RECOVERY OF LOW BULL:COW RATIOS OF MOOSE IN INTERIOR ALASKA

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ABSTRACT: During 1996–1999, hunters killed an estimated 24–30% of the pre-hunt bull moose (*Alces alces*) in Game Management Unit 20A. As a result, the 1999 post-hunt bull:cow ratios declined to 24:100, well below the management objective of 30:100. During 2000 and 2001 we shortened the hunting season from 25 to 20 days to reduce the harvest of bull moose, but kill rates of bulls remained high (23–27%) and ratios remained unacceptably low (22–26 bulls:100 cows). Subsequently, to recover bull:cow ratios to 30:100, hunters were restricted unit-wide to taking bulls with 1) spike-fork antlers, 2) antlers ≥50 inches wide, or 3) ≥3 brow tines on ≥1 antler. These restrictions were in place from 2002-2007, but results occurred rapidly. After only 2 years of antler restrictions, hunters killed an average of 36% fewer bulls compared with the previous 2-year average harvest rate ($\bar{x}$ = 715 during 2000–2001 and 455 during 2002–2003). Comparing these same 2-year periods, average kill rates of bulls declined from 25% to 12% of the pre-hunt bull population, average number of hunters declined 24% (1,568 to 1,187), and the average hunter success rate declined from 34% to 29%. Bull:cow ratios increased from 26:100 to 32:100 after 2 years of antler restrictions. With an additional 2 years (2004–2005) of antler restrictions and high harvest of cow moose, bull:cow ratios reached 38:100. Modeling indicated that the bull:cow ratio would have stabilized at 33:100 without the high harvest of cows. The recovery of bull:cow ratios to our objective of 30:100 with 2 years of antler restrictions allowed 1) bull seasons to be lengthened from 20 to 25 days beginning in 2004 and, 2) a limited number of drawing permits for any bull during 2006–2007. Elsewhere, similar selective harvest strategies should also allow recovery of bull:cow ratios, unless the total kill rate of bulls is higher than estimated here.

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Key words: Alaska, *Alces alces*, antler restrictions, bull:cow ratios, Game Management Unit 20A, recovery, selective harvest strategy.

Historically, low bull:cow ratios (10:100) of moose (*Alces alces*) resulted where hunter access was good, and hunting was restricted largely to any bull (Rausch et al. 1974). Low bull:cow ratios did not occur in remote inaccessible areas (60–80:100, Gardner 2002), so we infer that humans, not wolves (*Canis lupus*) and bears (*Ursus americanus* and *Ursus arctos*), caused the skewed ratios by selectively killing bull rather than cow moose. To recover low bull:cow ratios, selective harvest strategies (SHS) were first implemented in British Columbia in 1980 (Child 1983, Child and Aitken 1989). These SHS were based on limiting hunters to particular bulls with regulations on antler architecture. In Alaska, SHS were first initiated on the Kenai Peninsula in 1987 (Schwartz et al. 1992). Selective harvest strategies spread rapidly to other Alaska roadside areas during 1988–1993 because of low bull:cow ratios.

This is the first paper that describes successful recovery of bull:cow ratios in interior Alaska. High kill rates of bull moose by hunters in Game Management Unit 20A (Unit 20A) during 1996–1999 resulted in post-hunt bull:cow ratios declining below the management objective of 30:100. During 2000–2001 we shortened the hunting season to reduce the harvest of bull moose, but bull:cow ratios remained low. In 2002, hunters were restricted unit-wide to taking bulls with 1) spike-fork antlers, 2) antlers ≥50 inches wide, or 3) ≥3 brow tines on ≥1 antler. We report the effects of these antler-based SHS on 1) total kill of bull moose by hunters, 2) kill rate of pre-hunt bull moose numbers, 3) hunter participation, 4) hunter success rate, 5) antler size of harvested bulls, and 6) bull:cow ratios.

STUDY AREA

Our study area encompassed Unit 20A immediately south of Fairbanks and across the Tanana River. The study area is in interior Alaska and is centered on 64°10′N latitude and 147°45′W longitude. The study area encompasses 17,601 km^2, but only 13,044 km^2 contains topography and vegetation used characteristically by moose. Gasaway et al. (1983), Boertje et al. (1996), and Keech et al. (2000) described the physiography, habitat, climate, and factors limiting moose during 1963–1997. Young and Boertje (2004) described hunter access, moose seasons, and bag limits from the 1960s through the early 2000s, moose population status from 1997-2003, and the use of calf hunts to increase yield. Young et al. (2006) described impediments and achievements of managing Unit 20A moose for elevated yield. Moose in Unit 20A (1997–2005) exhibited the lowest nutritional status documented for non-insular, wild moose in North America (Boertje et al. 2007). Boertje et al. (2009) described how predation and reproduction affected the harvest of moose during 1996–2007.

METHODS

Estimating Harvest and Hunter Statistics

We monitored reported moose harvest, hunter participation, hunter success rates, and antler characteristics of the harvest using a mandatory harvest report card system (Schwartz et al. 1992). To estimate the number of moose killed by hunters, we multiplied the reported harvest by 1.34 (47/35) based on the reported harvest of 35 radio-collared moose and an additional 12 radio-collared moose that died from unreported harvest (6) and wounding loss (6) in Unit 20A during 1996–2006 (Boertje et al. 2009). We focused this study on the kill of bull moose; bulls included all males ≥15 months of age. We derived the pre-hunt bull kill rate based on pre-hunt bull numbers (Gasaway et al. 1992). We estimated the pre-hunt bull numbers each year by adding the total estimated kill of bulls by hunters, which occurred in September, to the aerial estimates of November bull numbers. We derived hunter success rate using the reported harvest.

We primarily compared results from the 2 years prior to SHS (2000 and 2001) versus the first 2 years of SHS (2002–2003) because those 4 years had 20-day hunting seasons, whereas all other years (1996–1999 and 2004–2005) had 25-day seasons. We used Student's *t*-tests to compare total kill, kill rate, hunter participation, hunter success rate among years, and antler size in the harvest. We assumed significance at $\alpha = 0.05$.

Estimating Moose Population Characteristics

We flew moose population estimation and composition surveys (1999–2005) each November, except in 2002 due to poor survey conditions. To calculate moose numbers, we used spatial statistics (Kellie and DeLong 2006, Ver Hoef 2008) and a sightability correction factor of 1.21 (Boertje et al. 2009). To estimate the finite annual population growth rate (λ), we fitted population estimates during 1996–2004 with a trendline through parametric empirical Bayes estimates (Ver Hoef 1996:1048). We used the Student's *t*-test to compare mean bull:cow ratios prior to and after the initiation of SHS. We assumed significance at $\alpha = 0.05$.

Modeling to Assess Effect of Cow Moose Hunts on Bull:Cow Ratios

We used a deterministic model using Microsoft® Office Excel 2003® software to compare bull:cow ratios with and without harvests of cow moose. Cows included all females ≥15 months of age. Input variables included annual estimates of the number of bulls and cows killed by hunters, annual survival rates of bulls and cows, and calves:100 cows observed during November surveys. Also, during the initial year we input the number of bulls, cows, and calves. We backdated the model to the year 1991 and varied survival rates until output values were similar to estimates obtained from annual surveys. Output values included annual post-hunt moose numbers, bull:cow ratios, and λ. In the initial model we used empirical estimates of 98, 161, 698, and 794 cow moose killed by hunters during 2002–2005. We then ran the same model using a simulated adult kill of 10 cows (i.e., estimated illegal kill) during 2002–2005. The result was paired bull:cow ratios with and without harvests of cows during the 4 years of unit-wide SHS.

RESULTS

Harvest Statistics

The mean estimated kill of bull moose by hunters declined 36% after SHS were initiated (Table 1). Specifically, the mean kill of 455 bulls taken during 2002–2003 was lower (P = 0.003, df = 2) than the mean kill of 715 bulls taken during the 2 years prior to SHS (2000–2001). Mean kill of bulls by hunters was not lower during 2004–2005 ($\bar{x}$ = 577, P = 0.079, df = 2) when the SHS season was lengthened from 20 to 25 days. The mean estimated kill rate of 12% of the pre-hunt bull population during 2002–2003 was lower (P = 0.029, df = 2) than the 2-year mean 25% kill rate observed prior to SHS (Table 1). Kill rates remained lower ($\bar{x}$ = 14%, P = 0.026, df = 2) after the SHS season was lengthened from 20 to 25 days.

Hunter Participation and Success

The mean reported number of hunters declined (24%, P = 0.002, df = 2) after SHS were initiated (Table 1). Mean reported hunter success rates also declined (P = 0.034, df = 2) from 34% to 29% after SHS were initiated. Success rates remained lower ($\bar{x}$ = 25%, P = 0.004, df = 2) after the SHS season was lengthened from 20 to 25 days.

Antler Size of Harvested Bulls

We observed a shift away from 30- to 40-inch antlered bulls and toward ≥50-inch antlered bulls in the harvest after SHS were implemented (Table 1). The mean proportion of 30- to 40-inch antlered bulls declined (P = 0.019, df = 2) in the harvest from 30% to 6%. Conversely, the mean proportion of ≥50-inch antlered bulls increased (P = 0.023, df = 2) from 26% to 49% in the harvest. These trends continued into 2004–2005 when the SHS season was extended 5 days (30- to 40-inch antlered bulls: $\bar{x}$ = 7%, P = 0.019, df = 2; ≥50-inch antlered bulls: $\bar{x}$ = 52%, P = 0.009, df = 2). We observed no change in the proportions of <30-inch ($\bar{x}$ = 22% vs. 23%, P = 0.607, df = 2) or 40- to 50-inch antlered bulls ($\bar{x}$ = 21% vs. 19%, P = 0.417, df = 2) in the harvest.

Bull:Cow Ratio of the Population

The mean bull:cow ratio increased (P = 0.006, df = 4) by 11 bulls:100 cows after SHS were implemented when comparing data from 1999–2001 ($\bar{x}$ = 24) versus 2003–2005 ($\bar{x}$ = 35, Table 1). However, SHS alone did not increase the bull:cow ratio because high harvests of cows during 2004–2005 also contributed to the increase in the bull:cow ratio (Fig. 1). Modeling indicated that without the harvest of cows, the bull:100 cow ratio would have increased to only 33 in 2005 rather than the 38 observed. Regardless, when comparing the observed bull:cow ratios pre-SHS ($\bar{x}$=24) versus the simulated bull:cow ratios without the harvests of cows ($\bar{x}$ = 33,

Table 1. Characteristics of the bull moose (≥15 months of age) population, reported harvest and kill of bulls by hunters, and hunting regulations for bulls in Game Management Unit 20A, Interior Alaska, 1996–2005.

Year	Season length/ Bag limit[a]	No. bulls: 100 cows	90% CI	Pre-hunt bull population[b]	Reported harvest	Total kill of bulls[c]	Pre-hunt kill rate (%) of bulls	Reported no. of hunters	Reported success rate[d] (%)	Reported harvest rate (%) by antler width (inches)				
										<30	30–40	40–50	50+	Unk
1996	25 day/Any bull	39		3,289	604	809	24.6	1,636	36.9	23	29	21	25	3
1997	25 day/Any bull	33		3,454	620	831	24	1,595	38.9	22	28	25	22	4
1998	25 day/Any bull	31		2,995	608	815	27.2	1,652	36.8	17	28	23	27	5
1999	25 day/Any bull	24	17–31	3,010	669	897	29.8	1,574	42.5	19	24	24	30	3
2000	20 day/Any bull	22	15–29	2,668	534	715	26.8	1,584	33.7	23	27	22	26	2
2001	20 day/Any bull	26	18–34	3,069	534	715	23.3	1,551	34.4	21	33	20	26	1
2002	20 day S-F/50	–[e]	–[e]	3,414[f]	350	469	13.7	1,185	29.5	25	5	17	52	1
2003	20 day S-F/50	32	25–39	3,975	328	440	11.1	1,189	27.6	21	7	21	45	6
2004	25 day S-F/50	35	27–43	3,901	400	536	13.7	1,638	24.4	16	7	25	49	3
2005	25 day S-F/50	38	33–42	4,252	461	618	14.5	1,816	25.4	11	6	27	54	3

[a] "Any bull" bag limit occurred in 14,325 km^2 (81%) of the 17,601 km^2 in Game Management Unit 20A. We designated unitwide selective harvest strategies as "S-F/50", which included restricting harvest to bulls with 1) spike-fork antlers, 2) antlers ≥50 inches wide, or 3) ≥3 brow tines on ≥1 antler.

[b] Pre-hunt bull population equaled number of bulls estimated from November surveys plus estimated total kill of bulls by hunters.

[c] Total kill of bulls equaled reported harvest of bulls x 1.34, based on a radio-collared sample of moose killed by hunters (47/35).

[d] Reported success rate equaled reported harvest divided by reported number of hunters.

[e] No data.

[f] Data on post-hunt bull numbers were interpolated from adjacent years.

Fig. 1), bull:cow ratios remained different ($P = 0.002$, df = 4).

DISCUSSION

Using antler-based SHS, bull:cow ratios increased from about 26 bulls:100 cows to above our objective of 30 bulls:100 cows in 2 years, 2002–2003. We documented that SHS reduced kill and pre-hunt kill rates of bulls, hunter participation, and hunter success rates. After the initiation of SHS, bull:cow ratios increased to a 3-year average of 35 bulls:100 cows, but the increase above 33 bulls:100 cows apparently resulted from liberal harvests of cows during the last 2 years (Fig. 1).

When comparing 3-year averages pre- and post-SHS, bull:cow ratios increased from 24 to 35 with ratios as high as 38. With SHS on the Kenai Peninsula, average bull:cow ratios increased from 16 to 25 with ratios as high as 29 (Schwartz et al. 1992). Schwartz et al. (1992) reported a 27% decline in the mean harvest of bull moose when comparing 5-year periods pre- ($\bar{x}$ = 636) and post-SHS ($\bar{x}$ = 466); whereas, we observed a 36% decline in the mean harvest of bulls when comparing 2-year periods pre- (2000–2001) and post-SHS (2002–2003).

After SHS were implemented on the Kenai Peninsula, the distribution of the harvest of bulls shifted toward yearlings and away from 30- to 40-inch antler class with little change in the proportion of bulls ≥50-inches (Schwartz et al. 1992). We also observed a shift away from bulls in the 30- to 40-inch antler class. However, we also observed a shift toward bulls with ≥50-inch antlers, presumably because our higher bull:cow ratio had resulted in a larger proportion of large antlered bulls in the population.

Unlike the Kenai study, we observed little change in the proportion of ≤30-inch bulls (i.e., yearlings). We speculate that hunters had difficulty identifying yearling bulls because of poor antler development in Unit 20A. For example, during a flight prior to the hunt in 2007, we observed 6 (22%) of 27 known-age, radio-collared yearlings with antlers consisting of small spikes (2–8 cm). Poor antler development among yearlings was likely related to the low nutritional status of this population (Boertje et al. 2007).

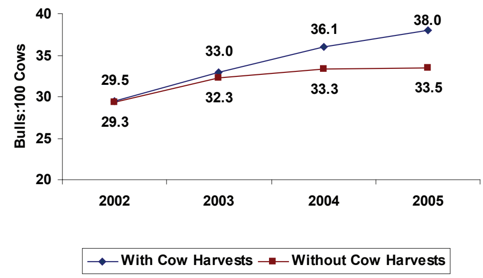

Fig. 1. Estimated post-hunt bull:cow ratios with and without cow moose harvests, Game Management Unit 20A, Interior Alaska, 2002–2005.

The rapid recovery of bull:cow ratios allowed us to elevate the harvest of bulls after 2 years. Recovery of bull:cow ratios to 30:100 was a secondary management objective during this study. The primary objective was to improve nutritional status of moose by encouraging greater harvest (Boertje et al. 2007). Therefore, during 2004–2007, when the post-hunt bull:cow ratios exceeded our management objective of 30 bulls:100 cows, we encouraged greater harvest of bulls using 2 methods. First, 5 days were added to the hunting season with SHS during 2004–2005. Subsequently, we issued a limited number of drawing permits for any bull during 2006–2007 (Schwartz et al. 1992). We recognize that increasing harvest of cows, not bulls, was the most effective method to decrease population size, but hunts targeting cows were difficult to implement and far more controversial than hunts targeting bulls (Young and Boertje 2004, Young et al. 2006).

We know that low bull:cow ratios result from hunters favoring bulls versus cows, based on data from favored roadside hunting areas (10 bulls:100 cows, Rausch et al. 1974). In contrast, in remote, lightly hunted areas, we observed 60–80 bulls:100 cows.

We demonstrate that SHS were a key factor allowing bull:cow ratios to increase from 26:100 to 32:100 in 2 years. Bull:cow ratios should increase elsewhere where similar SHS are implemented, unless kill rates of bulls are higher than estimated here.

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