AGE-RELATED ANTLER CHARACTERISTICS IN AN INTENSIVELY MANAGED AND NUTRITIONALLY STRESSED MOOSE POPULATION

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ABSTRACT: We studied age-related antler characteristics of moose (*Alces alces*) in Alaska Game Management Unit 20A (during 2007–2010) because of concerns about poor antler development given the population's high density and unusually low nutritional status. A comparative study was conducted in and near our study area in the early 1970s, when moose density was lower and nutritional status was moderate. Poor antler development was an important concern for 2 reasons: 1) low annual recruitment of bull moose into the harvestable 50-inch (127-cm) antler class in the study area might restrict local harvest when the "Intensive Management" harvest objective was to specifically reduce moose density, and 2) retarded antler growth in yearling and 2-year-old bulls could bias bull:cow and yearling:cow ratios. Regression analysis of antler spread over age indicated that average antler spreads of 50 inches (127 cm) occurred when bulls reached an estimated age of 6.0 years. When using corrected annuli counts of known-age animals, bulls reached antler spreads of 50 inches (127 cm) at 5.6 years of true age in the 1970s versus 6.2 years in this study. We surmised that the difference of <1 year was not a significant management concern, particularly given the wide variation in antler spread in each age class. As a result, we retained a strategy that restricted harvest largely to bulls with antler spreads ≥50 inches (127 cm). During low-level aerial surveys, 22% (11/51) of known-aged, radio-collared yearling bulls, had spiked antlers ≤3 inches (7.6 cm) in length, which likely resulted in their misclassification as females during standard surveys. Presumably, 19% (8/43) of known-age, 2 year-old bulls would probably be misclassified as yearling bulls based solely on brow and main palm separation, the primary characteristic used to distinguish between yearling and 2 year-olds. When antler spread and antler length were used as primary aerial classification criteria, we correctly classified all known-aged, 2 year-old bulls. We recommend survey personnel be trained to scrutinize subadult moose to reduce the likelihood of misclassifying yearling and 2 year-old bulls with retarded antler growth in high-density, nutritionally stressed moose populations.

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Between 1997–2005, moose (*Alces alces*) in Alaska Game Management Unit 20A (Unit 20A, Fig. 1) exhibited the lowest nutritional status documented for noninsular, wild moose in North America, including 14 other Alaskan populations. Boertje et al. (2007) based the low nutritional status on relatively low reproductive rates, low body weights of short-yearlings, and high browse utilization.

Unit 20A moose have been intensively managed and studied resulting in 12 publications and largely focused on management, biology, ecology, and demography. Early

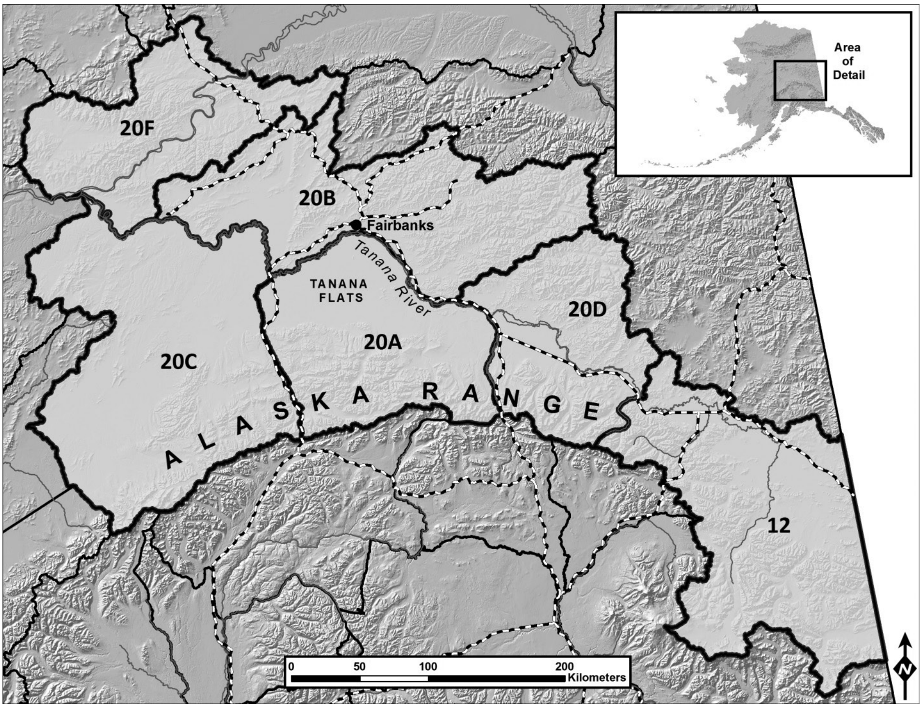

Fig. 1. Location of Game Management Unit 20A in Interior Alaska, USA.

and summary research described factors limiting moose during 1963–1997 (Gasaway et al. 1983, Boertje et al. 1996, Keech et al. 2000), as well as hunter access, moose seasons, and bag limits from the 1960s through early 2000s, moose population status from 1997 to 2003, and the use of calf hunts to increase yield (Young and Boertje 2004). Further, Young et al. (2006) detailed the regulatory and biological history of Unit 20A moose from the 1960s through the early 2000s, describing impediments, achievements, and recommendations for managing high-density moose. Boertje et al. (2007) described relevant signals to begin liberal antlerless hunts to halt population growth, and Boertje et al. (2009) later described how relatively low predation allows continued increase in moose density despite low nutrition. These data helped convince stakeholders to elevate harvest beginning in 2004 through selective harvest strategies that led to eventual recovery of low bull:cow ratios (Young and Boertje 2008). Concerning habitat relationships, Seaton et al. (2011) reported on correlations between proportional browse use in late winter and nutritional condition, and Paragi et al. (2015) described browse removal, plant condition, and twinning rates before and after short-term changes in moose density. Unit 20A has served as an example of when decades-old (1970s), and at times, imprudent moose management, had an overwhelming influence on attempts to implement more recent (2000s) management strategies (Young and Boertje 2011).

The role of long-term, low nutritional status on age-specific antler development was not previously investigated in Unit 20A.

However, a comparative study of age-related antler spread was conducted in our study area in the early 1970s when moose density was lower and twinning rates were more moderate than during this study in 2007–2010 (Gasaway, 1975 Alaska Department of Fish and Game [ADFG] brochure). Given the lower nutritional status of moose during this study, we hypothesized that bulls would delay reaching average 50-inch (127-cm) antler spreads compared to the 1970s.

A potential delay in entering the 50-inch (127 cm) antler class was an important consideration because reduced annual recruitment would undesirably restrict bull harvest when objectives were to maximize harvest to reduce browse degradation and meet harvest objectives set by the Board of Game under the Intensive Management regulation (Young et al. 2006, Boertje et al. 2009). A selective bull harvest strategy was implemented in Unit 20A beginning in 2002 and was eventually successful in recovering the low and declining bull:cow ratios (Young and Boertje 2008); low bull:cow ratios in 1999–2001 resulted from any-bull and no cow harvests. The selective harvest strategy implemented in Unit 20A is hereafter referred to as the spike-fork/50-inch antler restriction, which restricted harvest to bull moose with: 1) spike-fork antlers, 2) antlers ≥50 inches wide, or 3) ≥3 brow tines on ≥1 antler (Fig. 2; Schwartz et al. 1992).

We had two primary objectives: 1) to investigate the potential for a nutrition-mediated delay in bulls reaching 50-inch antler spreads by comparing age-related antler spreads from the early 1970s to 2007–2010, and 2) to characterize antler development of young bulls of known-age that were captured and radio-collared at 10 months (Boertje et al. 2007). The purpose of the latter objective was to correct, as necessary, misclassifications of yearling and 2-year-old bulls during early winter aerial surveys (Gasaway et al. 1986, Kellie and DeLong 2006).

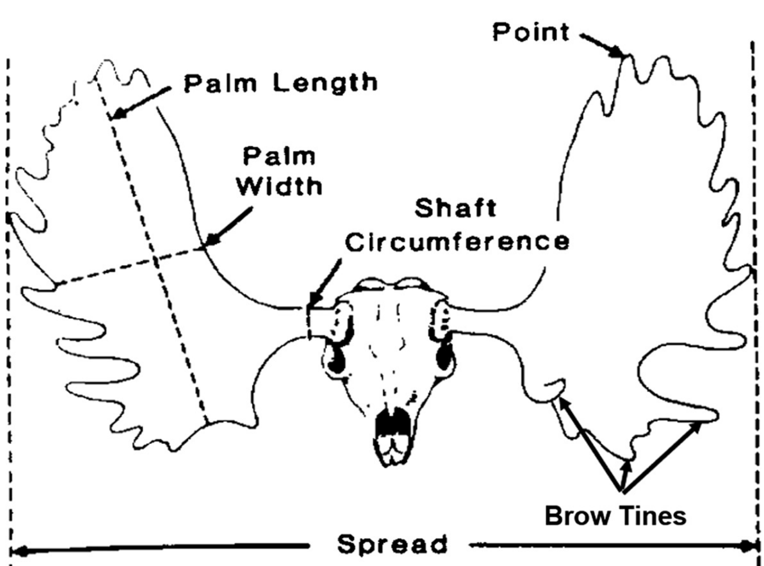

Fig. 2. Antler diagram (Gasaway et al. 1987 with Brow Tines label added by Young and Boertje) used to classify age classes of moose during aerial surveys in Game Management Unit 20A in Interior Alaska, USA.

STUDY AREA

The Unit 20A study area is in interior Alaska immediately south of Fairbanks centered on 64° 10′ N latitude and 147° 45′ W longitude (Fig. 1). It encompasses 17,601 km^2, but only 13,044 km^2 contains topography and vegetation characteristically used by moose. The study area was described in detail by Gasaway et al. (1983), Boertje et al. (1996), and Keech et al. (2000). The northern portion consists of poorly drained lowlands (Tanana Flats) with elevations ranging from 130 to 300 m. The southern portion consists of the northern foothills and mountains of the Alaska Range with elevations up to 4,000 m. Lowland vegetation is a mosaic of shrub and young forest dominated by seres, climax bogs, and mature black spruce (*Picea mariana*) and eastern larch (*Larix laricina*) forest. Vegetation in the hills, foothills, and mountains grades from taiga at lower elevations to shrub-dominated communities with alpine tundra at higher elevations. The climate is typical of Interior Alaska where temperatures frequently reach 25 °C in summer and −10 to −40 °C in winter. Snow depths are generally <80 cm.

METHODS

Age-Related Antler Spread

To collect antler spread data from a range of classes, we required that successful hunters from a limited, any-bull draw hunt (2007–2010) provide antlers and lower front incisors to ADFG personnel who measured antler spread (Fig. 2; Gasway et al. 1987). We used counts of cementum annuli from incisors to estimate age, but the methodology for counting annuli differed between the 1970s and this study. Fortunately, an average correction factor to true age was available from each study, given respective comparisons with known-age teeth. Gasaway et al. (1978) found that subtraction of 0.5 years from the average estimated age was required to best approximate average true age with the 1970s aging techniques. Boertje et al. (2015) found that an addition of 0.2 years from the average estimated age was required to approximate average true age, given more recent aging techniques (Matson's Laboratory, Milltown, Montana, USA). We did not have correction factors for individual teeth in either study.

To determine the average age at which bulls attained an antler spread of 50 inches (127 cm), we regressed antler width with estimated age (n = 599 bulls) to derive a trend line (2nd order polynomial) using Microsoft®Excel Windows®07 software (Redmond, Washington, USA). We compared our trend line with that derived in the 1970s (Gasaway, 1975 ADFG brochure). We had no raw data on age-related antler spreads from the 1970s for further comparisons.

Antler Development

We conducted low-level aerial inspection of known-age, 1 and 2 year-old radio-collared bulls in late August to estimate the proportion that might be misclassified during standard surveys. We hypothesized that observers would not identify antlers ≤3 inches (7.6 cm) in length during standard aerial surveys. Criteria used to distinguish between yearling and 2 year-olds during standard aerial surveys included brow and main palm development, antler spread, and antler length (S. DuBois, W. Gasaway, and D. Roby, ADFG, unpublished report). During standard aerial surveys, we distinguished between yearling and 2-year-olds primarily with brow/main palm separation, secondarily on antler width, and lastly on antler length (Fig. 2). Antler characteristics of yearlings were: 1) no brow/main palm separation, 2) antler spread ≤3.0 × head width (≤30 inches [76.1 cm]), and 3) antler length ≤1.2 × head width (≤12 inches [30.5 cm]). Antler characteristics of bulls ≥2-years old were: 1) brow/main palm separation, 2) antler spread >3.0 × head width (>30 inches), and 3) antler length ≥2.0 × head width (≥20 inches [50.8 cm]). Aerial survey techniques were described by Gasaway et al. (1986) and Kellie and DeLong (2006).

RESULTS

Age-Antler Spread

We collected antler width data and a tooth (I1) for aging from 106 bulls in 2007, 154 in 2008, 174 in 2009, and 165 in 2010 (n = 599). A significant relationship was found between antler spread (inches, Y) and age (years, X):

$$Y = -0.3479X^2 + 6.9342X + 20.753; \quad R^2 = 0.66, P < 0.001. \quad (1)$$

Bulls first reached an average antler spread of 50 inches at 6.0 years of estimated age and 6.2 years of true age. We observed wide variation in antler spread in each age class with substantial overlap among age classes; antler spread of 50 inches occurred at 3 years and older (Fig. 3).

Antler Development/Composition

We classified antler characteristics of 15 month–old and 27 month–old bulls on 27 August 2007 (n = 6 and 14), 22-23 August 2008 (n = 5 and 17), and 17-19 August 2009 (n = 0 and 12). Twenty-two percent (11/51) of known-age, yearling bulls had spiked antlers ≤3 inches (7.6 cm) that were likely undetected during standard surveys. Nineteen percent (8/43) of known-age, 2 year-old bulls were probably misclassified as yearlings based on brow/palm separation alone - the primary antler characteristic used to differentiate between the age classes during aerial surveys. Conversely, when using antler spread and antler length as primary classification criteria, we correctly classified all known-age, 2 year-old radio-collared bulls (n = 43) during aerial inspection.

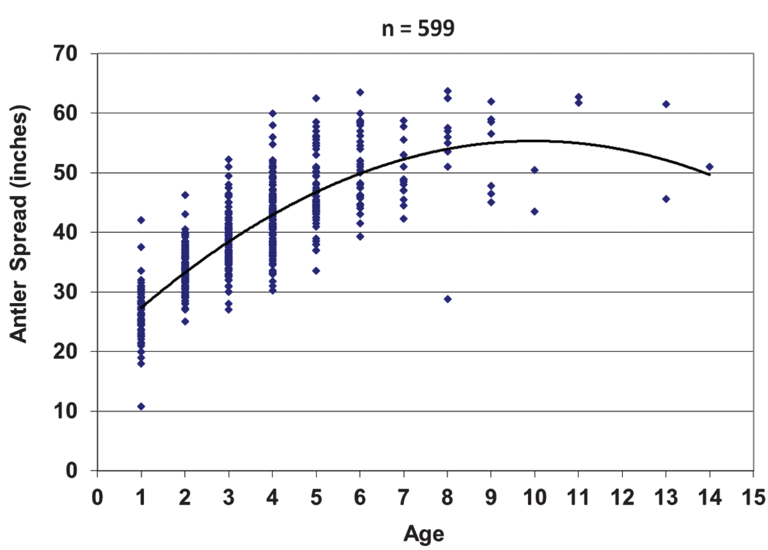

Fig. 3. The significant ($P < 0.001$) relationship between antler spread and age of moose (n = 599) in Game Management Unit 20A, Interior Alaska, 2007–2010.

DISCUSSION

Age-Antler Spread

We surmised that the estimated delay in reaching a 50-inch antler spread associated with reduced nutritional status was too small to have meaningful biological or management significance, particularly given the wide variation in antler spread in each age class (Fig. 3). After correcting estimated ages to true ages, we concluded that, on average, bulls in populations affected by elevated density and unusually low nutrition delayed reaching 50-inch antler spread by 0.6 years. Our comparison was made with the Gasaway et al. (1987) sample (n = 91) from all of Unit 20 (i.e., Units 12, 20A, 20B, 20C, 20D, 20E, and 20F in Interior Alaska; Fig. 1), where antler spreads reached an average of 50 inches at 5.6 years of true age (6.1 years estimated age) in the early 1970s. Moose densities in Unit 20 in the early 1970s were lower than densities during this study; for example, density in Unit 20A in the early 1970s (ca. 500 moose/1,000 km^2) was about half that in this study (1,060 moose/1,000 km^2) (Gasaway et al. 1983, Young 2012). Further, the average twinning rate in northcentral Unit 20A during the early 1970s (16%, range = 12–18%) was >2x higher than in this study (7%, range = 3–10%) (Boertje et al. 2007, Young 2012).

It is possible that a negative lag effect on nutritional condition of the population was realized in the early 1970s due to elevated moose densities in the 1960s. For example, moose numbers were declining substantially in the late 1960s and early 1970s in Interior Alaska primarily due to periodic deep snow, excessive harvest, and increased wolf predation (Gasaway et al. 1983). Twinning rates were twice as high in the 1960s, averaging 14% (n = 9 years, range = 4–21%) versus 7% (n = 4 years, range = 3–10%) during this study (Boertje et al. 2007, Young 2012). Nutritional condition appeared to peak in the study area during 1977–1982 when twinning rates averaged 37% (n = 6 years, range = 30–47%; Boertje et al. 2007). Clearly, our data comparisons between 2007–2010 and the early 1970s were between time periods of low versus moderate moose condition/nutrition. We speculate that a longer delay (i.e., >0.6 years) in reaching the 50-inch antler spread might be evident when comparing data between periods of low and high moose nutrition.

Given that a large percentage of the yearling and 2 year-old bulls in Unit 20A had retarded antler development during this study, it is not surprising that bulls delayed reaching 50-inch antler spreads. Keech et al. (1999) reported that neonate moose with low birth weight remained among the smallest individuals in their cohort during the first 10 months of life. Similar results are known for young of other ungulate species under natural conditions (Schwartz et al. 1994, Schultz and Johnson 1995, Pelabon 1997).

Antler Development/Composition

Presumably, bull:cow ratios were biased low for several years prior to this study because some yearling bulls were misclassified as cows during standard surveys. We estimated that the initial bull:cow ratios were 2.5 bulls:100 cows lower than corrected ratios. For example, during standard aerial surveys in 2010, we reported there were 2,311 bulls (including 639 yearling bulls) and 7,325 cows, or 31.6 bulls:100 cows (Young 2012). Assuming 22% of the yearling bulls were misclassified as cows, the corrected estimate would be 2,452 bulls (including 780 yearling bulls) and 7,184 cows, or 34.1 bulls:100 cows.

Yearling bull:cow ratios, a measure of annual survival from 6 to 18 months of age, would also have been biased low. In 2010, we estimated that the initial yearling bull:cow ratio was 2.2 yearling bulls:100

cows lower than the corrected ratio (8.7 versus 10.9 yearling bulls:100 cows). Misclassifying yearling bulls as cows would also bias the calf:cow ratio lower, but the difference was minimal (<1 calf:100 cows) because of the high proportion of cow moose in the population.

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Although unusually low nutritional condition had a measureable effect on delaying recruitment into the harvestable 50-inch antler class, we considered this delay (< 1 year) too small to warrant a change in our selective harvest strategy. We also felt encouraged to retain the selective harvest strategy because of the high annual survival rate of bulls in the 2- through 6-year age classes - 97–98% when excluding human causes of mortality (R. Boertje, unpublished data). In high-density, nutritionally stressed moose populations, sub-adult moose should be highly scrutinized for antler spread and length during aerial composition surveys to reduce the likelihood of misclassifying yearling and 2-year-old bulls.

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