Criteria to improve age classification of antlerless elk

Bruce L. Smith and Trent L. McDonald

Abstract Wildlife managers routinely survey age and gender compositions of elk (*Cervus elaphus*) during winter to assess population demographics and to prescribe and evaluate harvest strategies. We measured precision of replicated field classifications of antlerless elk conducted during 1996–1999 on the National Elk Refuge, Wyoming. We found classification discrepancies of 14% for elk calves. Next we examined morphometrics collected from 349 individuals from 2 populations of elk in northwest Wyoming. A model constructed from the combined data set accurately predicted the ages of 93% of calves, yearlings, and adults. There were age-specific, quantitative differences in head morphology among calf, yearling, and adult elk. Using quantitative differences and photographic images, we developed illustrations and descriptions that can help observers distinguish calves from older elk. Use of these guides should improve indexing of population recruitment, based on calf:cow ratios, that wildlife mangers use to model population growth and to design annual harvests.

Key words age classification, body mass, *Cervus elaphus,* elk, management, population surveys, recruitment

State and federal wildlife managers routinely classify elk (*Cervus elaphus*) by age and gender during aerial and ground-based population surveys to assess population demographics. These surveys are generally conducted when elk are concentrated on winter ranges. Winter surveys provide more representative estimates of age and gender composition of populations than surveys made during other seasons because a larger proportion of populations are observed in winter (Lovaas et al. 1966, Samuel et al. 1987, Carpenter 2000). In unhunted populations, recruitment rates derived from classification surveys are used to measure population-regulating processes (Houston 1982, Coughenour and Singer 1996). In hunted populations, classifications help to assess effectiveness of hunting season designs on harvest of age-gender classes, to formulate upcoming seasons, and to predict population response to harvest strategies through age-structured simulation modeling (Anderson 1991, White 2000, Raedeke et al. 2002).

Considering the widespread dependence on classification surveys by state, federal, and provincial agencies to monitor and manage elk populations (Raedeke et al. 2002), criteria used to distinguish age classes of antlerless elk are surprisingly absent in the literature. Aging techniques presumably are learned on the job from experienced coworkers. Documentation of the range of morphological variation, potential for misclassification, and expected precision of age classifications of elk would clarify the limitations of composition data and provide a basis for instructional materials in classification methods.

Wildlife managers routinely classify elk into 4 categories: calves, females, yearling males, and mature males (Taber et al. 1982). Calves are young of the year, females are ≥1-year-old, yearling males carry antlers lacking brow tines, and mature males are ≥2 years old and have branched antlers with brow tines. Classification of yearling males provides information on effects of hunter harvest and potentially

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survival of the previous year's calves (assuming a 50:50 sex ratio of calves). To estimate survival of female calves to yearling age when yearling females are not classified, one must assume that female survival is similar to survival of males. This is not always true for calves (Smith and Anderson 1998), and harvest regulations or hunter preference may favor removal of yearling males over yearling females from a population (Peek et al. 1982, Carpenter 2000).

In addition to measuring survival, managers may wish to distinguish yearling females because they are far less fecund than ≥2-year-old females (Kimball and Wolfe 1979, Taber et al.1982, Smith and Robbins 1994). However, yearling females are not classified separately during winter population surveys, except rarely by very skilled observers at very close range. Body size of yearling females is variable and intermediate between that of older females and calves (Dean et al. 1976), and there is considerable risk of misclassifying yearling females on this basis alone.

Wildlife managers consider calves readily distinguishable from older antlerless elk in winter. Nevertheless, skilled observers apparently err in classifying calves even at close range (<50 m), as we shall see later. Without evaluating how reliably calves can be discriminated from older antlerless elk, accuracy of winter calf:cow ratios and inferences about productivity and recruitment are problematic. Thus, we evaluated apparent accuracy of winter classifications of elk in northwest Wyoming and developed guidelines to distinguish among age classes of antlerless elk.

Study area

This study encompassed winter feedgrounds of the Jackson and Afton elk herds in northwest Wyoming. State and federal wildlife managers feed 70% of the Jackson herd on the National Elk Refuge (NER; elevation = 1,890 m) adjacent to the town of Jackson, Wyoming, and 3 feedgrounds 16–27 km east of NER in the Gros Ventre River basin (elevation = 2,225 m; Smith 2001). Jackson received 420 mm precipitation annually and mean January temperature was -9.3°C (National Oceanic and Atmospheric Administration 1970–1986).

The Afton herd is fed in winter at the Grey's River and Forest Park feedgrounds, located 42 and 55 km, respectively, south of Jackson, Wyoming. Measurements were collected from elk at the Grey's River feedground (elevation = 1,750 m). Boyce (1989), Smith (2001), and Wyoming Game and Fish Department (2000 [Region 1 Annual Big Game Unit Reports, 1999, Cheyenne, Wyoming, unpublished report]) described these migratory elk herds and the environment they occupy.

Methods

Each February, state and federal wildlife managers count and classify elk distributed along feed lines at supplemental feeding sites on the NER (Figure 1). Two long lines of pelleted alfalfa are spread on the ground about 50 m apart. Feed trucks then pass slowly between these lines as 2 observers on each side of the truck independently count elk calves. Other observers count yearling males, adult males, and total numbers of elk. State and federal agency personnel with ≥5 years experience count calves. Thus, the classification counts are replicated independently from distances of 20–35 m (Smith and Robbins 1994).

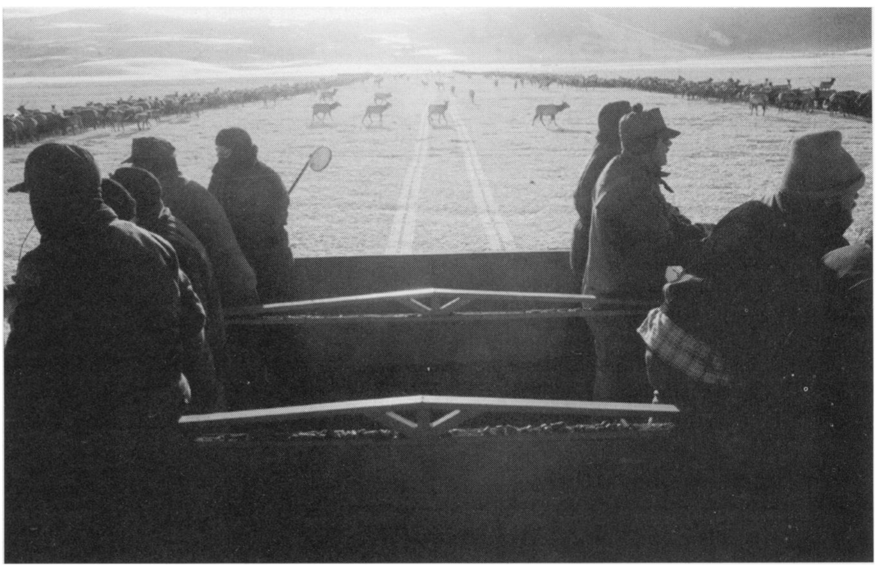

Figure 1. The annual elk classification count is conducted from feed wagons on the National Elk Refuge, Wyoming, each February by state and federal wildlife managers. Photo by Angus Thuermer, *Jackson Hole News*.

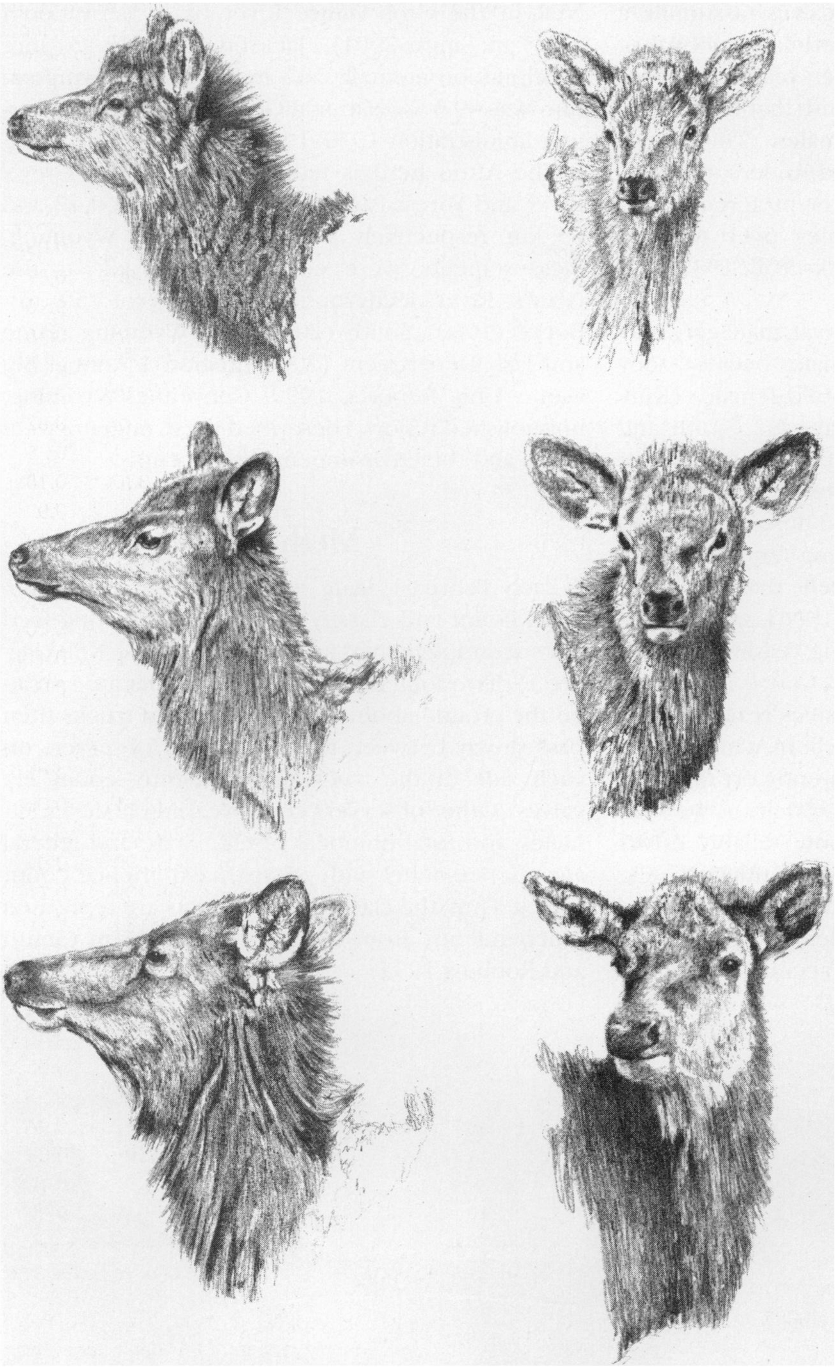

Figure 2. Profile and frontal views of a representative calf (top), yearling female (center), and adult female elk (bottom) during late fall–winter.

The length and shape of the head are recognized generally as diagnostic in separating calves from older antlerless elk. To characterize these differences, we measured morphological characteristics of 263 antlerless elk from the Jackson elk herd during October 1991–March 1997. Of these, hunters harvested 127 elk during late October to mid-December. Another 136 elk had died on the NER during December–April, were immobilized on the NER, or were captured in corral traps on the NER and Gros Ventre feed grounds during February and March.

We measured length of each elk's rostrum, interorbital width, and right ear length with retractable steel tapes. Rostral length was the straight-line distance from the anterior corner of the eye to the tip of the nose. Ear length was the distance from the tip of the ear to the bottom of the ear opening. Interorbital width was the distance between the outer edge of the orbits.

We obtained the same measurements from 89 additional elk of the Afton herd trapped at the Grey's River feed ground. Relocations of ear-tagged, neck-banded, and radiocollared elk indicate <1% interchange between the Jackson and Afton elk herds (Boyce 1989, Smith and Robbins 1994, Smith and Anderson 2001).

We wanted to learn why yearlings were sometimes misclassified as calves (and calves as yearlings) and whether yearlings were distinguishable from females ≥2 years old. To do so, we used one-way analysis of variance and Tukey's post hoc tests to examine differences in all 3 morphological measurements among calves, yearling females, and females ≥2 years old (Sokal and Rohlf 1981). Based on means of each variable measured and photographs of elk of known age, we illustrated frontal and profile views of calves, yearling females, and older females (Figure 2).

We conducted stepwise discriminant analysis with the SAS procedure STEPDISC (SAS Institute Inc. 1999) to compute accuracy of discriminating among calf, yearling, and adult elk from measurements of rostral length, interorbital width, and ear length. Stepwise analysis assumed that the vectors of body measurements taken from each individual were distributed independently and identically as 3-dimensional normal random vectors (Goldstein and Dillon 1978). We used the full data set of 349 individuals (352 minus 3 elk from the Jackson herd lacking ear length measurements) in stepwise discriminant analysis. We set both α_{enter} and α_{exit} at 0.15 in the stepwise procedure. This liberal variable selection suited our desire to include any of the 3 morphometrics that may improve discrimination of ages, particularly yearling and adult.

Following stepwise variable selection, we completed 3 separate discriminant analyses of elk morphometrics from: 1) the Jackson herd, 2) the Afton herd, and 3) both herds combined. In addition, we classified elk from the Afton herd based on the Jackson herd discriminant analysis and we classified elk from the Jackson herd based on the Afton herd discriminant analysis. In each analysis, equality of the 3 within-age-class covariance matrices was tested to assess whether linear or quadratic discriminant analysis was indicated. The test for homogeneity of within-age-class covariance matrices was significant at $\alpha=0.1$ in all cases, so we conducted quadratic discriminant analysis (Morrison 1976).

We summarized the discriminant analyses by tallying numbers of elk predicted to be in each age class. We estimated probabilities of misclassification in 2 ways. We used cross-validation, whereby each observation was classified using a discriminant function computed on all other observations in the same data set. We also assessed classification errors by classifying each observation in one herd's data set from a discriminant analysis developed from data of the other herd. We used the SAS procedure DISCRIM to perform these analyses (SAS Institute Inc. 1999).

Table 1. Replicated counts of elk calves made by observers on feed trucks on the National Elk Refuge, Wyoming, during annual classification surveys, February 1996–1999. Two observers on each side of a feed truck independently counted elk calves.

Year	Feedground	Side of vehicle	Total elk counted	Number of calves counted/ observer	Mean difference[a]
1996	Shop	Right	171	40/38	0.05
1996	Shop	Left	976	301/280	0.07
1996	Nowlin	Right	2,025	201/222	0.10
1996	Nowlin	Left	992	118/138	0.16
1996	Poverty Flats	Right	335	48/50	0.04
1996	Poverty Flats	Left	1,263	102/139	0.31
1996	McBride	Right	1,955	192/80	0.82[b]
1996	McBride	Left	2,287	239/343	0.36
1997	Shop	Right	1,007	395/330	0.18
1997	Shop	Left	155	62/63	0.02
1997	Nowlin	Right	3,176	382/536	0.34
1997	Nowlin	Left	825	124/133	0.07
1997	Poverty Flats	Right	1,518	118/128	0.08
1997	Poverty Flats	Left	937	74/82	0.10
1997	McBride	Right	1,625	66/100	0.41
1997	McBride	Left	1,493	42/45	0.07
1998	Shop	Right	218	44	
1998	Shop	Left	0	0	
1998	Nowlin	Right	991	149/151	0.01
1998	Nowlin	Left	961	133/131	0.02
1998	Poverty Flats	Right	1,283	96/120	0.22
1998	Poverty Flats	Left	988	183/200	0.09
1998	McBride	Right	2,186	166/204	0.21
1998	McBride	Left	1,807	120/143	0.17
1999	Shop	Right	1,157	347/287	0.19
1999	Shop	Left	685	254/270	0.06
1999	Nowlin	Right	356	51/57	0.11
1999	Nowlin	Left	466	22/33	0.40
1999	Poverty Flats	Right	1,746	127/138	0.08
1999	Poverty Flats	Left	395	58/61	0.05
1999	McBride	Right	1,486	56/58	0.04
1999	McBride	Left	921	21/19	0.05
1996-99	Grand $\bar{x}$				0.14
1996-99	SE				0.02

[a] Difference in number of calves counted divided by the $\bar{x}$ no. calves counted.

[b] Agitated behavior of the elk led to poor observational conditions, high error rate, and exclusion of this datum point from calculation of the grand $\bar{x}$ error.

Results

Classification findings

Observer differences in replicated field classifications of elk calves averaged 14% (Table 1). Precision of these classifications was correlated inversely with total number of elk classified ($R^2_{1,28}=0.22$, $P=0.009$), but not with number of calves classified ($P=0.30$). When the group sizes of elk classified were <1,000, observer differences in calf classifications averaged <9%.

Rostral length, ear length, and interorbital width differed ($P \leq 0.001$) among calves, yearlings, and adults (Table 2). In that order, all 3 variables entered the discriminant function during stepwise

Table 2. Means ($\bar{x}$), standard errors (SE), ranges, and 1-way analysis of variance (ANOVA) results of measurements (mm) taken from 263 calf, yearling female, and adult female elk of the Jackson herd during fall and winter, 1991–1997.

Character measured	Statistic	Animal age class: Calf	Yearling	Adult	Test result (P) [a]: Calf:yearling	Yearling:adult	Calf:>calf
	n	70	68	125			
Rostral length							
	$\bar{x}$	18.6	23.1	27.1	<0.001	<0.001	<0.001
	SE	0.17	0.18	0.13			
	Range	15–22	20–26	23–30			
Interorbital width							
	$\bar{x}$	13.9	16.0	17.8	<0.001	<0.001	<0.001
	SE	0.13	0.13	0.10			
	Range	11–15	14–18	15–21			
Ear length							
	$\bar{x}$	17.7	19.6	20.3	<0.001	<0.001	<0.001
	SE	0.13	0.13	0.10			
	Range	14–20	18–22	18–22			

[a] Probabilities of pairwise Bonferroni post hoc tests.

variable selection, based on their relative contribution to the model. Rostral length accounted for 86% of the variation among the 3 age classes.

Based on results of the stepwise procedure, we used all 3 variables in subsequent discriminant analyses. Classification capability varied among the 3 models at 80-99% of calves, 84-86% of yearlings, and 86-93% of adults. The model generated from the combined Jackson and Afton data provided the greatest accuracy (Table 3). The estimated probability of age misclassification by the 3 variables ranged from 0.01 to 0.37 during cross validation of the same data set and from 0.13 to 0.30 when a discriminant function built on one herd's data was used to classify elk in the other herd (Table 4).

In addition to rostral length, ear length, and interorbital width, we initially measured the distance between the base of the ears and neck circumference of each elk. However, the former measurement was too dependent on the position of the ears to be unbiased, particularly on immobilized or dead animals. Although neck circumference differed among calves, yearling females, and females ≥2 years old ($P \leq 0.001$), this measurement was not considered useful to evaluate age of animals in the field because true neck circumference was confounded by the mane.

Table 3. Cross-validated classification results from discriminant analyses conducted on data from the Jackson herd, the Afton herd using the discriminant analysis from the Jackson herd, and the combined Jackson and Afton herds.

Herd	Known Age class	Sample size	Predicted age class (%): Calf	Yearling	Adult
Jackson	Calf	68	67 (98.5)	1 (1.5)	0
Jackson	Yearling	68	5 (7.4)	58 (85.2)	5 (7.4)
Jackson	Adult	124	0	9 (7.3)	115 (92.7)
Afton	Calf	56	45 (80.4)	11 (19.6)	0
Afton	Yearling	19	1 (5.3)	16 (84.2)	2 (10.5)
Afton	Adult	14	0	2 (14.3)	12 (85.7)
Combined	Calf	124	123 (99.2)	1 (0.8)	0
Combined	Yearling	87	5 (5.8)	75 (86.2)	7 (8.0)
Combined	Adult	138	0	10 (7.2)	128 (92.8)

Description of age classes

Calves. Elk calves have shorter, narrower heads than older elk (Figure 2). The juvenile appearance of calves results from their significantly shorter rostrum, their most discriminating feature relative to yearlings (Table 2). In profile, the rostrum appears concave or "dished," as Murie (1951) depicted in skull illustrations. This appearance results partly from the topknot of hair on the crown of the head (Figure 2). However, rostrums of particularly large calves have a straighter appearance in profile similar to yearlings. Relative to head length, neck length is similar in calves and older elk, but absolute

Table 4. Estimated probabilities of age misclassification of elk from the Jackson and Afton herds, Wyoming, based on discriminant analyses.

Elk herd	Probability of age class misclassification: Calf	Yearling	Adult	Total
Jackson herd	0.02	0.15	0.07	0.08
Afton herd	0.02	0.37	0.14	0.11
Combined Jackson and Afton herds	0.01	0.14	0.07	0.07
Afton herd based on Jackson analysis	0.20	0.16	0.14	0.16
Jackson herd based on Afton analysis	0.13	0.15	0.30	0.16

length of the neck is noticeably shorter in calves than older animals. Like rostral length, this is a function of the incomplete skeletal development of calves. The mane hair appears shorter on calves than on older elk and along the back of the neck may stand more erect than on older animals.

Yearling females. Yearlings were most often misclassified in discriminant analyses, somewhat more often as adults than as calves (Table 3). All 3 morphological features of the head are intermediate between calves and females ≥2 years old, as the skull is still growing. Frontally, the width of the head more closely resembles adults than calves (Table 2). Although in profile the rostrum is nearly straight like adults, most yearlings retain a slightly dished facial appearance (Figure 2). The topknot is less prominent than on calves and, in combination with greater interorbital width and rostral length and a smoother mane, leads to yearlings resembling adults more than calves.

Adult females. By their third winter, females have achieved nearly complete development of the skull. Subtle differences in musculature and pelage produce hints about the relative age of adult females, but all adults have longer, straighter rostrums than calves and most yearlings. A broad head, full mane, and slightly smaller ears, relative to the mass of the head, are distinguishing features (Figure 2).

An observer may be tempted to use body size to decide the age of questionable animals. Although their smaller body size helps distinguish calves from older elk, the suite of morphological attributes described and illustrated here are more definitive than body size. Body mass extremes of yearlings approximate those of large calves and small adults (Table 5).

Table 5. Body mass (kg) of elk trapped from the Jackson herd at the National Elk Refuge, 1971–1973, and from the Afton herd at the Grey's River feed ground, 1967–1974.

Elk herd	Age	Sample size	Body mass $\bar{x}$	SE	Range
Jackson[a]	Calf	22	110.7	3.44	68.9–138.3
	Yearling female	16	161.6	3.11	136.1–179.6
	Adult female	99	224.8	2.10	165.5–273.5
Afton[b]	Female calf	84	100.8	1.71	
	Male calf	89	111.6	1.63	
	Yearling female	84	163.0	1.79	
	Adult female	56	219.2	2.89	

[a] Data from Smith, B. L., and R. L. Robbins. 1984. Pelleted alfalfa hay as supplemental winter feed for elk at the National Elk Refuge. Unpublished report, National Elk Refuge, Jackson, Wyoming, USA.

[b] Data from Dean et al. (1976).

Discussion and management implications

Our discriminant analysis models correctly classified calves, yearlings, and adults in 92% of elk from Jackson and 84% of elk from Afton, using the Jackson herd model (Table 4). Classification results, including cross validation, were weakest for the Afton herd, raising concern that a model developed for one herd may not be appropriate for other herds. Small sample sizes from the Afton herd may have contributed to the results as much as interherd variation. It is reassuring that a model constructed from the combined Jackson and Afton data produced the best classification results (<7% misclassification rate for all 3 age classes).

Yearlings were most often misclassified. Using the Jackson herd model, yearling females were discriminated from older females and from calves 85% of the time for the Jackson herd and 84% for the Afton herd (Table 3). Under optimum field conditions, we were 90% accurate in selecting only yearling females for deployment of radiocollars at the NER during February and March 1994–1997. Of 40 animals immobilized from large, free-ranging herds, 36 yearling females, one male calf, and 3 2-year-old females were captured by immobilization with a dart gun from feed trucks when only yearling females were sought. We do not recommend separating yearlings from adults during routine population surveys, because misclassification of yearling females would likely be high under most field conditions.

Field classifications during 1996–1999 indicated a 14% discrepancy between replicated classifications of elk calves. Because true ages of these free-ranging animals were unknown, the accuracy of classifications by experienced observers was uncertain. By comparison, discriminant analyses produced expected misclassifications of 1.5% of calves as older animals and 7.4% of older animals as calves in the Jackson herd and 0.8% and 5.8%, respectively, in the combined Jackson and Afton herds (Table 3). These error rates result from using just 3 morphometrics to evaluate and assign class membership (calf or older).

The 14% mean discrepancy in field classifications of calves suggests that assumptions drawn from elk classifications are flawed by observer error, probably to a greater degree than generally acknowledged. Under field conditions, several factors may contribute to classification error. Similarity of features of very large calves and small yearling females will inevitably confound classification of some animals. Inadequate frontal and profile views of each animal may produce erroneous class assignments. Individual observer knowledge and experience, which we seek to improve, is an unmeasured source of classification error. Finally, we found declining precision of calf classifications with increasing group size, but this may be of less significance among elk populations that are not artificially concentrated at feed grounds. Contrarily, feed-ground elk were classified from exceptionally close range compared to most ground and aerial surveys.

In contrast to the limitations of our mathematical modeling, observers may note additional information available in the field—such as the concave facial profile of calves, pelage appearance, and maternal-offspring behavior—that should enhance classification efficiency. The descriptions and illustrations in this guide may improve observers' skill during field classifications by providing specific characteristics to note and visual images of the age classes to compare. We suggest testing the training value of these classification tools during field trials of known-age animals or during simulation trials such as those previously conducted for mountain goats (Smith 1988).

Wildlife professionals frequently classify elk from aircraft, rather than from the ground, to maximize efficiency and to access large samples of populations. Accuracy of classifications obtained from aerial versus ground surveys will depend on training and experience of observers; class and capability of aircraft used; proficiency of the pilot; distance, angle, and duration of observation; and environmental conditions (Samuel et al. 1987). Biologists largely rely on rostral length and body size to distinguish calves from older antlerless elk during aerial surveys. A discriminant analysis of the Jackson herd data, that used only rostral length as an independent variable, distinguished 95% of calves from antlerless elk $\geq$1 year old. Error rate increased to 11% for the Afton herd based on the discriminant analysis of the Jackson herd. Trained and experienced field personnel may achieve similar accuracy in calf:cow ratios. Errors in counting the total numbers of cows and calves in each group of elk encountered also influence accuracy of classifications. We caution population biologists and wildlife managers who formulate models, decisions, and management programs from these data that classification surveys provide only an approximation of truth.

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