Bighorn Harvest Management in Alberta

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Management Interpretations and Recommendations:

- Harvest of bighorns in 2014 was lower than in recent years. Likewise low harvests occurred in 1996 and 2002. No statistically significant temporal trend exists in the harvest of bighorns during the past 20 years.
- Aerial surveys indicate no trend in the abundance of bighorns, and counts have been remarkably consistent over time.
- Declines in the proportion of 4 & 5 year-old rams and increasing age of rams in the harvest is consistent with poor nutrition associated with reduced non-trophy sheep harvests. This is consistent throughout the range of bighorns in Alberta because harvests of non-trophy sheep have been severely curtailed.
- We documented that non-trophy sheep harvests contribute significantly to horn growth and ultimate length of horns in rams.
- Deteriorating range condition and poor growth of bighorns can be improved by prescribed fire on seasonal ranges and by increasing the harvest of non-trophy bighorns.
- Demographic influence (phenotypic rescue) of rams dispersing from unhunted areas (e.g., national parks) causes an increase in the horn size of rams harvested in areas adjacent to these refuges.
- Genetic mixing of rams from unhunted areas with hunted populations can swamp any possible genetic consequence of hunter selectivity.
- We contend that horn size selection by hunters is weak. No published study has unequivocally demonstrated that selection by hunters has altered the genetic quality of bighorns in Alberta.
- Drastic reductions in hunter opportunity occur when harvest is restricted to full-curl rams.
- Declines in horn size in bighorns during the past 40 years have been very small and the rate of change is slow suggesting that there is no urgency in making changes until we have resolved the mechanisms behind this decline.
- Changing harvest regulations would be premature given that David Hik's resiliency study will be completed in a few months.

Introduction

Throughout the distribution of wild sheep in North America the focus of management is invariably for harvest of trophy rams. Indeed, wild sheep is the only species of ungulate in North America managed this way. A paper by Coltman *et al.* [2003] drew attention to the possibility that the genetics of horn size might be diminished by trophy hunting for large horns. However, as Postma [2006] and Hadfield *et al.* [2010] pointed out, and Coltman [2008] has acknowledged, the observed decline in horn size of rams on Ram Mountain, Alberta might not be genetic and could not be distinguished from environmental effect. In this case, the environmental effect was range deterioration as a consequence of carrying too many animals on a limited range [Jorgenson *et al*. 1993, 1998; Festa-Bianchet *et al*. 2004; Wishart 2006]. Although hunter selection might be causing deterioration in horn size of bighorns on Ram Mountain, the evidence is inadequate.

Yet, we believe that there are a number of reasons why such genetic erosion is not happening: (1) selection is weak and most hunters shoot the first legal ram that they have a chance to harvest, (2) heritability for traits under strong sexual selection will be low therefore the response to selection will be weak; nutrition invariably dominates as a cause of horn and antler variation in ungulates, (3) rams move among ranges including in and out of parks and protected areas where there is no hunting, and such genetic mixing would swamp any possible response to selection [Tenhumberg *et al*. 2004, Pelletier *et al*. 2014], (4) harvest reduces mean age and size of rams but the most fit rams still contribute most to the next generation, and (5) natural and sexual selection is still at work favouring larger animals, e.g., winterkill, even when reduced age decreases average horn size among males [Traill *et al.* 2014].

Patterns in the composition of hunter harvest can be explained by erosion of condition of animals as a consequence of managing herds at carrying capacity of the range [Jorgenson *et al*. 1993, 1998; Festa-Bianchet *et al.* 2014]. So few adult rams are harvested (1-2%) that hunting has negligible consequences to population density and therefore populations are largely at the carrying capacity set by vegetation growth.

With the release of the Draft Bighorn Sheep Management Plan for Alberta in June 2015 the sustainability of the bighorn trophy harvest has received renewed interest and attention. Since 1974 data have been recorded on all harvested bighorn rams and an analysis of these data resulted in concern that hunter harvest has declined in recent years, from a peak in 1992 [Festa-Bianchet 2015]. Furthermore, a slight decline in mean horn length and base circumference, as well as an increase in the average age of harvested trophies has been documented [Festa-Bianchet *et al*. 2014]. This has caused concern that the current management of bighorns might be reducing the number of trophy rams available to hunters. The reasons for these declines have been a source of debate with evidence for both ecological and genetic causes being put forward, and discussion over the relative importance of these factors is ongoing [Boyce 2015a, 2015b; Festa-Bianchet 2015; Festa-Bianchet *et al.* 2014; Pelletier *et al*. 2014]. Here we analyse some of the claims made by the contributors to this debate and identify areas where further data might clarify the management issues.

Total harvest:

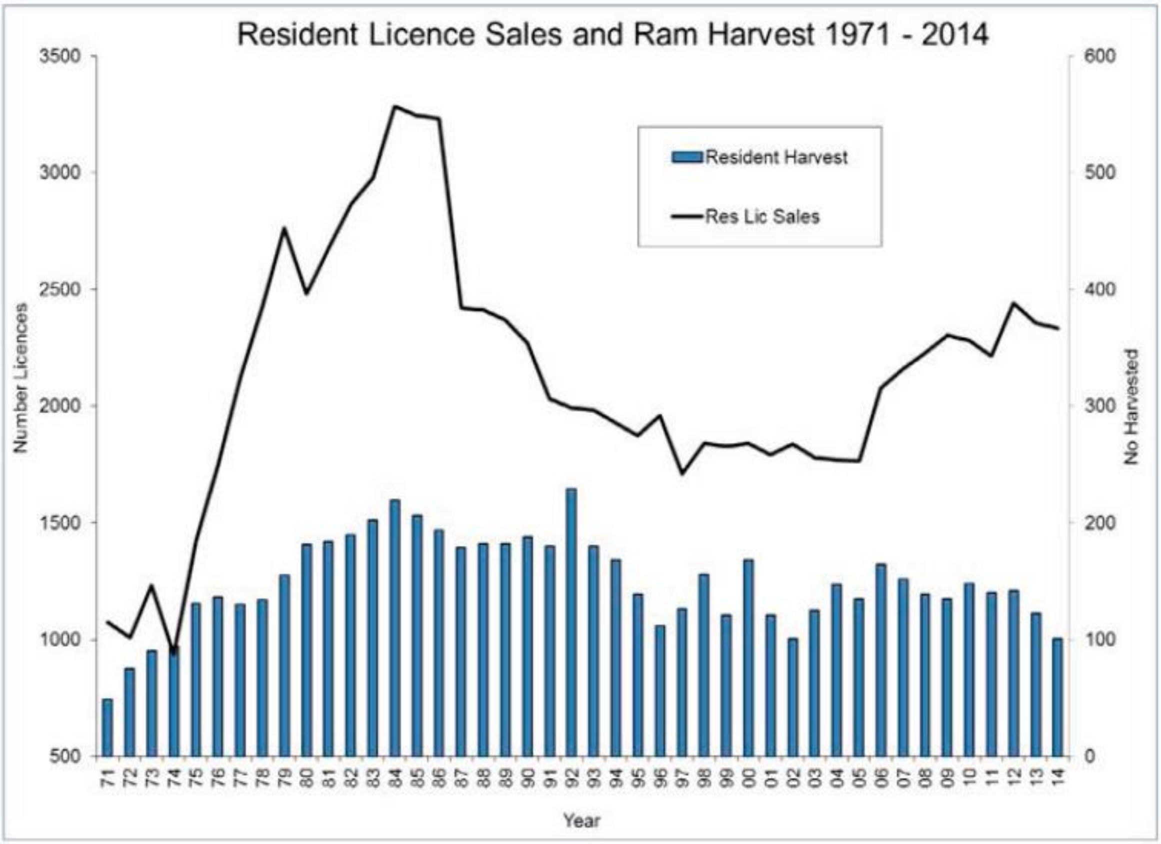

Figure 1: Trophy harvest total for residents from 1971 to 2014 and resident license sales [Festa-Bianchet 2015].

Harvests of trophy bighorns increased from 1971 to the mid-1980's, remained relatively constant throughout the 1980s, and declined from a peak in 1992 before remaining relatively constant during the last 15-20 years (Figure 1). While trophy harvest has declined relative to the 1980s to mid-1990s, there is no statistically significant trend in the number of rams harvested during the past 20 years (Figure 2). Over this time period there is yearly variation, with 2002 and 2014 being particularly poor years, but no overall trend (TS Linear Model, $P = 0.607$).

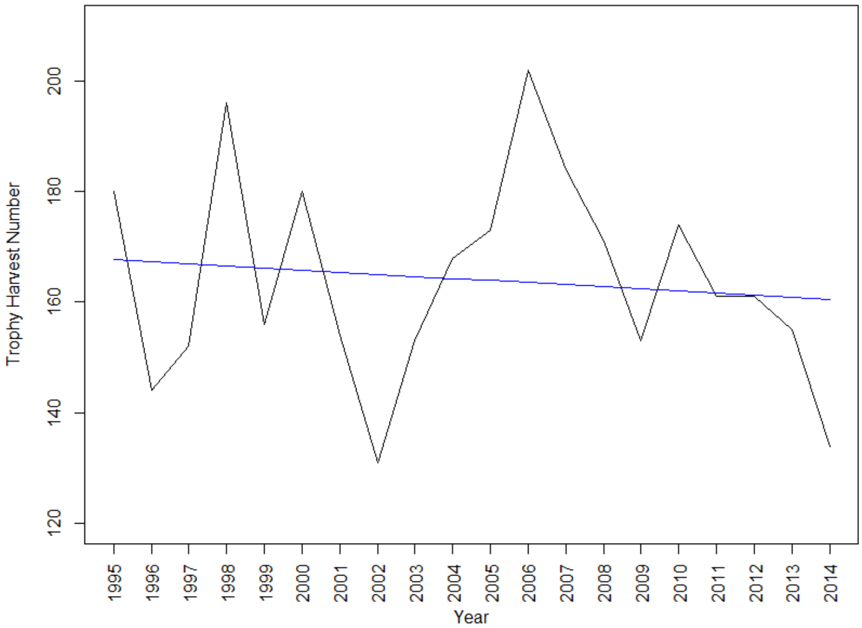

Figure 2: Total harvest of trophy male bighorns from 1995 to 2014. The blue line shows the non-significant trend during this 20-year period.

During this same period it is clear that hunter success (harvest divided by resident licence sales) has declined from a success rate of nearly 12% in 1992 to 5.5% today [Festa-Bianchet *et al*. 2014]. This might reflect decreased availability of rams during this period, but given that there has not been a decrease in the number of rams harvested, this decline in hunter success simply appears to be a result an increase in resident licence sales from 1995 onwards. One possible interpretation is that the increased number of licences (hunters) has not affected harvest due to the majority of readily accessible legal rams already being harvested.

Horn length, base circumference and age at harvest:

Mean horn length and horn-base circumference of harvested rams were reported to have declined between 1980 and 2010. Horn length of harvested rams declined by 3 cm or 3.5% between 1980 and 2010. However, horn length was lower in 1974 and increased up to 1980, before the slight decline. Base circumference also had a slight decline [Festa-Bianchet et al. 2014].

The pattern of average age at death for trophy rams has increased over time from 6.8 years to 7.5 years and the proportion of 4 and 5 year olds in the harvest has decreased from about 25% in the 1980s to less than 10% [Festa-Bianchet *et al*. 2014]. This suggests that the growth of bighorn rams has slowed over time.

We updated these models to include the latest 2011-2014 data to check if these trends were continuing.

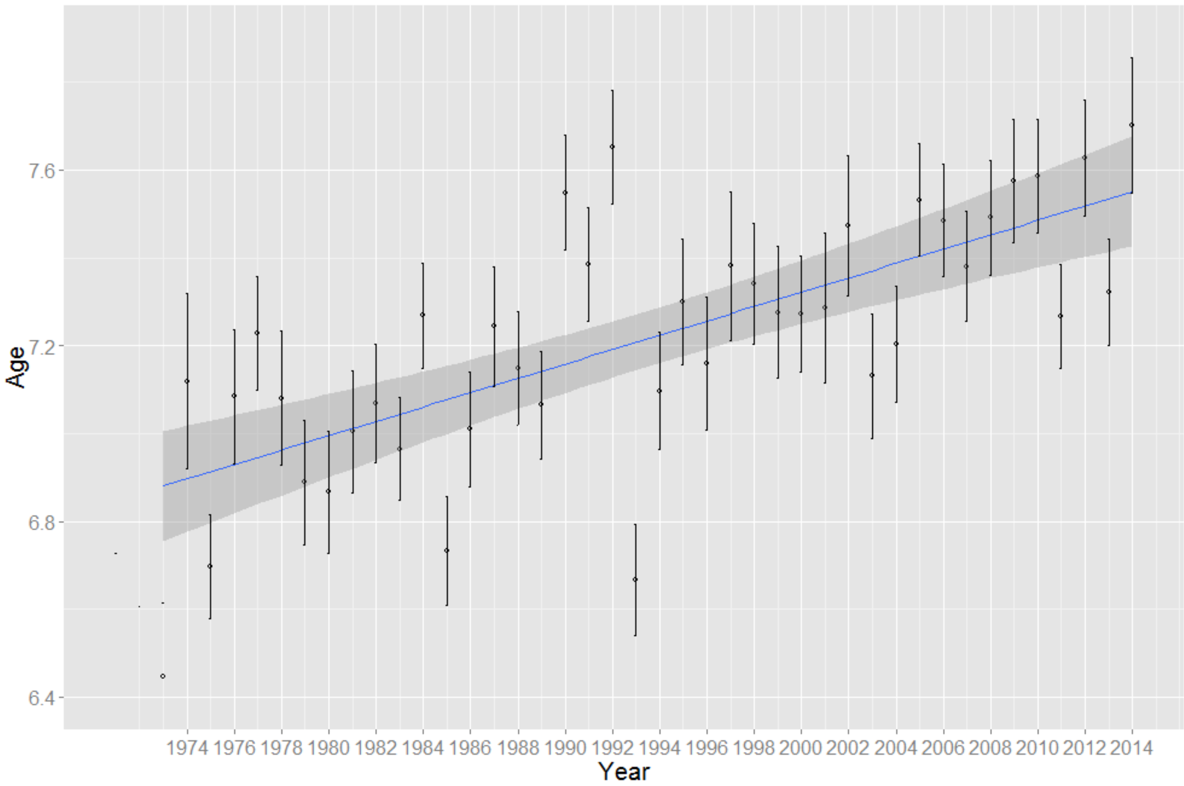

Figure 3: Age at death for bighorn trophies harvested between 1974 and 2014.

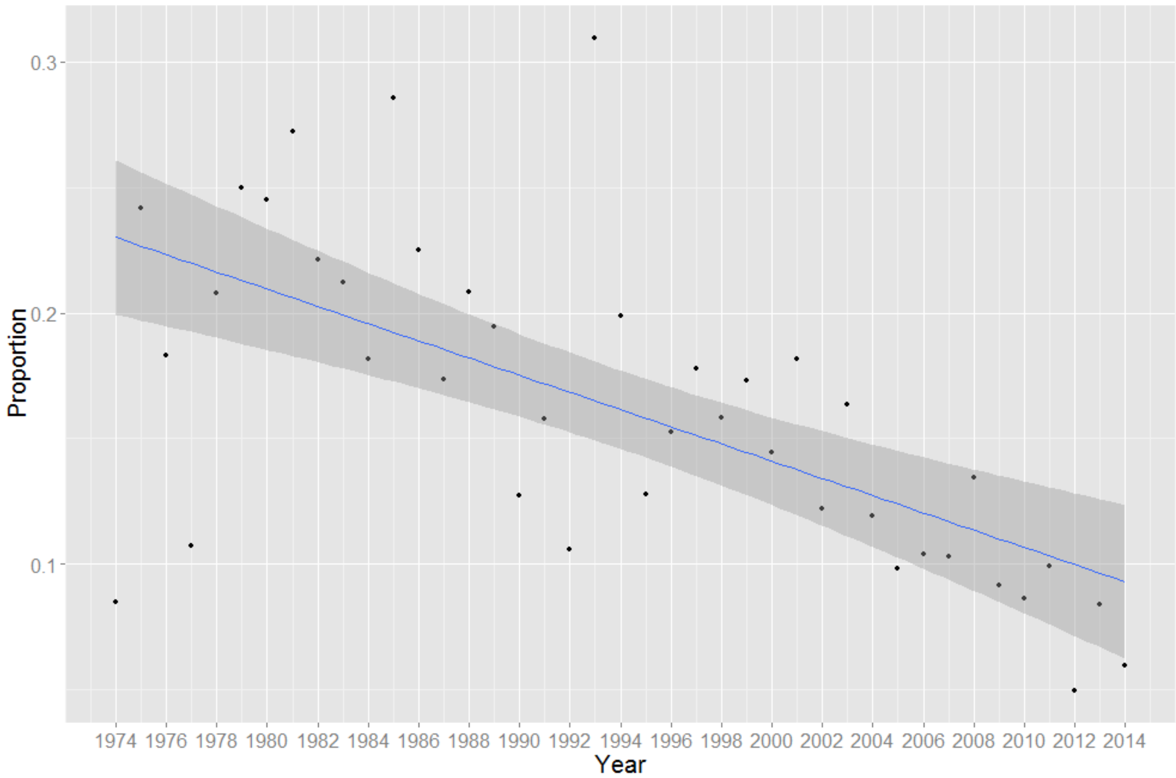

Figure 4: Proportion of 4 and 5 year old sheep in the bighorn trophy harvest between 1974 and 2014.

Indeed, the age at death has continued to increase while the proportion of 4 and 5 year old sheep in the bighorn trophy harvest has continued to decline (Figure 3, 4). This suggests that growth of bighorn rams continues decline, meaning it takes longer for rams to reach the legal 4/5 curl definition.

Reasons for decline

Both ecological and genetic effects have been postulated as the driving causes of the reduced growth of rams. Two main arguments have been put forward, with differing management solutions:

1. Hunter selection for large rams has caused artificial selection against fast-growing bighorns, thereby reducing the size of harvested rams and reducing ram growth rate. A change in management has been proposed to expand the number of WMUs with full-curl regulation to reduce harvest pressure on fast-growing rams thereby reducing selection.
2. The condition of bighorn sheep ranges has been degraded because populations have been maintained at carrying capacity, thereby reducing nutrition causing reduced ram growth rate as demonstrated in the Ram Mountain study [Jorgenson *et al.* 1998; Wishart 2010]. In this case an increase in the non-trophy harvest has been proposed to reduce population densities to stimulate density-dependent responses of increased growth and productivity [Boyce 2015a,b].

Artificial Selection:

Because fast-growing rams are killed by hunters upon reaching legal status they are less likely to pass on their genes compared to slow-growing rams, potentially setting up an artificial selection gradient favouring rams with slower growth. For older rams horn length has a positive correlation with mating success but rams that might be successful at an older age are likely to be shot before achieving this high reproductive success [Coltman *et al.* 2002]. This hypothesis was presumably supported by a pedigree analysis carried out using data from Ram Mountain, which claimed to show evolution caused by artificial selection [Coltman *et al*. 2003]. However, methods used in this paper were criticised for failing to disentangle genetic and environmental responses, therefore producing unreliable estimates of the genetic effect [Postma 2006; Hadfield *et al*. 2010]. These data have been reanalysed taking this into account, but the results have not been reviewed or published and are therefore not yet available for discussion [Festa-Bianchet 2015]. Recently a modelling study using the Ram Mountain data found that inheritance of bighorn body mass was weak and that as horn length and body mass are correlated, any evolutionary effect in this system is likely to be very weak [Traill *et al.* 2014]. The authors argue that observed declines are likely to be demographic effects. However this study in turn was criticised for using lamb mass, which has a weak relationship with paternal mass in their model, and for modelling hunting selection on adult mass rather than horn size whereas hunters are selecting animals with the largest horns, not the largest mass [Hedrick *et al.* 2015].

Dispersal from harvest refuges to harvested populations can counteract the directional change from hunters [Tenhemberg *et al.* 2004]. Moderate dispersal of rams from harvest refuges (e.g., national parks) will genetically swamp any selection by hunters. Bighorn rams harvested in WMUs adjacent to harvest refuges have on average 3% longer horns than those harvested far from refuges [Pelletier *et al*. 2014]. The authors argued that because declines in horn growth and age at harvest were similar in both near and far areas that dispersal does not protect bighorn sheep from the genetic effects of selective harvesting. However, these declines actually can be explained by the environmental effects of poor range condition in populations consistently maintained at carrying capacity on all areas, both near and far from the parks. The larger horn size in areas immediately adjacent to national parks is consistent with a demographic influence caused by rams dispersing out of the parks (phenotypic rescue), and likewise perfectly consistent with the Tenhumberg *et al.* [2004] hypothesis that genetic mixing with animals in a protected area would completely swamp any possible genetic effect of hunter selectivity. Without data on the genetics of these bighorn populations it is not possible to disentangle environmental and genetic effects.

Range degradation:

Harvesting to reduce population size below carrying capacity to induce density-dependent responses such as faster growth rate is fundamental to sustainable management of animal harvests [Boyce *et al*. 1999; Xu *et al.* 2005]. Data from the Ram Mountain study showed that non-trophy harvest reduced population size resulting in rapid growth of ewes and rams and faster horn growth by rams. When the population was then allowed to increase the size of ram horns declined as a result of range degradation [Jorgenson *et al*. 1998; Wishart 2010], although vegetation data were not available.

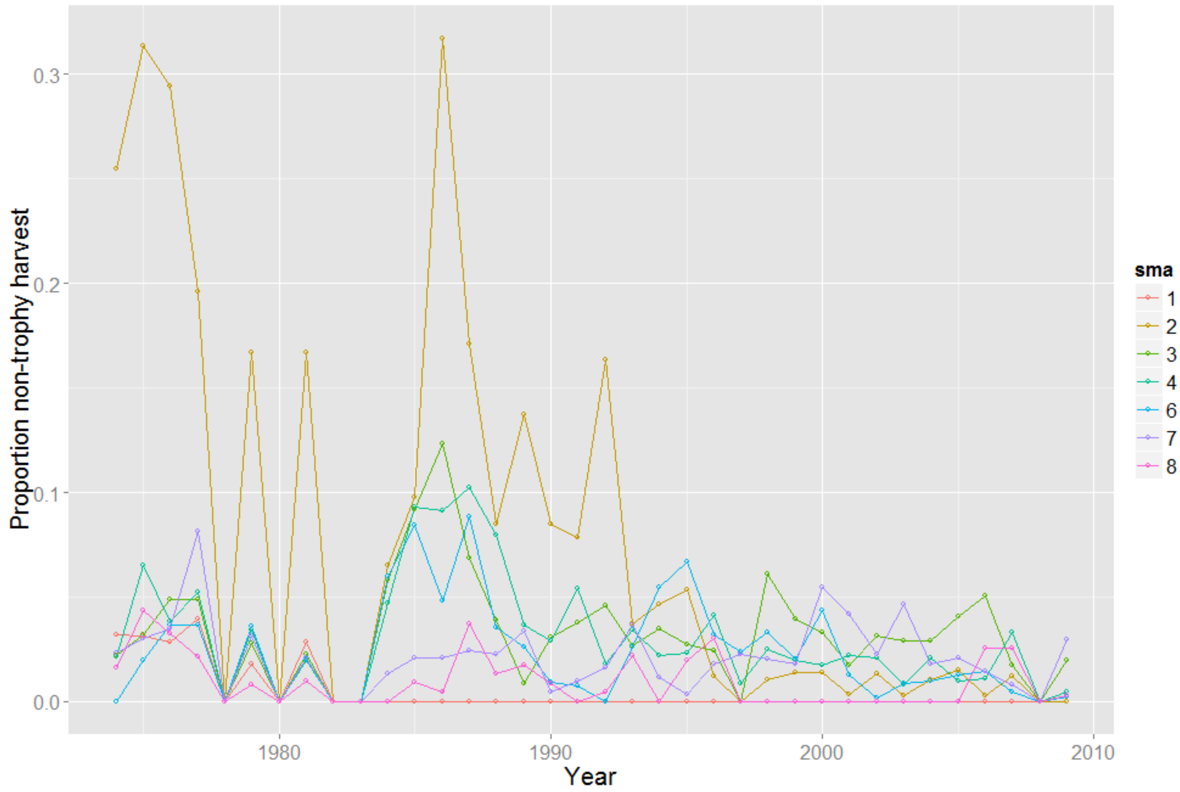

Figure 5: Non-trophy harvest as a proportion of population size for each Sheep Management Area (SMA). Data for SMA 2 are likely inaccurate due to unreliable aerial surveys.

We incorporated data from non-trophy harvests into analyses of horn length, base circumference, and age at harvest. Data for the non-trophy harvest in a consistent format were available only from 1974 to 2009. The proportion of non-trophy harvest for the population size for each SMA was used as an additional predictor variable in the models of Festa-Bianchet *et al.* [2014]. The non-trophy harvest variable was incorporated as a 'lagged' effect in which we used the mean non-trophy harvest proportion over the 10 years prior to the harvest of the ram. This meant that we could analyse bighorn trophy data only from 1981 to 2009, because before 1981 there were not the requisite 10 years of non-trophy harvest data available. No data were available for SMA 5.

Variables	Coeff.	SE	*P*	*N*
Horn length				
Age	4.455	0.245	<0.001	5,538
Age^2	-0.149	0.015	<0.001	
Harvest Year	17.222	5.146	<0.001	
Harvest Year^2	-0.004	0.001	<0.001	
Non-Trophy Prop.	10.411	4.808	0.030	

Horn Base				
Age	-0.058	0.014	<0.001	5,533
Harvest Year	-0.014	0.003	<0.001	
PDO	0.121	0.055	0.028	
Age				
Harvest Year	10.652	1.941	<0.001	5,548
Harvest Year^2	-0.003	0.0005	<0.001	
PDO	-0.598	0.061	<0.001	
Non-Trophy Prop.	-2.687	1.520	0.077	

Table 1: Estimates from linear mixed-effect models with SMA as a random effect. These models mirror those of Festa-Bianchet *et al.* [2014] except that we included the proportion non-trophy harvest as a covariate, data from SMA 5 were excluded, and analysis included data from 1981-2009 only due to the availability of non-trophy harvest data.

Non-trophy harvest had a positive effect on horn length but no detectable effect on base circumference. There was a marginally non-significant negative effect of non-trophy harvest on age (Table 1). This indicates that non-trophy harvest can indeed increase horn length [Jorgenson *et al*. 1998; Boyce 2015b] and suggests a possible influence on reducing the age of bighorn rams at harvest. We note that data on population size were gathered using aerial surveys, which are subject to error and have not always been carried out frequently for all SMAs, but there is no reason that this error would compromise the non-trophy harvest effect.

Research needs:

Paul Frame, Alberta Environment & Parks, is collaborating with me and a new Ph.D. student (to be recruited) on a new experimental manipulation of cougar harvests in Wildlife Management Units (WMUs) of Alberta. Currently cougars are taken almost exclusively by houndsmen during a hunt that begins on Dec 1 and terminates Feb 28 or when a quota has been reached for a harvest area [Knopff et al. 2014]. We will randomly select 1/3 of the mountain WMUs containing hunted bighorn populations where cougar harvests will be permitted beginning August 25 when bighorn hunting begins until February 28. Hunters will be able to purchase a cougar licence to use while hunting other species such as ungulates. All cougars must be registered at a Fish & Wildlife office within 24 hours of harvest and a tooth will be removed for age determination. Likewise, all bighorn rams harvested must be measured and registered by an authorized officer.

Undertaking this project might validate concerns that cougar predation is reducing bighorn populations [Festa-Bianchet *et al.* 2006; Bourbeau-Lemieux *et al*. 2011]. Alternatively, we might actually see increased bighorn survival and abundance caused by triggering a density-dependent response caused by cougar predation, i.e., the Hydra effect [Boyce *et al.* 1999, Abrams 2009]. Hunter harvest on most WMUs is currently restricted to a small number of adult rams (4/5 or full curl) that has essentially no consequence for density dependence. We propose that for another randomly selected 1/3 of the WMUs with bighorn hunting, non-trophy sheep harvests will be restored, issuing licences at 1987 levels, again with the hypothesis being the Hydra effect and a prediction that horn growth will be increased for rams as was observed in the long-term Ram Mountain study [Jorgenson *et al*. 1993, 1998; Wishart 2006]. We propose that remaining WMUs will be managed under existing management regimens as a control. A Ph.D. student will be recruited at the University of Alberta to conduct the study under the supervision of Mark Boyce. Monitoring of bighorn populations will be conducted by Alberta Environment & Parks using helicopter surveys, and detailed measurement of horn growth of rams will be obtained when hunters register their kills.

Conclusions

Bighorn management in Alberta has been highly successful allowing continued yields and sustained populations of bighorns for several decades. Undoubtedly both genetic and environmental factors influence growth rate of bighorn rams. As shown in the earlier Ram Mountain studies [Jorgenson *et al*. 1993, 1998; Wishart 2006], our analysis of existing data indicates that horn growth and size has been enhanced by non-trophy sheep harvests. Whether or not selective harvest by hunters has any consequence is unclear, and the relative importance of genetics and nutrition has not been resolved, and requires continuing investigation. A study at the University of Alberta by David Hik is currently studying the importance of climatic conditions and range condition (NDVI) on bighorn ranges in northern Alberta similar to published work on thin-horned sheep conducted in the Yukon [Loehr *et al*. 2010], which will shed light on the role of genetics, climate and range condition to bighorn growth and horn size. Further studies on the genetics of bighorn rams and publication of the updated Coltman *et al*. [2003] analysis would help to clarify the postulated role of selection [Festa-Bianchet 2015]. Given the lack of consensus on the management implications of existing data, changes to management regulations should proceed with caution.

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