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Sheep Pneumonia

Western North America is home to many distinct species of charismatic megafauna. One of these species is the bighorn sheep (*Ovis canadensis*) which ranges from southern Canada down to Mexico, most often in mountainous regions. They prefer areas that are rocky and steep to easily avoid predators, but feed on grasses requiring them to move to less rocky areas. Today, the wild population of bighorn sheep is around 49,000 and is considered to be a stable population according to the IUCN (Festa-Bianchet, M, 2020). However, it is estimated there were as many as 2 million individuals in this range during the 19th century ("Bighorn Sheep" n.d.). There are many possible causes for this decline including habitat fragmentation, human encroachment, excessive hunting by humans prior to hunting regulations, and disease. One potential disease that may have led to the decline but is also greatly preventing recovery of populations today is known as sheep pneumonia.

Sheep pneumonia is most likely caused by a bacterium called *Mycoplasma ovipneumoniae,* (Besser et al. 2008). However, there are several other ways that an individual can contract the disease, including through poor living conditions, getting water into the lungs, and certain parasites as well as viruses. Once infected with the disease, an individual may display several different symptoms including coughing, labored breathing, decreased activity levels and movement, fever, and a thick yellowish nasal discharge (Van Metre 2018). These symptoms will then often lead to death in the wild. Some antibiotic treatments have proven to be successful in individual cases but not on a large scale due to issues with dosage and administration as well as expenses (*Montana Bighorn Sheep Conservation Strategy* 2010). The most common cause however is through the bacterial avenue. It is believed that the bacteria originated in domestic cervids as it is commonly carried by domestic sheep and goat populations today (Cassirer et al. 2018). Domestic sheep were one of the first livestock species to be domesticated which took place in the middle east between 6000-11000 years ago (Chessa et al. 2009). The bacterium has likely existed in the population for

the course of this time, and genetic resilience has developed within the domesticated herds (Cao et al. 2021). It has been shown that up to 88% of domesticated herds can carry the bacteria, while showing no signs of the illness (Cassirer et al. 2018). This genetic resistance was not present in the wild sheep of North America who would not be exposed to the bacteria until domestic sheep made their way over from Europe.

Today, many farmers in the western United States will turn out their domestic sheep and goat herds onto public land for grazing during the summer months. This is a result of the vast expanses of rather undeveloped federal land owned by the government that is perfectly suitable for cervid grazing. This practice of grazing animals on federal lands also occurs in horses and cattle. The public land that farmers graze their sheep on often overlaps with big horn sheep habitat as they have similar nutrition needs. This leads to close interactions between the two species either through direct contact, or indirectly through feces, saliva, and shared water sources. This interaction seems to be the primary strategy of spread between the reservoir of bacteria in domestic herds, and the wild bighorn sheep herds, with the male bighorn sheep being the main point of initial contact (Cassirer et al. 2013). This is because the females often stay higher in the mountains to protect their young from predators, while the males travel down the slopes further which is often where the domestic sheep are grazing. Once established in a bighorn sheep herd, the disease will spread intra-specifically. In adults, mortality is highest in the fall, but main herd mortality is in the lambs in the spring and summer. It has been shown that in wild herds, it is possible for a ewe to be a carrier of the disease which she then transmits to her lambs who eventually succumb to the disease (Cassirer et al. 2018). In fact, up to 88% of lamb mortality is caused by the pneumonia in outbreak years, who can also spread it to other lambs in the herd as they interact with each other (Besser et al. 2008). Since the lambs are carrying most of the disease burden, population recruitment is extremely low in these herds which often causes drastic population declines several years later as the adults die off and there are few offspring to replace them. These low recruitment rates have been a primary factor in limiting population recovery efforts in many herds throughout the country (Cassirer et al. 2013, 2018, 2022).

This has led to many different management strategies being developed and tested to try and decrease the effects of the disease on the wild herds. However, it has been noted that tracking the spread is often difficult due to the terrain and conditions surrounding their habitat. As well as

a general lack of knowledge for how exactly the disease spreads, what other strains of bacteria cause it, and if there are genetically resistant individuals in the wild herds (Cassirer et al. 2013, Sells et al. 2016, Cassirer 2022).

One strategy for decreasing the effects of the disease is to increase the health of the wild herds. This has been attempted through antibiotic treatment of infected individuals, mineral supplements, anthelmintic treatments and selective culling of sick individuals from herds (Cassirer et al. 2018). However, as Dr. Cassirer pointed out in an interview, these strategies are impractical to perform on a large scale as well as very expensive (Cassirer 2022). There is currently no effective vaccine for the disease either, which is also predicted to be too expensive and impractical to administer on a large scale.

As a result of the impracticality of increasing the health of all bighorn sheep herds, much of the current management is a reactive management system with managers culling whole herds, as well as performing herd augmentations and reintroductions after a disease outbreak to try to recover the population (Sells et al. 2016). This is also a very expensive and time-consuming approach to managing the disease and again encounters the problem of having difficulty detecting the disease until after is has decimated lamb recruitment. The wildlife managers are then constantly trying to play catch up with the spread and recover a population before the next population gets decimated, while never really preventing any infection.

There are other strategies of managing the disease that do focus on prevention. These strategies focus on decreasing the risk of spillover from the reservoir of domestic sheep and goats (Cassirer et al. 2018). Four main risk factors have been identified in the transmission of the bacteria between domestic and wild herds. These factors include the amount of private land that is within a herd's range, the amount of weed control that is performed on their range, which is when people intentionally use goats and sheep to get rid of weeds and shrubs in a specific area, the neighbor risk, which is if nearby herds have recently had an outbreak of the disease, and the density of the herd of interest (Sells et al. 2016). Using these four main categories, Sells et. al. was able to develop a generalized model to allow land managers to make preventative decisions based on the risk of disease spread to their herd. This model not only takes into account the four risk factors, but also takes into account the time frame that the manager is looking to manage for, the public, legal, and ethical factors as well as the economic factors including expenses related to the

prevention measures in addition to how these actions will affect yearly hunting allocations and revenue from big game tags in the area. All these factors are incorporated into the model to allow managers to decide which actions would be most beneficial for the specific herd of interest. This model allowed room for flexibility in how drastic of measures each action would take, and the predicted outcome of multiple different management decisions on the future of the herd. For example, several possible preventative management actions to address the weed control factor include public education if the risk was low or deemed not critically important, changing the times of year weed control was allowed in the area for a medium risk, or fully banning weed control using domestic cervids in that area if the risk was critical and it would be logistically feasible in that area. It was important to develop this model because it is not a one sized fits all model and it allows managers to make the best possible decisions for individual herds based on the available information, while still having some continuity among managers and organizations (Sells et al. 2016).

Many organizations however are beginning to use a combination of preventative and reactive measures to manage their herds. Montana Fish Wildlife and Parks for example has implemented several different strategies which are stated in their Bighorn Sheep Conservation Strategy report (*Montana Bighorn Sheep Conservation Strategy* 2010). Making this report in general is also an example of things states are doing in order to manage their bighorn sheep populations, as several different states have similar plans. The state of Montana has adopted the policy that if any bighorn sheep is known to have come into contact with a domestic sheep or herd, that bighorn needs to be lethally removed from the population in order to prevent the spread to the rest of the bighorn herd (*Montana Bighorn Sheep Conservation Strategy* 2010). While this may seem like a drastic measure, it has been shown in experimental trials that up to 98% of bighorn sheep that come into contact with a domestic population will end up contracting the disease (Cassirer et al. 2018). Although transmission rates are likely lower in a wild setting, and transmission cannot be guaranteed, managers have decided that it is worth the risk to kill an individual rather than potentially letting the disease get carried back to the herd. This is both a preventative and reactive measure as it is reactive to initial exposure but preventing further spread. An example of a preventative measure they have begun to implement is in coordinating the times that weed control grazing is permitted in overlapping areas. By doing this, domestic sheep can still improve the habitat by doing the weed control, but if managers time it to the right months of the

year, there is a much lower chance of bighorn sheep being in the area and a lower chance of disease transmission. They have also begun to establish buffer zones of 13.5km around known big horn sheep ranges in order to prevent interaction of domestic sheep and bighorn sheep. These strategies seem to be logistically feasible on a larger scale and work to address several of the main risk factors addressed above.

Perhaps the most comprehensive management plan for bighorn sheep that addresses specifically the prevention and management of sheep pneumonia was put out by the Wild Sheep Working Group (Wild Sheep Working Group 2012). This plan includes a guide to best manage this issue with specific recommendations for different groups of people and types of managers. This plan suggests that the Western Association of Fish and Wildlife Associations (WAFWA) completes risk assessments, removes exposed individuals, limits disease spread through translocations, and coordinates with sheep farmers for location and timing of grazing permits. Land management agencies are instructed to eliminate grazing overlap with buffer room between domestic and wild sheep, have methods for removal in the case of interaction, and promote the development and upkeep of suitable habitat for bighorn sheep populations. The plan goes on to suggest conservation organizations aid in education efforts and negotiate alternative grazing options with private farmers. And finally, private land owners and farmers are guided to prevent interaction by using best management practices, to stay educated on the effects of the disease on wild populations and to have protocols in place to prevent and react to straying individuals (Wild Sheep Working Group 2012).

This plan again works to prevent the spread of the disease according to the four main risk factors, as well as address what happens when individuals are exposed to domestic sheep. The plan provides direct and specific management practices to be carried out by all who are involved in the grazing of domestic sheep. These policies are not taken lightly and have even gained legal support in certain cases. One example of this was a court ruling in Idaho that mandated the separation of wild and domestic sheep (U.S. District Court, Idaho Case 09-0507-BLW) on federal lands after managers knowingly allowed grazing in areas that would expose the bighorn sheep to disease, leading to potential devastation of an already endangered herd (“Huge win for bighorn sheep in Idaho” 2017).

While this plan sounds like it would be highly effective in managing the disease, Dr. Cassirer pointed out a few limitations of the plan, including that wildlife managers do not have control of where and when private farmers graze their sheep on private lands (Cassirer 2022). Being that the population of bighorn sheep is not restricted to federal lands but the grazing policies to protect them are, bighorn sheep on private lands are still largely exposed to potentially contracting the disease which they can then easily spread to neighboring herds. With the cultural value of private landownership in this country, this issue is unlikely to resolve any time soon.

In addition to the Wild Sheep Working Group conservation plan, Dr. Cassirer said that in an ideal world with unlimited funding she would like to investigate why domestic sheep are resistant to the disease, but bighorn sheep are not, exactly how the bacteria spreads, how the disease works more specifically, and to increase education and research on the issue at hand. She thinks that there is a solution out there somewhere and we need more creative projects and ideas in order to make progress (Cassirer 2022).

While there are many different strategies for dealing with this disease, and seemingly mixed results at the outcomes, hope it not lost for bighorn sheep yet. As awareness for the issue continues to spread and more funding is raised through donations, harvest tags, and other research avenues, we will continue to learn about this disease and how to effectively manage it. Even though efforts of those involved have not shown drastic increases in population growth so far, many new groups have been formed with the common interest of protecting big horn sheep and many civilians have been educated on the value of conservation for one of North Americas most charismatic megafauna. There has also been unity between environmental groups, policy makers and law makers which is essential in effective conservation but often difficult to achieve. Populations still remain high throughout the country, so there is still time and hope of getting the disease under control and preserving this species for many years to come.

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