995a. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management* 48:2-17.
- Provenza, F. D. 1995b. Tracking variable environments: There is more than one kind of memory. *Journal of Chemical Ecology* 21:911-923.
- Provenza, F. D., and J. J. Villalba. 2006. Foraging in domestic vertebrates: linking the internal and external milieu. Pages 210-240 *in* B. L. Vels, editor. *Feeding the domestic vertebrates: from structure to function*. CABI Publishing, Oxfordshire, United Kingdom.
- Provenza, F. D., J. J. Villalba, L. E. Dizba, S. B. Atwood, and R. E. Banner. 2003. Linking herbivore experience, varied diets, and plant biochemical diversity. *Small Ruminant Research* 49:257-274.
- Provenza, F. D., J. J. Villalba, S.Y. Landau, M. A. Huffman, and C. D. Cheney. 2011. The wisdom body: nutrition, health, and nature's pharmacopeia. *Evolutionary Biology* in press.

- Putman, R. J., and B. W. Staines. 2004. Supplementary winter feeding of wild red deer *Cervus elaphus* in Europe and North America: justifications, feeding practice and effectiveness. *Mammal Review* 34(4):285-306.
- Robbins, C. T. 1993. *Wildlife feeding and nutrition*. Second edition. Academic Press, San Diego, California, USA.
- Rost, G.R. 1975. Response of deer and elk to roads. Thesis, Colorado State University, Fort Collins, USA.
- Savory, A. 1988. *Holistic resource management*. Island Press, Washington D.C., USA.
- Schlichting, C. D., and M. Pigliucci. 1998. Phenotypic evolution: a reaction norm perspective. Sinauer Associates, Sunderland, Massachusetts, USA.
- Schmidt, K. T. and H. Hoi. 2002. Supplemental feeding reduces natural selection in juvenile red deer. *Ecography* 25:265-272.
- Schmidt, K. T. 2005. Land of plenty. *Natural History* 114: 44-49.
- Schultz, R.D., Bailey, J.A., 1978. Responses of national park elk to human activity. *Journal of Wildlife Management* 42:91–100.
- Short, J. L., and J. E. Knight. 2003. Fall grazing affects big game forage on rough fescue grasslands. *Journal of Range Management* 56:213-217.
- Simitzis, P.E., S. G. Deligeorgis, J. A. Bizelis, and K. Fegeros. 2008. Feeding preferences in lamb influenced by prenatal flavour exposure. *Physiology and Behavior* 93:529–536.
- Skinner, B.F. 1981. Selection by consequences. *Science* 213:501-504.

- Skovlin, J. M., P. J. Edgerton, and B. R. McConnell. 1983. Elk use of winter range as affected by cattle grazing, fertilizing, and burning in Southeastern Washington. *Journal of Range Management* 36:184-189.
- Smith, B.L. 2001. Winter feeding of elk in North America. *Journal of Wildlife Management* 65:173-190.
- Smith, E. P. 2002. BACI designs. Pages 141-148 *in* A. H. El-Shaarawi and W. W. Piegorsch, editors. *Encyclopedia of environmetrics Vol. 1*. John Wiley & Sons, Chichester, United Kingdom.
- Squibb, R. C., F. D. Provenza, and D. F. Balph. 1990. Effect of age of exposure on consumption of a shrub by sheep. *Journal of Animal Science* 68:987-997.
- Stewart-Oaten, A., W. M. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? *Ecology* 67:929-940
- Summers, D. D. 2005. Vegetation Response of a Wyoming Big Sagebrush (*ArtemesiaTridentata* ssp. *Wyomingensis*) Community to Six Mechanical Treatments in Rich County, Utah. Thesis, Brigham Young University, Provo, Utah, USA.
- Thorhallsdottir, A. G., F. D. Provenza, and D. F. Balph. 1990. Ability of lambs to learn about novel foods while observing or participating with social models. *Applied Animal Behavior Science* 25:25-33.
- Thorne, E. T. 2001. Brucellosis. Pages 372–395 *in* E. S. Williams and I. K. Barker, editors. *Infectious diseases of wild mammals*. Iowa State Press, Ames, USA.

- Thorne, E. T., M. S. Boyce, P. Nicoletti, and T. J. Kreeger, editors. 1997. Brucellosis, bison, elk and cattle in the greater Yellowstone area: defining the problem, exploring solutions. Wyoming Game and Fish Department, Cheyenne, USA.
- Torstenson, W. L. F., M. W. Tess, and J. E. Knight. 2002. Elk management strategies and profitability of beef cattle ranches. *Journal of Range Management* 55:117-126.
- Tzack, A. G., E. D. Ungar, S. Y. Landau, A. Perevolotsky, H. Muklada, and J. W. Walker. 2009. Breed and maternal effects on the intake of tannin-rich browse by juvenile goats (*Capra hircus*). *Applied Animal Behavior Science* 119:71-77.
- Ujvari, M., H. J. Baagoe, and A. B. Madsen. 2004. Effectiveness of acoustic road markings in reducing deer-vehicle collisions: a behavioural study. *Wildlife Biology* 10:159-164.
- Underwood, A. J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological Applications* 4:3-15.
- VerCauteren, K. C., J. A. Shivik, and M. J. Lavelle. 2005. Efficacy of animal-activated frightening device on urban elk and mule deer. *Wildlife Society Bulletin* 33:1282-1287.
- Vieira, M. E., M. M. Conner, G. C. White, and D. J. Freddy. 2003. Effects of archery hunter numbers and opening dates on elk movement. *Journal of Wildlife Management* 67:717-728.

- Villalba, J.J., F.D. Provenza, and R.E. Banner. 2002. Influence of macronutrients and activated charcoal on utilization of sagebrush by sheep and goats. *Journal of Animal Science* 80:2099-2109.
- Wambolt, C. L. 1996. Mule deer and elk foraging preferences for 4 sage-brush taxa. *Journal of Range Management* 49:499-503.
- Wambolt, C. L., M. R. Frisina, K. S. Douglas, and H. W. Sherwood. 1997. Grazing effects on nutritional quality of bluebunch wheatgrass for elk. *Journal of Range Management* 50:503-506.
- Werner, S. J., and P. J. Urness. 1998. Elk forage utilization with rested units of rotation grazing systems. *Journal of Range Management* 51:14-18.
- Wertz, T. A., L. E. Erickson, and A. Blumton. 2001. Conflict resolution by adaptive management: moving elk where they want to go. *Western States and Provinces Deer and Elk Workshop* 4:59-66.
- Wiedmeier, R.D., F.D. Provenza, and E.A. Burritt. 2002. Exposure to ammoniated wheat straw as suckling calves improves performance of mature beef cows wintered on ammoniated wheat straw. *Journal of Animal Science* 80:2340-2348.
- Wiedmeier, R.D., J.J. Villalba, A. Summers, A. Hansen, and F. D. Provenza. 2011. Eating a high-fiber diet during pregnancy increases intake and digestibility of a high-fiber diet by offspring. *Journal of Animal Science* in press.
- Williams, E. S., M. W. Miller, T. J. Kreeger, R. H. Kahn, and E. T. Thorne. 2002. Chronic wasting disease of deer and elk: a review with recommendations for management. *Journal of Wildlife Management* 66:551-563.

Wright, K. L. 1983. Elk movements, habitat use, and the effects of hunting activity on elk behavior near Gunnison, Colorado. Thesis, Colorado State University, Fort Collins, USA.

Yeo, J. J., J. M Peek, W. T. Wittinger, and C. T. Kvale. 1993. Influence of rest-rotation cattle grazing on mule deer and elk habitat use in east-central Idaho. *Journal of Range Management* 46:245-250.

APPENDICES

APPENDIX A. Narrative of Elk Response

Winter of 2004/2005

The winter of 2004/2005 started mildly with warm temperatures and low snow depths. Previously scheduled cow elk hunts were concluded by Dec. 15th, and elk were distributed across the east side of Deseret Land and Livestock (DLL). On December 26-30, 2004 in conjunction with a large snowstorm, approximately 800 elk were observed in the vicinity of the historic feeding grounds, and another 200 elk were counted in the Northeast corner of the ranch near the highway and neighboring landowners' haystacks. Historically DLL had begun feeding elk in mid-December, but no feed was given at this time. On January 10, 2005 another large snowstorm hit the area and we decided that the risk of elk leaving the ranch and being hit on the highway and raiding neighboring haystacks was too great, and DLL began feeding.

The 200 elk from the Northeast corner were herded back to the traditional feeding grounds where feeding had begun, with the hope that the winter feed being given in that area would keep them there. Approximately 125 of the herded elk returned to the northeast corner the next day. DLL personnel again herded those animals back to the feeding grounds. Approximately 20 cows and calves would not leave northeast corner despite herding and hazing efforts on snowmobiles. Those 20 animals spent the winter in the Northeast Corner of the ranch and raided several neighboring haystacks throughout the winter. If the hunting season had not been over, they would have made excellent candidates for harvest.

The remainder of the elk, approximately 1,200, spent the winter on the feeding grounds receiving hay from DLL. I counted a peak number of 1,261 elk on the feeding

grounds on Feb. 4, 2005. Elk were given feed 7 days a week for approximately 65 days until mid-March when the snow had sufficiently melted and elk began to disperse.

While elk were congregated on the feeding grounds I placed 5, 25 pound molasses based 25% protein blocks in the area. Elk did not consume the protein blocks.

Adjustments based on 2004/2005 Results

While we were not successful at completely eliminating winter elk feeding on DLL the first winter, we made progress. DLL did not feed elk until the 10th of January approximately 3 weeks later than the average feeding start date. In addition, we learned other valuable lessons, and we adjusted our approach accordingly. Based on the results of winter 2004/2005 we extended the dates for cow elk hunters until the end of January. We worked with the neighboring landowner, DLL, the UDWR, and sportsmen's groups to have elk-proof fencing installed around raided haystacks in the summer of 2005 to give a larger buffer for elk that might leave the ranch during the winter months searching for food. We also instigated a summer supplement familiarization and training program to get elk accustomed to eating molasses based supplement blocks (see appendix B Elk Use of Molasses Based Low Moisture Supplement Blocks In Northern Utah).

Winter of 2005/2006

The winter of 2005/2006 started off similar to the previous winter, warm temperatures with little snow. The study area did not receive any significant or lasting snow, snow depths for the winter were below average, and elk stayed dispersed across rangelands on the east side of the ranch. As the winter progressed, groups of elk

occasionally traveled to the traditional feeding grounds, but they were met by cow elk hunters and soon left the area. Cow elk hunters were scheduled until the end of January, and a larger proportion of the harvest took place later in the hunting season in December and January. DLL did not feed any elk during the winter of 2005/2006. Since the inception of the feeding program in 1983 DLL had fed elk every winter until the winter of 2005/2006.

I placed several types of nutrition supplement in the safe zone, these included 3 formulations of low-moisture, molasses-based block, 2 different mineral block formulations, and granular mineral and salt mixes. I monitored these supplements on a regular basis throughout the winter. Despite our summer familiarization efforts in which elk had consumed multiple types of molasses based supplements, during winter we detected little to no use of the dispersed supplements. I also tested low-moisture molasses-based protein blocks in a pen study with captive elk at Hardware ranch and observed no consumption of the blocks. After the winter of 2006/2007 I suspended the nutrition supplement portion of the study based on repeated observations and trials indicating that the tested forms of dispersed nutrition supplements were not used by elk (See appendix B Elk Use of Molasses Based Low Moisture Supplement Blocks In Northern Utah).

Winter of 2006/2007

In one final attempt to use dispersed supplement to influence winter elk distribution I placed 10, 1-ton bales of hay in the safe zone on November 16, 2006. I was hoping to intercept elk moving towards the feeding grounds and attract and hold elk in

the safe area. There was little elk use of the hay in that area, and during observation flights I counted less than 5 bull elk using the hay. Placing dispersed hay did not appear to be effective in stopping migrating elk, or luring wintering elk into a specific area. Perhaps significant numbers of migrating elk had not encountered the hay. Or perhaps elk were not familiar with this new winter supplement strategy and chose instead to continue on to the traditional feeding grounds.

Based on elk population estimates and herd unit population objectives, DLL increased cow elk permits from approximately 250 per year to roughly 350 in 2006/2007. This presented both an additional challenge to achieve sufficient harvest, and an additional tool of extended hunting pressure to influence elk distribution. Again, DLL scheduled cow elk hunters through the end of January, which allowed us to continue to put significant hunting pressure on cow elk for an extended period of time. As the season progressed, hunters applied constant pressure on groups of elk that arrived at the traditional feeding grounds. While snow depth did not appear to be an issue affecting forage availability, cold temperatures seemed to play a role in elk behavior. In mid-January 2007 the daily low temperatures dropped below -10 F for several days. Elk started forming larger groups of several hundred animals and moving to the northeastern portions of the ranch. Elk were herded back to the southwest on several occasions using trucks. Despite the herding efforts, large groups of elk continued moving to the northeast. These movements caused sufficient concern that DLL provided some supplement. On three occasions elk were herded from the northeast corner of the ranch approximately 7 miles to the southwest where they were supplemented with hay. On Jan. 20, 2006 DLL put out 10, 1-ton bales of hay, on Jan. 24, 2006 DLL gave an additional 2,

1-ton bales, and on Jan. 26, 2006 elk were again moved and given 6 more 1-ton bales.

These supplements were meant to hold elk in desired wintering areas so they would not return to the problem areas. Elk movements to the northeast stopped, temperatures warmed slightly, and the elk broke back into smaller groups that were more evenly dispersed across the east side of the ranch.

Winter of 2007/2008

This was the 4th winter since the inception of the project. During this winter DLL experienced an extreme conditions with deep snow and colder than normal temperatures. Under the old management strategy this would have been considered a severe winter and led to intensive and expensive feeding efforts. Instead, freshly armed with new tools and several years of successfully reducing winter feeding, DLL fed for only 65 days rather than 90-100 days, and fed only 4 times per week rather than 7. The feed bill was \$35,000 rather than \$70,000 as it likely would have been under traditional feeding practices. The ranch still fed a peak count of 1200 elk, but overall fed 40-60% less than in years past under the old management strategy. DLL accomplished this without any increase in depredation or human-wildlife conflicts.

Winters of 2008/2009 and 2009/2010

These were the 5th and 6th winters since the inceptions of this project. Both these winters were relatively warm with lower than average snow depths. No elk were fed during the winter of 2008/2009 or the winter of 2009/2010 (see table 3 on page 42 for a complete summary of elk feeding during and post-project).

Appendix B. Elk Use of Molasses-Based Low-Moisture
Supplement Blocks in Northern Utah

INTRODUCTION

Wildlife managers in Western North America have been feeding elk in the winter for nearly 100 years. Giving supplemental winter feed to elk can compensate for a shortage of natural winter range and may boost elk populations while also helping to prevent commingling with livestock and depredation of winter feed intended for livestock. In contrast to these benefits, elk herds that winter on feeding grounds have a significantly higher prevalence of brucellosis than elk that winter “out” (Dean 2004). There is also significant concern regarding the transmission of brucellosis from elk to cattle (Meagher and Meyer 1994, Ferrari and Garrot 2002). Research suggests that current winter-feeding practices may also facilitate the spread of Chronic Wasting Disease (CWD) (Williams et al. 2002, Miller et. al 2004, Galey 2005). Many see the discontinuation of winter-feeding programs as a necessary step to decrease the risk of disease outbreaks.

Disease transmission from wildlife to livestock, elk/livestock winter range conflicts, and elk population dynamics are all politically sensitive and socially charged issues. These are important topics for Various State Departments of Agriculture, the National Cattlemen’s Association, Farm Bureau, State Fish and Wildlife Agencies, numerous sportsmen and environmental groups and affected State legislatures. It is important that wildlife managers appropriately and proactively understand and deal with these potentially volatile situations. In light of these concerns, it is prudent that wildlife and livestock managers gain the knowledge and management experience necessary to

significantly reduce or end the need to feed elk during winter. It is, however, equally important to maintain productive ranges, big game herds, and livestock operations.

There is an ongoing research project in Northern Utah to investigate various methods to change elk behavior with the goal of reducing or eliminating reliance on supplemental winter feeding while minimizing depredation and human-wildlife conflicts. This project involves testing a combination of tools and techniques to train elk to use new foods and habitats during winter. These tools include range improvements, strategic grazing by cattle to enhance habitat for elk, dispersed supplementation, hunting, and herding. Through this work, wildlife managers may gain a more thorough understanding of winter-feeding behavior in large ungulates, which will assist wildlife managers in developing winter-feeding practices and policies for elk in the West. This report addresses the use of dispersed supplement blocks to influence winter elk distribution.

If used by elk, dispersed supplementation can move and settle elk in desired areas during winter. In this experiment dispersed supplemental feeds in the form of alfalfa hay, mineral, salt, molasses, and molasses-based low-moisture blocks (lmb) were used to lure elk to desired areas, to intercept moving/migrating elk, and to hold elk in desired areas. This feed was intended to supplement the natural diet of the elk, rather than serve as a replacement.

Some nutritional supplements can counteract toxins present in available winter forage and allow animals to ingest more of the vegetation naturally available to them without adverse effects (Provenza et al. 2003). Ultimately, this research is aimed at finding a dispersed winter supplement that is logistically feasible and that will maximize the use of available winter range for elk.

The lmb appears to have many of the qualities that would make a good dispersed winter supplement. Lmb contains high levels of protein and energy along with essential trace minerals. But, most importantly lmb is a low maintenance feed that can be placed and left unattended for extended periods of time. However, there has been some debate regarding the palatability of lmb, or any molasses based supplement, to elk.

OBJECTIVES

The purpose of this study is to evaluate the potential of lmb as a dispersed winter supplement for elk. The experiment was initiated to help answer the following questions: Will elk eat molasses? Will they eat molasses based lmb? Can lmb influence elk distribution in winter?

STUDY AREA

The testing took place at two separate sites in Northern Utah during the summer of 2005, and winter of 2005-2006. Consumption of lmb and other supplements by free ranging elk on Deseret Land and Livestock Ranch (DLL) in Rich County Utah was monitored. Pen trials were also conducted using captured elk at Hardware Ranch Wildlife Management Area (HR) in Cache County Utah.

DLL is located in Northeastern Utah. The ranch straddles the boundaries of Rich, Weber, and Morgan counties in Utah, and a small portion of the Ranch is located in Uintah county Wyoming. DLL is comprised of approximately 82,963 ha of private land, and contains 6,070 ha of Bureau of Land Management (BLM) land within its boundaries. Elevations range from 1,920 m on the northeastern portion of the ranch to 2,650 m in the

more rugged western mountainous regions. The estimated elk population on DLL is 2,500 animals.

Hardware Ranch Wildlife Management Area is comprised of 7,690 ha located at the top of Blacksmith Fork Canyon in Cache County Utah. This state run winter-feeding area winters approximately 600 elk annually from the nearby Cache and Ogden units. Elk were trapped and held in February 2006 to facilitate brucellosis testing mandated by the State of Utah Department of Agriculture.

MATERIALS AND METHODS

DLL Summer Range

Three supplement sites were selected on elk summer range at DLL: The Wall, Blue Ridge, and Monument Ridge. These sites historically hold high elk densities in the summer. The Wall and Blue Ridge were also historic sheep salting sites, and elk eat the salt-rich dirt in these areas. All sites were selected based on the potential to expose large numbers of elk to the selected supplements.

In mid June 2005 I placed at each site two 56.8 kg tubs of Crystal-Phos lmb supplement, two 56.8 kg tubs of Stablelyx lmb supplement, one tub containing 11.4 kg granular salt, one tub containing 11.4 kg granular mineral mixed, and one molasses based 20% protein block. Elk used significant salt and mineral mixes during June. There was no significant consumption of the lmb or protein block. On July 1st the salt and mineral tubs at each site were replaced with one tub containing 11.4 kg granular salt mixed with dry molasses, one tub containing 11.4 kg granular salt mixed with liquid molasses (see

Fig. B-1), one tub containing 11.4 kg granular mineral mixed with dry molasses, and one tub containing 11.4 kg granular mineral mixed with liquid molasses.

1 L of liquid molasses was added to each liquid molasses mix, and 0.57 kg of dry molasses was added to each dry molasses mix. On 7/29/2005 molasses concentration was increased to 2 L of liquid molasses per 11.4 kg salt or mineral, and 1.42 kg of dry molasses per 11.4 kg salt or mineral.

Different colored bands were spray painted on each tub for supplement identification from a distance (See table B-1 and Fig. B-2). I had planned to observe and document use from a distance with binoculars and spotting scope. In the early summer there were some successful observations (Fig. B-2), but as temperatures increased elk fed nocturnally and observations were no longer possible. A motion-activated camera was placed at one site, but the elk destroyed the camera (see Fig. B-3). Frequent summer thunderstorms made measuring changes in the volume of supplement in tubs ineffective (see Fig. B-4). Tub consumption was monitored via visual estimates of supplement consumption. There was also some observed use by deer and moose in these sites. All trials were conducted in pastures where domestic cattle were not present.

Table B-1. *Color-coding for summer supplement tubs at Deseret Land and Livestock ranch, Utah, summer 2005.*

Supplement Type	Color Code
Stablelyx	White
Crystal-Phos	Yellow
Mineral and Liquid Molasses	Orange
Mineral and Dry Molasses	Gray
Salt and Liquid Molasses	Blue
Salt and Dry Molasses	No Color (Black)

DLL Winter Range

Five supplement sites were selected on elk winter range at DLL. These sites were also chosen based on historic observed elk use. At each site I placed 1, 56.8 kg tub of Crystal-Phos lmb, 1, 56.8 kg tub of Stablelyx lmb, 1 mineral block, and 1 molasses based 20% protein block. The supplements were placed on Oct. 16th 2005. After observing almost no use for 1.5 months, a small amount of alfalfa (*Medicago sativa*) hay was placed in the vicinity of the supplements on Dec. 3, 2005 (see Fig. B-5). I also placed cut sainfoin (*Onobrychis viciifolia*) on top of the lmb tubs at 1 site (see Fig B-6). I continued to place alfalfa hay at the supplement sites until Jan. 14, 2006. Supplement consumption was monitored at these 5 sites once per week, as access would permit, until Jan. 31 2006. Supplement use was classified into 5 levels (see Table B-2). The tubs were collected and removed on May 18, 2006 after the snow melted.

Table B-2. *Classification of winter supplement use at Deseret Land and Livestock ranch, Utah, winter 2005/2006.*

Symbol	Level of Use Description
N	No Use
T	Trace, < 3 licks/bites
S	Small, 4-10 licks/bites
M	Medium, entire surface covered with licks/bites
L	Large, noticeable decrease in volume

Hardware Ranch Pens

At HR lmb was tested inside a 20 m x 80 m pen with 24 cow elk, and 68 calf elk for 10 days. The elk were fed a diet of grass hay, and the lmb tubs were also placed

inside the pen. During the last two days, 2 tubs containing 11.4 kg each of pure dry molasses were also placed inside the pen.

RESULTS

DLL Summer Range

During the testing period from 1 July 2005 to 18 Aug. 2005 elk consumed significant quantities of both the salt and mineral mixes containing increasing concentrations of molasses (See Table B-3). However, there was no apparent consumption of lmb or molasses-based 20% protein block. Elk quickly consumed the salt and mineral mixes, but did not consume lmb or protein block, even if empty salt and mineral mix tubs were not refilled each week. On July 19, 2005 at Site 3, Monument, two tubs containing 11.4 kg of pure dry molasses were set out. No salt or mineral was present in this mix. This pure dry molasses was completely consumed by July 28, 2005. Despite this molasses consumption event, there was still no consumption of lmb during the remainder of the testing thru Aug 18, 2005.

DLL Winter Range

There was very little use of lmb on the winter range at DLL (see table B-4). In summary, on 68 separate observations lmb appeared to have been used 5 times, 3 trace uses on the Stablelyx and 2 uses, 1 trace, one small on the Crystal-Phos. The highest level of documented use of lmb was observed 10 Dec. 2005. This use was on the Crystal-Phos block and was categorized into the Small category with 4-10 licks on the

surface of the block (see Fig. B-7). There were 27 total observations for the alfalfa hay, and I observed a large use 19 times. Data is summarized in tables B-4 and B-5.

Table B-3. *Summer supplement consumption by elk on Deseret Land and Livestock ranch, Utah, July 1, 2005 – Aug. 18, 2005.*

Supplement Type	Site 1 The Wall	Site 2 Blue Ridge	Site 3 Monument	Total Consumed At All Sites
Salt w Dry Molasses	22.8 kg	22.8 kg	22.8 kg	68.2 kg
Salt w Wet Molasses	22.8 kg	11.4 kg	11.4 kg	45.5 kg
Mineral w Dry Molasses	11.4 kg	22.8 kg	22.8 kg	56.8 kg
Mineral w Wet Molasses	11.4 kg	22.8 kg	11.4 kg	45.5 kg
Crystal-Phos LMB	trace	trace	trace	trace
Stablelyx LMB	trace	trace	trace	trace
Pure Dry Molasses*	NA	NA	22.8 kg	22.8 kg
Protein Block	none	none	none	none

* Pure dry molasses was only tested one time, and only at site 3.

Hardware Ranch Pens

At Hardware Ranch 24 cows and 68 calves were held in a pen for 10 days with limited diet selection. During this period there was no use of lmb. However, all of the pure dry molasses placed in the pen on day 8 was consumed by day 10.

DISCUSSION

We did not observe significant consumption of lmb by free ranging elk at Deseret Ranch, nor by captive elk at Hardware Ranch. This may be due to differences in the contents of the respective supplements that were tested, physical formulation of the LMB supplement, presence of alternative sources of nutrition, or need for further training of elk to familiarize the animals with LMB supplements. Elk consumed granular mineral mixes and granular salt mixes containing ingredients similar to those contained in the LMB (see

Table B-6). Elk also consumed these salt and mineral mixes when molasses was added. There were some slight differences in the mineral contents of the mixes. The granular mineral and salt mixes did not contain cobalt, manganese, or potassium,

Table B-4. *Winter supplement use by elk at Deseret Land and Livestock ranch, Utah, winter 2005/2006.*

Date	Site				
	Alkali	Crane	W. Kate	E. Kate	Stacey
<i>On 10/16/2005 nutrition supplements were placed at each of the locations</i>					
11/1/2005	N	N	N	N	N
11/7/2005	N	N	N	X-T	N
11/12/2005	N		N	N	N
11/19/2005	N	N	N	N	N
11/29/2005	N	N	N	N	N
12/3/2005	N	N	N	N	N
<i>On 12/3/2006 alfalfa hay was placed at sites</i>					
12/10/2005	N	N	H-L	H-L, R-S, C-S	N
12/13/2005	N	N	N	M-S	H-L
12/20/2005	H-L		H-L	H-L	H-L
12/27/2005	N	H-L	H-L, R-T	H-L	H-L
1/7/2006	H-L		H-L, R-S	H-L, P-S	H-L
<i>After 1/7/2006 no more hay was placed at sites</i>					
1/14/2006	H-L		H-L	H-L, R-M, P-M	H-L, C-T, R-T
1/21/2006	N			X-T, C-T	X-T
1/31/2006	N			N	
4/4/2006			N	N	
4/18/2006	N	N	N	N	N

Key

Supplement Type	
H	hay (alfalfa)
C	Crystal-Phos
X	Stablelyx
R	mineral block
P	protein block

Level of Elk Use	
	site not accessible
N	no use
T	trace, < 3 licks/bites
S	small, 4-10 licks/bites
M	medium, entire surface covered
L	large, noticeable decrease in volume

which were present in the LMB supplements. It is a possibility that these minerals discouraged elk from consuming the LMB.

However, an alternative explanation may be that the physical formulation (hardness) of the LMB rather than small variations in the content was responsible for the small level of consumption by elk. Perhaps the physical hardness, and effort required to consume a significant portion of the LMB, prevented elk from ingesting enough of the LMB to register positive post-ingestive feedback. The other known food and mineral sources consumed by elk at DLL are significantly softer and required less effort to consume. With additional training it may be possible to teach elk to eat hard blocks but only if they consume enough to be reinforced by the nutrients they contain. Elk may more readily consume LMB that has been crushed into a granular form. The hardness/coarseness of the LMB could be increased gradually until the elk will eat it in its solid form. However, after rainstorms the surface of the LMB softened, with some of the supplement going into a rainwater solution. In this softened state elk could have easily consumed significant quantities of LMB, but they did not do so.

During the summer supplement trials we supposed that the abundance of acceptable nutritional alternatives may have reduced consumption of LMB. However, when we removed the granular salt and mineral supplements there was still no consumption of LMB. In the winter at DLL nutritional availability was greatly reduced, yet we saw very little consumption of LMB. In addition, even in the pens at Hardware Ranch, with severely limited nutritional alternatives, we still did not observe consumption of lmb.

Table B-5. Summary of winter use of low moisture block and alfalfa hay by elk on Deseret Land and Livestock ranch, Utah, winter 2005/2006.

Level of Use Description	Crystal-Phos	Stablelyx	Alfalfa
no use	66	65	8
trace, < 3 licks/bites	1	3	0
small, 4-10 licks/bites	1	0	0
medium, entire surface covered	0	0	0
large, noticeable decrease in volume	0	0	19
Total Number of Observations	68	68	27

Notes:

Alfalfa hay was only present 12/3/05 to 1/14/06

Stablelyx and Crystal-Phos were present from 10/16/2005 to 4/18/2006

Table B-6. Contents of mineral supplement and low moisture block supplements tested at Deseret Land and Livestock ranch, Utah, 2005-2006.

Ingredient*	Granular Mineral	Crystal-Phos LMB	Stable-lyx LMB
Crude Protein			12.0%
Crude Fat		3.0%	5.0%
Crude Fiber		2.0%	2.5%
Calcium	14.5%	8.0%	1.5%
Phosphorus	6.0%	8.0%	1.0%
Salt	29.0%		14.0%
Potassium		2.0%	2.5%
Magnesium	1.5%	2.5%	0.8%
Cobalt		10 ppm	5 ppm
Copper	1,500 ppm	1,000 ppm	250 ppm
Iodine	80 ppm	50 ppm	6.6 ppm
Manganese		4,000 ppm	880 ppm
Selenium	24 ppm	13.2 ppm	.73 ppm
Zinc	3,000 ppm	3,000 ppm	880 ppm
Vitamin A	150,000 IU/lb	200,000 IU/lb	30,000 IU/lb
Vitamin D3	20,000 IU/lb	20,000 IU/lb	5,000 IU/lb
Vitamin E	200 IU/lb	200 IU/lb	250 IU/lb
Biotin			10 mg/lb
Thiamin			30 mg/lb

* Percentages are Guaranteed Analysis maximum percentage.

Based on our results it may take additional effort and training to teach elk to use LMB supplements. The aforementioned possible explanations for low levels of consumption could be investigated through further research and training, which may help wildlife managers use a LMB supplement to influence the distribution and feeding habits of elk. We found that elk do not necessarily have an aversion to molasses, but at the same time do not seem to consume LMB. While LMB may still have potential as a tool for wildlife managers, we did not observe significant consumption by elk at our study areas in northern Utah.

LITERATURE CITED

Dean, R., M. Gocke, B. Holz, S. Kilpatrick, T. Kreeger, B. Scurlock, S. Smith, E.T.

Thorne, and S. Werbelow. 2004. Elk feedgrounds in Wyoming. Wyoming Game and Fish, Cheyenne, USA.

Ferrari, M.J., and R. A. Garrott. 2002. Bison and elk: brucellosis seroprevalence on a shared winter range. *Journal of Wildlife Management* 66:1246-1254.

Galey, F. 2005. Wyoming Brucellosis Coordination

Team Report and Recommendations, Jan. 11, 2005. State of Wyoming, Cheyenne, USA.

Meagher, M., and M. E. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. *Conservation Biology* 8:645-653.

Miller, M.W., E.S. Williams, N. T. Hobbs, and L.L. Wolfe. 2004. Environmental sources of prion transmission in mule deer. *Emerging Infectious Diseases* 10:1003-1006.

Provenza, F.D., J.J. Villalba, L.E. Diziba, S.B. Atwood, and R.E. Banner. 2003.

Linking herbivore experience, varied diets, and plant biochemical diversity.

Small Ruminant Research 49:257-274.

Williams, E.S., M.W. Miller, T.J. Kreeger, R.H. Kahn, and E.T. Thorne. 2002.

Chronic wasting disease of deer and elk: a review with recommendations for

management. Journal of Wildlife Management 66:551-563.



Fig. B-1. Granular salt and liquid molasses mix at Deseret Land and Livestock ranch, Utah, summer 2005.



Fig. B-2. Elk and supplement tubs at Site 2, (Blue Ridge) at Deseret Land and Livestock ranch, Utah, summer 2005.



Fig. B-3. *Motion-activated camera damaged by elk at Site 3 (Monument) on Deseret Land and Livestock ranch, Utah, summer 2005.*



Fig. B-4. Granular salt with dry molasses after a thunderstorm on Deseret Land and Livestock ranch, Utah, summer 2005.



Fig. B-5. Alfalfa hay placed at winter elk supplement site on Deseret Land and Livestock ranch, Utah, winter 2005/2006.



Fig. B-6. *Cut sanfoin placed atop low-moisture block tub at winter elk supplement site 1 (Alkali) on Deseret Land and Livestock ranch, Utah, winter 2005/2006.*



Fig. B-7. *Highest observed level of elk use of low-moisture block on Deseret Land and Livestock ranch, Utah, winter 2005/2006.*