



REDUCING DISEASE RISK TO DALL'S SHEEP AND MOUNTAIN GOATS FROM DOMESTIC LIVESTOCK POSITION STATEMENT

THE ALASKA CHAPTER OF THE WILDLIFE SOCIETY



INTRODUCTION

This position statement brings attention to the risk of disease transmission from domestic animals and recommends practices to maintain the health of wild populations of Dall's sheep and mountain goats in Alaska. The Alaska Chapter welcomes input and discussion related to these recommendations by contacting the Chapter at TWSAlaska@gmail.com.

SUMMARY¹

Diseases transmitted by domestic sheep and goats are a major cause of mortality and reduced reproduction in bighorn sheep populations in western North America, and have caused the extirpation of some bighorn populations. Respiratory disease (pneumonia), in particular, is a serious problem that has often caused widespread die-offs of bighorn sheep following contact with domestic sheep. In recent outbreaks of respiratory disease, wildlife managers have resorted to culling of sick animals or entire populations, lacking other means to limit disease spread. To prevent disease introductions, wildlife managers throughout western North America have increased efforts to establish and maintain separation between bighorn sheep and domestic sheep and goats. Alaska has not experienced widespread domestic livestock grazing or use of pack animals other than horses, thus a proactive and precautionary approach should be taken to avoid the introduction and establishment of many serious diseases of domestic livestock in Dall's sheep and mountain goat populations. The potential consequences of contact with domestic animals in Alaska are greater than in the other western states because wild sheep and goats are free of and believed to have very low resistance to many domestic livestock diseases. Furthermore, any diseases that are introduced could be spread widely throughout the large contiguous ranges of Dall's sheep and mountain goats that occur in Alaska.

FINDINGS

1. Many bighorn sheep populations in the western United States disappeared or were greatly reduced in abundance during the 19th and 20th centuries. These reductions often coincided with the introduction and presence of domestic sheep. Experiments have clearly shown that bighorn sheep have a high probability of contracting fatal pneumonia following contact with visibly normal domestic sheep. Substantial evidence has linked major die-offs in bighorns to contact with domestic sheep or goats. Domestic sheep and goat diseases continue to prevent or slow the recovery of many bighorn sheep populations.
2. Due to climate, land ownership, economics, and remoteness, large numbers of domestic animals have not been widely pastured in wild sheep and goat habitats in Alaska. As a result, transmission of diseases from domestic livestock to Dall's sheep and mountain goats has been limited. Large-scale die-offs from respiratory or other diseases have not been detected. The

¹ Appendix A presents several in-depth reviews of livestock/wildlife disease relationships that form the basis of our recommendations and discusses high-risk diseases.



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bacteria *Mycoplasma ovipneumoniae* (a primary pneumonia pathogen) has never been documented in Alaska. However, evidence of exposure to other livestock diseases has been documented among some Alaskan Dall's sheep and mountain goat populations, including the same contagious ecthyma (sore mouth) known from domestic sheep and the skin parasite known as sheep ked (*Melophagus ovinus*).

3. Domestic sheep and goats pose the highest risk to Dall's sheep and mountain goats in Alaska, but other livestock (including cattle and llamas) also carry diseases that can pose a significant risk to wild sheep and goats. Horses are considered low risk.

4. Fewer large-scale die-offs and major disease problems have been documented in mountain goats than in bighorn sheep. However, mountain goats are susceptible to many of the same diseases as wild sheep. Contact with domestic sheep or goats could result in disease with serious long-term consequences for mountain goat populations.¹

5. Healthy Dall's sheep and mountain goat populations in Alaska are unique and economically important. Dall's sheep are not found in any other U.S. state, and a large majority of the country's mountain goats are found in Alaska. The value of healthy Dall's sheep and mountain goat populations to the residents of Alaska and the U.S. is inestimable. Tourism, which has a large focus on wildlife, is the second largest private sector employer in the state. Hunters spent more than \$7 million dollars to pursue Alaska Dall's sheep and contributed an estimated \$2.5 million to the state's economy in 1983, the last year for which data are available. (No data are available for mountain goats.) When adjusted for inflation, these contributions are more than double in today's dollars.

6. Changes are occurring that will collectively increase exposure of Dall's sheep and mountain goats in Alaska to livestock disease. These include:

- Increased grazing of sheep, goats, cattle, llamas or other livestock in wild sheep and goat habitats (which may result from land conveyance to private ownership and from increases in local livestock production due to a warming climate and rising costs of imported meat).
- Increasing global movement and trade of livestock, which will facilitate introduction of new diseases.
- Climate changes may reduce barriers to disease transmission (for example, by a northward shift in the ranges of intermediate hosts) and increase physiological stress and disease susceptibility.

7. The potential consequences of a single disease transmission event are uniquely high for Dall's sheep and mountain goats in Alaska. To date, Dall's sheep and mountain goats have not been exposed to most livestock diseases. Their immune systems are therefore naïve, and resistance to these diseases may be extremely low. In addition, Alaskan Dall's sheep and mountain goats occur in large blocks of near-continuous habitat, so that an introduced disease could spread to a large portion of Alaska herds (e.g., Dall's sheep in the entire Brooks Range). Lack of major geographic barriers separating subpopulations of Alaskan wild sheep or goats



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might allow diseases to persist indefinitely once introduced. Thus, the acceptable level of risk of contact with domestic livestock should be set at a very low level.

8. The practice of using domestic goats and llamas as pack animals in alpine areas of Alaska is perceived to be increasing and may be a greater threat than ranching activities at lower elevations. Domestic goats are closely related to sheep and share many of the same diseases. Apparently healthy pack goats tested in Idaho commonly carried strains of pneumonia-causing bacteria that have caused die-offs in bighorn sheep. Because of their ability to negotiate steep terrain, pack goats and llamas are often taken directly into core wild sheep and goat habitats. Although pack animals may be more closely observed for signs of illness and are typically more closely tended than other livestock, many disease organisms that can seriously affect wild sheep and goats are carried by domestic animals without signs of the disease. Furthermore, direct contact between animals is not necessary for the spread of some diseases. For example, paratuberculosis (Johne's disease) bacteria shed in the feces of cattle, sheep, and other ruminants, can remain viable and infective in soil for a year. Recognizing these risks, several federal land managers have closed areas to pack goat use, and wild sheep conservation organizations have provided incentives to discontinue commercial pack goat outfitting in bighorn sheep habitat. Llamas are more distantly related to Dall's sheep and mountain goats, and thus may be less likely to transmit pathogens. However, recent reviews have concluded that the potential for disease transmission from llamas is sufficiently large to warrant precautionary measures.¹

9. Due to the lack of widespread domestic sheep and goat grazing in or near wild sheep and goat habitats in Alaska, it is possible to manage proactively to keep disease risks low by maintaining separation. In contrast, livestock producers in the western states and provinces with a long tradition of domestic sheep and goat grazing may be greatly affected by measures to ensure separation between wild and domestic species. This greatly increases the economic and social costs of protecting wild sheep and goats from domestic diseases in places other than Alaska.

RECOMMENDATIONS

1. Appropriate borough, state, federal, and private agencies and organizations should develop proactive programs and policies to minimize the potential for disease transmission to wild sheep and mountain goat populations including:
 - Raise awareness among the public, livestock owners, and wildlife and land managers about the mechanisms and potential for transmission of diseases from domestic sheep, goats, cattle, llamas, and alpacas to wild sheep and goats; the consequences of disease introductions: and preventative measures;
 - Expand disease monitoring in domestic animals and wildlife populations;
 - Conduct research to understand risk of transmission from direct and indirect contact (e.g., feces) and methods to minimize this risk where livestock do occur on or near wild sheep and goat range.



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2. The transport, use as pack stock, and pasturing of domestic sheep and goats (including exotic breeds and hybrids) should be prohibited within occupied Dall's sheep and mountain goat habitat in Alaska because of recognized risks and substantial negative consequences of disease transmission.
 - The Alaska Board of Game and Federal Subsistence Board should prohibit the use of domestic sheep or goats as pack stock for hunting in Dall's sheep and mountain goat habitats;
 - The transport, use, or pasturing of domestic sheep and goats should be prohibited on state and federally managed public lands within or near occupied Dall's sheep and mountain goat habitats;
 - Private landowners should be advised of the potential adverse consequences and encouraged to refrain from the use or pasturing of domestic sheep and goats on lands adjacent to or within Dall's sheep and mountain goat habitats.

3. Use of camelids such as llamas in Dall's sheep and mountain goat habitat should be minimized² and precautions taken to reduce potential for transmission of disease, including:
 - Increase monitoring of diseases in domestic llamas and alpacas;
 - Develop a herd health certification program for camelids, including herd-wide Johne's disease-free status;
 - Encourage close confinement (e.g., tethering) of camelids if they are used in wild sheep and goat habitat;
 - Encourage research to assess the risks of disease transmission between domestic camelids and wild sheep and goats.

4. The Alaska Department of Fish and Game should take a lead role in coordinating interagency efforts to maintain the health of wild sheep and goat populations. Actions should include:
 - Establish a wild sheep and goat working group to address disease prevention and monitoring;
 - Formulate action plans that address instances of contact between domestic livestock and wild sheep and goats and instances of disease outbreaks in wild sheep or goats.

5. Federal land management agencies should develop Alaska-specific policies for domestic livestock management in Dall's sheep and mountain goat habitats.

² Although prohibiting camelids from Dall's sheep and mountain goat habitats in Alaska may be warranted to reduce potentially high disease risk, there is currently less information with which to support that measure.



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Appendix A.

This is a summary and discussion of pertinent information in three recent reviews (sections I-III) and other literature (section IV) on the risks and means of prevention of disease transmission to wild sheep and mountain goats from domestic animals.

I. The Western Association of Fish and Wildlife Agencies (WAFWA) unanimously endorsed [*Recommendations for Domestic Sheep and Goat Management in Wild Sheep Habitat*](#) prepared by their Wild Sheep Working Group (2012). This group focused on bighorn sheep, but it considered all wild sheep in western states and provinces.

Conclusions include:

- “Over the past 30 years, increasing evidence has underscored the potential risk of disease transmission from domestic sheep and goats to wild sheep.”
- “The risk of disease transmission from domestic sheep and goats to wild sheep is widely recognized.”
- “Effective separation [between wild sheep and domestic sheep and goats] should be a primary management goal of state, provincial, territorial and federal agencies responsible for the conservation of wild sheep.”
- “It is generally acknowledged (Garde et al. 2005) that thinhorn sheep [Dall’s sheep, Stone sheep] in Alaska and northwestern Canada are likely naïve to exposure to many organisms carried by domestic species, compared to wild sheep occurring in southern Canada and the continental U.S. **Until this is confirmed and the effects of exposure to infections organisms are clearly understood, it is essential that no association occurs between thinhorn sheep and domestic sheep or goats.**” [emphasis added]

Recommendations:

- “Land management agencies responsible for domestic sheep and goat grazing allotments, trailing routes, vegetation management, use as pack stock, or any other uses involving domestic sheep and goats should only authorize such use(s) outside of occupied wild sheep range.”
- The report recommended to Fish and Wildlife Agencies that: “The use of domestic sheep and goats as pack animals by persons that travel in identified wild sheep habitat should be prohibited by the appropriate management agency.... Where legislation or regulations are not already in place, an outreach program to inform potential users of the risks associated with that activity should be implemented to discourage use of domestic sheep or goats as pack animals.”

II. Helen Schwantje and Craig Stephen prepared a report (2003) titled “[*Communicable Disease Risks to Wildlife From Camelids in British Columbia*](#).” They reported findings from a review of literature, diagnostic lab records, blood and fecal sample collection from select farms, and surveys of owners of South American camelids (primarily llama and alpaca).

Conclusions:

- “Based on these data, we can conclude that South American camelids in BC and wild ungulates in the province share similar susceptibilities to a range of viral, bacterial, and parasitic pathogens.”
- “The epidemiology and microbial ecology of many of the agents of concern coupled with the nature of wildlife interactions indicates that fecal-borne organisms and the respiratory spread of *Pasteurella* spp. are of most concern. Some of these organisms are ubiquitous in the BC environment, others do not survive long without a host and it is unknown whether camelids would increase the risk of exposure to a significant level.”



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- “The overall risk varies, based on the scenarios in question. **On a province-wide basis, the risk is low, but for specific vulnerable wildlife, the risk can be high.**”
- There is sufficient basis for concern to advise a precautionary approach to managing disease risks to wildlife from camelids.

Recommendations:

A variety of simple steps can be undertaken to mitigate these risks. Major areas on which to focus risk management strategies are:

- Prevent vulnerable wildlife and their habitat from making contact with camelids and their wastes.
- Ensure a standard of health care for camelids being used for backcountry trekking purposes; and
- Subject animals recently imported to BC to special consideration.

A variety of existing regulations, guidelines and standards of practice can be applied to reduce risks by regulating access to wilderness areas of special concern and to ensure a standard of health for camelids entering backcountry areas.

AK Chapter TWS comments: The authors identified many disease organisms in BC llamas with potential to infect wildlife. In BC, however, many of these organisms had already been documented at some time in wildlife of the province. In this situation, additional risk from llamas used in backcountry is low in comparison to a situation, more similar to Alaska's, in which a wildlife population is unexposed to most livestock diseases. However, the authors recognized a situation which may be more similar to that in Alaska: an example of “vulnerable wildlife” included “a population of thinhorn sheep never before exposed to domestic species.”

[III. Examining the Risk of Disease Transmission Between Wild Dall's Sheep and Mountain Goats, and Introduced Domestic Sheep, Goats, and Llamas in the Northwest Territories \(Garde et al. 2005\).](#)

Conclusions:

“Our results indicate that there are potentially a number of important pathogens of domestic sheep, goats, and llamas that pose a real and significant disease risk for Dall's sheep and mountain goats. This risk assessment suggests that although there are many variables and unknowns regarding disease susceptibility and risk in Dall's sheep, there are substantial risks associated with the introduction of domestic sheep, goats and llamas near Dall's sheep range in the NWT. Unfortunately there is less known about mountain goats, and based on the literature, we were unable to state clear risks associated with contact between this species and domestic sheep, goats and llamas. However, given the naïve state of both Dall's sheep and mountain goats, we suspect that any contact between these species and domestic sheep, goats and llamas could result in disease with serious outcomes for populations of these valuable game animals.”

Recommendations:

“Our Risk Assessment indicates that contact between domestic sheep or goats and wild Dall's sheep or mountain goats would **likely** result in significant disease in the wild species with substantial negative and long term effects on population dynamics and sustainability. We strongly advise that **domestic goats not be used as pack animals, and that domestic sheep and goats not be pastured anywhere in the vicinity of Dall's sheep or mountain goat ranges within the NWT.** [Emphasis is the authors'.] This recommendation is consistent with the practical experience and recommendations of bighorn sheep managers and biologists throughout Canada and the United States. Experience gained from events in the US and southern Canada clearly highlights the substantial economic and social costs associated with trying to remedy the effects of disease introduction to wild sheep populations from



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domestic sheep and goats. Conversely, contact between llamas and wild Dall's sheep or goats **may** result in disease in wild species, but there is insufficient data available to clearly assess the role of camelids as a source of disease at this time (for additional information see "[Communicable Disease Risks to Wildlife from Camelids in British Columbia](#) [Schwantje and Stephen 2003])."

AK TWS Comments; The situation in the Northwest Territories is very similar to that found in Alaska in which grazing of livestock has been minimal and Dall's sheep and mountain goats are largely free of livestock diseases. Their findings and recommendations are most pertinent to Alaska and have been relied upon heavily in formulation of this position statement.

IV. Domestic Livestock Disease Agents that pose a high risk to Alaska Dall's sheep and mountain goats:

Several infectious agents that were judged to pose a high risk to wild sheep and mountain goats (Garde et al. 2005) will be highlighted. That report as well as other reviews (Schwantje and Stephen 2003, Schommer and Woolever 2008, Wild Sheep Working Group 2012, Wehausen et al. 2011) can be referred to for more complete treatments. These disease relationships and the associated risks are far from completely understood. The following accounts will attempt to provide a sense of specific potential risks.

Respiratory disease:

Respiratory disease resulting in pneumonia is the most serious and devastating disease at a population level that is shared by domestic and bighorn sheep (Schommer and Woolever 2008). Several pathogenic strains of the bacteria *Pasteurella multocida*, *P. trehalosi* (= *Bibersteinia trehalosi*), and *P. haemolytica* (= *Manheimia haemolytica*) have been implicated in most pneumonia-related die-offs in wild sheep. Transmission of *Pasteurella* is by direct contact and aerosolization (potentially up to 60 feet); with little persistence in the environment (Dixon et al. 2002). Other organisms may also be involved in a complex manner in respiratory disease which, despite extensive study, remains poorly understood. It has proven difficult to identify organisms causing outbreaks in bighorns, which has made it difficult to pinpoint sources or causes of epidemics. However, a growing body of evidence from both laboratory and field experience indicates that contact between domestic sheep or goats and bighorn sheep often results in fatal disease in bighorn sheep herds.

In 6 inoculation trials, a total of 13 bighorn and 9 domestic sheep were inoculated with *P. haemolytica* cultured from domestic sheep. None of the domestic sheep died but 12 bighorn sheep died (Wehausen et al. 2011). Dall's sheep were also shown to be susceptible to lethal pneumonia when inoculated with *P. haemolytica* (Foreyt et al. 1996).

In 10 planned contact experiments, 23 bighorn sheep were penned with healthy domestic sheep and/or argali/mouflon sheep hybrids. All 23 bighorns died of respiratory disease following contact with domestic sheep or were euthanized when close to death. All domestic and hybrid sheep remained healthy. In other pen experiments, 2 of 9 bighorn sheep penned with domestic goats, 1 of 9 penned with cattle, and 0 of 3 bighorn sheep penned with llamas died of respiratory disease (Wehausen et al. 2011). In these experiments, pathogenic strains of *Pasteurella* were not cultured from the goats or llamas, although they have been isolated from these species on other occasions. Healthy pack goats in Idaho have been tested and 35 of 45 were found to harbor pathogenic strains of *Pasteurella haemolytica* (Ward et al. 2002) and *Pasteurella haemolytica* was identified in llama/alpaca submissions to the British Columbia Animal Health Centre (1992-2000; Schwantje and Stephen 2003).

Numerous observations of large population declines in bighorn sheep from pneumonia which have occurred following contact with domestic sheep (or goats) provide substantial circumstantial evidence that respiratory disease agents are transmitted from domestic animals to bighorn sheep, with often serious consequences (Martin et al. 1996). In 1980, nose-to-nose contact was observed between domestic and bighorn sheep through the fence of a 5.4 km² enclosure at Lava Beds national Monument. Bighorn sheep began dying of pneumonia 2-3 weeks later and all 43 in the herd subsequently died (Foreyt and Jessup 1982). In 1995, a feral goat was found in association with bighorn sheep just prior to a large pneumonia related die-off of bighorn sheep (50-75% of the herd) in the Hells



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Canyon area of Idaho/Washington/Oregon (Cassirer et al. 1996). Bighorn sheep that were associating with this goat were found to carry some identical strains of *Pasteurella* and showed increasing titers on blood tests for some viruses shared with the goat, indicating that transmission of these organisms had occurred in the wild. Despite being one of the most well-studied wild bighorn pneumonia die-offs, a single primary pathogen could not be identified and a source could therefore not be definitively stated (Rudolph et al. 2007). A major bighorn die-off in Colorado occurred in 1997-98 following discovery of a single domestic sheep with bighorns on winter range (George et al. 2008). Though the sheep was removed promptly, *Pasteurella* pneumonia spread through the bighorn herd. Twenty eight percent of the herd subsequently died, the disease spread to two nearby herds, lamb recruitment was very low for 2-3 years, and mortality from pneumonia occurred in adults for an additional two years. Nine years later, the population was estimated at half the size prior to the outbreak. A respiratory disease die-off in bighorns following close contact with cattle has also recently been documented (Wolfe et al. 2010).

Attempts to control *Pasteurella* through vaccination of bighorns have been largely ineffective (Schommer and Woolever 2008). During the winter of 2009-2010, widespread pneumonia outbreaks occurred among bighorn sheep in several western states. With very limited options, wildlife managers widely used culling of sick animals to attempt to limit spread of the disease. A study of eight pneumonia outbreaks in bighorns in 2008-2010 showed little commonality of *Pasteurella* species in sick bighorns, but *Mycoplasma ovipneumoniae* was found in greater than 95% of sick animals (Besser et al. 2012). This study suggests that *M. ovipneumoniae* is a primary disease agent and that it acts to induce secondary infection by other pathogens, especially *Pastuerella*.

***Mycoplasma ovipneumoniae*:**

Mycoplasma is a genus of small bacteria that lack a cell wall. *M. ovipneumoniae* is often found in bighorn sheep with respiratory disease in association with *Pasteurella* bacteria. It is likely transmitted between animals in a similar manner (through nose-to-nose contact and aerosols from coughing or sneezing). It is more difficult to culture and identify than *Pastuerella* bacteria and so its role in respiratory disease may have been underestimated. It may act as the primary agent in respiratory disease outbreaks by increasing susceptibility of infected animals to other bacteria (Besser et al. 2008, 2012). It has not been detected in Alaska Dall's sheep (Zarnke 1989) and this may be a key reason that, despite the presence of some strains of *Pasteurellas* thought to be pathogenic, large respiratory disease die-offs in Alaska Dall's sheep have not been observed. A captive Dall's sheep herd suffered severe pneumonia disease attributed to *M. ovipneumoniae* after two members were housed next to infected domestic sheep, demonstrating susceptibility of Dall's sheep to this pathogen (Black et al. 1988). It is highly prevalent in domestic sheep and goats (Besser et al. 2012, Miller et al. 2011).

***Mycoplasma conjunctivae* (infectious keratoconjunctivitis, IKC):**

Three to four weeks following the dispersal of approximately 100 domestic goats onto bighorn sheep habitat in the Silver Bell Mountains of Arizona, bighorn sheep were observed with infectious keratoconjunctivitis (IKC, an ocular disease that usually causes temporary blindness, Jansen et al. 2006). Some bighorns died before recovering from blindness. Detailed evidence strongly suggested that domestic goats transmitted the IKC to bighorn sheep.

Mycoplasma conjunctivae and *Branhamella* spp. with nearly identical rRNA sequences were documented in both domestic goats present and infected bighorn sheep. None of the goats removed from bighorn habitat had active lesions, though one had healed lesions consistent with IKC.

Johne's disease (Paratuberculosis):

Johne's disease (*Mycobacterium avium paratuberculosis*) is a serious gastrointestinal disease in livestock leading to chronic wasting (severe weight-loss). The causative bacteria survives in the environment up to a year. Because of a long incubation period, animals may shed the bacteria in their feces for 15-18 months before exhibiting any physical signs. Some infected animals can shed the bacteria in their feces but remain without signs of disease. Free ranging bighorn sheep and mountain goats in several Colorado and Wyoming herds have been diagnosed with the disease, as were captive Dall's and Stone's sheep and mountain goats in a Yukon captive facility. Clinical disease has been rare in llamas in North America; however, in a serological survey of British Columbia llamas, 10% tested positive, indicating possible exposure to the disease or a cross-reacting agent. Williams (2001) and others indicated that transmission of Johne's disease from domestic goats or llamas used as pack animals to bighorn sheep or mountain



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goats is unlikely because survival of the bacteria in dry alpine environments is thought to be poor, healthy animals rarely excrete large numbers of bacteria, and horizontal transmission is uncommon. However, the long-term persistence of Johne's disease in some wild herds of bighorn sheep and mountain goats demonstrates that transmission under natural conditions does occur.

Contagious Ecthyma (CE, Sore Mouth):

This is a common viral infectious dermatitis of farmed sheep and goats that results in scabby sores, often around the mouth, nose, and eyes. Severe cases may result in starvation or lameness. It is transmittable to humans. CE has been detected only sporadically in several Dall's sheep populations in a wide distribution across Alaska, most commonly in lambs, and has recently resulted in mortality among adult mountain goats near Juneau. The crusts that are shed from lesions are highly infective and persist in the environment for up to 20 years leading to transmission potential without direct contact. Garde et al. (2005) recognized the potential for transmission from domestic sheep, goats, and llama. CE also occurred in Silver Bell Mountains bighorn sheep which were exposed to domestic goats. The CE virus from Alaska Dall's sheep has been typed and found to be identical to CE of domestic sheep (Kimberlee Beckmen, pers comm.). Although infections and mortalities appear to be sporadic, this disease is now established in at least some Alaska wild sheep and goat populations.

Parainfluenza-3:

This virus causes respiratory disease, often by predisposing the respiratory tract to secondary bacterial infection (particularly *Mannheimia haemolytica*). It is common in cattle, goats, and domestic sheep. Antibodies to PI3 were documented in llamas in BC and camelids worldwide, but significance is unknown. Transmission occurs during close contact. It is associated with die-offs in bighorn sheep (Garde et al. 2005).

***Muellerius capillaris* lungworms:**

Muellerius capillaris is a common lungworm in domestic sheep and goats. All five bighorn sheep which survived 6 months in a pasture with 4 domestic goats infected with *Muellerius sp.* began shedding *M. capillaris* larvae, indicating transmission from goats to bighorn sheep occurred (Foreyt et al. 2009). First stage larvae are shed in feces, where they can survive for months. Infective larvae develop within slugs or snails where they can survive for the life of that host (Garde et al. 2005.)

Sheep nasal bot fly (*Oestrus ovis*):

The sheep nasal bot fly is a common parasite in domestic sheep (less common in goats). It also infects llamas. It is not known if larvae fully develop within llamas, but clinical signs are similar to domestic sheep (Fowler 1998 in Garde et al. 2005). *Oestrus ovis* causes severe sinusitis and is thought to be responsible for high mortality rates, averaging 41%, of bighorns in Zion National Park (Bunch et al. 1978).

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