ARE ALBERTA'S TROPHY RAMS DECLINING IN QUALITY AND QUANTITY?

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Abstract: In Alberta, hunting of trophy sheep by provincial residents has been conducted since 1968 on an unlimited entry basis using 4/5th curl to define a legal ram. Under such a regime, rams with rapidly growing horns and the potential to reach a large size can be harvested as young as 4–5 years of age, before they achieve the high breeding success facilitated by large horns. Artificial selection pressure against fast-growing and larger rams has been reported in the Ram Mountain population where trophy hunting was associated with declines in both body mass and horn length over a 30 year period. It is unknown whether other populations may be similarly affected. Following concerns expressed by hunting organizations over a decline in availability of large rams, we analyzed data from 7,054 trophy rams harvested over 36 years (1974–2009). We used linear and linear mixed-effect models to look for temporal changes in horn length, basal circumference, and harvest age at the provincial level and in 8 Sheep Management Areas (SMAs) considered separate metapopulations. Provincially, annual ram harvests have declined since the 1990's while at the SMA scale, harvests in 5 of 8 SMAs have declined with 3 remaining stable. Average ram age at harvest increased provincially from 6.7 to 7.5 years, as a result of a decline in the proportion of young (4–5 years) rams in the harvest, indicating that rams now need to be older to reach legal size. Horn length increased with age at both scales of analysis. Surprisingly, base circumference declined with harvest age, likely because larger rams are shot at younger ages, while smaller rams survive. Over time, horn length and circumference decreased provincially when controlling for age, but temporal trends varied amongst SMAs. Declining growth rates in some areas reduced the number of rams available for harvest and rams of harvestable size are now smaller. Fast-growing rams are shot when young and removed from the population before prime breeding age. Alternate hunting strategies are required to protect fast-growing young rams if provincial objectives of maximizing the production of trophy rams are to be achieved. Habitat factors may also have to be manipulated if environmental influences also are contributing to declines in horn growth.

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Key words: *Ovis canadensis*, Rocky Mountain bighorn sheep, horn morphology, harvest age, artificial selection, harvest strategies, species management.

Trophy bighorn sheep in Alberta are managed to maximize production of trophy rams and to maximize opportunities to hunt (Environmental Protection 1993). Although the provincial harvest of trophy sheep and provincial population estimates have remained relatively stable over the past 35 years, concerns have been expressed over the size and number of trophy rams. A detailed study of one intensively monitored population at Ram Mountain has provided strong evidence of artificial selection through unrestricted trophy hunting by Alberta residents (Bonenfant et al. 2009; Coltman et al. 2003; Coltman et al. 2005).

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The same study has shown that although ram horn size has a strong hereditary component, it is also affected by environmental conditions including population density (Coltman et al. 2005; Festa-Bianchet et al. 2004; Jorgenson et al. 1998). Declines in horn size in trophy hunted populations of bighorn sheep and other mountain ungulates have now been reported by several other studies (Garel et al. 2007; Hengeveld and Festa-Bianchet 2011; Pérez et al. 2011), although in the absence of control data from unhunted populations it is difficult to quantify how much of these temporal declines may be due to artificial selective pressures and how much to possible changing environmental conditions. In addition, trophy hunting is likely to have a strong effect on male age structure (Milner et al. 2007). Bighorn ram mating success increases with age (Coltman et al 2002), thus hunting may have substantial effects on the distribution of male mating success, although no study has been able to quantify these effects.

The possible effects of artificial selection on horn size in wild sheep remain controversial and are likely affected by many natural and management-affected variables, such as changes in population density and plant productivity, harvest intensity, level of selectivity and the presence of harvest refugia (Festa-Bianchet and Lee 2009). Although harvest records have several inherent limitations (Pelletier et al. 2012), they provide a potentially useful opportunity to examine long-term trends in the age and size of harvested rams. We analyzed harvest records from trophy sheep in Alberta to determine whether the age, horn length and basal circumference of rams, and harvest rates, have changed over time at a provincial scale and within sheep management areas.

STUDY AREAS

Bighorn sheep in Alberta are distributed across the contiguous Rocky Mountain Range and in isolated mountain complexes of Ram Mountain and Shunda. Protected Areas, including both national and provincial parks, border or encompass much of the sheep range. DNA analyses of horn core samples from bighorn rams were used to divide the provincial sheep population into eight genetically identifiable subpopulations, or sheep management areas (SMAs; Fig. 1).

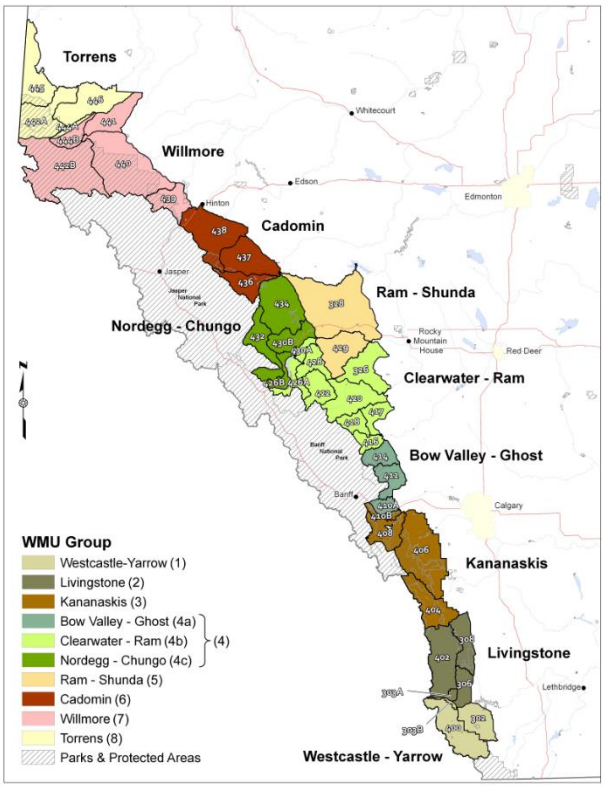

Fig. 1. Sheep Management Areas (SMAs) in Alberta, Canada. Numbers in brackets refer to the eight SMAs.

METHODS

We analyzed age and horn data from 7,054 trophy rams harvested over 36 years (1974–2009). Age was estimated based on horn annuli (Geist 1966), and measurements included base circumference and total length. For those SMAs where the definition of 'legal' ram was changed from 4/5-curl to Full-curl in 1996 (Westcastle-Yarrow and Ram-Shunda), only data up to 1995 were analyzed. While it would be useful to analyze registration data collected post implementation of the full curl requirement, the sample size available at present was too low for meaningful evaluation. Measurements from 116 illegally-harvested rams (including 51 that were less than 4/5 curl) were included in the analyses.

Linear models were used to examine temporal trends in horn size and age of harvested rams at both the provincial scale and then for each SMA (Fig. 1). In all cases, we also tested for possible nonlinear effects of either ram age or harvest year by including a quadratic term. Province-wide analyses were conducted using linear mixed effect models and accounted for possible regional

differences by including the SMA where each ram was harvested as a random effect. Inclusion of SMA as a random effect means that data for rams from SMAs that typically produce larger horns were adjusted for a SMA-specific effect before being included in the analysis. That step prevents, among other things, spurious results that may be caused by annual differences in the distribution of the harvest among SMAs with different characteristics. All statistical analyses were conducted using R version 2.10. The 'lme4' package was used to fit mixed effects models (Bates et al. 2008).

RESULTS

Age of Harvested Rams

Provincially, the average age of harvested rams increased from 6.7 to 7.5 years between 1974 and 2009 (Fig. 2a; t-value = 6.994, $P < 0.001$). This increase was mostly due to a gradual decline of the proportion of rams aged 4 or 5 years in the harvest (Fig. 2b; $r^2 = 0.31$, slope ± SE: 0.003 ± 0.0008, $P < 0.001$). From 1974 to 1990, 20–30% of rams harvested in 12 of 17 years were aged 4 or 5 years. In 2005–2009, these young rams made up less than 15% of the harvest.

Analyses of age at harvest in different SMAs broadly confirmed the overall increasing trend detected at the provincial level (Fig. 3). Within each SMA, the increase in age of harvested rams over time appeared due primarily to a decrease in the proportion of rams aged 4 or 5 years in the harvest.

Horn Length and Basal Circumference

Provincially, the average horn length and base circumference of harvested rams showed a significant quadratic trend, with an apparent increase from 1975 to about 1990, followed by a decline (Table 1). These temporal changes were only evident when the age of each animal harvested was accounted for.

Temporal trends in horn length and basal circumference of harvested rams varied among SMAs. SMAs showing a decline in horn length or basal circumference over time (linear or quadratic) accounted for 77% or 91% of the total harvest from 1974–2009, respectively. Only SMAs 6 and 8 showed a significant increase in horn length over

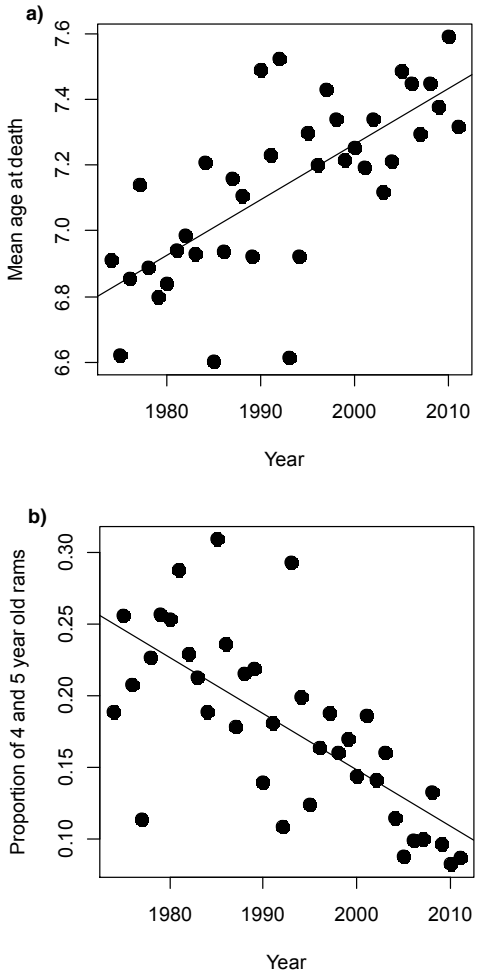

Fig. 2. Data from bighorn rams harvested in Alberta from 1974 to 2009 showing a) the average age and b) the proportion of rams aged 4 or 5 years.

time, while no SMAs showed an increasing trend in base circumference.

Horn length of harvested rams increased with age at both the provincial and SMA scales (Fig. 4a). With the exception of SMA 8, where horn length appeared to increase linearly with age, the effect of age on horn length was usually quadratic. In contrast, basal circumference surprisingly declined with age for rams aged 6 years and older at both the provincial and SMA scales (Fig. 4b).

DISCUSSION

In Alberta, the age of harvested rams increased from 1974–2009, while horn size decreased slightly during this 36-year period. Provincially, the average age of harvested rams rose by almost a year during this time, as a result of a 10% decline in the proportion of young (4–5 years) rams in the

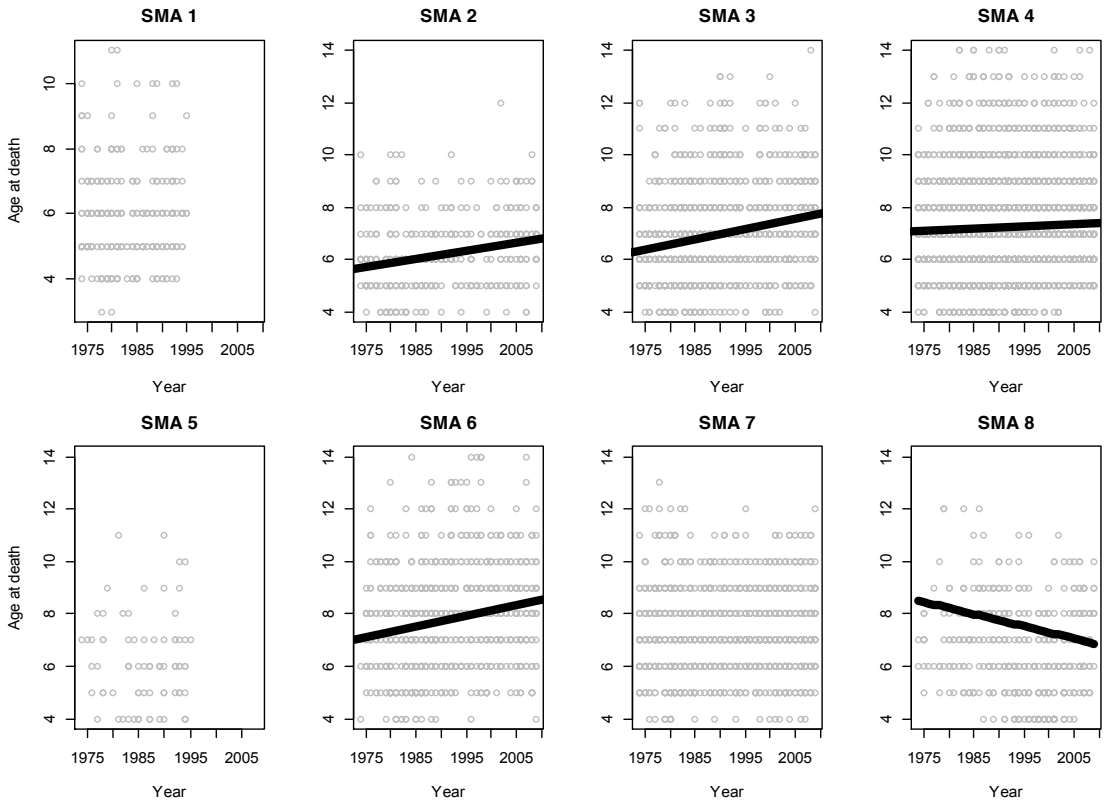

Fig. 3. Relationship between the year of harvest and age for bighorn sheep rams harvested in each Sheep Management Area (SMA) in Alberta. Black lines show significant temporal trends.

harvest. Since 1990, the average horn length and basal circumference of harvested rams in the province decreased when ram age was controlled for in analyses. These trends towards increasing ram age, decreasing proportion of young rams in the harvest and declining horn size over time were evident also for most sheep management areas in Alberta, although results varied among SMAs. Noteworthy too is that basal circumference declined slightly with age for rams aged 6 years or older, contrary to expectations. Together, these results suggest that rams in recent years need to be older to reach legal size than previously, and that fast-growing, larger rams are shot at younger ages than slow growing rams. These conclusions are consistent with research findings from bighorn sheep populations in British Columbia (Hengeveld and Festa-Bianchet 2011) and Spanish Ibex (*Capra hispanica*; Perez et al. 2011).

Table 1. Effect of year and age at harvest on a) horn length and b) horn base circumference (cm) estimated using linear mixed effect models accounting for sheep management area for bighorn ram in Alberta, 1974-2009.

	Variables	Coefficient	SE	P-value	N
a) Horn Length					6938
	Harvest year	17.594	3.0954	<0.001	
	Harvest year^2	-0.004	0.0008	<0.001	
	Age	4.787	0.2182	<0.001	
	Age^2	-0.163	0.0138	<0.001	
b) Horn Base					6933
	Harvest year	6.672	1.0322	<0.001	
	Harvest year^2	-0.002	0.0003	<0.001	
	Age	0.120	0.0727	0.098	
	Age^2	-0.010	0.0046	0.022	

Since horn growth is a highly heritable trait, the loss of fast-growing rams before they can contribute to recruitment could result in artificial selection

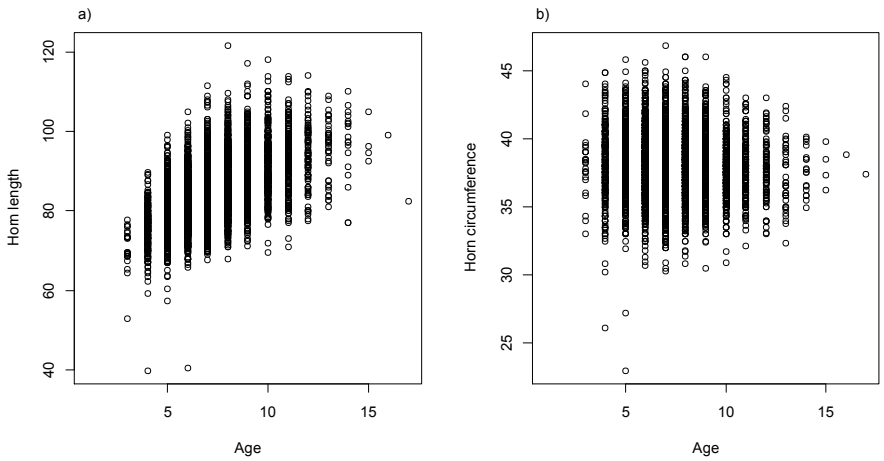

Fig. 4. Data from bighorn rams harvested in Alberta from 1974 to 2009 showing a) total horn length and b) base circumference in cm.

against large horns (Coltman et al. 2003). To achieve high breeding success, bighorn sheep must have large horns and survive to 7 years or older (Coltman et al. 2002). In Alberta, however, under the current unlimited entry hunt with 4/5-curl restriction, fast-growing rams may reach trophy size and be harvested at 4 or 5 years old. High harvest pressure could result in removal of most fast-growing rams and in turn, favor the reproduction of small, slow-growing rams. While the ram harvest rate of the sheep population is low (2–3%), the harvest rate of the trophy ram population is high (40–60%). During winter surveys conducted post-hunt, trophy rams across all SMAs comprise on average 4.8% (range 1.6–13.3%) of the sheep classified (unpublished data). In some SMAs in the province, it is estimated that more than 90% of rams are apparently harvested in the year they attain legal status. Such high harvest levels may result in strong artificial selection against large rams. Artificial selection has been reported in sheep populations at Ram Mountain (Coltman et al. 2003) and in British Columbia (Hengeveld and Festa-Bianchet 2011). Currently, we know little about the possible role of protected areas as refugia against selective harvest. It is known that rams may migrate to hunted areas from protected areas for the rut, after the hunting season (Hogg 2000).

Although the decrease in bighorn sheep horn size in Alberta over the past 35 years may be attributable to artificial selection through selective hunting (Coltman et al. 2003), it may also be partly due to environmental changes (Rughetti and Festa-Bianchet 2012). Other factors that may contribute to a decline in horn growth over time include climatic conditions and habitat quality associated with sheep densities (Jorgenson et al. 1998; Rominger and Goldstein 2006; Wishart 2006). At the provincial scale, however, declines in horn size are unlikely to be due to an increase in sheep density, as the Alberta sheep population has remained relatively stable for the last few decades (Jorgenson 2008). To more conclusively attribute changes in horn growth and horn size to various environmental influences or hunting pressure, annuli or increments should be measured in both hunted (provincial) and protected populations (e.g. National Parks).

Alternate hunting strategies are required to protect fast-growing young rams if provincial objectives of maximizing the production of trophy rams are to be achieved. Harvest options that are being discussed include limited entry hunts, full curl restrictions and shortened hunting seasons, among others. Prescribed burns and access management are continuing to occur across sheep range to address environmental influences that may also be contributing to declines in horn growth.

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