CONSERVATION IMPLICATIONS OF WINTER-FEEDING POLICIES FOR MULE DEER IN UTAH

by

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

of

DOCTOR OF PHILOSOPHY

in

Wildlife Biology

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UTAH STATE UNIVERSITY
Logan, Utah

2008

ABSTRACT

Conservation Implications Of Winter-Feeding Policies

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Utah State University, 2008

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Policies regulating wildlife winter-feeding programs may have long-term impacts on conservation and future management of both target and non-target species. In 2000, the Utah Wildlife Board, upon reviewing input from a series of public regional meetings, adopted a Utah Big Game Winter-Feeding Policy. The Utah Division of Wildlife Resources used this policy to regulate winter-feeding programs for mule deer in northern Utah, 2001-2005. I monitored the program effects on mule deer biology, activity and migration, and winter browse utilization and productivity.

While feed rations generally compensated for protein and energy deficiencies, they may overlook mineral deficiencies. To determine if mule deer could select for feeds that contained minerals that may be deficient in native browse, I conducted experimental feeding trials using copper supplements.

Feeding program success on increasing mule deer winter survival depends heavily on timely implementation. Therefore, I evaluated the utility of a modified body condition index to use deer-vehicle collision carcasses to monitor herd nutritional status, and applied this information to weather data to assist in determining when to implement winter-feeding programs. Lastly, I surveyed a random sample of Utah stakeholders to determine if the policy developed through the regional meeting process reflected wider public opinion rather than traditional consumptive users.

This winter-feeding enhanced body condition, and increased adult female survival. When dynamics of fed and non-fed study groups were modeled over five years, the model predicted both populations were declining, with a lower rate of decline in the fed population. The primary cause of mortality for fed and non-fed groups, deer-vehicle collision, nullified benefits accrued from feeding.

Deer may have balanced the effects of sagebrush and bitterbrush toxins with nutrients from feed rations, thus resulting in increased browsing of bitterbrush. Fed deer browsed over less area, and migrated earlier in fall and later in spring. Mule deer also selected a consistent proportion of copper-amended rations, suggesting plain rations are nutritionally inadequate.

Although most Utah stakeholders were unaware of Utah's big game winter-feeding policy, most believed winter-feeding was an important mule deer management strategy in Utah. When given a choice between using management funds to support winter-feeding or habitat projects, stakeholders preferred funding habitat restoration.

(204 pages)

ACKNOWLEDGMENTS

It is impossible in this brief tribute to thank all who helped me pursue this dissertation. In particular, however, I must thank Terry Messmer for his partnership in all aspects of the project. His experienced commitment and enthusiasm for the work has been unfailing, and instrumental to obtaining successful results. And his ability to perceive the underlying issues and principles has forever shaped my own perceptions. In addition, Fred Provenza has lent his experience and moral support throughout. Their friendship and mentoring are strengthening, and most deeply appreciated.

Other individuals contributed in important ways to this project. David Turner, Susan Durham, and Mary Conner provided excellent advice about study design and statistical analysis. The work could not have been completed without the help of excellent field assistants Shane and Kyle Koyle, Rusty Kaiser, Aaron Peterson, John Barnes, Mark Ewell, Ben Peterson, Dax Mangus, and Aron Bauer. In addition I would like to thank Cecelia, Esther, Gaye, Lana, and others who unfailingly helped with business support.

This project was largely funded by the Utah Division of Wildlife Resources and I thank them for making it possible for me to be involved in this project. Additional support was provided by Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension. The U.S. Forest Service granted access to several of the study sites.

Finally I thank my family for these many years of support. The example and wisdom of my parents and brothers has ever shaped my outlook and goals in life. I thank my sons and daughter for their unselfish support and assistance. Lastly, and most importantly, I thank my husband, Ken, for his never-failing help, his practical counsel, his physical assistance, and his belief in me. Although words are inadequate, thank you.

Chris Peterson

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CHAPTER 1

INTRODUCTION

Wildlife management has been defined as the art and science of managing wildlife populations to balance species needs with stakeholder desires. Under the North American Model of Wildlife Conservation, stakeholders who value wildlife populations for consumptive and non-consumptive recreation largely fund management actions through license and permit fees (Prukop and Regan 2005). Thus when desired wildlife populations decline, managers are as concerned for the welfare of the species as they are for the impact the decline may have on funds (i.e., lost agency revenue because of reduced license sales) available to manage the species.

When wildlife populations decline managers attempt to identify the contributing factors. This may involve research, surveys, intensive monitoring and mathematical models to predict the likely outcome of strategies or actions implemented to reverse these declines. Management actions, designed to increase natality or reduce mortality can be characterized as either direct or indirect.

Indirect management strategies are actions that are conducted to create or enhance wildlife habitat. The population benefits of habitat management projects are typically accrued over time. Direct management strategies include actions that result in immediate effects on natality or mortality. These can include predator control and emergency feeding of wildlife to ameliorate the impacts of severe winter weather. Direct management actions may be preferred by stakeholders because they perceive an immediate population benefit.

Recently, declines in wild ungulate populations, particularly mule deer

(*Odiocioleus hemionius*), are of major concern for western states' wildlife managers and their stakeholders (Smith 2001). Mule deer have long been an important game species, as mule deer hunting has generated substantial revenue for wildlife agencies through license sales and excise taxes on guns and ammunition (Gray 1993, Heffelfinger and Messmer 2003).

In many areas mule deer population declines appear to be related to rapid urban growth that is impacting winter ranges (Urness 1980, Smith 2001, Ouellet et al. 2001). Thus, efforts to increase ungulate populations in these situations often include direct management methods such as winter-feeding programs to supplement both the quantity and quality of existing browse (Smith 2001).

Benefits attributed to winter programs may include enhanced body condition (Baker and Hobbs 1985, Wiklund et al. 1996, Peterson and Messmer 2007), and increased survival and productivity (Ozoga and Verme 1982, Hobbs 1989). But some feeding programs have also contributed to degradation of traditional winter ranges (Doman and Rasmussen 1944, Mautz 1978, Cooper et al. 2006), increased mortality (Doman and Rasmussen 1944), and altered behavior (Schmitz 1990, Murden and Risenhoover 1993, Tarr and Pekins 2002, Peterson and Messmer 2007). A better understanding of interactive program effects, (i.e., plant-herbivore interactions and human perceptions of feeding programs), is crucial to the development and implementation of policies that may optimize the effects of supplemental nutrition in the long-term survivability and productivity of mule deer populations (Knowlton 1976, Connolly 1981, McNay and Voller 1995).

Winter-Feeding and Mule Deer Management

Each winter a certain portion of a mule deer herd will die. For a deer to survive winter, its nutritional status and condition at the end of the season must be high enough to meet continued maintenance costs that accrue until dietary intake provides sufficient nutrients for recovery and growth (Urness 1980). Several authors have reported that winter-feeding programs have resulted in increased survival and populations of mule deer (Severson 1981, Short 1981, Baker and Hobbs 1985, White 1992, Robbins 1993). However, Robinette et al. (1973) found that herd productivity increased only if a large proportion of the herd used the feed rations. Thus, the interaction between deer physiological status and age, the nutritional gain provided by winter feed rations, and the energy costs associated with severe winter conditions may limit benefits in all but the most extreme winter conditions (Verme 1962, Doenier et al. 1997, Tarr and Pekins 2002).

Due to their relatively higher fat and muscle content and relatively lower metabolic costs, adult does may not be as influenced by winter-feeding programs as fawns (Moen 1968, Verme and Ozoga 1980, Tarr and Pekins 2002). Still, many does may die later in spring, or during birth of fawns, due to delayed effects of malnourishment (Urness 1980). Because of the delay, these losses often are not attributed to winter malnourishment.

The current year fawns may have higher risk of mortality under severe conditions than adult does because of their smaller size and fat reserves, and higher relative metabolism (Moen 1968, Verme and Ozoga 1980, Parker et al. 1984). High winter fawn mortality impacts herd productivity and limits deer population growth (Unsworth et al.

1999, DelGiudice et al. 2002). Although winter-feeding may increase fawn survival (Tarr and Pekins 2002), this benefit may be mitigated if larger more dominant deer exclude fawns from obtaining adequate amounts and/or proportions of winter-feed rations (Ozoga 1972, Easton 1993, Tarr and Pekins 2002). This exclusion in combination with higher basal metabolic rates for fawns and increased behavioral stress may result in increased weight loss and subsequent mortality for fawns at feed stations (Ozoga and Verme 1982).

Winter losses in a deer population will normally be replenished by reproduction in the spring. Thus, evaluating the cause of mortality may aid in developing strategies to reverse declining mule deer populations (Bleich and Taylor 1998). For example, mortality attributed directly to predation may be indirectly facilitated by malnourishment-induced weakness. Likewise, mortality directly attributed to disease or parasites may be indirectly due to malnourishment (Robbins 1983). Often, overlooked indirect causes may add valuable insight into factors regulating herd size.

Feeding and Malnourishment

Does exhibiting poor nutritional status following severe winter conditions may survive and bear live, but malnourished fawns that can not survive (Verme 1962, Urness 1980, Tarr and Pekins 2002). Thus, high survival of does alone may not equate to good fawn survival or productivity (Kitts et al. 1956, Verme 1962, Mundinger 1981, Robbins 1993). High survival of does in combination with low survival of fawns will reduce herd productivity and population growth (Unsworth et al. 1999, DelGiudice et al. 2002).

Several authors have argued that productivity of does is largely determined by the degree of nutritional restrictions during winter (Kitts et al. 1956, Verme 1962, Mundinger

1981, Robbins 1993). Accordingly, winter-feeding that increases nutritional status may increase the productivity of does (Severson 1981, Short 1981, Baker and Hobbs 1985, White 1992, Robbins 1993). However, the benefit of increased fawn production may not translate into increased herd population if the fawns do not reach maturity, incorporate into the herd, and/or produce fawns of their own.

Body Condition and Mule Deer Winter Survival

Throughout summer and fall, mule deer must accumulate enough nutrient reserve to compensate for seasonal times when they are unable to feed (Cuthill and Houston, 1997). From late summer through fall, mule deer divert excess nutrients from growth into storage as fat and muscle. During winter, use of this storage directly influences their survival and productivity (Wallmo et al. 1977, Baker and Hobbs 1985, Olson and Lewis 1994). During this annual cycle, mule deer exhibit morphological and physiological changes, i.e., body condition stages, which managers can use to gauge the health of an animal (Riney 1960, Kistner et al. 1980). Stages of body condition may be assessed with several fitness indices, including serum, marrow fat, and organ fat (deCalesta et al. 1975, Verme and Ozoga 1980, DelGiudice and Seal 1988, Harder and Kirkpatrick 1996, Sakkinen et al. 2000). Due to the individual morphological and physiological variability of animals, the use of more than one body condition index increases accuracy of interpretation (Ransom 1965, Smith et al. 1975, DelGiudice and Seal 1988).

A degree of weight loss is generally a part of mule deer normal annual energy cycling. At earlier stages of malnourishment, as deer use stored nutrients of body tissues to access adequate daily required nutrients, the animal is generally able to fully recover and successfully reproduce. However, when malnourishment progresses past specific threshold levels wherein the majority of body reserves are used, the animal may not be able to recover and will die regardless of the amount or quality of feed provided. DelGiudice and Seal (1988) proposed 3 general levels of malnourishment and observable effects: early, prolonged reversible, and prolonged irreversible. Mule deer generally experience no long-term effects during the first 2 levels of malnourishment (Torbit et al. 1985). These early levels, typical of normal winters, are characterized by weight loss <28% and fluctuating serum urea nitrogen (SUN) levels. A low SUN level, <20 mg/dL, indicates the individual has ample body fat and dietary energy, and is not catabolizing protein (Torbit et al. 1985). Elevated SUN levels, and SUN/C ratios are associated with increased dietary protein when receiving supplemental rations, or with increased catabolism of endogenous protein when intake is restricted to reduced availability of browse (Parker et al. 1993, Moen and DelGiudice 1997). Extreme winter conditions may result in the 3rd level, which is characterized by weight loss >28%, SUN levels $\geq$40 mg/dL, and SUN/C ratios $\geq$23. Deer that reach the 3rd level generally do not recover, regardless of improved weather conditions and/or access to feed.

Management Concerns and Winter-Feeding

Habitat Impacts. Browsing influences plant diversity, and regulates ecosystem processes through altering the mortality, reproductive potential, and distribution of plants (Coley et al. 1985, McArthur et al. 1988, Lambers et al. 1998, Hobbs 1996, Brits et al. 2002). Use of supplemental feed rations affects mule deer browsing and habitat use (Oh et al. 1968, Ullrey et al. 1975, Belovsky and Schmitz 1993, Illius and Jessop 1996). Supplemental feeds of high quality and quantity potentially increase energy gain per unit time, thereby increasing time available for longer rest periods, to compensate for deep snow or difficult terrain (Torbit et al. 1985, Parker et al. 1996, 1999), or increasing time available for more selective browsing (Murden and Risenhoover 1993, Doenier et al. 1997). Increased selectivity in browsing increases browsing pressure on more preferred plants (Ozoga and Verme 1982, Baker and Hobbs 1985, Schmitz 1990). This pressure may result in long-term alterations of habitat and landscapes (Cooper et al. 2006, Brits et al. 2002, Porter et al. 2002).

To obtain and balance ingestion of sufficient dietary minerals, many animals require a diversity of forage species (Ohlson and Staaland 2001, Provenza et al. 2002). When palatable nutritious forage is limiting, deer will use less palatable forage (Longhurst et al. 1968, Provenza et al. 2002). Less palatable forage species may contain increased plant secondary compounds that limit ingestion or reduce nutrient absorption (Robbins et al. 1987, Vourch et al. 2002). Winter-feeding programs supply increased nutrients that affect deer preference for available forage. Altered mule deer preference on winter ranges with low forage diversity, e.g., areas with deep snow cover and resulting low availability of diverse forage, may change the balance of vegetation species and structure.

Migration Initiation and Duration. Migration to a great extent is based on ecological opportunity (Alerstam et al. 2003). Migration in mule deer is an adaptive behavior which is believed to in some cases be initiated when total nutrient intake on-site is less than that available on transitional range, or on the following season's range (Wallmo and Regelin 1981, Loft et al. 1989). Timing of fall migration enables deer to optimize their energy storage before winter (Wallmo and Regelin 1981, Parker et al. 1996). Timing of spring migration maximizes a does' energy intake during the critical, energy expensive, final 2 months of pregnancy (Wallmo and Regelin 1981, Parker et al. 1996). Therefore, if feed rations raise their winter nutritional plane, deer may remain longer on winter range (Schmitz 1990, Kucera 1992, Doenier et al. 1997, Sabine et al. 2002, Mahoney and Schaefer 2002). In the fall, nutrient intake may decline below that available on winter sites where deer are fed supplements. Thus, supplemented deer may also migrate sooner in the fall and arrive on winter range earlier than non-supplemented deer. Long-term consequences may include changes in migration status of an individual or herd and altered winter range landscapes as described in the previous section (Schmitz 1990, Kucera 1992, Augustine and McNaughton 1998, Sabine et al. 2002, Mahoney and Schaefer 2002).

Winter-Feeding Program Management Considerations

Role of Minerals. Although not of common consideration, mineral deficiencies may be more limiting to wildlife than deficiencies in energy and protein (McDowell et al. 1993, Lyon 1966, Severson 1981, Hobbs and Swift 1985, Hodgman et al. 1996). Likewise, chronic and/or low-level deficiencies may be more widespread than observations indicate (Robbins 1983, Flueck 1994). Mineral deficiencies may increase susceptibility to disease, non-infectious abortion, and parasites (Robbins 1983, McDowell et al. 1993). Animals with these deficiencies may access enough specific minerals to grow and reproduce exhibiting no obvious symptoms, yet still have reduced health and productivity (Underwood 1977, Flueck 1994). However, this reduced productivity is often attributed to factors such as severe weather, disease, parasites, or inadequate winter forage resources rather than mineral availability (Robbins 1983).

Mineral nutrients vary in distribution and availability through time and space (Julander et al. 1961, Ohlson and Staaland 2001, McDowell 1992), with climate, and with the availability and interaction of other nutrients and minerals (McDowell et al. 1993, Schultz et al. 1994, Adrian et al. 2000). The availability of specific minerals may decrease as plant communities mature (McDowell et al. 1993), and also vary widely in different plant species (Grace and Wilson 2002). In addition, availability is affected by browsing intensity and patterns of use (Langlands et al. 1982, McDowell et al. 1993).

Browsing intensity and patterns of use are influenced by mineral requirements that vary with animal density, gender, age, and stage of metabolism and life cycle (Rombach et al. 2002, Schultz et al. 1994). Mineral deficiencies may increase when overall intake is reduced due to factors such as the low protein (<7.0 %) or increased lignin content associated with winter diets (McDowell et al. 1993). Thus, animals such as mule deer that are adapted to varied diets may suffer from seasonal deficiencies related to seasonal dietary restrictions as well as seasonal requirements of growth and reproduction.

Information concerning deer mineral requirements is very limited (Robbins 1983, Jones and Hanson 1985), and frequently is obtained from captive deer. However, mineral levels in captive deer may not be applicable to free-ranging, wild deer (Barboza et al. 2003, Powell and DelGiudice 2005). Thus there is a need for information of mineral levels in free-ranging, wild deer.

Program Timing. Winter conditions affect mule deer condition, survival and productivity. Still, mule deer in good condition can withstand severe winter conditions for 30 to 60 days (deCalesta et al. 1975, Wallmo et al. 1977, Torbit et al. 1985, Wakeling and Bender 2003). The actual number of days a deer may survive is related to its condition, age, and severity of winter conditions during this time (Doman and Rasmussen 1944, DelGiudice and Seal 1988). Thus, information concerning the stage of malnourishment of the herd may aid managers in determining when to implement a winter-feeding program.

Increased intake of nutrients from supplemental feed may add to the number of days an animal may survive severe conditions by reducing the rate at which deer fitness levels decline (Urness 1980, Parker et al. 1999). Several states have policies regarding winter-feeding programs (Utah Division of Wildlife Resources 2000, Idaho Fish and Game Commission 2006, Oregon Department of Fish and Wildlife 2003), however, implementing these policies is often governed more by local interest or political pressure than by biology (UDWR 2003). For increased efficacy, the decision to implement a winter-feeding program should be based on site-specific information of the biology and ecology of the herd, as well as the human dimensions of the area affected.

Stakeholder Perceptions of Wildlife Feeding

Sociological values associated with wildlife are increasingly diverse and constantly changing (Kennedy et al. 1995). Many of these values and attitudes are not based on economics, but represent more holistic concepts (Iso-Ahola 1980, Kennedy et al. 1995, Conover 2002). Historical, consumptive wildlife values such as hunting appear to be decreasing, while more non-consumptive values such as wildlife viewing/feeding are increasing (Daigle et al. 2002, Deruiter and Donnelly 2002). Additionally, these activities have contributed to increased public interest in wildlife conservation and the public policy and decision making process. Management that was based on simple, linear, cause-effect relationships such as hunting, is no longer adequate (Kennedy 1985, Riley et al. 2003, Brown and Decker 2005). Managing the decision-making process and the people making the decisions are equally as important as managing wildlife (Decker and Chase 1997, Godfrey 2003). As well, Decker and Chase (1997) indicate there may be increased social acceptance and compliance with policy and regulation when there is increased public involvement in the decision-making process. In recognition of these factors, several state wildlife agencies have developed and refined the decision making process to increase public participation (Decker and Chase 1997).

This is also true in the case of winter-feeding programs. Utah and other states have developed winter-feeding polices that reflect public interest. However, even given this process, few people actually participate (Krannich and Teal 1999). Thus policies developed using these processes may actually reflect the tyranny of the minority, rather than a majority (Duda et al. 1998, Mortenson and Krannich 2001).

Peterson (C. Peterson, Utah State University, unpublished data) found participation by local residents in backyard winter-feeding programs on a scale that potentially may impact the state's wildlife-feeding policy. Over the 3-year study, she observed numerous caches of apples, supermarket refuse fruits and vegetables, leaf piles, and commercial wildlife feed blocks and pellets distributed throughout urban and winter deer range areas. Furthermore, when the Utah Division of Wildlife Resources advertised it would be implementing a feeding program for mule deer wintering in the area, local program coordinators, as well as Peterson, were beset with calls from local people who desired to participate. Extensive, unorganized use of winter-feeding programs throughout an area may increase human-wildlife conflicts in that area through increasing numbers and density of deer near or crossing roads, increasing browse pressure on urban landscape plantings, and increasing numbers of non-migratory deer.

As it is often perceived to be an interest of and supported by mainly sportsmen, little is actually known about public interest, involvement in, and support for wildlife-feeding. One way to compensate for this limitation is the use of public opinion surveys to determine the range of public interest and involvement in and support for public wildlife-feeding programs. This knowledge would be useful in helping managers plan for, discourage use of winter-feeding, or avoid specific problems that might arise.

Study Purpose

The purpose for this study was to determine conservation implications of Utah's Big Game Winter-Feeding Policy (UDWR 2000). This policy was approved by the Utah Wildlife Board to guide big game winter-feeding operations in Utah. This research was the first ever conducted to evaluate the effect of this policy on mule deer herds in northern Utah. In particular, the UDWR was interested in learning if winter-feeding of mule deer would increase mule deer survival and productivity. In addition, the UDWR was concerned about potential published negative consequences of wintering feeding, public perceptions of the policy, and ultimately implications the policy may have on mule deer conservation in Utah. To address these concerns and information needs, we evaluated the biological, behavioral, ecological, and sociological effects of the winter-feeding program conducted in northern Utah from 2002-2007.

To evaluate biological effects of the feeding program, we hypothesized that if winter malnourishment was the major cause of mortality for this herd, the supplemental rations would increase nutritional status as evidenced by body condition indices, and this would lead to increased survival, productivity, and ultimately larger populations of fed vs. non-fed deer. Observations regarding body condition, survival, productivity, and major causes of mortality from 2001-2007 for fed and non-fed deer, are reported in chapter 2.

Feeding programs also affect the interactions of deer behavior with habitat, specifically browse utilization and production. Deer behavior is based on time/energy ratios. Factors that alter these ratios potentially affect deer behavior, altering use of the habitat on both a daily basis and through time. We hypothesized that utilization of the supplemental rations would change deer time/energy ratios and affect habitat use. This would result in increased utilization of winter browse in areas nearest the feed stations. Increased utilization of browse could result in decreased browse production. We estimated utilization and production of both sagebrush and bitterbrush, and observed deer activity across 4 zones on feed and non-feed sites.

As timing of migration may be affected by availability of nutrients on winter sites, we hypothesized that increased nutrition from feed rations would result in fed deer migrating earlier in the fall and later in the spring, as evidenced through initiation and conclusion dates of migration, and duration on seasonal ranges. Therefore we evaluated the timing of fall and spring migration and duration on summer and winter range of 100 radio-collared adult does. Results concerning both behavior and browse are reported in chapter 3.

Commonly, winter-feeding programs are designed to increase deer survival and productivity through addressing daily requirements for energy and protein. Although often difficult to detect and overlooked, mineral deficiencies may have greater relative impact on survival and productivity. However, interaction of minerals, nutrients of feed rations, and deer behavior may prevent mineral supplementation through feed rations. Therefore we decided to evaluate the mineral status of both fed and non-fed deer, and determine if deer would use a mineral amended ration. These observations are reported in chapter 4.

In addition, benefits from feeding programs of increased deer survival and productivity appear to be related in part to timely implementation of the feeding program. Weather conditions are largely unpredictable as to severity, timing, and duration. Body condition indices aid in evaluating deer nutritional status, but may be difficult for managers to consistently employ due to logistic constraints, and may not adequately reflect herd nutritional status. Thus, although the efficacy of feeding programs may be increased through implementation in response to severe conditions but before herd nutritional status declines and not within the survivable time frame, very little information exists to aid in identifying this point in time. For that reason, we developed and evaluated a methodology to assist managers in answering the question of when to implement a feeding program. This methodology and evaluation are reported on in chapter 5.

Utah's big game winter-feeding policy was formed and adopted by the Utah Wildlife Board following a series of open public meetings addressing the issue of winter-feeding of wildlife. As these meetings are largely attended by traditional consumptive wildlife users, i.e., hunters/anglers, the policy may not reflect the public view. To determine if Utah's big game winter-feeding policy reflects the views of both consumptive and non-consumptive wildlife stakeholders in Utah, we administered a mailback survey to a random sample of Utah's stakeholders. The results of this survey are reported in chapter 6.

This research was approved by the Utah State Institutional Animal Care and Use Committee (Permit #1084) and the Institutional Review Board at Utah State University (IRB # 1716).

Dissertation Format

This dissertation is written in a multiple paper format. The introductory and conclusion chapters follow Utah State University School of Graduate Studies formatting guidelines. Chapters 2, 3, 4, and 6 are written according to the Journal of Wildlife Management (JWM) Research Article guidelines, while chapter 5 is written to JWM Research Note guidelines.

Literature Cited

Adrian, F., R. Danielsson, and B. Jones. 2000. The 'mysterious' disease in Swedish moose. Concentrations of trace elements in liver and kidneys and clinical chemistry. Comparison with experimental molybdenosis and copper deficiency in the goat. The Science of the Total Environment 249:107-122.

Alerstam, T., A. Hedenstrom, and S. Akesson. 2003. Long-distance migration: evolution and determinants. Oikos 103:247-260.

Augustine, D. J., and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. Journal of Wildlife Management 62:1165-1183.

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Barboza, P. S., E. P. Rombach, J. E. Blake, and J. A. Nagy. 2003. Copper status of muskoxen: A comparison of wild and captive populations. Journal of Wildlife Diseases 39:610-619.

Belovsky, G. E., and O. J. Schmitz. 1993. Owen Smith's evaluation of herbivore foraging models: what is constraining? Journal of Evolutionary Ecology 7:525-529.

Bleich, V. C., and T. J. Taylor. 1998. Survivorship and cause specific mortality in five populations of mule deer. Great Basin Naturalist 58:265-272.

Brits, J., M. W. van Rooyen, and N. van Rooyen. 2002. Ecological impact of large herbivores on the woody vegetation at selected watering points on the eastern basaltic soils in the Kruger National Park. African Journal of Ecology 40:53-60.

Brown, T. L., and D. J. Decker. 2005. Research needs to support community-based wildlife management: Global perspectives. Human Dimensions of Wildlife 10: 137-140.

Coley, P. D., J. P. Bryant, and F. S. Chapin, III. 1985. Resource availability and plant antiherbivore defense. Science 22:895-899.

Connolly, G. E. 1981. Limiting factors and population regulation. Pages 245-286 *in* O. C. Wallmo, editior. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, USA.

Conover, M. R. 2002. Resolving human-wildlife conflicts: the science of wildlife damage management. CRC Press, Boca Raton, Florida, USA.

Cooper, S. M., M. K. Owens, R. M. Cooper, and T. F. Ginnett. 2006. Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66:716-726.

Cuthill, I. C., and A. I. Houston. 1997. Managing time and energy. Chapter 5 *in* J. R. Krebs and N. B. Davies, editors. Behavioural Ecology: An Evolutionary Approach. Blackwell Science, Malden, Maryland, USA.

Daigle, J. J., Hrubes, D., and Ajzen, I. 2002. A comparative study of beliefs, attitudes, and values among hunters, wildlife viewers, and other outdoor recreationists. Human Dimensions of Wildlife 7:1-19.

deCalesta, D. S., J. G. Nagy, and J. A. Bailey. 1975. Starving and refeeding mule deer. Journal of Wildlife Management 39:663-669.

Decker, D. J., and L. C. Chase. 1997. Human dimensions of living with wildlife—a management challenge for the 21st century. Wildlife Society Bulletin 25:788-795.

DelGiudice, G. D., M. R. Riggs, P. Joly, and Wei Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. Journal of Wildlife Management 66:698-717.

DelGiudice, G. D., and U. S. Seal. 1988. Classifying winter undernutrition in deer via serum and urinary urea nitrogen. Wildlife Society Bulletin 16:27-32.

DeRuiter, D. S., and M. P. Donnelly. 2002. A qualitative approach to measuring determinants of wildlife value orientations. Human Dimensions of Wildlife 7:251-271.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Doman, E. R., and D. I. Rasmussen. 1944. Supplemental feeding of mule deer in northern Utah. Journal of Wildlife Management 8:317-338.

Duda, M. D., S. J. Bissell, and K. C. Young, editors. 1998. Wildlife and the American mind: public opinion on and attitudes toward fish and wildlife management. Responsive Management National Office, Harrisonburg, Virginia, USA.

Easton, D. E. 1993. Spatial responses of white-tailed deer to year round supplemental feeding in northern Florida. Thesis, University of Florida, Gainesville, USA.

Flueck, W. T. 1994. Effect of trace elements on population dynamics: Selenium deficiency in free-ranging black-tailed deer. Ecology 75:807-812.

Godfrey, B. E. 2003. What have we learned about public land allocation in the 200 years since Lewis and Clark? WAEA Presidential Address, Denver, Colorado, USA.

Grace, N. D., and P. R. Wilson. 2002. Trace element metabolism, dietary requirements, diagnosis and prevention of deficiencies in deer. New Zealand Veterinary Journal 50:252-259.

Gray, G. G. 1993. Wildlife and people: the human dimensions of wildlife ecology. University of Illinois Press, Chicago, USA.

Harder, J. D., and R. L. Kirkpatrick. 1996. Physiological methods in wildlife research. Pages 275-306 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Heffelfinger, J. R., and T. A. Messmer. 2003. Introduction to mule deer conservation. Pages 1-12 *in* J. C. deVos, Jr., M. R. Conover, and N. E. Headrick, editors. Mule Deer Conservation: Issues and Management Strategies. Western Association of Fish and Wildlife Agencies and Jack H. Berryman Institute. Jack H. Berryman Institute Press, Utah State University, Logan, USA.

Hobbs, N. T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation mode. Wildlife Monograph No. 101.

Hobbs, N.T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695-713.

Hobbs, N. T., and D. M. Swift. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. Journal of Wildlife Management 49:814-822.

Hodgman, T. P., B. R. Davitt, and J. R. Nelson. 1996. Monitoring mule deer diet quality and intake with fecal indices. Journal of Range Management 49:215-222.

Idaho Fish and Game Commission. 2006. Rules governing emergency feeding of antelope, elk, and deer of the Idaho Fish and Game Commission. Idaho Fish and Game Commission, Boise, USA.

Illius, A.W., and N. S. Jessop. 1996. Metabolic constraints on voluntary intake in ruminants. Journal of Animal Science 74:3052-3062.

Iso-Ahola, S. E. 1980. The socialization process. Pages 129-161 *in* The social psychology of leisure and recreation. Brown, Dubuque, Iowa, USA.

Jones, R. L., and H. C. Hanson. 1985. Mineral licks, geophagy, and biochemistry of North American ungulates. Iowa State University Press, Ames, USA.

Julander, O., W. L. Robinette, and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. Journal of Wildlife Management 25:54-60.

Kennedy, J. J. 1985. Viewing wildlife managers as a unique professional culture. Wildlife Society Bulletin 13:571-579.

Kennedy, J. J., B. L. Fox, and T. D. Osen. 1995. Changing social values and images of public rangeland management. Rangelands 17:127-132.

Kistner, T. P., C. E. Trainer, and N. A. Hartmann. 1980. A field technique for evaluating physical condition of deer. Wildlife Society Bulletin 8:11-17.

Kitts, W. D., I. McT. Cowan, J. Bandy, and A. J. Wood. 1956. The immediate post natal growth in Columbian black-tailed deer in relation to the composition of the milk of the doe. Journal of Wildlife Management 20:212-214.

Knowlton, F. 1976. Potential influence of coyote predation on mule deer populations. Pages 111-118 *in* G. W. Workman and J. B. Low, editors. Mule deer decline in the West-a symposium. Utah State University, Logan, USA.

Krannich, R. S., and T. L. Teel. 1999. Highlights from a public survey. Attitudes and opinions about wildlife resource conditions and management in Utah: Results of a 1998 statewide general public and license purchaser survey. D. E. Dolsen and S. Phillips, editors. Utah State University Institute for Social Science Research on Natural Resources, Utah Division of Wildlife Resources, Salt Lake City, USA.

Kucera, T. E. 1992. Influences of sex and weather on migration of mule deer in California. Great Basin Naturalist 52:122-130.

Lambers, H., F. S. Chapin III, and T. L. Pons. 1998. Plant physiological ecology. Springer, New York, New York, USA.

Langlands, J. P., J. E. Bowels, G. E. Donald, , A. J. Smith, D. R. Paull, and H. I. Davies. 1982. Deposition of copper, manganese, selenium and zinc in the ovine foetus and associated tissues. Australian Journal of Agricultural Research 33:591-605.

Loft, E. R., R. C. Bertram, and D. L. Bowman. 1989. Migration patterns of mule deer in the central Sierra Nevada. California Fish and Game 75:11-19.

Longhurst, W. M., H. K. Oh, M. B. Jones, and R. E. Kepner. 1968. A basis for the palatability of deer forage plants. Transactions of North American Wildlife and Natural Resources Conference 33:181-192.

Lyon, J. L. 1966. Problems of habitat management for deer and elk in the northern forests. U.S. Forest Service, Research paper INT-24, Intermountain Forest and Range Experiment Station, Ogden, Utah, USA.

Mahoney, S. P., and J. A. Schaefer. 2002. Long-term changes in demography and migration of Newfoundland caribou. Journal of Mammalogy 83:957-963.

Mautz, W. W. 1978. Nutrition and carrying capacity. Pages 321-348 *in* J. L. Schmidt and D. L. Gilbert, editors. Big game of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

McArthur, E. D., A. C. Blauer, and S. C. Sanderson. 1988. Mule deer-induced mortality of mountain big sagebrush. Journal of Range Management 41:114-120.

McDowell, L. R. 1992. Minerals in animal and human nutrition. First edition. Academic Press, New York, New York, USA.

McDowell, L. R., J. H. Conrad, and F. G. Hembry. 1993. Minerals for grazing ruminants in tropical regions. Second edition. Animal Science Department, Center for Tropical Agriculture, University of Florida. Library of Congress Catalog number 92-76027.

McNay, R. S., and J. M. Voller. 1995. Mortality causes and survival estimates for adult female Columbian black-tailed deer. Journal of Wildlife Management. 59:138–146.

Moen, A. N. 1968. Energy balance of white-tailed deer in the winter. Transactions of North American Wildlife and Natural Resources Conference 33:224-236.

Moen, R., and G. D. DelGiudice. 1997. Simulating nitrogen metabolism and urinary urea nitrogen:creatinine ratios in ruminants. Journal of Wildlife Management 61:881-894.

Mortenson, K. G., and R. S. Krannich. 2001. Wildlife managers and public involvement: letting the crazy aunt out. Human Dimensions of Wildlife 6:277-290.

Mundinger, J. G. 1981. White-Tailed Deer Reproductive Biology in the Swan Valley, Montana**.** The Journal of Wildlife Management 45:32-139.

Murden, S. B., and K. L. Risenhoover. 1993. Effects of habitat enrichment on patterns of diet selection. Ecological Applications 3:497-505.

Oh, K. K., M. B. Jones, and W. M. Longhurst. 1968. Comparison of rumen microbial inhibition resulting from various essential oils isolated from relatively unpalatable plant species. Applied Microbiology 16:39-44.

Olson, R., and A. Lewis. 1994. Winter big game feeding: an undesirable wildlife management practice. Department of Range Management, Cooperative Extension Service, University of Wyoming, Report B-1003, Laramie, USA.

Ohlson, M., and H. Staaland. 2001. Mineral diversity in wild plants: benefits and bane for moose. Oikos 94:442-454.

Oregon Department of Fish and Wildlife. 2003. Oregon's mule deer management plan. Oregon Department of Fish and Wildlife. Portland, USA.

Ouellet, J.-P., M. Crete, J. Maltais, C. Pelletier, and J. Huot. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129-136.

Ozoga, J. J. 1972. Aggressive behavior of white-tailed deer at winter cuttings. Journal of Wildlife Management 36:861-867.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Parker, K. L., G. D. DelGiudice, and M. P. Gillingham. 1993. Do urinary urea nitrogen and cortisol ratios of creatinine reflect body-fat reserves in black-tailed deer? Canadian Journal of Zoology 71:1841-1848.

Parker, K. L., M. P. Gillingham, T. A. Hanley, and C. T. Robbins. 1996. Foraging efficiency: energy expenditure versus energy gain in free-ranging black-tailed deer. Canadian Journal of Zoology 74:442-450.

Parker, K. L., M. P. Gillingham, T. A. Hanley, and C. T. Robbins. 1999. Energy and protein balance of free ranging black-tailed deer in a natural forest environment. Wildlife Monographs 143:1-4.

Parker, K. L., C. T. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Porter, W. P., J. L. Sabo, C. R. Tracy, O. J. Reichman, and M. Ramankutty. 2002. Physiology on a landscape scale: Plant-animal interactions. Integrative and Comparative Biology 42:431-453.

Powell, C. P., and G. D. DelGiudice. 2005. Birth, morphologic, and blood characteristics of free-ranging white-tailed deer neonates. Journal of Wildlife Diseases 41:171-183.

Provenza, F. D., J. J. Villalba, and J. P. Bryant. 2002. Foraging by herbivores: linking the biochemical diversity of plants with herbivore culture and landscape diversity. Pages 387-422 *in* J.A. Bissonette and I. Storch, editors. Landscape ecology and resource management: making the match. Island Press, New York, New York, USA.

Prukop, J., and R. J. Regan. 2005. The value of the North American Model of Wildlife Conservation: An International Association of Fish and Wildlife Agencies position. Wildlife Society Bulletin 33:374-377.

Ransom, A. B. 1965. Kidney and marrow fat as indicators of white-tailed deer condition. Journal of Wildlife Management 29:387-399

Riley, S. J., W. F. Siemer, D. J. Decker, L. H. Carpenter, J. F. Organ, and L. T. Berchielli. 2003. Adaptive impact management: an integrative approach to wildlife management. Human Dimensions of Wildlife 8:81-95.

Riney, T. 1960. Field technique for assessing physical condition of some ungulates. Journal of Wildlife Management 24:92-94.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Second edition. Academic Press, San Diego, California, USA.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, New York, New York, USA.

Robbins, C. T., T. A. Hanley, A. E. Hagerman, O. Hjeljord, D. L. Baker, C. C. Schwartz, and W. W. Mautz. 1987. Role of tannins in defending plants against ruminants: reduction in protein availability. Ecology 68:98-197.

Robinette, W. L., C. H. Baer, R. E. Pillmore and C. E. Knittle. 1973. Effects of nutritional change on captive mule deer. Journal of Wildlife Management 37:3112-325.

Rombach, E. P., P. S. Barboza, and J. E. Blake. 2002. Utilization of copper during lactation and neonatal development in muskoxen. Canadian Journal of Zoology 80:1460-1469.

Sabine, D. L., S. F. Morrison, H. A. Whitlaw, W. B. Ballard, G. J. Forbes, and J. Bowman. 2002. Migration behavior of white-tailed deer under varying winter climate regimes in New Brunswick. Journal of Wildlife Management 66:718-728.

Sakkinen, H., A. Stein, O. Holand, K. Hove, E. Eloranta, S. Saarela, and E. Ropstad. 2000. Plasma creatinine concentration in semi-domestic free ranging reindeer, and in reindeer under defined feeding conditions. Advances in Ethology 35:76-83.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54:522-532.

Schultz, S. R., M. K. Johnson, S. E. Feagley, L. L. Southern, and T. L. Ward. 1994. Mineral content of Louisiana white-tailed deer. Journal of Wildlife Diseases 30:77-85.

Severson, K. E. 1981. Food habits and nutritional relationships of mule deer in Southwestern United States. Pages 149-164 *in* P. F. Ffolliott and S. Gallina, editors. Deer biology, habitat requirements, and management in Western North America. Instituto de Ecologia, A.C. Mexico, D.F.

Short, H. L. 1981. Nutrition and Metabolism. Pages 99-128 *in* O. C. Wallmo, editor. Mule and black-tailed deer of North America. University of Nebraska Press. Lincoln, USA.

Smith, B. 2001. Winter feeding of elk in western North America. Journal of Wildlife Management 65:173-190.

Smith, S. H., J. B. Holter, H. H. Hayes, and H. Silver. 1975. Protein requirement of white-tailed deer fawns. Journal of Wildlife Management. 39:582-589.

Tarr, M. D., and P. J. Pekins. 2002. Influences of winter supplemental feeding on the energy balance of white-tailed deer fawns in New Hampshire, U.S.A. Canadian Journal of Zoology 80:6-15.

Torbit, S. C., L. H. Carpenter, D. M. Swift, and A. W. Alldredge. 1985. Differential loss of fat and protein by mule deer during winter. Journal of Wildlife Management 49:80-85.

Ullrey, D. E., W. G. Youatt, H. E. Johnson, L. D. Fay, R. L. Covert, and W. T. Magee. 1975. Consumption of artificial browse supplements by penned white-tailed deer. Journal of Wildlife Management 39:699-704.

Underwood, E. J. 1977. Trace elements in human and animal nutrition. Academic Press, New York, New York, USA.

Unsworth, J. W., D. F. Pac, G. C. White. 1999. Mule deer survival in Colorado, Idaho and Montana. Journal of Wildlife Management 63:315-326.

Urness, P. J. 1980. Supplemental feeding of big game in Utah. Utah Division of Wildlife Resources, Publication No. 80-8. Salt Lake City, USA.

Utah Division of Wildlife Resources. 2000. Big game winter feeding. Utah Division of Wildlife Resources, Publication W5WLD-2, Salt Lake City, USA.

Utah Division of Wildlife Resources. 2003. Statewide management plan for mule deer. Utah Division of Wildlife Resources, Salt Lake City, USA.

Verme, L. J. 1962. Mortality of white-tailed deer fawns in relation to nutrition. Proceedings of the National Deer Disease Symposium 1:15-38.

Verme, L. J. and J. J. Ozoga. 1980. Effects of diet on growth and lipogenesis in deer fawns. Journal of Wildlife Management 4:315-324.

Vourch, G., J. Russell, and J.-L. Martin. 2002. Linking deer browsing and terpene production among genetic identities in Chamaecyparis nootkatensis and Thuja plicata (Cupressaceae). The Journal of Heredity 93:370-376.

Wakeling, B. F., and L. C. Bender. 2003. Influence of nutrition on mule deer biology and ecology. Pages 93-118 *in* J. C. deVos, Jr., M. R. Covover and N. E. Headrick, editors. Mule deer conservation: issues and management strategies. Jack H. Berryman Institute Press, Utah State University, Logan, USA.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30:122-127.

Wallmo, O. C., and W. L. Regellin. 1981. Rocky mountain and intermountain habitats-food habits and nutrition. Pages 387-399 *in* O.C. Wallmo, editor. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, USA.

White, R. G. 1992. Plenary lecture: nutrition in relation to season, lactation, and growth of north temperate deer. Pages 407-417 *in* R.D. Brown, editor. The biology of deer, Springer-Verlag Press, New York, New York, USA.

Wiklund, E., A. Andersson, G. Malmfors, and K. Lundstrom. 1996. Muscle glycogen levels and blood metabolites in reindeer (*Rangifer tarandus tarandus L.*) after transport and lairage. Meat Science 42:133-144.

CHAPTER 2

BIOLOGICAL EFFECTS OF WINTER-FEEDING OF MULE DEER IN NORTHERN UTAH[1]

ABSTRACT Benefits attributed to winter-feeding mule deer (*Odocoileus hemionus*) are largely site specific. Few studies have examined the long-term effects of winter-feeding on mule deer productivity. We studied the effects of a winter-feeding program conducted in northern Utah from 2001-2007 on body condition, mortality causes, productivity, and survival of 92 adult female deer (does) that were captured and radio-collared on 4 feed and 4 non-feed sites. We monitored over-winter fawn and adult mortality and determined the causes of mortality for the deer herds studied. We used cohort survival data in Program Mark to predict population trends in fed and non-fed deer. Although fed does exhibited increased body condition (P = 0.05), fawn production (P = 0.36) and overall mid-winter recruitment rates (fed=0.58, SE=0.022; non-fed=0.57, SE=0.04) did not differ. Deer vehicle collision and malnourishment were the major mortality causes for fed and non-fed does. Survival in radio-collared fed deer (s = 0.80, se = 0.03) was slightly, but not significantly higher than for non-fed deer (s = 0.73, se = 0.05, P = 0.121). The model predicted that both study populations were declining, however the fed population declined at a slower rate. Our results reinforce the arguments that any benefits accrued from feeding mule deer are site specific, and that even though small short-term increases in survival may be realized from such efforts, these gains may not mitigate population declines.

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[1] Coauthored by Peterson, C. C., and T. A. Messmer.

INTRODUCTION

Herd productivity and growth in mule deer (*Odocoileus hemionus*) populations are largely driven by survival of adult does. Mule deer survival and productivity also have been directly related to winter habitat conditions (Parker and Robbins 1984, Austin and Urness 1985, Olson and Lewis 1994, Robbins 1993). Thus, doe survival may generally be affected more by range condition than by unusual weather conditions (White and Bartmann 1998, Carpenter 1998).

In areas where winter range was in poor condition or deep snow reduced browse accessibility, feeding programs have been used to mitigate winter mortality (Urness 1980, Doenier et al. 1997). However, results regarding the benefits of winter-feeding programs on overall herd survival and production are mixed.

Ozoga and Verme (1982) reported improved individual body condition in fed deer. Robinette et al. (1973), Ozoga and Verme (1982), and Baker and Hobbs (1985) documented increased survival and productivity. Baker and Hobbs (1985) reported that although feeding of deer may increase adult survival, it did not eliminate large winter losses due to severe conditions. Some other reported outcomes of feeding programs include degraded range (*Odocoileus virginianus*, Cooper et al. 2006), increased competition (Schmitz 1990), altered distribution of animals on the landscape and changed use of habitat (Murden and Risenhoover 1993), and altered migration (Peterson and Messmer 2007).

The differing effects of feeding programs on mule deer are largely attributed to site specific conditions (Doenier et al. 1997, Smith 2001, Tarr and Pekins 2002, Peterson and Messmer 2007). Site-specific factors may include placement, type, and number of feed stations used (Ozoga and Verme 1982, Schmitz 1990, Page 2006), nutritional content of supplements (Doman and Rasmussen 1944, Schoonveld et al. 1974, Ouellet et al. 2001), inappropriate animal condition indices (Saltz and Cook 1993, Moen and DelGiudice 1997, DelGiudice et al. 2000), and timely implementation of feeding (deCalesta et al. 1975). Because deer that are fed may continue to browse, site-specific characteristics such as available browse also may influence efficacy of feeding (Hubert et al. 1980, Doenier et al. 1997, Ouellet et al. 2001). Given these site-specific variables, the effects of feeding programs on mule deer herd population may be determined only through site-specific monitoring over time (Doenier et al. 1997).

In 2001, the Utah Division of Wildlife Resources (UDWR) implemented emergency winter-feeding for mule deer in northern Utah that continued through winter 2004-2005. This management action created the opportunity to evaluate the long-term effects of winter-feeding on mule deer biology in northern Utah. The primary objectives of this study were to determine if survival, productivity, and causes of mortality differed for cohorts of fed and non-fed mule deer over multiple, consecutive years under variable environmental conditions. The study populations shared summer and transitional ranges but occupied different winter ranges. We hypothesized that if malnourishment was a major cause of mortality for this herd, supplemental feeding would lead to increased mule deer nutritional status as evidenced by body condition indices, and translate into increased survival, productivity, and ultimately a larger overall population. We conducted this study in the Cache-Wasatch Mountains of northern Utah.

STUDY AREA

Our study area was bisected by U.S. Highway 89 which extended from Logan, UT, northeast to the west shore of Bear Lake at Garden City, UT, and by U.S. Highway 91 on the west face of the Cache-Wasatch Mountains (Fig. 2-1). Elevations range from 1,350 meters to 2,997 meters. Higher elevations in the unit provided mule deer fawning and summer range, while lower elevations constituted critical mule deer winter range. Winter ranges were typically associated with a narrow belt of sagebrush-bitterbrush habitat (*Artemisia tridentata-Purshia tridentata)* along foothills. This winter range was highly fragmented due to increasing urbanization (UDWR 2003). Range vegetation of the area was typical of the Intermountain West (West 1983).

The area typically has warm, dry summers, and cold, snowy winters. During this study, weather extremes were recorded for snow accumulation, high and low temperatures, and severe drought (Utah Climate Center, December 01, 2007).

METHODS

Study Sites

We identified 19 potential study sites and randomly assigned 4 as treatment and 4 as control sites. All sites had similar vegetation types, slope, aspect, elevation, and climate, and were located in the mouths of canyons within critical winter range. Sites were centered on a location with easy access for feed distribution. McClure (2001) reported maximum winter home ranges of about 469 hectares for mule deer that wintered in the study area. In general, distance from bedding to feeding site for deer in winter in northern Utah does not exceed 1500 m (D. Austin, Utah Division of Wildlife Resources, retired, personal communications). To minimize the chance of overlapping use of treatment and control sites by individual deer, we used this information to define the radius of each circular experimental site as 1500 m, inclusive of 706 ha, then located the center of treatment sites >3 km from the center of control sites.

Feeding Operations

Daily *ad libitum* feeding was initiated by local sportsmen under the supervision of the UDWR in late December of winter 2001-2002 (hereafter called winter 2001), and in early January in winter 2002-2003, 2003-2004, and 2004-2005 (hereafter referred to as winter 2002, winter 2003, and winter 2004, respectively). All winter-feeding programs were terminated concurrent with spring green-up in mid-to-late March. No feeding was conducted in winter 2005-2006 (hereafter called winter 2005).

Feed rations consisted of whole corn (*Zea mays*), high-quality alfalfa hay (*Medicago sativa*), and commercially formulated 14% protein pellets. Rations were distributed in poly-resin half-barrels separated by 5-10 meters. Rations were provided at a recommended rate of 0.9 kg/deer/day (D. Austin, UDWR, unpublished report).

Radio Telemetry

From January through early March of 2001-2005, we captured mule deer in Clover Traps (Rongstad and McCabe 1984) on all feed and non-feed sites. To reduce stress, captured animals were hobbled, fitted with blinders, and immediately processed on site (DelGiudice et al. 1990, Millspaugh et al. 2000). The information collected included blood samples, age, weight, and body condition estimates (Severinghaus 1949, Pedersen and Pedersen 1975, Kistner et al. 1980). Each adult doe was fitted with a radio-collar with mortality sensor (AVM Instrument Co., Ltd., Colfax, CA). The study protocol was approved by the Utah State Institutional Animal Care and Use Committee (Permit #1084).

Body Condition Indices

To evaluate body condition, we developed an index (hereafter referred to as modified body condition index or MBC) by combining metrics from field techniques for evaluating deer and range livestock condition (Harris 1945, Riney 1960, Kistner et al. 1980, Austin 1984, Bennett and Wiedmeier 1992, Momont and Pruitt 1998). Our MBC index was based on manual and visual evaluations of fat deposits and muscling on rump, withers, ribs-brisket, and back, and a subjective appearance score. Each deposit area was ranked individually. The mean of the 4 scores was then added to the subjective score to assign an overall condition score (C. Peterson, Utah State University, unpublished data). Body condition scores ranged from 5 to 15 where 5 = poor, 10 = fair, and 15 = good (Harris 1945).

To evaluate physiological condition for captured deer, we drew veinous blood samples from the jugular using 20-cc syringes with 20-G, 3.75-mm needles and immediately placed the samples in 2, 10-ml red top glass tubes (Pedersen and Pedersen 1975) in insulated bags to protect them from excessive temperature changes. Blood samples were centrifuged and submitted within 24-48 hrs to Logan Intermountain Health Care Laboratory Services for evaluation of serum urea nitrogen (SUN), creatinine (C), and SUN/C (Kirkpatrick et al. 1975, Parker et al. 1993, DelGiudice et al. 1994).

We correlated body condition and serum indices in a Friedman's super graph (S-Plus 2003, Friedman 1984), and assessed the strength of correlation between the indices with a Spearman Correlation Test. We tested for main effects of feeding, year, and feeding*year interaction with a mixed model. Site was included in the model as a random factor nested within feed (SAS 2001). Degrees of freedom were calculated using the Satterthwaite method (Zar 1999). We considered tests with $P \leq 0.05$ significant.

Mortality

Radio-collared does were monitored 2-3 times/week. When a mortality signal was detected, carcasses were located and examined within 48 hours, and the cause of mortality was determined using protocols described by Harris (1945), Gill and O'Meara (1965), Ransom (1965) and Trainer et al. (1981). Mortalities were assigned to 1 of 7 categories; 1) deer vehicle collision (DVC), 2) predation, 3) malnourishment, 4) complications incidental to parturition, 5) poaching, 6) causes incidental to age, 7) unknown/other (Carrel et al. 1999, Mayer et al. 2002). When mortality occurred within 14 days of capture, we removed it from evaluation to reduce bias from possible capture myopathy (Williams and Thorne 1996). When there was no apparent cause of death, we took the carcass to the USDA Veterinary Diagnostic Lab in Logan, UT for a detailed necropsy. To test for differences in cause of annual mortality for fed and non-fed does, we evaluated these data using a Pearson's chi-square test of homogeneity of proportions. Because of small cell counts we based the p-value on all possible permutations, rather than on an asymptotic assessment (SAS 2001). Inferential tests with $P \leq 0.05$ were considered significant.

We also determined the overall causes of over-winter mortality for the deer herds using each site. Each study site was surveyed for deer carcasses twice weekly throughout the winter. We estimated age and condition of each carcass by evaluating tooth eruption and wear, estimated body condition using our MBC index and by visual assessment of femur marrow fat (Kistner et al. 1980, Harder and Kirkpatrick 1996), and examined and necropsied each carcass to determine cause of mortality (Kistner et al. 1980, Harder and

Kirkpatrick 1996, Oliver 1997). As with radio-collared does, if the apparent cause of death could not be determined in the field, the carcass was transported to the USDA Veterinary Diagnostic Laboratory in Logan, UT for a detailed necropsy.

Additionally, in the early spring following migration, we stratified each study site according to terrain and vegetation and surveyed sites on foot or horseback to locate current-season carcasses. Carcasses were evaluated for cause of mortality as described above. To test the homogeneity for causes of over-winter mortality, we pooled data over years and treatments, and used a chi-square test ($P \leq 0.05$).

Herd Composition Data

We conducted deer classification counts over 3 to 5 consecutive days on all study sites in both early and late winter periods to determine herd composition (Pollock et al. 1985). Surveys consisted of counting all deer visible from a 1-mile observational track emanating from the site-center-point, over a 1 to 2-hour period, and classified animals observed as adult (buck or doe), fawns, or unknown. With this information we determined the rate of decline in fawn/adult ratios of fed and non-fed groups by calculating the difference between early and late winter fawn/adult ratios. Ratios were evaluated with an Analysis of Variance of a 2-way factorial in a split-plot design with a separate analysis for each year ($P \leq 0.05$; SAS 2001).

Productivity

During each fawning period, mid-May through mid-July, we monitored radio-collared does to determine reproductive status and identify specific fawning grounds. When fawning was imminent, each doe was visually monitored to determine the number of fawns produced. Because feeding was not implemented in 2006, fawn/doe ratios for this year were dropped from analysis. Fawn/doe data of radio collared does were weighted according to the percentage seen relative to availability on each site. We tested weighted fawn/doe ratios for effects of feeding, year, and site with a repeated measures mixed model, repeated over 4 years (SAS 2001). Site was included in the model as a random factor nested within treatment ($P \leq 0.05$).

Annual Survival

To analyze annual survival for radio-collared deer, we pooled data by season; 1) winter and feeding season, 25 December–30 April, 2) fawning season and summer, 1 May–31 August, and 3) fall and hunting season, 1 September–24 December. If a radio-collared doe was re-sighted at least once during the season, it was recorded as a re-sight. We calculated survival probabilities for 3 seasons and estimated survival, using the known fate model in Program Mark (White and Burnham 1999). Because seasonal survivals were unequal, we standardized all estimates to annual survival probabilities using unequal time intervals in Program MARK ($P \leq 0.05$).

Because a major objective of this study was to determine if the winter-feeding benefited mule deer populations over time in northern Utah, we developed models to predict the effects of feeding on survival and recruitment on population size. To conduct this evaluation, we constructed 11 models using Program MARK. To account for possible extraneous sources of temporal and spatial variation (environmental stochasticity), and assess the effects of feeding on mule deer survival we included year, season, and site in all models.

Sites were ranked according to habitat quality. Habitat quality was assigned subjectively as poor, fair, good, or excellent based on our experience, in concert with an assessment of the relative proportion of the site that was degraded and the frequency of human disturbance. We defined degraded winter range as historic winter range lacking the winter browse component, including sagebrush, bitterbrush, and associated species, due to past urban and/or agricultural practices. Poor-quality habitat was defined as sites that have more than 50% degraded winter range and constant human activity on more than half of the site. Fair quality habitat was characterized with degraded winter range on 25-50% of the site and constant human activity on less than half of the site. Good quality was defined as degraded range, and periodic heavy human activity on 25-50% of the site. Excellent quality habitat was defined as little degraded winter range, and limited human disturbance on less than 25% of the site. Habitat quality of feed sites ranked as 2 excellent, 1 good, and 1 fair. Non-feed site rankings were 1 excellent and 3 good quality. Although not a major factor of this study, we included the quality rankings as a continuous covariate for all models including site, and used Akaike's Information Criterion to correct for small sample bias (AICc), and Akaike weights to rank models (Burnham and Anderson 2002).

A secondary objective was to assess the effect of the major cause of mortality on survival. This effect was evaluated by removing all mortalities attributed to the cause from the input data set and re-running the analysis in Program Mark as previously described. This allowed for comparison of survival for fed and non-fed deer, both including and excluding the major cause of mortality. We used a Wald-statistic to assess all survival differences (Agresti 1996).

Population Model Construction and Parameterization

To investigate the effects of feeding on population dynamics, we used classification count data to construct a stochastic, stage structured population model. To keep the model consistent with the timing of composition surveys from which model recruitment was estimated, we used a post-reproductive census structure. Thus, we modeled the female population in annual time steps, referenced to the time of annual herd composition surveys in December. Because we classified yearlings as adults, we included only 2 age classes of females in the model, fawns (*J*) and adults (*D*). As no data were collected on fawn (6-18 months) survival we used adult survival rates for both age categories of deer; thus $S_J = S_A$ in the model. The proportion of male/female fawns did not become explicit in the model until December. At this point we assumed a 50:50 sex ratio denoted as g in the model. We defined recruitment as fawns/doe in late winter, calculated from the known herd class counts and denoted as R in the model. Harvest was not included in the model because antlerless deer have not been harvested in this unit for the past 5 years and are not expected to be harvested in the near future (UDWR 2002; D. DeBloois, UDWR, personal communications). The basic form of the model is:

$$N_T(t) = N_D(t) + N_J(t),$$

and the equations to project the population from year *t* forward to year *t+1* are:

$$N_D(t+1) = N_D(t) \times s_A + N_J(t) \times g \times s_A,$$

$$N_J(t+1) = N_D(t) \times s_A \times R, \text{ and}$$

$$N_T(t+1) = N_D(t+1) + N_J(t+1).$$

We used annual field estimates to parameterize the population model. Annual survival estimates came from a S(group + year) model in Program Mark, and recruitment estimates came from average annual fawn/doe ratios. Temporal stochasticity was included based on variation in annual survival and recruitment estimates. For each fed and non-fed deer group, annual survival was estimated from 2001-2006 and annual recruitment from 2003-2006. We included temporal (process) and sampling variance in the variance of annual estimates. For lack of enough annual estimates to partition out the 2 types of variance, we did not use a variance components approach to remove sampling variation (Burnham and White 2002). The inclusion of sampling error inflates the variance estimates (White 2000, Morris and Doak 2002). Thus, variance estimates on predicted population size were biased high, and the confidence interval on the difference in number of deer between fed and non-fed deer was biased long.

All simulations were run in Excel (Microsoft Office XP Enterprise Professional, Microsoft Corporation, USA). The initial population vector was derived from a population estimate of 7,000 deer (D. Austin, UDWR, personal communication), and the average proportions of females and fawns from composition counts conducted 2003-2006 for each group, fed and non-fed. We did not include stochasticity in the initial proportion of fawns and does in the model because variance in these parameters did not change the predicted estimates past the third year, which is when the population went to its stable age distribution given the data-based range in initial proportions. We ran 1000 simulations based on a parametric bootstrap of vital rates using a beta distribution to match observed means and variance to estimate the expected population size for feeding and non-feeding management scenarios. Using survival and recruitment estimates, and their variance observed for the feeding and non-feeding groups, we estimated the predicted mean population size and the difference for the 2 groups at the end of 5 years. We chose 5 years because it represents the length of a typical deer management plan.

RESULTS

Radio Telemetry

We captured and radio-collared 92 mule deer does (fed n=53, non-fed n=39). These deer were monitored from May of 2002 through January of 2006.

Condition Indices

Body condition indices were previously determined and reported in an article in the Journal of Wildlife Management by Peterson and Messmer (2007). In general, fed deer maintained higher body condition, higher C, and lower SUN/C levels than non-fed deer.

Annual Doe Mortality

Fourteen radio-collars (15%) were found without a carcass present. Thus, we were unable to determine the fate of these animals. At the conclusion of this study, 53 of the 92 radio-collared does had died (58%), including 28 of 53 fed deer (53%), and 25 of 39 non-fed deer (64%). The cause of mortality was determined for 43 of the 53 (81%) radio-collared does (Table 2-1) and did not differ for fed and non-fed does ($\chi^2_6 = 1.85$, $P = 0.97$). Due to location and associated clues, mortalities classed as unknown did not include a possibility of DVC. The primary causes for mortality were DVCs (fed n=10, 40%; non-fed n=8, 29%) and malnourishment (fed n=9, 32 %; non-fed n=8, 32%). DVC mortalities occurred predominantly, though not exclusively, from February –April and August-November. Malnourishment mortalities occurred mainly from February-April.

Over-Winter Deer Mortality

Over-winter deer mortality surveys revealed 404 mortalities on feed sites and 326 on non-feed sites. Total number of mortalities on all sites (n=730) varied from 261 in winter 2001, to 74 in winter 2002, 194 in winter 2003, 79 in winter 2004, and 122 in winter 2005 (χ^2_5 = 18.9, P = 0.002). Of all winter survey mortalities, 11% were attributed to DVC, 8% to predation, 59% to malnourishment, and 22% to unknown/other causes. Poaching and causes incident to parturition accounted for <1% each. Cause of over-winter mortality varied by year (χ^2_{20} = 418, P $\leq$ 0.001). Eighty-six percent of mortalities in winter 2001 were attributed to malnourishment whereas in winter 2002, 55% were due to DVC, and in winter 2003 14% were due to predation. In winter 2004, 20% of mortalities were attributed to malnourishment and 70% to unknown/other causes. In winter 2005 there were fewer mortalities due to DVC than expected, only 2%, and more than expected due to predation, 14%. Data pooled over treatment indicated there were more DVCs than expected on non-feed sites, and fewer than expected on feed sites (χ^2_5=51, P $\leq$ 0.001).

Herd Composition Data

Fawn/adult ratios of both fed and non-fed groups declined ($F_{1,6}$ = 0.22, P = 0.66). Fed fawn/adult declines ranged from 13% in winter 2005 to 36% in winter 2003 (Table 2-2). Non-fed fawn/adult declines ranged from 9% in winters 2002 and 2005 to 80% in winter 2001.

Annual Productivity

Summer fawn/doe ratios of radio-collared fed and non-fed groups did not differ (treatment*year: $F_{3,13.6}$ = 1.17, P = 0.36; treatment: $F_{1,9.08}$ = 0.01, P = 0.91; year: $F_{3,13.6}$ = 2.76, P = 0.08; Table 2-3).

Annual Survival

We included 90 does in the analysis of survival, 52 in the feed and 38 in the non-feed groups. On the basis of minimum AICc (Akaike's Information Criterion) the best model was S(.), in which survival is constant between fed and non-fed groups, as well as being constant through time and across sites (Table 2-4). The second best model, which was 0.6 ΔAICc units from the top model, was S(group) in which survival differed between the fed and non-fed groups, but was constant through time and across sites. Because this was the best model with fed and non-fed groups, and because it is similar to the top model, we used this model to estimate survival in the population model (Burnham and Anderson 2002)

In this study, both fed and non-fed groups were declining (Table 2-5). Although survival for fed deer (s = 0.80, SE = 0.03) was slightly higher than for non-fed deer (s = 0.73, SE = 0.05), this difference was not significant (P = 0.121, one-sided test). The effect of DVC on survival was similar to the effect of feeding, though non-significant. Removing the effect of DVCs increased survival of fed deer to 0.84 (SE = 0.033, P = 0.19), and of non-fed deer to 0.79 (SE=0.05, P = 0.19).

Population Model

Following 1,000 simulations, the model predicted that under similar environmental conditions, at the end of 5 years the average population size for fed and non-fed deer would respectively be 4,980 and 3,101 (range 17-3,741, 95% CI; Fig. 2-2).

DISCUSSION

The population models developed based on the deer herd metrics we recorded predicted that these populations were declining. However, in this study, feeding of high quality supplements enhanced mule deer winter body condition and resulted in slight, if non-significant increases in doe survival. The slightly higher annual survival of fed does over several years, although not significant, when modeled over time predicted that the rate of decline in fed deer was lower than non-fed deer. These results parallel those reported by Robinette et al. (1973), Ozoga and Verme (1982), Baker and Hobbs (1985), and Langenau (1996).

Body condition, SUN, and SUN/C varied annually, probably in response to severity of winter conditions (Torbit et al. 1985, Parker et al. 1996). All condition indices indicated fed deer maintained higher nutritional condition throughout the winter season. This increased nutritional level during later stages of gestation (late winter and early spring) may affect the health and survival of newborn fawns. Enhanced body condition that leads to increased survival of does during severe winters may also mitigate population fluctuations (Bartmann et al. 1992).

The two most frequent causes of mortality for our study populations were DVC and malnourishment. The number of DVCs we recorded was 3 times higher than reported for other mule deer herds (Sawyer and Lindzey 2001). The effect of the high number of DVCs on doe survival was similar to that reported for a mule deer herd inhabiting range near Estes Park, CO, mule deer herd (Conner 2004). Overall the impact of DVC on decreased survival was slightly greater than the effect of the feeding program on increased survival.

More mortality attributed to malnourishment occurred in winters with the most severe conditions when feeding was conducted. However, feeding did not decrease the percent of total mortalities attributed to malnourishment. Generally the average duration of survival of normal winter malnourishment (30-60 days) depends on not only the severity and duration of the conditions, but also on the initial condition of the deer and of the winter habitat (deCalesta et al. 1975, Wallmo et al. 1977, Anderson 1981, DelGiudice et al. 1990, Olson and Lewis 1994). This strongly suggests that there may be other factors involved in malnourishment.

Although feeding programs may increase body condition and survival (Ullrey et al. 1975), the onset of severe storms coupled with normal winter malnourishment may increase metabolic costs beyond survivable levels (Kistner et al. 1980, Baker and Hobbs 1985, Smith 2001). This effect may be greater in fawns because of their higher relative metabolic rates (Moen 1968, Verme and Ozoga 1980, Parker et al. 1984, DelGiudice et al. 2002, Picton 1979, Hobbs 1989). In addition, it may not be possible to prevent fawn mortality on feed sites due to increased competition and indigestibility of feed rations (Doman and Rasmussen 1944, Langenau 1996). We observed consistent and obvious agonistic behavior between adult deer and fawns, tending to reduce fawn access to feed rations, even when feed stations were well dispersed and abundantly filled. However, when competition and severity of conditions was reduced as in winters 2002-2003 and 2005-2006, fawn/adult ratios still declined. Severe winter conditions did not occur equally on all sites and may have contributed to the high variability. The inference from these data is that feeding programs do not meet the needs of all fawns under most conditions, and benefits are more likely to occur during the most severe conditions (Baker and Hobbs 1985).

In addition, distribution of corn, hay, and formulated pellets, although high in energy and protein, does not address the possibility of other nutrient deficiencies. Seldom addressed but common chronic or low level mineral deficiencies reduce survival (Robbins 1983, McDowell 1992), and productivity (Underwood 1977, Robbins 1983, Flueck 1994). Furthermore, mineral deficiencies may increase seasonally with food shortages, with typical winter low protein high lignin diets, or with the increased requirements of gestation (Robbins 1983, McDowell 1992).

Mortality data for non-radio collared deer pooled over feed and non-feed sites indicated there were more DVCs than expected on non-feed sites, and fewer than expected on feed sites. Although all sites were bisected by roads, ~25% of 2 feed sites were located within municipal boundaries and roads on 1 non-feed site experienced heavier, faster traffic. As a result, residents and municipal road maintenance personnel regularly collected and disposed of DVCs from the 2 affected feed sites resulting in decreased numbers of DVC mortalities on theses sites. In addition, it is possible that some mortality on the 2 affected feed sites was attributed to other causes, when in fact, it was DVC carcasses from outside of the site, discarded on the site so as to be out of sight of the public. Thus, the proportions of over-winter mortality for non-radio collared deer due to DVC, malnourishment, and predation may be biased.

Mountain lions (*Felix concolor*), bobcat (*Lynx rufus*), and coyotes (*Canis latrans*) were present on all of the study sites and some mortalities were due to predation. In addition, mortalities due to predation were usually heavily scavenged. Most sign indicating predation was erased by the time of spring mortality surveys. Therefore some mortalities assigned to unknown/other causes, may have been due to predation. Still, predation during this study was minimal, particularly in view of mortalities due to DVC and malnourishment.

Fawn production by our radio-collared does was highly variable. Extremes in winter weather coupled with differential quality of winter range habitat may again have played a role in this variability. Alternatively, the variability may have been due to the small sample sizes and few years of the study. Still, our fawn/doe ratios compare favorably with some high ratios reported for this herd from 1930-1950 (Robinette 1976). Growth of mule deer populations is determined by survival of does (Carpenter 1998, White and Bartmann 1998, Unsworth et al. 1999). Due to their relatively greater body mass, does are less susceptible to winter kill than are fawns. Average doe survival for mule deer in the intermountain west is 5-12% higher (mean = 0.85, SE = 0.011; Unsworth et al. 1999) than for this population. Our model suggested that even small increases in doe survival attributed to winter-feeding can affect population trends over the long term.

MANAGEMENT IMPLICATIONS

Although the models developed on the data we recorded for our study populations predicted that the slight increase observed in survival for fed deer would mitigate population declines when compared to non-fed deer, these benefits were nullified by DVC mortalities. Furthermore, deteriorating winter range habitat conditions and increased human disturbance exacerbated these losses. To reverse the population declines, managers and stakeholders will need to implement management actions that address cumulative impacts.

If the goal of a winter-feeding program is to increase survival, the efficacy of the program would be increased by assessing site-specific factors such as weather conditions, browse production, deer condition, and numbers. This requires consistent localized monitoring of deer, range, and weather conditions in areas historically prone to weather events leading to a perceived need to feed. Furthermore, the final benefit from winter-feeding can only be determined from careful establishment of the program goal(s), and considering the long-term results.

ACKNOWLEDGMENTS

We thank D. Turner, S. Durham, and M. Conner for statistical advice. This project was funded by the Utah Division of Wildlife Resources, Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension. The U.S. Forest Service granted access to several of the study sites.

LITERATURE CITED

Agresti, A. 1996. An introduction to categorical data analysis. John Wiley and Sons, New York, New York, USA.

Anderson, A. E. 1981. Morphological and physiological characteristics. Pages 27-98 *in* O. C. Wallmo, editor. Mule and black-tailed Deer of North America. University of Nebraska Press, Lincoln, USA.

Austin, D. D. 1984. Fat depth at the xiphod process: a rapid index to deer condition. Great Basin Naturalist 44:178-181.

Austin, D. D., and P. J. Urness. 1985. Values of four communities for mule deer on ranges with limited summer habitat. Journal of Range Management 38:167-171.

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Bartmann, R. M., G. C. White, and L. H. Carpenter. 1992. Compensatory mortality in a Colorado mule deer population. Wildlife Monographs 121:1-39.

Bennett, J. A., and R. D. Wiedmeier. 1992. Visual body condition score as a measure of range animal response. Rangelands 14:296-298.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Burnham, K. P., and G. C. White. 2002. Evaluation of some random effects methodology applicable to bird ringing data. Journal of Applied Statistics 29:245-264.

Carpenter, L. H. 1998. Deer in the West. Pages 1-10 *in* Proceedings of the 1997 deer/elk workshop, Rio Rico, Arizona. Arizona Game and Fish Department, Phoenix, USA.

Carrel, W. K., R. A. Ockenfels, R. E. Schweinsburg. 1999. An evaluation of annual migration patterns of the Paunsaugunt mule deer herd between Utah and Arizona. Arizona Game and Fish Department Research Branch. Technical Report Number 29, Phoenix, USA.

Conner, M. M. 2004. Estimation of mule deer population size, survival, and a description of movements in Rocky Mountain National Park. In collaboration with Hobbs, N. T., and M. W. Miller. Prepared for Rocky Mountain National Park.

Cooper, S. M., M. K. Owens, R. M. Cooper, and T. F. Ginnett. 2006. Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66:716-726.

deCalesta, D. S., J. G. Nagy, and J. A. Bailey. 1975. Starving and refeeding mule deer. Journal of Wildlife Management 39:663-669.

DelGiudice, G. D., K. E. Kunkel, L. D. Mech, and U. S. Seal. 1990. Minimizing capture-related stress on white-tailed deer with a capture collar. Journal of Wildlife Management 54:299-303.

DelGiudice, G. D., L. D. Mech, and U. S. Seal. 1994. Undernutrition and serum and urinary urea nitrogen of white-tailed deer during winter. Journal of Wildlife Management 58:430-436.

DelGiudice, G. D., K. D. Kerr, L. D. Mech, and U. S. Seal. 2000. Prolonged winter undernutrition and the interpretation of urinary allantoin:creatinine ratios in white-tailed deer. Canadian Journal of Zoology 78:2147-2155.

DelGiudice, G. D., M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. Journal of Wildlife Management 66:698-717.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Doman, E. R., and D. I. Rasmussen. 1944. Supplemental feeding of mule deer in northern Utah. Journal of Wildlife Management 8:317-338.

Flueck, W. T. 1994. Effect of trace elements on population dynamics: Selenium deficiency in free-ranging black-tailed deer. Ecology 75:807-812.

Friedman, J. H. 1984. A variable span smoother. Laboratory for Computational Statistics, Technical Report 5, Department of Statistics, Stanford University, California, USA.

Gill, J. D., D. C. O'Meara. 1965. Estimating time of death in white-tailed deer. Journal of Wildlife Management 29:471-486.

Harder, J. D., and R. L. Kirkpatrick. 1996. Physiological methods in wildlife research. Pages 275-306 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Harris, D. 1945. Symptoms of malnutrition in deer. Journal of Wildlife Management 9:319-322.

Hobbs. N. T. 1989. Linking energy balance to survival in mule deer: development and test of a simulation model. Wildlife Monographs 101:1-39.

Hubert, G. F., A. Woolf, and G. Post. 1980. Food habits of a supplementally-fed captive herd of white-tailed deer. Journal of Wildlife Management 44:740-746.

Kirkpatrick, F. L., D. E. Buckland, W. A. Abler, P. F. Scanlon, J. B. Whelan, and H. E. Burkhart. 1975. Energy and protein influences on blood urea nitrogen of white-tailed deer fawns. Journal of Wildlife Management 39:692-698.

Kistner, T. P., C. E. Trainer, and N. A. Hartmann. 1980. A field technique for evaluating physical condition of deer. Wildlife Society Bulletin 8:11-17.

Langenau, E. E. 1996. Artificial feeding of Michigan deer in winter. Wildlife Division Report Number 3244, Lansing, Michigan, USA.

Mayer, M. S., T. K. Fuller, R. D. Deblinger, and J. E. McDonald. 2002. Can low-precision population and survival estimates of deer be accurate? Wildlife Society Bulletin 30:440-448.

McClure, M. F. 2001. Energy, fractal movement patterns, and scale-dependent habitat relationships of urban and rural mule deer. Thesis, Utah State University, Logan, USA.

McDowell, L. R. 1992. Minerals in Animal and Human Nutrition. First edition. Academic Press, New York, New York, USA.

Millspaugh, J. J., M. A. Coleman, P. J. Bauman, K. J. Raedeke, and G. C. Brundige. 2000. Serum profiles of American elk, Cervus elaphus, at the time of handling for three capture methods. Canadian Field Naturalist 114:196-200.

Moen, A. N. 1968. Energy balance of white-tailed deer in the winter. Transactions of North American Wildlife and Natural Resources Conference 33:224-236.

Moen, R., and G. D. DelGiudice. 1997. Simulating nitrogen metabolism and urinary urea nitrogen:creatinine ratios in ruminants. Journal of wildlife management 61:881-894.

Momont, P. A., and R. J. Pruitt. 1998. Condition scoring of beef cattle. Utah State University, Cooperative Extension System, Report CL720, Logan, USA.

Morris, W. F., and D. K. Doak. 2002. Quantitative conservation biology. Sinauer and Associates, Sunderland, Massachusetts, USA.

Murden, S. B., and K. L. Risenhoover. 1993. Effects of habitat enrichment on patterns of diet selection. Ecological Applications 3:497-505.

Oliver, M. N. 1997. California deer condition index: a field technique for scoring body condition. California Department of Fish and Game and the School of Veterinary Medicine, University of California, Los Angelos, USA.

Olson, R., and A. Lewis. 1994. Winter big game feeding: an undesirable wildlife management practice. Department of Range Management, Cooperative Extension Service, University of Wyoming, Report B-1003, Laramie, USA.

Ouellet, J.-P., M. Crete, J. Maltais, C. Pelletier, and J. Huot. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129-135.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Page, B. D., and H. B. Underwood. 2006. Comparing protein and energy status of winter-fed white-tailed deer. Wildlife Society Bulletin 34:716-724.

Parker, K. L., and C. T. Robbins. 1984. Thermoregulation in mule deer and elk. Canadian Journal of Zoology 62:1409-1412.

Parker, K. L., C. T. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Parker, K. L., G. D. DelGiudice, and M. P. Gillingham. 1993. Do urinary urea nitrogen and cortisol ratios of creatinine reflect body-fat reserves in black-tailed deer? Canadian Journal of Zoology 71:1841-1848.

Parker, K. L., M. P. Gillingham, T. A. Hanley, and C. T. Robbins. 1996. Foraging efficiency: energy expenditure versus energy gain in free-ranging black-tailed deer. Canadian Journal of Zoology 74:442-450.

Pedersen, R. J., and A. A. Pedersen. 1975. Blood chemistry and hematology of elk. Journal of Wildlife Management 39:617-620.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Picton, H. D. 1979. A climate index and mule deer fawn survival in Montana. International Journal of Biometeorology 23:115-122.

Pollock, K. H., R. A. Lancia, M. C. Conner, and B. L. Wood. 1985. A new change-in-ratio procedure robust to unequal catchability of types of animal. Biometrics 41:653-662.

Ransom, A. B. 1965. Kidney and marrow fat as indicators of white-tailed deer condition. Journal of Wildlife Management 29:387-399

Riney, T. 1960. Field technique for assessing physical condition of some ungulates. Journal of Wildlife Management 24: 92-94.

Robinette, W. L., C. H. Baer, R. E. Pillmore, and C. E. Knittle. 1973. Effects of nutritional change on captive mule deer. Journal of Wildlife Management 37:3112-325.

Robinette, W. L. 1976. Probable causes of the recent decline of mule deer in western U. S. summary. Pages 125-127 *in* Mule deer decline in the West: A symposium, G. W. Workman, and J. B. Low, editors. Utah State University, Logan, USA.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, San Diego, California, USA.

Robbins, C. T. 1993. Wildlife feeding and nutrition. Second edition. Academic Press, San Diego, California, USA.

Rongstad O. J., and R. A. McCabe. 1984. Capture techniques. Pages 655-676 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvannia, USA.

Saltz, D., and D. E. Cook. 1993. Effect of time and snow dilution on cortisol:creatinine ratios in mule deer urine. Journal of wildlife management 57:397-399.

SAS Institute Inc. 1999-2001. SAS procedures guide, release 8.2 edition. SAS Institute Incorporated, Cary, North Carolina, USA.

Sawyer, H., and F. Lindzey. 2001. Sublette mule deer study. Final report. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, USA.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54:522-532.

Schoonveld, G. G., J. G. Nagy, and J. A. Bailey. 1974. Capability of mule deer to utilize fibrous alfalfa diets. Journal of Wildlife Management 38:823-829.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Smith, B. L. 2001. Winter feeding of elk in western North America. Journal of Wildlife Management 65:173-190.

S-PLUS 6.2 for Windows. 2003. Insightful Corporation, Seattle, Washington, USA.

Tarr, M. D., and P. J. Pekins. 2002. Influences of winter supplemental feeding on the energy balance of white-tailed deer fawns in New Hampshire, U.S.A. Canadian Journal of Zoology 80:6-15.

Torbit, S. C., L. H. Carpenter, D. M. Swift, and A. W. Alldredge. 1985. Differential loss of fat and protein by mule deer during winter. Journal of Wildlife Management 49:80-85.

Trainer, C. E., J. C. Lemos, T. P. Kistner, W. C. Lightfoot, and D. E. Toweill. 1981. Mortality of mule deer fawns in southeastern Oregon, 1968-1979. Oregon Department of Fish and Wildlife, Wildland Research Report 10, USA.

Ullrey, D. E., W. G. Youatt, H. E. Johnson, L. D. Fay, R. L. Covert, and W. T. Magee. 1975. Consumption of artificial browse supplements by penned white-tailed deer. Journal of Wildlife Management 39:699-704.

Underwood, E. J. 1977. Trace elements in human and animal nutrition. Academic Press, New York, New York, USA.

Unsworth, J. W., D. F. Pac, and G. C. White. 1999. Mule deer survival in Colorado, Idaho and Montana. Journal of Wildlife Management 63:315-326.

Urness, P. J. 1980. Supplemental feeding of big game in Utah. Utah Division of Wildlife Resources, Publication 80-8, Salt Lake City, USA.

UDWR. 2002. Utah Division of Wildlife Resources Antlerless Addendums. Utah Division of Wildlife Resources, Salt Lake City, USA.

UDWR. 2003. Statewide management plan for mule deer. Utah Division of Wildlife Resources, Salt Lake City, USA.

Verme, L. J. and J. J. Ozoga. 1980. Effects of diet on growth and lipogenesis in deer fawns. Journal of Wildlife Management 4:315-324.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30:122-127.

West, N. E. 1983. Temperate deserts and semi-deserts. Pages 321-471 i*n* N. E. West, editor. Ecosystems of the world. Volume 5. Elsevier Science Publication, Amsterdam, Netherlands.

White, G. C. 2000. Population viability analysis: data requirements and essential analysis. Pages 288 - 331 *in* L. Boitani and T. K. Fuller, editors. Research techniques in animal ecology – controversies and consequences. Columbia University Press, New York, New York, USA.

White, G. C., R. M. Bartmann. 1998. Mule deer management – what should be monitored? Pages 104-120 *in* J. C. deVos, editor. Proceedings of the 1997 Deer/Elk Workshop, Rio Rico, Arizona, Arizona Game and Fish Department, Phoenix, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study Supplement 46:120-138.

Williams, E. S., and E. T. Thorne. 1996. Exertional myopathy (capture myopathy). Pages 181-193 *in* A. Fairbrother, L. N. Locke, and G. L. Hoff, editors. Non-infectious diseases of wildlife. Iowa State University Press, Ames, USA.

Zar, J. H. 1999. Biostatistical analysis. Fourth edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Table 2-1. Frequency and percentage of 53 monitored fed and non-fed mule deer mortalities due to 6 causes, northern Utah, 2001-2007.

			Treatment			
Mortality Cause (n=53)	Total Number	Total %	Fed Number (n=28)	Fed %	Non-fed Number (n=25)	Non-fed %
DVC*	18	34	8	29	10	40
Predation	2	4	1	4	1	4
Malnourishment	17	32	9	32	8	32
Parturition Related	2	4	1	4	1	4
Poaching	1	2	1	4	0	0
Age Related	3	5	2	7	1	4
Unknown**/Other	10	19	6	21	4	16

*DVC=deer-vehicle-collision.

**Unknown does not include any possibility of DVC.

Table 2-2. Over-winter fawn mortality, mean fawns/100 adults for general population fed and non-fed deer, by early and late winter periods, northern Utah, 2001-2007.

		Treatment			
		Feed	%	Non-feed	%
Winter	Period	Fawns/100 Adults	Decline	Fawns/100 Adults	Decline
2001-2002	Early	63		51	
	Late	48	24	10	80
2002-2003	Early	45		23	
	Late	33	27	21	9
2003-2004	Early	64		60	
	Late	41	36	32	47
2004-2005	Early	68		36	
	Late	49	28	28	22
2005-2006*	Early	45		44	
	Late	39	13	40	9

* Winter 2005-2006 was a non-feed year on both feed and non-feed sites.

Table 2-3. Fawn production by monitored fed and non-fed female mule deer, northern Utah, 2001-2007.

	Treatment			
	Feed		Non-feed	
Winter	Fawns	Does	Fawns	Does
2002-2003	9	7	6	6
2003-2004	19	20	10	9
2004-2005	27	34	6	12
2005-2006*	29	33	22	21
2006-2007*	20	19	7	7

* Winters 2005-2006 and 2006-2007 were non-feed years on both feed and non-feed sites.

Table 2-4. Model selection results from analysis of doe survival for fed and non-fed groups, northern Utah, 2001-2007.

Model[a]	No. of parameters	AIC_c	ΔAIC_c	Akaike weights	Model likelihood	Deviance
{S(.)}	1	340.87	0.00	0.31	1.00	338.86
{s(group)}	2	341.46	0.60	0.23	0.74	337.44
{S(group*site) }	4	342.51	1.65	0.13	0.44	334.45
{S(group+site) }	3	343.35	2.48	0.09	0.29	337.31
{S(group+season)}	4	344.36	3.50	0.05	0.17	336.29
{S(group+year) }	7	345.06	4.19	0.04	0.12	330.87
{S(group*year) }	11	345.48	4.61	0.03	0.10	323.02
{S(group*season)}	6	347.55	6.68	0.01	0.04	335.41
{S(group+year+seasonr)}	9	347.94	7.07	0.01	0.03	329.63
{S(group+t)}	18	348.81	7.94	0.01	0.02	311.62
{S(group*t) }	34	367.12	26.25	0.00	0.00	294.88

[a] Group = fed or non-fed deer, site=feeding site quality, season=winter, summer, or fall, t = season and year, that is survival is different for each time period, or in this case, different for each season of each year.

Table 2-5. Field based estimates of vital rates for does used in a population model, northern Utah, 2001-2007.

Group	Parameter[a]	Data time frame	Estimate	Variance[b]
Feed	Survival	2001-2006	0.799	0.004
	Recruitment	2003-2006	0.584	0.016
	Initial prop. fawns	2003-2006	0.318	
	Initial prop. does	2003-2006	0.469	
Non-feed	Survival	2001-2006	0.715	0.006
	Recruitment	2003-2006	0.569	0.024
	Initial prop fawns	2003-2006	0.381	
	Initial prop does	2003-2006	0.533	

[a] Survival and recruitment were based on averages of annual estimates, while estimates of initial proportion fawns and does were based on average proportion for all years.

[b] No variance was included in the model for the initial proportion of fawns and does.

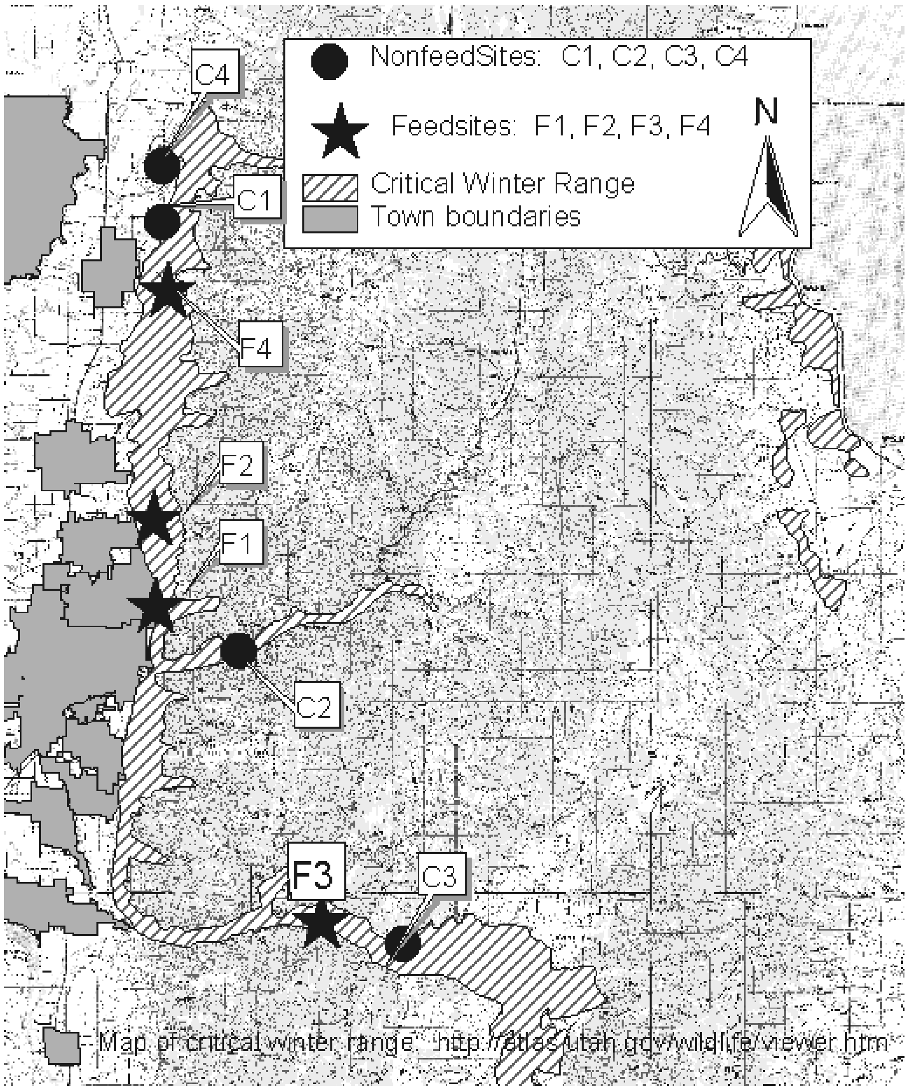

Figure 2-1. Location of treatment (feed=F) and control (non-feed=C) sites, northern Utah, 2001-2007.

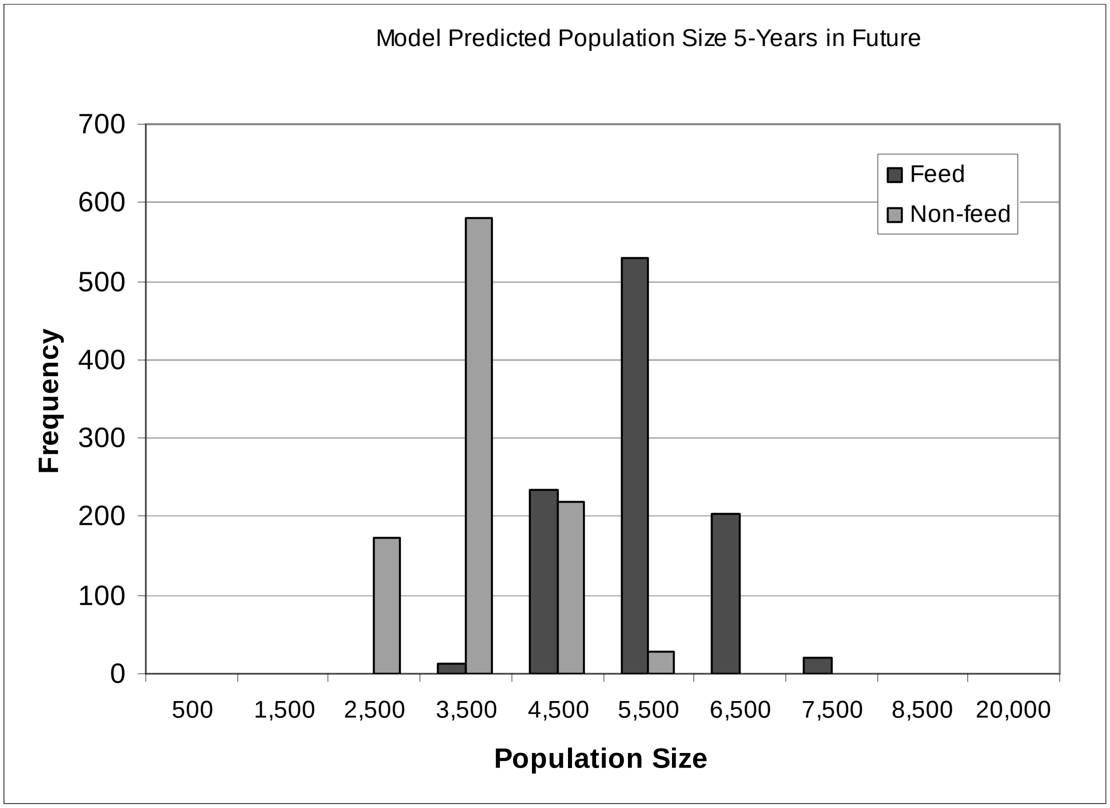

Figure 2-2. Histogram of predicted mule deer doe population sizes at the end of 5 years for fed and non-fed groups with 1000 simulations, northern Utah, 2001-2007.

CHAPTER 3

EFFECTS OF WINTER-FEEDING ON MULE DEER MIGRATION AND WINTER HABITAT IN NORTHERN UTAH[2]

ABSTRACT While winter-feeding programs may improve time-energy budgets for mule deer (*Odocoileus hemionus*), the effects on seasonal migration and winter range browse may mitigate these benefits We studied effects of supplemental feed rations on mule deer migration, and utilization and production of sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) on winter ranges where the feeding was conducted Feeding increased the mean duration on winter range from 7 to 51 days depending on the year ($F_{1,41} = 11.94$, $P = 0.0013$). Feeding also decreased mean duration on summer range by 14 to 19 days from 2003 to 2005 ($F_{3,96} = 3.19$, $P = 0.03$). Winter-feeding did not affect utilization or production of sagebrush, but increased utilization of bitterbrush 300% in winter 2003 and 854% in winter 2004 (treatment*year: F3,28 = 11.22, P <0.001), and production of bitterbrush by 171% in fall 2002 ($F_{1,5.2} = 4.31$, $P = 0.09$). Fed deer tended to concentrate within 375m from feed stations compared to more dispersed activity by non-fed deer ($\chi^2_{12} = 387$, $P \leq 0.001$). This magnified the effect of the winter-feeding on bitterbrush. These results suggest that prolonged and repeated use of the same sites for winter-feeding programs can impact behavior, further impacting winter range condition.

INTRODUCTION

Winter-feeding programs for deer (*Odocoilius* spp.) can increase energy gain per unit of time feeding and alter time-energy budgets (Ozoga and Verme 1982, Baker and

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[2]Coauthored by Peterson, C. C., T. A. Messmer, and F. D. Provenza.

Hobbs 1985, Schmitz 1990, Doenier et al. 1997). However, there is some concern about how altered time-energy budgets might affect traditional behaviors such as migration and concomitantly winter range condition in terms of browse production. Given annual variability in the effects of supplemental feeding programs on deer (Doenier et al. 1997), and the interactions of ration type, deer density, sex and age, and weather severity (Tarr and Pekins 2002), reports regarding the success and consequences of winter-feeding programs have been mixed (Doman and Rasmussen 1944, Ullrey et al. 1975, Schoen and Wallmo 1979, Dasmann 1981, Ouellet et al. 2001).

Interactions between plants and herbivores affect the composition and characteristics of plant and animal communities across landscapes (Swihart and Bryant 2001, Smith 1952). Variation in utilization through the season may alter plant communities as animals remove specific plant species, parts, and age classes (Bilbrough and Richards 1993, Augustine and McNaughton 1998, Krannitz and Hicks 2000). The resulting changes in plant communities affect the options and preferences of herbivores. Changes in the kinds and amounts of nutrients and secondary compounds in plants affect animal nutrition and health that in turn affect behaviors such as browsing, ruminating, and resting (Moen 1968, Kautz et al. 1982, Parker et al. 1996, Provenza et al. 2003). For example, mule deer (*O. hemionius*) may continue to browse when fed supplemental rations (Schmitz 1990, Peterson and Messmer 2007), and their increased preference for browse may remove desireable browse shrubs from the landscape (Murden and Risenhoover 1993).

As these interactions evolve through time, behaviors such as migration also may be affected resulting in altered duration on winter and summer ranges (Augustine and

McNaughton 1998, Alerstam et al. 2003). These behavioral responses in turn impact the food and habitat preferences of herbivores, as interactions between plants and herbivores are altered. Most of the reported long-term negative effects on habitat of emergency winter-feeding programs tend to be site specific (Gill and Carpenter 1985). While white-tailed deer (*O. virginianus*) migration was not affected by year-round feeding (Ozoga and Verme 1982), mule deer in northern Utah spent more time on winter range and less time on summer range (Peterson and Messmer 2007). As fawns learn food and habitat selection behaviors from their mother, a single season of feeding has the potential to affect behavior of multiple generations (Nelson 1979, Loft et al. 1989).

In winter 2001-2002, the Utah Division of Wildlife Resources (UDWR) implemented an emergency winter-feeding program for mule deer in northern Utah. We evaluated the effects of this program on mule deer behaviour and utilization of sagebrush (*Artemisia tridentata* ssp.) and bitterbrush (*Purshia tridentata*). Our objective was to determine if feeding altered mule deer migration, daily activity on the winter range, winter browse utilization and productivity.

STUDY AREA

This study was conducted in the Cache-Wasatch Mountains of northern Utah. The area was bisected by U.S. Highway 89 which extends from Logan, UT northeast to the west shore of Bear Lake at Garden City, UT. Elevations range from 1,350 meters to 2,997 meters. Higher elevations provide mule deer fawning and summer range, while lower elevations constitute critical mule deer winter range typically associated with a narrow belt of sagebrush, bitterbrush and juniper (*Juniperus* spp.) habitat along foothills and major drainages. Vegetation of the area is typical of the Intermountain West with big sagebrush (*A. tridentata tridentata*) along lower drainages, and Vasey sagebrush (*A. tridentata vaseyana*) on steeper slopes and benches (West 1983, Shultz 1984). The area experiences warm, dry summers, and cold, snowy winters. Effects of a drought peaked in 2002-2003. Precipitation increased slowly from 2004-2007.

METHODS

Study Sites

We identified 19 potential study sites and randomly assigned 4 as treatment and 4 as control sites. All sites had similar vegetation types, slope, aspect, elevation, and climate, and were located in the mouths of canyons within critical winter range. Sites were centered on a location with easy access for feed distribution. McClure (2001) reported maximum winter home ranges of about 469 hectares for mule deer that wintered in the study area. In general, distance from bedding to feeding site for deer in winter in northern Utah does not exceed 1500 m (D. Austin, Utah Division of Wildlife Resources, retired, personal communications). To minimize the chance of overlapping use of treatment and control sites by individual deer, we used this information to define the radius of each circular experimental site as 1500 m, inclusive of 706 ha, then located the center of treatment sites >3 km from the center of control sites.

Feeding Operations

Incident to severe winter conditions, in winter 2001-2002 (hereafter called winter 2001) the UDWR implemented a mule deer winter-feeding program in northern Utah. The feeding program reached ~10% of the herd population estimated at ~15,000. An estimated 45-50% of the herd died, including 80-90% of fawns, 40-60% of bucks, and

20-30% of does (D. Austin, UDWR, unpublished report). The feeding program was also implemented in winter 2002-2003 (hereafter called winter 2002), a very mild winter, to facilitate trapping of mule deer for evaluation of the feeding program, and again in winters 2003-2004 and 2004-2005 (hereafter called winter 2003 and winter 2004, respectively) due to severe winter conditions. All winter-feeding programs were terminated in mid-to-late March. Due to mild conditions, feeding was not conducted in winter 2005-2006 (hereafter called winter 2005).

Feed rations consisted of whole corn (*Zea mays*), high-quality alfalfa hay (*Medicago sativa*), and commercially formulated 14% protein deer pellets, and were distributed in poly-resin half-barrels separated by 5-10 meters. Rations were provided *ad libitum* at a minimum recommended rate of 0.9 kg/deer/day (D. Austin, UDWR, unpublished report).

Seasonal Migrations

We captured 100 adult mule deer in Clover Traps (Rongstad and McCabe 1984) from January to March, 2001 through 2005. We restrained captured animals with blinders and hobbles, fitted each deer with a radio-collar with mortality sensor (AVM Instrument Co., Ltd., Colfax, CA, USA), and released it on site (Severinghaus 1949, Pedersen and Pedersen 1975). The entire handling protocol was approved and is on file with the Utah State Institutional Animal Care and Use Committee (Permit #1084).

We monitored radio-collared deer two times per week using flight (Cessna 185 fixed wing) and ground surveillance to determine the extent and duration of use of winter and summer range (Loft et al. 1989). We triangulated all telemetry data with Locate II (Nams 2000) to estimate locations that were placed in 1 of 4 categories: 1) visual identification; 2) two to three bearings; 3) one to two bearings adjusted according to the terrain and bounce; and 4) flight monitored (Loft et al. 1989, White and Garrott 1990). To establish seasonal ranges we mapped all locations in ArcView Geographic Information Systems 3.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA) and evaluated these ranges to determine migratory status, duration of use, and range fidelity for each deer. We classed a deer as migratory if it used seasonal ranges that did not overlap, and as resident if it used overlapping summer and winter ranges or only changed the size of home range according to season (Brown 1992, Nicholson et al. 1997).

We combined data over all years for deer on feed versus non-feed sites to evaluate migration and activity (SAS 2000). Our initial analysis of 1,996 observations from winter 2002, a feeding year, indicated that activity differed by gender. However, when post-antler-shed unknown-gender observations were excluded, the remaining 1,705 observations indicated a low probability of gender-associated differences in activity. Therefore, we did not include gender-associated activity differences in the final analysis.

There were 2 levels of treatment (fed or not), a sample size of 100 does, and 4 levels of year (SAS 2000). We converted migration dates to relative number of days from January 1 of each year for analysis, and calculated the mean number of days to migration initiation and conclusion for both treatment and control deer. From these mean values we computed the mean duration of use of seasonal range for each group. We evaluated differences in duration on seasonal ranges between fed and non-fed deer with a generalized linear mixed model with a Poisson distribution with a Log function. Degrees of freedom were calculated using the Kenward-Rogers method. We used a Tukey

Kramer adjustment to evaluate the significance of pairwise comparisons.

Mule Deer Activity Zones

From a center point where feeding was conducted on feed sites and where feeding would most likely have been conducted on non-feed sites due to accessibility, we stratified each site into 4 zones: I = 0-187m, II = 188-375m, III = 376-750m, IV = 751-1500m (Fig. 3-1). We used these zones to evaluate vegetation utilization and production and to monitor deer activities. On all sites, zone 1 had the least browse, was the lowest in elevation and had level topography. Zones 2 and 3 had more browse and extended up across steep slopes with the steepest slopes occurring in zone 3. Zone 4 had more browse than Zones 2 and 3, and was at the highest elevations, but had less slope than Zones 2 and 3.

Using binoculars and spotting scopes, we monitored mule deer activity 3 to 5 times/week on all study sites at random times of the day and week under all weather conditions from December through March of winter 2002 (a feed year) and winter 2005 (a non-feed year). We determined the frequency of 5 levels of activity (resting, walking, feeding, alert, fleeing) (Kufeld et al. 1988, Relyea et al. 1994) across the 4 zones on each site. We evaluated differences in activity between zones for fed and non-fed deer with Pearson's χ^2 of homogeneity of proportions (SAS 2000).

Browse Production and Utilization

We randomly established from 3-9, 13-m^2 circular plots in each zone in areas of sagebrush/bitterbrush cover and constructed two, 9-m^2 utilization exclosures on each site. Zones 1-2 contained relatively more Big sagebrush, zones 3-4 contained relatively more

Vasey sagebrush. We used double-sampling ocular estimation with reference units (Pechanec 1937, Austin and Urness 1983) to estimate current annual growth (CAG) as a measure of browse production (Lyon 1968, Anderson et al. 1972). We clipped and weighed check units at least once per sampling period. Immediately following spring migration, we used reference units from within the exclosures to estimate utilization on all plots from October 2002 to September 2006. We air-dried 50-100g samples of check units in paper bags and calculated the percent air-dry weights for all CAG and utilization estimates.

Current annual growth was estimated for sagebrush and bitterbrush on 90 random plots (Fig. 3-1) on feed sites in October and early November of 2002, 2003, and 2005, but early, deep snows precluded access to browse and prevented CAG measurements in October, 2004. Current annual growth was also estimated for sagebrush and bitterbrush on 62 plots on non-feed sites in 2002, but in fall 2003 and 2005 deep snows and inaccessibility reduced CAG measurements to 24 plots on 1 site. Utilization of browse was estimated for sagebrush and bitterbrush on 90 plots on feed sites in April of 2003, 2004, 2005, and 2006. Browse utilization was also estimated for sagebrush and bitterbrush on 62 plots on non-feed sites in 2002, but logistic constraints reduced utilization measurements to 24 plots on 1 site from 2004-2006.

We analyzed air dry browse production and utilization data on feed versus non-feed sites through generalized linear mixed models (GLMMIX) with SAS software. We tested for main effects and interactions due to treatment, zone and year. For utilization we used a Beta distribution with a Logit function and Kenward-Rogers degrees of freedom (SAS 2000). As the Beta distribution resulted in utilization values of zero being interpreted as missing data, we recoded zero values as 0.0001. For production, we used a Gamma distribution with a Log function, and Kenward-Rogers degrees of freedom (SAS 2000). Given the modest degree of replication among sites (n = 8), and the influence of several factors such as weather, sample size, snow frozen to foliage, and wildfire, we consider P-values of 0.10 significant.

RESULTS

Seasonal Migrations

We recorded over 5,000 telemetry locations from May 2002 through January 2007. Of 61 fed deer, 8 (13%) died before we could determine their migratory status. Of the 39 non-fed deer, 9 (23%) died before their migratory status was determined. Eleven fed deer (21%) were resident and 42 (79%) were migratory. Eight non-fed deer (27%) were resident and 22 (73%) were migratory.

Duration on both winter and summer range varied by year (winter: $F_{3,71} = 14.30$, $P \leq 0.001$; summer: $F_{3,96} = 10.34$, $P \leq 0.001$). Fed deer arrived earlier and departed later on winter range, whereas on summer range fed deer arrived later and departed earlier than non-fed deer. Feeding increased annual mean duration on winter range by 7 to 51 days ($F_{1,41} = 11.94$, P = 0.001) (Table 3-1). Fed deer stayed on winter range 50 days longer than non-fed deer in winter 2003 ($F_{3,71}= 8.46$, $P \leq 0.001$). Fed deer stayed on summer range 14-19 days less than non-fed deer in 2003, 2004 and 2005 ($F_{3,96} = 3.19$, P = 0.03) (Table 3-2). In 2005 a non-feed year, fed deer also remained on summer range 14 days less than non-fed deer.

Mule Deer Activity

In winter 2002 the activities of fed and non-fed deer differed by zone (χ^2_{12} =387, $P \leq 0.001$; Fig. 3-2). On a daily basis, fed deer traveled back and forth from their resting areas in the dense cover of zones 3-4, to the feed stations. Fed deer browsed in all zones in near proximity to the travel route, but fed more (60%) in zone 1 than non-fed deer (23%). Non-fed deer browsed throughout more of the activity zone ($\chi^2_{12} = 91$, $P \leq 0.001$). Due to mild conditions, winter 2005 was a non-feed year even though conditions were more severe than in winter 2002 when feeding was conducted to facilitate trapping of deer. Throughout winter 2005, feeding activity by deer on feed sites increased 12% even as it decreased 15% for deer on non-feed sites (Fig. 3-3; $\chi^3_{19} = 12$, $P \leq 0.001$).

Browse Production

Mean production of sagebrush showed no effect from feeding ($F_{1,6}$=0.08, P = 0.79), but increased 4% (25 kg/ha) from fall 2002 (695 kg/ha) to fall 2003 (721 kg/ha), and 25% (178 kg/ha) from fall 2003 to fall 2005 (898 kg/ha) (year: $F_{2,188} = 3.57$, P = 0.03). On average, production of sagebrush was 48% higher in zones 1 and 2 (915 kg/ha) than in zones 3 and 4 (618 kg/ha) (zone*year: $F_{3,17.5} = 2.64$, P = 0.08). Production of bitterbrush was greater on feed sites compared with non-feed sites by 171% in fall 2002 (539 kg/ha), 75% in fall 2003 (515 kg/ha), and 55% in fall 2005 (630 kg/ha) (treatment*year: $F_{2,19.5} = 3.26$, P = 0.06; Fig. 3-4). Mean production of bitterbrush on all sites increased 19% (62 kg/ha) from fall 2002 (327 kg/ha) to fall 2003 (389 kg/ha), and 29% (117 kg/ha) from fall 2003 to fall 2005 (505 kg/ha) (year: $F_{2,19.5} = 6.37$, P = 0.01). There was no difference in Bitterbrush production across zones (zone: $F_{3,78}$= 0.97, P = 0.41).

Browse Utilization

There was no effect of feeding on utilization of sagebrush (0.02 kg/ha) (treatment: $F_{1,7}$= 0.06, P = 0.81), but utilization varied from 0.04 kg/ha in spring 2004 to 0.05 kg/ha in spring 2006 (year: $F_{3,57}$ = 8.45, P = $\leq$0.001). Utilization of sagebrush varied by zone: 0.01 kg/ha in zone 1, 0.02 kg/ha in zone 2, 0.03 kg/ha in zone 3, and 0.02 kg/ha in zone 4 (zone: $F_{3,99.6}$ = 2.34, P = 0.08). Feeding interacted with year to affect utilization of bitterbrush ($F_{3,28}$ = 11.22, P $\leq$0.001; Fig. 3-5). Although utilization of bitterbrush was 65% higher on non-feed sites (non-fed=0.18 kg/ha, fed=0.11 kg/ha) in spring 2003, utilization on feed sites was 300% higher (0.24 kg/ha) in spring 2004, 854% higher in spring 2005 (0.30 kg/ha), and 302% higher in spring 2006 (0.17 kg/ha) than on non-fed sites. The utilization of bitterbrush also varied across zones from 0.23 kg/ha and 0.26 kg/ha in zones 1-2, respectively, to 0.06 kg/ha in zone 3, and 0.07 kg/ha in zone 4 (treatment*zone: $F_{3,9}$ = 3.54, P = 0.06; Fig. 3-6).

DISCUSSION

Winter-feeding programs implemented only occasionally may result in little short-term damage to habitat (Gill and Carpenter 1985, The Wildlife Society 2006). However, small effects on browse species, particularly in arid climates, can have long-term impacts through altering plant community structure and species composition (Wandera et al. 1992, Jeffries et al. 1994, Manier and Hobbs 2006, Ward 2006). Previous research suggests that changes in nutrient availability may modify animal nutritional status, as well as food and habitat selection behaviors (Moen 1968, Kautz et al. 1982, Parker et al. 1996), migratory behavior (Augustine and McNaughton 1998), and may alter vegetation (Murden and Risenhoover 1993). This winter-feeding program may have altered mule deer migratory behavior, habitat use, and ultimately contributed to deterioration of the winter browse component on feeding sites.

Annual and seasonal migratory behaviors are affected by site nutrient availability (Wallmo and Regelin 1981, Senft et al. 1987, Loft et al. 1989, Augustine and McNaughton 1998). Although some studies have shown little or no effect of supplemental feeding on migration or seasonal movements of white-tailed deer (*O. virginianus*; Ozoga and Verme 1982, Lewis and Rongstad 1998), these behaviors differ in the more migratory mule deer. Through reducing browse utilization earlier in the season, rations may extend browse availability later into the season, enabling fed deer to remain on site longer than non-fed deer. Furthermore, the ability to cope with plant secondary compounds (PSCs) such as terpenes in sagebrush and tannins in bitterbrush, increases with increased nutritional status and body condition (McArthur et al. 1991, Illius and Jessop 1995, Provenza et al. 2003). This interaction of nutrients and PSCs may lead to further increased nutrient availability on feed sites, and contribute to delayed spring migration.

As increased numbers of mule deer fawns learn to remain on winter range for extended periods, the proportion of resident deer likely will increase. This will result in increased utilization of winter range during summer, and reduce the carrying capacity of winter range during winter. Thus, small scale responses not initially considered important may actually have long-term impacts that result from interactions among history (of the deer), necessity (due to environmental vagaries), and chance (short- and longer-term weather events).

Effect of Feeding on Mule Deer Activity

The feeding program in winter 2002 not only increased the numbers of deer congregating and feeding in zone 1, but also affected how deer used the surrounding zones. Fed deer tended to browse repeatedly over the same trails as they approached and left feed stations. In addition, fed deer traveled further from bed sites to feed. After feeding at the stations, fed deer moved up into zones 3-4 where they bedded and continued to browse. Density of deer in these bedding areas was greater than on non-feed sites. Increased herd density limits forage selectivity and affects plant structure and cover (Augustine and McNaughton 1998). The numbers and activities of non-fed deer were more evenly distributed across all zones.

Both groups increased feeding activity through the season in winter 2002. Although winter 2005 was a more severe winter than winter 2002, the feeding program was not implemented. Still, deer on the former feed sites increased feeding activity whereas deer on non-feed sites decreased feeding activity through the season. As increased snow depth restricted access to browse and decreased the nutrient/cost ratio (Parker et al. 1996), non-fed deer may have reduced the costs by decreasing the time spent feeding (Nudds 1980). However, on feed sites the higher production of bitterbrush possibly resulting from higher utilization in winter 2001, increased availability and provided a higher nutrient/cost ratio than on non-feed sites. Thus deer on these former feed sites continued to maximize their nutrient intake through increased feeding (Schmitz 1990, Mautz 1978 a,b). Although the increased availability of nutrients on feed sites supports this theory, the increased snow depths in winter 2005 may have affected our ability to see and count bedded deer. This could have biased our counts.

Interaction of Deer Diet Selection and Browse Production

Winter forage selection by deer has different effects on sagebrush and bitterbrush (Welch and Wagstaff 1992, Bilbrough and Richards 1993, Bergman, 2001). Due to placement and numbers of terminal growth buds, and resource allocation patterns, sagebrush declines with heavy utilization whereas bitterbrush, more tolerant of increased use, may initially respond with higher production (Wandera et al. 1992, Bilbrough and Richards 1993, Wambolt et al. 1998, Bergman, 2001) that gradually declines over time. However, if utilization of bitterbrush remains high for multiple years, production may decrease due to increased decadence and mortality**.** In this study, because of the high deer densities in winter 2001, browse utilization was likely much heavier than during the following years. This possibly led to the relatively higher production of bitterbrush and lower production of sagebrush on feed sites in 2002. Production of bitterbrush relative to sagebrush gradually decreased the following years, probably due to reduced utilization resulting from reduced numbers of deer, and increased response of sagebrush to greater precipitation (Shultz 1984). If deer populations and utilization remained high, decadence and mortality would decrease production of bitterbrush, resulting in decreased carrying capacity for mule deer.

During winter 2002, lower utilization of bitterbrush on feed sites was possibly because fed deer replaced part of their normal intake of bitterbrush with feed rations, whereas non-fed deer had no such replacement. However, in the more severe winters 2003 and 2004, fed deer may have utilized nutrients in rations to detoxify tannins in bitterbrush, and so utilization of bitterbrush increased on feed sites (Provenza et al. 2003). Multiple years of heavy use may ultimately decrease productivity of bitterbrush

(Bilbrough and Richards 1993), and result in decreased carrying capacity for mule deer (Franzmann and Schwartz 1985, Boer 1992).

Utilization of both species varied annually with mule deer selection of sagebrush possibly related to the availability of bitterbrush and feed rations, as well as deer density. Deer selected very little of either subspecies of sagebrush until deep snow or heavy utilization reduced the availability of bitterbrush, and/or increased nutrients from feed rations possibly enabled deer to detoxify terpenes from sagebrush (Provenza et al. 2003). However, much of the sagebrush on the study sites was located where snow accumulated in some years, possibly blocking utilization that otherwise might have occurred. With the reduced numbers of deer and variable snow cover in winters 2002-2004, neither utilization nor production of sagebrush varied.

The treatment*year effect on production, and the treatment*year and treatment*zone effects on utilization of bitterbrush may in part have resulted from deer congregating on feed sites, and continuing to browse as opposed to the more dispersed use of habitat by non-feed deer (Cooper et al. 2006). However, these interactions may also be in part due to the increased nutrients of feed rations enabling deer to detoxify tannins in bitterbrush, increased duration on these winter sites by fed deer (Peterson and Messmer 2007), the greater preference of deer for bitterbrush over sagebrush (Bilbrough and Richards 1993), and the changing accessibility of browse due to variable snow depths and deposition sites each year.

MANAGEMENT IMPLICATIONS

Prolonged and repeated use of the same sites to feed deer as part of emergency winter-feeding programs altered mule deer habitat use and migration in northern Utah.

The feeding program potentially may decrease carrying capacity of the winter range by increasing resident deer and year-round use of limited winter range. Managers must be cognizant of these impacts and be prepared to implement alternative measures such as rotating feed sites to mitigate habitat impacts if winter-feeding is implemented.

ACKNOWLEDGMENTS

We thank D. Turner and S. Durham for statistical advice. This project was funded by the Utah Division of Wildlife Resources, Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension. The U.S. Forest Service granted access to several of the study sites.

LITERATURE CITED

Alerstam, T., A. Hedenstrom, and S. Akesson. 2003. Long-distance migration: evolution and determinants. Oikos 103:247-260.

Anderson, A. E., D. E. Medin, and D. C. Bowden. 1972. Mule deer numbers and shrub yield-utilization on winter range. Journal of Wildlife Management 36:571-578.

Augustine, D. J., and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. Journal of Wildlife Management 62:1165-1183.

Austin, D. D., and P. J. Urness. 1983. Overwinter forage selection by mule deer on seeded big sagebrush-grass range. Journal of Wildlife Management 47:1203-1207.

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Bergman, M. 2001. Ungulate effects on their food plants: responses depending on scale. Dissertation, Swedish University of Agricultural Sciences, Umea, Sweden.

Bilbrough, C. J., and R. J. Richards. 1993. Growth of sage brush and bitterbrush following simulated winter browsing: mechanisms of tolerance. Ecology 74:481-492.

Boer, A. H. 1992. Fecundity of North American moose (*Alces alces*): a review. Alces Supplement 1:1-10.

Brown, C. G. 1992. Movement and migration patterns of mule deer in southeastern Idaho. Journal of Wildlife Management 56:246-253.

Cooper, S. M., M. K. Owens, R. M. Cooper, and T. F. Ginnett. 2006. Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66:716-726.

Dasmann, W. 1981. Deer range improvement and management. McFarland and Company, Jefferson, North Carolina, USA.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Doman, E. R., and D. I. Rasmussen. 1944. Supplemental winter feeding of mule deer in northern Utah. Journal of Wildlife Management 8:317-338.

Franzmann, A. W., and C. C. Schwartz. 1985. Moose twinning rates: a possible condition assessment. Journal of Wildlife Management 49:394-396.

Gill, R. B., and L. H. Carpenter. 1985. Winter feeding --- a good idea? Proceedings of the Western Association of Fish and Wildlife Agencies 65:57-66.

Illius, A.W., and N.S. Jessop. 1995. Modeling metabolic costs of allelochemical ingestion by foraging herbivores. Journal of Chemical Ecology 21:693-719.

Jeffries, R. L., D. R. Klein, and G. R. Shaver. 1994. Vertebrate herbivores and northern plant communities: reciprocal influences and responses. Oikos 71:193-206.

Kautz, M. A., G. M. Van Dyne, L. H. Carpenter, and W. W. Mautz. 1982. Energy cost for activities of mule deer fawns. Journal of Wildlife Management 46:704-710.

Krannitz, P. G., and S. L. Hicks. 2000. Browsing of Antelope Bitterbrush (Purshia tridentata: Rosaceae) in the South Okanagan Valley, British Columbia: age preferences and seasonal differences. American Midland Naturalist 144:109-122.

Kufeld, R. C., D. C. Bowden, and D. L. Schrupp. 1988. Habitat selection and activity patterns of female mule deer in the front range, Colorado. Journal of Range Management 41:515-522.

Lewis, T. L., and O. J. Rongstad. 1998. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northwest Wisconsin. Canadian Field-Naturalist 112:75-81.

Loft, E. R., R. C. Bertram, and D. L. Bowman. 1989. Migration patterns of mule deer in the central Sierra Nevada. California Fish and Game 75:11-19.

Lyon, L. J. 1968. Estimating twig production of serviceberry from crown volumes. Journal of Wildlife Management 32:115-119.

Manier, D. J., and N. T. Hobbs. 2006. Large herbivores influence the composition and diversity of shrub-steppe communities in the Rocky Mountains, USA. Oecologia 146:641-651.

Mautz, W. W. 1978*a*. Nutrition and carrying capacity. Pages 321-348 *in* J. L. Schmidt and D. L. Gilbert, editors. Big game of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

Mautz, W. W. 1978*b*. Sledding on a bushy hillside: the fat cycle in deer. Wildlife Society Bulletin 6:88-90.

McArthur, C., A. B. Hagerman, and C. T. Robbins. 1991. Physiological strategies of mammalian herbivores against plant defenses. Pages 103-111 *in* R. T. Palo and C. T. Robbins, editors. Plant defenses against mammalian herbivory. CRC Press, Boca Raton, Florida, USA.

McClure, M. F. 2001. Energy, fractal movement patterns, and scale-dependent habitat relationships of urban and rural mule deer. Thesis, Utah State University, Logan, USA.

Moen, A. N. 1968. Energy balance of white-tailed deer in the winter. Transactions of North American Wildlife and Natural Resources Conference 33:224-236.

Murden, S. B., and K. L. Risenhoover. 1993. Effects of habitat enrichment on patterns of diet selection. Ecological Applications 3:497-505.

Nams, V. O. 2000. Locate II. http://www.nsac.ns.ca/envisci/staff/vnams/Locate.htm

Nelson, M. E. 1979. Home range location of white-tailed deer. U.S. Deptartment of Agriculture, North Central Forest Experiment Station, Paper NC-173, St. Paul, Minnesota, USA.

Nicholson, M. C., R. T. Bowyer, and J. G. Kie. 1997. Habitat selection and survival of mule deer: tradeoffs associated with migration. Journal of Mammalogy 78:483 504.

Nudds, T. D. 1980. Forage preference: theoretical considerations of diet selection by deer. Journal of Wildlife Management 44:735-740.

Ouellet, J.-P., M. Crete, J. Maltais, C. Pelletier, and J. Huot. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129-136.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Parker, K. L., M. P. Gillingham, T. A. Hanley, and C. T. Robbins. 1996. Foraging efficiency: energy expenditure versus energy gain in free-ranging black-tailed deer. Canadian Journal of Zoology 74:442-450.

Pechanec, J. F. 1937. A comparison of some methods used in determining percentage utilization of range grasses. Journal of Agricultural Research 54:753-765.

Pedersen, R. J., and A. A. Pedersen. 1975. Blood chemistry and hematology of elk. Journal of Wildlife Management 39:617-620.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Provenza, F. D., J. J. Villalba, L. E. Dziba, S. B. Atwood, and R. E. Banner. 2003. Linking herbivore experience, varied diets, and plant biochemical diversity. Small Ruminant Research 49:257-274.

Relyea, R. A., I. M. Ortega, and S. Demarais. 1994. Activity monitoring in mule deer: assessing telemetry accuracy. Wildlife Society Bulletin 22:656-661.

Rongstad, O. J., and R. A. McCabe. 1984. Pages 655-676 *in* K. Halls, editor. Capture techniques. White-tailed deer ecology and management. Wildlife Management Institute and Stackpole Books, Harrisburg, Pennsylvania, USA.

SAS. 2000. SAS procedures guide, release 8.2 edition. SAS Institute Incorporated, Cary, North Carolina, USA.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54:522-532.

Schoen, J. W., and O. C. Wallmo. 1979. Timber management and deer in SouthEast Alaska: current problems and research direction. Pages 68-85 *in* Sitka black-tailed deer: proceedings of a conference in Juneau Alaska. U. S. Forest Service, Juneau, USA.

Senft, R. L., M. B. Coughenour, D. W. Bailey, L. R. Rittenhouse, O. E. Sala, and D. M. Swift. 1987. Large herbivore foraging and ecological hierarchies. BioScience 37:789-799.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Shultz, L. M. 1984. Taxonomic and geographic limits of Artemisia subgenus tridentatae (Beetle) McArthur (Asteraceae: anthemideae). Pages 20-28 *in* Proceedings—symposium on the biology of Artemisia and Chrysothamnus. U.S. Department of Agriculture, General Technical Report INT-200, Intermountain Forest Service Research Station, Provo, Utah, USA.

Smith, A. D. 1952. Digestibility of some native forages for mule deer. Journal of Wildlife Management 16:309-312.

Swihart, R. K., and J. P. Bryant. 2001. Importance of biogeography and ontogeny of woody plants in winter herbivory by mammals. Journal of Mammalogy 82:1-21.

Tarr, M. D., and P. J. Pekins. 2002 Influences of winter supplemental feeding on the energy balance of white-tailed deer fawns in New Hampshire, U.S.A. Canadian Journal of Zoology 80:6-15.

The Wildlife Society. 2006. Baiting and supplemental feeding of game wildlife species. Sonant, K., and D. Maestro, editors. The Wildlife Society, Bethesda, Maryland, USA.

Ullrey, D. E., W. G. Youatt, H. E. Johnson, L. D. Fay, R. L. Covert, and W. T. Magee. 1975. Consumption of artificial browse supplements by penned white-tailed deer. Journal of Wildlife Management 39:699-704.

Wallmo, O. C., and W. L. Regelin. 1981. Rocky mountain and intermountain habitats-food habits and nutrition. Pages 387-399 *in* O. C. Wallmo, editor. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, USA.

Wambolt, C. L., W. W. Fraas, and M. R. Frisina. 1998. Bitterbrush (*Purshia tridentata Pursh*) growth in relation to browsing. Great Basin Naturalist 58:28-37.

Wandera, J. L., J. H. Richards, and R. J. Mueller. 1992. The relationship between relative growth rate, meristematic potential and compensatory growth of semiarid-land shrubs. Oecologia 90:391-398.

Ward, D. 2006. Long-term effects of herbivory on plant diversity and functional types in arid ecosystems. Pages 142-164 *in* K. Danell, R. Bergstrom, P. Duncan, and J. Pastor, editors. Large herbivore ecology, ecosystem dynamics and conservation. Cambridge University Press, New York, New York, USA.

Welch, B. L., and F. J. Wagstaff. 1992. 'Hobble Creek' big sagebrush vs. antelope bitterbrush as a winter forage. Journal of Range Management 45:140-142.

West, N. E. 1983. Temperate deserts and semi-deserts. Pages 321-471 *in* N. E. West, editor. Ecosystems of the world. Volume 5. Elsevier Science Publication, Amsterdam, Netherlands.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

Table 3-1. Mean duration on winter range of fed and non-fed deer, northern Utah, 2001-2006.

Treatment	Year	Mean # Days	Standard Error Mean	DF	Standard Error	t value	P value
Feed	2002-2003	178	11	71	0.06	86	$\leq$0.001
	2003-2004	157	7	64	0.05	109	$\leq$0.001
	2004-2005	167	7	49	0.04	120	$\leq$0.001
	2005-2006	164	8	64	0.05	110	$\leq$0.001
Non-feed	2002-2003	127	12	71	0.10	50	$\leq$0.001
	2002-2004	107	7	61	0.07	69	$\leq$0.001
	2004-2005	131	8	47	0.06	78	$\leq$0.001
	2005-2006	157	11	66	0.07	73	$\leq$0.001

Table 3-2. Mean duration on summer range of fed and non-fed deer, northern Utah, 2001-2006.

Treatment	Year	Mean # Days	Standard Error Mean	DF	Standard Error	t value	P value
Feed	2003	131	7	64	0.05	92	≤0.001
	2004	132	7	51	0.05	98	≤0.001
	2005	116	6	61	0.05	91	≤0.001
	2006	136	9	96	0.06	78	≤0.001
Non-feed	2003	150	11	67	0.07	69	≤0.001
	2004	149	10	57	0.07	71	≤0.001
	2005	130	9	53	0.07	71	≤0.001
	2006	123	10	96	0.08	58	≤0.001

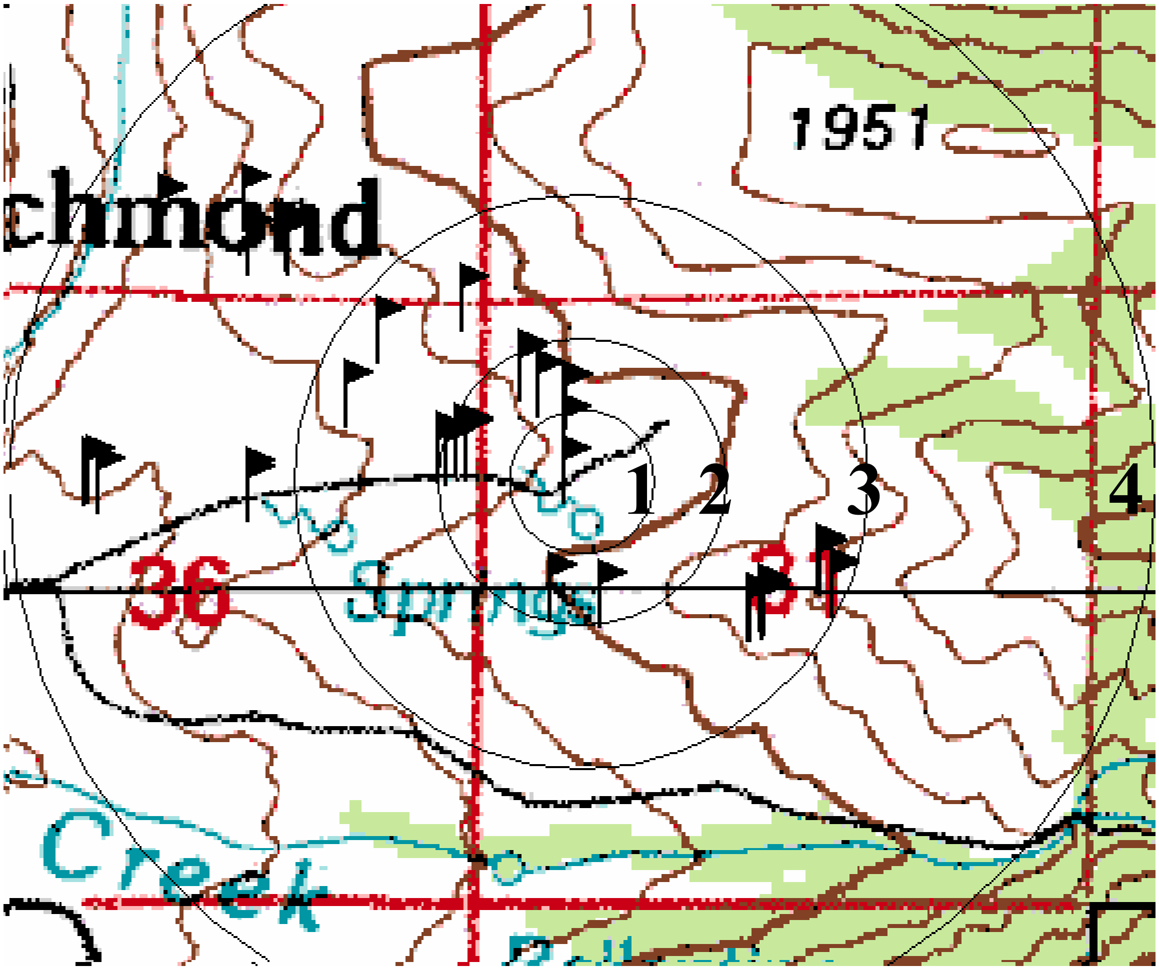

Figure 3-1. Study site design with 4 zones and random distribution of vegetation plots, northern Utah, 2001-2006. (Zone 1 radius is 188 m with 11 ha, zone 2 radius is 375 m with 44 ha, zone 3 radius is 760 m with 176 ha, and zone 4 radius is 1500 m with 706 ha).

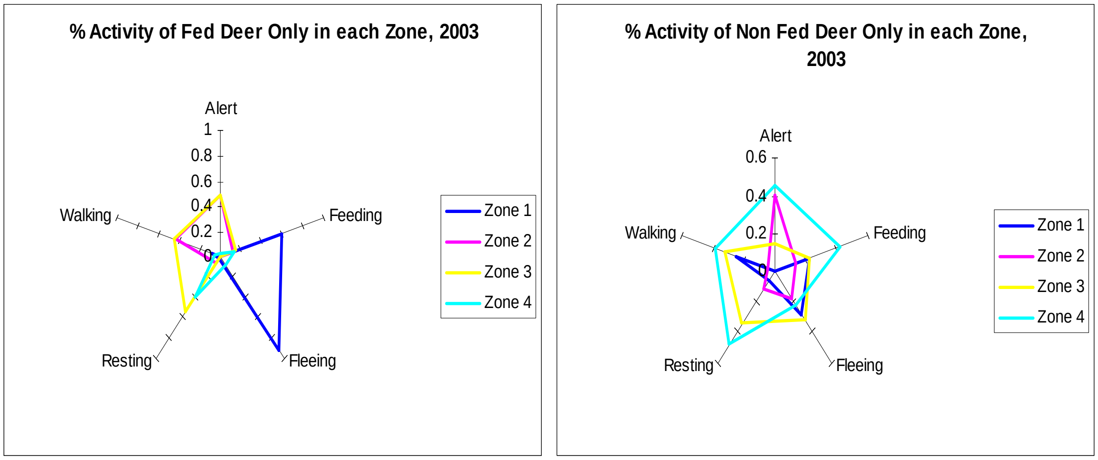

Figure 3-2. Frequency of mule deer activities including walking, resting, fleeing, feeding, and alert, in 4 zones for fed and non-fed deer, northern Utah, 2001-2006.

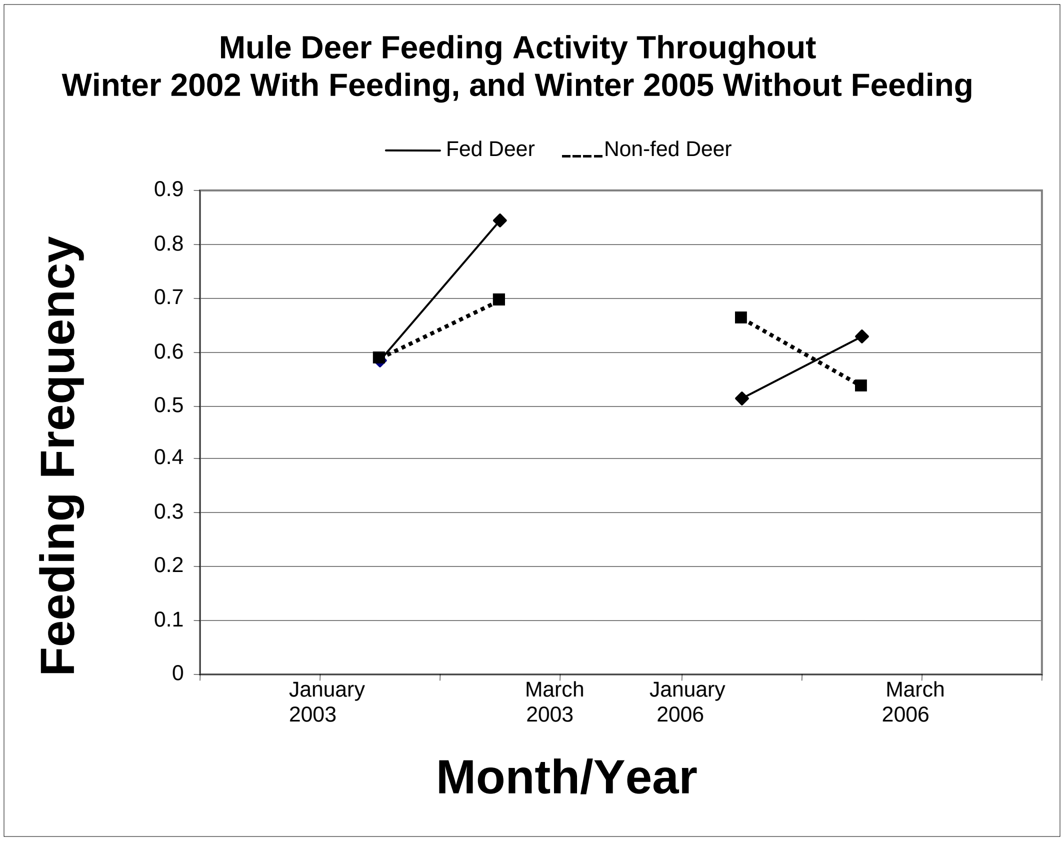

Figure 3-3. Frequency of feeding activity by fed and non-fed deer in winter 2002 with supplemental rations, and winter 2005 without supplemental rations, northern Utah, 2001-2006.

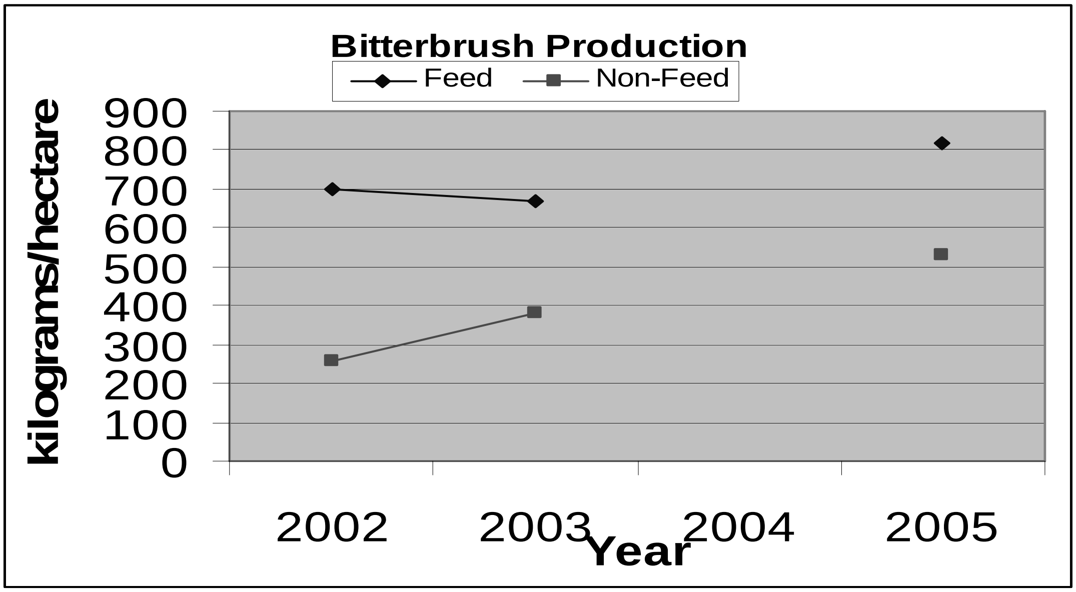

Figure 3-4. Mean production of bitterbrush estimated from current annual growth (CAG) on feed and non-feed sites, northern Utah, 2001-2006.

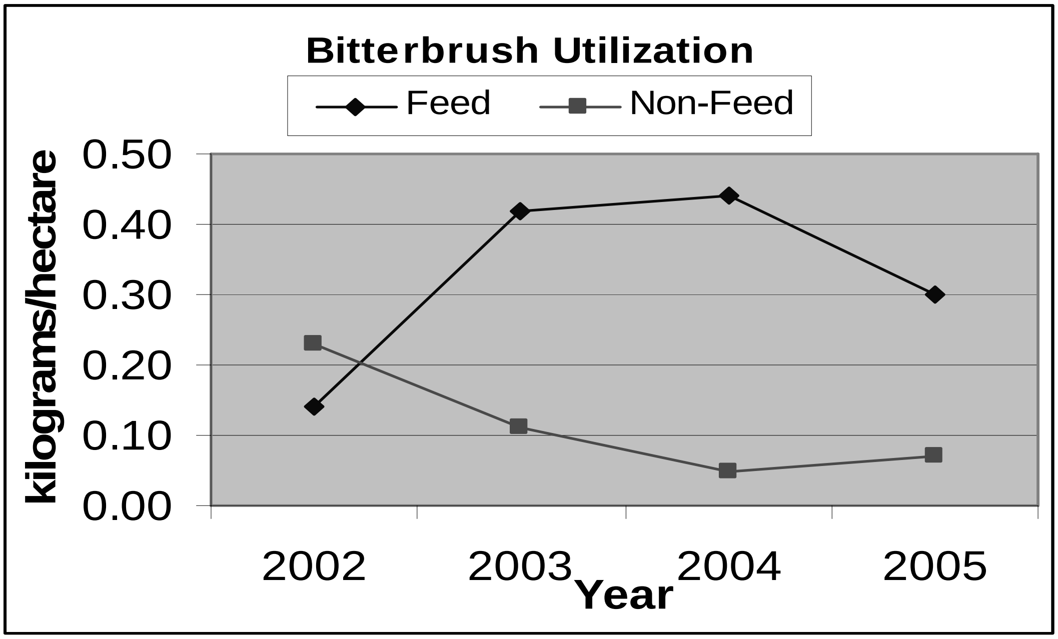

Figure 3-5. Estimated mean utilization of bitterbrush by fed and non-fed deer, northern Utah, 2001-2006.

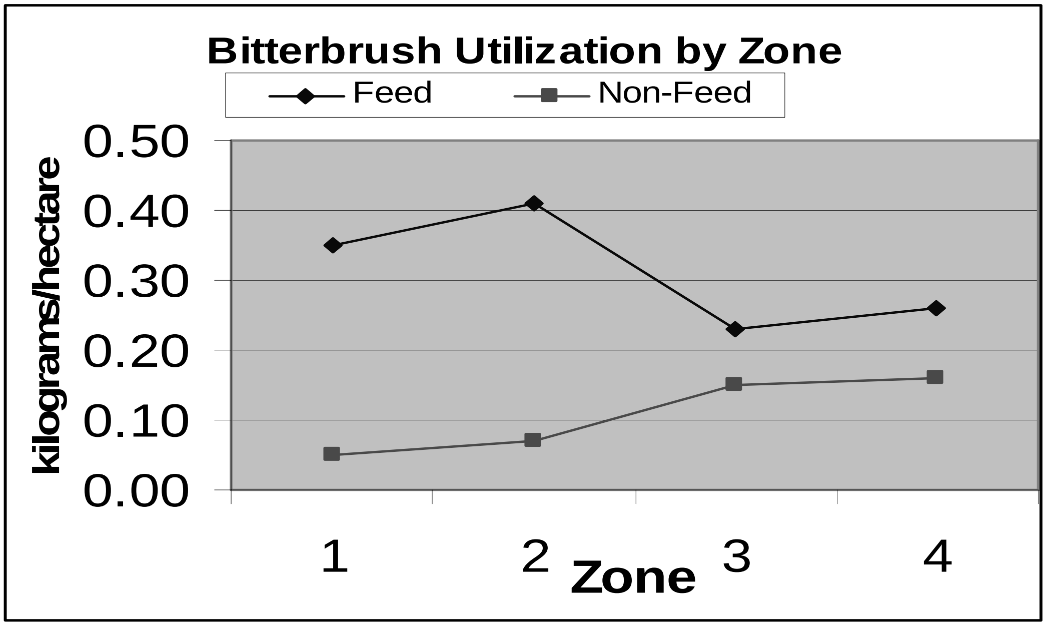

Figure 3-6. Estimated annual utilization of bitterbrush by fed and non-fed deer, across zones, northern Utah, 2001-2006.

CHAPTER 4

ASSESSING MINERAL STATUS AND DIET SELECTION OF WINTER-FED MULE DEER[3]

ABSTRACT Though mineral deficiencies may increase seasonally with reduced quality and quantity of winter forage, and may limit wildlife production more than protein and energy deficiencies, most winter-feeding programs address only the latter. We assessed the mineral status of mule deer (*Odocoileus hemionus*) during a winter-feeding program in Utah. We found that both serum and liver samples of fed deer were marginal to low in Se, Zn, and Cu. We also found that fed deer selected forages high in selenium (Se), zinc (Zn) and copper (Cu). When we offered fed deer on winter range a choice between Cu-amended and plain ration, they selected a diet of 42% Cu-amended ration. During spring, they did not decrease intake of the Cu-amended ration as quickly as the plain ration ($F_{3, 67}$=5.02, $P < 0.003$). The efficacy of mule deer winter-feeding programs may increase if site-specific feed rations were formulated to rectify low levels of minerals in mule deer.

INTRODUCTION

Mineral deficiencies affect wildlife health (Robbins 1983, McDowell et al. 1993), and production (Underwood 1977, Flueck 1994). Mineral deficiencies may increase seasonally with food shortages (Robbins 1983), with winter diets low in protein or high in lignin (McDowell et al. 1993), or with the increased requirements of gestation (Robbins 1983). Marginal to low-level mineral deficiencies, more common than generally thought (Robbins 1983, Flueck 1994), are especially difficult to detect as animals may show no obvious symptoms even as their productivity declines (Underwood

[3] Coauthored by Peterson, C. C., F. D. Provenza, and T. A. Messmer.

1977).

While feeding programs have been used to compensate for seasonal dietary restrictions of elk (*Cervus elaphus*) and deer (*Odocoileus* spp) (Urness 1980, Ozoga and Verme 1982, Baker and Hobbs 1985, Schmitz 1990, Doenier et al. 1997), most address only deficiencies in protein and energy (Baker and Hobbs 1985, Murden and Risenhoover 1993, Ouellet et al. 2001, Page and Underwood 2006). Rarely do feeding regimes target mineral deficiencies, although these may limit wildlife survival and production more than energy and protein deficiencies (Lyon 1966, Severson 1981, Hobbs and Swift 1985, McDowell et al. 1993, Hodgman et al. 1996).

Objectives

Considerable research has examined the effects of deficiencies in protein and energy on deer body condition, survival, and production (Doman and Rasmussen 1944, Schoonveld et al. 1974, Saltz and Cook 1993, Moen and DelGiudice 1997, Ouellet et al. 2001). However, little work has evaluated the relationship between mineral deficiencies and animal behavior. Our objectives were to determine if free-ranging mule deer in a supplemental feed program exhibited low levels of minerals, and if so, if they would select a mineral amended feed ration.

STUDY AREA

The study area, located in northeastern Utah (41.85 ºN, 111.75 ºW), was characterized by warm dry summers and cold snowy winters. Elevations ranged from 1350m-2997m. Higher elevations in the unit were mule deer fawning and summer range, while lower elevations were critical mule deer winter range. Winter ranges were typically associated with a narrow belt of sagebrush-bitterbrush habitat (*Artemisia-Purshia* spp.) along foothills.

Vegetation on all feed and non-feed sites, characteristic of mule deer winter range in the Intermountain West, was comprised of sagebrush (*A.* spp.), bitterbrush (*P. tridentata*), bigtooth maple (*Acer grandidentatum*), Utah juniper (*Juniperus osteosperma*), and multiple species of grasses and forbs interspersed with hay fields and livestock farms. Cheatgrass (*Bromus tectorum*), broom snakeweed (*Gutierrezia sarothrae*), bulbous bluegrass (*Poa bulbosa*), balsamroot (*Balsamrhiza sagittata*), and mulesear (*Wyethia amplexicaulis*) were common on lower elevations (Welsh and Moore 1973).

METHODS

Study Site

The study site was located on critical mule deer winter range at the base of a south face sagebrush steppe bench. The bench provided an elevated (3-4 m) observation area within 5 m of the feed trials. From 30-105 deer used the site during the trials. Maximum snow depth on the field was 60 cm with average snow depth of 30 cm.

Feeding Operations

Mule deer were supplemented at this site during winters 2001-2004 as part of an emergency winter-feeding program implemented by the Utah Division of Wildlife Resources (UDWR). Rations consisted of high-quality alfalfa hay, whole corn, and deer pellets. Feed pellets were analyzed for 29 minerals at the USDA Veterinary Diagnostic Laboratory in Logan, UT, using ICP-MS.

Mineral Status of Deer

As part of a project to evaluate the effects of the emergency winter-feeding program from 2001-2004, we captured 78 mule deer in Clover traps across 4 feed sites and 4 non-feed sites. Four of these deer were captured on our study site, 42 were from 3 nearby (< 8 km) feed and non-feed sites, and the remaining deer were from the general area. Radio-telemetry confirmed these deer were part of the same general herd (Peterson and Messmer 2007).

We restrained captured deer with blinders and hobbles, collected blood samples, and then released the deer on-site. We drew blood samples from the jugular using 20-cc syringes with 20-G, 3.75-mm needles and immediately placed the samples in 2, 10-ml red top glass tubes (Pedersen and Pedersen 1975). We also took liver samples from fresh carcasses of mortalities in the study areas. All samples were delivered to the USDA Veterinary Diagnostic Laboratory in Logan, UT for ICP-MS analysis of 29 minerals. Individual mineral concentrations were assessed against curves of known standards, and evaluated for range, median, and mean. Values were also evaluated between fed and non-fed deer using notched boxplots and QQb2b histograms (Emerson and Strenio 1983, Zar 1999). These descriptive statistics were compared with the range of values presented in the literature from other studies to identify an element of interest for the field trial on preference.

Mineral Content in Vegetation

The best way to assess mineral deficiency following serum and liver mineral analyses is to assess the mineral content of preferred browse species (McDowell et al. 1993). From January 1-20, 2006, we observed the selection of plant species and individual plants by mule deer on the study sites and assigned 3 preference levels to 10 forage species. Species ranked as 1 were high preference; they were selected and represented major consumption at a site. Most of these species were not as consistently distributed as others and deer appeared to travel to these sites specifically to select these species in greater amounts than more common but low preference species, but in lesser amounts than moderate preference species. Species ranked as 2 were of moderate preference; they were more evenly distributed through the habitat than high preference species. They were selected in small amounts consistently throughout the feeding period, mixed with other species, and selected in total amounts greater than high preference forage. Species ranked 3 were low in preference; they were of low to frequent occurrence and used only occasionally and in relatively small amounts.

We followed >20 individual deer trails in fresh snow and sampled current annual growth (CAG) of the 10 preferred species. Each sample combined 15-20 g cuttings from each of a minimum of 5 individual preferred plants of the species. These samples were immediately delivered to the USDA Veterinary Diagnostic Laboratory, Logan, UT for mineral analyses as described previously.

Though Se and Zn were low for deer in this study, serum Se and Zn were higher for fed deer. This indicates that the rations distributed in the feeding program increased dietary Se and Zn. Based on a compilation of the information on both serum and tissue samples of deer, as well as analyses of forage samples, we determined that Cu was limiting in the diets of mule deer on both feed and non-feed sites. We then formulated a ration and determined if deer would use a Cu-amended ration.

Cu-Amended Ration

We formulated a pelleted ration with or without Cu (Table 4-1). Based on veterinary recommendation, deer intake averages 2.5% of body weight, and daily dietary Cu requirements averages 10ppm (J. Hall, DVM, Ph.D, Diplomat A.B.V.T., personal communications). From observed amounts of feed consumed and numbers of deer utilizing the rations, we estimated the mean proportions of browse and pellets consumed/deer/day during the acclimation period (90% browse, 10% pellets), and calculated the amounts of Cu ingested from each food source from the ICP-MS results for forage samples and the mean proportions consumed. The difference between these amounts and the daily requirement was the amount we estimated an "average" deer needed from the mineral-amended pellets (e.g., 27 ppm). However, to avoid possible toxicity if a deer consumed pellets as 100% of the diet, the rations were formulated at 25ppm Cu, from CuS.

Cu-Acceptance Trial

To accustom deer to being fed on the trial site, each day from January 23 to 10, 2006, we placed supplemental corn and hay rations in 8, 95-liter poly-resin barrels. Hay and corn that remained were left for feeding overnight. We also randomly distributed the plain and Cu-amended pellets in 4 rows (2 rows of plain, 2 rows of Cu) of wooden food boxes (15 cm x 30 cm), with 5 boxes/row. The boxes were distributed over a 15 m by 30 m area. From February 11 to March 6, immediately following this 2-week acclimation period we alternated daily distribution of plain and treated pellets between rows with 23 kg of each pellet type.

Every 5 minutes during a daily 45-60 minute feed session, we scanned the 4 rows of pellets for the proportions of deer using plain and Cu-amended pellets. When possible the scan included the identification of individual deer. Immediately following each trial, we removed and weighed the plain and Cu-amended pellets. We evaluated the relationship between amounts of Cu-amended and plain pellets used with a non-parametric bivariate smoother, "loess curve" (Cleveland 1979, Emerson et al. 1983).

RESULTS

Species Preference

Species ranked as 1 or highly preferred included gray sagewort (*A. ludoviciana)*, alfalfa (*Medicago officinale*), bigtooth maple (*Acer granditatum*), bitterbrush (*Purshia tridentata*), and a grass mix of *Agropyron spicatum*, *A. spicatum, Bromus tectorum*, *Poa bulbosa*, and *P. pratensis*. Species ranked as 2 or of moderate preference included ragweed (*Ambrosia* spp.), preferred sagebrush (*A. tridentata vaseyana*), and *Epilobium minutum*. The two species ranked as 3 or least preferred were Common sunflower (*Helianthus* spp.), and not-preferred sagebrush (*A. t. vaseyana). A. tridentata vaseyana* was ranked in both categories 2 and 3 because deer consistently browsed from some plants but not others; as a result, we sampled both the preferred and the non-preferred plants for mineral analyses.

Forage Select Mineral Composition

High-preference forage was highest in Mo, lowest in Cu, and contained moderate levels of Se and Zn (Table 4-2). Moderate-preference forage contained the most Cu, Se, and Zn with moderate amounts of Mo. Lowest-preference forage had moderate levels of Cu, but was lowest in Se, Mo, and Zn. Preferred sagebrush contained 70% more Zn, 65% more Cu and 190% more Se than non-preferred sagebrush. It also had 33% less Mo than non-preferred sagebrush.

Mineral Status of Deer

The majority of the mineral levels from the 78 mule deer serum samples were within standard ranges (Table 4-3; Puls 1994). However, compared with standard values for Se (mean=0.13ppm, range 0.06-0.20ppm), Cu (mean =0.95ppm, range 0.6-1.3ppm), and Zn (mean=0.8ppm, range 0.6-1.0ppm; Puls, 1994), levels in our samples were marginal to low for serum Se (mean=0.13ppm, range 0.06-0.20ppm), Cu (mean =0.95ppm, range 0.6-1.3ppm), and Zn (mean=0.8ppm, range 0.6-1.0ppm).

Notched boxplots of data pooled from 2003-2005 indicated serum of fed deer had 34% more selenium and 24% more Zn than non-fed deer (Fig. 4-1, 4-2). Serum of fed deer contained similar Cu as non-fed deer (Fig. 4-3).

All 7 liver samples from fed deer were low in Se (mean=0.19 ppm), and marginally low in Cu (mean=28.47 ppm; Se normal range 0.2-1.1ppm, Cu normal range 20-140ppm; Table 4-4).

Copper Trials

The numbers of deer utilizing the rations varied from 26 to 75 during the acclimation period when hay, whole corn, and plain pellets were distributed from January 23 to February 10. The numbers of deer varied from 30 to over 100 from February 11 through March 23 when the acceptance trials were conducted with plain and Cu-amended pellets.

During the 29-day trial, deer selected an average of 42% Cu-amended pellets (mean = 9.27 kg/day, range =1.8-22kg/day) and 58% plain pellets (mean = 12.8kg/day, range = 3.8-26.5kg/day). From February 11 through March 13 with the advent of the spring green-up, the amount of Cu-amended pellets eaten/deer/day decreased at a slower rate than the plain pellets (Fig. 4-4; $F_{3, 67}$=5.02, $P < 0.003$).

DISCUSSION

Mule deer fed supplemental rations in northern Utah had marginal to low levels of Se, Cu, and Zn. Other mineral concentrations in fed deer were similar to standard values (Puls 1994). Serum and liver concentrations of Mo were similar to standard values (Puls 1994), which suggests Mo did not exacerbate a Cu deficiency. Fed deer had increased levels of Se and Zn, but not Cu, suggesting the plain rations mitigated these low-level deficiencies for Se and Zn, but not for Cu.

Copper deficiency is widespread among ruminants (McDowell 1985). However, diagnosis of Cu deficiency is complicated as it can be due to very low dietary copper or to interference of Cu absorption through interaction with other minerals such as high levels of Mo (Robbins 1983). Still, cases of Cu-deficiency resulting in declining wildlife populations have been described for free-ranging moose (*Alces alces*) (Frank et al. 2000, O'Hara et al. 2001, Custer et al. 2004), muskoxen (*Ovibos moschutus*) (Blakely et al. 2000, Barboza et al. 2003), black-tailed deer (*O. hemionus*) (Flueck 1994), and pronghorn antelope (*Antilocapra americana*) (Miller et al. 2001).

Liver analyses offer a more accurate assessment of Cu levels as the liver is the major organ for storage of Cu (McDowell 1992, Littledike et al. 1995). Serum levels of Cu may appear to be normal for some time even as Cu stores in the liver are becoming increasingly deficient (Mackintosh et al. 1986, Kincaid 2000, Blakely et al. 2000, J. Hall, DVM, Ph.D, Diplomat A.B.V.T., personal communications). In our study, liver Cu concentrations of fed deer were all in the lower range of known values. Thus, Cu was selected as the mineral for the preference trials.

Ruminants such as deer show aversions to plants with excesses, or deficient in specific nutrients (Provenza 1995, 1996), and mule deer have long been observed to show preferences for specific plants (Smith 1950). Mule deer in this study preferred specific sagebrush plants, and avoided other plants of the same subspecies growing in close proximity. Deer also selected forage species that averaged higher content of the minerals in deer that were low to marginal in amounts. The preferred plants and species may have been selected on the basis of their higher Cu and Se content. Dietary mixing of these species with those of lower preference might enable deer to balance intake of multiple minerals.

Throughout the trial, deer alternated feeding between plain and Cu-amended pellets. Though deer consumed less of the Cu-amended pellets than the plain pellets some deer consistently selected Cu-amended pellets as a proportion of their daily diet. When deer arrived at the feed trial each day, specific deer walked quickly from box to box until they reached one that contained Cu pellets. Although we were unable to measure how much each deer ate, 18 individuals from the herd of 60-100 deer selected Cu pellets more frequently than plain, and approximately 15 deer were never observed selecting Cu pellets. These observations likely reflect differences in requirements among individuals even of the same sex and age. While we typically calculate average values for nutrient requirements for herbivores, there is no such thing as an “average” animal (Provenza et al., 2003).

In the spring as forage increased in availability and nutritional value, deer decreased intake of the Cu-amended pellets more slowly than of plain pellets, which suggests the deer may have still received benefit from supplemental Cu in their diets. As different forage species are affected by spring growth at different times, species with higher amounts of Cu may become more available, reducing need for Cu pellets. In addition, spring migration may reduce competition for high-Cu forage and thus decrease need for Cu rations.

Collectively, our findings suggest mule deer in northern Utah may experience site-specific mineral deficits and that they may select diets that rectify these deficits. While the ability of animals to self-select diet to meet nutritional needs has been debated, there is growing evidence of these abilities in herbivores (Provenza and Villalba, 2006), and sheep are able to select diets that rectify deficits of Na, P, and Ca (Villalba et al., 2006, 2008). These results with mule deer raise further questions and suggest a need for more research to determine if specific individuals experiencing a mineral deficit can self-select mineral-amended rations and forages. Further research should investigate variation among individuals in mineral deficits and the proportion of herds that experience such deficits, determine if selection of amended rations replenishes a deficiency, and if individuals can balance mineral content in various feed rations to avoid toxicity and deficiency.

Finally, the additional nutrients in rations provided in winter-feeding programs can increase preference of deer for high-quality browse (Murden and Risenhoover 1993). Winter-feeding programs for mule deer (*O. hemionus*) generally increase numbers of deer congregating on feed sites and their use of browse (Schmitz 1990, Peterson and Messmer

2007). If browse with adequate mineral content is limited or reduced in abundance due to feeding programs, then ever-increasing deer use may reduce the availability of all mineral rich foods, resulting in chronic mineral deficiencies as the landscape is altered.

MANAGEMENT IMPLICATIONS

For increased efficacy of winter-feeding programs, the rations provided should supply minerals likely to be deficient in the diet, based on biological and ecological information of the herd and winter range. Supplemental minerals should be offered separately to provide for individual nutrient requirements of deer, and permit diet mixing to enable balanced diets (Provenza and Villalba 2006). Provision of a mixed mineral supplement may not work as too much of one mineral can limit consumption, or lead to toxicity/deficiency of other minerals.

ACKNOWLEDGEMENTS

This project was funded by the Utah Division of Wildlife Resources, Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension. The U. S. Forest Service granted access to several of the study sites.

LITERATURE CITED

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Barboza, P. S., E. P. Rombach, J. E. Blake, and J. A. Nagy. 2003. Copper status of muskoxen: a comparison of wild and captive populations. Journal of Wildlife Diseases 39:610-619.

Blakely, B. R., S. J. Kutz, S. C. Tedesco, and P. F. Flood. 2000. Trace mineral and vitamin concentration in the liver and serum of wild muskoxen from Victoria Island. Journal of Wildlife Diseases 36:301-307.

Clauss, M., and E. S. Dierenfeld. 1999. Susceptibility of yak (*Bos grunniens*) to copper deficiency. Veterinary Record 145:436-437.

Cleveland, W. S. 1979. Robust locally weighted regression and smoothing scatterplots. Journal of the American Statistical Association 74:829-836.

Custer, T. W., E. Cox, and B. Gray. 2004. Trace elements in moose (Alces alces) found dead in Northwestern Minnesota, USA. Science of the Total Environment 330:81-87.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Doman, E. R., and D. I. Rasmussen. 1944. Supplemental feeding of mule deer in northern Utah. Journal of Wildlife Management 8:317-338.

Emerson, J. D., and J. Strenio. 1983. Boxplots and batch comparisons. Pages 58-93 *in* D. C. Hoaglin, F. Mosteller, and J. W. Tukey, editors. Understanding robust and exploratory data analysis. Wiley and Sons, New York, New York, USA.

Flueck, W. T. 1994. Effect of trace elements on population dynamics: Selenium deficiency in free-ranging black-tailed deer. Ecology 75:807-812.

Frank, A., R. Danielsson, and B. Jones. 2000. The 'mysterious' disease in Swedish moose. Concentrations of trace elements in liver and kidneys and clinical chemistry. Comparison with experimental molybdenosis and copper deficiency in the goat. Science of the Total Environment 249:107–122.

Hobbs, N. T., and D. M. Swift. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. Journal of Wildlife Management 49:814-822.

Hodgman, T. P., B. R. Davitt, and J. R. Nelson. 1996. Monitoring mule deer diet quality and intake with fecal indices. Journal of Range Management 49:215-222.

Kincaid, R. L. 2000. Assessment of trace mineral status of ruminants: A review. Proceedings of the American Society of Animal Science 77:1-10.

Littledike, E. T., T. E. Wittum, and T. G. Jenkins. 1995. Effect of breed, intake, and carcass composition on the status of several macro and trace minerals of adult beef cattle. Journal of Animal Science 73:2113-2119.

Lyon, J. L. 1966. Problems of habitat management for deer and elk in the northern forests. U.S. Forest Service, Research paper INT-24, Intermountain Forest and Range Experiment Station, Ogden, Utah, USA.

Mackintosh, C. G., P. R. Wilson, N. S. Beatson, K. Turner, and P. Johnstone. 1986. Preliminary report of the liver:serum copper relationship in red deer. Pages 156-164 *in* Proceedings of a deer course for veterinarians, Number 3, Deer Branch of the New Zealand Veterinary Association.

McDowell, L. R. 1985. Nutrition of grazing ruminants in warm climates. Animal Feeding and Nutrition. Academic Press, London, United Kingdom.

McDowell, L. R. 1992. Minerals in animal and human nutrition. First edition. Academic Press, New York, New York, USA.

McDowell, L. R., J. H. Conrad, and F. G. Hembry. 1993. Minerals for grazing ruminants in tropical regions. Second edition. Animal Science Department, Center for Tropical Agriculture, University of Florida. Library of Congress Catalog number 92-76027.

Miller, M., S. Amsel, J. Boehm, and B. Gonzales. 2001. Presumptive copper deficiency in hand-reared captive pronghorn (*Antilocapra americana*) fawns. Journal of Zoo and Wildlife Medicine 32:373-378.

Moen, R., and G. D. DelGiudice. 1997. Simulating nitrogen metabolism and urinary urea nitrogen:creatinine ratios in ruminants. Journal of Wildlife Management 61:881-894.

Murden, S. B., and K. L. Risenhoover. 1993. Effects of habitat enrichment on patterns of diet selection. Ecological Applications 3:497-505.

O'Hara, E. M., G. Carroll, P. Barboza, K. Mueller, J. Blake, V. Woshner, and C. Willetto. 2001. Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. Journal of Wildlife Diseases 37:509-522.

Ouellet, J.-P., M. Crete, J. Maltais, C. Pelletier, and J. Huot. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129-135.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Page, B. D., and H. B. Underwood. 2006. Comparing protein and energy status of winter-fed white-tailed deer. Wildlife Society Bulletin 34:716-724.

Pedersen, R. J., and A. A. Pedersen. 1975. Blood chemistry and hematology of elk. Journal of Wildlife Management 39:617-620.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Provenza, F. D. 1995. Postingestive feedback as an elementary determinant of food preference and intake in ruminants. Journal of Range Management 48:2-17.

Provenza, F. D. 1996. Acquired aversions as the basis for varied diets of ruminants foraging on rangelands. Journal of Animal Science 74:2010-2020.

Provenza, F. D., and J. J. Villalba. 2006. Foraging in Domestic Vertebrates: Linking the internal and external milieu. Pages 210-240 *in* V. L. Bels, editor. Feeding in domestic vertebrates: from structure to function. CABI Publishing, Oxfordshire, United Kingdom.

Provenza, F. D., J. J. Villalba, L. E. Dziba, S. B. Atwood, and R. E. Banner. 2003. Linking herbivore experience, varied diets, and plant biochemical diversity. Small Ruminant Research 49:257-274.

Puls, R. 1994. Mineral levels in animal health. Diagnostic data. Second edition. Sherpa International, Clearbrook, British Columbia, Canada.

Robbins, C. T. 1983. Wildlife Feeding and Nutrition. Academic Press, San Diego, California, USA.

Saltz, D., and D. E. Cook. 1993. Effect of time and snow dilution on cortisol:creatinine ratios in mule deer urine. Journal of Wildlife Management 57:397-399.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54:522-532.

Schoonveld, G. G., J. G. Nagy, and J. A. Bailey. 1974. Capability of mule deer to utilize fibrous alfalfa diets. Journal of Wildlife Management 38:823-829.

Severson, K. E. 1981. Food Habits and nutritional relationships of mule deer in Southwestern United States. Pages 149-164 *in* P. F. Ffolliott and S. Gallina, editors. Deer biology, habitat requirements, and management in Western North America. Instituto de Ecologia, A. C. Mexico, D. F.

Smith, A. D. 1950. Inquiries into differential consumption of juniper by mule deer. Utah Fish and Game Bulletin 9:4.

Underwood, E. J. 1977. Trace elements in human and animal nutrition. Academic Press, New York, New York, USA.

Urness, P. J. 1980. Supplemental feeding of big game in Utah. Utah Division of Wildlife Resources, Publication 80-8, Salt Lake City, USA.

Villalba, J. J., F. D. Provenza, J. O. Hall, and C. Peterson. 2006. Phosphorus appetite in sheep: dissociating taste from postingestive effects. Journal of Animal Science 84:2213-2223.

Villalba, J. J., F. D. Provenza, and J. O. Hall. 2008. Learned appetites for calcium, phosphorus and sodium in sheep. Journal of Animal Science 86:738-747.

Welsh, S. L., and G. Moore. 1973. Utah plants: tracheophyta. Third edition. Brigham Young University Press, Provo, Utah, USA.

Zar, J. H. 1999. Biostatistical analysis. Fourth edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Table 4-1. Formula for plain deer pellets used in northern Utah, 2002-2005.

Ingredient	Pounds/ton	kg/ton	%
Alfalfa	460	207	23.0
Barley	220	99	11.0
Beet Pulp	270	121.5	13.5
Calcite	20	9	1.0
Corn	400	180	20.0
Molasses	140	63	7.0
Mono-Cal	20	9	1.0
Salt	20	9	1.0
Soy Meal	170	76.5	8.5
Wheat	280	126	14

Table 4-2. Mean amounts (ppm) of copper, selenium, molybdenum and zinc preferred forage species of mule deer, ranked as high, moderate, and low preference in northern Utah, 2002-2005.

Preference	Copper		Selenium		Molybdenum		Zinc	
	Range	mean	range	mean	range	mean	range	mean
High	2.82-9.25	5.96	0.07-0.26	0.15	0.25-3.02	1.47	12.56-46.8	23
Moderate	2.05-15.89	7.9	0.08-0.29	0.18	0.64-1.22	0.896	8.48-53.07	29
Low	4.97-9.61	7.29	0.1-0.1	0.1	0.79-0.95	0.87	15.35-17.21	16
Sagebrush: Preferred		15.89		0.10		0.64		26.12
Sagebrush: Not Preferred		9.61		0.26		0.95		15.35

Table 4-3. Serum and liver mineral content, expressed as mean and range, for fed and non-fed mule deer (*Odocoileus hemionus*) in northern Utah, 2002-2005.

Source	Type	SUN		Creatinine		Glucose	
		mean	range	mean	range	mean	range
Serum	Fed	19.72	5-34	1.53	1.1-2.1	145.60	103-256
	Non-Fed	19.16	6-33	1.53	1-2.2	108.83	62-143
Liver	Fed	.	.	.	.	.	.

Source	Type	Ag		Al		As	
		mean	range	mean	range	mean	range
Serum	Fed	<0.001	<0.001- <0.001	0.08	0.017-0.728	0.00	0.001-0.01
	Non-Fed	0.00	<0.001- <0.001	0.08	0.001-0.930	0.00	0.001-0.01
Liver	Fed	0.01	0.001-0.02	0.25	0.075-0.925	0.02	0.002-0.042

Source	Type	B		Ba		Be	
		mean	range	mean	range	mean	range
Serum	Fed	0.29	0.14-0.48	0.10	0.056-0.189	<0.002	<0.001-<0.001
	Non-Fed	0.34	0.01-0.64	0.10	0.044-0.244	0.11	0.108-0.108
Liver	Fed	0.38	0.23-0.59	0.04	0.018-0.057	0.00	0.001-0.001

Source	Type	Ca		Cd		Co	
		mean	range	mean	range	mean	range
Serum	Fed	93.77	50-109	0.00	0.001-0.005	0.00	0.001-0.001
	Non-Fed	93.88	47-112	0.00	0.001-0.002	0.00	0.001-0.001
Liver	Fed	62.49	44-76	0.20	0.112-0.325	0.06	0.036-0.086

Source	Type	Cr		Cu		Fe	
		mean	range	mean	range	mean	range
Serum	Fed	0.45	0.211-1.152	0.88	0.561-1.436	21.08	1.6-500
	Non-Fed	0.43	0.314-1.059	0.88	0.616-1.265	14.96	1.3-445
Liver	Fed	0.28	0.209-0.373	28.47	4.49-54.4	353.11	70-523

Source	Type	K		Li		Mg	
		mean	range	mean	range	mean	range
Serum	Fed	411.9	160-1517	0.03	0.007-0.098	26.09	21-37
	Non-Fed	439.8	144-1446	0.03	0.007-0.175	28.60	16-42.5
Liver	Fed	2528.5	1333-3420	0.02	0.006-0.044	144.21	60-226

Source	Type	Mn		Mo		Na	
		mean	range	mean	range	mean	range
Serum	Fed	0.01	0.003-0.026	0.01	0.002-0.035	3436.13	1664-4025
	Non-Fed	0.00	0.002-0.021	0.01	0.002-0.126	3418.47	1595-3971
Liver	Fed	3.33	2.373-4.803	0.68	0.429-1.194	835.80	432-1382

Source	Type	Ni		P		Pb	
		mean	range	mean	range	mean	range
Serum	Fed	0.01	0.004-0.010	106.53	62.28-165.78	0.00	0.00-0.013
	Non-Fed	0.01	0.005-0.015	92.70	57.39-137.98	0.00	0.001-0.012
Liver	Fed	0.01	0.007-0.028	3175.2	2252-4234	0.05	0.013-0.129

Source	Type	Sb		Se		Si	
		mean	range	mean	range	mean	range
Serum	Fed	0.00	0.001-0.001	0.11	0.063-0.175	10.42	6.71-27.24
	Non-Fed	0.00	0.001-0.001	0.09	0.055-0.143	9.57	6.335-24.43
Liver	Fed	0.01	0.002-0.013	0.19	0.095-0.349	48613.4	15.96-340139

Source	Type	Sn		Sr		Tl	
		mean	range	mean	range	mean	range
Serum	Fed	0.00	0.001-0.003	0.07	0.029-0.120	<0.002	<0.001-<0.001
	Non-Fed	0.00	0.001-0.001	0.07	0.027-0.126	<0.002	<0.001-<0.001
Liver	Fed	0.01	0.001-0.036	0.05	0.02-0.109	0.00	0.001-0.005

Source	Type	V		Zn	
		mean	range	mean	range
Serum	Fed	0.04	0.023-0.069	0.75	0.383-2.086
	Non-Fed	0.04	0.021-0.069	0.61	0.351-2.002
Liver	Fed	0.03	0.007-0.067	84.17	27.18-179.79

Table 4-4. Serum and liver concentrations (ppm) of copper (Cu), molybdenum (Mo), and selenium (Se) in fed and non-fed mule deer in northern Utah, 2002-2005.

	Mineral					
Type	Cu		Mo		Se	
Fed/Nonfed (n)	μ	range	μ	range	μ	range
Fed						
Serum	0.88	0.56-1.44	0.01	0.002-0.04	0.12	0.06-0.18
Liver	28.47	4.49-54.40	0.68	0.43-1.2	0.19	0.10-0.35
Non-fed						
Serum	0.88	0.62-1.27	0.02	0.002-0.13	0.09	0.06-0.14

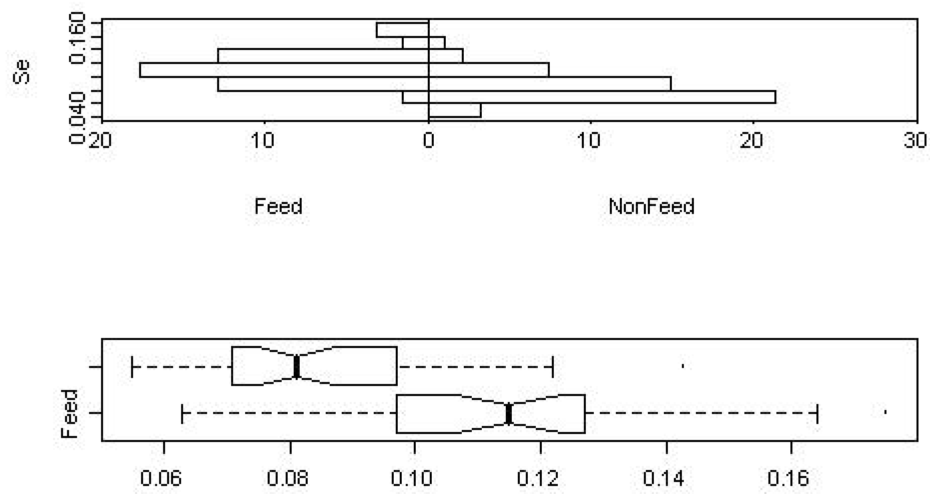

Figure 4-1. Notched boxplot and back-to-back histogram of serum Se levels in fed and non-fed mule deer, northern Utah, 2002-2005.

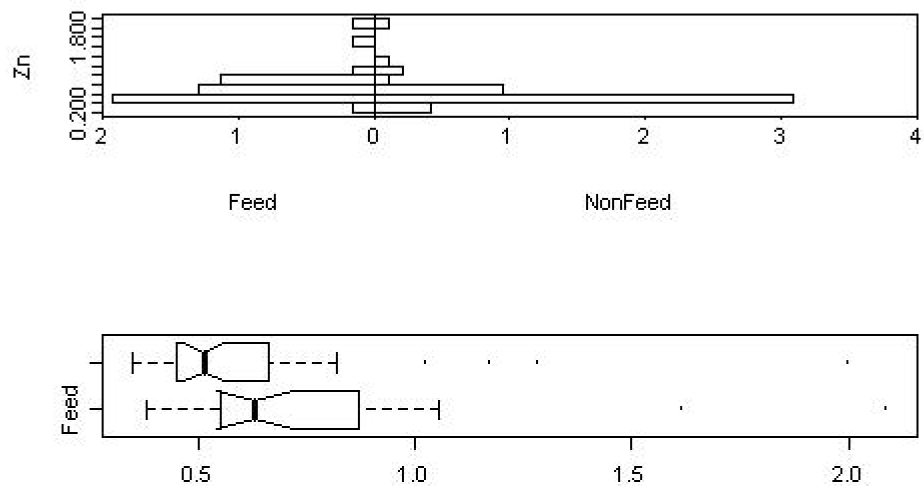

Figure 4-2. Notched boxplot and back-to-back histogram of serum Zn levels in fed and non-fed mule deer, northern Utah, 2002-2005.

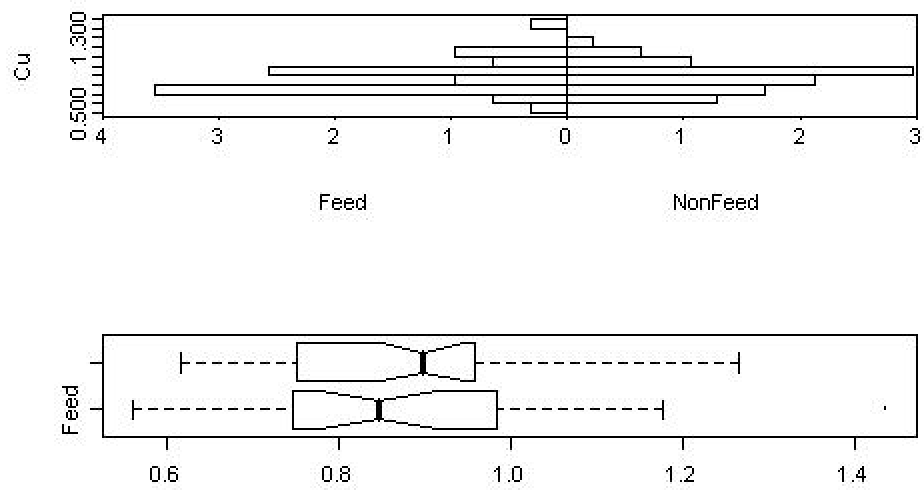

Figure 4-3. Notched boxplot and back-to-back histogram of serum Cu levels in fed and non-fed mule deer, northern Utah, 2002-2005.

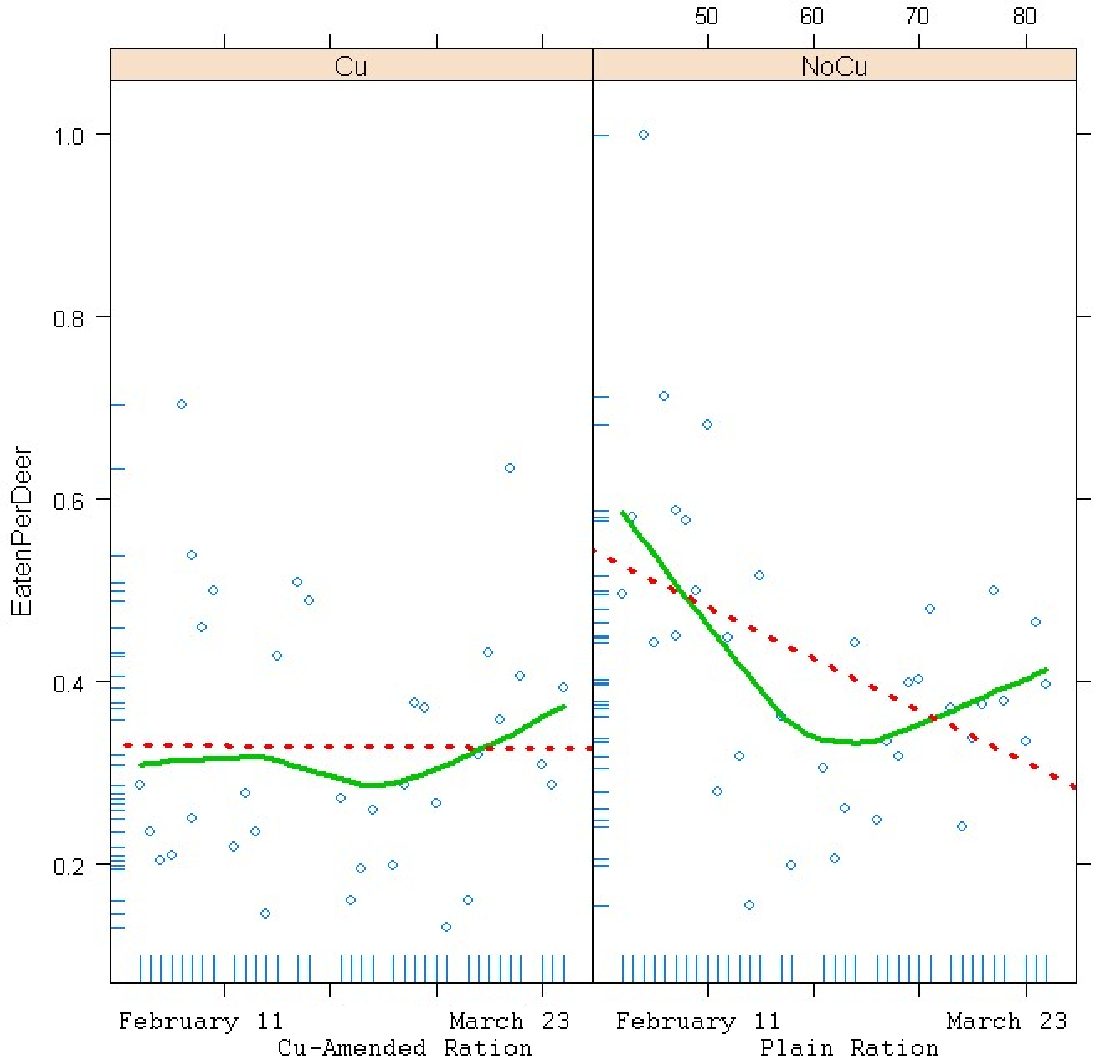

Figure 4-4. Amounts of Cu-amended and plain pellets eaten by mule deer (*Odocoileus hemionus*) from February through March, 2006. (The green line represents the mean value of the 'smoothed' data; the dashed red line represents the slope).

CHAPTER 5

MODIFIED BODY CONDITION INDEX TO ASSESS MULE DEER WINTER NUTRITIONAL STATUS[4]

ABSTRACT Many western states have policies regarding winter-feeding of big game. Most decisions to initiate winter-feeding programs are based on public perception of weather severity, rather than animal or herd nutritional status. We developed a modified body condition (MBC) index that rapidly assesses individual mule deer (*Odocoileus hemionus*) nutritional status through evaluation of fat and muscle deposits in 4 body areas of deer vehicle collision (DVC) carcasses. Assessment of multiple carcasses provided an estimate of herd nutritional status over time. The MBC index is strongly correlated to an organ fat condition index, the California Mule Deer body condition index (Spearman correlation coefficient = 0.89). We developed a methodology based on the MBC index that managers could use in conjunction with environmental data to help decide if and when to initiate winter-feeding. We assessed the usefulness of this methodology in 3 winters. The decision methodology provided an estimate of mule deer herd nutritional status and efficiently determined a date for initiation of a winter-feeding program during three winters in Utah.

INTRODUCTION

Policies regulating winter-feeding programs for big game animals have been implemented in many western states largely in response to stakeholder concerns (Utah Division of Wildlife Resources 2005, Oregon Department of Fish and Wildlife 2003, Idaho Fish and Game Commission 2006). Although these programs are expensive

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[4] Coauthored by Peterson, C. C., and T. A. Messmer.

(Musclow 1984, Smith 2001), they remain popular with sportsmen even though published reports regarding the benefits are mixed (Doenier et al. 1997, Smith 2001, Tarr and Pekins 2002, Peterson and Messmer 2007). In most cases, initiation of winter-feeding programs is dictated by onset of severe environmental conditions. However, increased individual survival and productivity resulting from winter-feeding largely have been attributed to feeding programs implemented before deer nutrient reserves decline (deCalesta et al. 1975).

Previous research has addressed winter-feeding program factors such as ration formula (Doman and Rasmussen 1944, Schoonveld et al. 1974, Musclow 1984, Ouellet et al. 2001), ration amount (Ozoga and Verme 1982, Baker and Hobbs 1985), duration of feeding (Smith 2001, Schmidt and Hoi 2002), and distance between feed stations (Ozoga and Verme 1982, Schmitz 1990, Page and Underwood 2006). However, little information concerning timing of implementation of feeding programs is readily available for management (Urness 1980, Ozoga and Verme 1982).

Because early or unusually severe environmental conditions are unpredictable it is difficult to determine at the onset of these conditions if deer survival will be impacted. Feeding programs implemented too early may result in dependency or other altered behavior, as well as unnecessary expense. Alternatively, delaying implementation of feeding programs to when deer already may have reached irreversible levels of malnourishment may not mitigate mortality (DelGiudice et al. 1994). Depending on the severity of environmental conditions, healthy mule deer are able to survive 30-60 days of winter-related malnourishment (Ozoga and Verme 1982, Baker and Hobbs 1985, Schmitz 1990). Thus, benefits of winter-feeding programs are more likely to accrue if programs are initiated before deer nutritional status declines, but not within the survivable 30-60 day time frame.

Although several indices, e.g., marrow fat, organ fat, serum analysis, etc., are helpful in determining body condition (deCalesta et al. 1975, Verme and Ozoga 1980, DelGiudice and Seal 1988, Harder and Kirkpatrick 1996, Oliver 1997, Sakkinen et al. 2000), they are time consuming, labor intensive, and prone to misuse (Cook et al. 2007). We designed and evaluated a methodology to assist in determining when to implement winter-feeding programs. The decision methodology is based on a modified body condition (MBC) index employing visual and manual inspection of recent mule deer mortalities from deer vehicle collision (DVC) in northern Utah. This methodology could provide managers with a quick field technique for assessing mule deer herd nutritional status at the onset of and throughout winter. If winter-feeding is an option, managers could use this methodology to help determine when to feed. Initiating feeding programs at the optimum time may not only increase survival but also reduce costs.

STUDY AREA

This study was conducted in the Cache-Wasatch mountain range of northern Utah in the winters of 2003-2004, 2005-2006, and 2006-2007. The mule deer population in the area was estimated at 7,000 following $\geq$ 50% winterkill in winter 2001-2002 (D. Austin, Utah Division of Wildlife Resources, unpublished report). Elevations range from 1350 meters to 2997 meters. Higher elevations in the unit provide mule deer fawning and summer range while lower elevations constitute critical mule deer winter range.

A major highway, US 89, follows the course of the Logan River and Beaver Creek, running both across and with major migration routes of mule deer. At lower elevations it runs through critical mule deer winter range. The riparian area through which US 89 runs is also important summer fawn rearing habitat. A second major highway, US 91, parallels the west face of the Cache-Wasatch range and runs through critical mule deer winter range. It cuts across many stream courses connecting the foothills to the fawn rearing and winter habitat of the Cub, Little Bear, and Bear Rivers. Because of these road networks and increasing traffic volumes, high incidence of deer vehicle collisions occur during migrations, during fawn rearing, and when deer are on the winter range (Sullivan et al. 2004).

METHODS

We developed the MBC index by combining objective and subjective metrics from field techniques for evaluating deer and range livestock condition (Riney 1960, Kistner et al. 1980, Austin 1984, Bennett and Wiedmeier 1992, Momont and Pruitt 1998) with levels of malnourishment described by DelGiudice and Seal (1988). The objective metrics included manual and visual evaluation of fat deposits and muscling on rump, withers, ribs-brisket, and back. The malnourishment level of each of the individual deposit areas was characterized as early (good), prolonged reversible (fair), or prolonged irreversible (poor). Mule deer generally experience no long-term effects from early or prolonged reversible malnourishment (Torbit et al. 1985, DelGiudice et al. 1988). Deer that exhibit prolonged irreversible malnourishment are characterized by >28% weight loss and likely are unable to recover. Using a scale modified after Oliver (1997) and Kistner et al. (1980), a deposit showing early malnourishment was scored as 15 points, prolonged reversible malnourishment as 10 points, and prolonged irreversible as 5 points (Table 5-1). We computed a mean score over all 4 areas of each carcass (hereafter this is referred to as the objective score).

We also assigned each carcass a subjective score for overall appearance. When the subjective score differed from the objective score, we used the subjective score to either raise or lower the objective score by no more than 5 points. This was done to compensate for individual morphological variation. Individual variation may result in some deer having more defined bony protuberances. Objective inspection may indicate declining condition; however, subjective evaluation of the overall appearance including age assessment, quality of the coat and sexual traits may suggest the animal is simply young and rapidly growing, or that it is normally not inclined to heavy muscling and fat accumulation. For example, one carcass was a yearling female, estimated at 63 kg. The objective mean score was 10, in the fair range (rump=10, withers=10, ribs-sternum=10, back=10). However, the weight was unusually high for a yearling female in this area, the legs were unusually long, and the appearance was very feminine. There were no obvious parasites, i.e., ticks or pharyngeal bots that had been prevalent on most other carcasses that season, and the coat quality was excellent with full color and thickness. The subjective score was 15, in the good range. The average of the two scores raised the overall score 5 points into the good range.

During the 2003-2004 and 2006-2007 winters, we used both the MBC index and Oliver's (1997) California Mule Deer Condition (CDC) index to estimate body condition scores for fresh (<48 hrs) DVC carcasses collected from roads and fields throughout the study area. Correlation between the two indices for winters 2003-2004 and 2006-2007 was characterized using Spearman's rank correlation. During winter of 2004-2005 we used only the MBC index.

The decision methodology involves three criteria: (1) a minimum tolerable MBC index for the deer herd (i.e., a herd body condition maintenance standard), (2) a minimum acceptable precision level for interval estimates of mean body condition, and (3) a confidence level for interval estimates of mean body condition. Parameter values are determined by the manager; here we have used 11, 2, and 80%, respectively. Beginning in early October we recorded one or both indices, as noted above, to establish baseline body conditions for the herd. As each additional carcass was collected, we computed the cumulative mean MBC index to date and a confidence interval for that mean. Initiation of a feeding program was indicated when three conditions were met: (1) the lower confidence limit of the cumulative mean fell below the minimum tolerable MBC index, (2) the difference between the cumulative mean and the lower confidence limit (i.e., the observed confidence interval half-width) was less than the minimum acceptable precision level, and (3) the probable remaining length of season was in excess of the 30-60 day survivable time frame.

RESULTS

We evaluated 73 DVC carcasses in the winter of 2003-2004, and 34 carcasses each in the the winters of 2004-2005 and 2006-2007. Generally, the MBC index required 5-10 minutes to complete; the CDC index required 30-40 minutes for completion. The MBC index correlated well with the CDC index. Correlation was higher when >1 person evaluated, and discussed evaluations of carcasses (2 person evaluation: winter 2003-2004 =0.93; 1 person evaluation: winter 2006-2007 =0.77).

On January 13 in winter 2003-2004, the lower confidence limit of the cumulative mean body condition score (=10.66) dropped below the minimum tolerable body condition score (=11), the observed confidence interval half-width (12.31 – 10.66 = 1.65) was less than the minimum acceptable precision level (=2) (Table 5-2, Fig.5-1), and on average $\geq$60 days remained before spring green-up. Consequently, the decision methodology indicated that a feeding program should be initiated to maintain the health of the deer herd. In winters 2004-2005 (Fig.5-5) and 2006-2007 (Fig. 5-6), the lower confidence limit of the cumulative mean body condition score never dropped below the minimum tolerable body condition score. Consequently, the decision methodology indicated that a feeding program was not necessary.

DISCUSSION

The MBC index provided an adequate metric for rapid assessment of mule deer body condition. The MBC index was as effective as the CDC index in estimating animal body condition and nutritional status, but application of the MBC index was easier and faster. The CDC index required fresher and less damaged carcasses because it could not be used to estimate condition scores for organs extensively damaged by vehicle impacts, or those that had started to deteriorate during warmer periods. Consequently, DVC carcasses more than 48 hours old were more often and completely evaluated using the MBC index than the CDC index.

We acknowledge that because of site-specific conditions, e.g., deep snow or road salt accumulation, some animals may be repelled from or attracted to roads in non typical numbers or proportions (Rost and Bailey 1979). Thus nutritional status derived from available DVC carcasses may not be representative of the herd (Rabe et al. 2002).

Consistent training was needed to obtain accurate scores from both indices. Initial training that simultaneously employed both indices improved our ability to consistently estimate condition with the MBC index. Furthermore, periodic use of both indices, as well as concurrent scoring of >1 carcass helped maintain training. Periodic scoring and discussion of carcass evaluations by more than one person reduced observer bias, and aided in maintaining consistency amongst different observers.

In areas with a history of high deer winterkill related to severe winter conditions we recommend the following protocol for use of the MBC index and decision methodology to inform the implementation of winter-feeding programs. Evaluations of DVC carcass body condition should begin 2 months prior to severe-stress conditions. This not only increases the probability of obtaining a sample size within the desired confidence limits but will aid in establishing the time and conditions that result in a declining trend in body condition. Precision of the estimate of mean body condition, and thus usefulness of the decision methodology, increases as the number of carcasses increases. The number of carcasses required for an adequate sample is dependent on the desired confidence level and the maximum limit of desirable precision, both of which are set by the manager. Through multiple years of consistent use of the MBC methodology the manager may apply site-specific knowledge of environmental conditions to adapt the methodology to each site.

For example, beginning evaluation of DVC carcasses in October in northern Utah supplied adequate sample size by early January for 80% CI. Winter conditions in northern Utah generally begin in mid to late November with snow accumulation increasing through December. Deer are able to access browse and cover into December. Usually, south slopes melt off following storms, permitting continued accessibility to winter browse. On average, severe conditions begin to moderate through March and availability of spring forage increases by early April. Generally, deer in good condition in mid-January are able to survive an average winter. Therefore, in this area by this time, the manager considers the degree of decline in DVC condition in concert with management objectives, and current and predicted environmental conditions to determine when, or if winter-feeding should be initiated. In winter 2003-2004, use of the MBC index suggested implementing the feeding program 1 week after the UDWR implemented the program. In both winters 2004-2005, and 2005-2006 the MBC index suggested feeding was not necessary. Still, the feeding program was implemented in winter 2004-2005. Data from spring mortality surveys suggested there was no need to feed in either of these winters. Use of the MBC index methodology would have prevented unnecessary implementation and expense.

Assessing stages of malnourishment with the MBC index, combined with information of environmental conditions for deer will allow managers to make more informed decisions about implementing winter-feeding.

MANAGEMENT IMPLICATIONS

The MBC index provided biological decision criteria for implementing winter-feeding programs in Utah. It is up to the manager to use this information in conjunction with information on environmental conditions, e.g., temperatures, snow accumulation, length of season, range conditions, etc., to determine if and when feeding should be implemented. If used in combination with these additional data, the MBC index may also be used to identify herds with the highest winter mortality risks and in need of the greatest management focus.

Acknowledgements

This project was funded by the Utah Division of Wildlife Resources, Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, the Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension. The U.S. Forest Service granted access to several of the study sites.

LITERATURE CITED

Austin, D. D. 1984. Fat depth at the xiphoid process: a rapid index to deer condition. Great Basin Naturalist 44:178-181.

Baker, D. L., and N. T. Hobbs. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934-942.

Bennett, J. A., and R. D. Wiedmeier. 1992. Visual body condition score as a measure of range animal response. Rangelands 14:296-298.

Cook, R. C., T. R. Stephenson, W. L. Myers, J. G. Cook and L. A. Shipley. 2007. Validating predictive models of nutritional condition for mule deer. Journal of Wildlife Management 71:1934-1943.

deCalesta, D. S., J. G. Nagy, and J. A. Bailey. 1975. Starving and refeeding mule deer. Journal of Wildlife Management 39:663-669.

DelGiudice, G. D., and U. S. Seal. 1988. Classifying winter undernutrition in deer via serum and urinary urea nitrogen. Wildlife Society Bulletin 16:27-32.

DelGiudice, G. D., L. D. Mech, and U. S. Seal. 1994. Undernutrition and serum and urinary urea nitrogen of white-tailed deer during winter. Journal of Wildlife Management 58:430-436.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235-243.

Doman, E. R., and D. I. Rasmussen. 1944. Supplemental feeding of mule deer in northern Utah. Journal of Wildlife Management 8:317-338.

Harder, J. D., and R. L. Kirkpatrick. 1996. Physiological methods in wildlife research. Pages 275-306 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Idaho Fish and Game Commission. 2006. Rules governing emergency feeding of antelope, elk, and deer of the Idaho Fish and Game Commission. Idaho Fish and Game Commission, Boise, USA.

Kistner, T. P., C. E. Trainer, and N. A. Hartmann. 1980. A field technique for evaluating physical condition of deer. Wildlife Society Bulletin 8:11-17.

Momont, P. A., and R. J. Pruitt. 1998. Condition scoring of beef cattle. Utah State University, Cooperative Extension System, Report CL720, Logan, USA.

Musclow, R. W. 1984. Emergency big game feeding in Utah past—present—future. C. Quinn and game management staff, editors. Utah Department of Natural Resources, Division of Wildlife Resources, Publication 85-4, Salt Lake City, USA.

Oliver, M. N. 1997. California deer condition index: a field technique for scoring body condition. California Department of Fish and Game and the School of Veterinary Medicine, University of California, Los Angeles, USA.

Oregon Department of Fish and Wildlife. 2003. Oregon's mule deer management plan. Oregon Department of Fish and Wildlife. Portland, USA.

Ouellet, J.-P., M. Crete, J. Maltais, C. Pelletier, and J. Huot. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129-135.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:281-301.

Page, B. D., and H. B. Underwood. 2006. Comparing protein and energy status of winter-fed white-tailed deer. Wildlife Society Bulletin 34:716-724.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Rabe, M. J., S. S. Rosenstock, and J. C. deVos, Jr. 2002. Review of big-game survey methods used by wildlife agencies of the western United States. Wildlife Society Bulletin 30:46-52.

Riney, T. 1960. Field technique for assessing physical condition of some ungulates. Journal of Wildlife Management 24:92-94

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43:634-641.

Sakkinen, H., A. Stein, O. Holand, K. Hove, E. Eloranta, S. Saarela, and E. Ropstad. 2000. Plasma creatinine concentration in semi-domestic free ranging reindeer, and in reindeer under defined feeding conditions. Advances in Ethology 35:76-83.

Schmidt, K. T., and H. Hoi. 2002. Supplemental feeding reduces natural selection in juvenile red deer. Ecography 25:265-272.

Schmitz, O. J. 1990. Management implications of foraging theory: evaluating deer supplemental feeding. Journal of Wildlife Management 54:522-532.

Schoonveld, G. G., J. G. Nagy, and J. A. Bailey. 1974. Capability of mule deer to utilize fibrous alfalfa diets. Journal of Wildlife Management 38:823-829.

Smith, B. L. 2001. Winter feeding of elk in western North America. Journal of Wildlife Management 65:173-190.

Sullivan, T. L., A. F. Williams, T. A. Messmer, L. A. Hellinga, and S. Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer-vehicle collisions during mule deer migration. Wildlife Society Bulletin 32:907-915.

Tarr, M. D., and P. J. Pekins. 2002. Influences of winter supplemental feeding on the energy balance of white-tailed deer fawns in New Hampshire, U.S.A. Canadian Journal of Zoology 80:6-15.

Torbit, S. C., L. H. Carpenter, D. M. Swift, and A. W. Alldredge. 1985. Differential loss of fat and protein by mule deer during winter. Journal of Wildlife Management 49:80-85.

Urness, P. J. 1980. Supplemental feeding of big game in Utah. Utah Division of Wildlife Resources, Publication 80-8, Salt Lake City, USA.

Utah Division of Wildlife Resources. 2005. Emergency big game winter feeding. Utah Division of Wildlife Resources, W5WLD-2, Salt Lake City, USA.

Verme, L. J., and J. J. Ozoga. 1980. Effects of diet on growth and lipogenesis in deer fawns. Journal of Wildlife Management 4:315-324.

Table 5-1. Description of modified body condition (MBC) index values as applied to mule deer in northern Utah, 2001-2007.

Site	Score	Condition	Description
Rump	15	Good	Tailhead is full. Spinal processes are well covered. Hips have square appearance and are well covered; femur is deep; thigh muscling is full.
	10	Fair	Spine is covered, but not thickly. Hip bones are not prominent, but hips are not square in appearance. Thigh is thick and well rounded, but femur is not deep.
	5	Poor	Tailhead is thin and loose. Rear spinal processes are becoming prominent. Hips are bony and easily outlined. Thigh is thin and femur is easily outlined.
Withers	15	Good	Sex specific variation: males may be much broader than females. Vertical profile of top into shoulder is a rounded inverted 'U' or 'V'. Spinal processes may be obvious but are well bordered with flesh. Junction of neck and shoulder is well filled in and thick.

	10	Fair	Spinal processes are becoming prominent but are still bordered with some flesh. Vertical profile of top into shoulder is an inverted 'V'; males may be flatter. Junction of neck and shoulder is more angular, less filled in.
	5	Poor	Spinal processes are prominent with little flesh to either side. Top into shoulder is a sharp inverted 'V'. Top edge and depth of scapula are easily felt. Junction of neck and shoulder is thin and sharply angled.
Ribs-Sternum	15	Good	Sex specific variation: males are thicker and may be less bony than females. Ribs feel very thickly covered, sternum feels thick and fat—may be slightly indented on center line. Shoulder to elbow is thick and rounded.
	10	Fair	1-3 ribs visible; none are thickly indented. Sternum still well covered, but feels hard half of length. Shoulder to elbow is flatter, but not bony.
	5	Poor	>3 ribs easily felt and deeply indented between. Sternum feels hard most of length and width. Rib-sternum connection hard, no fleshy covering. Shoulder is thin, elbow is prominent.

Back	15	Good	Back feels solid, square and broad; muscle and fat are thick on both sides of spinal processes from hips forward 10-12cm.
	10	Fair	Spinal processes from hips forward 10-12cm are easily felt but still bordered with muscle.
	5	Poor	Prominent spinal processes between hips and forward toward shoulder. Little muscle remains.
Appearance	15	Good	Rich, full color. Solid, smooth, full connections between body sections. Well filled in behind, and around eyes.
	10	Fair	Nothing obviously good or poor in appearance.
	5	Poor	Dull, flat coat. Angular and sunken connections between body sections. Clearly depressed behind and around eyes.

Table 5-2. Cumulative mean body condition of deer-vehicle collision (DVC) carcasses in winter 2003-2004, a moderately severe winter, with lower confidence limits for the mean as applied to mule deer in northern Utah, 2001-2007.

Date	mean	lclm
03 Oct	15.	
23 Oct	15.	
31 Oct	15.	
15 Dec	15.	
21 Dec	15.	
22 Dec	14.17	12.94
22 Dec	14.29	13.26
05 Jan	14.38	13.49
05 Jan	13.89	12.86
05 Jan	14.00	13.08
06 Jan	13.64	12.67
10 Jan	13.33	12.36
13 Jan	12.31	10.66
15 Jan	12.50	10.96
15 Jan	12.33	10.89

[mean is the mean body condition score for the cumulative data to date; lclm is the lower 80% confidence limit for the mean; lower width is the difference between the mean and the lclm (i.e., the width of the lower half of the CI)].

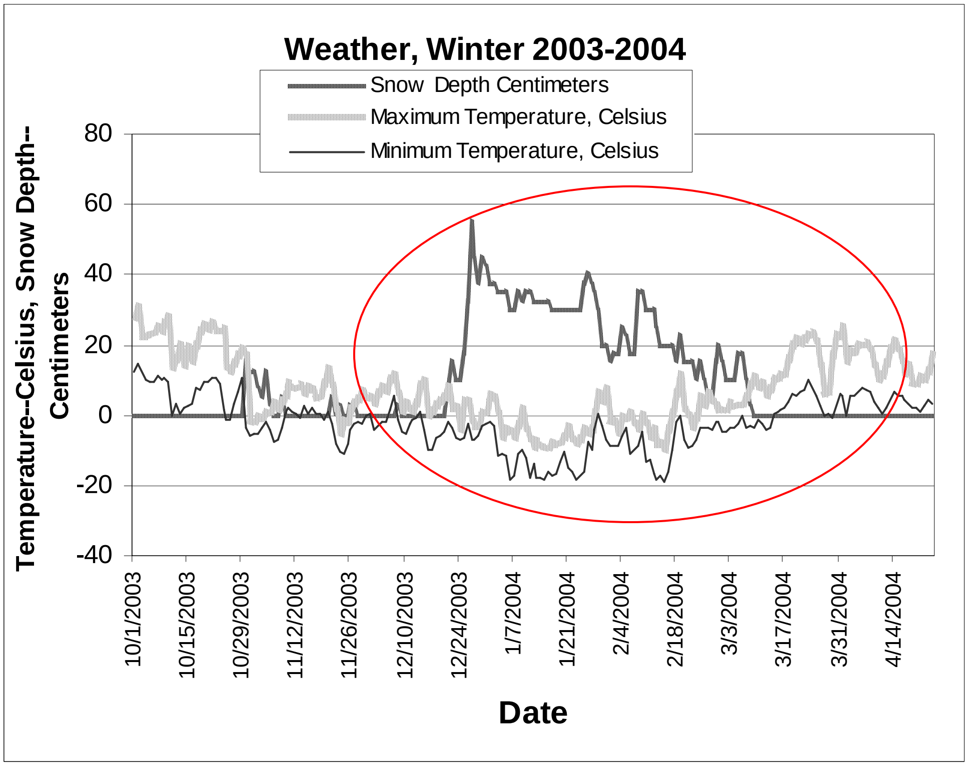

Figure 5-1. Average snow accumulation, and maximum and minimum temperatures in winter 2003-2004; Utah Climate Center, American Association of State Climatologists, Utah State University, Logan, Utah, USA.

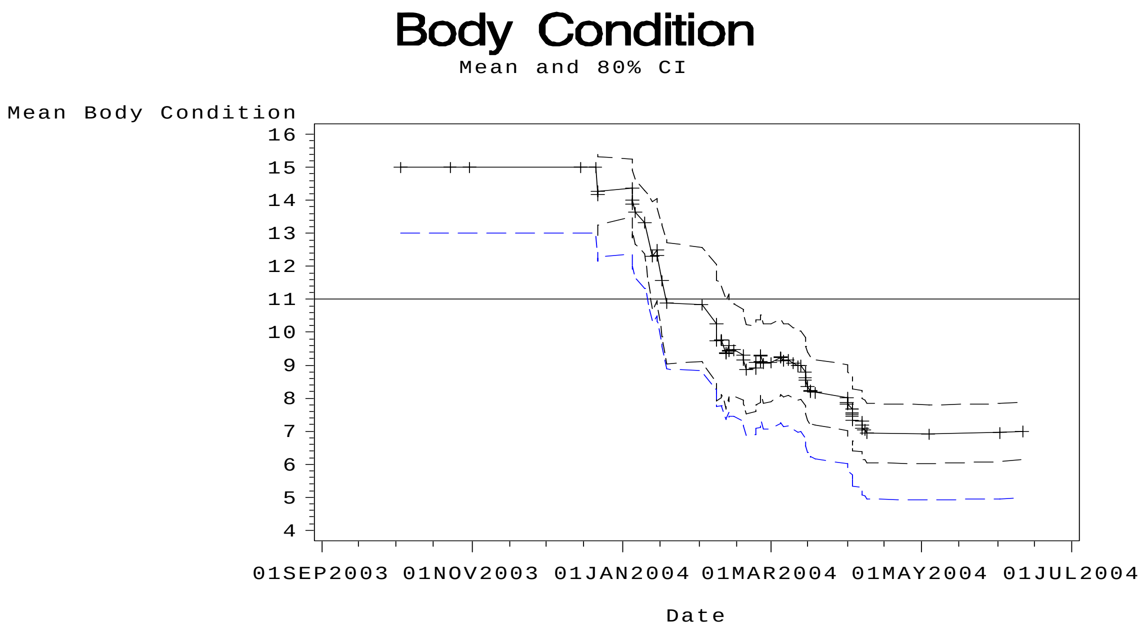

Figure 5-2. Winter 2003-2004 cumulative mean body condition of DVC carcasses, with 80% confidence interval and the maximum limit of desirable precision, illustrating the decision methodology for implementation of winter-feeding as applied to mule deer in northern Utah, 2001-2007.

(+ is the mean for the cumulative dataset to date. The solid black line connects the means. The dashed black lines are the upper and lower confidence limits. The dashed blue line marks the lower_range, i.e., the maximum limit of desirable precision. The horizontal, solid black line marks a body condition criterion that was pre-determined. Here it was set at a body condition score of 11).

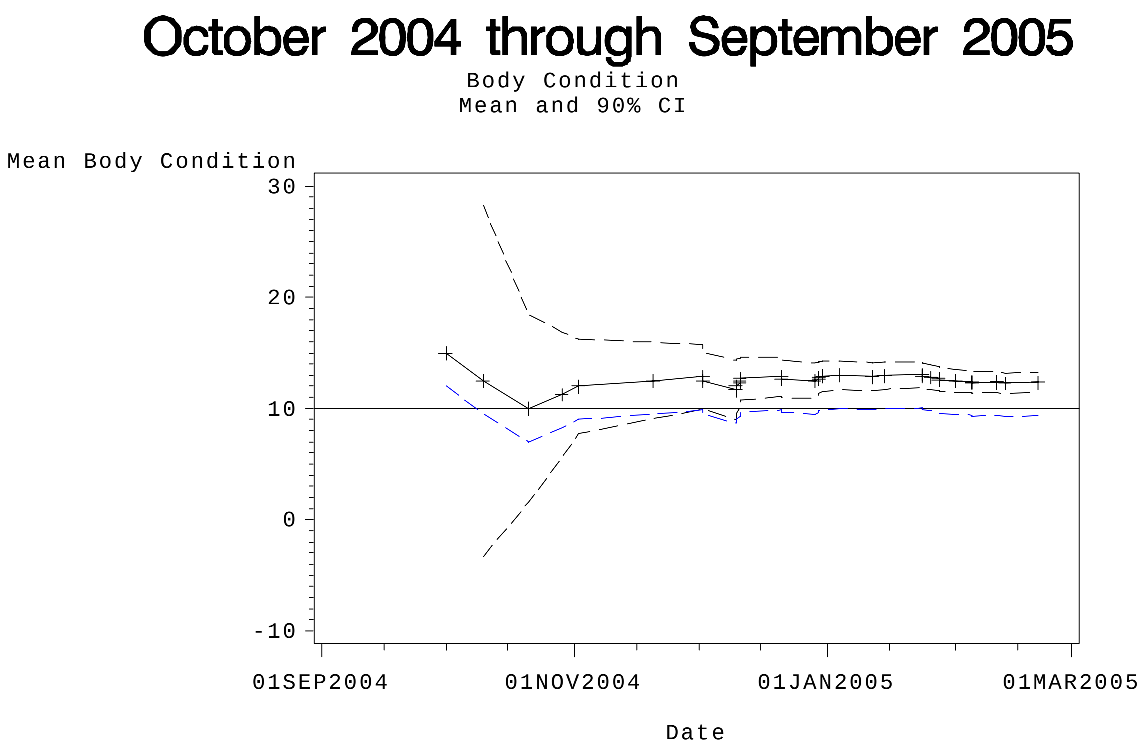

Figure 5-3. Winter 2004-2005 cumulative mean body condition of deer-vehicle collision (DVC) carcasses, with 90% confidence interval and the maximum limit of desirable precision, illustrating the decision methodology for implementation of winter-feeding as applied to mule deer in northern Utah, 2001-2007.

(+ is the mean for the cumulative dataset to date. The solid black line connects the means. The dashed black lines are the upper and lower confidence limits. The dashed blue line marks the lower range, i.e., the maximum limit of desirable precision. The horizontal, solid black line marks a body condition criterion that was predetermined. Here, it was set at a body condition score of 10).

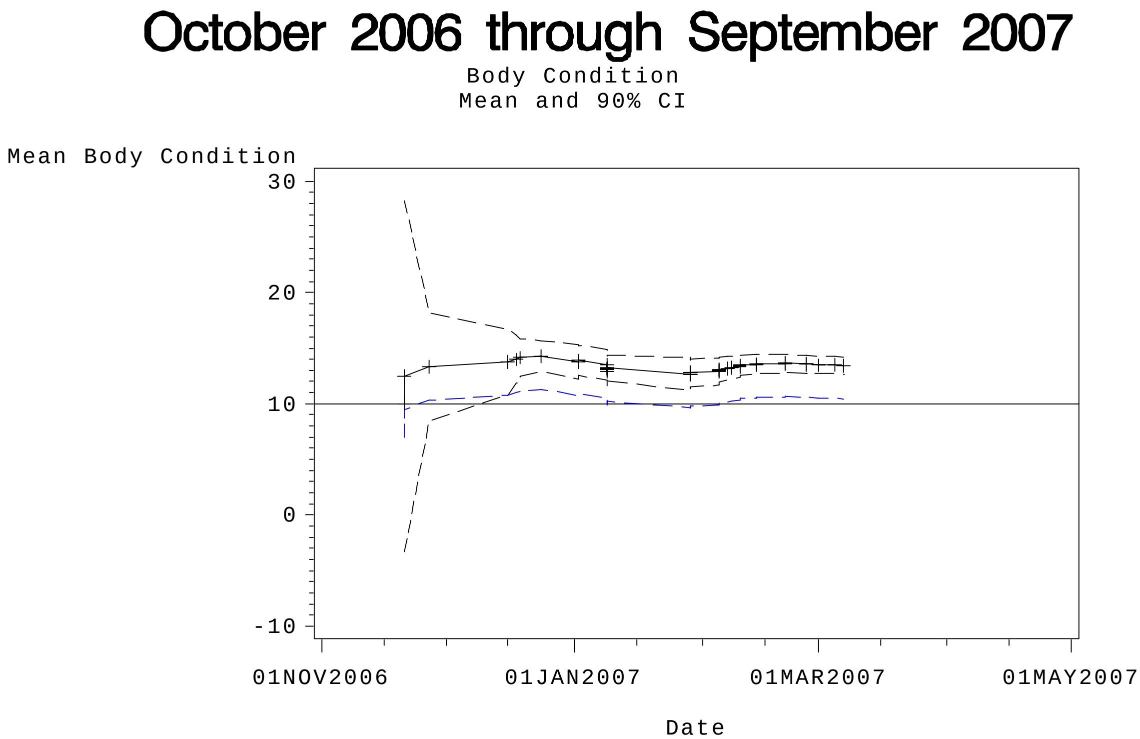

Figure 5-4. Winter 2006-2007 cumulative mean body condition of deer-vehicle collision (DVC) carcasses, with 90% confidence interval and the maximum limit of desirable precision, for use in predicting when to feed, Utah mule deer winter-feeding study, 2001-2007.

(+ is the mean for the cumulative dataset to date. The solid black line connects the means. The dashed black lines are the upper and lower confidence limits. The dashed blue line marks the lower range, i.e., the maximum limit of desirable precision. The horizontal, solid black line marks a body condition criterion that was pre-determined. Here, it was set a body condition score of 10).

CHAPTER 6

UTAH STAKEHOLDER PERCEPTIONS AND ATTITUDES REGARDING WINTER-FEEDING OF MULE DEER[5]

ABSTRACT Many state wildlife agencies develop their management policies using a public input process which relies on open meetings. Because these meetings tend to be dominated by consumptive users, these policies may not reflect all potential stakeholders values and interests. In 2000, the Utah Wildlife Board, after a series of public meetings, adopted a statewide policy for feeding mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*). To determine if this policy reflected the views of all Utah stakeholders, we implemented a mail-back survey to 600 randomly selected households representing 3 groups of Utahns— metropolitan, non-metropolitan, and urban/rural interface. The urban/rural group consisted of residents in Cache County. This northernmost county in Utah has a long tradition of residents feeding deer in winter. More respondents (83%) reported they had participated in non-consumptive activities such as wildlife viewing in the last 5 years, than reported consumptive activities such as hunting (27-38%). Most respondents (65-75%) believed winter-feeding programs are essential to management of mule deer ($\chi^2_6 = 7.02$, P = 0.32). Although respondents believed that feeding programs increased deer numbers, support for feeding was greater among urban/rural interface respondents ($\chi^2_6 = 21.24$, $P \leq 0.01$). However, 71% were reluctant to support feeding programs at the expense of habitat restoration projects ($\chi^2_6 = 11.64$, P = 0.07). Respondents that reported they like to watch wildlife were also more likely to feed ($\chi^2_1 = 17$, P < 0.001), and support spending public money for deer and elk winter-feeding

[5] Coauthored by Peterson, C. C., and T. A. Messmer.

programs ($\chi^2_1 = 18$, $P < 0.01$). In general, non-metropolitan and urban/rural interface groups were more supportive of allowing anyone to feed deer and elk ($\chi^2_4 = 18.65$, $P < 0.01$), however they also reported more wildlife related damage, 53% and 33% respectively ($\chi^2_2 = 16.83$, $P < 0.01$).

INTRODUCTION

Traditionally, Utah's long-time residents have placed high value on the state's wildlife (Krannich and Teel 1999). The state has experienced rapid population growth in the past 20 years. When urbanization rapidly impacts previously rural communities, the accompanying sudden shift in values may create conflicts over management of wildlife (Jacob and Schreyer 1980, Schneider and Hammitt 1995, Vaske et al. 2000, Brunson et al. 2001). As community socio-economics diversify, stakeholder interests in non-consumptive practices such as wildlife viewing tend to increase (Westley 1995). Subsequently, some stakeholders may engage in activities (i.e., feeding wildlife) that create additional opportunities for viewing and ameliorate the effects of severe weather on wildlife (Duda et al. 1998, Manfredo 2002). In response to such shifts, state wildlife agencies have implemented information programs to educate stakeholders on how and what to feed wildlife, as well as the benefits and potential liabilities of winter-feeding programs (Duda et al. 1998).

Large scale winter-feeding of wildlife has typically been conducted by sportsmen who had a vested interest in a given species. These programs have largely been focused on big game and upland game species (Leopold 1940, Trefethen 1975). Concomitantly, state agencies have made concerted efforts to include sportsman organizations in decision and policy making regarding these programs.

In general, most policy decisions regarding wildlife management are made through a public process that involves regional meetings which are primarily attended by consumptive users, e.g., sportsmen (Krannich and Teel 1999). In 2000, the Utah Wildlife Board approved a statewide Big Game Feeding Policy using a public meeting process (Utah Division of Wildlife Resources 2003). Although, more Utahns engage in non-consumptive wildlife-related activities than hunt or fish, few non-consumptive stakeholders participated in the public meetings that led to formalizing this policy (Krannich and Teal 1999).

The Utah Division of Wildlife (UDWR) implemented the policy in 2001 in northern Utah to abate the effects of severe winter weather on mule deer (*Odocoileus hemionius*). The winter-feeding program was continued through winter 2004-2005. Peterson and Messmer (2007) evaluated the effects of the winter-feeding on mule deer survival and productivity. During the evaluation period, researchers frequently interacted with local residents who were strongly divided regarding the policy and program benefits. Many were not aware of the policy (C. Peterson, Utah State University, unpublished data). Because few Utah non-consumptive stakeholders participated in the meetings where the policy was formalized, there was a need to assess stakeholder perceptions (Krannich and Teel 1999).

We surveyed a random sample of Utah metropolitan and non-metropolitan residents in winter of 2006-2007 to determine public attitudes and perceptions about winter-feeding of wildlife. We also wanted to assess respondent participation in and support for wildlife feeding, and determine how human-wildlife interactions may affect their perceptions. Specifically we were interested in determining if any differences existed between Utah stakeholders according to the nature of human-wildlife interactions, consumptive and non-consumptive wildlife interests, and by residence (metropolitan, non-metropolitan, and urban/rural interface).

STUDY AREA

Most of Utah's population now resides in 6 counties (U.S. Census Bureau, 2006). Generally the growth in the metropolitan areas is concentrated in areas that were once prime critical winter range for big game. Twenty-three of the remaining counties are considered non-metropolitan with farming and ranching as major occupations (U.S. Census Bureau 2006). One county, Cache, has recently achieved metropolitan status. This county, located in a valley at the northernmost end of the state, is representative of an urban/rural interface area. Relative to many other areas in the state, this county has limited amounts of winter range with historically high numbers of deer. Recognizing the potential impacts of increased urban populations on winter deer and elk (*Cervus elaphus*) herds, residents of Cache County have a long tradition of feeding big game to reduce winter mortality.

We compared the attitudes of a random sample of urban/rural interface residents (hereafter U/R Interface) who have long-term familiarity with winter-feeding, to Utah residents in metropolitan, and non-metropolitan areas. To select sample populations, we stratified the remaining 28 counties in the state according to population (U.S. Census Bureau, 2006). Counties with populations exceeding 100,000 were classed as metropolitan (5 counties, hereafter called Metro); counties with populations less than 100,000 were classed as non-metropolitan (23 counties, hereafter called Non-metro).

METHODS

Sample Population

The data for this study were acquired from a self-administered mail survey conducted January through March of 2007 (Appendix A). Questionnaires were mailed to a random sample of 600 individuals each from the 3 strata. The sample was limited to English speaking households listed in telephone directories. Recipients were instructed to have an adult (18 years or older) with the birthday nearest the time of receipt of the questionnaire be the respondent. Mailing information was acquired from Survey Sampling International, Inc., Fairfield, Connecticut, USA.

Questionnaire Administration

We developed and implemented a questionnaire following Dillman (2000). The questionnaire consisted of 18 multiple part questions divided into 4 sections: 1) respondent characteristics, 2) attitudes and perceptions, 3) participation and support, and 4) human-wildlife interactions.

Demographic questions were designed to determine respondent age and sex, educational background, metropolitan vs. non-metropolitan history, and affiliation with sportsman organizations and the UDWR. To determine if the respondents felt their views were being represented by the UDWR and sportsman organizations, they were asked to state their level of satisfaction with several policy statements supported by these organizations.

To determine attitudes and opinions about the benefits of winter-feeding programs for mule deer, respondents were asked to agree or disagree with 6 general statements regarding program effectiveness. The relative strength of agreement or disagreement for these statements was measured on a 5-point Likert scale (1=strongly disagree to 4=strongly agree; an optional "don't know" response was also provided). To identify where respondents obtain their information, they were provided 6 common sources of information and asked to assign a value to each using a 5-point Likert scale (0 = not important to 4 = extremely important).

Respondents' levels of participation in and support for wildlife feeding programs were evaluated using a series of questions to determine past and current experience with feeding wildlife, to include time and cost commitments. Respondents also were asked to identify who should pay for and be allowed to conduct winter-feeding programs.

Because previous experiences with wildlife can affect respondent perceptions and support for these programs (Messmer et al. 1998), we asked them to identify past positive or negative interactions with wildlife. To assess non-consumptive interests, respondents were asked a series of questions regarding their participation in wildlife-viewing activity, to include time and cost commitments.

We initiated the survey in January, because winter conditions usually peak at this time and it coincides with the greatest public interest and awareness of wildlife feeding. Our sample populations were mailed an introductory letter explaining the purpose of the survey. Ten days later a survey packet including a cover letter, survey, and additional introductory letter was mailed to each survey recipient. This was followed at 10-17 day sequential intervals with reminder/thank you cards and two additional survey packets, to each non-respondent (Dillman 2000).

To test for non-response bias, we conducted a phone survey that included a sample of questions selected from the original survey. These questions addressed the major points of interest in the survey, e.g., respondent demographics, participation in consumptive and non-consumptive activities, level of agreement or disagreement with statements concerning the effectiveness of winter-feeding programs, the respondent's human-wildlife interactions, and affiliation with sportsman organizations. This survey was administered to a random sample of 60 of the 982 non-respondents (6%). The questionnaire and study methodology were approved by the Institutional Review Board at Utah State University (IRB # 1716).

Data Analysis

Stakeholder responses were analyzed to determine if any differences exist between Non-metro, Metropolitan, and U/R Interface respondents regarding wildlife feeding programs. We used descriptive statistics and pair-wise comparisons to examine responses. Non-response bias phone survey results were evaluated for differences from mail-back survey results with descriptive statistics and pair-wise comparisons. Chi-square goodness of fit tests evaluated binomial responses and chi-square homogeneity of proportions tests were used to evaluate nominal data with $P \leq 0.05$ used as the critical value for determining statistical significance of relationships (Conover 1999).

RESULTS

Response Rates and Non-Response Bias

Response rates were determined by calculating the proportion of completed/returned surveys to the total number of deliverable surveys. The urban/rural sample population returned 181 surveys (112 undeliverable and 3 unusable) resulting in a 37% response rate. Metropolitan residents returned 146 surveys (72 undeliverable and 3 unusable) yielding a 28% response rate. Non-metro residents returned 197 surveys (103 undeliverable and 5 unusable) for a 40% response rate. Mail-back questionnaire and phone survey responses did not differ in direction of response ($P \leq 0.50$). However, mail-back questionnaire respondents tended to express stronger levels of disagreement and agreement with statements than phone survey participants.

Demographics

Most respondents (70-75%) were male, between the ages of 35-74 (73-83%), and tended to be well educated (Table 6-1). The Urban/Rural Interface and Non-metro respondents had stronger and more recent rural ties than their Metropolitan counterparts ($\chi^2_{10} = 208$, $P \leq 0.001$). More Non-metro respondents considered themselves to be a sportsman/woman ($\chi^2_2 = 6.22$, $P = 0.04$). More respondents believed that the state wildlife agency better represented their views than sportsmen groups (agency 64-71%, sportsmen groups 53-61%; $\chi^2_{12} = 95$, $P < 0.01$), and more U/R Interface respondents felt sportsman groups did not represent their views ($\chi^2_8 = 22$, $P < 0.01$).

Respondent Perceptions and Attitudes

Most respondents (65-75%) were supportive of the statement that winter-feeding programs are essential to management of mule deer ($\chi^2_6 = 7.02$, $P = 0.32$; Table 6-2). Most respondents from all 3 groups (66-71%), and 73-79% of those who had fed or watched wildlife supported use of public money for winter-feeding programs for deer and elk (all: $\chi^2_2 = 1.15$, $P = 0.56$; fed: $\chi^2_1 = 17.55$, $P < 0.01$; watched: $\chi^2_1 = 18.21$, $P < 0.01$). However, they were reluctant to support diverting money from habitat restoration projects to feeding operations: 71% of respondents did not consider winter-feeding programs a more efficient use of money than habitat restoration (χ^2_6 = 11.64, P = 0.07). Respondents (85%) also expressed concerns that winter-feeding programs could increase the spread of wildlife diseases (χ^2_6 = 6.91, P $\leq$ 0.33). Although respondents strongly agreed that feeding programs increased deer numbers, support was greater among U/R Interface respondents (95% U/R Interface, 79% Metro, 78% Non-metro; χ^2_6 = 21.24, P $\leq$ 0.01). Most respondents (56-62%) did not think feeding programs increase property damage and/or deer vehicle collisions (χ^2_6 = 6.66, P = 0.35). And most respondents from all groups (89-95%) thought the programs increase wildlife viewing opportunities (χ^2_6 = 9.16, P $\leq$ 0.17). Most respondents considered personal experiences, media, scientific publications and UDWR publications to be important as sources of information. Metropolitan respondents placed less value on friends and family as a source of information (χ^2_8 = 17, P = 0.03).

Participation in Feeding Wildlife

Although 40-44% of respondents reported feeding wildlife in the past 5 years (χ^2_2 = 0.72, P = 0.70), U/R Interface and Non-metro were slightly more likely to have fed deer and elk (χ^2_4 = 9, P = 0.06). All groups were similar in time invested in feeding wildlife (χ^2_6 = 6.03, P = 0.42), with 95% of those who fed wildlife spending up to 50 hours/year. In addition, 53% to 68% of respondents who fed wildlife spent \$50.00 or less/year, 20% to 27% spent \$52.00 to \$100.00/year, and 8% to 21% spent \$101.00 to \$500.00/year.

Most respondents (83-85%) thought the UDWR should be allowed to feed deer and elk (χ^2_4 = 9.51, P = 0.05 (Table 6-3). Most (74-80%) also supported feeding by sportsmen, if supervised by the state wildlife agency ($\chi^2_4 = 12.86$, P = 0.01). Although support for feeding deer and elk by residents operating independently was not high, there was more support for such programs from U/R Interface and Non-metro (23%; $\chi^2_4 = 18.65$, P < 0.01).

Respondents who fed wildlife (Table 6-4) were more supportive of permitting local residents to feed deer and elk with or without the supervision of the UDWR ($\chi^2_2 = 17$, P < 0.01). These respondents tended to be older (>34 yrs; $\chi^2_3 = 9$, P < 0.03), with more rural backgrounds ($\chi^2_5 = 13$, P < 0.03). They also reported experiencing more wildlife related damages ($\chi^2_1 = 13.78$, P < 0.01), wildlife benefits ($\chi^2_1 = 21$, P < 0.01), and believed that feeding increases numbers of deer and elk ($\chi^2_3 = 7.57$, P = 0.06). In addition, they were 17% more likely to participate in wildlife viewing ($\chi^2_1 = 17$, P < 0.01, $\chi^2_2 = 30$, P < 0.01, respectively), and spent more money ($\chi^2_4 = 28$, P < 0.01) and time on wildlife viewing ($\chi^2_4 = 40$, P < 0.01; Table 6-6).

Human Wildlife Interactions

Most respondents (52-57%) reported positive interactions with wildlife (Table 6-5). These interactions included photography (71%), hunting (43%), and other benefits such as a feeling of well-being related to environmental health (18%); only 17 (4%) of respondents reported financial profit. Respondents who participated in wildlife-associated recreation believed the UDWR (71-76%) better represented them than did sportsman organizations (60-62%; $\chi^2_4 = 37$, P < 0.01). However, more U/R Interface residents (31%) than Non-metro (19%) and Metro (23%) respondents reported that they had received no benefit from wildlife in the past 5 years ($\chi^2_2 = 6.78$, P = 0.03).

Many respondents (17-50%) also reported negative interactions with wildlife in the past 5 years (Table 6-5). These included landscape damage (43%), wildlife vehicle collisions (32%), and agricultural damage (16%). Only 5 (2%) reported a loss of personal or family safety due to wildlife and only 4 (2 %) respondents reported an incident of wildlife related disease. Most negative interactions reported were by Non-metro and U/R Interface ($\chi^2_2 = 16.83$, $P = 0.01$). For example, 50% of deer vehicle collisions (DVC) were reported by Non-metro (n=41), 33% by U/R Interface (n=27) ($\chi^2_2 = 9$, $P = 0.01$), and 50-63% of landscape and agricultural damage was Non-metro, with 32-33% reported by U/R Interface ($\chi^2_2 = 17$, $P = 0.01$). The estimated costs of these negative interactions with wildlife were mostly under $1,000.00 (n=136, 29%), with 39 (8%) estimated at between $1,000-$10,000 and only one (<1%) estimated at over $10,000 ($\chi^2_4 = 6$, $P = 0.46$).

Wildlife Viewing

More Non-metro respondents (90%) participated in wildlife viewing than U/R Interface (80%) and Metro (77%: $\chi^2_2 = 10.3$, $P < 0.01$). More Non-metro (36%) than U/R Interface (28%) and Metro (31%) respondents also reported they plan time specifically for watching wildlife ($\chi^2_4 = 9.5$, $P < 0.05$). The average annual hours spent watching wildlife was similar for all groups, with 80% or more of each group spending 50 hours or less/year (Table 6-6). Annual average expense for watching wildlife was also similar for all groups with 7-9% spending more than $500/year (Table 6-6).

Respondents who watch wildlife were more likely to feed wildlife ($\chi^2_1 = 17$, $P < 0.01$), and support spending public money for winter-feeding programs ($\chi^2_1 = 18$, $P <$

0.01). As well, they were more likely to favor permitting anyone to feed deer or elk (χ^2_2 = 28, P < 0.01). They were more rural in residence now (χ^2_5 = 17, P < 0.01) and throughout their adult lives (χ^2_5 = 17, P < 0.01), and more likely to consider themselves to be a sportsman/woman (χ^2_1 = 42, P ≤ 0.01), have purchased a hunting or fishing license (χ^2_1 = 18, P ≤ 0.01), and belong to a sportsman organization (χ^2_1 = 8, P < 0.01). Furthermore they were more likely to feel their opinions were represented by both sportsman organizations (χ^2_4 = 37, P ≤ 0.01), and the UDWR (χ^2_4 = 38, P ≤ 0.01).

DISCUSSION

This survey was designed to reach non-consumptive users who typically do not participate in Utah's public policy meetings (Krannich and Teel 1999). Most of our respondents (83%) reported they had participated in non-consumptive activities such as wildlife viewing in the last 5 years. This compares to 81% reported by the 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (NSWAR). Forty-six percent of our survey respondents also reported participating in consumptive activities, primarily hunting and fishing, in the past 5 years compared to 39% reported by the NSWAR (2006). These results suggest that our survey reached a higher proportion of non-consumptive users than are engaged in Utah's public meeting process (Krannich and Teel 1999). Even with the increased representation of these respondents in our survey, the attitudes and perceptions expressed about winter-feeding program were similar. This suggests that the current UDWR winter-feeding policy was representative of most Utah wildlife stakeholders.

Survey respondents, regardless of residence, were generally supportive of agency supervised programs to manage deer and elk in Utah. They also perceived that there were risks associated with feeding (i.e., disease, short-term benefits vs. long-term benefits), and thus were hesitant to support state sponsored feeding programs at the expense of habitat restoration projects.

The Urban/Rural Interface respondents (i.e., Cache Valley residents) and Non-metro respondents placed a higher value on winter-feeding programs than Metro respondents. They were more likely to believe that the programs benefitted deer and elk even though they also reported more damage. Many of these respondents, particularly those in the Cache Valley had increased opportunity and access to participate in, observe the effects of winter-feeding programs, and view wildlife than did their Metro counter parts (Musclow 1984, Austin unpublished). Thus they may have been more willing to overlook the increased wildlife damage and favor allowing anyone to feed deer and elk.

The question that remains to be answered and was beyond the scope of our survey is: Did feeding increase damage or was it actually a mitigating factor? People who live in areas with high winter concentration of deer and elk have few cost effective options for preventing damage (Hygnstrom et al. 1994). Haystacks, fences, crops, orchards, and yards in rural areas may be susceptible to increased damage in winter from high deer and elk densities (Swihart et al. 1995, Conover 2002). Thus, rural residents may attempt to reduce damage by feeding in other areas to draw the animals away from high value crops and yards. This can be an expensive proposition and thus may increase individual support for using public money for winter-feeding programs.

Many respondents noted that observing mule deer and elk in the wild was a preferred activity. The opportunity for most people to observe these species occurs during migration or when they are concentrated on the winter range. Some respondents reported they fed deer and elk supplemental feed rations to not only help them survive winter, but to increase viewing opportunities.

Public surveys enable managers to determine if policies and programs implemented based on the input received at public meetings adequately represent all stakeholder views. Both consumptive and non-consumptive stakeholders surveyed believed winter-feeding programs are essential to mule deer management. However, stakeholders clearly valued long-term approaches to management, such as habitat restoration, and were hesitant to implement feeding programs at the expense of habitat improvement.

MANAGEMENT IMPLICATIONS

The high value Utahns place on wildlife (Krannich and Teel 1999), including mule deer, is reflected in participation in both consumptive and non-consumptive recreational activities such as hunting, wildlife viewing, and wildlife feeding. Utah wildlife managers have become increasingly aware and supportive of efforts to incorporate non-consumptive as well as consumptive values into wildlife management (Decker and Chase 1997, Mortenson and Krannich 2001). This was evident in the big game feeding policy.

Our results validated that Utah's winter-feeding policy for deer and elk represents the views of Utah wildlife stakeholders. Our observations further demonstrate that non-consumptive stakeholders were concerned about wildlife and their management. Mortenson and Krannich (2001) reported that Utah stakeholders support the efforts of the UDWR to manage the state’s wildlife. Our survey results reaffirmed this support. Nurturing cooperative working partnerships with this support base are critical to the success of management of northern Utah's mule deer.

ACKNOWLEDGEMENTS

This project was funded by the Utah Division of Wildlife Resources, Sportsmen for Fish and Wildlife, Sportsmen for Habitat, the Pope and Young Club, the Bridgerland Outdoor Coalition, the Utah Chapter of the Wildlife Society, Jack H. Berryman Institute for Wildlife Damage Management, Quinney Professorship for Wildlife Management, S. J. and Jesse E. Quinney Foundation, Utah State University Wildland Resources Department, and Utah State University Extension.

LITERATURE CITED

Brunson, M. W., L. Huntsinger, and M. P. McClaran. 2001. Future social changes and the rangeland manager. Rangelands 23:33-35.

Conover, W. J. 1999. Practical nonparametric statistics. Third edition. John Wiley and Sons, New York, New York, USA.

Conover, M. R. 2002. Resolving human-wildlife conflicts: the science of wildlife damage management. CRC Press, Boca Raton, FL, USA.

Daigle, J. J., Hrubes, D., and Ajzen, I. 2002. A comparative study of beliefs, attitudes, and values among hunters, wildlife viewers, and other outdoor recreationists. Human Dimensions of Wildlife 7:1-19.

Decker, D. J., and L. C. Chase. 1997. Human dimensions of living with wildlife---a management challenge for the 21st century. Wildlife Society Bulletin, 25:788-795

Dillman, D. D. 2000. Mail and internet surveys the tailored design method. Second edition. John Wiley and Sons, Inc., New York, New York, USA.

Duda, M. D., S. J. Bissell, and K. C. Young, editors. 1998. Wildlife and the American mind: public opinion on and attitudes toward fish and wildlife management. Responsive Management National Office, Harrisonburg, VA, USA.

Hygnstrom, S. E., R. M. Timm, and G. E. Larson. 1994. Prevention and control of wildlife damage. Cooperative Extension Division Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, NE, USA.

Jacob, G. R., and R. Schreyer. 1980. Conflict in outdoor recreation: A theoretical perspective. Journal of Leisure Research 12:368-380.

Krannich, R. S., and T. L. Teel. 1999. Highlights from a public survey. Attitudes and opinions about wildlife resource conditions and management in Utah: Results of a 1998 statewide general public and license purchaser survey. D. E. Dolsen and S. Phillips, editors. Utah State University Institute for Social Science Research on Natural Resources, Utah Division of Wildlife Resources, Salt Lake City, Utah, USA.

Leopold, A. 1940. Game management. University of Wisconsin Press, Madison, WI, USA.

Manfredo, M. J. 2002. Wildlife viewing: a management handbook. Oregon State University Press, Corvallis, USA.

Messmer, T. A., M. W. Brunson, D. Reiter, and D. G. Hewitt. 1998. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27:75-85.

Mortenson, K. G., and R. S. Krannich. 2001. Wildlife managers and public involvement: letting the crazy aunt out. Human Dimensions of Wildlife 6:277-290.

Musclow, R. W. 1984. Emergency big game feeding in Utah past—present—future. C. Quinn and game management staff, editors. Publication 85-4. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah, USA.

National Survey of Wildlife-Associated Recreation. 2006. The 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U. S. Department of the Interior, Fish and Wildlife Service, and U. S. Department of Commerce. U. S. Census Bureau.

Peterson, C. C., and T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.

Riley, S. J., W. F. Siemer, D. J. Decker, L. H. Carpenter, J. F. Organ, and L. T. Berchielli. 2003. Adaptive impact management: An integrative approach to wildlife management. Human Dimensions of Wildlife 8:81-95.

Schneider, I. E., and W. E. Hammitt. 1995. Visitor response to outdoor recreation conflict: a conceptual approach. Leisure Sciences 17:223-234.

Swihart, R. K., P. M. Picone, A. J. DeNicola, and L. Cornicelli. 1995. Ecology of urban and suburban white-tailed deer. Pages 35-44 *in* J. B. McAninch, editor. Urban deer: a manageable resource? Proceedings of the 1993 Symposium of the North Central Section, The Wildlife Society. 55th Midwest Fish and Wildlife Conference, St. Louis, Missouri, USA.

Trefethen, J. B. 1975. An American crusade for wildlife. Winchester Press, New York, New York, USA.

U. S. Census Bureau. 2006. Annual estimates of the population for counties of Utah: April 1, 2000 to July 1, 2005 (CO-EST2005-01-49). Population Division, U. S. Census Bureau.

Utah Division of Wildlife Resources. 2003. Statewide management plan for mule deer. Utah Division of Wildlife Resources Publication W5WLD-2. Salt Lake City, USA.

Vaske, J. J., P. Carothers, P. Donnelly, M. P. Baird, and B. Baird. 2000. Recreation conflict among skiers and snowboarders. Leisure Sciences 22:297-313.

Westley, F. 1995. Governing design: The management of social systems and ecosystem management. Pages 391-427 *in* L. H. Gunderson, C. S. Holling, and S. S. Light, editors. Barriers and Bridges to the Renewal of Ecosystems and Institutions. Columbia University Press, New York, New York, USA.

Table 6-1. Demographics of Metro, Non-metro, and Urban/Rural Interface respondents reported as percentages, Utah mule deer winter-feeding survey, 2007.

Characteristic	Metro (n=146)	Non-metro (n=197)	U/R Interface (n=181)	P
Sex				= 0.51
Male	75	70	72	
Female	25	30	28	
Age				= 0.15
18-34	9	10	16	
35-54	47	38	39	
55-74	36	41	34	
>74	8	11	11	
Education				= 0.06
<12 years	4	4	3	
12 years	15	13	16	
Professional	31	44	28	
4 year College	27	24	27	
Graduate Degree	23	15	26	
Sportsperson				= 0.04
Yes	50	57	44	
No	50	43	56	

License To Hunt/Fish				= 0.44
Yes	47	50	43	
No	53	50	57	
Sportsman Member				= 0.77
Yes	9	11	9	
No	91	89	91	
Current Residence				$\leq$ 0.001
Rural Farm	1	12	8	
Non-Farm	1	23	10	
Town	1	16	6	
Small City	31	43	46	
City	29	6	26	
Metropolitan Area	36	0	4	
Residence During Youth				= 0.01
Rural Farm	21	22	27	
Non-Farm	7	8	7	
Town	5	12	16	
Small City	19	32	29	
City	20	13	13	
Metropolitan Area	27	13	8	

Residence As Adult				$\leq$ 0.001
Rural Farm	2	13	11	
Non-Farm	1	14	8	
Town	1	10	7	
Small City	28	39	39	
City	33	14	27	
Metropolitan Area	35	11	8	

Table 6-2. Attitudes and perceptions of Metro, Non-metro, and U/R Interface respondents about wildlife-feeding, Utah, 2007.

	Metro %		Non-metro %		U/R Interface %	
Attitude/Perception	Agree	Disagree	Agree	Disagree	Agree	Disagree
Feeding is Essential	65	35	63	37	78	22
More Efficient	31	69	22	78	35	65
Increases Disease Risk*	41	59	50	50	54	46
Increases Deer Numbers*	80	20	78	22	95	5
Increases Property Damage*	38	62	39	61	39	61
Increases Viewing Opportunity	89	11	92	8	95	5

* P-value <0.05

Table 6-3. Responses of Metro, Non-metro, and U/R Interface respondents when asked who should be allowed to conduct winter-feeding programs for deer and elk, Utah mule deer winter-feeding survey, 2007.

Group	Support	Metropolitan %	Non-metro %	U/R Interface %
UDWR	No	4	11	6
	Yes	85	84	83
Sportsmen + UDWR	No	15	16	5
	Yes	74	74	80
Sportsmen Alone	No	57	62	46
	Yes	18	24	28
Residents + UDWR	No	19	18	9
	Yes	66	67	74
Residents Alone	No	65	64	49
	Yes	13	23	23

Table 6-4. Responses of non-consumptive and consumptive respondents as percentages, Utah mule deer winter-feeding survey, 2007.

Category		Non-Consumptive		Consumptive
		Feed	Watch	Hunt/Fish
Winter-feeding Is Essential		74	69	67
Feeding More Efficient Than Habitat		28	28	24
Feeding Increases Risk Of Disease		40	50	54
Believe Feeding Increases Numbers		89	85	81
Feeding Increases Property Damage		36	38	34
Feeding Increases Viewing Opportunity		94	91	92
Permit Anyone To Feed		29	23	25
Consider Self To Be A Sportsperson		52	56	79
Member Of Sportsman Organization		11	12	18
Purchased Hunt/Fish License		46	51	.
Support Spending Public Money To Feed		79	73	73
Represented By Sportsman Organization		84	62	76
Represented By UDWR		84	76	80
Male		69	72	88
Age:	18-34	7	11	13
	35-54	40	43	47
	55-74	43	38	36
	>74	10	9	5

Education:	High School Graduate	13	12	13
	Professional/Some College	34	36	40
	4-year College Degree	30	26	27
	Graduate Degree	20	22	16
Interactions: Negative (Collision, Agricultural, Landscape)		18, 12, 29	17, 9, 24	17, 9, 23
Interactions: Positive (e.g., Photography, Hunting)		66, 29	62,37	63, .

Table 6-5. Reported positive and negative human-wildlife interactions of Metro, Non-metro, and U/R Interface respondents, Utah mule deer winter-feeding survey, 2007.

Interaction		Metro %	Non-metro %	U/R Interface %
Positive				
	Business Revenue	3	4	3
	Activity Such As Photography	57	54	52
	Activity Such As Hunting	27	38	31
	Wildlife Watching**	77	90	80
	Other, i.e., sense of well-being	15	13	12
	None*	23	19	31
Negative				
	Wildlife Vehicle Collision*	10	21	15
	Disease	0	1	1
	Loss Of Personal/Family Safety/Health	0	2	1
	Agricultural Economic Loss***	1	14	7
	Landscape Damage***	12	29	20
	Other, i.e., "dirt and waste"	1	3	4

*P-values <0.05; **P-values<0.01; ***P-values <0.001.

Table 6-6. Expenses of Metro, Non-metro, and U/R Interface wildlife viewers, Utah mule deer winter-feeding survey, 2007.

	Metro		Non-metro		U/R Interface	
	#	%	#	%	#	%
Hours						
10 or less	43	33	49	26	62	35
11-50	47	36	81	44	59	33
51-100	6	5	25	13	13	7
>101	9	7	14	8	10	6
Dollars						
$20.00 or Less	46	35	60	32	70	40
$21.00-$100.00	28	21	59	31	37	21
$101.00-$500.00	29	18	39	21	23	13
>$500.00	7	5	13	7	13	7

CHAPTER 7

CONCLUSIONS

The mule deer (*Odocoileus hemionus*) populations monitored during this study were declining. Although winter-feeding enhanced the body condition and increased survival in the fed radio-collared mule deer does we studied, it did not increase productivity. When adult doe survival rates for fed and non-fed deer were modeled over a 5-year period, the rate of decline predicted for fed mule deer was less than that for the non-fed deer.

Major causes of winter mortality for both fed and non-fed deer were deer-vehicle collisions (DVCs) and malnourishment. The winter range study area has undergone dramatic changes in the last couple decades. The winter ranges in northern Utah now are bisected by an expanded and upgraded highways system. Deer-vehicle collisions are now commonplace as the vehicle traffic volumes and speeds associated with a rapidly expanding human population have increased. Additionally, increased urbanization has resulted in the loss of critical winter range, further concentrating mule deer in remnant habitats. In severe winters, this creates increased human-wildlife conflicts as deer search forage and cover in urban areas.

The winter-feeding programs we studied also altered mule deer behaviors. Fed deer migrated earlier in the fall and later in the spring, resulting in increased duration on winter range, and decreased duration on summer range. This magnified the effects of the winter-feeding program on habitat, and will likely lead to increased numbers of urban deer, with increased deer-human conflicts.

Increased utilization of bitterbrush by fed deer resulted in greater production of bitterbrush (*Purshia tridentata*) on feed sites and increased utilization of bitterbrush within 188m of the feed stations. If herd population declines are reversed in the future, or if numbers of deer remaining on these sites year round increases, greater utilization will likely result in reduction of bitterbrush and of carrying capacity for deer. The winter-feeding programs we studied were implemented in northern Utah to ameliorate these human-induced impacts. If mule deer herds are to be sustained in northern Utah, winter-feeding alone as implemented during this study will not achieve this end result.

Conservation strategies seeking abatement of mule deer population declines in northern Utah must incorporate vegetation management that addresses animal nutritional needs. Correlating vegetation management with nutrient availability on each site may better enable deer to balance toxins and nutrients of available browse (Nolte et al. 2004). If specific nutrients are lacking, then site-specific formulation and placement of feed rations coupled with the development of high energy and nutrient rich resource or food patches may be needed to promote better utilization of winter range browse. The correct design and placement of feed stations would decrease impact on newly planted and rehabilitated range, or increase impact on decadent range (Cooper et al. 2006). As an example, more dispersed distribution of feed rations would result in decreased densities of deer congregating on sensitive habitat.

Specific mineral deficiencies, and forage and ration selection we observed in fed deer suggest the feed rations used during the study may not have been meeting the individual animals nutritional needs. Mineral deficiencies, particularly of selenium and copper, may affect herd productivity (Flueck 1994). Fed deer had increased selenium but decreased copper. In addition, deer preferred forage and rations that were high in copper, suggesting the feed rations may be used to mitigate seasonal deficiencies that may result in reduced productivity, and failure of feed programs to increase productivity.

The modified body condition index methodology we developed increased the liklihood of timely implementation of the winter-feeding program. Consistent correlation of historic and current weather conditions with the modified body condition index for DVC carcasses would enable managers to not only monitor general herd condition, but also identify factors that lead to migration, or to serious decreasing body condition. Furthermore, it would supply a factual basis for management decisions to feed deer.

The winter-feeding program we evaluated was implemented under a Big Game Winter-Feeding Policy that was adopted in 2000 by the Utah Wildlife Board. Prior to adoption, these polices were presented to the public in a series of regional meetings. These meetings by their very nature are dominated by consumptive users. Thus policies developed through this process may not reflect the views of all agency stakeholders. This was not the case of the winter-feeding policy.

Both consumptive and non-consumptive stakeholders believed winter-feeding programs are essential to mule deer management. However, stakeholders clearly valued long-term approaches to management, such as habitat restoration, and were hesitant to implement feeding programs at the expense of habitat improvement.

The high value Utahns place on wildlife (Krannich and Teel 1999), including mule deer, is reflected in participation in both consumptive and non-consumptive recreational activities such as hunting, wildlife viewing, and wildlife-feeding. Utah wildlife managers have become increasingly aware and supportive of efforts to incorporate non-consumptive as well as consumptive values into wildlife management

(Decker and Chase 1997, Mortenson and Krannich 2001). Their ability to sense the pulse of Utah stakeholders was evident in the big game feeding policy.

Our observations throughout this research suggest that non-consumptive stakeholders were concerned about wildlife and their management. Mortenson and Krannich (2001) reported that Utah stakeholders support the efforts of the UDWR to manage the state's wildlife. Our survey results reaffirmed this support. Nurturing cooperative working partnerships with this support base are critical to the success of management of northern Utah's mule deer.

Literature Cited

Cooper, S. M., M. K. Owens, R. M. Cooper, and T. F. Ginnett. 2006. Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66:716-726.

Decker, D. J., and L. C. Chase. 1997. Human dimensions of living with wildlife—a management challenge for the 21st century. Wildlife Society Bulletin 25:788-795.

Flueck, W. T. 1994. Effect of trace elements on population dynamics: Selenium deficiency in free-ranging black-tailed deer. Ecology 75:807-812.

Krannich, R. S., and R. L. Teel. 1999. 1998 Utah deer and elk management opinion survey final project report. Institute for Social Science Research on Natural Resources, Utah State University, Logan, USA

Mortenson, K. G., and R. S. Krannich. 2001. Wildlife managers and public involvement: letting the crazy aunt out. Human Dimensions of Wildlife 6:277-290.

Nolte, D. L., B. A. Kimball, K. R. Perry, J. J. Villalba, and F. D. Provenza. 2004. Effects of forage nutritional quality (energy and protein) on deer acceptance of foods containing secondary metabolites. Wildlife Damage Management, Internet Center for USDA National Wildlife Research Center-Staff Publications, University of Nebraska, Lincoln, USA.

APPENDIX

Public Perceptions Of Winter-Feeding Programs For Mule Deer And Other Wildlife In Utah

Art by Mark LeFevre

CONDUCTED BY
Utah State University Extension Service
Jack H. Berryman Institute for Wildlife Damage Management

ID#________________

(for internal records purposes only)

START HERE

Section I: Attitudes And Opinions About Winter-Feeding Of Wildlife

1. How strongly do you agree or disagree with the following statements about winter-feeding of mule deer. (*Please circle one response for each statement).*

	Strongly Disagree	Disagree	Agree	Strongly Agree	Don't Know
a. Winter-feeding programs are essential to mule deer management.	1	2	3	4	DK
b. Winter-feeding programs are a more efficient use of money than habitat restoration projects.	1	2	3	4	DK
c. Winter-feeding increases risk of transmission of wildlife diseases.	1	2	3	4	DK
d. Winter-feeding increases mule deer numbers.	1	2	3	4	DK
e. Winter-feeding increases property damage from mule deer including deer-vehicle collisions.	1	2	3	4	DK
f. Winter-feeding programs increase wildlife viewing opportunities.	1	2	3	4	DK

2. How important are each of the following in forming your opinions about wildlife-feeding? Wildlife winter-feeding ranges from backyard bird-feeding to state-approved programs. (*Please circle one number for each*).

	Not important	Slightly Important	Moderately important	Very Important	Extremely important
a. Personal experiences	0	1	2	3	4
b. Friends/family	0	1	2	3	4
c. Media: newspapers, magazines, television	0	1	2	3	4
d. Scientific publications	0	1	2	3	4
e. Utah Division of Wildlife Resources information	0	1	2	3	4
f. Other (*please specify*) ____________	0	1	2	3	4

Section II: Participation In And Support For Wildlife-Feeding.

We would like to understand how strongly people do or do not support wildlife-feeding programs. Winter-feeding of wildlife ranges from backyard bird-feeding projects to state approved programs.

1. Have you fed wildlife in the past 5 years?

1☐ No ● <u>*Skip to #5*</u>.

2☐ Yes

2. (If yes) What do you do to prepare to feed wildlife? (*check each that applies*)

1☐ buy feed

2☐ buy equipment

3☐ clean/repair/distribute feeders

4☐ other (*please specify, i.e., store hay or apples for deer, etc.*)

____

3. What kinds of animals do you feed? (*check each that applies*)

1☐ deer, elk

2☐ song birds

3☐ pheasants, wild turkeys

4☐ other (*please specify*)______________________________________

4. a. Please estimate the number of hours you spend feeding wildlife each year. (*check one)*

1☐ 10 or less

2☐ 11-50

3☐ 51-100

4☐ Over 100

b. Estimate your average annual expense; include feed and equipment.

1☐ $50 or less

2☐ $51-$100

3☐ $101-$500 per year

4☐ $501-$1,000 per year

5☐ Over $1,000 per year

5. **Should public money be used to support mule deer/elk winter-feeding programs in Utah?** 1☐ No 2☐ Yes

6. Who should be allowed to conduct mule deer/elk winter-feeding programs?

(*Please circle one response for each option*).

	No	Yes	No Opinion
a. Utah Division of Wildlife Resource (DWR) biologists	1	2	0
b. Local sportsmen groups in cooperation with Utah DWR	1	2	0
c. Local sportsmen groups operating independently	1	2	0
d. Local residents under direct supervision of Utah DWR	1	2	0
e. Local residents operating independently	1	2	0

Section III: Human-wildlife Interactions

1. Which of the following negative interactions have you had with wildlife in the past 5 years ? (*please check each that is applicable to you*).

a. Wildlife-vehicle collision	1☐
b. Diseases transmitted by wildlife	2☐
c. Loss of personal or family safety and/or health	3☐
d. Agricultural economic losses, i.e., hay or crop eaten by deer or elk	4☐
e. Landscape and/or other property damage	5☐
f. Other (*please specify*) ________________________________	6☐
g. None 7☐	

If you answered 'None', please skip to #3.

- ***If you HAVE personally experienced problems caused by wildlife in the past 5 years please continue with #2.***

2. What were your estimated damages in the past 5 years? *(please check one).*

1☐ Under $100

2☐ $100 - $999

3☐ $1,000 - $10,000

4☐ Over $10,000

3. Which of the following positive interactions have you had with wildlife

in the past 5 years ? (*please check each that is applicable to you*).

a. Revenue from business associated with wildlife	1☐
b. Recreation activity such as photography	2☐
c. Recreation activity such as hunting	3☐
d. Other (*please specify*) ________________________________	4☐
e. None 5☐	

4. a. Do you watch wildlife?

1☐ No ● *If 'No', please <u>skip to Section IV on page 6</u>.*

2☐ Yes

b. If Yes, do you <u>plan time</u> for watching wildlife?

1☐ No

2☐ Yes

c. Please estimate the average number of hours you spend watching wildlife each year. *(please check one response).*

1☐ 10 or less

2☐ 11 – 50

3☐ 51 – 100

4☐ Over 100

d. Estimate your average annual expense for watching wildlife; include equipment, i.e., binoculars, spotting scopes, field guides, etc., and travel costs. (*please check one*)

1☐ $20 or less

2☐ $21-$100

3☐ $101-$500

4☐ Over $500

5. Please check each species that you recognize on sight.

1☐ Mule deer	2☐ Black-capped chickadee
3☐ Mallard	4☐ Downy woodpecker
5☐ Marten	6☐ Golden eagle
7☐ Elk	8☐ Kingfisher
9☐ Red squirrel	10☐ Red-tailed hawk

Section IV: Tell Us About Yourself.

Please take a few minutes to complete this last section. This information is essential for determining if attitudes and opinions may be related to a person's background or experience. Again, all answers are strictly confidential.

1. a. Where do you currently live? (*please check one response*)

1☐ rural farm or 2☐ rural non-farm,

3☐ town of under 2,500 or 4☐ small city of 2,501-25,000,

5☐ large city of 25,001-100,000 or 6☐ metropolitan area of over 100,000

b. Where did you live during most of your youth? (*please check one response*)

1☐ rural farm or 2☐ rural non-farm,

3☐ town of under 2,500 or 4☐ small city of 2,501-25,000,

5☐ large city of 25,001-100,000 or 6☐ metropolitan area of over 100,000

c. Where have you spent most of your adult life? (*please check one response*)

1☐ rural farm or 2☐ rural non-farm,

3☐ town of under 2,500 or 4☐ small city of 2,501-25,000,

5☐ large city of 25,001-100,000 or 6☐ metropolitan area of over 100,000

2. a. Are you: 1☐ male or 2☐ female?

b. Your age is: 1☐ 18-34 2☐ 35-54 3☐ 55-74 4☐ over 74

3. What is your highest level of education? (*please check one response*)

1☐ Did not complete high school

2☐ Completed high school

3☐ Professional training or some college

4☐ 4 year college degree

5☐ Graduate degree

4. a. Do you consider yourself to be a sportsman or sportswoman?

1☐ No

2☐ Yes

b. Have you purchased a hunting or fishing license in the past 3 years?

1☐ No

2☐ Yes

c. Are you a member of a sportsman's organization? (*such as RMEF, SFW, DU*)

1☐ No

2☐ Yes

5. Please circle one response for each statement:

	No	Some-times	Usually	Always	No Opinion
Sportsman organizations represent my opinions.	1	2	3	4	0
The Utah Division of Wildlife Resources represents my opinions.	1	2	3	4	0

6. Use the space below if you have any additional comments or observations.

Please close and tape or staple the corners of your completed questionnaire and place it in the mail.
No additional postage is necessary.

Thank you for your cooperation!

CURRICULUM VITAE

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Education

- Ph.D. in Wildlife Biology, Utah State University (USU), spring 2008. Focus: ungulate biology and physiology, plant-herbivore interactions, human-wildlife conflicts, and wildlife nutrition.
- M.S. in Wildlife Biology, Utah State University (USU), 2005. Title: Mule deer and emergency winter-feeding. Focus: big game habitat management, plant-herbivore interactions, and wildlife damage management.
- B.S. in Botany, Brigham Young University (BYU), 1974. Minors in chemistry and horticulture.

Experience

Utah State University: 2001-present

- Doctoral Research Assistant. January 2005 –present. Jack H. Berryman Institute, FRWS, USU, Logan, Utah, 84322-5230. Supervisor: Dr. Terry A. Messmer, 435-797-3975. Designed and implemented a research program to evaluate the effects of supplemental feeding of mule deer in northern Utah. Included capturing 100 mule deer, blood sampling, live body condition scoring, necropsy, radio-telemetry, mineral deficiency preference field trials, ocular estimation of browse productivity and utilization with reference units, design and implementation of mail-back public survey, ArcView, SAS, supervised 7 technicians.
- Master's Research Assistant. September 2001 – January 2005. Jack H. Berryman Institute, FRWS, USU, Logan, Utah, 84322-5230. Supervisor: Dr. Terry A. Messmer, 435-797-3975. Designed and implemented a research program to evaluate the effects of supplemental feeding of mule deer in northern Utah. Included capturing mule deer, blood sampling, radio-telemetry, live body condition scoring, necropsy, ArcView, SAS, supervised 8 technicians.

Educator/Teaching: 1973-present.

- Laboratory Instructor. 1973. Undergraduate botany class, Brigham Young University, Provo, Utah, USA.
- Boy Scouts of America Volunteer: 1977--1995
- Home School Educator. 1982-2001. Taught grades 1-10. Courses included English, Math, Algebra, Geometry, Art, Music (voice, piano, guitar), General Science, Animal and Plant Science, Botany, Conservation of Natural Resources, Chemistry, Physics, History, Horsemanship and Horsepacking. Successfully graduated 3 students, 2 received college scholarships, all 3 received Bachelor Degrees (environmental education, aviation science-pending, geology), 1 received a Master's Degree in Geology (pending). Cove, Utah, USA.
- 4-H Wildlife Habitat Evaluation Program Coach. 1991-present. Coached 8 local 4-H Wildlife Habitat Evaluation Program (WHEP) teams. Five Senior Teams and 7 Junior Teams won the state WHEP competition. The 5 Senior Teams were invited to the National WHEP Competition, with three teams placing.8th, 4th, and 2nd, and with one member winning 2nd High Individual Overall.
- 4-H Horse Club Leader. 1990-2001. Taught western and English horsemanship skills to over 50 youth. Included basic care of horse and equipment, trail skills, stadium and cross-country jumping, competitive dressage and western riding skills. Emphasized safety and service. Led club in 10 yrs service in USFS Adopt-a-Trail program, annually maintained 10 miles of wilderness trail.

Business: 1977-2000.

- Timeless Treasures. 1977-1985. Designed, manufactured, and marketed over 2000 wood-burl clocks and tables. Wellsville, Utah, USA.
- Hummingbird Hill Trailrides. 1987-2000. Trained and cared for 8-18 horses, gave horseback riding lessons, took people from 14 countries on trailrides in the Mount Naomi Wilderness (USFS), specialized in wildlife/plant conservation, history, and education rides. Cove, Utah, USA.

Work: 1973-1975

- Research technician. 1974-1975. Intermountain Forest and Range Experiment Station. Projects: aspen and prescribed burns. Supervisor: Dr. Dale Bartos. Logan, Utah, USA.
- National Science Foundation. 1973. Oil-shale project environmental impact statement. Supervisor: Dr. Kimball T. Harper, Brigham Young University, Provo, Utah, USA.

Grants Awarded

- Peterson, C. C., and T. A. Messmer. 2002. $1,000.00 grant. An evaluation of the effects of increased dietary macronutrients on mule deer body condition, activity and sagebrush utilization. Annual Meeting of the Utah Chapter of The Wildlife Society. Utah, USA.
- T. A. Messmer, and Peterson, C. C. 2001-2004. Evaluating the effects of emergency winter-feeding on mule deer survival, production, and habitat conditions. Utah Division of Wildlife Resources. $86,020.00.

- Peterson, C. C. Pope and Young Club. 2003-2007. $16,000.00.
- Peterson, C. C. 2004-2006. Sportsmen for Habitat. Mule deer: Long range effects of short-term winter nutrient manipulation. $139,321.00.

Other Experience

- FCC General License, Amateur Radio.
- ATV, snowmobile, 4-wheel drive vehicles, tractors, woodworking.

Professional Memberships

- The Wildlife Society (TWS), 2002-present.
- Jack H. Berryman Institute for Wildlife Damage Management, 2003-present.

Professional Involvement

- Graduate Vice President Berryman Institute Student Group, 2007-2008.
- Journal Article Reviewer for Conservation Biology, and Human Wildlife Conflicts.

Awards and Honors

- 2000 National 4-H Volunteer Wildlife Leader of the Year Award, 66th North American Wildlife and Natural Resources Conference, Washington D.C., USA.
- 2000 Utah 4-H State Volunteer Leader of the Year. Price, Utah, USA.

Publications

- Peterson, C. C., T. A. Messmer. 2007. Effects of winter-feeding on mule deer in northern Utah. Journal of Wildlife Management 71:1440-1445.
- J. J. Villalba, F. D. Provenza, J. O. Hall, and C. Peterson. 2006. Phosphorus appetite in sheep: dissociating taste from postingestive effects. Journal of Animal Science 84:2213-2223.

Presentations and Posters

- Peterson, C. C., T. A. Messmer. 2006. Effects of winter-feeding on mule deer in northern Utah. Laramie, Wyoming, USA.
- Peterson, C. C. 2005. Mule deer and emergency winter-feeding. Regional Advisory Council Meeting, Brigham City, Utah, USA.
- Peterson, C. C., T. A. Messmer. 2005.   Mule deer and emergency winter-feeding. Utah Division of Wildlife Resources Regional Biologist Meeting. Ogden, Utah, USA.
- Peterson, C. C. 2005. Evaluating the Effects of Emergency Winter-Feeding and of Protein Supplement on Mule Deer Body Condition, Productivity, Behavior and Browse Utilization. Invited lecture, Dr. John Malechek, USU, Logan, Utah, USA.
- Peterson, C. C. 2005. Mule deer and emergency winter-feeding. MS Thesis. Utah State University, Logan, Utah, USA.
- Peterson, C. C., T. A. Messmer. 2005. Mule deer and emergency winter-feeding. Annual Meeting of the Utah Chapter of The Wildlife Society. Moab, Utah, USA.

- Peterson, C. C., T. A. Messmer. 2004. Evaluating effects of emergency winter-feeding on browse, mule deer body condition, productivity and behavior. Annual Meeting of the Utah Chapter of The Wildlife Society. Provo, Utah, USA.
- Peterson, C. C. 2004. Evaluating the Effects of Emergency Winter-Feeding and of Protein Supplement on Mule Deer Body Condition, Productivity, Behavior and Browse Utilization. Invited lecture, Dr. Fred Provenza, USU, Logan, Utah, USA.
- Peterson, C. C. 2004. Emergency or supplemental? 2004. Sportsmen for Fish and Wildlife meeting. Logan, Utah, USA.
- Peterson, C. C. 2004. Emergency or supplemental? Mule Deer Foundation banquet. Logan, Utah, USA.
- Peterson, C. C., T. A. Messmer. 2003. Mule deer mouthfuls. Annual Meeting of the Utah Chapter of The Wildlife Society. Logan, Utah, USA.
- Peterson, C. C. 2003. Mule Deer Mouthfuls 'or' Evaluating the Effects of Emergency Winter-Feeding and of Protein Supplement on Mule Deer Body Condition, Productivity, Behavior and Browse Utilization. WAFWA Elk and Deer Workshop. Jackson, Wyoming, USA. (poster).
- Peterson, C. C., T. A. Messmer. 2002. An evaluation of the effects of increased dietary macronutrients on mule deer body condition, activity and sagebrush utilization. Annual Meeting of the Utah Chapter of The Wildlife Society. Moab, Utah, USA.
- Peterson, C. C. 2005. Pope and Young Club. Audio-visual powerpoint on cd.