Introduction

The Whiskey Mountain bighorn sheep (WMBS) herd encompasses the northern Wind River Mountain Range in west central Wyoming (Figure 1). The herd has been an important component in bighorn sheep management for Wyoming and other western states for many decades. Recognized for years as the largest congregation of wintering bighorn sheep (*Ovis canadensis*) in the country, the herd has been a management focus for the Wyoming Game & Fish Department (WGFD), federal land management agencies, and non-government conservation groups for over half a century. From 1949 through 1995 over 1,900 bighorn sheep were captured and moved from the WMBS herd to establish new bighorn sheep herds or augment existing herds throughout the West. At its peak, the herd provided substantial recreational opportunity for hunters and photographers. In addition, the herd has become part of the identity for the town of Dubois.

Following a large, all-age die-off caused by pneumonia during the winter of 1990/1991 the bighorn sheep herd has consistently experienced low lamb production leading to continued population decline. Observations of the bighorn sheep herd over the past 32 years also reveal the persistence of bighorn sheep (lambs and adults) exhibiting nasal discharge, coughing, parasites, sinus tumors, and low body mass. All of these symptoms indicate bighorn sheep in the herd are generally unhealthy, likely subject to environmental stressors and continual exposure to contagious and transmissible pathogens resulting in chronic respiratory disease.

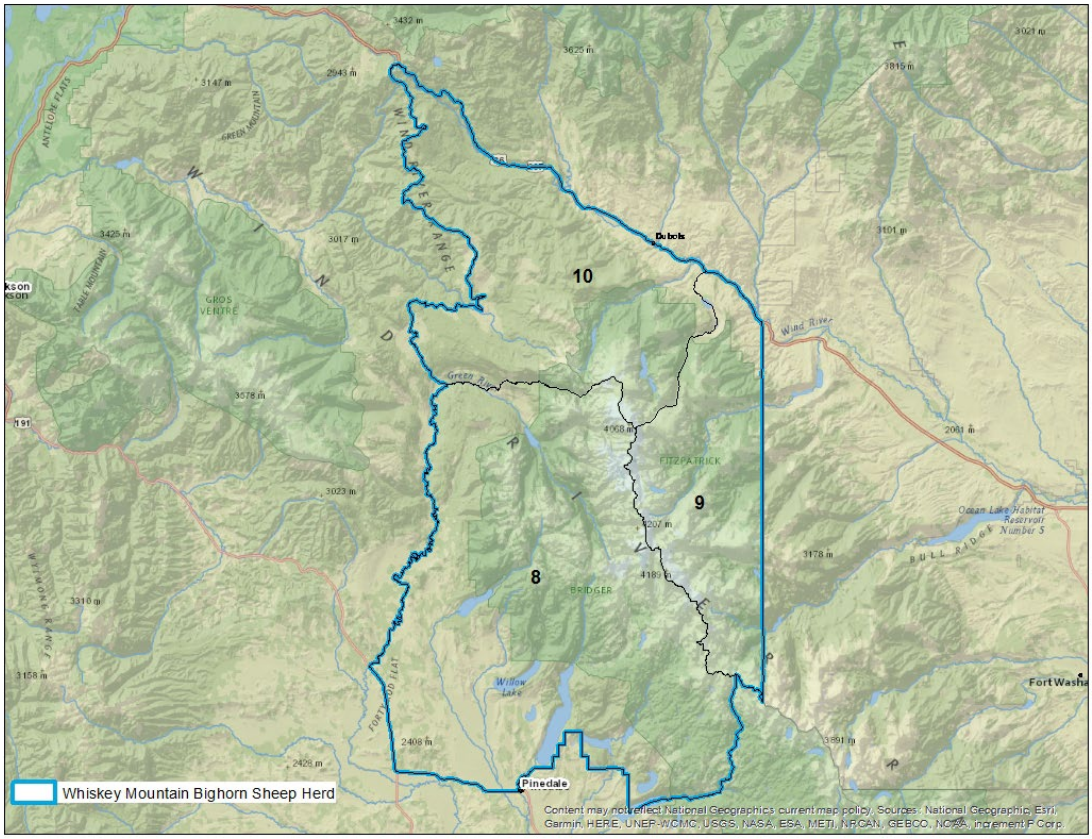

Figure 1. Whiskey Mountain Bighorn Sheep herd unit, Wyoming.

While overall the population has declined, sub-herds have responded differently regarding lamb productivity and recruitment. For example, the Red Creek sub-herd, located on the Wind River Reservation, has had suppressed lamb recruitment for decades while the Torrey Rim portion has gone through cycles of moderate to low lamb recruitment and the Sheep Ridge sub-herd experienced a significant decline starting in 2016 and has nearly vanished.

It has been widely accepted the bacteria *Mycoplasma ovipneumonia* (Movi) is a primary agent of respiratory disease in bighorn sheep (Besser et al. 2012b and Cassirer et al. 2018). A test and remove (T&R) program can improve lamb survival by removing identified chronic carriers of Movi (Garwood et al. 2020 and Almberg et al. 2021).

Based on research conducted by the University of Wyoming (UW), the presence and prevalence rate (31%) of Movi in both adult and juvenile bighorn sheep throughout the Whiskey Mountain herd has contributed to high lamb mortality (Rachel Smiley, pers. comm.). Clearly, pneumonia-induced mortality in lambs is a key factor limiting recovery of this bighorn sheep population.

As a starting point to address this issue, the Eastern Shoshone and Northern Arapaho Tribes, WGFD, UW, and US Fish and Wildlife Service (USFWS) implemented T&R of chronic carriers in the Red Creek sub-herd starting in the winter of 2021-22. In the first year, 7 chronic carriers (all ewes) were removed. Classification surveys conducted during January 2023, revealed more lambs on the ground than had been observed the previous 6 years ***combined***. While very preliminary, this increased lamb survival is encouraging after just one winter of removing chronic carriers. To date, a total of 11 chronic carriers (4 ewes in the second year) have been identified and removed. Additionally, Movi prevalence has declined to its lowest level in three years, from a peak of 71% in December 2021 when removals first began to 29% in March 2023.

The Whiskey Mountain bighorn sheep herd is currently estimated to be 300-500 animals. This is ~25% of the population prior to the all age die-off in the early 1990s. This population is continuing to decline and if that trajectory continues, it is clear this population will be extirpated in the near future.

Proposed Project

WGFD, in cooperation with the Eastern Shoshone & Northern Arapaho Fish and Game and USFWS, is proposing to expand T&R to the eastern segment of the Whiskey Mountain Bighorn Sheep Herd in Hunt Areas 9 and 10. This includes sheep on Torrey Rim, Whiskey Mountain, Sheep Ridge, Arrow Mountain, Dinwoody Ridge, Horse Ridge, and Dry Creek Ridge (Figure 2).

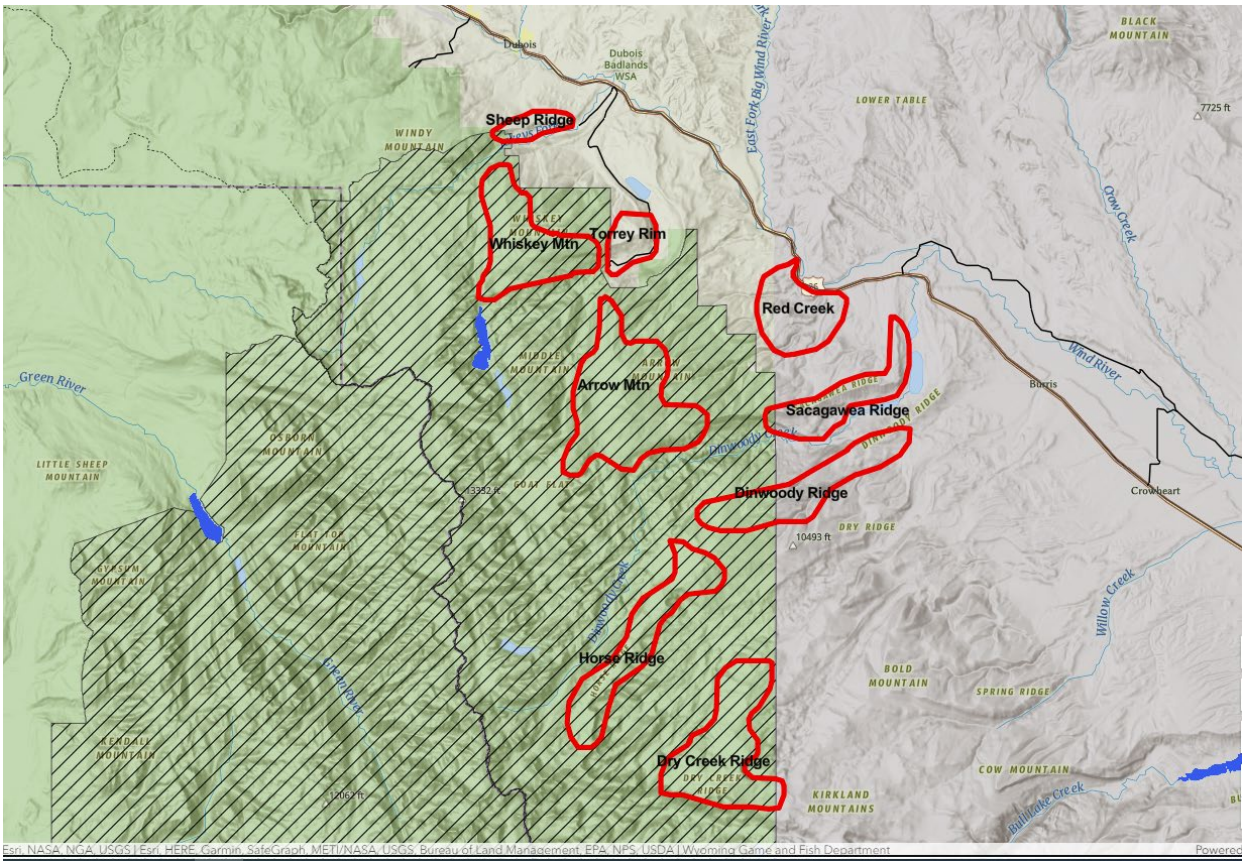

Figure 2. Identified WMBS sub-herds in Hunt Areas 9 & 10. .

Through personal communication with researchers, previous T&R studies, as well as WAFWA's Wild Sheep Working Group T&R guidelines (WAFWA 2021), removal of chronic carriers should be conducted after an outbreak has occurred. Implementing a T&R program after an outbreak allows managers to remove far fewer identified chronic carriers and may prevent another cycle of low lamb recruitment and reverse the trajectory of this iconic herd. T&R is not a management action that can be used to intervene in an acute pneumonia outbreak.

Lambs in a bighorn sheep population can be sentinels or indicators of the presence of Movi in a herd. While sheep in areas 9 and 10 have gone through cycles of low lamb recruitment for decades, recently they have rebounded from record low lamb ratios. The last two years, 2021&2022, personnel have observed a significant increase in lamb production (36:100 & 40:100 respectively) compared to 2017&2018 of (9:100 &10:100 respectively). While this is encouraging, we should not delay as this could be indicative of the end of an outbreak which is critical in the timing and efficacy of a T&R program.

We will attempt to capture all available adult ewes (Table 1) via aerial net-gunning, a drop net, and ground darting in sheep areas 9 and 10 when sheep are on their respective winter range (Dec – Mar). Rams will be tested opportunistically via drop net but the male cohort will not be targeted for T&R. The decision to only focus on adult ewes is based on feasibility of capturing rams and previous T&R research in both Hells Canyon, ID and Fraser River, BC. Both of these herds have

shown improvements in lamb recruitment without removing any rams. The primary chain of transmission regarding Movi is ewe to lamb (Besser et al. 2012a). Ewes and rams live apart for most of the year and have very little opportunity to contact young lambs in nursery groups. However, we do recognize rams as being a component in disease transmission and the possibility of infecting or re-infecting ewes and lambs in the fall and winter.

All captured animals will be sampled (both nasal and tonsil swabs) and marked with a GPS collar with two ear tags attached to the collar. The collars will be attached with a release mechanism that will release the collar after two years. The ear tags are to provide a way to visibly identify individual sheep for removal. During year one of captures we will test samples for Movi using a "field based" PCR setup and validate the results with PCR testing in a lab setting. This will increase our knowledge and understanding of any differences in detecting Movi using a slightly different approach. Based on comparisons of field vs. lab results and assuming the field test is validated, future testing will be done using a "field" PCR setup that will allow us to hold captured sheep for a short duration and either remove or release them in that time period. In the interim, all bighorn sheep will be released with a GPS collar and lab confirmed positives will be removed as quickly as possible before the lambing seasons. Lethal removal may occur through helicopter capture and personnel on the ground. Identified carriers that reside in the wilderness will be removed from the ground.

Sub-herd	Approx. no. of ewes	Year to Begin Survey
Torrey Rim	45	2023
Sheep Ridge	6	2023
Whiskey Mtn	15	2023
Arrow Mtn	15	2024
Dinwoody Ridge	25	2023
Horse Ridge/Dry Creek Ridge	10	2024
Total	116	

Table 1. Number of ewes is based on the last three years of classification data.

While we recognize the difficulties in capturing sheep at high elevation and in wilderness settings and the reality of sampling every adult ewe in this herd, it is prudent to test every ewe we can capture. However, Almberg et al. 2021 predicts sampling a high proportion of the population (i.e. ≥80%) of the herd and removing identified carriers will result in an increase in the population and a decrease in pathogen prevalence.

Previous and current research has taken alternative approaches to identify and then remove a chronic carrier. An individual either tests positive for Movi once and then is removed (Proctor et.al. 2023) or tests positive twice within a specified time frame and then removed. We are proposing to test once and remove all positives, with the exception of the Dinwoody sub-herd.

Very little data has been collected to date, so we will collar and test a portion of this sub-herd to get Movi prevalence and movement data. Capturing sheep in wilderness areas will be necessary and capturing a specific individual more than once in a specified time frame will be extremely difficult. This will hinder T&R specific to this herd by delaying the identification of chronic carriers and removing them, potentially increasing the risk of pathogen transmission. Furthermore, confining our criteria for identifying a chronic carrier using a temporal aspect may confound T&R specifically tailored to this herd. For example, if a ewe is captured and tests positive in year one, unable to capture in year two, and then tests positive again in year three, this will fall outside the parameters of most defined time frames and testing of that individual starts over, in effect making that first test unusable and prolonging the known status of that individual to four years. Whiskey sheep that tested positive once in December (N=5), 80% tested positive again. This is based on 38 animals tested. The Whiskey sheep showed no relationship between the number of times captured and being classified as a chronic carrier; defined by testing positive twice within a 12 month window. When pooling all of the sheep tested in his work (N=126), of the 12 that sheep tested positive once in December, 75% of those tested positive a second time (Kevin Monteith, pers. comm.).

To monitor the effectiveness of T&R on this herd, we will continue to classify bighorn sheep to gather lamb:ewe data, as well as, capture and test 25-30% lambs in each sub-herd in early winter following treatment. From classification data we will be able to see if there is a difference in post treatment lamb:ewe ratios. We will test lambs using PCR and ELISA for presence and exposure of Movi. Evidence of Movi exposure in lambs may be a strong indication that there is continued pathogen presence in adult ewes.

It is important to note that T&R is only one of three different management approaches to restore this iconic herd. Habitat improvement and preventing commingling with domestic sheep and goats are two other elements that play a big role in improving the health of the herd. Range expansion through habitat improvement will allow for better population recovery and may mediate both frequency and density dependent pathogen transmission. Movement data we gather from GPS collars deployed on sheep during the T&R portion will inform and identify areas for habitat improvement projects. It will also reveal movement habits of bighorn sheep outside of the herd unit.

In addition, continued testing and removal of identified carriers will continue to add to the body of data and increase our understanding of the role sinus tumors play in harboring pathogens in bighorn sheep. This has been evident in T&R in the Red Creek sub-herd. Currently, there is very little understanding of sinus tumors as testing and samples are only collected postmortem.

Another benefit to this project is identifying detection probability based on the number of collars in these sub groups. This may be used in combination with aerial classification flights and trail cameras. This will be helpful to design a sightability survey for high elevation bighorn sheep. Having a robust population estimate will help detect the efficacy of T&R and other management practices.

Schedule

Year One: Winter 2023-2024

- Continue testing in Red Creek/Sacagawea sub-herd through aerial captures.
- Begin T&R in Torrey Creek, Whiskey Mtn, and Sheep Ridge sub-herds through aerial net-gunning, drop net, and free dart captures. Remove all identified carriers before lambing season.
- Initial testing and collaring bighorn sheep on Dinwoody Ridge to estimate Movi prevalence and gather movement data for this sub-herd.
- Work with USFS to allow captures in the Glacier addition of the Fitzpatick wilderness. Assist USFS with the minimum tools analysis to allow wilderness captures in all of the Fitzpatrick Wilderness.
- Monitor lamb production.
- Initiate camera study (funded by WYWSF & WGBGLC) in fall/winter on Red Creek winter range to obtain abundance estimate. This will provide a pre and post treatment efficacy measurement in addition to monitoring lamb recruitment.

Year Two: Winter 2024 – 2025

- Continue T&R in Red Creek/Sacagawea sub-herd through aerial captures.
- Continue T&R in the Torrey Creek, Whiskey Mtn., and Sheep Ridge sub-herds if necessary.
- Begin T&R in Dinwoody Ridge, Arrow Mtn, Horse Ridge, and Dry Creek Ridge sub-herds.
- Remove all identified carriers before lambing season.
- Investigate new animal-side testing methods that will provide more mobility and efficiency for ground and aerial captures (BIOMEME, LAMP, and RPA).
- Continue monitoring sheep herd through ground and aerial classifications and the camera abundance study.

Year Three: Winter 2025 - 2026

- Late Fall 2025 - Capture and test lambs in Red Creek/Sacagawea sub-herd to assess Movi presence.
- Continue T&R in Red Creek/Sacagawea sub-herd if necessary.
- Continue T&R Torrey Creek, Whiskey Mtn, Sheep Ridge, Dinwoody Ridge, Arrow Mtn, Horse Ridge, and Dry Creek Ridge sub-herds if necessary.
- Remove all identified carriers before lambing season.
- Continue monitoring sheep herds through ground and aerial classifications and the camera abundance study.

Year Four: Winter 2026 - 2027

- Capture and test lambs in Torrey Creek, Whiskey Mtn, and Sheep Ridge sub-herd to determine Movi presence. Continue T&R if needed.
- Continue T&R in Dinwoody Ridge, Arrow Mtn, Horse Ridge, and Dry Creek Ridge sub-herds if necessary.
- Remove all identified carriers before lambing season.
- Continue monitoring sheep herd through ground and aerial classifications and the camera abundance study.

Year Five: Winter 2027-2028

- Capture and test lambs in Dinwoody Ridge, Arrow Mtn, Horse Ridge, and Dry Creek Ridge sub-herds to determine Movi presence.
- Evaluate testing results of lambs and need to continue T&R.

Proposed Budget

Description	2023	2024	2025	2026	2027
60 Telonics Recon collars w/release mechanism $1040/collar[1]	62,400	0	0	0	0
Activation Fee $30/collar	1,800	1,200	0	0	0
Monthly service fee $84/collar/year	4,200	8,400	8,400	4,200	2,100
Helicopter captures $1000/sheep[2]	53,000	40,000	25,000	20,000	20,000
Ground Captures Drugs/Darts/Telemetry	3,000	1,500	1,500	0	0
Drop Net	5,500	0	0	0	0
Lab Diagnostics & Support	25,000	1,500	1,500	1,500	1,500
Camera Study[3]	28,323	0	0	0	0
Helicopter Survey[4]	2,000	2,000	2,000	2,000	2,000
	185,223	**54,600**	**38,400**	**27,700**	**25,600**

Total Projected Cost: 331,523

[1]WGFD currently has 40 recon collars that were to be used on bighorn sheep for another project. This project has been postponed indefinitely. We are asking for 60 additional collars which will give us 100 recon collars on hand.

[2]Annual amount is based on the number of ewes in each sub-herd.

[3]Awarded in November 2022 and March 2023.

[4]Supplement flight time to increase annual survey efforts.

Funding

National Wild Sheep Foundation	**$151,600**	**Request**
Wyoming Wild Sheep Foundation	**$50,533**	**Request**
Midwest Wild Sheep Foundation	**$50,533**	**Request**
Wyoming Governor's Big Game License Coalition	**$50,534**	**Request**
Wyoming Wild Sheep Foundation (camera study)	***$17,500***	***In-hand***
WGBGLC (camera study)	***$10,823***	***In-hand***
Total	**$303,200**	**Requested**

Literature Cited

Almberg, E. S., K. R. Manlove, E. F. Cassirer, J. M. Ramsey, K. Lackey, J. A. Gude, and R. K. Plowright. 2021. Modeling management strategies for chronic disease in wildlife: predictions for the control of respiratory disease in bighorn sheep. Journal of Applied Ecology.

Besser, T.E., Cassirer, E.F., Highland, M.A., Wolff, P., Justice-Allen, A., Mansfield, K.M., Davis, M.A. & Foreyt, W.J. (2012a) Bighorn sheep pneumonia: Sorting out the etiology of a polymicrobial disease. Journal of Preventive Veterinary Medicine.

Besser, T. E., M. A. Highland, K. Baker, E. F. Cassirer, N. J. Anderson, J. M. Ramsey, K. Mansfield, D. L. Bruning, P. Wolff, J. B. Smith, and J. A. Jenks. 2012b. Causes of pneumonia epizootics among bighorn sheep, Western United States, 2008-2010. Emerging Infectious Disease 18:406–414.

Cassirer EF, Manlove KR, Almberg ES, Kamath PL, Cox M, Wolff P, et al. Pneumonia in bighorn sheep: Risk and resilience. Journal of Wildlife Management. 2018 Jan;82(1):32-45.

Garwood TJ, Lehman CP, Walsh DP, Cassirer EF, Besser TE, Jenks JA. Removal of chronic Mycoplasma ovipneumoniae carrier ewes eliminates pneumonia in a bighorn sheep population. Ecol Evol. 2020 Apr;10(7):3491-502.

Proctor, C., Ayotte, J. Fraser River Bighorn Sheep Disease Mitigation Program, 2022 Progress Report. January 2023.

WAFWA Wild Sheep Initiative. Test and remove for wild sheep: a user guide. 2021. https://wafwa.org/wp-content/uploads/2023/05/Test-and-Remove-User-Guide-Working-Document-June-2021.pdf