IDAHO DEPARTMENT OF FISH AND GAME

Jerry Mallet, Interim Director

Project W-160-R-26

Subproject 31

Job Progress Report

ELK ECOLOGY

Study IV: Factors Influencing Elk Calf Recruitment

Job No. 1: Pregnancy rates and condition of cow elk

Job No. 2: Calf mortality causes and rates

July 1, 1998 to June 30, 1999

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March 2000
Boise, Idaho

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

Financial support was provided by the Idaho Department of Fish and Game with funds from the Federal Aid in Wildlife Restoration Program (Project W-160-R-26) and the Rocky Mountain Elk Foundation. We thank members of our 1999 summer field crew that included Brad Wendling, Jake Bieker, Robbie Piehl, Cody Schroeder, and Hilary Smith; members of the Department staff in the Clearwater Region for their help conducting black bear bait-station routes; and the US Forest Service, Clearwater and Nez Perce National Forests, for administrative access and use of the Wilderness Gateway camping facilities.

PROGRESS REPORT
STATEWIDE WILDLIFE RESEARCH

STATE:	Idaho	**SUBPROJECT:**	Elk Ecology
PROJECT NO.:	W-160-R-26		
SUBPROJECT NO.:	31	**STUDY NAME:**	Factors Influencing Elk Calf Recruitment
STUDY NO.:	IV		
JOBS NO.:	1 and 2		

PERIOD COVERED: July 1, 1998 to June 30, 1999

JOB NO. 1: PREGNANCY RATES AND CONDITION OF COW ELK

ABSTRACT

As part of a larger effort to determine the factors responsible for poor or declining elk recruitment, we evaluated the body condition and pregnancy status of adult (> 2 years old) cow elk on contrasting study areas in north-central Idaho. Funding was inadequate to capture and evaluate cow elk as was done in 1997 and 1998. Therefore, we relied on samples collected by hunters during the 1997 and 1998 hunting seasons. The pregnancy rate in the Elk City Zone (GMUs 14, 15, 16) was about 10% lower than in 1997, whereas the pregnancy rate increased in GMU 23. Pregnant cows tended to exhibit better condition than cows that were not pregnant.

During 1998 the Department did not offer cow permits in the Lolo Zone. To collect pregnancy information, we collected fecal pellets from free-ranging cow elk in February and March. Steroid metabolite levels will be evaluated to determine pregnancy rates. These data are not yet available.

The research of Rachel Ash, a University of Idaho graduate student, is also part of this project and is presented in Appendix A. Her effort has 2 major aspects:

> Assessing body condition and nutritional status thorough morphometric and physiological indices.
>
> Elk reproductive endocrinology and behavior across nutritional planes.

INTRODUCTION

In Idaho, as in several surrounding states, elk calf recruitment has been chronically low or has declined in many key elk management units. This is cause for concern because recruitment replaces losses to hunting and other factors, thus allowing population stability or growth. There are a variety of factors that can influence recruitment, including elk density, habitat condition, nutrition, weather, pregnancy rates, predation, breeding conditions, and calf condition. Each factor probably plays a role, but which factors are significant and how they relate to each other remains to be addressed.

We are interested in identifying ultimate factors that have a major impact on recruitment, as well as understanding the underlying mechanisms. Within the context of this project, we consider 3 broad categories of ultimate factors: 1) elk density and habitat; 2) predation; and 3) age structure of bulls as being potentially important to elk in Idaho. This report addresses elk density and habitat and several closely-related factors.

Elk density is usually considered an ultimate factor that acts in conjunction with habitat (Caughley 1977, Caughley and Sinclair 1994). If habitat conditions are intrinsically poor, even moderate or low elk densities may be too high for the habitat and can lead to unsatisfactory recruitment rates. In contrast, if elk density is high enough to influence habitat condition and elk nutrition, this can lead to poor calf condition and higher rates of starvation, disease, and predation. Coughenour and Singer (1996) reported an indirect relationship between forage biomass and recruitment. They showed positive relationships between calf recruitment and precipitation levels, and between precipitation levels and forage biomass. They also showed a positive relationship between winter calf mortality rates and population density. DelGiudice et al. (1991) showed that nutritional deprivation was associated with higher elk densities, deep snow, and declines in calf:cow ratios from early to late winter.

Furthermore, relative habitat quality can change from season to season and from year to year. These changes can influence calf birth weight and growth rate regardless of elk density. Thorne et al. (1976) showed that calf birth weight and growth rate were directly linked to late winter-early spring weight loss of cows. Such weight loss could result from poor nutrition on summer or winter range because of low availability of forage, high elk density, or perhaps severe winter weather. Cook et al. (1996) showed that calf growth rates in summer and fall were directly linked to summer-fall nutrition.

Changes in habitat quality can also occur over longer time frames. Much of the north-central Idaho elk winter range was created by wildfires in the late 1800s and early 1900s (Leege 1968, Leege and Hickey 1977). Since then, and despite use of prescribed fire as a habitat management tool (Leege 1969, Peek et al. unpubl. manuscript), it is likely that succession of seral brushfields has led to declining quality and quantity of winter forage. However, while it is clear that calf recruitment has declined over much of this area, the relationship between habitat and recruitment on this range is poorly understood. It is important to recognize that the relationships among habitat quality and quantity, elk density, and productivity and recruitment are complex (Mitchell and Crisp 1981, Albon et al. 1983, Van Horne 1983, Hobbs and Swift 1985, Clutton-Brock et al. 1987, Hobbs and Hanley 1990), but such relationships must be explored more fully to properly manage elk populations.

Declining habitat condition and nutrition with high elk density may also lead to low pregnancy rates. Buechner and Swanson (1955) concluded that the high pregnancy rates (> 50%) of yearling cow elk in the Blue Mountains, WA, probably resulted from reduced population density due to harvest. They also suggested that better nutrition was the principal factor leading to high yearling pregnancies. Reduction of the elk herd in 1 drainage nearly doubled the available forage per individual, while yearling pregnancy rates in other herds in Washington and other states remained between 7% and 17% during the same years (Buechner and Swanson 1955).

Pregnancy rates have been shown to vary considerably throughout the western U.S. Yearling pregnancy rates were 26% in the Sun River, MT, herd in the early 1960s (Knight 1970); 22% in a captive population near La Grande, OR, recently (Noyes et al. 1996); 12% in the White River, CO, herd in the mid-1960s (Freddy 1987); but only 5% in Yellowstone National Park in the early 1950s (Kittams 1953) when the population was fairly high (> 13,500; Houston 1982).

Pregnancy rates for 2-year-olds have ranged from 64% to 96% in Yellowstone, Banff, and Jackson Hole National Park herds; the Sun River, MT herd; and the La Grande, OR captive herd (Kittams 1953, Buechner and Swanson 1955, Greer 1966, Knight 1970, Houston 1982, Noyes et al. 1996). Conversely, pregnancy rates of 2-year-olds in the White River, CO, herd averaged only 29% (Freddy 1987).

Pregnancy rates of >3-year-old cows is typically 69-95%, but decline in cow elk >13-15 years old (Kittams 1953, Buechner and Swanson 1955, Greer 1966, Knight 1970, Houston 1982, Freddy 1987, Noyes et al. 1996).

Though several of these studies are suggestive, the reasons behind variable pregnancy rates remain elusive because cause and effect is difficult to demonstrate. Nevertheless, Coughenour and Singer (1996) noted an inverse relationship between overall pregnancy rate and population density in Yellowstone. Pregnancy rates ranged from 87% with 4,200 elk in the population; to 82% in a population of 12,500-13,500; to 61% in a population of >17,700.

Statewide aerial survey data in Idaho suggest that recruitment is related to elk density (Gratson and Johnson 1995). Moreover early indications from a management experiment in Idaho where cow elk densities were manipulated experimentally indicate that reducing density can result in higher recruitment rates (Gratson and Zager 1994). Reduced recruitment rates at higher elk densities has also been documented for the northern Yellowstone National Park elk herd (Merrill and Boyce 1991, Houston 1982, Coughenour and Singer 1996), the Jackson Hole Elk Refuge herd (Boyce 1989), and the adjacent Grand Teton National Park herd (Boyce 1989).

Results from such studies are not sufficiently compelling to explain the chronically low or declining recruitment in several important GMUs in Idaho. Further, we do not currently have sufficient information on many of the factors that determine recruitment, such as pregnancy rates, predator densities, habitat condition, or nutrition of cows and calves for any of Idaho's GMUs. Thus it is essentially impossible to identify and evaluate the factors responsible for low or declining recruitment rates with currently available data. In general we suspect that pregnancy rates are adequate, although the long drought in the western U.S. may have led to poorer nutrition and declining pregnancy rates, particularly among yearlings and 2-year-olds. We also suspect that unimpeded plant succession on fire-maintained seral shrubfields in north-central Idaho may be leading to declining habitat quality and quantity. Mountain lions and bears are thought to be reasonably abundant and perhaps have increased in recent years, but there are too many unanswered questions related to predation to assume that it is a major and ultimate cause of low or declining recruitment.

Similarly, until very recently we believed that bull:cow ratios and bull age structure were sufficiently high in most of Idaho, and that the timing of calving and condition of calves entering winter as a result of early, synchronous breeding was good. However bull:cow ratios and bull age structure have declined in many of the same GMUs in which recruitment has declined. Conversely, other key units have always had low or moderated recruitment rates even when bull:cow ratios were high. Thus, without further research focusing on recruitment, it is difficult and unwise to take major management actions to address any of these potential causes of poor or declining elk recruitment rates.

We anticipate that this project will provide a better understanding of the factors influencing and controlling elk recruitment. Earlier research in Idaho has improved our understanding of bull elk population dynamics (Unsworth et al. 1993, Leptich et al. 1997, Gratson et al. 1996), whereas current and proposed research is providing vital information to help manage cow harvest properly (Gratson et al. 1993, 1995). The proposed study will answer questions regarding recently low or declining calf recruitment on some of Idaho's best elk range.

The primary objective for this phase of the project is to determine the pregnancy rates and condition for yearling, 2.5-year-old, and adult cow elk in GMUs exhibiting high calf recruitment and those exhibiting low recruitment rates.

STUDY AREA

We selected 2 contrasting study areas, the Lochsa River/North Fork of the Clearwater River and the South Fork of the Clearwater River, to investigate mechanisms potentially affecting elk recruitment (Table 1). The Lochsa/North Fork study area includes portions of GMUs 10 and 12 in north-central Idaho. It is bounded on the north, west, south, and east by Pierce, Orofino, Kooskia, and Castle Butte, respectively. The primary landowners are the Clearwater National Forest, Potlatch Corporation, and Idaho Department of Lands, with scattered private parcels. Topography ranges from a rolling patchwork of timbered parcels on the western private lands to large and rugged drainages on forested land in the central and eastern portions. Elevations range from 425 m at Syringa to 2,030 m at Castle Butte.

Vegetation types range from hay, pasture, and winter wheat fields on private lands to dry site ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) stands, to moist western hemlock (*Tsuga heterophylla*)/western red cedar (*Thuja plicata*) stands, and Engelmann spruce (*Picea engelmannii*)/subalpine fir (*Abies lasiocarpa*) stands at higher elevations. Further details of the general study area can be found in Unsworth et al. (1993).

The Lochsa/North Fork is characterized by poor recruitment, moderate access, possibly decadent habitats, and apparently high predator densities (Table 1).

The South Fork study area (GMU 15) is also in north-central Idaho. The majority of the area is under public ownership administered by the Nez Perce National Forest. Elevations range from 1,200 m at the western end of the winter range to 2,000 m at the peaks in the eastern portion of the GMU.

The higher elevations on the eastern portion of the study area are characterized by grand fir (*A. grandis*) and subalpine fir habitat types that grade into Douglas-fir and ponderosa pine on drier, warmer sites on the lower western portion (Cooper et al. 1991). Grand fir habitat types are the most common on the study area.

Logging is an important land use on the South Fork study area. Areas of heavy mining activity were the first sites harvested. Clearing for agriculture and timber needs of booming wartime and postwar economies have driven subsequent logging activities. The study area is highly roaded and livestock grazing is common. Additional details can be found in Baumeister (1992).

The South Fork has a relatively good recruitment history, good access, more recently disturbed habitats, and possibly lower predator densities than the Lochsa/North Fork (Table 1).

To broaden our database, we identified additional GMUs where we are collecting related data, but much less intensively. These extensive study areas include GMUs 14, 16, and 23. GMUs 14 and 16 are similar to GMU 15 and all 3 are included in the Elk City Zone (Compton 1998). GMU 23 provides a good contrast because the calf:cow and bull:cow ratios are relatively higher in this area.

METHODS

Funding was inadequate to allow us to capture and evaluate adult cows on each study area as in 1997 and 1998. Therefore, we relied on hunter-collected samples.

We enlisted sportsmen to obtain information regarding cow elk condition and pregnancy rates. In 1997 we asked controlled hunt permit holders in GMUs 10, 12, 14, 15, 16, and 23 to collect a series of samples (Table 2) from their harvested antlerless elk. Cow elk were not harvested in GMUs 10 and 12 in 1998. To simplify this task each permit holder received a package ("kit") containing collection materials and instructions before their hunting season. Hunters could deposit their completed kits at 1 of about 30 collection sites. Department personnel retrieved kits from collection points 1-4 times each week, depending on weather and other factors.

All samples were catalogued, and the kill date, girth and diastema measurements were recorded. The chest girth measurement was used to estimate the weight of the animal (Millspaugh and Brundige 1996), whereas the diastema may indicate growth rate (Anderson et al. 1974, Suttie and Mitchell 1983). Both I1s were extracted and used to determine the age of the animal (Keiss 1969). Kidneys and the attached fat, liver samples, and fecal samples were frozen for evaluation at a later date. Liver samples were tested for selenium levels at the Holm Lab at the University of Idaho.

We used the kidney and attached fat to generate a kidney fat index (KFI), that has been shown to index animal condition (Riney 1955, Ash et al. 1999). We calculated the KFI 3 different ways:

1. The "traditional" approach presented by Riney (1955) wherein a perpendicular cut is made through the fat at both ends of the kidney. Then the ratio of the weight of the remaining fat to the weight of the kidney is multiplied by 100 to generate a KFI.
2. The Starkey project (Noyes, pers. comm.) adopted the method presented by Monson et al. (1974), wherein all fat attached to the kidney is included in the KFI calculation.
3. Hundertmark et al. (1997) and Albon et al. (1986) simply recorded the mass of all the kidney fat, to the nearest gram, and used that as a KFI.

In cooperation with the Regional Wildlife Management staff, we collected fresh (< 2 days old) fecal samples during February and March from cow elk in accessible portions of GMUs 12 and 15 to evaluate pregnancy status. Samples will be sent to the Conservation and Research Center of the Smithsonian Institute for pregnancy evaluation (Stoops et al. 1999). As a check we will include fecal samples collected at the same time from captive animals of known pregnancy status.

RESULTS

In September 1998 we mailed about 1,250 collection kits to controlled hunt participants (cow hunters) in GMUs 14, 15, 16, and 23. The estimated success rate for 1998 permit holders was about 37% in the Elk City Zone (GMUs 14, 15, 16) and 47% in GMU 23. Of those successful hunters, 36%-51% collected the requested samples and deposited them at 1 of the drop points. As a result we received samples from nearly 200 harvested antlerless elk (Table 3).

Overall, adult (> 2 years old) cow elk harvested in the Elk City Zone had a higher pregnancy rate and higher selenium levels in the liver than those harvested in GMU 23 (Table 4). The pregnancy rate increased with later harvest dates in GMU 23, but remained unchanged in the Elk City Zone (Tables 9, 10).

Frequently hunters mistakenly removed a portion of the attached fat or otherwise compromised the kidney sample. We collected at least 1 useable kidney from 119 harvested animals, but only 77 of those also had a 2nd useable kidney. During 1998, 79 of the samples for cows > 2 years old contained at least 1 useable kidney, whereas 53 included 2 useable kidneys. Therefore the KFI is based on 1 kidney and attached fat and values are not comparable to other studies that used both kidneys and fat.

Pregnant animals in the Elk City Zone were younger and in better condition (as indexed by KFI) than animals that were not pregnant (Table 7). Pregnant elk in the McCall Zone were in better condition (based on weight and KFI), but ages were not different when compared to animals that were not pregnant (Table 8). This generally agrees with our 1997 findings (Gratson and Zager 1999) where pregnant animals tended to be in better condition than those that were not pregnant.

We also collected jaws from bulls harvested in the Lolo and Elk City Zones and cows harvested in the Elk City and McCall Zones. Diastema measures for yearling bulls were similar in the Lolo and Elk City Zones (Table 10). Cows were similar for McCall and Elk City Zones (Table 11).

DISCUSSION

In Idaho elk recruitment is declining or inadequate in several GMUs. As a result key elk populations are declining - a trend that concerns biologists, sportsmen, and recreationists. Predation is often cited as the primary reason for this decline, but a variety of factors may affect recruitment. We have chosen to take a broader view of the recruitment question by considering factors in addition to predation, such as:

- Habitat quality and structure as it affects:
  - Cow condition
  - Pregnancy rates
  - Calf condition
  - Calf vulnerability
  - Predator efficiency
- Bull:cow ratios
- Bull and cow age structures
- Road access and success rates of bear and lion hunters

We calculated the KFI 3 different ways. The KFIs generated by the Hundertmark et al. (1997) and Starkey (Monson et al. 1974) approaches were consistently higher than those based on the Riney (1955) method (Table 9). In 1997 the values generated by the 3 methods were strongly and significantly correlated (Gratson and Zager 1999). We chose to use the Riney index because it is published and widely accepted, and we saw little to be gained by using 1 of the modifications.

One of the shortcomings of KFI and other condition indices is lack of validation. We are addressing this issue as part of a graduate student project. A complete progress report for that work is found in Appendix A.

The Department offered no antlerless permits for the Lolo Zone in 1998 – and this is unlikely to change within the next few years. Therefore we were unable to obtain pregnancy data for cows in the Lolo Zone. Because this is such an important piece of information, we are collecting fresh fecal pellets from cow elk during February and March. Fecal steroid metabolite levels will be evaluated to estimate the pregnancy rate (Stoops et al. 1999). These data are not yet available.

In 1997 pregnancy rates within zones were higher for animals harvested late in the hunting season compared to those harvested earlier (Gratson and Zager 1999). We anticipated a similar pattern for the 1998 collection. However, in the Elk City Zone, which represents our largest and probably most representative sample, pregnancy remained at about 82% regardless of harvest date. It did increase somewhat in the McCall Zone, however.

Increasing pregnancy rates are expected for 2 reasons:

1. PSPB becomes an accurate test for pregnancy 30 days after conception (Weber et al. 1982, Wood et al. 1986, Willard et al. 1994, Noyes et al. 1997). Animals harvested during the early portion of the cow season may have conceived <30 days earlier and would not test pregnant.

2. An unknown portion of adult cows likely conceive during the 2nd or later estrous. These animals would not test pregnant unless they were harvested during 1 of the late cow hunts.

Why pregnancy rates increased in the Elk City Zone in 1997 but not in 1998 is unclear.

For cows in GMU 15, the late fall 1997 pregnancy rate of 95% is comparable to the spring 1998 rate of 93% obtained from captured animals. This implies that one can estimate the actual pregnancy rate from a late fall (>1 Nov or >15 Nov) sample of adult cow elk under similar ecological conditions. Hence, we believe that cow elk harvested after 1 November may provide a good estimate of pregnancy on our study areas. It follows, then, that the pregnancy rate in the Elk City Zone declined >10% between 1997 and 1998. As a further check, these pregnancy rates compare well with observed calf:cow ratios derived during winter aerial surveys.

Within a zone, pregnant animals tend to be in somewhat better condition (as indexed by weight and KFI) than those that are not pregnant (Tables 11, 12, 13). In the Elk City Zone, where we have the largest sample, pregnant animals were younger and in better condition than nonpregnant animals. Pregnant animals in the McCall Zone were also in better condition than those that were not pregnant, but there was no difference in age. These relationships are similar to those seen in 1997 (Gratson and Zager 1999), and agree with other reports of significant relationships between animal condition and fecundity in red deer (Mitchell and Brown 1974, Hamilton and Blaxter 1980, Albon et al. 1986).

During 1997 adult cows in the Lolo Zone tended to be in better condition than Elk City Zone cows during the fall, but in poorer condition in late winter (Gratson and Zager 1999). We do not know the reason behind this pattern but suspect that lower pregnancy rates and poorer calf survival in the Lolo Zone means that fewer adult cows face the energy demands of lactation during the summer/fall and are, therefore, in better condition during the fall. By spring these animals are in apparently poorer condition than their South Fork counterparts because of more difficult winter conditions. Another possibility is that spring/summer habitats in the Lolo Zone are higher in quality than those in the Elk City Zone. Therefore, the Lochsa/North Fork cows are able to maintain a higher nutritional level during the summer. Unfortunately, we do not have comparable data for 1998.

Our data from the Lochsa/North Fork and the South Fork (Gratson and Zager 1998, 1999; this report) suggest that the “recruitment problem” in north-central Idaho, and particularly the Lolo

Zone, is more than a question of predation. Our preliminary information suggests that Lochsa/North Fork cows exhibit:

Lower than expected pregnancy rates.
Apparently older age structure.
Poor calf survival rates (includes predation effects).

During the Lewis and Clark expedition (Coues 1893), the Lochsa/North Fork was mostly heavily forested and elk were present but not abundant. Wildfires during 1890-1934 resulted in vast shrubfields where timber once dominated (Peek et al. 1997). Because of the inherently low productivity of the Lochsa/North Fork, these habitats were not necessarily exceptional elk habitat, but they were markedly better than those before the wildfires. As a result the elk population grew steadily.

Generally elk habitat quality (and carrying capacity) declines as plant succession advances (Skovlin 1982). When declining habitat quality intersects with an increasing elk population, we expect the elk population to exhibit signs of declining vigor. We may be seeing this decline on the Lochsa/North Fork. Any increases, real or perceived, in predator density may simply hasten this decline.

Furthermore, more than 20 years of bulls-only hunting has resulted in a cow age structure skewed toward older animals (average 10 years old in March 1997 sample) on the Lochsa/North Fork. Because fecundity begins to decline at 8 (Greer 1966) to 12 (Bubenik 1982) years old, this age structure may also contribute to declining recruitment.

LITERATURE CITED

Alldredge, M. W. 1998. Clearwater elk study: draft study plan. Department of Wildlife Resources, University of Idaho, Moscow, ID, USA.

Albon, S. D., F. E. Guinness, and T. H. Clutton-Brock. 1983. The influence of climatic variation on the birth weights of red deer (*Cervus elaphus*). J. Zool. 46:295-298.

______, B. Mitchell, B. J. Huby, and D. Brown. 1986. Fertility in female red deer (*Cervus elaphus*): the effects of body composition, age and reproductive status. J. Zool. 209:447-460.

______, ______, and B. W. Staines. 1983. Fertility and body weight in female red deer: a density-dependent relationship. J. Anim. Ecol. 52:969-980.

Anderson, A. E., D. E. Medin, and D. C. Bowden. 1974. Growth and morphometry of the carcass, selected bones, organs, and glands of mule deer. Wildlife Monographs 39.

Anderson, K. A., and B. Isaacs. 1993. Determination of selenium in feeds, premixes, supplements and injectable solutions by ICP-AES hydride generation. J. Assoc. Off. Analytic. Chemist. 76:910-913.

______, and B. Isaacs. 1995. Simultaneous determination of arsenic, selenium and antimony by hydride generation for inductively coupled plasma spectrometry. J. Assoc. Off. Analytic. Chemist. 78:1055-1060.

Ash, R., D. Murray, P. Zager, and M. Gratson. 1999. Assessing body composition and nutritional status through morphometric and physiological indices and elk reproductive endocrinology and behavior across nutritional planes. Pages 58-78 in M. Gratson and P. Zager, Elk ecology. Study IV. Factors influencing elk calf recruitment. Job Prog. Rep., Fed. Aid Wildl. Restor., Proj. W-160-R-25. Idaho Dep. Fish and Game, Boise.

Baumeister, T. R. 1992. Ecology of white-tailed deer on summer-fall range in north-central Idaho. M.S. Thesis, Montana State Univ., Bozeman, MT, USA.

Boyce, M. S. 1989. The Jackson elk herd: intensive wildlife management in North America. Cambridge Univ. Press, NY, USA.

Brady, P. S., L. J. Brady, P. A. Whetter, D. E. Ullrey, and L. D. Fay. 1978. The effect of dietary selenium and vitamin E on biochemical parameters and survival of young white-tailed deer (*Odocoileus virginianus*). J. Nutr. 108:1439-1448.

Bubenik, A. B. 1982. Physiology. Pages 125-179 in J. W. Thomas and D. E. Toweill (comp.). Elk of North America: ecology and management. Stackpole Books, Harrisburg, PA, USA.

Buechner, H. K., and C. V. Swanson. 1955. Increased natality resulting from lowered population density among elk in southeastern Washington. N. Amer. Wildl. Conf. 20:560-567.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, NY, USA.

______, and A. R. E. Sinclair. 1994. Wildlife ecology and management. Blackwell Sci. Publ., Boston, MA, USA.

Clutton-Brock, T. H., M. Major, S. D. Albon, and F. E. Guinness. 1987. Early development and population dynamics in red deer. I. Density-dependent effects of juvenile survival. J. Anim. Ecol. 56:53-67.

Compton, B. (compiler). 1998. White-tailed deer, mule deer, and elk management plan. Draft II. Idaho Dept. of Fish and Game, Boise, ID, USA.

Cook, J. G., L. J. Quinlan, L. L. Irwin, L. D. Bryant, R. A. Riggs, and J. W. Thomas. 1996. Nutrition-growth relations of elk calves during late summer and fall. J. Wildl. Manage. 60:528-541

Cooper, S. V., K. E. Neiman, and D. W. Roberts. 1991. Forest habitat types of northern Idaho: a second approximation. U.S. Dep. Agric., For. Serv., GTR-INT-236.

Coues, E. (ed.). 1863. The history of the Lewis and Clark expedition. Dover Publ., Inc., New York, NY, USA.

Coughenour, M. B., and F. J. Singer. 1996. Elk population processes in Yellowstone National Park under the policy of natural regulation. Ecol. Appl. 6:573-593.

DelGiudice, G. D., L. D. Mech, and U. S. Seal. 1990. Effects of winter undernutrition on body composition and physiological profiles of white-tailed deer. J. Wildl. Manage. 54:539-550.

______, F. J. Singer, and U. S. Seal. 1991. Physiological assessment of winter nutritional deprivation in elk of Yellowstone National Park. J. Wildl. Manage. 55:653-664.

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

Freddy, D. J. 1987. The White River elk herd: a perspective, 1960-85. Tech. Publ. No. 37. CO Div. of Wildl., Fort Collins, CO, USA.

Gerhart, K. L., R. G. White, R. D. Cameron, and D. E. Russell. 1996. Estimating fat content of caribou from body condition scores. J. Wildl. Manage. 60:713-718.

Gratson, M. W., J. W. Unsworth, P. Zager, and L. Kuck. 1993. Initial experiences with adaptive resources management for determining appropriate antlerless elk harvest rates in Idaho. N. Amer. Wildl. Nat. Resourc. Conf. 58:610-619.

______, and B. K. Johnson. 1995. Managing harvest for sustainable ungulate populations. The Wildl. Soc., 2nd Ann. Conf., Portland, OR, USA. (abstract)

______, C. Whitman, and P. Zager. 1995. Lochsa elk ecology. Study II. Optimum yield of elk. Job 1. The effect of harvest on elk population size and composition in Idaho. Fed. Aid. Wildl. Restor., Job Prog. Rep, Proj. W-160-R-22. Idaho Dep. Fish and Game, Boise.

_____, ______, and P. Zager. 1996. Lochsa elk ecology. Study I, Job 2. The effects of road closures on elk mortality in north-central Idaho. Study I, Job 3. The effects of road closures on hunter density, distribution, and success in north-central Idaho. Fed. Aid. Wildl. Restor., Job Compl. Rep, Proj. W-160-R-23. Idaho Dep. Fish and Game, Boise, ID, USA.

______, and P. Zager. 1994. Lochsa elk ecology. Study II. Optimum yield of elk. Job 1. The effect of harvest on elk population size and composition in Idaho. Fed. Aid. Wildl. Restor., Job Prog. Rep, Proj. W-160-R-21. Idaho Dep. Fish and Game, Boise, ID, USA.

______, and ______. 1998. (Lochsa) elk ecology. Study II. Optimum yield of elk. Job No. 1. The effect of harvest on elk population size and composition in Idaho. Study IV. Factors influencing elk calf recruitment. Job No. 1. Develop a study plan. . Job. Prog. Rep., Fed. Aid Wildl. Restor., Proj. W-160-R-24, Subproj. 31. Idaho Dept. Fish and Game, Boise, ID, USA.

______, and _______. 1998. (Lochsa) elk ecology. Study I. Factors influencing elk calf recruitment. Job No. 1. Calf mortality causes and rates. Job No. 2. Predation effects on calf elk. Fed. Aid. Wildl. Restor., Job Prog. Rep, Proj. W-160-R-24. Idaho Dep. Fish and Game, Boise, ID, USA.

Greer, K. R. 1966. Fertility rates of the northern Yellowstone elk populations. Ann. Conf. West. State Fish and Game Comm. 46:123-128.

Gunn, R. G., J. M. Doney, and A. J. F. Russel. 1969. Fertility in Scottish Blackface ewes as influenced by nutrition and body condition at mating. J. Agric. Sci., Cambr. 73:289-294.

Hamilton, W. J., and K. L. Blaxter. 1980. Reproduction in farmed red deer. 1. Hind and stag fertility. J. Agric. Sci. 95:261-273.

Hebert, D. M., and I. M. Cowan. 1971. White muscle disease in the mountain goat. J. Wildl. Manage. 35:752-756.

Hobbs, N. T., and T. A. Hanley. 1990. Habitat evaluation: do use/availability data reflect carrying capacity? J. Wildl. Manage. 54:515-522.

______, and D. M. Swift. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. J. Wildl. Manage. 49:814-822.

Houston, D. B. 1982. The northern Yellowstone elk herd: ecology and management. Macmillan Publ. Co., Inc., NY, USA

Hundertmark, K. J., C. C. Schwartz, T. R. Stephenson, and S. L. Kennedy. 1997. Moose research center reports. Fed. Aid. Wildl. Restor., Res. Prog. Rep., Alaska Dep. of Fish and Game, Anchorage, AK, USA.

Keiss, R. E. 1969. Comparison of eruption-wear patterns and cementum annuli as age criteria in elk. J. Wildl. Manage. 33:175-180.

Kittams, W. H. 1953. Reproduction of Yellowstone elk. J. Wildl. Manage. 17:177-184.

Knight, R. R. 1970. The Sun River elk herd. Wildl. Monogr. 23.

Kuck, L., and J. Rachael (eds.). 1998. Statewide surveys and inventories: elk. Fed. Aid. Wildl. Restor., Job Prog. Rep, Proj. W-170-R-21. Idaho Dep. Fish and Game, Boise, ID, USA.

Leege, T. A. 1968. Prescribed burning for elk in northern Idaho. Proc. Ann. Tall Timbers Fire Ecol. Conf. 7:235-253.

______. 1969. Burning seral brush ranges for big game in northern Idaho. N. Amer. Wildl. Nat. Resourc. Conf. 34:429-438.

_____, and W. O. Hickey. 1977. Elk - snow - habitat relationships in the Pete King drainage, Idaho. Wildl. Bull. No. 6. Idaho Dep. Fish and Game, Boise, ID, USA.

Leptich, D. J., S. G. Hayes, and P. Zager. 1997. Elk mortality in the Coeur d'Alene drainage of northern Idaho. (draft.)

Melton, L., M. Tracy, and G. Moller. 1990. Screening trace elements and electrolytes by inductively coupled argon plasma spectrometry. Clinical Chemistry 36:247-250.

Merrill, E. H., and M. S. Boyce. 1991. Summer range and elk population dynamics in Yellowstone National Park. Pages 263-273 in R. B. Keiter and M. S. Boyce (eds.). The Greater Yellowstone Ecosystem: redefining America's wilderness heritage. Yale Univ. Press, New Haven, CT, USA.

Millspaugh, J. J., and G. C. Brundige. 1996. Estimating elk weight from chest girth. Wildl. Soc. Bull. 24:58-61.

Mitchell, B., and J. M. Crisp. 1981. Some properties of red deer (*Cervus elaphus*) at exceptionally high population density in Scotland. J. Zool., Lond. 193:157-169.

Monson, R. A., W. B. Stone, B. L. Weber, and F. J. Spadaro. 1974. Comparison of Riney and total kidney fat techniques for evaluating the physical condition of white-tailed deer. N.Y. Fish and Game J. 21:67-72.

Noyes, J. H., B. K. Johnson, L. D. Bryant, S. L. Finholt, and J. W. Thomas. 1996. Effects of bull age on conception dates and pregnancy rates of cow elk. J. Wildl. Manage. 60:508-517.

______, R. G. Sasser, B. K. Johnson, L. D. Bryant, and B. Alexander. 1997. Accuracy of pregnancy detection by serum protein (PSPB) in elk. Wildl. Soc. Bull. 25:695-698.

Peek, J. M., J. J. Yeo, K. Chang, T. A. Leege, G. R. McNeill, M. W. Schlegel, and P. Zager. 1997. A history of the Lochsa elk population and its habitat. Dep. of Wildl. Resources, Univ. of Idaho. (draft.)

Riney, T. 1955. Evaluating condition of free ranging red deer (*Cervus elaphus*), with special reference to New Zealand. N.Z. J. Sci. Technol. Sect. B 36:429-463.

Robbins, C. T. 1993. Wildlife feeding and nutrition. 2nd edition. Academic Press, New York, NY, USA.

Skovlin, J. M. 1982. Habitat requirements and evaluations. Pages 369-413 in J. W. Thomas and D. E. Toweill (comp.). Elk of North America: ecology and management. Stackpole Books, Harrisburg, PA, USA.

Stoops, M. A., G. B. Anderson, B. L. Lasley, and S. E. Shideler. 1999. Use of fecal steroid metabolites to estimate the pregnancy status of a free-ranging herd of tule elk. J. Wildl. Manage. 63:561-569.

Suttie, J. M., and B. Mitchell. 1983. Jaw length and hind foot length as measures of skeletal development of red deer (*Cervus elaphus*). J. of Zool., Lond. 200:431-434.

Taber, R. D., K. Raedeke, and D. A. McCaughran. 1982. Population characteristics. Pages 279-298 in J. W. Thomas and D. E. Toweill (comp.). Elk of North America: ecology and management. Stackpole Books, Harrisburg, PA, USA.

Thorne, T. E., R. E. Dean, and W. G. Hepworth. 1976. Nutrition during gestation in relation to successful reproduction in elk. J. Wildl. Manage. 40:330-335.

Unsworth, J. W., L. Kuck, M. D. Scott, and E. O. Garton. 1993. Elk mortality in the Clearwater drainage of north-central Idaho. J. Wildl. Manage. 57:495-502.

VanHorne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

Weber, B. J., M. J. Wolfe, and G. C. White. 1982. Use of serum progesterone levels to detect pregnancy in elk. J. Wildl. Manage. 46:835-841.

Willard, S. T., R. G. Sasser, J. C. Gillespie, J. T. Jaques, T. H. Welsh, Jr., and R. D. Randel. 1994. Methods for pregnancy determination and the effects of body condition on pregnancy status in Rocky Mountain elk (*Cervus elaphus nelsoni*). Theriogenology 42:1095-1102.

Wood, A. K., R. E. Short, A. E. Darling, G. L. Dusek, G. R. Sasser, and C. A. Ruder. 1986. Serum assays for detecting pregnancy in mule and white-tailed deer. J. Wildl. Manage. 50:684-687.

Table 1. Characteristics of the Game Management Units that are part of the elk recruitment project. (adapted from Gratson and Zager 1998).

GMU	10	12	14	15	16	23
Zone	Lolo	Lolo	Elk City	Elk City	Elk City	McCall
Calf:cow ratio[a]	Low	Low	High	High	Med	High
Elk density[b]	High	Med	Med	Med	Low	Med
Bull:cow ratio[c]	Low	Med	Med	Low	Low	High
Lion density[d]	?	?	?	?	?	?
Bear density[e]	Med	Med	Low	Low	Med	Med
Alternate prey[f]	Low	Low	Med	Med	Med	Med
Wolves[g]	Yes	No	No	Yes	Yes	Yes

[a] Low = 13-19:100; medium = 20-30:100; high > 30:100 on winter range (Kuck 1997).
[b] Low = < 2 cows/square mile; med = 2-3 cows/square mile; high = > 3 cows/square mile on winter range (Kuck 1997).
[c] Low = 13-17 bulls:100 cows; med = 18-25 bulls:100 cows; high => 25 bulls:100 cows on winter range (Kuck 1997).
[d] Based on harvest records (Beecham 1996).
[e] Based on scent station surveys of relative abundance and trends (Beecham 1996).
[f] Estimated by combining the relative abundance of white-tailed and mule deer from aerial surveys and a survey of wildlife managers in 1995 (Unsworth et al. 1995).
[g] Presence or absence of breeding wolves (USFWS files).

Table 2. Samples and data collected from adult cow and bull elk harvested in the Elk City, Lolo, and McCall Zones, 1998.

Samples and data collected	**Reason**
Jaw	Aging and growth rate
Blood	Pregnancy test (PSPB)
Kidneys and attached fat	Body condition
Liver (5 cm x 5 cm piece)	Selenium level
Chest girth	Estimate of body weight
Feces	Parasites
Harvest date	Interpretation aid

Table 3. Background information for hunting season collections.

Year	Elk City Zone 1997	Elk City Zone 1998	Lolo Zone 1997	Lolo Zone 1998	McCall Zone 1997	McCall Zone 1998
Permits available	1,250	850	1,850	0	400	400
No. hunters	1,147	774	1,615	0	359	322
Harvest	455	285	277	0	143	151
Hunter success	40	37%	17	0	40	47%
Kits returned	135	144	33	0	35	54
Compliance rate	30%	51%	12%	0	24%	36%

Table 4. Estimated weight, condition, and pregnancy rates for adult (>2 years old) cow elk harvested during the hunting season in 3 elk management zones in Idaho, 1997 and 1998.

	Elk City Zone		Lolo Zone		McCall Zone	
	1997	1998	1997	1998	1997	1998
Age (years)	8.0 *n*=97 sd=4.46	6.9 *n*=98 sd=3.65	8.9 *n*=24 sd=4.13		6.3 *n*=21 sd=4.54	6.5 *n*=30 sd=3.11
Weight (kg)	324 *n*=95 sd=34.38	335 *n*=88 sd=41.57	328 *n*=22 sd=31.55		331 *n*=20 sd=30.69	335 *n*=26 sd=46.39
Pregnancy rate (%)	81.2 *n*=85	82.1 *n*=84	50.0 *n*=20		47.1 *n*=17	77.3 *n*=22
KFI	101 *n*=43 sd=56.55	84 *n*=56 sd=65.09	129 *n*=10 sd=51.52		95 *n*=13 sd=58.42	92 *n*=23 sd=52.60
Selenium (mg/g)	1.19 *n*=90 sd=1.38	0.785 *n*=48 sd=1.22	0.46 *n*=23 sd=0.44		0.27 *n*=21 sd=0.34	0.50 *n*=28 sd=1.17

Table 5. Estimated weight, condition, and pregnancy rates for adult (>2 years old) cow elk harvested after 1 November in 3 elk management zones in Idaho, 1997 and 1998.

	Elk City Zone		Lolo Zone		McCall Zone	
Year	1997	1998	1997	1998	1997	1998
Age (years)	7.8 *n*=79 sd=4.50	7.0 *n*=73 sd=3.83	10.2 *n*=10 sd=2.79		8.4 *n*=8 sd=6.06	7.4 *n*=13 sd=3.01
Weight (kg)	325 *n*=77 sd=33.06	332 *n*=65 sd=41.31	319 *n*=8 sd=31.89		326 *n*=8 sd=28.60	360 *n*=12 sd=51.10
Pregnancy rate (%)	87.0 *n*=69	82.0 *n*=63	71.0 *n*=7		71.0 *n*=7	100 *n*=8
KFI	104 *n*=35 sd=59.05	70 *n*=36 sd=58.91	140 *n*=3 sd=46.52		62 *n*=3 sd=45.30	108 *n*=9 sd=54.75
Selenium (mg/g)	1.29 *n=74* sd=1.45	0.79 *n*=47 sd=1.23	0.58 *n*=9 sd=0.46		0.30 *n*=8 sd=0.49	0.72 *n*=12 sd=1.74

Table 6 Estimated weight, condition, and pregnancy rates for adult (>2 years old) cow elk harvested in the Elk City Zone, 1997 and 1998.

	Overall		> 1 Nov		> 15 Nov	
Year	1997	1998	1997	1998	1997	1998
Age (years)	8.0 *n*=97 sd=4.46	6.9 *n*=98 sd=3.66	7.8 *n*=79 sd=4.50	7.0 *n*=73 sd=3.83	7.0 *n*=45 sd=4.32	7.0 *n*=64 sd=3.79
Weight (kg)	324 *n*=95 sd=34.38	335 *n*=88 sd=41.57	325 *n*=77 sd=33.06	332 *n*=65 sd=41.31	325 *n*=43 sd=32.61	334 *n*=57 sd=43.53
Pregnancy rate (%)	81.2 *n*=85	82.1 *n*=84	87.0 *n*=69	82.0 *n*=63	95.0 *n*=37	83.3 *n*=54
KFI	101 *n*=43 sd=56.55		104 *n*=35 sd=59.05	70 *n*=36 sd=58.81	112 *n*=11 sd=74.80	70 *n*=36 sd=58.91
Selenium (mg/g)	1.19 *n*=90 sd=1.38	0.79 *n*=48 sd=1.22	1.29 *n*=74 sd=1.45	0.79 *n*=47 sd=1.23	1.5 *n*=41 sd=1.70	0.80 *n*=42 sd=1.30

Table 7. Characteristics of pregnant vs. nonpregnant adult cow elk determined from animals harvested in the Elk City Zone, 1997 and 1998.

	Pregnant		Not pregnant	
Year	1997	1998	1997	1998
Age (years)	8.2 *n*=69 sd=4.12	6.3 *n*=69 sd=3.25	8.4 *n*=16 sd=5.77	9.2 *n*=15 sd=4.95
Weight (kg)	329 *n*=68 sd=32.55	331 *n*=63 sd=38.91	312 *n*=15 sd=37.11	337 *n*=14 sd=41.10
KFI	104 *n*=32 sd=60.05	90 *n*=43 sd=58.26	92 *n*=7 sd=48.84	48 *n*=9 sd=41.00
Selenium (mg/g)	1.21 *n*=65 sd=1.43	0.75 *n*=33 sd=1.10	1.48 *n*=10 sd=0.64	0.69 *n*=7 sd=0.52

Table 8. Characteristics of pregnant vs. nonpregnant adult cow elk determined from animals harvested in the McCall Zone, 1997 and 1998.

	Pregnant		Not pregnant	
Year	1997	1998	1997	1998
Age (years)	6.9 *n*=8 sd=4.03	6.0 *n*=17 sd=2.76	6.3 *n*=9 sd=5.81	5.5 *n*=5 sd=3.74
Weight (kg)	313 *n*=8 sd=2.18	340 *n*=15 sd=43.15	337 *n*=9 sd=26.46	319 *n*=5 sd=34.02
KFI	102 *n*=1	100 *n*=14 sd=52.21	77 *n*=8 sd=39.92	48 *n*=4 sd=42.45
Selenium (mg/g)	0.38 *n*=8 sd=0.49	0.75 *n*=15 sd=1.56	0.23 *n*=9 sd=0.21	0.34 *n*=5 sd=0.35

Table 9. Comparison of 3 kidney fat indices (KFIs).

	Riney[a]		Starkey[b]		Hundertmark[c]	
	1997	1998	1997	1998	1997	1998
Elk City Zone	202 *n*=24 sd=104.2	84 *n*=56 sd=65.09	286 *n*=24 sd=162.4	120 *n*=56 sd=116.80	668 *n*=24 sd=372.9	259 *n*=56 sd=222.31
Lolo Zone	251 *n*=5 sd=114.9		346 *n*=5 sd=156.4		775 *n*=5 sd=328.8	
GMU 23	189 *n*=8 sd=78.3	92 *n*=23 sd=52.06	261 *n*=7 sd=117.7		614 *n*=7 sd=272.6	254 *n*=24 sd=157.39

[a] Riney, T. 1955. Evaluating condition of free ranging red deer (Cervus elaphus), with special reference to New Zealand. N.Z. J. Sci. Technol. Sect. B 36:429-463.

[b] Monson, R.A., W.B. Stone, B.L Weber, and F.J. Spadaro. 1974. Comparison of Riney and total kidney fat techniques for evaluating the physical condition of white-tailed deer. N.Y. Fish and Game J. 21:67-72.

[c] Hundertmark, K.J. C.C. Schwartz, T.R. Stephenson, and S.L. Kennedy. 1997. Moose research center reports. Fed. Aid Wildl. Restor., Res. Prog. Rep., Alaska Dep. of Fish and Game, Anchorage.

Table 10. Average age (all animals) and diastema measures (calves and yearlings) for bull elk harvested in the Lolo and Elk City Zones, 1998.

	Lolo Zone	Elk City Zone
All bulls		
n	26	25
Avg. age	3.6	2.4
sd	2.160	1.453
Calves		
n	n/a	3
Avg. diastema	n/a	103.6
sd		3.910
Yearlings		
n	8	9
Avg. diastema	105.6	102.5
sd	2.546	5.852

Table 11. Average age (all animals) and diastema measures (calves and yearlings) for cow elk harvested in the Elk City and McCall Zones, 1998.

	McCall Zone	Elk City Zone
All cows		
n	44	145
Avg. age	4.8	5.5
sd	3.653	4.194
Calves		
n	7	19
Avg. diastema	86.3	84.3
sd	4.581	5.608
Yearlings		
n	5	12
Avg. diastema	98.7	99.4
sd	4.866	4.520

JOB NO. 2: CALF MORTALITY CAUSES AND RATES

ABSTRACT

The objectives of this study are to determine elk (*Cervus edaphus*) calf mortality rates and causes of mortality and how elk density, calf condition, habitat, and abundance of alternate prey may influence calf mortality in north-central Idaho. The Lochsa/North Fork has had a declining elk herd in which calf:cow ratios have declined since the early 1990s to very low levels. The South Fork has had a stable to slightly declining elk herd in which calf:cow ratios are stable and at moderate levels. From July 1998 through May 1999, we continued to monitor mortality and determine causes of death of radio-collared elk calves captured in 1998 on these study areas. Annual survival of calves calculated as a simple percentage was 12% (2/17) on the Lochsa/North Fork and 40% (8/20) on the South Fork, similar to annual survival of 1997 captured calves. Between mid-August 1998 (end of last reporting period) and May 1999, 1 calf on the Lochsa/North Fork dropped its radio collar, 2 calves on the Lochsa/North Fork and 1 on the South Fork were killed by mountain lions (*Puma concolor*), and 2 calves on the South Fork were harvested during the elk hunting season. We captured, radio-collared, and monitored 31 additional neonates on the Lochsa/North Fork and 23 neonates on the South Fork in spring and summer 1999 to facilitate evaluating the effects of predation on calf survival (Job 3). We also captured 30 known-aged calves 44 times from a captive elk herd in north-central Idaho to obtain baseline data for assessing wild calf condition and to validate aging criteria for wild calves.

INTRODUCTION

In north-central Idaho, as in some areas of several surrounding states, elk recruitment has been chronically low or has declined since the 1980s or early 1990s in many key game management units (GMUs) (Gratson and Johnson 1995). This declining or low recruitment is primarily limited to the north-central portion of Idaho (Gratson and Zager 1998, Bomar et al. 1999). Declining and low recruitment is cause for concern because recruitment generally must at least replace losses of adults to hunting and other factors to allow population stability or growth. Hunting losses typically account for >85% of the annual mortality of adult bulls and can be managed by manipulating hunter numbers and success through changes in season timing and length, sex and antler point restrictions, legal hunting equipment and techniques, open and closed road densities, and cover amounts and juxtaposition (Thomas 1991, Unsworth et al. 1993, D. J. Leptich et al., Idaho Department of Fish and Game, unpublished data, Gratson et al. 1997). Annual mortality of adult females is typically <15% in the absence of significant hunting pressure and increases proportionately as the number of antlerless permits and season length increases (D. J. Leptich et al., Idaho Department of Fish and Game, unpublished data). In contrast, information on the mechanisms that are responsible for variation in elk recruitment in Idaho is lacking and the development of methods to manage elk recruitment is in its infancy.

There are a number of demographic parameters that may affect elk recruitment: pregnancy rates, birth rates, and calf survival. This study addresses calf survival rates. Elsewhere we address elk recruitment from a statewide, spatial pattern perspective (Bomar et al. 1998) and the questions of pregnancy, birth rates, and cow condition (Zager and Gratson 1999). There are also a variety of factors that may influence these parameters, such as elk density, habitat condition, nutrition, weather, predation, breeding conditions, and calf condition. Three of these stand out as potentially important and mostly ultimate as opposed to proximate factors influencing calf recruitment in Idaho: 1) the balance between elk density and habitat; 2) predation; and 3) the age structure of bulls.

Elk density is usually considered an ultimate factor that typically acts in conjunction with habitat, because habitat sets the upper bound on elk density (Caughley 1977, Caughley and Sinclair 1994). If habitat conditions are intrinsically poor, even moderate or low elk densities may be too high for the habitat and can lead to unsatisfactory recruitment rates. In contrast, if elk density is high enough to influence habitat condition and elk nutrition, this can lead to poor calf condition and higher rates of starvation, disease, and predation. Coughenour and Singer (1996) reported an indirect relationship between forage biomass and recruitment. They showed positive relationships between calf recruitment and precipitation levels, and between precipitation levels and forage biomass. They also showed a positive relationship between winter calf mortality rates and population density. DelGiudice et al. (1991) showed that nutritional deprivation was associated with higher elk densities, deep snow, and declines in calf:cow ratios from early to late winter.

Alternatively, habitat quality can decline so as to influence calf birth weight and growth rate regardless of elk density. Thorne et al. (1976) showed that calf birth weight and growth rate were directly linked to late winter-early spring weight loss of cows. Such weight loss could result from poor nutrition on summer or winter range because of low availability of forage, high elk density, or perhaps severe winter weather. Cook et al. (1996) showed that calf growth rates in summer and fall were directly linked to summer-fall nutrition. It has long been recognized that much of the north-central Idaho elk winter range was created by wildfires in the early 1900s (Leege 1968, Leege and Hickey 1977). Since then, and despite use of prescribed fire as a habitat management tool (Leege 1969, J. Peek et al., University of Idaho, unpublished data), it is likely that succession of seral brushfields has led to declining quality and quantity of winter forage. However, while it is clear that calf recruitment has declined over much of this north-central Idaho “brushrange,” current habitat conditions and the relationship between habitat and recruitment on this range is poorly understood. It is important to recognize that the relationships among habitat quality and quantity, elk density, and productivity and recruitment are complex (Mitchell and Crisp 1981, Albon et al. 1983, Van Horne 1983, Hobbs and Swift 1985, Clutton-Brock et al. 1987, Hobbs and Hanley 1990). However, these relationships must be understood to more successfully manage elk populations.

Statewide aerial survey data in Idaho suggest that recruitment is negatively related to elk density on a broad scale (Gratson and Johnson 1995, Bomar et al., 1999). Moreover, early indications from a management experiment in Idaho where cow elk densities were manipulated experimentally, indicate that reducing density can result in higher recruitment rates (Gratson and Zager 1994). Reduced recruitment rates at higher elk densities has been documented for the northern Yellowstone National Park elk herd (Houston 1982, Merrill and Boyce 1991, Coughenour and Singer 1996), the Jackson Hole Elk Refuge herd (Boyce 1989), and adjacent Grand Teton National Park herd (Boyce 1989).

Predation on calves has been documented in a number of studies, but little research until recently has investigated causes of mortality from birth to recruitment as yearlings. Hornocker's (1970) investigation of mountain lion predation on elk and deer in central Idaho was mostly restricted to winter predation. Similarly, current research in Colorado is investigating rates and causes of calf mortality after calves have reached 6 months age (Freddy 1995).

Two important factors to consider when investigating predation and calf mortality are the density of alternate prey and prey condition. If alternate prey are readily available, we might expect higher calf recruitment rates than if alternate prey are scarce (e.g., Holling 1959, Murdoch 1969, Gasaway et al. 1983). On the other hand, availability of alternate primary prey may allow predators to thrive where they might not otherwise if only large secondary prey such as moose *(Alces alces*) and elk are available. In north-central Idaho, the 2 major predators of elk calves are mountain lions and black bears (Schlegel 1986). The primary prey of mountain lions are likely mule deer, white-tailed deer, or elk, depending on relative abundance and vulnerability of each (Hornocker 1970, K. Murphy, University of Idaho, unpublished data). In contrast, with the exception of short periods of time during the spring and early summer when bears prey on elk and deer neonates (Schlegel 1986) and fall and early spring when they scavenge deer and elk carcasses, the primary foods of Idaho black bears are likely invertebrates and plants (Beecham and Rohlman 1994).

To evaluate the effect of predation on elk recruitment one must also consider calf health and condition, because poor condition may essentially predispose calves to die from predation or other means (e.g., Errington 1934, Hornocker 1970, Roberts and Wolfe 1974, Mech 1977). Under these conditions, causes of calf mortality may be compensatory, and managing predation pressure may do little to improve elk recruitment.

In north-central Idaho in the mid-late 1970s, 58% of 86 calves radio-collared shortly after birth died from natural causes (Schlegel 1986). Of these, 98% died due to predation and 2% as a result of disease. Predation by black bears accounted for at least 67% of the mortality by predators and mountain lions accounted for at least 20%. Blood serum values and calf weights suggested that calves were in good condition at capture. Moreover, survival rates of calves increased in the year following removal of 75 bears from the study area and calf:cow ratios increased for 2 winters following removal. However, these results were confounded by the fact that calf:cow ratios also increased in nearby drainages in which bears were not removed. Schlegel (pers. comm.) suggests that year-to-year variation in predation rates by black bears may result from variations in the abundance and proximity of spring forage for bears to calving areas.

Continuing research in the Blue Mountains of western Washington has documented rates and causes of calf mortality (Myers et al. 1996). Fifty percent of 101 radio-marked calves died: 55% due to predation by mountain lions, 23% to bears, 4% to coyotes, and 11% to unknown predators. Unlike central Idaho, predation rates were disproportionately higher on male calves. Myers (pers. comm.), like Schlegel (pers. comm.), suggests that calf predation rates may be closely related to the distribution and abundance of forage. Thus, weather and its influence on forage conditions may account for year-to-year variation in predation rates.

Smith and Anderson (1996) reported markedly lower calf mortality in the Jackson Hole and Grand Teton National Park areas, although predation remained the primary cause of calf deaths. They found a mortality rate of only 15% for 164 radio-collared calves, and only 1 calf died between age 27 days and the fall hunting season. Of the mortality, 68% was due to predation, primarily by bears, but also by coyotes (*Canis latrans*). Predation was disproportionately higher on male calves and those born earlier in the calving season. Summer herd composition surveys showed that higher calf:cow ratios were associated with higher April precipitation levels.

Singer et al. (1992) and Coughenour and Singer (1996) reported that 32% of 127 radio-marked calves died during the summer and 21% died during the winter in Yellowstone National Park. Nearly all summer mortality was due to predation by grizzly bears, black bears, and coyotes, whereas winter mortality was mostly associated with malnutrition during the severe winter of 1988-1989, following the drought and extensive wildfires of 1988. Singer et al. (1992) suggested that summer predation rates on calves were density-independent, whereas winter malnutrition was mostly density-dependent. Survival of calves tended to be positively related to weight, and lighter calves were born following the drought and fires of 1988 and severe winter of 1988-1989.

The effect of bull age structure on calf recruitment is being investigated in northeastern Oregon under fenced, experimental conditions (Noyes et al. 1996, Johnson pers. comm.). With an adequate number of mature bulls in the population, most calves are born in early summer and over a short period. Calves gain approximately 1-2 kg/day; thus, those that have a longer growing season go into winter larger and in better physical condition, perhaps influencing survival (Cook et al. 1996).

The objectives of this study are to determine elk calf mortality rates and causes of mortality and how elk density, calf condition, habitat, and abundance of alternate prey may influence calf mortality in north-central Idaho. We recognize that factors responsible for lower average recruitment rates in some north-central Idaho GMUs may be different than factors responsible for declining trends in these GMUs. Thus, there are 2 sets of questions, 1 addressing variation among averages across geographic boundaries and the other addressing variation among years, or trends, within geographic boundaries. It is also important to define a time scale and we are interested in averages and trends over periods of 5-20 years.

STUDY AREAS AND METHODS

We are investigating calf survival and causes of mortality in 2 contrasting study areas to identify factors associated with declining and low elk recruitment compared to areas with stable and moderate-to-high recruitment. The North Fork/Lochsa study area includes the south-central portion of GMU 10, which is the North Fork Clearwater River drainage, and the north-central portion of GMU 12, which is the Lochsa River drainage. The area is bounded on the south by U.S. Highway 12 and the Lochsa River, on the west by U.S. Forest Service roads 101 and 500 up to Hemlock Butte, on the north by the North Fork Clearwater River, and on the east by

Toboggan Ridge Road (U.S. Forest Service road 581). The study area is entirely within the Clearwater National Forest.

Calf:cow ratios are low in GMUs 10 and 12 and have been declining since the early 1990s. The most recent aerial surveys show calf:cow ratios between 5 and 15 calves:100 cows. Elk density has also declined and recent aerial surveys show cow elk densities of approximately 0.8-1.2/km^2. Bull:cow ratios have averaged approximately 18 in recent years. We suspect alternate prey (deer [*Odocoilius virginianus*, *O. hemonius]*) abundance to be relatively low compared to our other study area. We also suspect that bear densities are moderate to high compared to our other study area and that mountain lion densities are similar to our other study area. Bear harvest has been between 100 and 140 (1.6-2.3 bears harvested/100 km^2) annually since the early 1990s in GMUs 10 and 12. Mountain lion harvest has been between 30 and 54 (0.5-0.9 lions harvested/100 km^2).

The North Fork/Lochsa study area consists of rugged mountainous terrain rising from approximately 425 m to 2,030 m on Castle Butte. Vegetation types range from seral shrubfields created as a result of large historical fires and some small prescribed burns (Leege 1969) to open ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) stands on dry sites, western hemlock (*Tsuga heterophylla*)/western red cedar (*Thuja plicata*)/grand fir (*Abies grandis*) stands on lower and often moist sites, to lodgepole pine (*Pinus contorta*) and Engelmann spruce (*Picea engelmannii*)/subalpine fir (*Abies lasiocarpa*) stands at higher elevations. Because of the rugged nature of the terrain, little timber harvest has occurred. Road access is poor. There are approximately 0.3 km of open road (open to motorized vehicles)/km^2 on the North Fork/Lochsa.

The South Fork study area consists generally of the northern half of GMU 15, which is the South Fork Clearwater drainage. The area is bound on the south by the South Fork Clearwater River and U.S. Highway 14, although it also includes Mill Creek and Johns Creek drainages to the south; on the east by Elk City; on the north by U.S. Forest Service road 464; and on the west by the South Fork Clearwater River and U.S. Highways 13 and 14. The area lies entirely within the Nez Perce National Forest.

Calf:cow ratios are generally stable and have averaged 30-35 since the early 1990s in GMU 15. Elk density is approximately 0.4 cows/km^2. Bull:cow ratios have averaged approximately 15 in recent years. Alternate prey (deer) abundance has been relatively high on the South Fork compared to generally low densities of deer abundance on the North Fork/Lochsa study area. We also suspect that bear densities are low to moderate compared to the North Fork/Lochsa study area and that mountain lion densities are similar to the North Fork/Lochsa study area. Bear harvest has been between 39 and 86 (0.8-1.8 bears harvested/100 km^2) since the early 1990s in GMUs 14, 15, and 16. Mountain lion harvest has been between 21 and 51 in Unit 15 (0.9-2.2 mountain lions harvested/100 km^2).

Topography and terrain is similar to the Lochsa/North Fork, but generally less rugged and more rolling. Similarly, vegetation types on the South Fork are the same as those occurring on the Lochsa/North Fork, but with less seral brushfields and more grassy rangeland types. Evidence of timber harvest is apparent throughout the study area and much of the area has been logged since the early 1900s, producing a patchwork pattern of logged and unlogged sites.

Road access is higher in the South Fork study area, averaging approximately 0.9 km open roads/km^2, principally due to timber harvest operations.

During late May and early June 1997-1999, we searched 1-10 ha (2.5-25 ac) areas around cow elk using a helicopter to locate and capture neonate calves on portions of the Lochsa/North Fork and South Fork study areas (Schlegel 1986). Cows were located primarily by searching the more open habitats - brushfields, clearcuts, meadows, grasslands, and open timber and by locating radio-collared cows that were captured in March 1997 or 1998. Calves were captured by hand, blindfolded, and hobbled. Sex of each captured calf was determined by visual inspection of the genitals.

The age of calves (days) was tentatively estimated by considering a number of characters (Johnson 1951). We categorized: hair moisture, ear dampness, upper canine length, premolar and molar teeth length, navel bloodiness and degree of scabbing, umbilical cord presence, hoof hardening, raggedness of the hooves, hoof staining, hardening of dew claws, and stature and stability of the calf. To also estimate age, we measured front incisor length (mm) protruding through the membrane and navel umbilicus diameter (mm) with calipers. Right front hoof growth (hoof hairline to ridged growth line) (0.1 mm) was measured with calipers to investigate the potential relationship with calf age, as has been done with white-tailed deer fawns (Sams et al. 1996). The importance of each character in estimating calf age was differentially and subjectively weighted. We relied heavily on hardening of the dew claws, bloodiness of the navel, and incisor tooth length. For example, we placed most importance on all 3 characters to indicate the calf was 0-1 day old, but we primarily used incisor tooth length to assign an age within Johnson's (1951) age classes b (2-4 days), c (5-7 days), and d (8 and 8+ days). Other characters were also used to assign a final (tentative) estimated age.

Approximately 35 ml of blood were drawn from the jugular vein for nutritional and condition analyses. Serum trace mineral levels (Fe, Zn, Ca, Mg, Cu, and P) and blood selenium were determined at the University of Idaho Analytical Science Laboratory, Holm Research Center. Serum analysis was conducted at the Forest Wildlife Populations and Research Group, Minnesota Department of Natural Resources. Rectal temperature and heart rate were measured whenever possible. Calf stress was categorized as "very excited and moving around a lot," "moving occasionally," or "generally calm" to help interpret blood parameter values.

Right hind leg length (tip of hoof to proximal end of fibula/tibia to 0.1 cm) and chest girth (just posterior to front legs to 1 cm) were measured with a tape (Schlegel 1986) to obtain 2 indices of body size. Calf weight (nearest 0.45 kg) was measured using a Pesola scale and day 1 weight was predicted using calf growth rates of both Johnson (1951) and Smith et al. (1997). Each calf was eartagged and fitted with an expandable, drop-off, motion-sensitive, 4-hr delay ("mortality") radio collar (Schlegel 1986). Behavioral reactions of the cow associated with each calf and reaction of the calf to helicopter chase were categorized, as were reactions by the cow during calf processing and after calf release. Time each calf was captured, time blood was drawn, time released, location, and cover type were also recorded. We attempted to relocate radio-collared calves later during the day of capture or the following day and visually search for an associated cow to provide evidence on the likelihood of abandonment due to capture activities.

Radio-collared calves were monitored daily from the day of capture until the end of capture operations in mid-June using a helicopter. Thereafter, we used a fixed-wing aircraft to both monitor radio status and to radio locate calves daily though early July. During the rest of July, August, and into September, we monitored calves 2-3 times/week. After September, we monitored calves approximately 1-3 times/month.

We walked in on calves upon detecting radio collars on "mortality" mode. We immediately made a preliminary site and calf carcass inspection during the period we were monitoring (and capturing) calves using a helicopter. Later that day or the next we then completed a full site inspection and field necropsy. During the period we used a fixed-wing aircraft to monitor and locate calves, we attempted to reach the calf carcass within a day of detecting a collar on mortality mode and conduct a full site inspection and field necropsy.

We inspected calf mortality sites and performed field necropsies to determining cause and conditions of death by following a detailed protocol (Gratson et al. 1997). Field personnel were provided site inspection and field necropsy training. Dead calves that were essentially whole (not extensively fed upon by predators or scavengers) were taken to the Washington Animal Disease Diagnostic Laboratory at Washington State University for complete necropsy and histopathology, pathology, parasitology, virology, and bacteriology investigations.

We recorded bear sightings as we searched for calves from a helicopter to obtain a crude index of relative bear abundance in relation to effort (bears sighted/hour flying) in calving habitats on the 2 study areas. Location, number of bears in group, and color phase (black, brown, cinnamon, blond) and age class (adult, yearling, cub) of each individual were recorded (Schlegel 1986).

We also conducted black bear scent station surveys on both study areas from early July to mid-August to provide an index of relative bear abundance (Rohlman 1986, Beecham and Rohlman 1994) and, potentially, a population estimate based on mark-recapture methodology using tetracycline-laced baits (Garshelis and Visser 1997). All possible 8-km routes (open roads, closed roads [closed to motorized travel], and U.S. Forest Service trails >8-km long) were first identified throughout the 2 study areas. A random sample of these routes (>60%) on each area was selected and a bacon bait was hung at 1.6 km intervals along routes (5 stations/route). The bait station consisted of 0.45 kg of bacon fat laced with 4500 mg tetracycline hung approximately 2.4 m above ground on a >20 cm dbh tree. Anise oil was used at the bait station as an additional attractant. In 1999, unlike in 1997 and 1998, we did not use 4-point barbed wire around the bole of bait trees in an effort to collect hair from bear visiting the bait. Instead, we placed 4-point barbed wire approximately 1 m above the ground around the perimeter of bait trees (1-5 m away) to snag bear hair. Bear hair and claw marks on the bait tree helped verify visitation by bears. Bait stations were revisited 20 days after bait placement to determine bait status and visitation. Bear hair on perimeter wire was collected for DNA identification to evaluate assumptions of mark-recapture estimation. The proportion of stations and routes visited by bears served as indices of the bear population, similar to the sardine bait station index used throughout Idaho (Rohlman 1986).

In 1999 the main study areas were each split into 2 areas (North Fork/Lochsa into North Fork and Lochsa; South Fork into North Side South Fork and South Side South Fork) for calf capture and monitoring to facilitate an experimental evaluation of the effects of predator densities on calf survival that will begin in fall 1999. Data from these 1999 captured calves is reported in Job 3.

Because use of Johnson's (1951) aging criteria can result in calf ages with high uncertainty, we are developing an aging technique using known-aged calves from an enclosed elk herd near the Starkey Experimental Forest and Range, LaGrande, OR (J. Cook, National Council for Air and Stream Improvement, unpublished data) and validating the aging model using known-aged calves from an enclosed herd near Moscow, ID. We captured these calves by hand and obtained data similar to those for wild calves. Some calves were captured multiple times between birth and 15 days.

RESULTS AND DISCUSSION

Results from calves captured in May and June 1997-1998 and monitored through mid-August 1997-1998 were reported in Gratson and Zager (1999). From mid-August 1998 through May 1999, we continued to monitor survival and determine proximate causes of death of radio-collared elk calves captured in 1998. Annual survival of calves expressed as a simple percentage was 12% (2/17) on the Lochsa/North Fork and 40% (8/20) on the South Fork, similar to annual survival of 1997 captured calves.

Between mid-August 1998 and May 1999, 1 calf on the Lochsa/North Fork dropped its radio collar, 2 calves on the Lochsa/North Fork and 1 on the South Fork were killed by mountain lions (*Puma concolor*), and 2 calves on the South Fork were harvested during the elk hunting season. Analyses of annual survival rates (Pollock et al. 1989) and the relationship between survival and elk density, calf condition, and alternate prey abundance are in progress.

We captured, radio-collared, and monitored 31 additional neonates on the North Fork/Lochsa and 23 neonates on the South Fork in spring and summer 1999 to facilitate evaluating the effects of predation on calf survival. Preliminary results from 1999 calves are presented in Job 3.

Information on bear observations during calf capture operations, bear population indices using visits to bait stations, and preliminary results of a winter lion survey in the Lochsa/North Fork are also presented in Job 3.

We captured 30 known-aged calves 44 times from a captive elk herd in north-central Idaho to obtain baseline data for assessing wild calf condition and to validate aging criteria. Analyses are in progress.

LITERATURE CITED

Albon, S. D., F. E. Guinness, and T. H. Clutton-Brock. 1983. The influence of climatic variation on the birth weights of Red deer (*Cervus elaphus*). Journal of Zoology 46:295-298.

Becker, E. F. 1991. A terrestrial furbearer estimator based on probability sampling. Journal of Wildlife Management. 55:730-737.

Beecham, J. J. 1998. Black bear. Study I, Job 9. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-170-R-22. Idaho Department of Fish and Game, Boise, Idaho, USA.

Beecham, J. J., and J. Rohlman. 1994. A shadow in the forest: Idaho's black bear. University of Idaho Press, Moscow, Idaho, USA.

Bomar, L., J. M. Scott, E. O. Garton, P. Zager, and M. W. Gratson. 1998. Elk ecology. Study III. Statewide elk data analysis. Job. No. 1. Analysis of statewide elk population and habitat dataset. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-160-R-25. Idaho Department of Fish and Game, Boise, Idaho, USA.

Boyce, M. S. 1989. The Jackson elk herd: intensive wildlife management in North America. Cambridge University Press, New York, New York, USA.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, New York, USA.

Caughley, G., and A. R. E. Sinclair. 1994. Wildlife ecology and management. Blackwell Scientific Publications, Boston, Massachusetts, USA.

Clutton-Brock, T. H., M. Major, S. D. Albon, and F. E. Guinness. 1987. Early development and population dynamics in red deer. I. Density-dependent effects of juvenile survival. Journal of Animal Ecology 56:53-67.

Cook, J. G., L. J. Quinlan, L. L. Irwin, L. D. Bryant, R. A. Riggs, and J. W. Thomas. 1996. Nutrition-growth relations of elk calves during late summer and fall. Journal of Wildlife Management 60:528-541.

Coughenour, M. B., and F. J. Singer. 1996. Elk population processes in Yellowstone National Park under the policy of natural regulation. Ecological Applications 6:573-593.

DelGiudice, G. D., F. J. Singer, and U. S. Seal. 1991. Physiological assessment of winter nutritional deprivation in elk of Yellowstone National Park. Journal of Wildlife Management 55:653-664.

Errington, P. L. 1934. Vulnerability of bobwhite populations to predation. Ecology 15:110-127.

Freddy, D. J. 1995. Estimating survival rates of elk and developing techniques to estimate population size. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-153-W-9. Colorado Division of Wildlife, Fort Collins, Colorado, USA.

Garshelis, D. L., and L. G. Visser. 1997. Enumerating megapopulations of wild bears with an ingested biomarker. Journal of Wildlife Management 61:466-480.

Gasaway, W. C., R. O. Stephenson, J. L. Davis, P. E. K. Shephard, and O. E. Burris. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monograph 84.

Gratson, M. W., and B. K. Johnson. 1995. Managing harvest for sustainable ungulate populations. The Wildlife Society, Second Annual Conference, Portland, Oregon, USA. (abstract).

Gratson, M. W., and P. Zager. 1994. Lochsa elk ecology. Study II. Optimum yield of elk. Job 1. The effect of harvest on elk population size and composition in Idaho. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-160-R-21. Idaho Department of Fish and Game, Boise, Idaho, USA.

Gratson, M. W. and P. Zager. 1997. Elk productivity and recruitment in Idaho: study plan. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-160-R-24. Idaho Department of Fish and Game, Boise, Idaho, USA.

Gratson, M. W., C. Whitman, and P. Zager. 1997. Elk ecology. Study I. Road closures and bull elk mortality. Job 2. The effects of road closures on elk mortality in north-central Idaho. Job Completion Report, Project W-160-R-23. Idaho Department of Fish and Game, Boise, Idaho, USA.

Hobbs, N. T., and T. A. Hanley. 1990. Habitat evaluation: do use/availability data reflect carrying capacity? Journal of Wildlife Management 54:515-522.

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

Holling, C. S. 1959. Some characteristics of simple types of predation and parasitism. Canadian Entomology 91:385-398.

Hornocker, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildlife Monograph 21.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, Inc., New York, New York, USA.
Houston, D. B. 1982. The northern Yellowstone elk herd: ecology and management. Macmillan Publishing Company, Inc., New York, New York, USA.

Johnson, D. E. 1951. Biology of the elk calf, *Cervus elaphus nelsoni*. Journal of Wildlife Management 15:396-410.

Leege, T. A. 1968. Prescribed burning for elk in northern Idaho. Proceedings Annual Tall Timbers Fire Ecology Conference 7:235-253.

__________. 1969. Burning seral brush ranges for big game in northern Idaho. North American Wildlife and Natural Resources Conference 34:429-438.

__________, and W. O. Hickey. 1977. Elk - snow - habitat relationships in the Pete King drainage, Idaho. Wildlife Bulletin No. 6., Idaho Department of Fish and Game, Boise, Idaho, USA.

Leptich, D. J., S. G. Hayes, E. O. Garton, and P. Zager. In review. Elk mortality in the Coeur d'Alene drainage of northern Idaho. Journal of Wildlife Management 00:000-000.

Mech, L. D. 1977. Wolf-pack buffer zones as prey reservoirs. Science 198:320-321.

Merrill, E. H., and M. S. Boyce. 1991. Summer range and elk population dynamics in Yellowstone National Park. Pages 263-273 in R. B. Keiter and M. S. Boyce (eds.), The Greater Yellowstone Ecosystem: redefining America's wilderness heritage. Yale University Press, New Haven, Connecticut, USA.

Mitchell, B., and J. M. Crisp. 1981. Some properties of red deer (*Cervus elaphus*) at exceptionally high population density in Scotland. Journal of Zoology 193:157-169.

Murdoch, W. W. 1969. Switching in general predators: experiments on predator specificity and stability of prey populations. Ecological Monograph 39:335-354.

Myers, W. L., B. Lyndecker, W. Moore, and P. E. Fowler. 1996. Investigations of calf elk mortalities in southeast Washington: a progress report 1992-1995. Washington Department of Wildlife, Olympia, Washington, USA. (unpubl. rep.).

Noyes, J. H., B. K. Johnson, L. D. Bryant, S. L. Finholt, and J. W. Thomas. 1996. Effects of bull age on conception dates and pregnancy rates of cow elk. Journal of Wildlife Management 60:508-517.

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

Roberts, M. W., and J. L. Wolfe. 1974. Social influences on susceptibility to predation in cotton rats. Journal of Mammalogy 55:869-872.

Rohlman, J. 1986. Black bear scent station index. Federal Aid in Wildlife Restoration, Job Completion Report, Project W-160-R. Idaho Department of Fish and Game, Boise, Idaho, USA.

Sams, M. G., R. L. Lochmiller, E. C. Hellgren, W. D. Warde, and L. W. Varner. 1996. Morphometric predictors of neonatal age for white-tailed deer. Wildlife Society Bulletin 24:53-57.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in north-central Idaho. Journal of Wildlife Management 51:622-630.

Schlegel, M. 1986. Movements and population dynamics of the Lochsa elk herd. Study I, Job 3. Factors affecting calf elk survival in the Lochsa elk herd. Federal Aid in Wildlife Restoration, Job Completion Report, Project. W-160-R. Idaho Department of Fish and Game, Boise, Idaho, USA.

Singer, F. J., K. S. Symonds, and B. Berger. 1992. Predation of Yellowstone elk calves. Park Science 13:18.

Smith, B. L., and S. H. Anderson. 1996. Patterns of neonatal mortality of elk in northwest Wyoming. Canadian Journal of Zoology 74:1229-1237.

Thomas, J. W. 1991. Elk vulnerability - a conference perspective. Pages 318-319 in A. G. Christensen, L. J. Lyon, and T. N. Lonner, eds. Proceedings of Elk Vulnerability Symposium. Montana State University, Bozeman, Montana, USA.

Thorne, T. E., R. E. Dean, and W. G. Hepworth. 1976. Nutrition during gestation in relation to successful reproduction in elk. Journal of Wildlife Management 40:330-335.

Unsworth, J. W., L. Kuck, M. D. Scott, and E. O. Garton. 1993. Elk mortality in the Clearwater drainage of north-central Idaho. Journal of Wildlife Management 57:495-502.

__________, F. A. Leban, D. J. Leptich, E. O. Garton, and P. Zager. 1994. Aerial survey: user's manual with practical tips for designing and conducting aerial big game surveys. Second edition., Idaho Department of Fish and Game, Boise, Idaho, USA.

Van Sickle, W. D., and F. G. Lindzey. 1991. Evaluation of a cougar population estimator based on probability sampling. Journal of Wildlife Management 55:738-743.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Zager, P., and M. W. Gratson. 1998. Lochsa elk ecology. Study IV. Factors influencing elk calf recruitment. Job 1. Pregnancy rates and condition of cow elk. Federal Aid in Wildlife Restoration, Job Progress Report, Project W-160-R-24. Idaho Department of Fish and Game, Boise, Idaho, USA.

APPENDIX A.

EVALUATING CONDITION INDICATORS IN ROCKY MOUNTAIN ELK

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INTRODUCTION

Productivity and recruitment in many elk populations are now declining, particularly in Idaho, southeastern Washington, and Oregon. In eastern Oregon and southeastern Washington, an area that supports about 70,000 elk, late-winter calf:cow ratios have declined from about 60-65 calves:100 cows in the 1950s to 25-30 during the 1990s. These ratios have ranged as low as 10-15 during the last several years in several game management units, and there is no indication that the decline has stabilized (Schommer 1991). Similar declines are occurring in some herds in Idaho as well. Over thirty percent of the game management units in Idaho show calf:cow ratios below 30 calves:100 cows (Idaho Fish and Game files).

In addition to declining calf:cow ratios, several herds in Washington are declining. During the last 10 years, herds in the Blue Mountains and the Olympic Mountains have declined by 30%, while the Nooksack herd has experienced a 70% decline. In addition, pregnancy rates in adult cows in these herds are well below an expected level for wild ungulate populations. Idaho reports a 72% pregnancy rate for the Lochsa herd in 1997 (Gratson and Zager 1998) and Washington and Oregon have pregnancy rates ranging from 45% to 90% (Washington Department of Fish and Game). These declining trends pose a concern from not only an ecological standpoint but from an economic one as well. For example, from 1976-1990, elk hunter recreation days declined over 200%, and associated lost revenues to rural communities in northeast Oregon alone was estimated at $4.5 million each year, a combined loss of about $40 million over the 15-year period (Schommer 1991). The declines in productivity are contributing to substantial budgetary shortfalls of game departments in several western states.

Biologists have insufficient data from which to reliably deduce the extent or potential causes of these declines. It has been hypothesized that nutrition is an important factor. Research on ruminant stock in captive settings has clearly established the role of nutrition on reproductive performance, but determining the effects of nutrition of wild herds is difficult. One reason for this is that techniques necessary for practical, reliable, and cost-effective monitoring of condition and nutritional status of elk herds is limited. Many vegetation-based methods are difficult and expensive to implement in a manner that has relevance to free-ranging herds, and many animal-based methods (e.g., serum and urine chemistry, various fat indices) are not particularly accurate, practical, and/or adequately tested (Harder and Kirkpatrick 1994). In addition, very little work has been done in large ungulate research assessing the role of nutrition and condition on reproductive performance. Without the appropriate technology and data on relations between nutrition, herd dynamics, and reproductive physiology, it is not surprising that management agencies typically ignore nutrition because its effects are subtle, multifaceted, and complicated and, therefore, often remain unnoticed (Cook et al. 1996).

This study was designed to evaluate the precision and accuracy of various condition indicators as predictors of fat, protein, and total gross energy content of the animals carcass.

This study is funded by Idaho Fish and Game, United States Forest Service, Oregon Department of Fish and Game, Rocky Mountain Elk Foundation, National Council for Air and Stream Improvement, and the University of Idaho.

Background Information

To date wildlife biologists have used several approaches to determine the condition of ungulates. These include serum/urine indices, marrow and kidney fat indices, body weight, body composition, and visual evaluation of the carcass. In addition to these the livestock industry relies heavily on body condition scoring systems and ultrasound to make many management decisions for their intense production systems (Edmonson et al. 1989, Wright and Russel 1984, Wildman et al. 1982).

It is apparent that research on condition indicators of elk has been lacking. Garrott et al. (1997); Vagnoni et al. (1996); Garrott (1996); DelGuidice et al. (1991a), (1991b); Wolfe et al. (1982); Pederson and Pederson (1975); Vaughn et al. (1973); Knight (1969); Herin (1968); Weber et al. (1972); and Follis (1972) comprise all the published literature on serum and urine chemistry of elk. Much of the work is old, not validated, or conducted using limited experimental designs. Although Oregon Department of Fish and Wildlife has developed an extensive data set for kidney fat levels, very little work has been conducted to validate the kidney fat index and various marrow fat indices for elk. And no work has been done on elk for body composition or visual evaluation of the carcass. Body condition scoring systems are making their way into caribou (Gerhart et al. 1996) and moose (Hundertmark et al. 1997; Franzmann 1977) research, but, again, nothing has been undertaken for elk.

Though most approaches that have been developed and used for evaluation of nutrition and nutritional condition in ungulates will be assessed in this study (See Table 1), three techniques will be emphasized because they allow for sampling of live and, at least under certain conditions, dead animals. These are a body condition scoring system (BCS), ultrasound, and serum/urine chemistry. Although the primary goal is to determine live animal techniques, the dead animal techniques listed in Table 1 will be evaluated as well, since the data collection by management agencies this point has been on the dead animal. For the biologist to interpret any of that past data, evaluation of these techniques is critical as well.

OBJECTIVES

The purpose of this study is to provide validated animal-based techniques that will enhance the ability of managers and researchers to monitor and track nutrition and condition of elk. This work will emphasize techniques that:

1. Are useful for assessing nutritional condition, rather than just short-term nutritional status.
2. Are practical and reliable for routine applications by managers and adequately sensitive to be used in research settings.
3. Can be used on live and dead animals.

METHODS

This study was implemented using captive elk facilities located at Kamela, Oregon. The Kamela site (Cook et al. 1996b) consists of 20 pens ranging from 0.1 to 2 acres in size. Each pen has facilities for individualized feeding, weighing, and collecting physiological samples including urine collection. Also, parts of the study were conducted at Oregon State University and at the University of California in Davis.

Data collection began in autumn 1998 and was completed in March 1999, with 3 primary periods of data collection being mid-September, December, and March. These periods were selected to coincide with time periods in which management agencies are likely to obtain hunter-killed samples and/or periods when nutritional stress in free-ranging animals is most likely a relevant issue.

Forty-three captive-raised cow elk were available for this study: 17 yearlings; 19, 2-3 year-olds; and 7 older animals. Beginning in mid-summer 1998, these cows were separated into 3 groups, for each period of the study. Each group was again separated approximately 2½ months prior to the data collection period into 3 nutrition treatments, such that animals in poor, moderate, and good nutritional condition were available for the study. At the time of each data collection period, a urine sample was collected three days prior to processing the animal, and BCS, ultrasound, live animal morphometric measurements, and a serum sample was collected the next day (Table 1). The animals were then transported to the meat processing facility at Oregon State University in Corvallis where they were euthanized, processed, and all dead animal measurements taken. Half carcasses were frozen in ODFW freezer facilities located near Corvallis. In addition, 6 wild elk captured from the Starkey Experimental Station and Ladd Marsh were used in the analysis. These animals were captured in mid-February and processed at Starkey. All measurements were taken on the day of processing. Half carcasses were frozen until they could be transported to UC Davis.

Euthanasia was required to provide an accurate and unbiased estimate of the amount of energy (i.e., nutritional condition) contained within the animal's body. Unbiased estimates of total energy of the body are obtained by homogenizing the carcass and sampling the homogenized tissue to determine water, fat, protein, and ash content. These protocols are time consuming, expensive, and impractical for management and many research applications, but were required to assess the precision and accuracy of the condition indicators (Robbins 1993). Numerous examples of these procedures exist (Gerhardt et al. 1996, Stephensen 1995, Watkins et al. 1991, DelGiudice et al. 1990, Hout and Picard 1988, Adamczewski et al. 1987). Half of the carcass was frozen in ODFW freezers located at Corvallis and then shipped to UC Davis where it was homogenized in a whole body grinder and samples were taken for chemical analysis. The other half of the carcass was used to assess mandibular and femur marrow fat, and numerous dead animal morphometric measurements (Table 1).

Estimates of total gross energy content, fat, and protein will be compared statistically to each of the various condition indices using bivariate and multivariate analyses. Effects of season and age will be included as covariates in this analysis to assess and account for these potentially confounding factors.

RESULTS AND DISCUSSION

Although not all data are in hand (serum and urine results are incomplete), some preliminary results can be discussed. We will emphasize 6 techniques in the following paragraphs. It should be noted that the preliminary analysis on these techniques is straight regression. The effects of age, season, and body mass have not been incorporated into the analysis at this time.

<u>Live Animal Measurements</u>

Body Condition Scoring and Ultrasound

Body condition scoring (BCS) involves palpation of selected areas of the body (withers, ribs, and rump) to determine relative fatness. Although somewhat subjective, BCS has been developed in the livestock industry and is used routinely in animal husbandry and livestock research (Edmonson et al. 1989; Wright and Russel 1984; Wildman et al. 1982; Jeffries et al. 1961). The approach has been largely ignored in the big game literature, but recently Gerhart et al. (1996) published an evaluation of a scoring system for caribou. Cook et al. (unpubl. data) modified Gerhart's BCS for elk in an attempt for greater objectivity, and have been using it for monitoring condition of elk cows and calves since autumn 1996. In addition to BCS, recent evaluations using ultrasound to measure fat in moose (Stephensen 1995) and caribou (Adamczewski et al. 1987) have produced promising results. Stephenson's methods were adapted to elk and ultrasound measurements were taken on cow elk in this study as well.

Initial results for both techniques are promising (the modified BCS was used in this project). Figure 1 shows data across all seasons for both BCS and the ultrasound measurement of maximum fat depth. Both techniques seem to predict total fat fairly accurately (r^2 = 0.88 and 0.92). Although the data on the graph are fitted to a straight line, it is apparent that the ultrasound data has a somewhat curvilinear relationship to total fat. Below approximately 5% body fat, animals have utilized most of the rump fat except for a very thin layer. Thus, a wide range of conditions can still exist without any evidence of rump fat. Due to this curvilinear relationship, we experimented with other ultrasound measurements (mainly muscle groups) that may be useful in this lower range of condition once an animal begins to catabolize muscle tissue. These measurements include two scapula measurements, a loin measurement between the 12^{th} and 13^{th} ribs, and a gluteus maximus muscle. These data have not yet been rigorously analyzed.

The same curvilinear relationship seems to exist with BCS as well. Part of this problem is how the system is scaled. There are 3 areas of emphasis that are scored: ribs, withers, rump. The Cook et al. modified BCS system was initially scaled such that animals in excellent condition never attained a maximum score on the ribs or withers. We are in the process of rescaling this scoring system to utilize the entire scale for all 3 measurements. Not only does this spread out the upper end of the scale, it has the same effect on the lower end, thereby alleviating the curvilinear problem.

Dead Animal Measurements

Though most of the data have not been rigorously analyzed for effects of age and season, 4 of the dead animals measurements attained are worth noting.

Kidney Fat Index

The most popular technique being used by management agencies is the kidney fat index (KFI). This method follows that described by Rhiney (1955). For this study the Rhiney method was evaluated, as well as using the entire perirenal fat mass to determine the kidney fat index (“full”). Figure 2 shows the relationship for this “full” technique. In addition, Anderson et al. (1990) suggested only using the weight of the perirenal fat mass to try and alleviate the seasonal effect found with KFI. This does not incorporate the weight of the kidney at all into the equation. Figure 2 shows the relationship for this technique as well. An interesting point to note graphically is the difference in spread of points between the 2year-olds versus the yearlings and adults.

Percent Marrow Fat

Another popular technique is to obtain percent marrow fat from both the femur and mandible. This study evaluated both techniques by using the oven dry method as described by Neiland (1970).

Figure 3 shows the relationship between femur marrow fat and total percent fat. The line shown on the current graph is drawn by hand. Nevertheless, the relationship is obviously curvilinear, as has been reported in other studies (Watkins et al. 1991). Due to the extreme nature of this curve, femur fat greater than 85% (approximately) or 6% total fat will not give a true indication of an animal’s condition. Unfortunately we had only 3 points below 70% femur fat (2 adults and

1 yearling), but it seems that even in that region accurately assessing an animal's condition is still difficult. Very small changes in percent fat result in very large differences in percent femur fat.

It may be difficult for mangers to obtain a femur sample, so we also looked at mandible fat and its relationship to both femur fat and total fat. In other publications focusing on hunter kill or depredated animals (Ballard et al. 1981, Cederlund et al. 1986, Okarma 1989), there is a strong linear relationship between the 2 marrow fats. This would suggest that the curve for mandible fat would be curvilinear as well. After all the data was evaluated and every animal was grouped into 1 graph, no relationship was found. To understand the lack of relationship, we did 2 things. Results were graphed according to age, which is shown in Figure 4. The yearling relationship begins to take the expected curvilinear response. The adult data are much closer to what would be expected though there are not enough points to know the exact shape of the curve. The interesting graph is for the 2-year-olds. As mentioned above, the 2-year-old kidney fat data is more skewed than either of the other age groups. The same phenomenon exists for the mandible marrow fat data. There is no relationship apparent for 2-year-olds. The first explanation for this may have been how fast we had to bring the animal's condition down. Many of the 2-year-olds were in excellent condition at the start of the study and needed to be brought down in condition very quickly. But that explanation does not seem plausible because the animals in the high nutrition group (who did not lost weight) are just as skewed as animals that were forced to lose weight. The next step was to assess the drying technique. For 20 samples both the oven dry method and ether extract were used to determine fat. Although only one-third of the results are back, they do not suggest a problem with the drying technique. It seems as if mandible marrow may contain a higher percentage of nonfat residue than femur fat (Neiland 1970) which would give different results among methods, but this nonfat residue seems fairly consistent (approximately 8.5% ± 1.5%) across ages and conditions. This will be confirmed upon receiving all the results. If this remains constant, this would only shift data points to the left, not change the relationship. As it stands now, it appears that 2-year-olds may be in a transitional stage where many of these condition indicators will not work. If this is the case, classifying 2- or 2½-year-olds as adults in some data sets may be misleading.

Kistner Score

Though not used as frequently due to the multifaceted scoring system, the Kistner score (Kistner et al. 1980) was evaluated and faired quite well. This system was designed for deer and involves evaluation of the heart, pericardium, kidneys, omentum, brisket, rump, and a muscle score that scores in 5 unit increments. Figure 5 shows the relationship between the original Kistner Score and total percent fat. The $r^2 = 0.84$, but this system only allows scores to 100. This causes a cluster in the upper end of the scale. The reasoning for this is that elk seem to carry more internal fat than deer, especially on the heart. By scoring strictly according to the system, many elk had heart scores well above what would be expected for their condition. Low condition animals received the maximum score in some instances. To alleviate this problem we attempted to modify the scoring system. The bottom graph on Figure 5 shows the relationship between a modified Kistner score and total fat. The r^2 is improved slightly, but, more importantly, the data values are spread out more. Modifications were 2–fold: scores were evaluated in 1 unit increments rather than 5 units, and the maximum score for the heart was increased. In other words, 15 is the maximum heart score in the original scoring system. Since elk carry more fat, the maximum heart score was increased to 25 to accurately assess the heart. This will be rescaled to contain only scores 0-15 at a later date.

This scoring system is probably not very applicable in management situations due to the number of parts that need to be evaluated. As a whole, if every part is accessible, it fairs quite well at predicting animal condition. The next step will be to evaluate the system in parts. It may be that only two or three items would need to be scored to retain the high predictability of the whole system. Reducing the multiple parts would make it more practical in a management setting.

“Insertion” Technique

The “insertion technique” is very similar to the ultrasound rump fat measurement. Though feasible in some field situations, ultrasound machines may not be practical in other areas. Not only are they expensive, they are heavy (30-40 pounds with battery). Unfortunately, of all the techniques assessed, ultrasound predicts animal condition most accurately. Therefore, I tried to design a technique that would give the same information as the ultrasound machine without the expense and weight.

To obtain a rump fat measurement, 2 different areas are measured. These are referred to as the mid and max fat measurements. How to exactly obtain these measurements will be omitted at this point, but it is worth noting that the mid measurement can be found with only a tape measure. The max is obtained by moving the ultrasound probe posterior from the midpoint until the maximum fat depth is found visually. Without the machine, this measurement cannot be taken because this position varies from animal to animal.

Since the ultrasound machine is not required to obtain the mid measurement, I used a scalpel and sliced a slit about ½ in. long in the mid position. The slice only goes through the hide (about ½ cm). Once fat is visible, I quit slicing. I obtained a hide thickness using a special biopsy needle and calipers. I then slowly inserted the biopsy needle through the fat. Between the fat layer and the first muscle layer is a thin sheet of fascia that is tougher than fat and muscle. By *gently* inserting the needle, it is apparent when the needle hits this fascia layer due to a greater resistance. This distance is measured by calipers and is equivalent to the mid fat ultrasound measurement. To take it a step further, I attempted to find the max point since it more accurately predicts condition. I arbitrarily tried several distances from the mid position and found that 2½ inches posterior from the mid point most closely replicates the maximum measurement. Figure 6 shows the relationship between this second location and the ultrasound measurement. In all cases the difference is only a few millimeters. Though this technique may be tedious, it is cheap, involves very little equipment, and it could be done on both live and dead animals.

MANAGEMENT IMPLICATIONS

Clearly, there is a considerable need for practical techniques of proven reliability that managers can use for routine monitoring and research. Such techniques could be used to establish long-term trends of herd nutrition and condition that might help managers deduce causes of changes in population demographics. These techniques would be valuable to assess the results of adaptive management experiments that are intended to provide solutions to problems with declining productivity. For example, the data generated from this study will be used for ongoing studies initiated by Idaho, Oregon, and Washington to assess declining productivity in their respective states. Elk biologists in these 3 states are currently using some of the techniques mentioned above in their studies. Once these techniques are validated, managers will be provided with more accurate condition information on their herds.

LITERATURE CITED

Adamczewski, J. 1993. Indices of body condition and nutritional status. Pages 177-186. in J. Brad Stelfox (ed.). Hoofed Mammals of Alberta. Alberta, Canada.

Adamczewski, J. Z., C. C Gates, and R. J. Hudson. 1987. Fat distribution and indices of carcass composition in Coats Island caribou. Canadian Journal of Zoology 65:368-374.

Anderson, A. E., D. C. Bowden, and D. E. Medin. 1990. Indexing the annual fat cycle in a mule deer population. Journal of Wildlife Management 54:550:556.

Ballard, W. B., C. L. Gardner, and J. H. Westlund. 1981. Use of mandible versus long-bone to evaluate percent marrow fat in moose and caribou. Proceedings of the North American Moose Conference Workshop 17:147-164.

Cederlund, G. N., R. J. Bergstrom, F. V. Stalfelt, and K. Danell. 1986. Variability in mandible marrow fat in three moose populations in Sweden. Journal of Wildlife Management 50:719-726.

Cook, J. G., R. A. Riggs, A. R. Tiedemann, L. L. Irwin, and L. D. Bryant. 1996a. Large herbivore-vegetative feedback relations in the Blue Mountains Ecoregion. Pages 155-159 in W. D. Edge and S. L. Olson- Edge (eds.), Proc. symp. sustaining rangelands ecosystems. Oregon State Univ., SR953, Corvallis, OR. 213 pp.

Cook, J. G., L. J. Quinlan, L. L. Irwin, L. D. Bryant, R. A. Riggs, and J. W. Thomas. 1996b. Nutrition-growth relations of elk calves during late summer and fall. Journal of Wildlife Management 60:528-541.

DelGuidice, G. D., L. D. Mech, and U. S. Seal. 1990. Effects of winter undernutrition on body composition and physiological profiles of white-tailed deer. Journal of Wildlife Management 54:539-550.

DelGuidice, G. D., J. S. Francis, and U. S Seal. 1991a. Physiological assessment of winter nutritional deprivation in elk of Yellowstone National Park. Journal of Wildlife Management 55:653-664.

DelGuidice, G. D., U. S Seal, and L. D. Mech. 1991b. Indicators of severe undernutrition in urine of free-ranging elk during winter. Wildlife Society Bulletin19:106-110.

Edmonson, A. J., I. J. Lean, L. D. Weaver, T. Farver, and G. Webster. 1989. A body condition scoring chart for Holstein dairy cows. Journal of Dairy Science 72:68-78.

Franzmann, A. W. 1977. Condition assessment of Alaskan moose. Proceedings of the North American Moose. Conference13:119-127.

Garrott, R. A., R. G. White, D. B. Vagnoni, and D. M. Heisey. 1996. Purine derivative concentrations in snow-urine samples as a dietary index for free-ranging elk. Journal of Wildlife Management 60:735-743.

Garrott, R. A., J. G. Cook, J. G. Berardinelli, P. J. White, S. Cherry, and D. B. Vagnoni. 1997. Evaluation of the urinary allantoin:creatinine ratio as a nutrition index for elk. Canadian Journal of Zoology 75:1519-1525.

Gerhart, K. L., R. G. White, R. D. Cameron, and D. E. Russell. 1996. Body composition and nutrient reserves of arctic caribou. Canadian Journal of Zoology 74:136-146.

Harder, J. D., and R. L. Kirkpatrick. 1994. Physiological methods in wildlife research. Pages 275-306 in T. A. Bookhout (ed.), Research and management techniques for wildlife and habitats, fifth ed. The Wildlife Society, Bethesda, Maryland. 740 pp.

Herin, R. A. 1968. Physiological studies of Rocky Mountain elk. Journal of Mammalogy 49:762-764.

Hundertmark, K. J., C. C. Swartz, and T. R. Stephson. 1997. Estimation of body composition in moose. Federal Aid in Wildlife Restoration. Study 1.42. Alaska Department of Fish and Game.

Huot, J., and G. Picard. 1988. A simplified method for assessment of caribou body composition. Journal Wildlife Management 52:606-609.

Jeffries, B. C. 1961. Body condition scoring and its use in management. Tasmania Journal of Agriculture 32:19-21.

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.

Knight, R. R. 1969. Some chemical characteristics of elk blood. Bulletin for Wildlife Disease Association 5:8-10.

Neiland, K. A. 1970. Weight of dried marrow as indicator of fat in caribou femurs. Journal of Wildlife Management 34:904-907.

Okarma, H. 1989. Mandible versus long bone marrow fat in red deer. Acta Theriologica 9:537-544.

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

Rhiney, T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*) with special reference to New Zealand. New Zealand Journal of Science and Technology 36:429-463.

Schommer, T. 1991a. Analysis of big game statistics 1965-1990. Wallowa-Whitman National Forest. Part II: Deer. U.S. Forest Service, Wallowa-Whitman National Forest, Baker City, OR. 59 pp.

Schommer, T. 1991b. Analysis of big game statistics: 1965-1990. Wallowa-Whitman National Forest. U.S. Forest Service, Wallowa-Whitman National. Forest, Baker City, OR. 40 pp.

Stephensen, T. R. 1995. Nutritional ecology of moose and vegetation succession on the Copper River Delta, Alaska. M.S. Thesis, University of Idaho, Moscow.

Vagnoni, D. B., R. A. Garrott, J. G. Cook, and P. J. White. 1996. Use of urinary allantoin:creatinine ratios as an index of digestible dry matter intake in captive elk. Journal of Wildlife Management 73:427-432.

Vaughn, H. W., R. R. Knight, and F. W. Frank. 1973. A study of reproduction, disease, and physiological blood and serum values in Idaho elk. Journal of Wildlife Disease 10:293-301.

Watkins, B. E., J. H. Witham, D. E. Ullrey, D. J. Watkins, and J. M. Jones. 1991. Body composition and condition evaluation of white-tailed deer fawns. Journal of Wildlife Management 55:39-51.

Weber, Y. B., and M. L. Bliss. 1972. Blood chemistry of Roosevelt elk (*Cervus canadensis roosevelt)*. Comparative Biochemical Physiology 43:649-653.

Wildman, E. E., G. M. Jones, D. E. Wagner, R. L. Boman, H. F. Troutt Jr., and T. N. Lesch. 1982. A dairy cow BCS system and its relationship to selected production characteristics. Journal of Dairy Science 65:495-501.

Wright, I. A., and A. F. Russell. 1984. Partition of fat, body composition and body condition score in mature cows. Animal Production 38:23-32.

TABLE 1: A SUMMARY OF CONDITION INDICES (based on information from Adamczewski 1993, DelGiudice 1995, Saltz et al. 1995, Kucera 1997, and other sources).

Index/Measurement	Definition	Advantages	Disadvantages
Live animal measurements			
-Body conditioning score (BCS)	-scoring body condition visually or by palpation of fat deposits	-can be applied to the live animal -easy to use	-subjective -high variation
-Ultrasound	-use of real time ultrasound to measure of backfat between the 12th and 13th rib, at the tailhead, and shoulder.	-accurate -easily measured -useful predictor of dissectible fat	-could be impractical in a field situation -not for use in lean animals
-Girth measurement	-length of measurement from directly behind the front shoulder with a cloth tape	-closely correlated to body mass and eviscerated body mass	-may need additional validation
-Hind foot length	-straight length of lower hind limb	-easily measured -good indicator of growth rate	-valid only in growing animals -does not judge condition or nutritional status
-Hip height	-straight distance from tip of hip to tip of hoof	-easily measured -may be indication of energy stores in combination with other indices	-may be variable
-Whole body length	-straight distance from tip of nose to tip of tail or base of tail.	-easily measured -good measure of size -may indicate whole body ash content	-may be variable
-Body reserve index (BRI)	-body mass x BCS	-correlated to condition and productivity	-subjective
Serum and Urine Indices –probably indicator of short term nutritional status (T3, serum urea nitrogen, IGF-2, cortisol, triglycerides, urea nitrogen:creatinine, allantion:creatinine…)			
Organs and Carcass Measurements			
-Body mass	-weight of entire animal	-can be correlated to condition	-gut contents unknown -may be impractical in field situations
-Eviscerated body mass	-weight of animal without gut contents	-measure of size -correlated to condition	-time consuming -hard to measure
-Kidney fat index	-weight of fat on both kidneys x 100, divided by wt. of both kidneys	-easily measured	-can vary widely with season and nutrition

Index/Measurement	Definition	Advantages	Disadvantages
-Kidney fat mass	-total wt. of fat on both kidneys	-easily measured -relatively correlated to total fat over wide ranges of fatness	-kidney fat sometimes hard to identify on fat animals
-Femur and mandibular marrow fat	-proportion of fat in narrow central part of femur	-sensitive measure of fat in lean or starving animals -last fat source to be depleted	-only useful in lean animals
-Backfat	SEE ULATRASOUND IN LIVE ANIMAL MEASUREMENTS		
-Total fat, protein, ash, water	-chemical composition of whole animal	-complete measurement -standard for calibration of indices	-expensive -time consuming -requires whole animal to be ground up
-Kistner Score	-condition score based on appearance of internal subcutaneous fat and musculature	-simple -differentiates well between different classes	-subjective -valid in dead animals
-Lanka and Emmerich Fat Deposition Index	-assessment of body condition from body fat and the condition of the muscle mass	-simple	-subjective -valid in dead animals
-California Deer Condition Index	-condition scoring based on internal subcutaneous fat and rump musculature	-simple	-subjective -valid in dead animals

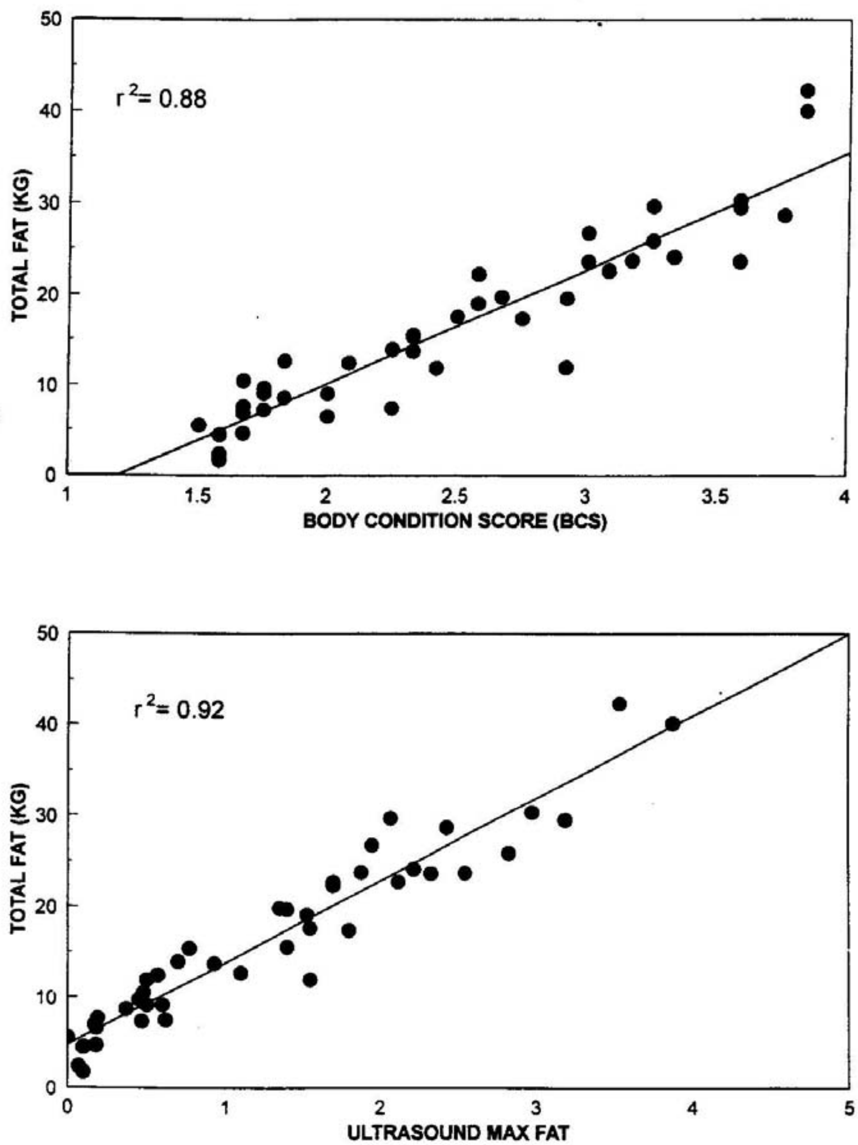

Figure 1. Body conditioning score and ultrasound (rump fat) correlations with total fat (kg).

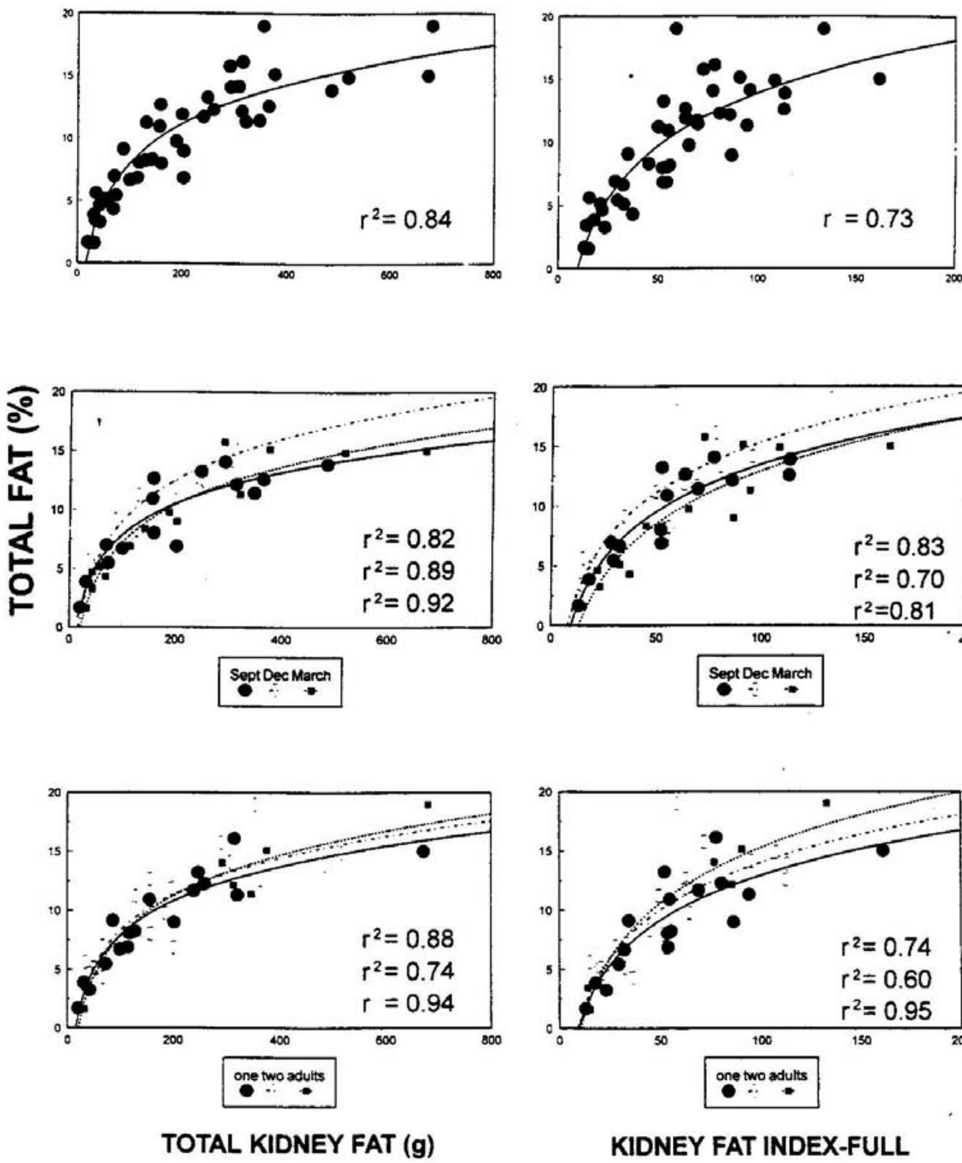

Figure 2. Correlations for kidney fat index full (keeping all the fat attached to the kidney) and total kidney fat (without taking kidney weight into consideration) with total percent fat of the animal. For each method, the top graphs depict data for all animals and all seasons. The middle graphs depict data per season, and the bottom graph depicts data per age.

Figure 2. Correlations for kidney fat index full (keeping all the fat attached to the kidney) and total kidney fat (without taking kidney weight into consideration) with total percent fat of the animal. For each method, the top graphs depict data for all animals and all seasons. The middle graphs depict data per season, and the bottom graph depicts data per age.

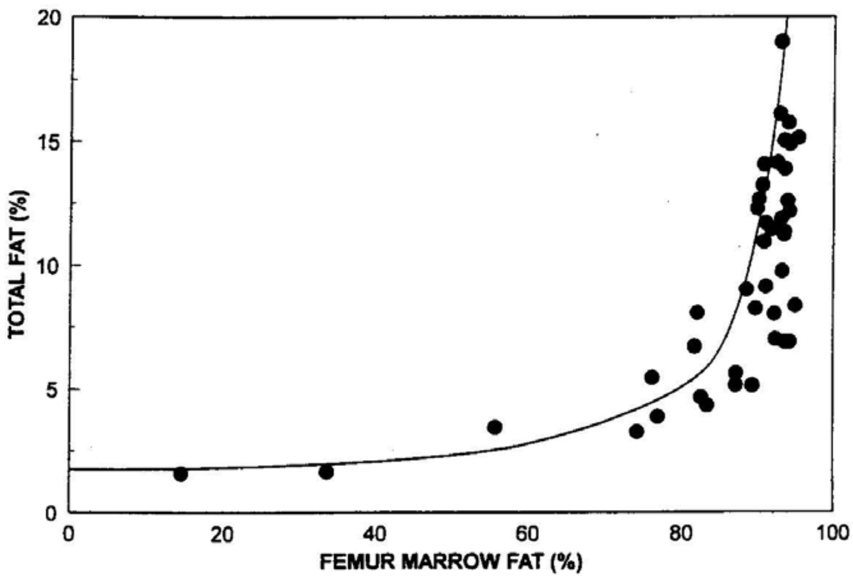

Figure 3. The relationship between percent femur marrow fat (oven dried method) and total fat (%). The curve is hand fitted.

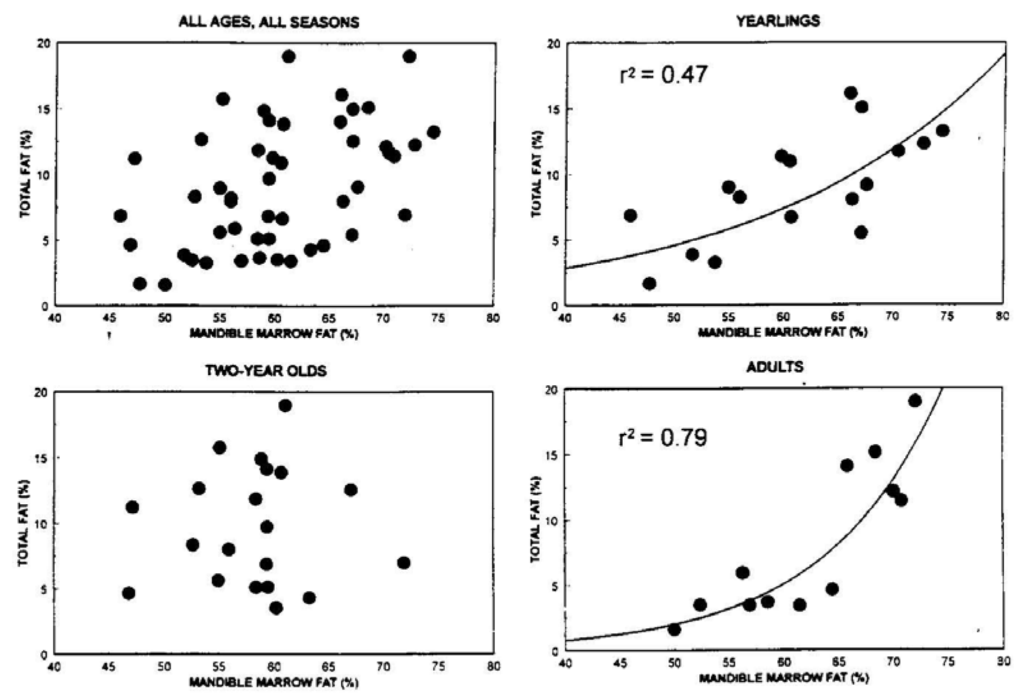

Figure 4. The relationship between percent mandibular marrow fat (oven dried method) and total fat. The first graph contains all animals for all seasons (N=49). The remaining graphs are separated according to age of the animal. Wild animals were included to increase the number of adult points.

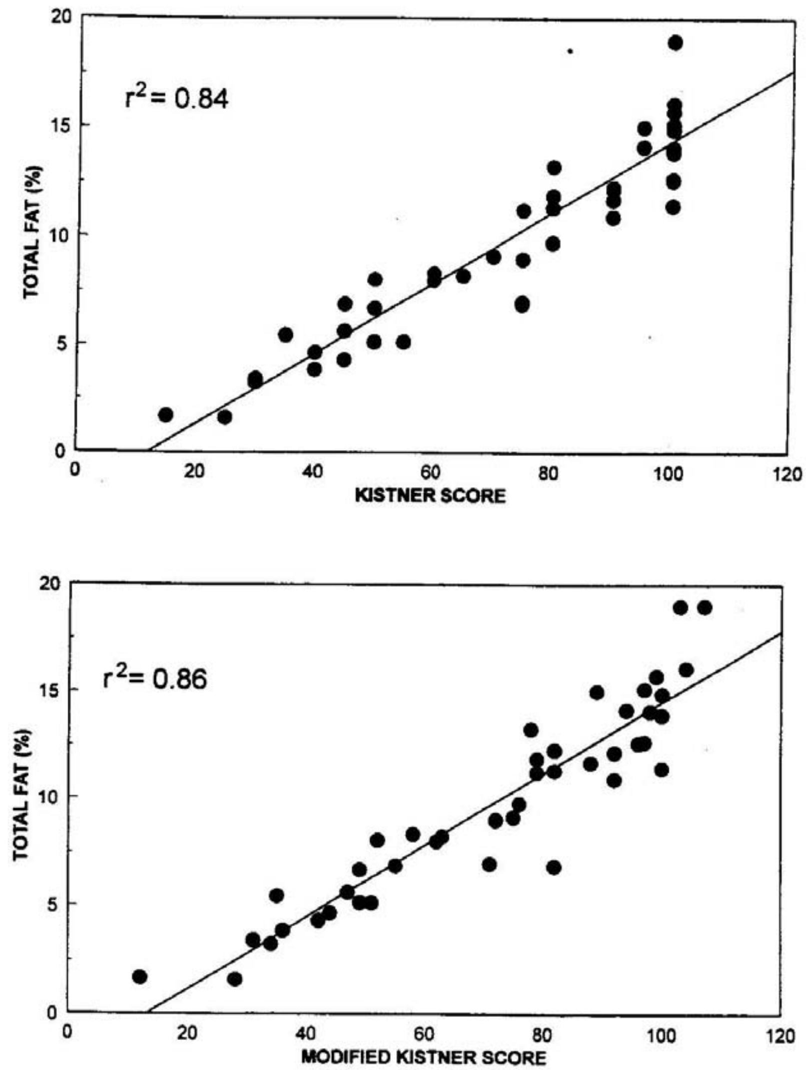

Figure 5. Relationship between original Kistner Score and the modified Kistner Score with total percent fat.

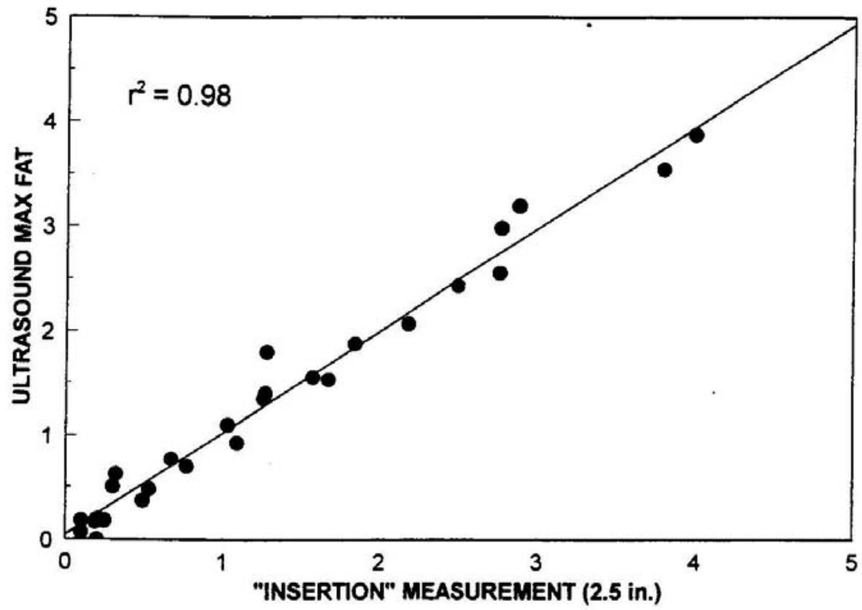

Figure 6. The correlation between the ultrasound max fat measurement and the insertion measurement taken 2.5 inches posterior from the ultrasound mid measurement (an attempt to mimic the ultrasound max location).

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