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Progress Report



ELK MODELING AND ECOLOGY

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**PROGRESS REPORT
STATEWIDE WILDLIFE RESEARCH**

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ELK MODELING AND ECOLOGY

Abstract

This project is comprised of two sub-investigations. The calf aging project uses data from two captive elk herds to explore aging criteria of neo-natal Rocky Mountain elk *Cervus elaphus* calves. The second project is to expand elk survival model concepts from the study-area scale to a broader level. We are currently constructing broad-scale elk vulnerability models for Idaho.

Calf Aging and Development Project

Background

Accurate estimation of age is very important in wildlife studies. One can find many ways to obtain age estimates for a variety of adult animals in the literature (Dimmick and Pelton 1996:169-214). Most of the techniques for Cervidae are used to determine age within a year to a year and a half for adult animals. These methods include eye lens weight and bone structure development for animals already dead, whereas techniques for live animals utilize tooth wear and cementum annuli (Brown and Chapman 1991, Dimmick and Pelton 1996). Daily and weekly estimates of age for live cervids cannot be determined from these techniques.

Obtaining weekly or daily estimates, specifically for newborn wild animals, is more difficult. Because young animals are hard to find and handle, and they grow rapidly within the first few weeks of life, this information is often challenging to acquire (Bartush and Garner 1979, Verme and Ullrey 1984). Although difficult to obtain, such precise estimates of age from birth may be very important in understanding the ecology of the youngest age class of animals.

Specifically for elk, approaches to aging newborns have been modified from quantitative techniques developed for white-tailed deer fawns (*Odocoileus virginianus*). Haugen and Speake (1958) developed a method, later modified by Sams et al. (1996), that relates the growth of the hoof to date of birth. Because hoof growth occurs from the leg hairline down, Haugen and Sams were able to utilize the distance between the hairline and a ridge on the hoof as the main predictor of age (Figure 1c). A second approach estimates date of birth of cervids using umbilicus condition, tooth eruption, and weight for newborn calves near Yellowstone (Smith et al. 1997). This method was developed from captured, wild neonates of unknown age. Johnson

(1951) also presented various qualitative methods for determining age of animals using various criteria, such as weight ranges, hair wetness, and umbilical cord condition. Although, these techniques have been adapted or developed for use in elk, they have never accounted for the full range of variation that one may encounter in elk calf development nor have any of these models been validated.

In this study, we expanded on these methods developed to age neo-natal elk by incorporating individual variation using random effects models and exploring a validation method (Johnson 1951, Haugen and Speake 1958, Sams et al. 1996, Smith et al. 1997). Using data from captive animals, we had four objectives.

Objectives

1. Develop a statistical model to predict age for Rocky Mountain elk calves that would be non-lethal and easy to implement in the field using morphological measurements.
2. Validate and calibrate the model to apply to wild populations.
3. Determine if the captive calves were representative of other elk calves from experimental and wild populations.
4. Determine if individual variation in growth could be explained by maternal nutrition.

Methods

Between 1996-1997 and 1997-1998, 83 Rocky Mountain elk calves were born from 63 captive cows at the Starkey Experimental Forest and Range Station (Starkey), near LaGrande, Oregon. From zero to 14 days from birth, each calf was measured and evaluated one to 14 times ($n = 981$ total measurements). Day zero was the calf's birthday. Not every calf was measured every day creating missing values in the data set. Three morphometric measurements were taken: weight (kg), hoof length (cm), and tooth length (cm) (Figure 1, Table 1). Mothers, or dams, and calves were part of a summer-autumn and winter experimental feeding study (Cook et al. 2004). The experiment examined this time period because summer-autumn and winter nutrition have a great impact on lactation, pregnancy, dam health, and survival of both mother and calf (Cook et al. 2004).

Before the rut in 1996, dams from this study were randomized to three different summer and autumn feeding treatment groups: high, medium, and low (Figure 2, Table 2) (see Cook et al. 2004 for more details). During winter of the first year, all of the cows were placed on a restricted winter diet (high diet) to initiate a 10% body mass loss (Table 3). The next year of the study, dams were re-randomized to new summer-autumn feeding groups (Figure 2, Table 2). Additionally, in 1998, non-lactating cows in the highest summer-autumn nutritional group were randomized to three winter feeding levels: high, medium, and low (Figure 2, Table 3). Eight yearling cows were also added to the study but were given no dietary restrictions.

The high nutritional treatment in the summer and autumn represented a diet that would “avoid restriction of reproductive performance without being substantially greater in digestible energy content than wild elk might obtain on native range” (Cook et al. 2004:17). The low nutritional treatment represented digestible energy levels “that elk might encounter in xeric coniferous forest zones of the Blue Mountains,” Oregon (Cook et al. 2004:17). The medium feeding level represented an average of those two levels (Cook et al. 2004). The high winter-feeding level was designed to induce 10% mass loss during winter. The low winter nutritional level was designed to “induce rapid weight loss”... and the medium “was intermediate between the low and high levels” (Cook et al. 2004:18) (Table 3). Animals were handled in accordance with care and handling guidelines developed for Starkey (Wisdom et al. 1993).

First, a regression equation to predict age between zero and 14 days since birth was constructed using linear mixed effects models (Pinheiro and Bates 2000). Models were fit using the nlme package in R (Ihaka and Gentleman 1996). Although data were collected in a longitudinal, repeated measures manner, under experimental conditions, the addition of random effects allowed flexibility to apply the final model to wild neonates sampled at random. Random effects were appropriate for two reasons. First, they can be used when various aspects of individuals’ behavior “may show some stochastic variation between units”; for example, when some individuals are intrinsically fast growers or slow growers. Second, they can be used when the researchers want the model inference to apply to other populations (Ott and Longnecker 2000, Pinheiro and Bates 2000, Diggle et al. 2002). An added benefit is that each random effect only used one degree of freedom for its variance component. We explored models containing fixed, main, higher order, and interaction terms and both random slopes and intercepts. A general form of a model containing both fixed and random slopes can be written as

$$Y = X\beta + Zb + \varepsilon$$

$$b \sim N(0, D)$$

$$\varepsilon \sim N(0, \Sigma),$$

where Y was a vector of age measurements for each calf, X was a matrix of individual calf measurements for each age, β was a vector for mean intercept and slopes, Z was a subset of the individual calf measurements, b was the random effects term that represented random variation around the population means, D was composed of compound symmetric submatrices multiplied by a constant $\sigma_{s_i}^2$ for each intercept and slope measuring between calf differences, and Σ was a within calf error variance-covariance matrix (Pinheiro and Bates 2000). We made the assumptions that 1) the model was correctly specified, and 2) the conditional residuals and residuals for each random effect were homogenous, homoscedastic, and normally distributed within and among groups. Model assumptions were explored graphically (Pinheiro and Bates 2000). We used Aikike’s Information Criteria (AIC) and likelihood ratio tests computed with restricted maximum likelihood effects (REML) estimates to compare between nested models with different random effects (Pinheiro and Bates 2000, Burnham and Anderson 2002). AIC and likelihood ratio tests computed with maximum likelihood (ML) estimates were used to compare models with differing fixed effects. Model fit was examined by plotting predicted vs. observed values.

The within calf error structure, Σ , could potentially result from repeated measurements taken on each calf. This serial correlation, or autocorrelation, might occur because an animal's body measurements are the response of some kind of time-varying stochastic process that may reflect some biochemical or physiological process occurring within the animal (Diggle et al. 2002:82). This physical process may make measurements taken close together in time more related than measurements taken farther apart. Various autocorrelation structures for the within calf measurements were added to the model. Models with different autocorrelation structures were assessed graphically with empirical semi-variograms and models compared using AIC computed with REML estimates (Pinheiro and Bates 2000).

Once the predictive model is parameterized, we will explore the sensitivity and elasticity of the fixed effects parameters. Sensitivity, or S , attempts to give a measure of the relative change in the output based upon a percent increase in a parameter estimate (Jorgenson and Bendoricchio 2001). We plan on doing this by refitting the model with normalized variables and calculating S , where $S = [\delta x/x] / [\delta P/P]$ where P is the parameter estimate. Also, we plan to calculate the average elasticity, E , of the response variable with respect to each fixed effect. It is calculated by multiplying the *slope* * $[x/y]$ for a linear model. Average elasticity measures the average percent change in Y for a given percent change in X with all of the other variables held constant (Cooper et al. 2002). For example, an elasticity of 0.45 for the weight variable would imply that a 1% increase in the weight variable would lead to a 0.45 increase in age, with all other variables held constant.

Models were validated using a ten-fold cross validation technique (Harrell 2001). Using this method, we randomly split the data into ten groups. We removed one group of data, refit the model, and predicted the age of the calves for the removed set (gregmisc package, R). This process was repeated ten times. Pearson correlation coefficients were estimated to determine the linear relationship between predicted and observed values. The ten Pearson correlation coefficients were then averaged.

An additional data set was also used for validation. This data set contained 48 weight, hoof, and tooth measurements from 32 elk calves at Moscow Mountain Elk Ranch (MMER), Moscow Idaho. These elk calves were hybrids of Rocky Mountain, Manitoban (*C. elapahus manitobensis*) and Roosevelt elk (*C. elapahus roosevelti*). Predicted ages were obtained using the full mixed effects model. A Pearson correlation coefficient was estimated to determine the linear relationship between the predicted and known age for the MMER elk calves.

We also applied the model to a wild population of elk calves captured and radio-collared along the Lochsa and North Fork of the Clearwater rivers. We used our random effects model to predict age of the wild newborns. We also predicted their age using Johnson's (1951) aging criteria. The two methods were compared graphically.

Second, differences in birth weight (one day old), increase in weight over time, daily weight gain, tooth growth, and hoof growth were tested to determine if there was a significant difference between sexes, years, and the 1996-1997 summer-autumn nutritional feeding groups using ANOVAs and a repeated measures MANCOVA in R. We did not explore the 1997-1998 data

(Figure 3) for differences among SAFGs because calves were confounded with nutritional feeding groups.

Finally, values for birth weight and daily weight gain were obtained from the literature to determine if the elk calves used in this study were comparable to elk calves from wild and other captive populations. We also plan to thoroughly compare values from Johnson (1951) with the morphological measurements of the elk calves from our study.

Current Results

Mixed Effects Model - Because not all measurements were taken at every period of observation, we only used measurements that contained complete records for sex, weight, hoof, and tooth. Models were built using 609 observations from 64 calves.

For the predictive model, we explored all random effects and fixed effects combinations and interactions. The final model was chosen because it best met the assumptions of a linear mixed effects model, was the best model using likelihood ratio tests, and had a low AIC. Because prediction was the intention of the modeling exercise, the model with the lowest AIC was not chosen because it did not adequately meet the assumptions of mixed effects models.

The final model contained a random intercept for each calf, random slopes for weight, hoof, tooth, and tooth squared; a moving average autocorrelation structure with a step of two; and all fixed effects (intercept, sex, weight, hoof, tooth, and tooth squared) (Table 4). All terms in this model were significant at the 0.05 level. Additionally, predicted values were very similar to observed ages (Figure 4).

For the ten-fold cross validation of the final model, we tried to randomly subdivide the number of calves into ten approximately equal subsets to be used for prediction. Because there were missing measurements for each calf, we were unable to get exactly equal subsets. Using each of these random subsets, we obtained predicted ages from the models and calculated correlation coefficients between observed and predicted ages (Table 5). Correlation coefficients varied between 0.768 and 0.976. For subsets with a high Pearson correlation coefficient, such as subset ten with an $r = 0.976$, the predicted and observed values had a good one to one linear relationship (Figure 5). For subsets with a lower correlation, there appeared to be one (subset four with an $r = 0.84$) or more calves (subset eight, $r = 0.787$) for which the model predicted very poorly. For the additional validation data set (MMER calves), the Pearson correlation coefficient between predicted and observed ages was 0.830 (Table 5). The final model consistently predicted the MMER calves to be older than their known ages (Figure 5). Finally, when the model was applied to the wild population, the model seemed to over-predict many ages. Model predictions did not seem to match predicted ages using Johnson (1951) aging criteria (Figure 6).

Birth weights - For the ANOVA comparing birth weight (weight at age = one day) between sexes and years, the overall model was significant ($p < 0.001$). Birth weights were only different between sexes ($p = 0.003$). Neither differences between years ($p = 0.79$) nor interaction term, sex*year, ($p = 0.93$) were significant in the model. Males were almost always larger than females at birth (mean male weight = 17.09 kg (0.4), mean female weight = 15.52 kg (0.23)).

We also explored differences between birth weights among summer-autumn feeding groups (SAFG) and sex for 1996-1997 elk calves (Figure 7). The overall model was significant ($p < 0.001$), but the main effect term and interaction terms for SAFGs were not significant. Additionally, mean birth weights were calculated for MMER elk calves. Average female birth weight (21.68 kg (1.4), $n = 7$) was slightly heavier than male birth weight (21.36 kg, $n = 1$).

Average birth weights were comparable to mean birth weights from other studies (Table 6). Most combined gender birth weights fell between 15.5 and 17.5 kg. Additionally, most of the other studies reported a higher birth weight for males than for females. Cook et al. (1996) reported the lowest combined mean birth weight (14 kg (0.0023)), while MMER had the highest average birth weight (21.52 kg (1.28)).

Growth rates - We also explored weight increase, tooth growth, and hoof growth for the 1996-1997 elk calves against time (age), between sexes, and among SAFGs. The interaction term for the overall MANCOVA was not significant (Wilke's lambda $p = 0.51$), but the main effects, sex and SAFG, were significant ($p = 0.0002$ and $p = 0.01$). We continued with separate ANCOVAs for tooth growth, hoof growth, and weight increase. For tooth growth, hoof growth, and weight gain, overall models were significant because animals grew over time ($p < 0.001$). Sex ($p = 0.009$), but not SAFG, was significant for weight regressed against time; for tooth and hoof growth, regressed against time only ($p < 0.001$) was significant (Figure 7).

Additionally, we explored the slope of weight against time, or daily weight gain, to see if there was any indication of early catch-up growth among SAFGs and between sexes. The overall model was not significant ($p = 0.62$). There were no differences in mean daily weight gain over time, among SAFGs, or between males and females. We calculated growth rates averaged for years, sexes, and feeding groups and compared this value to other mean daily weight gain in the literature (Table 7). Growth rates of elk calves from Starkey (0.77 kg/day (0.0004)) are comparable to other calves in other studies. Mean daily weight gain for MMER calves (0.71 kg/day (0.15)) was similar to Starkey calves. Calves from Smith et al. (1997) had the highest average daily weight gain (1.643 kg/day and 1.316 kg/day for males and females, respectively). Cook et al. (1996) had the lowest average weight gains (0.4 kg/day).

Current Discussion

Our model provides a method to objectively predict ages of wild elk. Instead of categorizing behavior, hoof softness, or umbilical condition (Johnson 1951), we provide an unbiased way to predict age during the first two weeks of life. We limited the prediction capabilities of our models to the first two weeks because that is when the majority of capture operations occur. Predictions beyond that are not advised because growth patterns do not remain linear throughout the course of development.

We chose weight, tooth length, and hoof length for our models because they are relatively easy to measure in the field during capture without great measurement error or between-researcher measurement variation. Additionally, these three body measurements were not highly correlated ($r < 0.75$). Furthermore, we specifically chose length of the outer edge of the first incisor tooth

because other studies have indicated that it is least affected by fetal and neonatal nutrition (Brown and Chapman 1991).

The inclusion of the individual calves as random effects allows the model to be used for other populations of elk. “A random effect is a reasonable description of [a] set of coefficients from a population of animals [that] can be thought of as a sample from a distribution” (Diggle et al. 2002:128). Although the model was created with a specific sample of calves, the original calf lineage was chosen at random from a wild population (Cook et al. 1996). Because of the random effects, inferences from this model may be drawn to other populations of similar calves. When predicting, the random effects only come into play when calculating confidence intervals for the age estimate.

Although not modeled, the variation imposed by feeding levels and elk calf mothers should be representative of the variation in conditions that could be found in the wild. Although hierarchically nested, we did not consider nutritional groups and mother random effects because the nutritional group was confounded with each calf. We explored inclusion of mother as a random effect, because some mothers had two calves, but inclusion of a mother random effect created unusual patterns in residuals. If we had included both feeding group and mother random effects, we could have quantified the amount of variation explained by mothers (or genetically linked variation) and feeding groups (nutritionally linked variation), using the intra-class correlation (Singer 1998).

Through cross validation with the Starkey data set, the final model appears to predict well ($r = 0.87$). Although the relationships between predicted and observed were strongly correlated, there were several calves for which the model predicted poorly. Such calves (e.g. calf 25 or 20) were born smaller and grew slower. These calves were not born to mothers in any particular summer-autumn or winter feeding group, nor did they die sooner than any of the others. These calves simply demonstrate individual expression of genetic or environmental variation.

Validation with the MMER data set was not as good. Although the correlation coefficient was fairly high, the model seemed to overestimate ages of these calves. We believe that the model performed poorly with these calves because they were heavier and larger than Starkey calves. The MMER were hybrids of Rocky Mountain, Manitoban, and Roosevelt elk. Roosevelt elk are “often considered to be [the] largest extant elk” (O’Gara 2002:45) and “Manitoban elk on good nutrition [are] heavier than Rocky Mountain elk” (O’Gara 2002:47). If these elk are larger as adults, they are most likely larger at birth. Additionally, these animals may have been larger at birth because they were being raised for meat and antler production. Like any husbandry operation, larger animals tend to get selected to maximize yield.

The nutritional condition of mothers during gestation did not greatly affect the parameter estimates. To make sure models were not sensitive to calves from different nutritional groups, additional models were built and validated using a subset of calves from the highest summer-autumn and winter feeding groups and a subset from only the lower summer-autumn and winter feeding groups. Using these two restricted data sets, parameter estimates changed slightly and predicted ages were within 0.5 days from the full model predictions. Because calves from

different nutritional groups did not seem to alter the model much, we decided that all of the data would better reflect variability that would be found in a wild population.

We recommend that the use of this model be restricted to Rocky Mountain elk calves. Use on other subspecies is not advised because sizes at birth and rate of growth between subspecies are very variable. For example, red deer (*C. elapahus elapahus*) birth weight and daily weight gain average around 8.5 kg and 0.35 kg/day, respectively, compared to 18 kg and 0.825 kg/day for Rocky Mountain elk calves (Haigh and Hudson 1993).

In the future, we would like to build the model with additional data, collected in a similar manner, from other Rocky Mountain elk populations. By adding populations, we could better model the random variations of growth and birth size. Until this is accomplished, researchers should consider recalibrating this model for other subspecies of elk and for use in other regions of the United States, where genetic stocks, habitat, and climate vary (Bridges et al. 2002).

Birth weights - In our study, we found that males were born heavier than females, mother's SAFG did not influence birth weights, and mean birth weights of elk calves from this study were comparable to elk calves from other studies. Similarity of our findings to other studies suggests that calves from different regions may be of similar weight at birth and our models could be aptly applied. We believe that when differences in birth weight occur, they are mainly a function of gender, physiological condition of the mother, and extreme environmental conditions.

We believe the differences that we found between males and females (17.09 kg (0.4) vs. 15.52 kg (0.23)) at birth are primarily caused by production of growth-promoting hormones, such as androgen and testosterone, which begin being produced early in gestation. In domestic cows, androgen concentrations are much higher in the serum of male fetuses, and testosterone begins to be synthesized by the testes on day 45 of gestation (Holland and Odde 1992). Our findings are similar to the results of Smith et al. (1997) and Wild et al. (1994). They found males to be 0.7 to 2.0 kilograms heavier than females.

Our results suggest that maternal nutritional restrictions in early gestation have little effect on calf birth weight. We found no significant differences between the birth weights of the summer-autumn feeding groups. We hypothesize that nutritional restriction during early gestation does not greatly affect birth size because the embryo/fetus is not utilizing a large percentage of the mother's resources at that time. Its demands are "easily met by placental exchange of endogenous nutrients" (Hafez and Dyer 1969:54, Adam et al. 1988). In studies on domesticated cows, nutritional restriction during early gestation had little effect on birth weight; although it may have delayed or impaired early developing organs, such as the brain and heart, and may potentially lead to a reduced chance of survival (Hafez and Dyer 1969, Holland and Odde 1992). Unless severely deprived during late gestation, most captive ungulate studies have shown that the fetus is not affected by early nutritional restriction (Holland and Odde 1992).

Although birth size is minimally influenced by early maternal nutrition, we believe that birth size is affected by changes in the intrauterine environment, or the physical environment of the

conceptus tissue. The conceptus tissues can be highly influenced by the mother's metabolism, physiological condition, and extreme external environmental conditions (Price and White 1985).

Maternal size, age and genotype, and previous lactational status (Holland and Odde 1992, Cook et al. 2004) directly relate to physiological conditions. The highly heritable factor, adult maternal size, quantified by body weight, is indicative of the "physiological capacity to the support the fetus and fetal growth" (Holland and Odde 1992:774). Numerous studies have shown that larger dams produce larger newborns because of increased maternal capacity to supply the fetus with nutrients (Albon et al. 1980, Blaxter and Hamilton 1980, Holland and Odde 1992, Friedel and Hudson 1993, Schwartz and Hundertmark 1993). Maternal age influences birth weights because competition for nutrients between the growing, young mother and the developing fetus may result in a lower neonatal birth weight (Holland and Odde 1992). For red deer, Blaxter and Hamilton (1980) found that there was no effect of dam age on the birth weight that could not be explained by the mother's pre-rut weight. Smaller, younger mothers produced smaller calves (Blaxter and Hamilton 1980). Genetics certainly influence the progression of fetal growth and development (Owens et al. 1993), but for domestic cows and sheep, there is only low (10-20%) to medium (30-40%) heritability of birth weight (Hafez and Dyer 1969).

Although "fetal growth proceeds along its course, protected by a resilient maternal buffer, attaining developmental horizons with a biological flexibility essential to survival" (Everitt 1967:132), there has been much research focusing on changes in birth weight due to environmental factors. External environmental factors that affect birth weight include climate (precipitation and temperature) (Albon et al. 1980), population density (Albon et al. 1987, Andersen and Linnell 2000), altitude (Holland and Odde 1992), habitat characteristics, and great nutritional restrictions during late gestation. Although extremes in temperature or high altitude may affect birth size, these factors are rarely important for wild animals because the intrauterine environment greatly buffers the fetus (Cameron 2002). On the other hand, nutritional deprivation during late gestation has produced controversial results in captive studies. Thorne et al. (1976) found that winter malnutrition affects birth weights of captive elk calves. Alternatively, Holland and Odde (1992:780) advocate that effects on birth weights seem to be "variable and, on average, relatively small". Effects may be "small" because of the mother's ability to metabolize her own body reserves to meet the energy and nutrient requirements of the growing fetus. Additionally, as long as chronic malnutrition does not occur, fetal catch-up growth may be possible if and when nutritional restrictions are amended. Haigh and Hudson (1993:50) found that drastic maternal food restrictions do not often produce substantial changes in birth weight because there is often ample opportunity between spring green-up and calving for the dam to attain a higher nutritional plane and fetal catch-up growth to occur.

Birth weights from this study are similar to birth weights in other studies. This resemblance affirms applicability of our mixed effects model aging to other elk populations. The calves from the literature with the lowest birth weight "developed diarrhea and varying symptoms of illness ≥ 3 weeks post capture" (Cook et al. 1996:532) and the two highest birth weights came from MMER (21.52 kg) and Robbins et al. (1981) (21.2 kg). These high birth weights could be a function of many additive causes such as differences in the intrauterine environment, genetics and hybridization of subspecies.

Although our birth weights are comparable among the different ranch, captive, and wild studies, variation among the populations could cause the aging model to over- or under-predict. To work with other populations, an intercept adjustment for size at birth should be considered or the model should be refit with additional data to account for genetic and environmental differences.

Growth rates - We found that there was no difference between the daily rate of weight gain, or acceleration of weight gain over time, between males and females or among SAFGs. We did not find differences in tooth or hoof growth between males and females or among SAFGs. Differences in weight gain occurred because males and females were born at different weights.

We believe that the summer-autumn feeding group did not affect neonatal growth rates because nutritional restriction did not continue throughout the rest of pregnancy. The cows were given high quality forage beginning in March. This diminished any effects on late gestational fetal growth and milk quality and yield (Haigh and Hudson 1993). Everitt (1967) suggests that growth immediately after birth is simply an extension of intrauterine growth and maternal nutrition. As long as the calf acquires adequate milk and important antibodies from colostrum, calf growth will be similar to intrauterine growth (Cameron 2002). At this point, additional food sources, such as grass and forbs, are not important because the four stomach chambers are still forming (Price and White 1985, Lyford 1988).

Our results, coupled with other rates from the literature, show that rate of weight gain during this short period appear similar across populations. The lowest daily weight gain was attributed to death and illness of the calves (Cook et al. 1996). Also, this growth rate was for July. By the second month, daily weight gain may have slowed. Smith et al. (1997) reported the highest birth weights. They asserted that their estimates of high daily weight gains were attributed to 1) the beneficial affects of winter supplementation, 2) bias in Johnson's (1951) study on wild calves, 3) superiority of free ranging dams' milk yields to captive animals because the mothers were allowed free choice in forage selection, and 4) incomparable results because rate of weight gain changes after the first week of life (Smith et al. 1997:35). If choice of good quality forage was the reason for fast growth, we expect calves born on ranches would exhibit the same fast growth reported by Smith et al. (1997). On ranches, mothers are either offered high quality forage or allowed free range to make good choices. Additionally, the MMER and Friedel and Hudson calves were born on elk ranches, where maximization of animal size was most likely a targeted objective. Calves from MMER and Friedel and Hudson had similar rates of weight gain as the Starkey animals instead of the increased rate found by Smith et al. (1997). As for incompatibility of results because of changes over time, we found no difference in the average daily weight gain over the first two weeks. Based on our data, we do feel that our results are incomparable with those calculated for one week of growth. Our estimates for the two-week period are even similar to rates of growth calculated for one month. Differences in mean daily weight gain between captive and wild animals need to be explored further. Findings could significantly influence applicability of our aging model and understanding of neonatal ungulate ecology.

Management Implications

Application of our mixed effects model to predict calf age is important for wildlife management because age may impart several important pieces of information about natural history and ecology of neonatal cervids. An estimate of age could be used to calculate date of birth, thus providing direct insights about growth rates, fetal implantation, birth date distributions, neonatal survival and their relationships. For example, date of birth has been linked to survival in many studies. Albon et al. (1987) found that early-born red deer calves had a 30% increased chance of summer survival. Winter survival also was higher in early-born calves, possibly because they had a longer summer season in which to gain weight Albon et al. (1987, Blaxter and Hamilton 1980) Information about herd condition may also be imparted by date of birth and age. Squibb et al. (1986) documented bimodal conception dates caused by regularly scheduled hunting seasons. Using collected reproductive tracts, they backdated date of conception, or age of the fetus, and speculated “heavy hunting pressure interfered with normal breeding” (Squibb et al. 1986:1). Knowing date of birth could more easily identify problems with conception date distribution. Once calibrated for wild populations, the model could be a vital tool in the management of the youngest portion of elk populations.

Future Goals

Our next goal is to explore the sensitivity and the elasticity of the parameter estimates. We also need to calibrate the model to be used on wild populations. With its current predictions, the model does not perform accurately enough. We need to develop a method to adjust its predictive abilities.

Estimating Survival Rates for Elk in Idaho

Background

We focus on the estimation of survival rates for elk and their relation to the habitat. Estimating survival rates is extremely important for wildlife managers and biologists because it is a primary demographic used to understand and manage elk populations. Survival estimates provide key information about changes in density and abundance of populations (Krebs 2001, Williams et al. 2001). Obtaining an estimate of survival could give insights about the future trajectory of abundance and density. It may also provide a reference for the health of a population. If there were major problems with disease, predation, or hunting, changes in survival would be noted. Additionally, survival rates could be easily targeted in management practices (Williams et al. 2001). By changing hunting regulations or habitat quality, wildlife managers can directly impact survival rates.

Exploration of survival rates may not only indicate how a population size might change, but also why it might change. Although most deaths are related to hunting season (at least for male elk), secondary factors that expose elk to hunting may be very important for explaining differences or changes in survival rates. Survival rates for the population may vary substantially in space and time as a “function of many demographic and environmental conditions, including food quality, weather, imbalance in sex ratios,” and other factors (Morrison et al. 1998, Krebs 2001, Williams

et al. 2001). In order to better understand survival rates and population demographics, we could couple environmental factors with survival rates to explore elk vulnerability. Previous research has examined factors such as sex, light penetration, density, weather, hunter density, and topography using many different survival analysis techniques at various spatial and temporal scales (Zager and Leptich 1991, Unsworth et al. 1998, DelGiudice et al. 2002, Wirsing et al. 2002).

We will explore two main categories of factors at consistent spatial scales: hunting-related and environmental. When dealing with spatial and temporal factors, scale is a very important feature to consider. “A shift in the relative importance of the variables or the perceived direction of a relationship [could occur] when spatial or temporal scales are changed” (Turner et al. 2001). Scale can be characterized by grain and extent. Previous studies have examined habitat structure and survival at various spatial grains and extents. Extents have included GMUs (Vales 1996), seasonal range (Unsworth et al. 1998), and buffers around points (Hayes et al. 2002). We will use one grain size and will explore two consistent spatial extents to determine the effects of habitat variables on survival.

Because almost all of the deaths occurred during the hunting season, we are limiting our temporal extent to the hunting season; therefore, concentrating on elk vulnerability rather than habitat effectiveness or winter range conditions. Elk vulnerability “deals with security for elk during the hunting season”, while habitat effectiveness is “a measure to be applied to non-hunting, summer and fall habitat situations” (Christensen et al. 1993:1-2). With this study, we hope to further understand the complex relationships between hunting practices, environmental conditions, and elk vulnerability.

Objectives

1. Explore how demographic and environmental factors affect an elk’s chance of survival in each of the three populations at two different spatial extents.
2. Develop a predictive, broad scale elk vulnerability model.

Data Collection

The data used in this project originate from four different Idaho Department of Fish and Game (IDFG) studies. Various IDFG biologists collected the data between 1984 and 1994 in three different parts of Idaho from radio-collared Rocky Mountain elk (*Cervus elaphus nelsoni*) (Table 8). The animals were captured by helicopter darting, net gunning, or trapping; radio-collared; and then relocated by aerial radio-telemetry at least once a week during the hunting season and one or more times a month the rest of the year. Age class and sex were recorded during collaring. Generally, when the animal was relocated, the coordinates of radio telemetry point locations were recorded and a site description was noted. The site description typically included slope, aspect, elevation, and main habitat type. Additionally, the elk were relocated and inspected post-mortem and an attempt was made to identify the source of mortality.

The datasets included in this analysis are from three different geographic areas of Idaho: Coeur d'Alene (CDA), the Lochsa River and North Fork of the Clearwater (Lochsa), and Sand Creek (Figure 8). These studies focused on male elk survival and thus have disproportionately high number of bulls in the study (Table 8).

The first dataset originates from a study conducted in Game Management Units (GMU) 3, 4 and 4A. A small portion of elk was relocated in Montana Hunting District 121. This area is characterized by steep terrain with dense cedar and conifer forests and open brush fields. The area is heavily roaded (>0.932 km/km²) (Leptich and Zager 1994). Both a cow and bull general rifle and archery season were held annually. Only GMU 4 had a muzzleloader season. The Montana hunting district had a seven-day either-sex season and a 28-day bull-only season. The Coeur d'Alene and Kaniksu national forests comprised much of the study area. This study was conducted from 1988 to 1994. See Leptich and Zager (1994) for a more detailed description of the area and the original study.

The second dataset comes from a study conducted along the Lochsa and North Fork of the Clearwater rivers, mostly in GMUs 10 and 12. Topography varied from steep slopes to flatter floodplains. Vegetation was highly mixed with open shrub fields and a mixture of Douglas-fir, ponderosa pine, Englemann spruce, and subalpine fir forests (Unsworth et al. 1998). Portions of the area had both high and low density of roads (1.94 km/km², 0.29 km/km²) (Unsworth et al. 1998). The population was exposed to rifle bull-only hunts. All GMUs except 16 had an archery season, and only GMUs 16 and 10A had muzzleloader seasons. Additional cow and bull controlled hunts were occasionally conducted. The Nez Perce and Clearwater national forests comprised most of the study area. The data comes from a series of studies conducted between 1984 and 1994. See Unsworth et al. (1998) and Gratson and Zager (1999) for a more detailed description of the area and the original study.

The third population comes from the Sand Creek area in GMUs 60, 60A, 61, 62, 63A, and Montana Hunting Districts 327 and 361. The study area is mainly located in Snake River Plain in southeastern Idaho, southwestern Montana, and northwestern Wyoming. The Targhee, Beaverhead, and Gallatin national forests and Yellowstone National Park comprise much of the study area. These areas were characterized by moderate to steep slopes, plateaus, and low, flat areas (Brown 1985). The vegetation is varied, with a mixture of deciduous, conifer, sand dunes, and high desert sagebrush communities at the various elevations. In the 1970s and 1980s, mountain pine beetle infested much of the merchantable lodgepole in the area (Brown 1985). An increase of logging and road building ensued to salvage much of the timber (Justin Naderman, personal communication). The animals of the Sand Creek population frequently crossed the state boundaries between Idaho, Wyoming, and Montana. GMUs 60A and 63A had no hunting except controlled hunts. These GMUs were frequently used as wintering grounds by many elk. The remaining Idaho units had a five-day annual bull rifle season. All units except GMUs 60, 60A, and 63A had an archery season, and only GMU 61 had a muzzleloader season. There were also frequent bull and cow controlled hunts in all units. The Montana hunting districts had a 35-day bull-only hunting season. See Brown (1985) for a more detailed description.

Methods and Current Progress

Because the main source of mortality was hunting-related (rifle, archery, muzzleloader, rifle-wounding and poaching) (Figure 9), we focused this study on the hunting season. We examined the time period from September 1 – November 30 because all hunting-related deaths occurred during this time period. We related the aerial radio telemetry point locations collected between these two dates to several environmental variables. Information for environmental variables was obtained using the literature and a Geographic Information System (GIS).

Seven variables were collected using various spatial layers in GIS: % of cool aspects, % forested areas, interspersion of habitat, Simpson's patch diversity index, contour density (Beasom 1983), road density (Unsworth et al. 1998, Hayes et al 2002), and hunter density (Hayes et al. 2002). All of the spatial layers were projected into NAD1927 UTM11 using Toolbox in ARC 8.0.

For spatial scale, we explored all variables at two different spatial extents and chose a 30 megapixel size for grain (Johnson et al. 2000). All data were collected using two different, contiguous buffer sizes for each radio telemetry point. The first buffer size was a 473 m fixed-radius circle around each point (70.28 ha). This distance was chosen because it encompassed a core hiding area of 40 ha (Lyon 1979) and/or the 2.5 ha of security area (Thomas et al. 1979, Hillis et al. 1991) and incorporated the largest known radio telemetry error of 473 m (Unsworth et al. 1998). The second distance was a 2077 m fixed-radius circle around each point (1352.22 ha). This distance was the median distance moved between consecutive points that were taken less than eight weeks apart (Boyce et al. 2003). All movements considered migratory were removed. This buffer size was chosen because it represented areas that the animal had the ability to use between relocations. By choosing such a large distance, we also felt that it encompassed much of the animal's seasonal home range. The median was chosen because it was a similar distance among all three study areas. In order to make consistent measurements between study areas, we wanted to choose a distance that would be meaningful in all of the populations. This median distance represented a pseudo-core area of the home range. We did not want to include migration movements because animals moved through large areas rather quickly and probably did not have the time to use the resources between locations to avoid mortality during that time. Consecutive distances more than eight weeks apart were removed because we could no longer distinguish between a movement within the seasonal area or a migration movement. Points were buffered using the Animal Movement extension in ArcView 3.0 when working with shapefiles and coverages. When working with raster data layers, points were buffered using the buffer function in ArcGrid. The information collected for each point was then averaged for each animal for each year.

Percent of cool and warm aspects was collected by first deriving aspect from a 30 m USGS National Digital Elevation model (DEM) using Spatial Analyst version 1.1 in ArcView 3.3; reclassifying aspect into cool (0° to 112.5° and 292.5° to 365°) and warm aspects (112.5° to 292.5°); and then using an AML in ArcInfo to buffer each point, convert each buffered point to a raster file, clip each raster buffer with the reclassified aspect, and deposit the number of pixels of cool and warm aspects for each buffer into a table. An AML was used because there were many points for each data set (CDA, $n = 317$; Sand Creek, $n = 694$; Lochsa, $n = 3949$). Percent cool aspects were then calculated by dividing the number of pixels of cool aspects by the total number

of pixels. We chose to reclassify aspect into cool and warm aspects because northern, cool aspects frequently have more productive vegetation and denser, forested areas. One study demonstrated that northern aspects produced 14% greater seasonal photosynthesis (Running 1984). These areas may provide a better refuge from hunters while meeting foraging needs during the hunting season.

Percent forested was calculated by first reclassifying the 1992 30 m USGS National Land Cover data (NLCD) into forested (including conifers, deciduous, and mixed conifer and deciduous forests with greater than 25% canopy cover) and non-forested (all other types). We used the AML to clip out each buffer from the reclassified NLCD and record the number of pixels of forested and non-forested areas. Percent cover was then calculated by dividing the number of forested pixels by the total number of pixels for each buffer. We used NLCD rather than GAP because the elk point locations extended into Montana and Wyoming. Each states' GAP layers were not collected in a consistent manner. Although NLCD provided less detail, it gives consistent cover data for the whole study area and allowed us to test our hypothesis that surviving elk tend to utilize forested areas more than elk that die during the hunting season.

Contour density was calculated by first deriving 30 m contour lines from the DEM using Spatial Analyst in ArcView 3.3 for Windows. Using the Xtools 3.0 extension in ArcView 3.0, contour lines were clipped to each buffer and the length of contours within each buffer was summed. We computed contour density by dividing the total length of contour lines by total buffer area (ha). We predicted that elk that survived longer would use steeper slopes than elk that died. Steeper slopes would provide more security because they would be more inaccessible by hunters.

Several road layers were used for road density. First, a 1:100,000 USGS Digital Line Graph (DLG) road layers (collected between 1986 and 1991) for the state of Idaho was merged with two other road layers from Wyoming and Montana. One road layer was developed by Montana Resource Information Services from 2000 Tiger Line Files, 1:100,000 scale, and the other was from the Northern Rockies Information Node, 1998 Tiger Line Files, 1:100,000 scale. Although the temporal scale of the Montana and Wyoming road layers does not match the time of the study, we do not believe that the number of roads changed enough for there to be measurable differences. Only primary, secondary, and tertiary roads, jeep trails, and four-wheel trails were included in the road layers. Foot trails were excluded. Using Xtools extension in ArcView 3.0, roads were clipped to each buffer and the length of all contours within each buffer was summed. Road density was then determined by dividing the total length of roads by the buffer area (ha). We predicted elk would be more susceptible to hunting mortalities in areas with higher road densities because hunters would have greater access to those areas and elk would be under greater duress because of other vehicular disturbances.

Interspersion and Simpson's diversity index of habitat types were calculated by first reclassifying the NLCD data into five different classes: open water, herbs and grasslands, shrubs, forests, and other. We then used the AML to clip out buffers from the NLCD. These raster buffers were used in Fragstats 3.3 (McGarigal et al. 2001) to calculate the landscape metrics. We used the eight cell rule for all calculations in Fragstats. We hypothesized that the spatial pattern of these patch types would be important to elk survival.

Hunter density was calculated using number of hunter days x length of the general rifle season divided by area of the buffer (Hayes et al. 2002). If an elk buffer was located in more than one GMU, a weighted average of hunter density was calculated by determining the percent of each buffer in each GMU. The length of the season was obtained from IDFG and Montana Fish, Wildlife, and Parks annual big game hunting rules and regulations booklets. The number of hunter days was obtained from IDFG annual reports (Kuck and Rachael 1997) and is being obtained from Montana FWP annual reports.

Two, non-spatial variables, season structure and age class, will also be explored. Season structure corresponds to the start of the general rifle season in Idaho. Prior to 1991, the start of the general rifle season began during the rut. After 1991, the start of the hunting season was delayed to begin after the rut. This difference will be included as a categorical variable. Age class will also be included as a categorical variable. Fawns, yearlings, 2.5-year-olds, and prime-age adults (≥ 3.5 years old) will be included as a category in the analysis.

Daily and monthly mean weather information has also been collected from Idaho State Climate Service for the closest NOAA weather station with the most complete dataset. We are currently in the process of developing the manner in which this data will be related to elk survival.

Currently, we are combining the elk information with the GIS data using SAS datasteps, graphing the data, and conducting preliminary univariate analyses. Next, we will relate all variables to the number of days the animal lived during the hunting season each year using a proportional hazards model. Proportional hazards model related the log instantaneous mortality rate to categorical and continuous covariates. The log instantaneous mortality rate can be modeled with a parametric distribution. By specifying a parametric distribution, it requires more stringent assumptions, but makes the predictive power of the model much greater. Parametric distributions will be explored graphically in SPLUS. If appropriate, we will use a specified distribution to model the log of the instantaneous mortality rate. Alternatively, we will use the Cox's proportional hazards model, which assumes no underlying distribution for the log hazard rate. Once the model type is selected, we plan on conducting model selection with AIC and AIC weights using a priori models. Additional model exploration will be conducted after the a priori models are tested and compared. Model assumptions will be checked graphically using residual plots in SPLUS and R.

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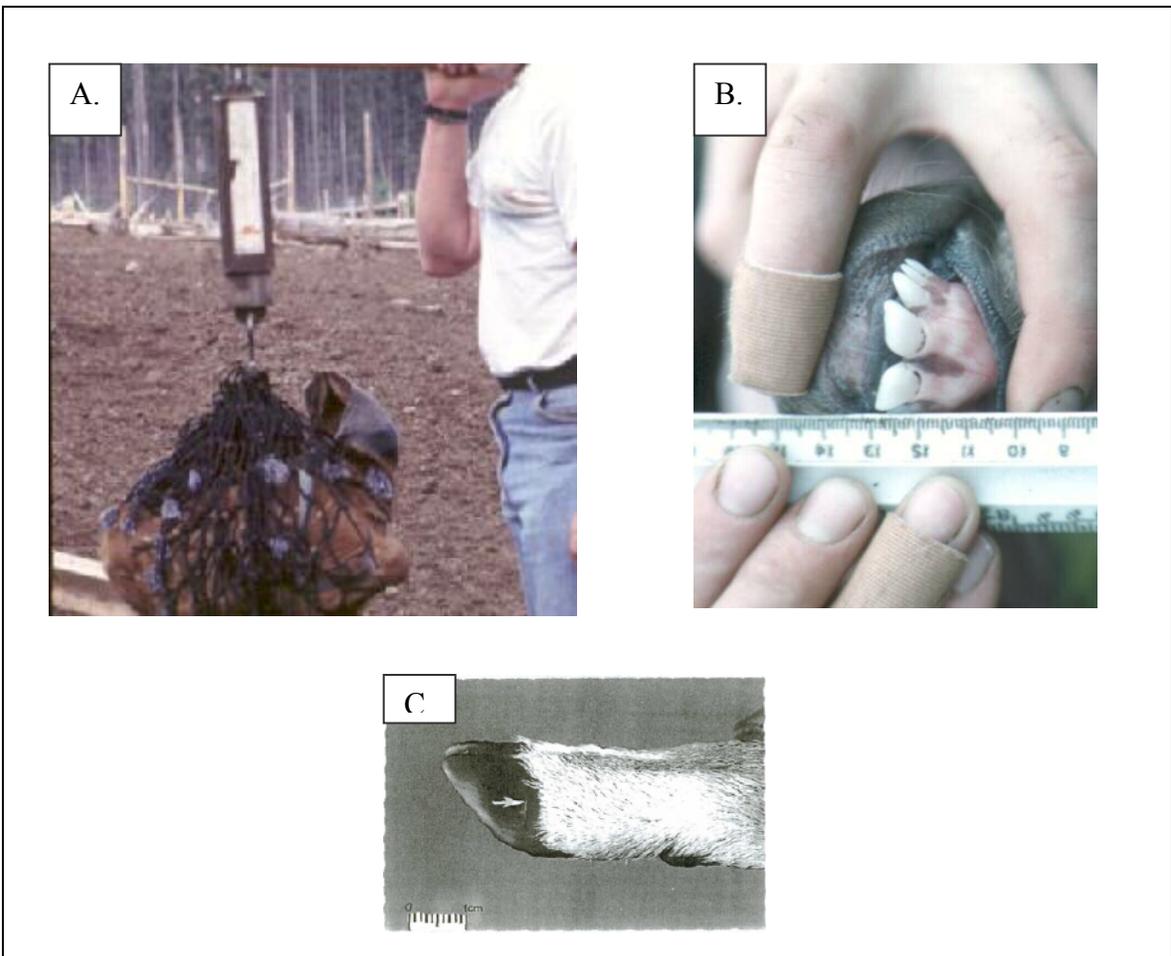


Figure 1. A. Spring scale used to measure elk calves. B: Measurement of outer edge of first incisor. C. Hoof line of elk calf. Arrow points to distance between the leg hairline and an indentation on the hoof. Hagen and Sams used this to predict age of neonatal cervids. Photo from Sams et al. 1996 (white-tailed deer).

SAFG 1996/1997

High

Medium

Low

SAFG 1997/1998

High

Medium

Low

SAFG 1997/1998

High

Medium

Low

Non lactating

WFG 1997/1998

High

Medium

Low

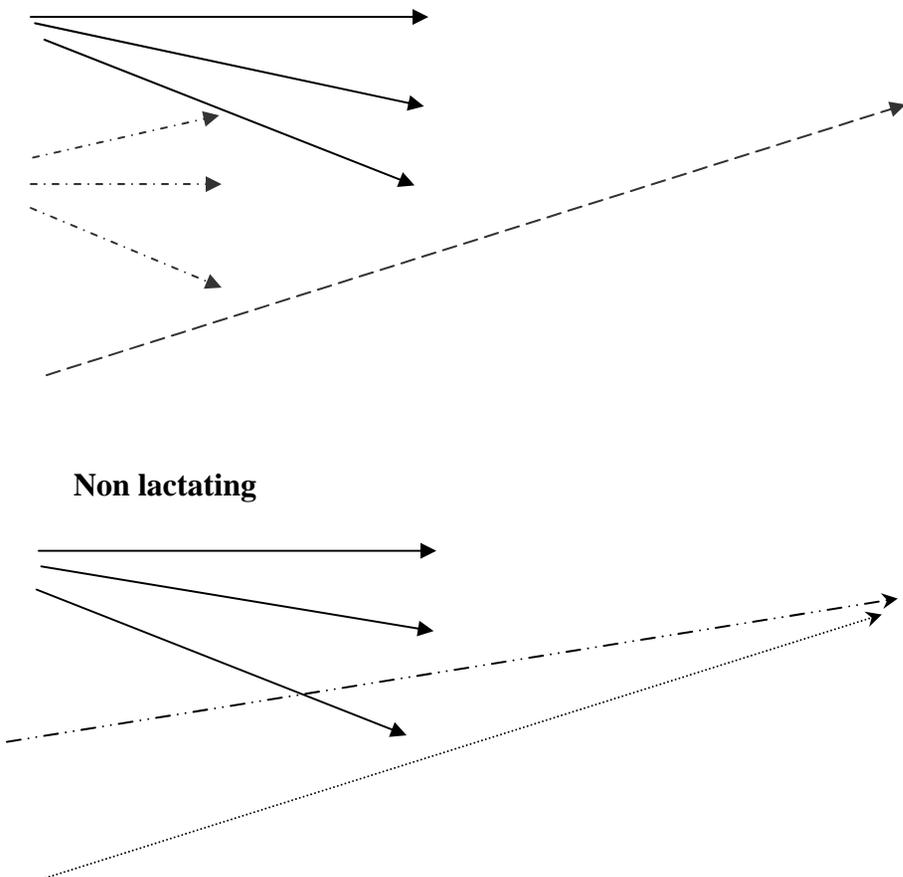


Figure 2. Experimental design used for the pregnant female elk used in nutritional feeding trials at Starkey Experimental Forest and Range, 1996-1998. The elk's offspring were used for aging model construction.

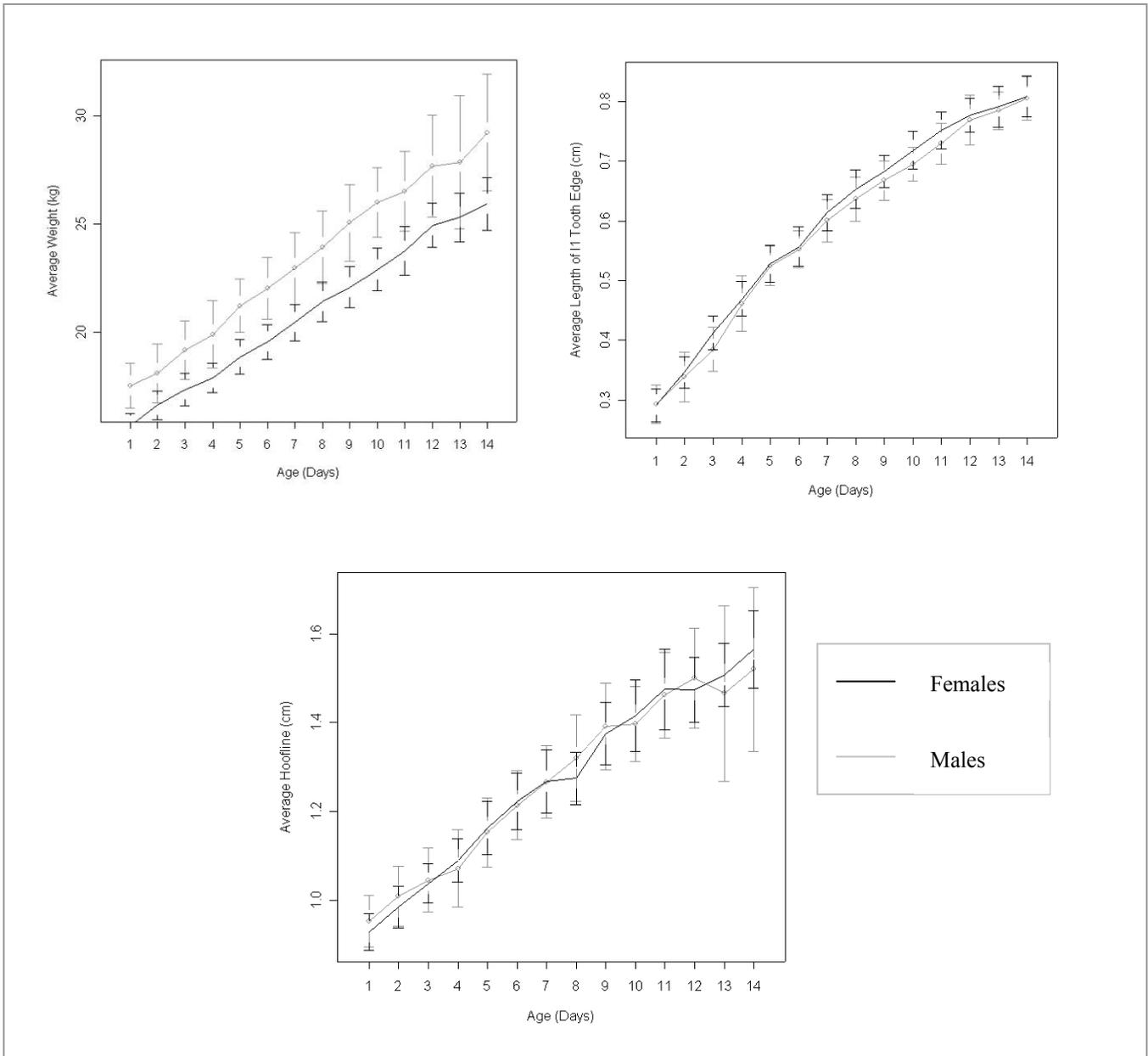


Figure 3. Average weight (kg), tooth edge length (cm), and hoof line length (cm) of Rocky Mountain male and female elk calves at Starkey Experimental Forest and Range, Oregon, 1997-1998.

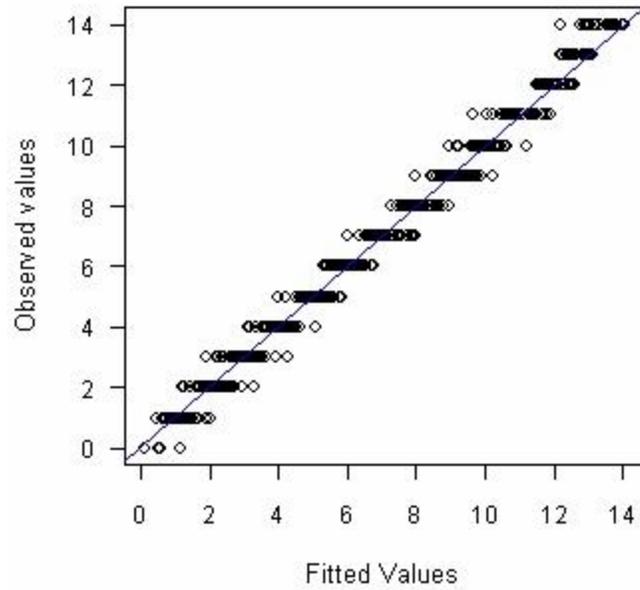


Figure 4. Ages predicted from morphometric mixed effects model vs. ages observed from elk calves, days 1-14, 1997-1998, at the Starkey Forest and Experimental Station, La Grande, OR.

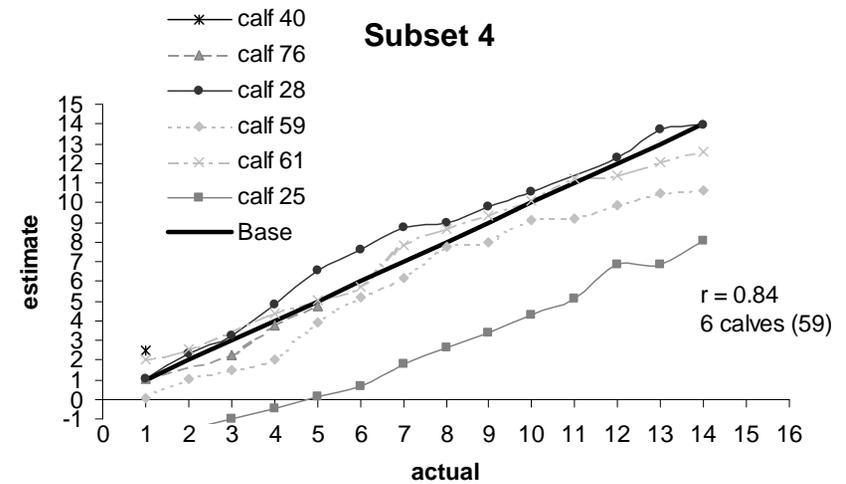
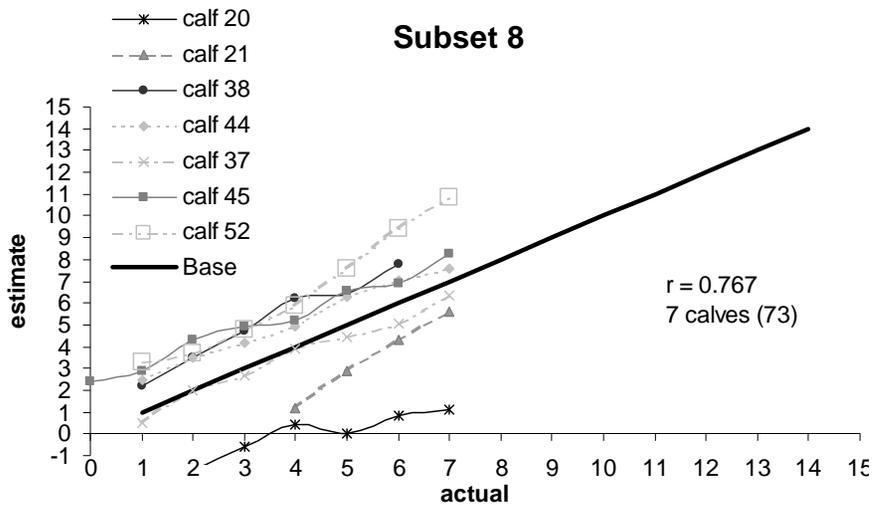
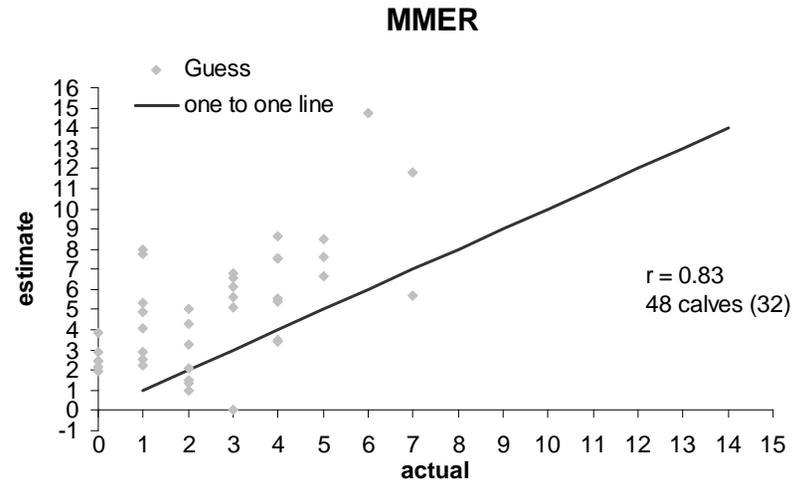
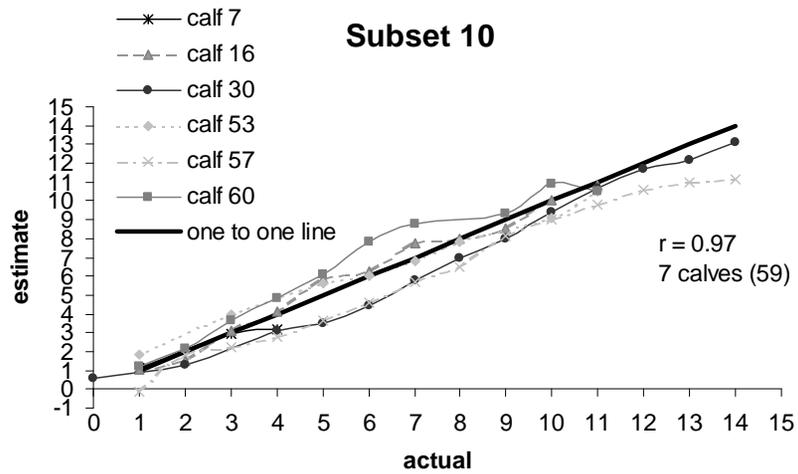


Figure 5. Relationship between known ages of elk calves and predicted ages of elk calves using the linear mixed effects model based on morphological measurements.

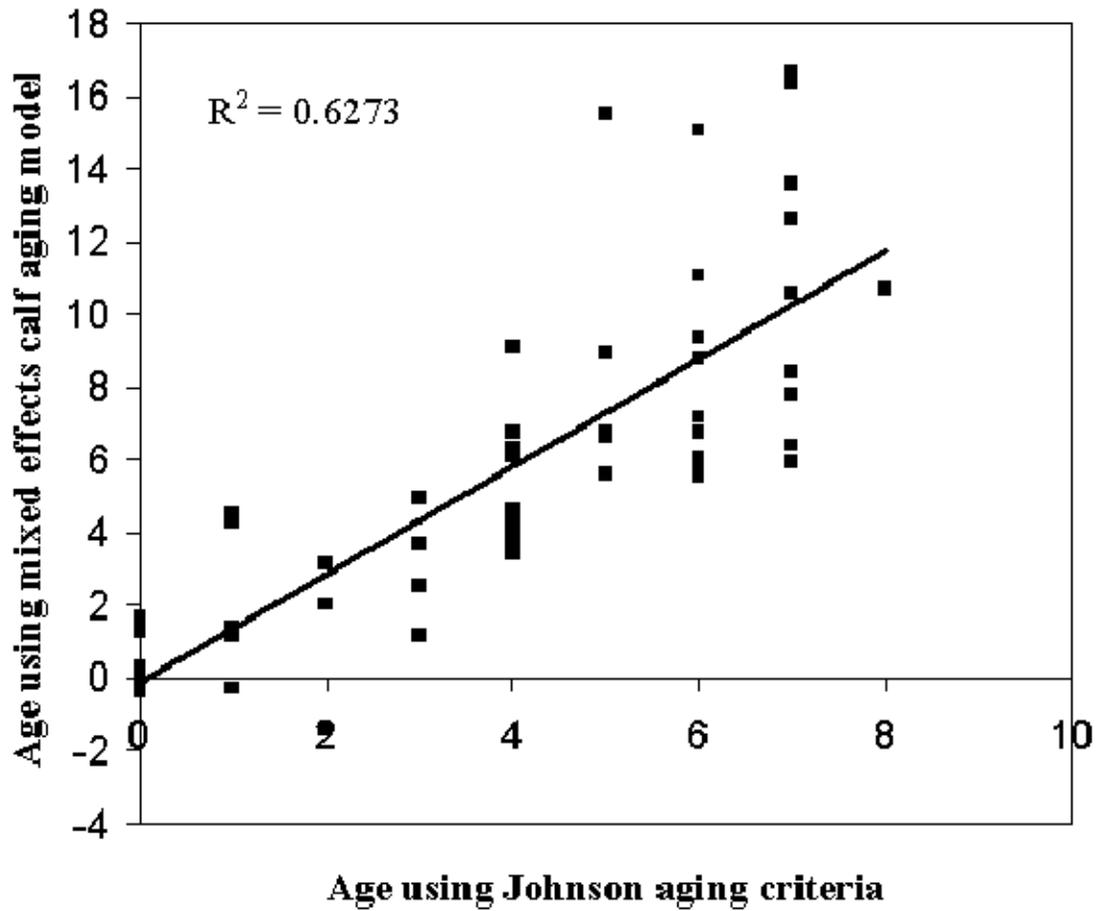


Figure 6. Age predicted using linear mixed effects model compared to age predicted with Johnson's (1951) aging criteria

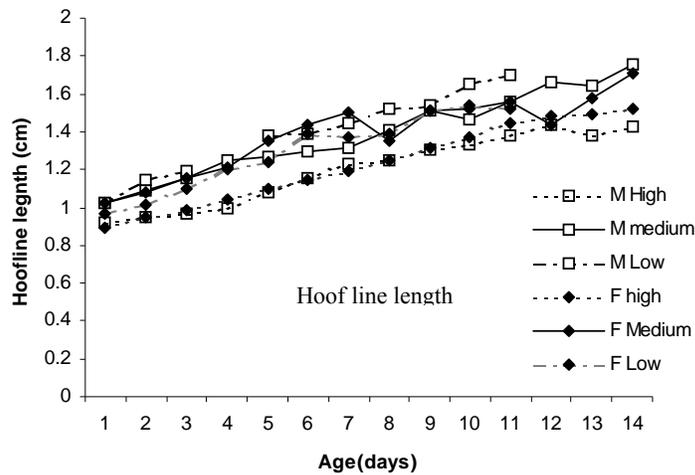
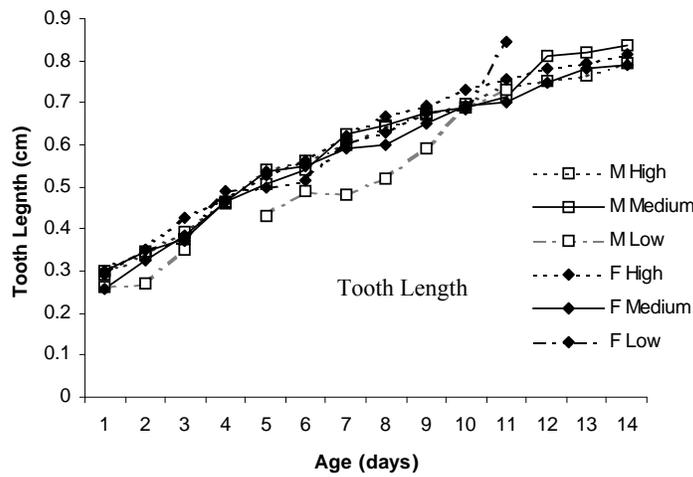
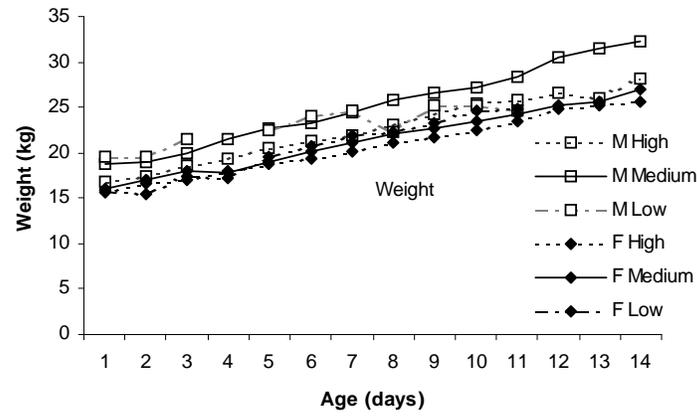


Figure 7. Figures of weight (kg), tooth edge length (cm), and hoof line length (cm) as a function of time for the three summer-autumn nutritional groups from elk calves at Starkey Experimental Forest and Range, 1996-1997.

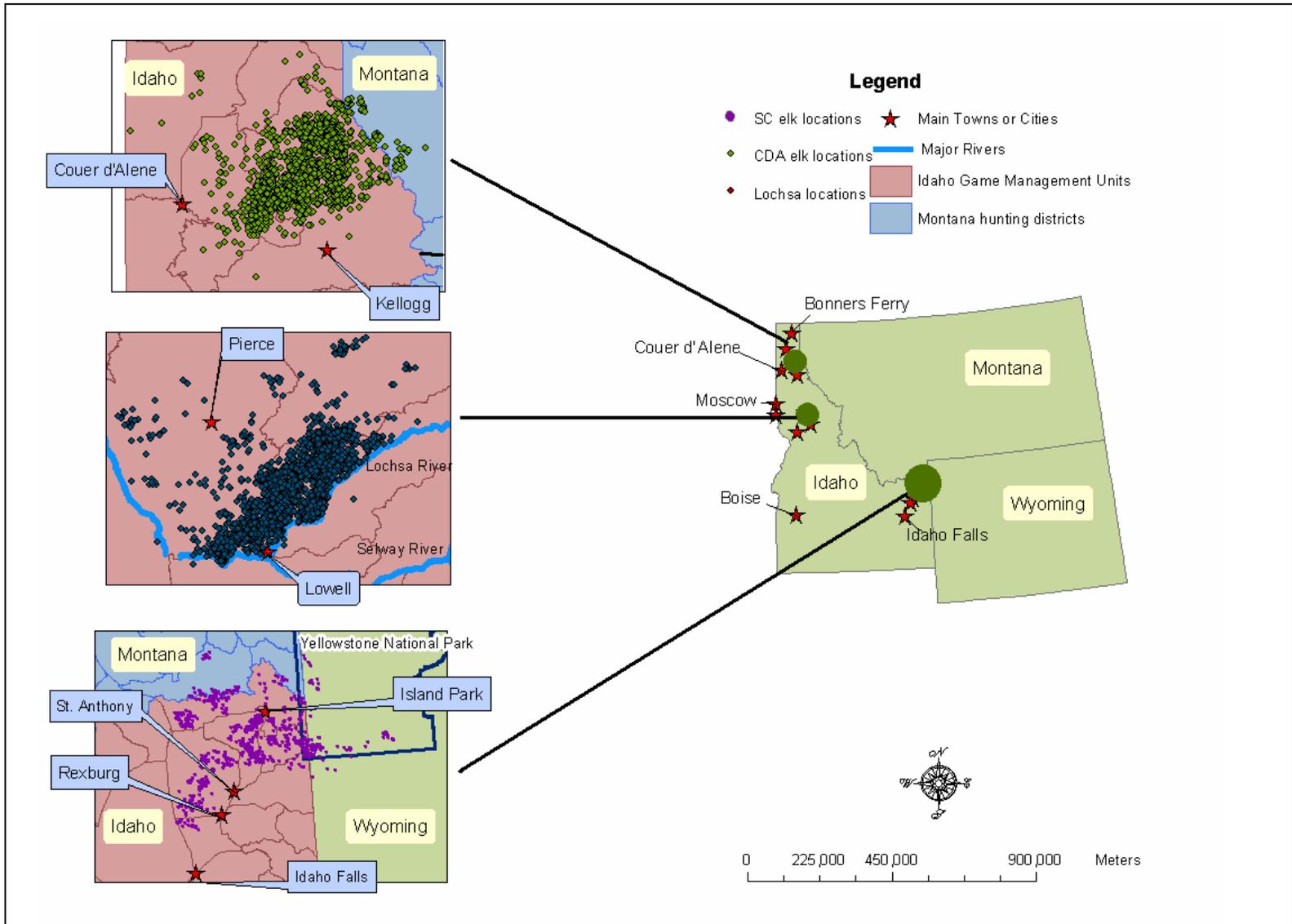


Figure 8. Locations of the three populations of elk (Coeur d'Alene, Lochsa, and Sand Creek) considered for the survival analysis subproject.

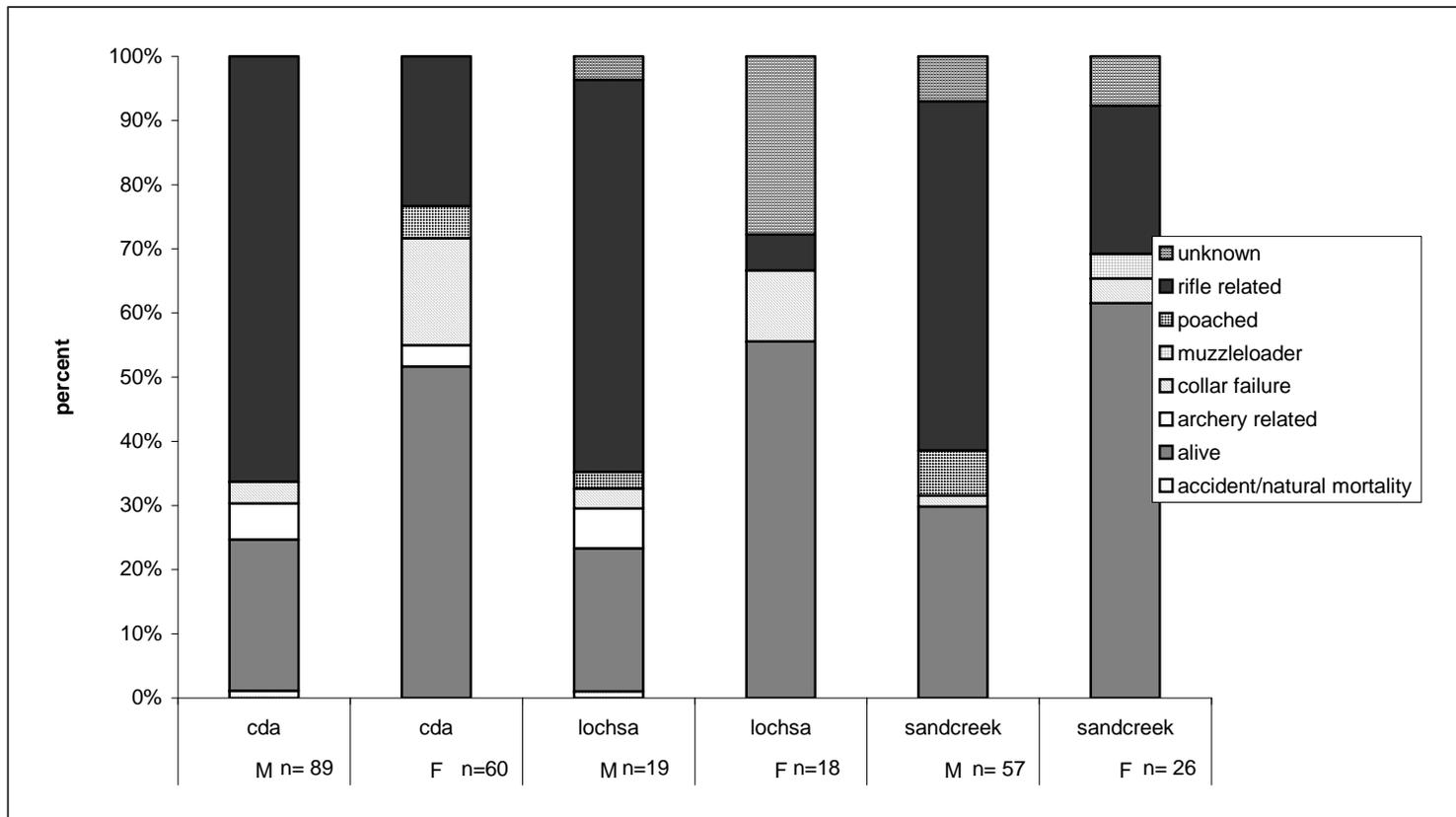


Figure 9. Causes of mortality expressed as a percent for the three populations (Coeur d'Alene, Lochsa, and Sand Creek) between September 1 and November 30 from the survival analysis subproject.

Table 1. Morphological measurements and descriptive characteristics from captive Rocky mountain elk calves *Cervus elaphus nelsoni* at Starkey Forest and Range Experiment Station, Oregon, 1997-1998.

Measurement	Description
Calf age	Age measured in days, 0 being day of birth
Sex	Male or female
Weight	Weight of calf measured using spring scale (kg)
Hoof	Distance from hairline to growth line on hoof (cm) using calipers (Figure 1)
Tedge	Length of I1 tooth taken from the outer edge using calipers (cm)

Table 2. Summer-autumn feeding regimes for cow elk, Starkey Forest and Range Experiment Station, Oregon, 1996 and 1997. CP: Crude protein (percent), GE: kcal of GE/g of food (percent), DDM and DE: kcal of DE/g of food. Table taken from Cook at al. 2004.

Year	Time period	Food type	Feeding level	CP	GE	DDM	DE
1996	Jul-Nov	Pellet	High	15.7	4.315	79.4	3.4
			Low	13.8	4.062	56.5	2.3
		Hay	High	15.5	4.316	61.9	2.7
			Medium	13.6	4.337	56.7	2.5
1997	Jul-Nov	Pellet	Low	8.0	4.333	54.2	2.4
			High	15.9	4.380	83.6	3.7
			Low	14.2	3.997	56.3	2.3
		Hay	High	15.3	4.350	59.1	2.6
			Medium	8.3	4.361	57.7	2.5
			Low	7.8	4.427	51.6	2.3

Table 3. Dry matter (g of DM/kg BM^{0.75}) and digestible energy (kcal of DE/kg BM^{0.75}) for three winter nutritional levels (high, medium, and low) for cow elk at Starkey Forest and Range Experiment Station, Oregon, 1997-1998. Table taken from Cook et al. 2004.

Date	Schedule	Winter feeding level					
		High		Medium		Low	
		DM	DE	DM	DE	DM	DE
11-13-97	Maintenance	82	195	82	195	82	195
12-27-97	Begin treatment	51	121	44	105	36	84
1-28-98	Adjust treatment	47	112	40	95	33	79
2-19-98	Adjust treatment	37	87	31	74	26	61
2-27-98	Adjust treatment	47	112	40	95	33	79
3-6-98	End treatment	67	159	67	159	67	159
3-18-98	Ad libitum	90	212	90	212	90	212
4-5-98	Ad libitum	100	308	100	308	100	308
4-13-98	Ad libitum	105	325	105	325	105	325

Table 4. Current final model for predicting age from morphometric measurements. Summary of SD for mixed effects, parameter estimates for fixed effects, and number of observations and groups used in the analysis.

Model: AIC = 1141.16, n = 609 from 64 calves					
Autocorrelation structure:			Autoregressive (2)		
theta 1:	0.53	theta 2:	0.384		
Random effects					
					SD
Variation attributed to calf intercept					2.76981
Random slope for weight					0.21428
Random slope for tooth					6.23242
Random slope for tooth*tooth					6.34419
Random slope for hoof line					2.19055
Residual error					0.51114
Fixed effects					
	B	SE	DF	t value	p value
Intercept	-10.9524	0.58482	541	-18.7278	<.0001
Weight	0.59197	0.03845	541	15.395	<.0001
Tooth	2.16339	1.35154	541	1.60069	0.11
Tooth*tooth	5.23758	1.36461	541	3.83815	0.0001
Hoof line	1.95301	0.40543	541	4.81709	<.0001
Sex (M)	-0.84101	0.35442	62	-2.37295	0.0208

Table 5. Pearson correlation coefficients between predicted age and actual age for each run of the ten-fold cross validation method.

Sub-sample	R	N	Number of animals
1	0.976	75	7
2	0.800	57	6
3	0.870	51	6
4	0.950	53	6
5	0.907	51	6
6	0.845	59	6
7	0.950	80	7
8	0.768	73	7
9	0.880	51	6
10	0.971	59	7
Mean rho	0.891	609	64
MMRE	0.830	48	32

Table 6. Mean birth weight of elk calves from both wild populations and experimental studies found in the literature.

Author	Location	Parental care	Type of study	Sex	Age of calf	Mean (kg)	SE (kg)	N
Model building set (Starkey)	Oregon	Captive mother	Experiment	Combined	1 day	16.15	0.23	81
				Female	1 day	15.52	0.23	49
				Male	1 day	17.09	0.4	32
Validation set (MMER)	Idaho		Ranch	Combined	1 day	21.52	1.28	8
				Female	1 day	21.68	1.4	7
				Male	1 day	21.36	-	1
Smith et al. 1997	NW Wyoming	Wild mother	Field study	Combined	<24 hours	15.9	0.2 ^c	165
				Female	<24 hours	15.5	0.25	75
				Male	<24 hours	16.2	0.26	90
Cook et al. 1996	National elk refuge	Captive mother	Experiment	Combined	Birth	15.7	0.3	86
	Starkey ERF	Bottle fed		Combined	Birth	14	0.023 ^a	67
Wild et al. 1994	Colorado	Captive mother		Female	<48 hours	15.5	-	1
				Male	<48 hours	17.5	-	1
				Female	<48 hours	16.6	1.2	5
Friedel et al. 1994	Alberta	Bottle fed		Female	<48 hours	16.6	1.2	5
Hudson et al. 1990		Captive mother	Ranch	Combined	Birth	17.7	0.3	1,084
			Experiment	Combined	Birth	17.85	0.57 ^d	12
Robins et al. 1981	Washington			Combined	12 hours	21.2	2.200	7
Thorne et al. 1976	W Wyoming			Combined	Birth	14.7	0.097 ^{a,d}	36
Johnson 1951	SW Montana	Wild mother	Field study	Combined	0-1 day	14.77	0.128 ^a	23
Rush 1932	Montana	-		Combined	-	16.81	2.498 ^b	-

^a SE approximated from range (Ott, 2000:91).

^b SD reported because N is unknown.

^c Birth weight calculated from adjusted means. See (Smith et al, 1997) for description.

^d Averaged over all feeding levels.

Table 7. Comparing daily weight increase from studies in the literature to animals used in model building.

Author	Method	Length of time	Sex	Growth rates (kg/day)	SE	N
Model building set (Starkey)	Captive mother	2 weeks	Both	0.77	0.0004	81
Validation set (MMER)				0.71	0.15	7
Smith et al. 1997	Wild mother	1 week	Female	1.316	-	-
			Male	1.643	-	-
Cook et al. 1996	Captive mother	1 month (July)	Both	0.44	-	-
Friedel et al. 1994		-		0.72	0.01	1,084
Wild et al. 1994		1 month		0.782	-	-
	Bottle fed			0.6235	-	-
Robins et al. 1981	Captive mother			0.7899	0.29855	7
Johnson 1951	Wild mother	2 weeks		0.9	-	16

Table 8. Number of males and females and the years that the studies were conducted for each of the four sample populations for the survival analysis subproject.

Year	Coeur d'Alene		Lochsa		Sand Creek	
	Females	Males	Females	Males	Females	Males
1984	-	-	-	-	26	1
1985	-	-	-	-	17	17
1986	-	-	6	30	8	20
1987	-	-	7	38	4	32
1988	10	11	9	45	2	20
1989	23	20	9	36	-	-
1990	26	20	13	41	-	-
1991	25	25	6	47	-	-
1992	26	27	3	54	-	-
1993	26	27	1	68	-	-
1994	21	30	1	31	-	-
Total	157	160	55	390	57	90
Total number of individual animals	60	89	18	193	26	57

Submitted by:

Peter Zager

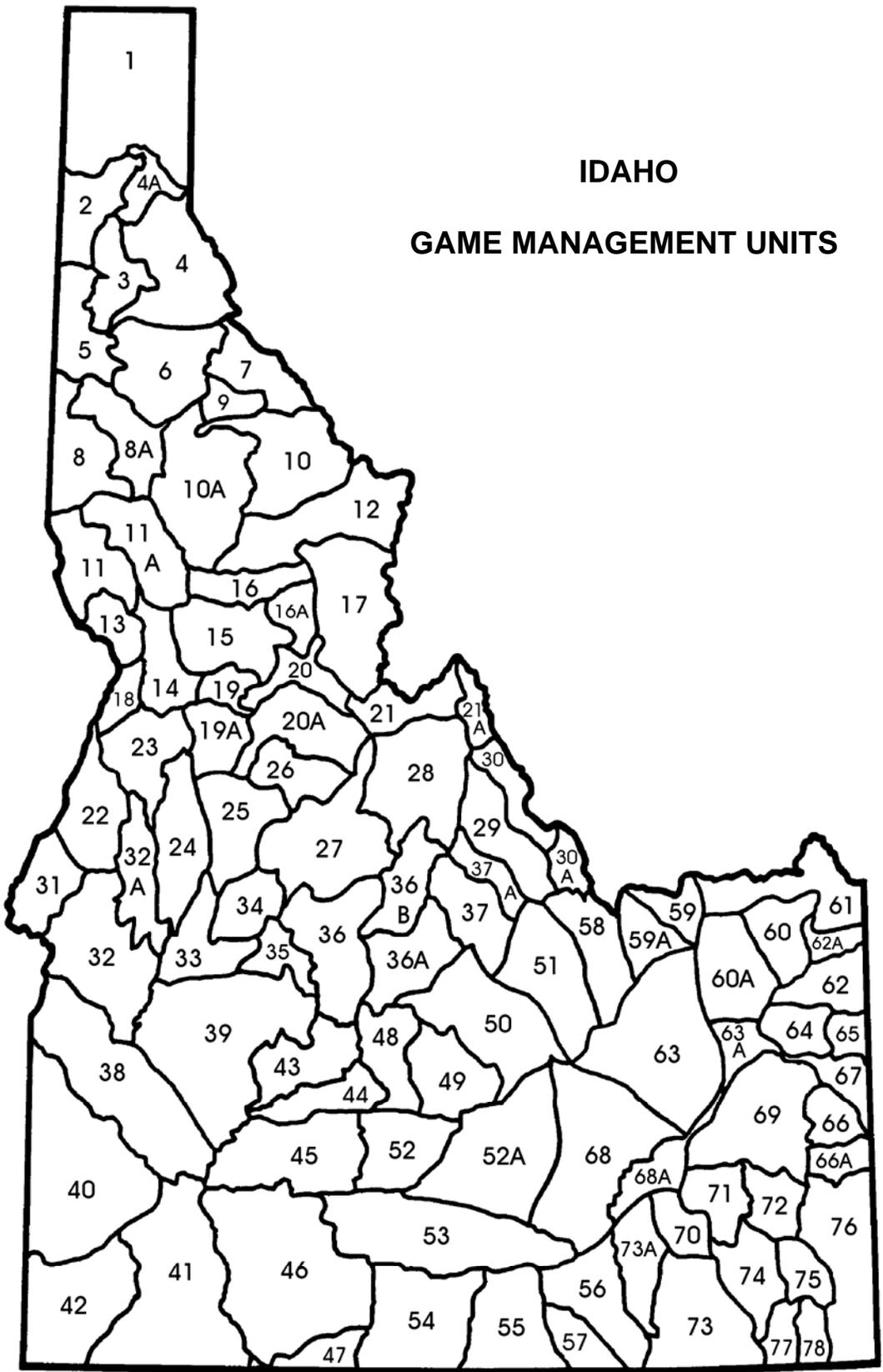
Principal Wildlife Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Dale E. Toweill
Wildlife Program Coordinator
Federal Aid Coordinator

James W. Unsworth, Chief
Bureau of Wildlife



IDAHO

GAME MANAGEMENT UNITS

FEDERAL AID IN WILDLIFE RESTORATION

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sale of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. The Idaho Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be responsible, ethical hunters. Seventy-five percent of the funds for this project are from Federal Aid. The other 25% comes from license-generated funds.

