

William Parker

Professor Elie Gurarie

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Sheep Pneumonia Final Write Up

One of the most culturally important species that dominates the mountain west region of the United States is *Ovis canadensis*. More popularly known as the bighorn ram. This species is historically relevant due to its usage as icons for sports teams and truck brands. Although it has been historically relevant in culture, *O. canadensis* has a greater importance as an environmental engineer and staple species of the rocky mountains environment. According to the IUCN's red list, there are currently 49,000 bighorns in the wild and their population is of least concern (IUCN 2019). It is surprising to realize however that 49,000 heads is an incredibly small population count when compared to the bighorn sheep's natural numbers. During the 19th century, there were a reported 1.5 to 2 million bighorn sheep roaming in the rocky mountains. Their subsequent population decline for the centuries that followed is known to be caused by human factors such as hunting and land development (Bighorn Sheep nd). As the Western United States continues to become a developed land despite its complex geography and as hunting continues to become a more common practice, the stability of the native bighorn sheep populations is in peril. As bighorn sheep are strong ecological engineers, the shallow grasslands that they thrive in will become disfigured if time goes on without their presence. Entire rocky mountain ecosystems will become uprooted and many large predators that rely on healthy bighorn populations will begin to suffer as well. It is because of these reasons that the re-establishment of *O. canadensis* populations to pre 19th century conditions should be a seriously studied and promoted environmental effort. If bighorn sheep are at a stable population and the carrying capacity sits above 1.5 million, what is standing in the way of populations recovering and rebounding in the west? The answer is simple and one not yet mentioned: disease (Foreyt and Jessup 1982, Cassirer et al. 2018).

Domesticated sheep (*Ovis aries*) are undoubtedly one of the most economically important species that are utilized and harvested within the United States. Sheep are farmed for their production of milk and meat and more importantly for their production of textile goods like wool and leather. The high value that is placed upon the goods that sheep produce has led to them

being a common farm animal on ranches in the western US where there is ample space for them to herd and graze. Their herding behavior, although it is beneficial for providing the flock with the protection it needs to avoid the common rocky mountain predator, comes with the cost of increased disease transmission in cases where the virus is transmitted through contact or bodily fluids. The science behind this occurrence is simple and common knowledge for anyone who remembers the 2020 Covid-19 pandemic. In the wild, when animals are spread out and less social, diseases spread slower due to animals coming into contact with each other far less often. For domesticated farm animals, they are constantly in contact with other members of their herd or flock. This constant close contact allows the diseases easy transmissions from one individual to another and this is why you see diseases such as the avian flu and sheep pneumonia spreading rapidly through populations (Venturino 2022). While flocking does help to prevent deaths due to predation, the sad fact about flocking is that the deaths that come as a result from infections that spread through the flocks can cause in some cases more deaths than deaths that would be caused by predators. This is the case for the native *O. canadensis* populations (Smith et al. 2014)

Native bighorn sheep haven't always been exposed to disease though. Their exposure to diseases such as the deadly sheep pneumonia epidemic only started when domestic sheep arrived. This is because the sheep pneumonia disease originates from the middle east where domestic sheep originated from. When domestic sheep were brought over to the new world for farming use, the sheep, of course, brought over their common infections too. Since the *O. canadensis* populations were never exposed to such a disease before the colonization of the new world, they haven't had any time to develop a natural immunity, leaving their populations open and susceptible. As mentioned before, the domestic sheep farms out west act as a natural reservoir for diseases such as pneumonia. When one individual in a pasture pen gets infected, there is practically no stopping the entire herd from getting infected. This means that when a native bighorn sheep comes into contact with these domesticated sheep and interacts with them socially through the fence, there is a high chance that the bighorn sheep will end up contracting this disease as well which can then be spread to other wild bighorn sheep or other sheep farms to act as other reservoirs (Cassirer et al. 2017) With a peak of 51 million sheep head in the late 1800s and a current sheep head count of around 5 million, there is a large probability that the effect of sheep pneumonia on *O. canadensis* and *O. aries* will continue to grow and increase the

negative effect that it has on native bighorn populations as well as the US economy. (Jones n.d., “USDA ERS - Sector at a Glance” n.d.)

So, how does the disease of sheep pneumonia have an effect on bighorn sheep? On the organismal level, pneumonia in sheep is an infection of the lung tissue that can be contracted from multiple sources. Various bacteria, viruses, and parasites can cause this disease in all age demographics of sheep populations. When sheep are infected with the pneumonic disease, the first symptom they show is a prolonged period of dullness or inactivity which can reduce time spent feeding and predator response times. As the infection continues, sheep will develop a fever greater than 103°F, coughing behavior, thick nasal discharge, rapid breathing, and a constant lagging behavior when following the herd (“Pneumonia in Sheep and Goats | OSU Sheep Team” n.d.). Not only does pneumonia affect the sheep in such a way that it can cause fatalities due to illness, especially in younger sheep, but pneumonia can also have such drastic effects on sheep behavior that it can lead to death due to predation as well. Thankfully, the variants of pneumonia that bighorn sheep contract are not apparently transmissible to predators or to humans. The only evidence of extraspecific transmission is from members of the *Ovis* genus to certain goat species such as *Capra aegagrus hircus* (Besser et al. 2017).

On the population level, sheep pneumonia is the driving factor for sheep mortality in the west. Studies performed in the Natural Bison Range of Western Montana have shown that the respiratory disease has caused an 85% decline in the bighorn sheep populations. In this case, the disease was introduced by a small group of young bighorn sheep on a short term exploratory foray in the early summer of 2016. The disease quickly spread from host to the entire population with peak mortality in September and October. Signs of mortality in this population continued in all age groups of the population until July of 2017. The study showed that ewes of the group were affected before the rams of the population, however by the end of the study, ram mortality was greater than ewe mortality (90% of 71 as compared to 79% of 84) (Besser et al. 2021). Based upon this study, it is clear that when this respiratory disease is introduced into native populations, there is a likelihood that the headcount can collapse into almost unrecoverable numbers. In cases where there are enough surviving members, genetic diversity is still drastically impacted. If this study is representative for the entire metapopulation of bighorn sheep, then it is clear that populations are incredibly susceptible to becoming extinct, extirpated in certain locations, or threatened. As disease spreads and mortality rates continue, it would not be

surprising to see *O. canadensis* moved from their “of least concern” status on the IUCN red list unless conservation efforts are started in order to prevent the spread of disease. As further evidence for the impact that pneumonia has on bighorn sheep has on bighorn populations, a study was performed on a bighorn population in the Black Hills region of South Dakota. This study documented the timing and causes of mortality events in neonate bighorn sheep in order to improve the understanding of the factors of population ecology that influenced bighorn sheep recruitment. This study found that of the 74 sheep neonates captured, 70 of those individuals (95%) died before becoming 52 weeks of age. It was determined that 25 (35.7%) of those individuals died as a result of pneumonia. The second and third largest reasons for neonate fatality were predation and starvation with 21 (30%) and 8 (11.4%) deaths respectively (Smith et al. 2014). It goes without saying that having 95% of neonates dying before reaching the one year mark will have extreme effects on the population's ability to rebound and reestablish; especially when this statistic is paired with the fact that bighorn lambs reach sexual maturity at roughly two years of age. Males are also unlikely to breed so early anyways because they will remain sexually dormant until they are much older and larger as they have to wait to be able to establish dominance (“Natural history” n.d.). With little to no neonates being able to reach the reproducing age, there is a clear reason to be concerned about the bighorn sheep's ability to reach a stable population. Without human intervention and aid, it is almost certain that native *O. canadensis* populations will fail and as a result, the entire rocky mountain ecosystem could potentially collapse.

Since the bighorn sheep populations are in desperate need of human help, what can feasibly be done to prevent the transmission and deaths of countless bighorn heads? When it comes to diseases, the most common method to prevent the spread is to develop a vaccine that grants immunity or to wait for immunity to establish itself. There are two problems with these solutions though. The first is that immunity can only develop if individuals that contract the disease survive and maintain the antibodies that can fight off viral and bacterial infections. Knowing that sheep pneumonia as well as other factors can cause up to 95% fatality in neonates, there is little chance that immunity can develop in populations to such a degree that fatalities due to disease are kept at a minimum. Since the bighorn sheep have yet to develop immunity naturally, it would make sense to force them into developing immunity via a vaccine before we gamble on whether they can develop it themselves. The second issue is that there are many

obstacles standing in the way of creating an effective vaccine. Foremost is the fact that there are many strains of sheep pneumonia circulating in sheep populations and immunity is not protective across strains. Therefore a single vaccine would not be effective. Secondly, wild sheep do not pass complete immunity to their offspring, so unless the vaccine was completely protective against infection (not just disease) it would likely not solve the problem of lack of recruitment of lambs caused by infection from their rams. Third, vaccine delivery in wild sheep would be difficult in most situations and impossible in others. Fourth, if they could be developed, vaccines would be useful in domestic sheep but not a priority since it hasn't been possible to do it yet, there would be limited effectiveness against multiple strains, and the market for the vaccine would be small so there is little financial or industry incentive for drug companies or the government to allocate resources towards a vaccine effort (Cassirer 2022). A second and more feasible method of preventing the pneumonic disease spread is to restrict it at the source. Domestic sheep are known to be a reservoir for pneumonia that is constantly introducing viral and bacterial strains into wild sheep populations. The way to stop the spread of pneumonia from the source is through double fencing. Farmers most commonly use a single fence to keep their sheep contained within a pasture for grazing (Heinse et al. 2016). While a single fence is sufficient for containing herds, contact between domesticated and wild animals is still plausible and common. In this case, roaming rams come across domestic sheep farms and approach the domesticated sheep, getting into close proximity to them on the other side of the fence. This close proximity allows the pneumonia to be spread from the domestic population to the wild population. If farmers implemented a double fence with sufficient space between the two fences, there would be a buffer that prevents the interaction between wild and domesticated sheep. This fenced isolation would easily prevent the spread, however, the problem with double fencing stems from a humanitarian and economic issue. A majority of sheep farmers are opposed to the idea of double fencing their properties due to the large pastures that they utilize, requiring a lot of fencing. Adding an additional fence that surrounds the initial fence with some distance between them would cost an extreme amount that farmers are not willing to pay. The cost does not even include the time and effort it will take to install the new fence. Sheep herding is already a dying business in the way that it is already becoming increasingly unprofitable with each year so getting farmers to commit to something so costly and seemingly unnecessary is extremely difficult. Farmers pastures are located on public land as well so there is no way to mandate that

farmers put up a second fence. The only way to make double fencing a common practice is to educate farmers about pneumonia to make them care, or to provide them with the funding to put up a secondary fence (Cassirer 2022). All in all, if double fencing is a common practice for sheep farms in the west, scientists hypothesize that we would see an apparent decrease in pneumonic infection rates and an increase in lamb recruitment; leading to a successful start of ram repopulation and a bright future (Cassirer 2022)

In conclusion, the drastic decline in population numbers of *Ovis canadensis* in the Rocky Mountain West region can solely be attributed to the spread of interspecific viral / bacterial infections which cause high rates of direct mortality as well as indirect mortality through increased predation probability. The high rates of infection are the only thing standing in the way of bighorn sheep returning to some resemblance of their pre-colonial population numbers and density. Stopping the spread of sheep pneumonia is the cornerstone to re-establishing populations and should be the figurehead of a more popular conservation movement. To start a positive restoration effort, either vaccines should be dramatically improved or sheep farmers in the west should consider committing to double fencing to save not only their sheep, but the wild and majestic bighorn sheep that call the same space home.

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