Montana's Sun River Bighorn Sheep (*Ovis canadensis*), Decimation to Restoration and Back Again…Ugh!

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ABSTRACT: The Sun River bighorn sheep (*Ovis canadensis*) herd has consistently been one of the largest and most robust native herds within Montana. Early European settlement records indicate bighorn sheep presence in the upper Sun River drainage area as early as 1866, although it is reasonable to assume that bighorn sheep have inhabited the upper Sun River drainage for a period well before then. By the early part of the 20th century, bighorn sheep numbers in this area were dramatically reduced. The causes most often cited were range competition from livestock and other big game animals, contact with domestic sheep (subsequent contraction of disease), and subsistence hunting. During the 1930s, bighorn sheep recovery began in the Sun River area due to the reversal of the previously noted conflicts. There have been five recorded die-off events for the Sun River herd (1924-25, 1927, 1936, 1983-84, and 2010-11). Post die-off events, herd reestablishment has been due to natural production, survivorship and recruitment. Beginning in spring 2010, a disease outbreak in Sun River sheep began (all age/gender die-off). This event arguably has had the largest population level impact on sheep in this area in the last century, reducing population levels over the next several years by as much as 70% coinciding with observed single digit lamb:ewe ratios. Pre- and post-die-off disease monitoring data portray somewhat unremarkable variability in pathogen presence, despite confirmed widespread infection of polymicrobial bacterial pneumonia including the presence of *Mycoplasma ovipneumoniae* during the die-off period. Taking a relatively hands off management approach, current (spring 2023) population surveys place Sun River sheep at over 400 animals, the highest observed number in a decade, with a calculated 38 lambs:100 ewes. Given the status and gradual, natural recovery of sheep to date, the hands-off management approach provides one example of the value of understanding all facets of herd history and allowing time and opportunity for natural herd recovery before enacting potential large scale hands-on management efforts.

Biennial Symposium of the Northern Wild Sheep and Goat Council 23:40-47;2022

KEY WORDS: *Bibersteinia trehalose*, bighorn sheep, disease, die-off, *Mannheimia, Mycoplasma ovipneumoniae (*Movi*), Pasteurella*, Sun River

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INTRODUCTION

The first recorded European explorations of the Sun River country were by Lewis and Clark in June of 1805, however, no bighorn sheep observations were noted. Rocky Mountain bighorn sheep presence in the upper Sun River drainage was first reported in 1866 (Couey 1950). Earlier reports exist in other locations within the Rocky Mountains, and it is reasonable to assume that bighorn sheep presence in the Sun River country has been persistent for at least the last two hundred years. Like other wild sheep populations, around the turn of the 20th century sheep numbers in this area declined due to range competition from livestock and other big game (primarily elk), contact with domestic sheep (and subsequent disease), and subsistence hunting (Picton 1975). However, bighorn sheep populations did not suffer complete eradication due to the natural topography of the area, natural bighorn sheep distribution across the landscape, and the ability for sheep to separate themselves from other livestock and big game concentrations. Unverified reports of good numbers of sheep were noted in 1908 and 1910 in two different locations within the Sun River area (Couey 1950).

By the 1930s, sheep numbers in the area were recovering and demonstrated overall general population stability for the next seven decades. By 1940, populations had recovered to the point of utilizing Sun River area sheep as a source population to help establish, reestablish, or augment other bighorn sheep populations in Montana. The first of many successful translocation efforts in this area was accomplished in 1942 with the last translocation event taking place in 2009 (Carlsen et al. 2010). Total sheep translocated from the Sun River area during the seven-decade period equates to nearly 1,200 individuals received in over 30 different locations within and outside the boarders of Montana. During this same period, hunting opportunity was also maintained as a high management priority with approximately 1,800 ram (either-sex) and 1,200 adult ewe licenses offered. Long-term average success rates for ram and adult ewe licenses near 90% and 60%, respectively.

However, despite research and management efforts to manage sheep populations within objective range to sustain herd health, beginning in late spring and summer seasons of 2010, clinical signs of sick and/or dead sheep began to occur, resulting in widespread population reduction in the proceeding years throughout the Sun River sheep range. The impacts of the 2010/2011 disease outbreak have had extensive implications and is arguably had the most significant influence on overall herd health and population performance in at least the last century. Understanding general sheep herd history and past and current management strategies related to current circumstances and disease prevalence has demonstrated its importance to making informed management decisions geared towards population recovery.

STUDY AREA

The upper Sun River drainage and surrounding occupied sheep habitat is in west central Montana along the eastern edge of the Rocky Mountains known as the Sawtooth Range (Figure 1). The area lies approximately 60 miles south of Glacier National Park and on the east edge of the Bob Marshall Wilderness. This area is comprised of Montana Fish, Wildlife & Parks (FWP) administrative bighorn sheep hunting districts (HD) 421, 422, 423 and 424. Together, these HDs represent over 2,900 km² of land with approximately 855 km² (30%) occupied by bighorn sheep during at least some portion of the year. Over 90% of the occupied sheep habitat is public land (U.S. Forest Service, Bureau of Land Management, or Montana Fish, Wildlife and Parks). Although less than 10% of the existing occupied sheep habitat is private land, these lands are important, especially during the late fall through early spring season.

Figure 1. General location and distribution of the Sun River Bighorn Sheep herd within Montana.

METHODS

This manuscript focuses primarily on broad management information and approaches with some research input. Therefore, methods briefly summarized pertain to annual bighorn sheep survey monitoring work as well as disease surveillance as part of management and statewide research efforts.

Population Surveillance

Annual bighorn sheep surveys are completed in spring, mid-summer and late fall. Depending on the area, accessibility and time of year, survey methods include aerial based efforts (A-Star, JetRanger or Hughes 500 helicopters or Piper PA-18 Super Cub fixed wing aircraft), four-wheel drive truck, foot (hiking), and horseback surveys. Optics used during survey work such as spotting scopes and binoculars, handheld GPS units, telemetry, and survey data sheets for consistent repeatability are considered standard equipment.

Spring surveys are completed via a variety of survey methods previously described and are focused on post winter survivorship and obtaining accurate classifications of individuals to portray lamb:ewe (yearling recruitment) and ram:ewe ratios as well as overall population numbers. Summer surveys are completed via helicopter with the primary focus on obtaining early season lamb production counts and subsequent lamb:ewe ratios. Late fall/early winter surveys utilize a variety of survey techniques and again, focus on obtaining representative lamb:ewe and ram:ewe ratios, as well as overall numbers. Fall surveys also portray overall herd performance prior to the primary winter period.

Disease Surveillance

Given lack of health related to issues for bighorn sheep in this area, focused disease surveillance efforts prior to 2010 were only completed as part of translocation work. Standard samples collected for disease testing during translocation work included general body condition scores, serum (blood) for viral testing, pharyngeal tonsil and nasal swabs for diagnostic bacterial culture testing, and fecal samples correlated with parasitology testing. Beginning in 2011 and due to widespread disease concerns, translocation work ceased within the study area and instead, focused more on opportunistic disease surveillance efforts. This included obtaining the same samples previously described for testing via ground darting, postmortem necropsies on viable carcasses found afield, and hunter collected samples upon harvesting a sheep. In 2013, FWP and Montana State University (MSU) began a multiyear statewide research program designed to assess factors driving bighorn sheep population dynamics across Montana (Garrott et al. 2021). Through this project, standardized sampling and testing methods were developed and refined. This included collection of many of the same or similar samples, however, also included improved methods to better detect pathogens. Culture- and PCR-based pathogen diagnostic tests were utilized upon collection of multiple tonsil and nasal swabs to test for a variety of pathogens to include *Pasteurellaceae species*, *Mycoplasma ovipneumoniae* (Movi), *Mannheimia spp*. and *Bibersteinia trehalose*. Exposure of sampled animals to Movi was also assessed using serum from blood collected. Other non-disease focused data collected during the Garrott et al. project included gender, age (estimated using incisor eruption patterns) (Hemming 1969), and lactation status of adult females. Ultrasonography was used to measure subcutaneous rump fat thickness of adult females and body condition was also assessed using skeletal palpation methods. Additionally, weight and hind foot length (Zannése et al. 2006, Garel et al. 2010) were measured for all adult females. For further information related to sample collections, refer the Garrott et al. (2021) final report.

RESULTS

Population Surveillance

Prior to 2010 and within the cumulative FWP trend survey areas, long-term average observed (minimum) number of sheep during annual surveys (spring season) tally just over 500 individuals (n=514). It is noteworthy that given the survey types utilized correlated with seasonal weather patterns, observability of sheep is variable from season to season or year to year, at times reflecting large fluctuations in sheep observations. April (spring) 2010 provided ideal survey conditions and subsequently population survey data produced not less than 933 bighorn sheep within established upper Sun River trend survey areas with a calculated lamb:ewe:ram ratio of 28:100:61 (Figure 2). In June, the first report of a clinically compromised sheep (ram) was observed on what would be classified as primarily winter range habitat and during summer 2010, limited reports of sick and/or dead sheep were reported. A late summer 2010 helicopter survey was completed as part of other big game survey work and of 51 sheep observed, no lambs were classified. By late fall 2010, the overall population declined by approximately 39% (n=568 observed sheep) and a lamb:ewe:ram ratio of 5:100:62. Approximately 4 months later, spring 2011 surveys produced further reduced numbers with 43% fewer sheep (n=535) than what was observed one year previous and lamb:ewe:ram ratios of 5:100:63 (Figure 2). Of the 535 sheep observed in spring 2011, only 13 lambs were classified. Spring 2018 survey observations hit a low point with population observations reduced by 71% (n=266 observed sheep), albeit with improved lamb recruitment at 30 lambs:100 ewes (Figure 2).

In general, the die-off impacted both males and females and across all ages. However, since 2018, overall populations have improved with

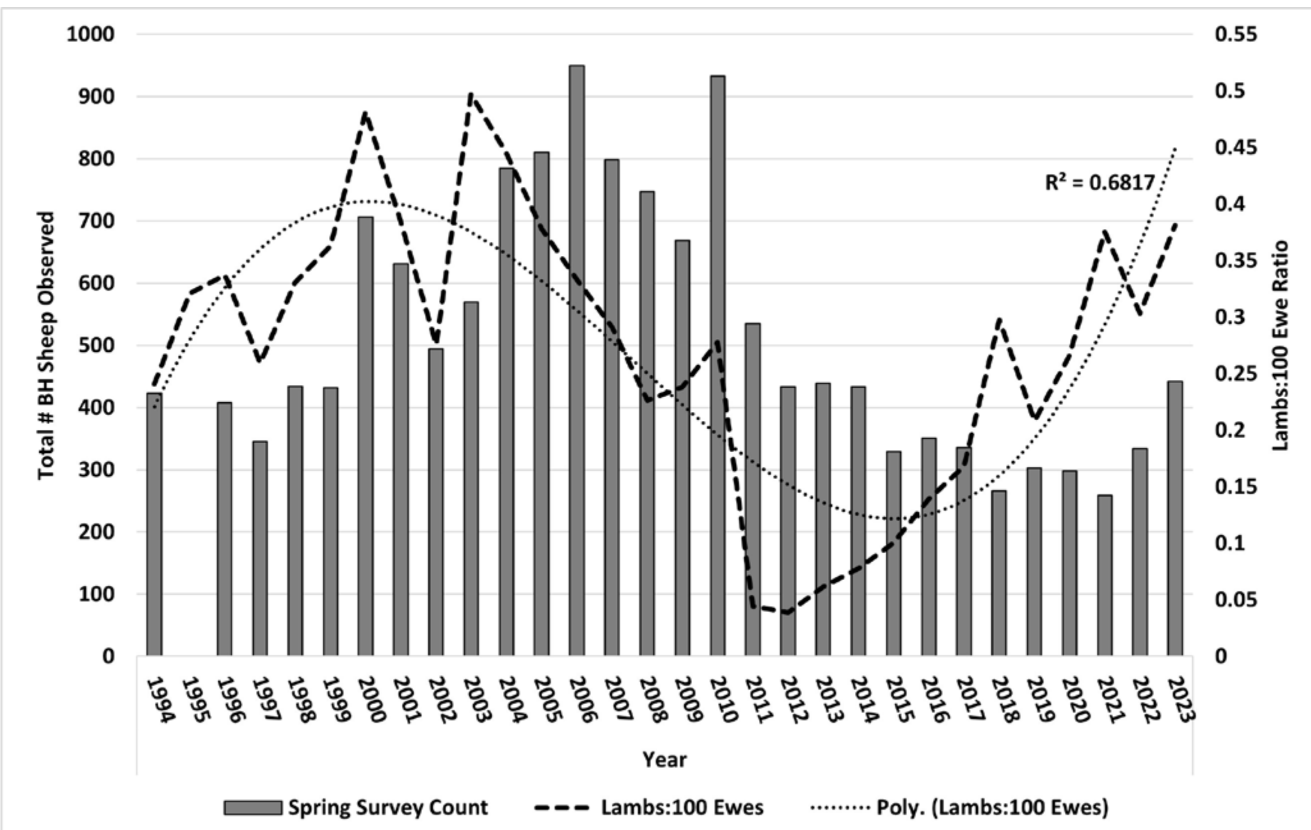

Figure 2. 30-year comparison (1994-2023) of total observed Sun River bighorn sheep and calculated lambs:100 ewes during annual spring surveys. Lamb:ewe ratios this time of year are focused on those lambs born the previous year (nearing their first birthday – recruitment) and is prior to the parturition period.

spring 2023 observations the highest in a decade (n=442) along with near long-term average (prior to the 2010/2011 die-off) lamb recruitment at 38 lambs:100 ewes (Figure 2). Due to the significant reduction in lamb survivorship, ram age structure and ram:ewe ratios also declined but with more recent improvement in lamb survivorship, ram numbers improved with a relatively strong cohort of two- to five-year-old rams in the population.

Disease Surveillance

Over a three-year period (2007-2009), and as part of efforts to help reduce sheep numbers closer to objective levels (in addition to adult ewe licenses offered), a total of 189 sheep (155 ewes, 20 rams, 12 lambs) were translocated from the upper Sun River area to other locales in MT and other states. As is routine with most translocation related work, disease sampling was completed during sheep processing prior to being placed in trailers for transport (Table 1). Culture positive results for individuals with general higher to lower prevalence rates included *B. trehalose*, *M. haemolytica* and *P. multocida*, in that order (Table 1). Parasites such as Coccidia, Lungworm and other intestinal parasites were detected with variable load levels (Table 1). Movi was detected using enzyme-linked immunoassay (ELISA) testing in which approximately 11% tested positive (Table 1).

In March 2011, and in response to the ongoing die-off event, limited ground darting effort was completed to sample sheep and test for pertinent pathogen prevalence. Seven individuals (5 ewes and 2 rams) were targeted during ground darting effort and similarly sampled for various pathogens. Five individuals were culture positive for *B. trehalosi* and one individual for *P. multocida*. Parasite prevalence was detected as well with four of six sheep sampled being positive for Coccidia and

Table 1. Pathogen and parasite detection from three time periods based on serology and culture based diagnostic testing as well as other sampling measures. Pathogens are noted as the actual number individuals tested (+ positive, - negative, etc.) and percentages are based on the number of samples submitted for testing.

CULTURE-BASED POSITIVE DIAGNOSTIC RESULTS									
		***Bibersteinia trehalosi* (%)**	***Mannheimia haemolytica* (%)**	***Pasteurella multocida* (%)**	***Mannheimia spp.* (%)**	***Pasteurella spp.* (%)**			
2007-2009 Translocation Samples		158 (84%)	55 (29%)	3 (2%)					
2011 Ground Dart Samples		5 (71%)		1 (14%)					
2014-2022 Management / Research Samples		40 (34%)	2 (2%)	18 (15%)	5 (4%)	5 (4%)			
DETECTION OF *Mycoplasma ovipneumoniae*									
	ELISA + (%)	**ELISA - (%)**	**ELISA suspect (%)**	**ELISA Indeterminate (%)**	**ELISA N/A (%)**	**PCR + (%)**	**PCR - (%)**	**Suspect (%)**	**PCR N/A (%)**
2007-2009 Translocation Samples	11 (6%)	89 (47%)	1 (<1%)						
2011 Ground Dart Samples	2 (29%)	5 (71%)				3 (43%)	3 (43%)		1 (14%)
2014-2022 Management / Research Samples	23 (19%)	13 (11%)		1 (<1%)	34 (29%)	15 (13%)	94 (79%)	5 (4%)	
***Pasteurella* Leukotoxin lktA**									
			PCR + (%)	**PCR - (%)**					
2014-2022 Management / Research Samples			3 (7%)	38 (93%)					
PARASITOLOGY									
		Coccidia		**Intenstinal parasites**		**Lungworm**			
2007-2009 Translocation Samples		Yes / Widspread (light parasite loads)		Yes / Widespread (light parasite loads)		Yes / Widespread (light parasite loads)			
2011 Ground Dart Samples		Yes (4 of 6) w/light parasite loads		Yes (4 of 6) w/light parasite loads		Yes (3 of 6) w/light parasite loads			
2014-2022 Management / Research Samples		Yes (16 of 20) variable w/light parasite loads		Yes (15 of 20) variable w/light parasite loads		Yes (20 of 20) w/light parasite loads			

intestinal parasites, albeit with light parasite loads. Lungworm was detected in three of six individuals, also with light parasite loads. Movi was tested for via both ELISA and polymerase chain reaction (PCR) tests. Two and three of the seven individuals sampled were positive for Movi via ELISA and PCR testing, respectively.

Lastly, from 2014 through 2022, additional disease sampling was completed as part of formal statewide research (Garrott et al., 2021), hunter harvest samples, field necropsies of viable carcasses, and concerted effort to redeploy GPS collars from research/monitoring mortalities to maximize collar life span. This equates to 119 individuals (60 ewes, 54 rams and 5 lambs). Based on culture results, *B. trehalosi* was detected in 40 individuals, *Mannheimia spp*. in 18 individuals and only a handful of positive detections for *M. haemolytica*, *P. multocida* and *Pasteurella spp*. (Table 1). Consistent and variable loads of Coccidia, Intestinal parasites and lungworm were detected among most individuals that were sampled in this regard (Table 1). Using ELISA testing methods, 72 individuals were sampled for Movi with 23 testing positive, however it is important to note 34 individuals had unavailable results. Using PCR testing methods, 114 individuals were tested, portraying 15 positive individuals and 5 that were defined as suspect (all others negative). *Pasteurella* Leukotoxin lktA was also tested for via PCR for 41 individuals. Three individuals were positive for P. Leukotoxin lktA.

In summary, over 300 sheep were sampled over a 16-year period providing a relatively strong set of pre- and post- disease event pathogen data. Sheep portrayed a wide variety of test results across multiple pathogens that allows for unique analysis with respect to pre- and post- population performance monitoring.

DISCUSSION

Before 2010, there have been four bighorn sheep die-offs recorded in this area in the last century. The first die-off occurred during 1924-25 with an estimated population loss of 70%. Forage competition with other big game (elk) and livestock was thought to be a major contributing factor. Other smaller die-offs were recorded in 1927 and 1936, but the magnitude is unknown. Field diagnosis of some of the dead sheep in the 1924-25 and 1927 die-offs indicated pneumonia as the cause of death (Marsh 1938). In 1983-84, an estimated loss of 30-50% of the population occurred. Estimates vary due to certain areas within the greater Sun River region had higher losses than others. The latter die-off was primarily caused by bronchophneumonia complicated by pulmonary nematodiasis. The true origin of the 1983-84 disease outbreak is unknown, although a plausible scenario consists of a disease outbreak that started in the spring of 1983 at Crowsnest Pass-Waterton Lakes National Park, Canada, worked its way south through Glacier National Park and eventually down the eastern flank of the Rocky Mountain Front and the Sun River region (Montana Fish, Wildlife & Parks 1984). Persistence of non-native pathogens in sheep in the Sun River area is assumed to be endemic to the area for decades. Except for a small transplant in 1999 in the northeastern range of bighorn distribution, all population growth post die-off has been the result of natural production, recruitment, and immigration.

Like the 1983/84 die-off, origins of the 2010/11 die-off are unknown. Although translocation captures completed in 2007-2009 period portrayed some level of pathogen presence that is known to cause die-off events, no observations of visibly unhealthy sheep were noted. Observations of sheep during winter (December) and spring (April) 2010 surveys also portrayed healthy individuals with no visible signs of sickness. Winter and early spring habitat conditions were considered normal for this time of year in this area, assumed to not be an added stress related event providing opportunity for disease expression. During approximately this same period, other wide-spread bighorn sheep die-off events occurred in

Western Montana (Dickson 2011), although are believed to be independent of the Sun River die-off given geographic distances and topographic variability between sheep ranges. One possible scenario that has been discussed is potential implications of translocated mountain goats into a portion of sheep habitat in the northern end of Sun River sheep distribution. In 2008 and 2009, a total of 25 mountain goats were trapped and translocated from two different sources within central and southcentral Montana. Interestingly, these two source herds were also areas that were initially established using translocated mountain goats from the Sun River area decades previous. Given current knowledge of potential pathogen mixing implications between wild sheep and goats, it is plausible that during the 2008/2009 period such interactions could have taken place and taken time to spread into a widespread disease event with existing local bighorn sheep. Unfortunately, disease results from the mountain goat transplants are limited and does not provide good conclusive perspective into this potential commingling scenario.

In reviewing pre- and post-die-off bighorn sheep disease results definitive conclusions related to potential novel pathogen introduction into the area is difficult. Culture-, ELISA- and PCR-based diagnostic test results gives no indication of novel pathogen arrival into the area, although variable prevalence rates. However, given the refinement of testing abilities over time, pathogens such as Movi, to include strain typing abilities, could allow for improved detection rates that were not available or at least not widely used prior to the most recent die-off event, hence, compromising making strong inferences between pre- and post- disease data. Nonetheless, disease data do show pertinent pathogens, such as Movi, present within Sun River sheep providing confirmation for the likely primary agent(s) causing widespread population declines during the decade succeeding 2010.

Despite an approximate 70% decline in upper Sun River area sheep populations, decisions made to heavily monitor, but not directly attempt to mitigate ongoing disease presence post die-off was not an easy decision to make and at times, was met with considerable consternation. Given the history of a general hands-off disease management approach and subsequent consistent recovery of bighorn sheep in this native herd, allowing time for processes to naturally play out was the ideal path forward for at least the immediate interim. Although it appears sheep are gradually making headway towards eventual recovery in this area, certain areas (sub-herds) are faring better than others, perhaps due to low level presence of pathogens persisting in some areas. Of course, with smaller herd sizes, additive impacts of potential habitat limitations (short- or long-term) predation, and annual weather events must also be considered. Test and removal management strategies has been considered, but at least for the interim, not something being pursued given generally herd stability, albeit at low levels in places, but improving lamb recruitment. Additionally, within range transplants (using source sheep from more productive sub-herds) is also being considered as one means to help bolster those sub-herds that appear to be slower to recover. The assumption being that little concern, if any, should be had with respect to introduction of novel pathogens if sheep were moved given assumed widespread distribution of the same pathogens within Sun River sheep range, and distances are far enough that movement of translocated sheep would not be all for not as/if they returned to their accustomed home range. However, as has been the case, continued monitoring is ongoing and such data will help make more informed decisions with respect to any such direct management approaches for upper Sun River sheep.

Ultimately, management of bighorn sheep in the upper Sun River drainage has a storied history within the borders of Montana. Although this latest chapter for this population of bighorn sheep has been a difficult road, recovering and maintaining this population as one of Montana's premier native sheep herds remains a high priority for not only the benefit of the natural resources of this area, but for future generations of Montana's to appreciate and enjoy.

ACKNOWLEDGMENTS

The information gathered and summarized in this manuscript is presented in recognition of all the good biologists, conservationists, researchers, graduate students and sportsmen and women that have worked and lived in the Sun River Country. Persistence of bighorn sheep in this area is a testament to their work and true appreciation for wild sheep and emphasizes the desire to continue to maintain a healthy and robust population of bighorn sheep in the Sun River area for generations to come.

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