EXHIBIT 6

“A Process for Finding Management Solutions to the Incompatibility Between Domestic and Bighorn Sheep”

August 2001

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"A PROCESS FOR FINDING MANAGEMENT SOLUTIONS
TO THE INCOMPATIBILITY BETWEEN DOMESTIC AND BIGHORN SHEEP"

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INTRODUCTION

Scientific research has proven that when bighorn sheep intermingle with domestic sheep, large numbers of bighorn sheep die (Ashmanskas 1995). Major bighorn sheep die-offs have occurred in every western state and have been reported from the mid 1800's to the present (Martin et al. 1996). In recent years, biologists and veterinarians have shown that even casual contact between bighorn and domestic sheep may lead to respiratory disease and fatal pneumonia in bighorns (Onderka and Wishart 1988). The role domestic sheep play in causing pneumonia in bighorn sheep is an important issue in multiple use management (Foreyt et al. 1994).

Presently, about 90 percent of all Rocky Mountain bighorn sheep and 20 percent of desert bighorn sheep in the United States spend all or part of their lives on National Forest System lands. Although domestic sheep allotments on National Forests in the west have greatly declined in number, they are still numerous in some areas. Many bighorn and domestic sheep managers are struggling with this issue because they don't have a good understanding of the incompatibility between the two species, and/or don't know how to address these issues and find potential solutions. Solutions are often difficult to develop and may become politically charged.

The purpose of this document is to describe a process for finding management solutions to the incompatibility between bighorn and domestic sheep. This paper is designed to be used by biologists and range conservationists at the Forest level. The process is divided into 3 parts:
(1) disease overview, (2) collaborative approach to identify issues and opportunities, and
(3) developing workable solutions. All parts are essential and must be intertwined to become an effective tool for solving domestic/bighorn issues. Overall recommendations are included as well as a question and answer section.

HISTORICAL PERSPECTIVE

Bighorn sheep were once abundant throughout Western North America. Archaeological studies indicate wild sheep were a significant ungulate food item for Native Americans (USDA Forest Service Report 1991). Bighorn populations began to decline dramatically in most areas about 1880. By 1900, many populations were eliminated (Buechner 1960). These historic population declines are attributed to over hunting, parasites, disease, competition with domestic livestock for forage, and competition with humans for space (Buechner 1960, Honess and Frost 1942).

Bighorn populations did not recover following enormous declines in the late 1880's and early 1900's. This is in contrast to the resilience of many other wildlife species such as deer and elk. Bighorns have demonstrated less tolerance than other native North American ungulates to poor range conditions, interspecific competition, over hunting and stress related to habitat loss (Desert Bighorn Council 1990). Most importantly, they have shown a much greater susceptibility to diseases (Goodson 1982).

In the last century, wild sheep populations have suffered from a wide variety of diseases, some that they have contracted from domestic sheep (Geist 1971). These include scabies, chronic frontal sinusitis, internal nematode parasites, bacterial pneumonia, foot rot, parainfluenza III virus, bluetongue virus, and contagious ecthyma (Desert Bighorn Council 1990).

Bighorn sheep recovery began during the 1960's and 1970's. State wildlife departments in partnership with land management agencies have ongoing efforts that include transplants into unoccupied habitat, augmentation of existing herds, and habitat manipulation. These efforts have had varying success rates; however, success has been consistently poor in areas where contact with domestic sheep occurred. Even with the ongoing recovery effort, current bighorn sheep numbers in the Western United States are estimated to be less than 10 percent of pre-settlement populations.

Historically, bighorn sheep played an ecological and social role. They were part of the prey base for the wolf, cougar, coyote, bear, and golden eagle. Vegetation abundance, evolution, and succession were influenced by herbivores including bighorn sheep. They were widely depicted in rock art indicating their significance to Native American people. Today, bighorn sheep continue to play an ecological role although a smaller one based upon their low numbers. They also continue to be highly prized socially as demonstrated by their extreme recreational value for hunting, wildlife viewing, and photography.

PART I DISEASE OVERVIEW

The following is a brief summary of the current information concerning disease transmission. Viruses, parasites, and bacteria can weaken or kill bighorn sheep. However, bacteria, primarily Pasteurella spp., have led to massive all age die-offs of bighorn sheep in every western state (Martin et al. 1996). Of the numerous pathogens affecting bighorn sheep, Pasteurella haemolytica is by far the most important respiratory pathogen of bighorn sheep leading to pneumonia and death (Foreyt 1993). Pasteurella multocida can also be important in the pneumonia complex.

There are over 70 varieties of P. haemolytica classified in either Biotypes A or T. Each biotype can have many serotypes or strains. Biotype T strains of P. haemolytica are found predominately in bighorns and other wild ruminants, while Biotype A strains are predominately in domestic sheep (Foreyt 1993, Jaworski et al. 1998). Research has shown that P. haemolytica (usually biotype A, serotype 2) is the major pathogen responsible for death in bighorn sheep after contact with domestic sheep. Martin et al. (1996), summarized over 30 published cases where bighorn die-offs are believed to have resulted from contact with domestic sheep. In most cases, between 75 and 100 percent of the bighorn herd died. Domestic sheep always remained healthy.

DNA fingerprinting was recently used to pinpoint the origin of bacteria leading to death in bighorn sheep (Foreyt et al. 1994, Jaworski et al. 1993). Pasteurella DNA isolated from dead bighorns originated in domestic sheep and had not been present in bighorn sheep before they were exposed to domestic sheep. The source of DNA was P. haemolytica (biotype A, serotype 2). Studies at

Washington State University, Edmonton, Canada, and at the Caine Veterinary Center, Boise, Idaho, have shown that specific types of P. haemolytica and P. multocida can be directly transmitted to bighorn sheep from domestic sheep (Onderka and Wishart 1988, Foreyt 1989, Foreyt 1990, Foreyt 1992, Hunter 1995a).

In wild situations, domestic sheep and bighorn sheep association almost always results in deaths of bighorns without affecting the domestic sheep. The finding of a shared P. haemolytica by DNA fingerprinting between domestic sheep and bighorn sheep in a Nevada study indicates this bacteria was transmitted between the two species under field conditions (Hunter 1995b). DNA analysis in the winter of 1995-96 in Hells Canyon during a bighorn die-off revealed that a feral goat and two bighorn sheep shared a genetically identical P. multocida and P. haemolytica (Rudolph et al. 1998). The subsequent die-off resulted in the death of in excess of 260 bighorn sheep in an eight-week period. The disease spread over 30 air miles and affected six bighorn sheep herds.

When bighorn sheep experience a pneumonia episode, all age mortality normally occurs. Lambs born to surviving ewes generally experience low survival rates for three to five years after the initial episode (Foreyt 1990, Coggins and Matthews 1992, Ward et al. 1992, Foreyt 1995, Hunter 1995a). Research indicates that lambs born in bighorn sheep herds that experienced a pneumonia episode usually die before three months of age (Foreyt 1990). It is likely that ewes surviving pneumonia remain carriers of pathogenic P. haemolytica for several years and transfer the bacteria to their lambs through nasal secretions. Lambs are protected by passive colostrum immunity early in life, but when this immunity wanes at six to eight weeks of age, they die from pneumonia. Low lamb survival rates usually continue for three to five years, delaying population recovery for many years.

All ungulates, except llamas, carry some strains of P. haemolytica (Foreyt 1995). However, experimental exposure of bighorn sheep to elk, deer, mountain goat, cattle, llama, and domestic goats has not resulted in pneumonia in bighorn sheep (Foreyt 1992, Foreyt 1993, Foreyt 1994). Bighorn sheep also appear to be attracted to domestic sheep and goats, but not cattle or llamas. Since Pasteurella transmission requires nose-to-nose contact or transfer of mucus through coughing or sneezing, it is most likely to occur between bighorn sheep and domestic sheep or goats. There are isolates of P. haemolytica from domestic sheep that are not lethal in bighorn sheep (Foreyt 1993). In addition, certain kinds of Pasteurella spp. are not toxic to one bighorn, but may be deadly in another.

Bighorn sheep die-offs due to pneumonia have occurred without any known association with domestic sheep (Goodson 1982, Onderka and Wishart 1984**,** Foreyt 1989, and Ryder et al. 1994). These die-offs were typically from P. haemolytica biotype T and serotypes 3, 4 and/or 10. The majority of these T-type die-offs are apparently triggered by some type of stressor, such as severe winter or drought conditions, population in excess of carrying capacity. The major difference between A- and T-type die-offs is the percent of the population lost. T-type incidents usually kill between 15 and 35 percent of the herd whereas 75 to 100 percent of the herd is typically lost in A-type incidents.

No studies report any bighorn sheep herds, fenced or free ranging, that have come into contact with domestic sheep and remained healthy. Several co-pasturing studies revealed that 40 of 42 (95 percent) bighorn sheep died from pneumonia after association with domestic sheep (Foreyt 1995). All domestic sheep remained healthy. Of all animals tested, only domestic sheep and mouflon sheep have been found to be incompatible with bighorn sheep.

No vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with deadly strains of P. haemolytica. Attempts have been made to develop such a vaccine for several years and are ongoing.

The incompatibility between domestic and bighorn sheep was tested in the United States District Court (Oregon) in 1995. The following summarizes United States Magistrate Judge Donald C. Ashmanskas' findings. "Scientific research supports a finding that when bighorn sheep intermingle with domestic sheep, large numbers of bighorn sheep die. While the exact reason for this result may be in question, it is clear that the die-offs occur. An incompatibility exists between the two species and there is no way to avoid the incompatibility other than to keep the domestics and the bighorns separate."

Most wildlife biologists and veterinarians have now concluded that bighorn and domestic sheep should not occupy the same ranges or be managed in close proximity to each other (Jessup 1980, Foreyt and Jessup 1982, Goodson 1982, Jessup 1982, Kistner 1982, Wishart 1983, Coggins 1988, Onderka and Wishart 1988, Foreyt 1989, Foreyt 1990, Desert bighorn Council 1990, Callan et al. 1991, Coggins and Matthews 1992, Foreyt 1992, Foreyt et al. 1994, Foreyt 1994, Pybus et al. 1994, Hunter 1995a, Onderka 1986, Hunt 1980, Foreyt 1995, Martin et al. 1996). Consequently, our current recommendation for minimizing pneumonia outbreaks in bighorn sheep is to maintain spatial or temporal separation between bighorn and domestic sheep on native ranges at all times. This is consistent with the following recommendations from leading bighorn sheep disease experts.

Valerius Geist, PhD, University of Alberta: "Domestic sheep are virtually toxic to bighorn sheep. The two species have to be kept apart and cannot be permitted to share any common ground."

William J. Foreyt, PhD, Washington State University: "If the wildlife management objective is to keep bighorn sheep alive, absolutely no physical contact with domestic sheep should be permitted."

Michael W. Miller, DVM, PhD, Colorado Division of Wildlife: "I believe segregating bighorn and domestic sheep on native ranges remains the single most effective management tool for preventing pneumonia epidemics in free-ranging bighorn sheep."

PART II COLLABORATIVE APPROACH

Management of bighorn sheep and domestic sheep in order to avoid physical interactions is often complex and potentially volatile issue. The intent of this paper is to describe a process managers can use in finding solutions benefiting both bighorn sheep and livestock operators. The live-stock industry and the associated ranch families in the western United States are important to America for many reasons. Ranching operations bolster local economies, preserve open spaces, provide critical winter range for big game and habitat for a multitude of wildlife species. They are an important part of Western heritage. The lifestyle that is so important to rural western citizens cannot occur without associated farms and ranches. Likewise, bighorn sheep are an important component of the west as well. They are important to the local residents, wildlife managers, hunters, conservationists, and to the many recreationists that visit or live in the western United States. Bighorn sheep are majestic symbols of the value of National Forests. Healthy bighorn populations are evidence that management for multiple use is working, providing an environment where wildlife can thrive in balance with other uses and values.

Forming a team of key participants that will work together from beginning to end to achieve mutually acceptable solutions is paramount. Although participation is totally voluntary, everyone who should be involved is invited to participate from the outset. Key participants will vary in each situation, but usually involve Forest Service line officers, biologists and range conservationists, livestock permittee(s), and State agency biologists and administrators. Agency managers work shoulder to shoulder with all participants to develop ideas and solutions.

Probably the most essential step in this sheep-specific process is to reach common understanding among all involved that incompatibility between domestic sheep and bighorn sheep exists and mixing the two species will eventually result in a bighorn sheep die-off. Without this fundamental understanding of the problem, collaborative efforts to develop potential solutions will probably not occur. It would be helpful in gaining understanding for all involved to have copies of the pertinent literature well before the initial meeting.

Each participant needs to recognize and respect the positions, needs, and concerns of others. It is the exchange of values and viewpoints to address problems and develop alternative solutions that is essential. Livestock permittee(s) may have been on the allotment for many years and the allotment and the way it is managed often has deep personal meaning. It is often not only life-style but deeply held cultural and social values that are at stake. High values are often associated with the existing ranch, and the allotment may be paramount to that value. Consequently, this issue often poses a significant threat to the permittee.

Biologists and interested publics, such as hunting organizations, have equally strong values associated with bighorn sheep. Die-offs represent many years of costly recovery effort lost. Full population recovery following a die-off requires many years**.** Loss of genetic diversity and herd memory of historical migration routes may be irreplaceable. Economically, the loss of potential hunting and wildlife viewing and photography may represent hundreds of thousands of dollars lost in essential State wildlife agency revenue, as well as lost revenue to local economies associated with these uses. In extreme cases, such as Sierra Nevada bighorn sheep, there is even the potential of federal listing as an endangered species with all that entails.

Discussions need to be open and objective to be productive. The goal is to look for long term solutions, not short term, quick fixes. The objective is to achieve reasonable alternatives keeping woolgrowers economically viable while protecting bighorn sheep. Bighorn sheep range may be on private, state, and federal lands, so solutions may include all of these lands. Decisions made in this process should be by consensus.

Other efforts employed to resolve resource management conflicts, such as outlined in the Coordinated Resource Management Guidelines (Cleary and Phillippi 1993), produced by the Society for Range Management (SRM), have developed rules for successful application of these types of processes. The following “cardinal rules” from that document should be considered:

- **Management by Consensus**. Participation is voluntary and consensus goes hand in hand with volunteerism. If everyone doesn’t agree, you go back to the drawing board and listen further to the dissenter’s needs.

- **Commitment**. All participants must be committed to the success of the program. Many will come in reserving judgment and keeping their options open to some extent, but at the very least they must have an open mind to accommodate commitment when the collective behavior of the group warrants it. Undermining the group is not acceptable.

- **Broad Involvement**. All interested parties should participate. To leave some caring interest out is to invite attack. If they too have needs, best to bring them in and hear them out. If their needs are not legitimate, you will eventually flush that out too.

- **Express Needs, Not Positions**. Expressing "positions" generates confrontation. Expressing "needs" generates compassion, trust, and group will to take care of legitimate needs. The group needs to discipline itself by reminding each other to express themselves in terms of needs rather than an expression of positions typical in adversarial posturing.

Techniques for conflict resolution and the basics of consensus development are discussed by Cleary and Phillippi, 1993. Many other sources are available and should be consulted when embarking on the process. Directly connected to the four cardinal rules are operating guidelines for interpersonal relationships that also might prove useful.

- Respect each other in words, tone, and expression.
- Discuss issues forcefully and pointedly, but not personally.
- Maintain a positive outlook, a positive approach.
- Avoid disparaging remarks about colleagues, organizations, agencies, the meeting.
- Be sensitive to other's feelings.
- Take time to affirm what you like, to affirm the good ideas.
- Take time for clarification and understanding.
- Take time to resolve problems and disagreements.
- Disagree without disdain.
- Don't leap to engage an issue – listen and clarify first.
- Avoid side conversations.
- Be open to other's points of view.
- Maintain flexibility.
- Maintain and share your sense of humor.
- Each person is responsible for their own and the group's adherence to these guidelines.

It might be important to consider recruiting an unbiased facilitator or moderator familiar with these types of processes. Skills necessary will include meeting management, communication, role clarification, teambuilding, working with diverse audiences and sometimes difficult people, visioning, goal and objective setting, decision making, and group maintenance. As an additional suggestion, if possible, selection of an unbiased individual that has trust already established with the group that is most fearful entering the process might accelerate teambuilding. Remember that collaboration flourishes in a climate of trust. Because the development of trust takes time, teamwork takes time. Although the collaborative process is time consuming and tedious, the results achieved have a much higher probability of being win-win for all involved. More complete information can be found in the 1993 SRM document.

PART III DEVELOPING WORKABLE SOLUTIONS

This section will be divided into five areas: steps of the process, complexity evaluation, examples, possible solutions, and development of a management strategy.

A. Steps Of The Process

The following steps have been successful in developing workable solutions:

- Step 1. Identify key parameters such as bighorn sheep herd specifics, maps, habitat descriptions, natural barriers, migratory behavior, domestic sheep numbers, and other specifics of the operation.
- Step 2. Identify areas of overlap and potential conflict.
- Step 3. Evaluate management complexity.
- Step 4. Develop site specific solutions for each bighorn sheep herd and domestic sheep allotment.
- Step 5. Develop a management strategy appropriate for the complexity of the management situation.

B. Complexity Evaluation

A complexity evaluation will be based on information supplied by key participants. Each participant will have a critical role in identification of final solution components. The permittee will provide information about his operation in terms of overall allotment management and long-term interest in domestic sheep grazing including interest in converting to cattle, allotment consolidation, allotment location preferences, economic considerations, and any other needs. The State wildlife management agency will need to have maps of occupied and historic sheep range, herd size, home range, migratory behavior, and lambing sites. It will also be important that the State prioritizes existing and potential herds. The Forest Service will supply allotment maps, trailing areas, timing and numbers of livestock on the allotment, details of the allotment management plan, whether bighorn habitat is continuous or isolated and whether any natural barriers to sheep movement exist. This usually will be done cooperatively with the state wildlife agency because sheep movements generally extend beyond the Forest boundary.

This evaluation will identify the complexity of the management situation and the areas of overlap where there is a potential for conflict. Design of a site-specific management strategy will then be based upon these parameters reflecting the level of complexity.

An initial stage of strategy development is to recognize the gradient of risk. As the complexity of the on-the-ground situation increases, the risk of a bighorn sheep die-off also increases as there is greater opportunity for contact between domestic sheep and bighorn sheep.

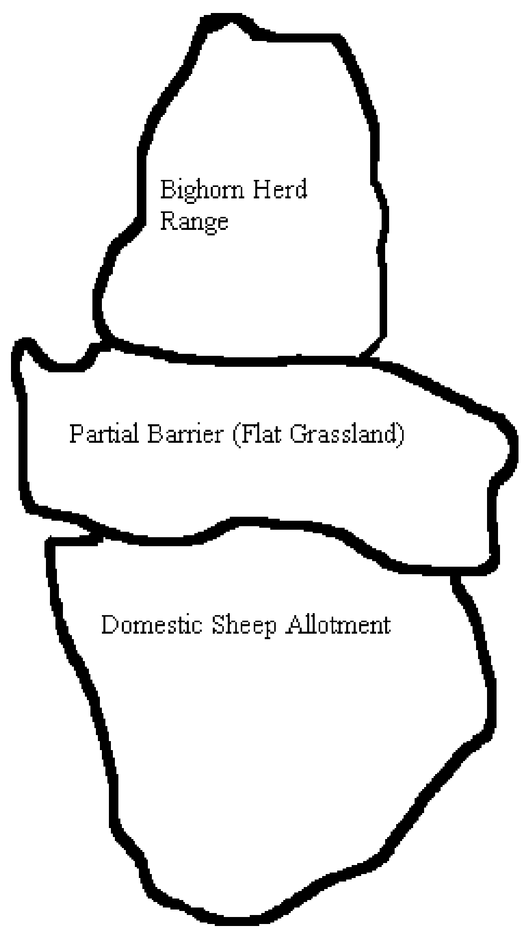
C. Examples

The following are real examples of a simple and complex situation used to illustrate steps 1 through 5 above:

Simple Management Situation:

- Bighorns -- One non-migratory herd with a small home range on isolated habitat.
- Domestics -- One six-month season allotment with no trailing and a cooperative permittee.
- Partial natural barrier available to help maintain separation of wild and domestic sheep.
- Primary conflict is the potential for the two species to mix in the fall when bighorn approach the flat grassland for water. The following illustration shows the situation graphically:

Figure 1. Simple Situation



The solutions identified to solve this potential use conflict were to use the partial barrier in combination with changing the rotation of the domestic sheep on the allotment to effectively increase the distance between species in the fall. The permittee returned to the pasture after livestock were removed to ensure that all stragglers were gathered. Water was developed at a remote site within bighorn habitat to reduce the need to go to water adjacent to domestic sheep. The permittee agreed to notify the State or Forest Service if bighorns were found near the domestic sheep.

Complex Management Situation:

Bighorns:

- Several migratory and non-migratory herds in continuous, large acreage habitat. Significant interchange among herds.
- Large areas of unoccupied historic habitat.
- State agency objectives to restore bighorn sheep to historic habitat using transplants at more than 20 unoccupied sites within the 1.2 million acres.

Domestics:

- Three large allotments trailing livestock up to 50 miles.
- Permittee wants to stay in the area. Area is not suitable for cattle.
- Four small farm flocks on private land.

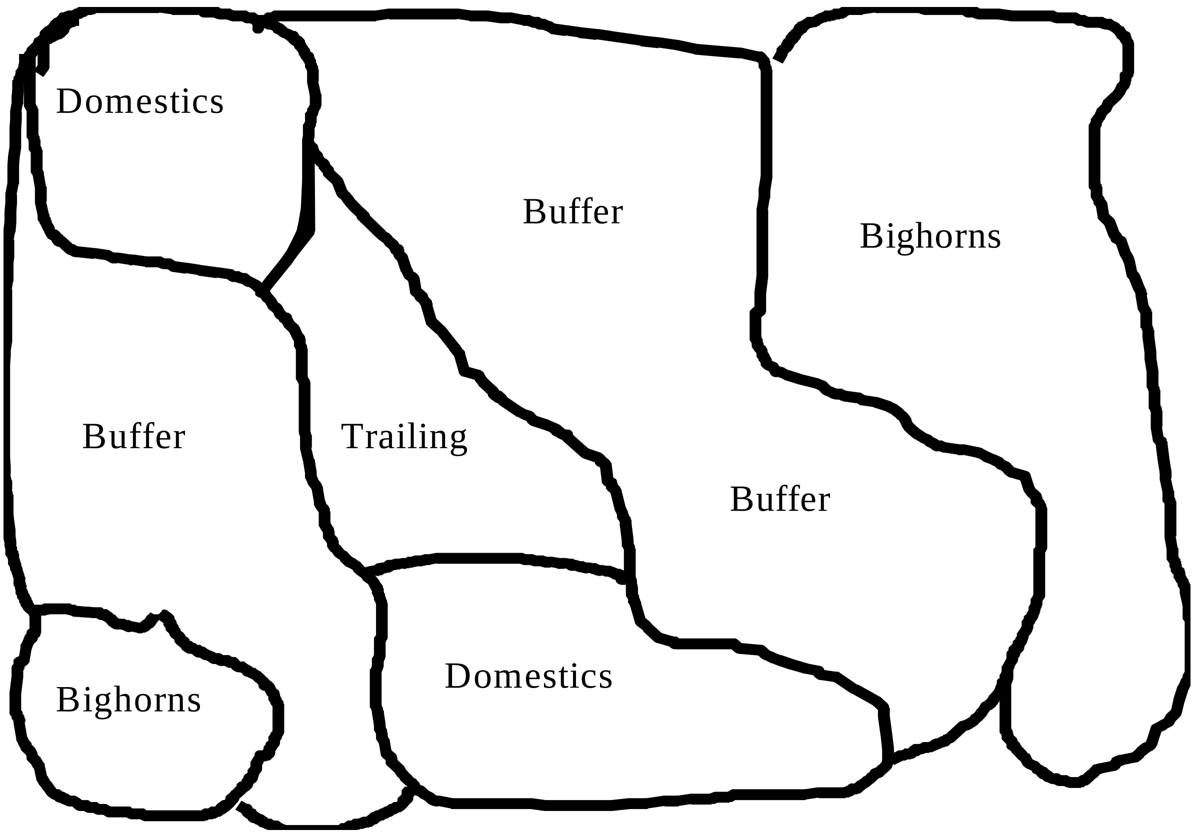
Habitat:

- No natural barriers.
- Previous management separated bighorn sheep and domestic sheep with 25-mile buffers.
- Die-offs continued in spite of buffers.

Repeated exchange between domestic and bighorn sheep has resulted in several minor and major die-offs over a 20-year period.

The following illustration shows the situation graphically.

Figure 2. Complex Situation.



The above example from Hells Canyon is approximately 50 square miles. Solutions included 25 mile buffers and very restrictive domestic management requirements. Both continued to be ineffective in keeping the two species separate. Other options considered were conversion to cattle, finding the permittee a replacement allotment elsewhere, economic incentive packages provided for the permittee to waive the permit back, closing the allotment thereby displacing the permittee, or simply living with continued die-offs. In this very difficult situation, and after 20 years of struggling to balance uses, three allotments were closed, the permittees were relocated to nearby large cattle allotments and/or economic incentives to waive the permit back to the government were supplied by an interested group. This decision was litigated and upheld.

D. Possible Solutions To Consider

The following is designed as a starting point for consideration when developing collaborative solutions. It is not all inclusive.

1. Changing components of the domestic sheep operation
    - Trucking vs. trailing sheep
    - Changing rotations
    - Intensive effort to gather strays
    - Timing and/or duration of use
    - Herding or improving the current herding situation

2. Moving domestic sheep to another allotment or dropping pastures

3. Conversion to cattle

4. Consider using natural barriers if topography allows for them

5. Habitat improvements
    - Burning
        - forage improvement
        - reduce conifer encroachment
        - reestablish migration corridors
    - Water developments
    - Salting

E. Development Of A Management Strategy

A "management strategy" is intended as a broad Forest approach to guide site specific bighorn and domestic sheep management. It is recommended in all situations, but is absolutely necessary in complex situations. It is in addition to developing site specific herd solutions. In most cases, the management strategy will result in a Forest Plan amendment. Many Forests are approaching the Forest Plan revision period. In these cases, revision provides a perfect opportunity to begin solving these types of conflicts through a suitability analysis. Regardless of the status of the Forest Plan, consider the following components for the strategy.

- Allotment management guidelines for domestic sheep that reduce the potential for interaction with bighorn sheep.

- Identify "domestic sheep emphasis" areas.

- Identify "bighorn sheep emphasis" areas.

- Identify a process for allotment review.

- Identify Forest Plan standards and guidelines to reduce conflicts between domestic and bighorn sheep.

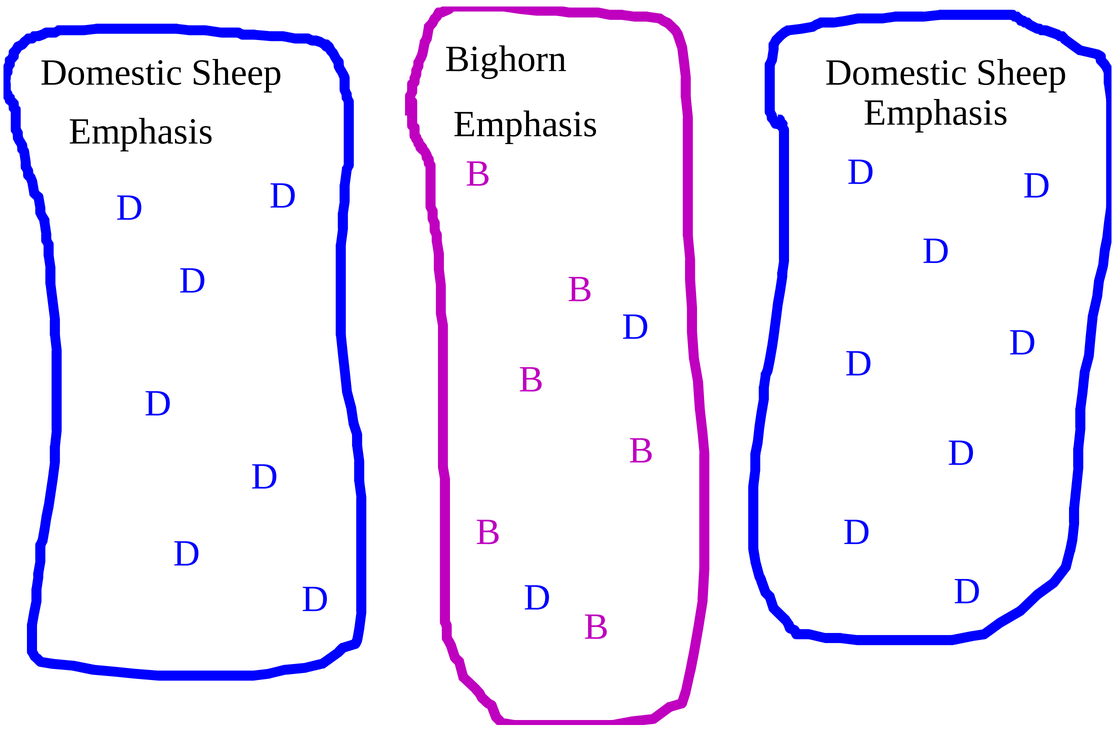
Four key factors are important to identify primary emphasis areas for bighorn sheep and domestic sheep:

- Bighorn home ranges and movements.
- Domestic sheep locations, trailing areas, and grazing rotations.
- Natural barriers to bighorn movements, such as lakes, reservoirs, large continuous forests, or desert.
- Suitable or historically occupied habitat.

Figure 3 below illustrates the emphasis area concept graphically. In this example, each of the 3 areas represent a large mountain range. The symbols D and B show the current locations of domestic sheep allotments (D) or bighorn sheep herds (B). Through a collaborative process, emphasis areas were completed and agreed upon. The two outside mountain ranges will continue to be managed for domestic sheep. No bighorn sheep will be introduced. In the center mountain range, alternatives were explored for reducing the contact between bighorn and domestic sheep. These alternatives took a few years to implement and included: incentives, converting to cattle, and moving to vacant allotments in the other two mountain ranges. Now completed, the center mountain range only contains bighorn sheep. A detailed example of how to develop emphasis areas and a management strategy is contained in Appendix A "Bighorn/Domestic Management Strategy for the Wallowa-Whitman National Forest."

Figure 3. Example of Emphasis Areas

D = Domestic Sheep Allotment B = Bighorn Herd



PART IV SUMMARY OF RECOMMENDATIONS

- Reach a common understanding with all key players concerning the incompatibility of domestic and bighorn sheep.
- Use a collaborative approach to develop solutions.
- Develop strategies to keep the species separate <u>at all times</u>.
- No matter how complex the management situation is, develop site specific solutions for each bighorn sheep herd.
- Develop management strategies when the situation is complex.
- Maintain management flexibility and opportunities for the livestock industry by leaving vacant sheep allotments open when they are not in conflict with other resource uses.

PART V QUESTIONS AND ANSWERS

1. Is the potential for bighorn die-offs higher when bighorn sheep population densities are high?

   Yes, especially when bighorn sheep populations are above carrying capacity. We encourage State agencies to keep population densities below carrying capacity for several reasons. High ram ratios can lead to more pioneering by young rams, especially in unhunted herds. This behavior can increase the risk of nose-to-nose contact with domestic sheep. In addition, bighorn die-offs have also occurred without association with domestic sheep when bighorn sheep densities were above carrying capacity. This appears to be a density related phenomenon.

2. How should small farm flocks be handled?

   Small farm flocks may or may not be a potential conflict. In most cases, gaining support is best done through educating owners of the risks and consequences of physical contact between the species. Personal contact and dialog is the best approach. A brochure titled "The Compatibility between Bighorn and Domestic Sheep" is available to use when making these contacts. It is available from the Foundation for North American Wild Sheep (FNAWS).

3. Should State agencies assume the risks of die-offs when reintroducing bighorn sheep where any potential for mixing with domestic sheep occurs?

   Yes. Several states have established a policy where they will assume this risk. Bighorns coming in contact with domestic stock are removed or destroyed. This is to prevent spreading disease to healthy bighorns. Encourage your cooperating State agency to adopt this policy.

4. Can different migratory behaviors of bighorns be used strategically in transplants to reduce the chance of mixing with domestic sheep?

Yes. Sheep obtained from non-migratory herds can provide more effective separation between the two species. However, remember that just because sheep came from non-migratory stock does not mean that they will not move. Young rams in particular will wander. That wandering may be extensive.

5. How can the Forest Service planning process be used to help eliminate bighorn and domestic sheep conflicts?

   Forest Plan Revisions provide the perfect opportunity to begin solving bighorn and domestic sheep conflicts. Planning regulations (36 CFR 219.20, 1982 planning regulation) require the Forest Service to conduct a "suitability analysis" for both livestock and wildlife. A suitability analysis identifies uses on the Forest that are not compatible. Since bighorns and domestics cannot co-exist in close proximity, Forest Plans should identify areas where conflicts are currently occurring, allocate those areas to either bighorns or domestic sheep, and develop strategies to eliminate the interactions in future years. (Note: Ongoing changes in the NFMA planning regulations may result in a change in this current requirement.)

   If a Forest Plan Revision is not in the foreseeable future, the Forest can decide to conduct a separate National Environmental Policy Act (NEPA) analysis to determine where conflicts exist and amend the existing Forest Plan to adopt strategies that will remedy the conflicts. Whether the analysis is completed through a Forest Plan Revision or through a Forest Plan Amendment, the key to success is looking at the problem at a large enough scale to have some management flexibility. In many situations the analysis might be more effective at a state level or on a multi-forest level.

6. What are some of the management strategies that can be effective in resolving bighorn and domestic sheep interactions?

   There are many options that can be used including:

   - Conversion of livestock kind from sheep to cattle. This must only be done after a completed range analysis indicates the allotment is capable of supporting cattle use. CAUTION: Many good domestic sheep allotments will never be good cattle allotments.

   - Relocating domestic sheep from a conflict allotment to a vacant allotment without bighorn/domestic conflicts. Many National Forests have sheep allotments that are now vacant. These vacant allotments might be used to shift domestic grazing away from conflict areas. CAUTION: Some allotments are vacant due to conflicts with other resources such as wilderness, T & E species, recreation, etc. Do not create or foster other resource problems by putting domestic sheep on a vacant allotment to solve a domestic/bighorn conflict.

   - Where the opportunity exists and can be done in an environmentally sound manner, permittees on conflict allotments can be prompted to move to non-conflict vacant allotments by offering them additional numbers or allotments.

   - There are several organizations that offer grants to the Forest Service to cover costs of solving bighorn/domestic conflicts. Costs that might be covered include NEPA analysis, publications and maps, etc.

- Many conflicts can be solved by modifying the allotment annual operating instructions changing rotation, trailing to trucking or improving herding.

7. When a bighorn die-off begins, is there anything that can be done?

   Maybe. A protocol has been developed by the Hells Canyon Restoration Committee for application of antibiotics and release of the animals on site. It has helped to reduce the losses of bighorn sheep in the wild. The key to its effectiveness is treatment of bighorns before they get into the later stages of pneumonia. It is an emergency measure that is expensive, but can be used as a last resort in an effort to save some of the herd. It may not be applicable in wilderness due to restrictions on use of helicopters. Additional information is available through Vic Coggins (Key Contact List attached).

8. Are there non-local interests that should be involved in conflict resolution with domestic and wild sheep management.

   Yes. FNAWS has been an active partner in bighorn sheep programs. They will be a very useful component as you work through these challenges. Further discussion concerning the value of their involvement is available through Melanie Woolever (Key Contact List attached).

9. Why hasn't the Forest Service adopted the Bureau of Land Management (BLM) Guidelines?

   The Forest Service believes that these issues can be best addressed on a site-specific basis using the Forest Planning process. The needs of bighorn sheep and of the domestic sheep operator can be meshed and balanced in a more effective manner locally. Also, situations vary in size and continuity of sheep habitat, topography, water availability, operator effectiveness, etc. These variations can be better accounted for using site-specific solutions.

10. Why not recommend a minimum buffer distance?

    A minimum buffer is not applicable across all National Forest situations and bighorn sheep habitats. For instance, the minimum buffer in Hells Canyon was 25 miles and yet was not effective in separating the species. Both species tend to wander and this area is a large block of continuous habitat which provides for wandering. On the other hand, the Lostine herd is separated from domestic farm flocks by a distance of about three miles. In this situation where farm flocks are separated by dense forest and topography, three miles is adequate. These examples illustrate why it is so important to develop site-specific solutions to these management challenges.

11. Is trailing of domestic sheep in occupied bighorn sheep habitat a problem? If so, can it be mitigated?

    Yes, it is a problem. Trailing in or near occupied bighorn sheep habitat needs to be prohibited if trailing timing coincides with the presence of wild sheep. The problem arises when trailing through densely vegetated areas. Even close herding is not completely effective in preventing stragglers and pioneers. Close herding can mitigate the impact when the trailing area is in the open and when bighorn sheep are utilizing a different portion of the range at the time.

12. Are there any examples of Forest Plan Standards and Guidelines addressing bighorn/ domestic sheep management?

    Yes. Examples from the Wallowa-Whitman and White River National Forests are provided in Appendices A and B, respectively.

13. Is there a viability issue with small, isolated populations of bighorn sheep?

    It is possible that this could be of concern. The Craig Wildlife Wildlands Institute began work addressing this issue related to the number of rams in the herd and those that actually breed. The risk to small populations increases as they become more isolated without genetic exchange. State agencies may want to supplement smaller herds to provide for genetic diversity. When addressing viability, remember it is most effectively addressed at large scales such as the Forest Planning level, consistent with the definition of viability in the NFMA planning regulation (36 CFR 219.19 of the 1982 planning regulations).

14. Can domestic goats transmit deadly bacteria to bighorn sheep?

    The current information on this issue is not definitive. Co-pasturing trials done by Dr. Foreyt with domestic goats and bighorn resulted in all bighorns remaining healthy. However, the most recent die-off in Hells Canyon was traced by DNA fingerprinting to a domestic goat that had been recently released in the wild. It is important to note that prior to release, the goat had recently been exposed to domestic sheep at a County Fair.

15. What should I do if there is pack goat use on my district?

    First determine if there is a potential for interaction with bighorn sheep. If there is, we recommend the following:

    - Animals should be tended and kept in sight at all times, especially when packing in areas where bighorn sheep are present.
    - Animals should be tethered or penned at night and not allowed to roam freely.
    - When bighorn sheep are in close proximity, pack goats should be moved quickly through the area and the wildlife gently hazed if necessary.
    - If it is determined that the pack goats are or have been in contact with domestic sheep, more stringent restrictions should be considered to ensure the goats do not make contact with the bighorn sheep.
    - Informational signing at trailheads should be used to explain the potential risks.

16. Is there a problem with llamas and disease transmission to bighorn sheep?

    There is not a problem with Pasteurella spp. transmission from llamas. There has been ongoing concern about Johnes disease transmission from llamas to bighorn sheep. However, there is no evidence to support the concern. Only 4 confirmed cases on Johnes disease have been documented in the United States in a population of approximately 100,000 llamas. Transmission requires repeated and prolonged nasal contact to high concentrations of bacteria (10-8 per gram). Animals shedding this number of bacteria are in the terminal stages of the disease. They are emaciated and weak which is incompatible with a viable pack animal. In short, this is not a problem for our bighorn sheep herds. For additional information, refer to the Johnes Disease Workshop Proceedings March 1996 available from Melanie Woolever.

17. What information can the State wildlife management agency provide that would be helpful in finding solutions?

    The State Agency will be a key player in developing solutions. An example from Wyoming Game and Fish is attached.

18. Are there any models available to help determine bighorn habitat suitability?

    Yes. There are five different Rocky Mountain bighorn sheep habitat models. They are discussed in Gudorf and Sweanor 1996, Shirokauer 1996, Smith et al.1991, Dunn 1993 and Johnson and Ringo 1995.

19. Is there anyone I can contact for help if I have more questions or need additional support?

    Yes. A Key Contact List is attached. Tim Schommer and Melanie Woolever work nationally in the Forest Service FULL CURL program. They are available to help you. Others on the Key List would also be willing to provide necessary support to help you work through this process.

20. Does Pasteurella or any other bacterial or fungal pathogen remain in the environment after domestic sheep leave the area?

    No. These pathogens die quickly outside of the host animal. Nose to nose contact is required for disease transmission to occur.

PART VI KEY CONTACT LIST

- Tim Schommer, Wallowa-Whitman NF, PO Box 907, Baker City, OR 97814, 541-523-1383
- Melanie Woolever, US Forest Service, R-2, PO Box 25127, Lakewood, CO 80225, 303-275-5007
- Vic Coggins, Oregon Dept. Fish & Wildlife, 65495 Alder Slope Rd., Enterprise, OR 97828, 541-426-3279
- Kevin Hurley, Wyoming Game & Fish, 356 Nostrum Rd., Thermopolis, WY 82443, 307-864-9375
- Bill Foreyt, Washington State University, Pullman, WA 99164, 509-335-6066
- Mike Miller, Colorado Division of Wildlife, 317 W. Prospect, Fort Collins, CO 80526-2097, 970-472-4348
- Karen Rudolph, University of Idaho/Caine Veterinary Training Center, 1020 E. Homedale Rd., Caldwell, ID 83605, 208-454-8657
- FNAWS Headquarters, 720 Allen Ave, Cody, WY 82414, 307-527-6261
- Jim deVos (desert bighorn sheep) Arizona Department of Game and Fish, 2221 W. Greenway Road, Phoenix, AZ 85023, 602-789-3247.
- Cal McCluskey, BLM, 1387 S. Vinnell Way, Boise, ID 83702, 208-373-4042
- Forest Service Regional Wildlife and Range Program Managers

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PART VIII APPENDICES

- **A**. Wallowa-Whitman N. F. Bighorn/Domestic Sheep Management Strategy
- **B**. White River NF Forest Plan Standards and Guidelines for Bighorn Sheep Habitat
- **C**. Wyoming Game and Fish Herd Unit Review pages
- **D**. Literature Review Regarding the Compatibility between Bighorn and Domestic Sheep

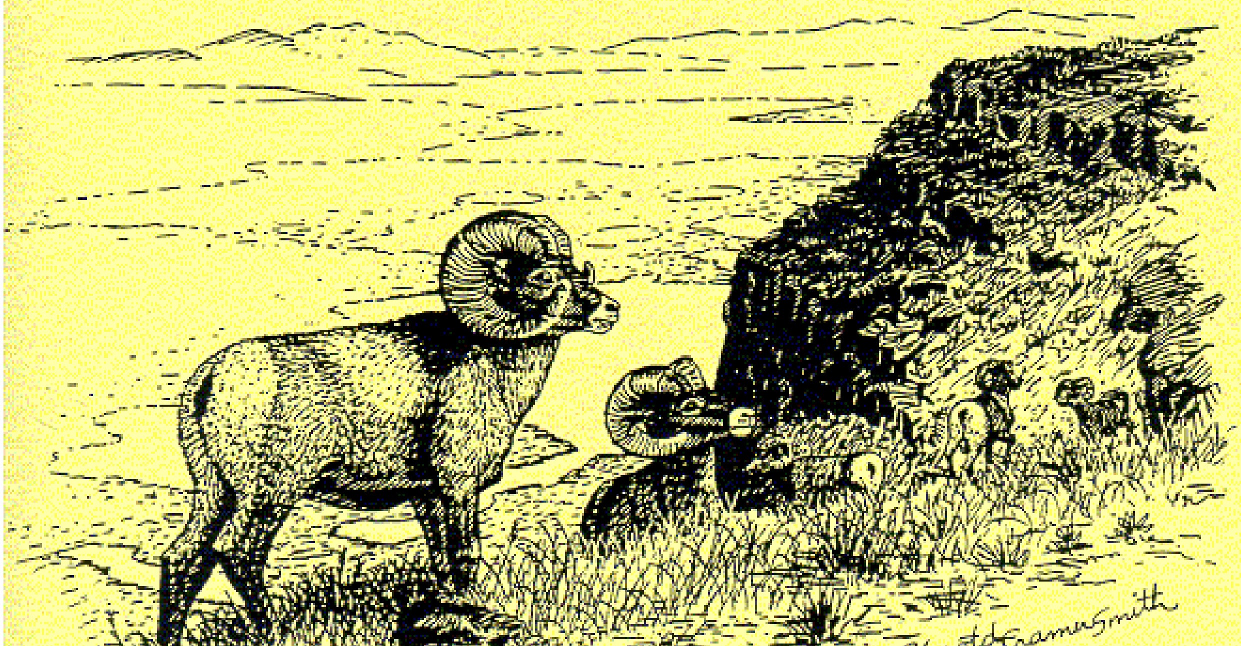
We sincerely appreciate the review and input provided to us by many domestic and bighorn sheep managers working together to solve this difficult management challenge.

APPENDIX A

BIGHORN/DOMESTIC SHEEP MANAGEMENT STRATEGY

FOR THE WALLOWA-WHITMAN NATIONAL FOREST

SEPTEMBER 1991



BIGHORN/DOMESTIC SHEEP MANAGEMENT STRATEGY
FOR THE WALLOWA-WHITMAN NATIONAL FOREST
1991

Prepared by:	Tim Schommer	Wildlife Biologist	WWNF
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	/s/Jim Lauman		Date 10/17/91
	Jerry Thiessen	Regional Supervisor	IDF&G
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	Bob Richmond	Forest Supervisor	WWNF
	/s/Bob Richmond		Date 10/3/91

I. INTRODUCTION

The following "Management Strategy" is intended as a broad Forest approach to guide site specific bighorn and domestic sheep management. This is not an Environmental Assessment document. It is only intended to replace the 1981 Bighorn/Domestic Sheep Guidelines currently in effect. After a 30 day public review process, we incorporated several of their suggested changes.

The document has the following objectives:

1. Develop a Forest Plan amendment which will move bighorn/domestic sheep management forward.

2. Decrease the potential for contact between bighorn and domestic sheep.

3. Allow bighorn reintroduction to proceed on specific areas, with restoration as the goal. Reintroduction would follow site specific analysis of these areas.

4. Identify a process for domestic sheep allotment review which will address bighorn/domestic sheep interaction within the context of NEPA.

5. Establish Forest-wide recognition of all existing bighorn sheep populations.

6. Incorporate this management strategy into the 1991 update of the State of Oregon Bighorn Sheep Management Plan.

A number of events have occurred over the last 20 years which have had an effect on the management of bighorn sheep on the Wallowa-Whitman National Forest (WWNF). In order to provide a basis for development of this management strategy, a brief overview of the history of bighorn sheep and their management is warranted.

Rocky Mountain bighorn sheep (Ovis canadensis canadensis) were native to much of the mountain and canyon country which currently comprises a large proportion of the Wallowa-Whitman National Forest in northeast Oregon and western Idaho. Specifically, historical accounts indicate that bighorns were numerous in the drainages in and around the Wallowa Mountains, the lower Imnaha River, Snake River, Grande Ronde River, Elkhorn Mountains, Powder River, and Joseph Canyon. Archaeological studies indicate wild sheep were the most important ungulate food item for Native Americans.

The California bighorn sheep (O. c. californiana) was found in the Burnt River canyon and on isolated mountains in the southern portion of the Wallowa-Whitman National Forest.

As European people settled the west, many of the activities either directly or indirectly had a negative impact on native bighorn sheep populations. Unregulated hunting, competition for forage with domestic livestock, and parasites and diseases introduced by domestic livestock were all factors which helped eliminate the bighorn from the state. The last native Rocky Mountain bighorn was seen in the Wallowa Mountains in the 1940's.

In Idaho, the Idaho Department of Fish and Game (IDFG) reintroduced 26 Rocky Mountain bighorn sheep into Granite Creek during 1975 and 1976. Seven bighorn ewes were released into nearby Bernard Creek in 1979. Both transplants flourished and reached an estimated herd size of 120 by 1983. In 1984, about 60% of the herd died of pneumonia. This was found to be caused by a disease called Pasteurella hemolytica. The bighorn population did not rebound from die-off. Thus, in 1990, the IDFG supplemented the herd with 31 more bighorns. The current status of the herd has not been evaluated, but IDFG believes it has continued to decline.

In 1971, the Oregon Game Commission reintroduced Rocky Mountain bighorns into the state when transplants were released on the Lostine River and on the Snake River at Battle Creek. The Battle Creek transplant failed within 2 to 3 years. A sizable herd, about 30 bighorns, developed and ranged along the Snake River from Wild Sheep Creek to Sand Creek until one winter in the early 1980's they suddenly disappeared. These sheep were thought to have migrated from Battle Creek. The Lostine River transplant flourished and grew to a herd size of 120 head. Limited hunting of rams was initiated in 1978 and trapping and transplanting to other release sites was initiated in 1977. This was accomplished in order to stabilize bighorn numbers in the Lostine herd while at the same time reintroduce bighorn sheep to additional historic habitats within their former range in Oregon. Some transplanting involved exchanging of Lostine stock for stock from the Salmon River drainage in Idaho so that sheep better suited to a release site and increased genetic diversity could be attained. This activity resulted in additional populations becoming established on the lower Imnaha River, Bear Creek, lower Minim River and the lower Grande Ronde River at Troy.

In 1981, concern for management of bighorn sheep in and around domestic sheep grazing allotments stimulated development of a document called the "White Paper" (Appendix D, #4) which outlined management guidelines designed to reduce potential conflicts between the 2 species.

In 1986, the Oregon Department of Fish and Wildlife (ODFW) developed a Bighorn Sheep Management Plan to provide management direction for reintroductions of bighorn sheep in Oregon and to provide public land management agencies a timeline on which to analyze proposed release sites. This document identifies proposed release sites and provides management direction for bighorn sheep in the future. The plan will be revised every 5 years with the first revision occurring in 1991.

Fifteen California bighorn sheep were reintroduced in 1987 on Bureau of Land Management lands along the Burnt River. The herd is slowly increasing and is now estimated to total about 35. They currently are adjacent to Forest Service lands, but are not known to drift onto the Forest.

An all age die-off of bighorn sheep on the Lostine River occurred in the winter of 1986. The disease agent was identified as Pasteurella hemolytica, which caused Pneumonia, and reduced the herd from 120 to 32 animals. Since Pasteurella hemolytica has remained in the surviving sheep for several years, it has been the primary factor preventing herd recovery to date.

Concern for the health and future of other existing bighorn herds caused ODFW and WWNF to decide to revise the 1981 "White Paper." The overall intent was to bring all concerned parties together in development of a series of management guidelines where all interests could participate equally. The primary area of concern was how to manage bighorn sheep and domestic sheep so contact between the two species could be minimized. The Bighorn/Domestic Sheep Task Force met three times and failed to reach consensus on the white paper revision. At that point, the document was turned over to the WWNF Supervisor and the ODFW NE Region Supervisor for their review and final decision. Immediately upon being jointly approved, implementation of the decision was contested by conservationist groups on the basis that the decision did not afford adequate protection to existing herds of bighorn sheep on the Forest. At that point, the WWNF issued a decision which suspended use of the guidelines, stopped all bighorn sheep transplanting efforts, and restocking vacant domestic sheep allotments, pending a broad Forest approach to the situation.

II. PROPOSED MANAGEMENT DIRECTION

1. Bighorn/Domestic Sheep Management Zones

The Bighorn/Domestic Sheep Task Force developed a "management zone" concept by dividing the lands administered by WWNF into nine Bighorn/Domestic Sheep management zones (see Appendix E). The zones were located to identify areas of higher and lower conflict between bighorn and domestic sheep. Areas of high conflict currently contain active domestic sheep allotments, areas of moderate conflict contain vacant domestic sheep allotments, and areas of low conflict do not contain domestic sheep allotments. A high conflict area would be one having a high probability that sometime during the grazing season domestic and wild sheep will come into close contact.

The use of management zones was developed to facilitate the objectives of restoring bighorn sheep populations and maintaining domestic sheep grazing as outlined in the Forest Plan. In areas where the potential for conflict is 1ow, NEPA analysis could be easily accomplished and bighorn populations restored. In areas where the risk is higher, the analysis process would become more complex. Entire allotments or groups of allotments would be analyzed and decisions would be made on how best to manage the existing and potential resources.

2. Locations of Potential Release Sites

The Task Force identified 20 potential release sites (see Appendix A and F). This list is not exclusive; other sites may be later identified. Not all of these sites are feasible under current management conditions, but are shown here to display potential. Eight of these twenty sites would be supplementing existing populations and 12 would be reintroduction of animals into unoccupied suitable habitats.

3. State Bighorn Sheep Management Plans

The emphasis of the States of Idaho and Oregon is to reintroduce bighorn sheep into all available and suitable habitats. Reintroduction will proceed according to the State Bighorn Sheep Management Plans.

Bighorn sheep will not be reintroduced into locations where it is probable they may come into contact with domestic sheep. Occasionally, bighorn may migrate outside of their designated range. If they come in contact with domestic sheep, bighorns will be considered "at risk" for disease transmission and potential loss of bighorn sheep. There is also the potential for a disease infected bighorn to leave the area and spread the disease to other bighorns. The State agency will assume the responsibility for bighorn losses and further disease transmission. If these situations occur, the State will take whatever action with infected bighorns that it feels necessary to reduce further losses.

Habitat improvement work, such as water developments and controlled burning, will be accomplished as needed, identified in an Environmental Assessment, and will be cooperatively funded when possible.

4. Management of Domestic Sheep Allotments - "Analysis Process"

Introduction: The Forest Plan for the WWNF allocates thirteen allotments as domestic sheep and two allotments for dual use (sheep and cattle). This means that a portion of the forage resources within those allotments are allocated for harvest by domestic sheep under the authority of a proper grazing permit and within constraints imposed by both the Forest Plan and the terms and conditions of the permit. Of the 15 allotments designated in the Forest Plan, five sheep allotments and two dual use allotments are currently stocked by domestic sheep under a permit. In addition, there are eight designated sheep allotments that are in a vacant status.

Analysis of domestic sheep allotments falls into one of two categories: Allotments are either active, indicating that there is a Term Grazing Permit issued that provides for stocking of the allotment by a prescribed-number of domestic sheep for a given season (or a preferred applicant has a priority for issuance of a permit), or the allotment is vacant. An allotment is considered to be vacant when either no Term Grazing Permit is in effect for that allotment or no priority applicant exists. The process for making decisions regarding each of these situations will be discussed separately.

Active allotments

Currently, Sheep Creek, Temperance-Snake, Mud Duck, McCarty, and Spring Creek are active sheep allotments (Appendix B and G). In addition, Mud and Davis Creek are designated for dual use (e.g., stocking is permitted by both domestic sheep and cattle).

Management of active allotments is conducted under the provisions of a Term Grazing Permit. This permit prescribes certain management activities under the Terms and Conditions of the Permit. The Allotment Management Plan is incorporated as a part of the Term Grazing Permit. This Plan sets the stage for prescribing management of the allotment, including the management of the permitted livestock.

The development of an Allotment Management Plan follows a combination of law, policy and direction, including that provided by the Forest Plan and National Environmental Policy Act (NEPA). Specifically, the initial step in the planning process is a public scoping to identify the issues and concerns associated with management of the allotment. From this scoping, a set of data needs is developed and a process for collecting the data is derived. Once the data is collected and analyzed, additional scoping and public involvement leads to development of alternative systems of management that address the issues and concerns. This step includes development of objectives for management and criteria to measure the effectiveness of each alternative against the issues and concerns.

The final part of the planning process involves selection of the preferred alternative by the Line Officer (usually the Forest Supervisor). This is done through completion of the Environmental Analysis and documentation of the decision in a public decision document.

This preferred alternative is then written in the form of an Allotment Management Plan. This plan will contain the objectives for the management of the allotment, prescribed management requirements (grazing systems, constraints, improvement developments, etc.), coordination requirements (such as for wildlife, recreation, etc.), livestock management requirements, etc. The plan will also contain monitoring plans based on short term implementation of standards and guidelines from the Forest Plan (ex: utilization standards), and long term monitoring of the effectiveness of the management practices in meeting the objectives of the plan.

In general, the Allotment Management Plan is expected to cover a ten to twenty year period. However, it is also expected the plan will be updated as needed. This can occur as a minor modification or may require a complete revision.

On the WWNF, all allotments are currently planned for new Allotment Management Plans within a ten year period. This schedule is based on a prioritization process that considers resource problems and conflicts. The more significant the problems or conflicts, the higher the priority assigned to the allotment. This schedule changes slightly from year to year based on accomplishments and budgets. The most up-to-date schedule can be found in the latest amendment to the Forest Plan.

In general, the Temperance-Snake and Mud Duck allotments are scheduled to be analyzed together within the next few years. Sheep Creek Allotment is not currently scheduled within the current five year period but would be scheduled within the second five years. McCarty and Spring Creek have recently completed plan updates and would not normally be re-visited for about ten years. Mud and Davis Creek Allotments are both planned for re-analysis and planning within the next five years.

<u>Vacant Allotments</u>

Currently, the Canyon, Big Canyon, Sheep Rock, Minam River, Standley-Huckleberry, Huckleberry, Indian Crane, and Chicken Hill allotments are designated as sheep allotments in the Forest Plan but are currently in a vacant status.

The process for making decisions on vacant allotments is determined by various laws and policies including NEPA, the Forest Plan, and manual direction on the permit grant process.

For a vacant domestic sheep allotment, there are a number of potential decisions that can be made. First, a Forest Plan decision exists that the allotment is suitable and available for stocking by domestic sheep. Therefore, the Forest Plan recognizes the area as an established domestic sheep allotment.

However, in some cases, there could be reasons for re-considering the kind of livestock to be permitted. This may include economics, potential changes to alleviate other resource problems or conflicts on either the vacant allotment or on other allotments, etc. This determination would be made following an analysis as to the potential suitability of the vacant allotment for other kinds of livestock. This information would be presented and a decision made through the NEPA process which would include public scoping and involvement in the decision making process.

If the preferred alternative, and the subsequent decision is made to change the kind of livestock from domestic sheep to cattle, the allotment would cease to be available for stocking by domestic sheep. Stocking of the allotment would then be conducted under the grant process (explained below) and management would be detailed through the development of an Allotment Management Plan (as described above).

Where there is no decision made to convert the kind of livestock to other than domestic sheep, a process called the grant process must be followed to stock the allotment. This process is basically a priority screening that provides for using the capacity available on the allotment to meet certain obligations including restoring past resource improvement reductions (including on other allotments), correcting overstocking on other National Forest allotments and, meeting the proportionate needs of other resources and values. In order to issue a permit under the grant process, there must be an Allotment Management Plan that meets current Forest Plan Direction and NEPA sufficiency.

This grant process is only a priority screening process that selects a preferred applicant for an allotment area that is already established through the Forest Plan. The decisions regarding stocking levels, seasons of use, management intensities, etc., are made through the NEPA process and are documented in the form of a public decision document and an Allotment Management Plan.

If the capacity, or a portion thereof, is granted under a Term Grazing Permit, the new permittee becomes responsible for compliance with the Terms and Conditions of the Term Grazing Permit and Allotment Management Plan.

Until such time as a NEPA decision is made regarding the allocation of the forage resources, the allotment remains as a designated domestic sheep allotment.

In general, these vacant allotments are considered to be a low priority for analysis and planning on the Forest. This is because certain other active allotments are considered to be in more need of planning to either correct current resource problems or to prevent resource problems and conflicts from occurring. This would generally mean that these vacant allotments would not be scheduled for analysis and planning until the last years of the planning cycle.

Finally, a decision can be made to close specific allotments if analysis shows that the allotment no longer provides suitable range, the allotment is not economically feasible to be stocked under current or projected management systems, the area within the allotment is to be designated for emphasis on a resource or resources where significant conflicts would exist with livestock grazing, or various other reasons. This closure of an allotment would need to occur through the NEPA evaluation process and would result in amendment of the Forest Plan.

III. BIGHORN/DOMESTIC SHEEP MANAGEMENT ZONES

Zone One -

Zone One is located north and northeast of Enterprise and covers approximately 225,000 acres (see Appendix E). Currently there are about 30 bighorns in upper Joseph Creek, 10-15 in lower Joseph, and about 30 adjacent to Cherry Creek (Appendix C and H). All populations are slowly increasing in size. There are no domestic sheep allotments within the zone, only cattle and horse allotments.

The Department considers this zone to have several areas of unoccupied suitable habitat. The task group feels zone one has a low risk for conflict between bighorn and domestic sheep. Consequently, this zone has the highest priority for reintroduction/supplementation. Four sites have been identified as shown in Appendix A.

This zone will be considered available for reintroduction/supplementation subject to a case-by-case Environmental Assessment. All future decisions will address at least the following:

a. Intended and mapped boundary of bighorn year round range and maximum bighorn population objective.

b. Identification and recognition of nearest domestic sheep population of other possible activities that could be a potential resource conflict.

c. An evaluation of range vegetation conditions and year-round forage supplies for the bighorn population size objective.

d. List of habitat improvement opportunities with corresponding map.

If bighorns are reintroduced and migrate outside of zone one, these animals will be considered "at risk." The Department can mitigate some of this potential by selecting non-migrating stock, if available. However, some sheep in any population will "pioneer," and look for new areas. In these cases, the Department will address these potential migrations when they occur.

Zone Two –

Zone Two is located east of Enterprise and continues to the Idaho border, covering about 300,000 acres. There are about 100 bighorns along the lower Imnaha River. This population is increasing slowly. Four of the seven Rocky Mountain bighorn sheep hunting permits allowed in Oregon are permitted in this zone. There is currently one vacant sheep allotment, Canyon, which was last grazed by sheep in 1977. Forty to fifty Forest Service horses currently winter graze a portion of this allotment.

Since this zone contains a vacant sheep allotment, no bighorn or domestic sheep would be reintroduced into the Canyon allotment until the "Analysis Process" is followed. Bighorns could be reintroduced outside of the Canyon allotment in zone two, if the conditions outlined in zone one management were met. If a decision is made to not restock the allotment with domestic sheep, zone one management would prevail. If restocking the allotment with domestic sheep is decided, zone four management would apply.

This zone has five potential reintroduction/supplements. Two of these, H and I, are far enough away from Canyon Allotment that ODF&W feels reintroductions would have a low risk. All five sites are considered high priority by the Department.

<u>Zone Three</u> -

Zone Three is located directly south of Enterprise and covers the entire west side of the Wallowa Mountains, about 400,000 acres. About 45 bighorns are located along the Lostine River (which once numbered 110 head), and about 40 head represent the Bear/Minam herd. Both populations are slowly increasing. This zone has two potential reintroduction sites.

The zone contains several cattle allotments and four vacant domestic sheep allotments (Minam River, Standley-Huckleberry, Huckleberry, and Sheep Rock). Since this zone contains vacant sheep allotments, no bighorn or domestic sheep would be reintroduced until the "Analysis Process" is followed. Bighorns could be reintroduced outside of these vacant allotments within zone 3, if the conditions outlined in zone one were met. If it was decided to not stock any of the 4 vacant allotments with domestics, zone one would apply. Zone four would apply if any of the vacant allotments would be restocked with domestics.

<u>Zone Four</u> -

Zone Four contains about 350,000 acres and lies just southeast of Enterprise. There are only 5 to 10 bighorns remaining in the Upper Hells Canyon herd. Once numbering about 40, there have been a couple of major die-offs since 1983. The Department has identified two areas for possible reintroduction, both of which are considered low priority because of an active domestic sheep operation.

Temperance/Snake and Mud Duck sheep allotments have been active for many years. The sheep winter along the Snake River and move to the upper Imnaha drainage in summer. As long as these allotments remain active, the Department has no plans for reintroducing bighorns. If these allotments ever became vacant, the "Analysis Process" would be followed prior to any restocking of bighorn or domestic sheep.

The existing bighorns or others that move into active sheep allotments in zone four are considered at risk. If bighorns are found in active sheep allotments, the agency that makes the initial finding will immediately notify the WWNF. State agency action in these situations will be to remove or eliminate the bighorns if they consider them a possible source of disease transmission to any established bighorn herd.

The following management guidelines will be used on active domestic sheep allotments to help resolve potential conflicts between domestic and bighorn sheep:

a. Culling of domestic sheep - all obviously sick or lame sheep will be removed from the band prior to entering the National Forest allotment.

b. Upon entering or leaving an allotment or when moving between major grazing areas, the permittee will make every effort to ensure that no domestic sheep are left behind. If strays are found, they will be removed from the allotment, returned to the band, or disposed of by the permittee after the permittee discovers the problem or within 3 days after being notified by the Forest Officer.

c. While on the allotment, domestic sheep will be routed according to the approved annual operating plan and will not be allowed to graze outside the area planned for use. If unforeseen circumstances cause a need to change, the change must be approved in advance by the Forest Service. If domestic sheep are grazed outside the scheduled area without written approval, this will be cause for adverse action against the term grazing permit. In addition, the permittee will be required to move the livestock back into the scheduled area as soon as the problem is discovered or within 3 days following notification by the Forest Officer. The Forest Service will not tolerate non-compliance with the annual operating plan, and appropriate timely corrective actions will be implemented.

d. The domestic sheep permittee will comply with all applicable state laws dealing with interstate transport of livestock. In addition, for situations where the domestic sheep will be grazing in areas near bighorn range, the Forest Service may require tests and veterinarian certification for certain other diseases prior to placement of the sheep on the allotment.

e. All domestic sheep herders will be required to promptly report sightings of any bighorn to the permittee, who will then pass on the information to ODF&W and the Forest Service for appropriate action. The period of time between initial bighorn sighting and reporting to ODF&W will rarely exceed ten days. If bighorn sheep are seen approaching the domestic sheep, the herder will take all precautions to keep the bighorns separate from the herd. These steps may include moving the domestic sheep, chasing off the bighorns, creating noises, or other means of harassment to discourage the approach of the bighorns.

Zone Five –

Zone five is located about 12 miles north of Wallowa and covers only about 38,000 acres. This area currently has no bighorns. Only one site (Mud Creek) has the potential for reintroduction. ODF&W considers this a very low priority for reintroduction because it is an active sheep allotment.

Two dual use sheep and cattle allotments, Mud and Davis Creeks, have been active for many years. As long as these allotments remain stocked with domestic sheep, the Department has no plans for reintroducing bighorns. Animal management for domestic sheep and bighorn strays will be the same as zone four.

Zone Six -

This area is the small fringe Forest land adjacent to the Grande Ronde River. There are currently no bighorn sheep, but there is one low priority location that ODF&W feels could support a small herd. Only one cattle allotment is within the area, and presents no conflicts with any potential bighorn reintroduction. The zone borders the N. end Transitory sheep allotment which could present potential conflicts in the future between wild and domestic sheep. Presently, however, there is a buffer between the two species.

Since most of bighorn habitat lies on the adjacent Umatilla National Forest, this document will defer any bighorn management within this zone to that Forest.

Zone Seven -

Zone seven is the Idaho portion of the HCNRA and covers about 120,000 acres. About 40 to 50 bighorns occupy two locations. Both populations are declining, and their current status is undetermined. The cause of the current die-off is undetermined at this time.

The Idaho Department of Fish and Game (IDFG) has identified three sites: Granite, Bernard, and Sheep Creeks for potential supplementation. Priority for all three sites is considered only moderate, due to Sheep Creek, a currently active sheep allotment. If the allotment no longer had domestic sheep grazing, the sites would have a high priority. Management of this allotment would be similar to zone four.

There is another sheep allotment on the Idaho side, Big Canyon, which has been vacant since 1982. The "Analysis Process" would be followed prior to restocking of either bighorn or domestic sheep.

Zone Eight -

The very southern edge of the Forest, near Dooley Mountain, comprises zone 8. In 1987, about 15 California bighorn sheep were introduced on Bureau of Land Management lands at the base of Hooker Gulch. The herd has grown to about 35 and is staying very close to where they were released. ODF&W does not feel, at this time, the zone has any other potential bighorn release sites.

Currently, there are no domestic sheep allotments in this zone. The 6 cattle and horse allotments should pose no conflicts with bighorns. If ODF&W identifies a potential release site, management of this zone would follow zone one.

Zone Nine -

The rest of the Forest is in this zone. There are no Rocky Mountain bighorn sheep populations. However, historical records show that bighorns occupied the Elkhorn Mountains. ODF&W has identified one moderate priority site in the Elkhorns that has potential to reintroduce bighorns. This is considered a low risk site, because there are no domestic sheep allotments nearby. For this site, zone one management would apply.

The north part of this zone has 2 active sheep allotments (Spring Creek and McCarty), and 2 vacant sheep allotments (Chicken Hill and Indian Crane). Currently, the north part of this zone has very little potential for bighorn reintroductions and ODF&W has no plans to do so.

Management for All Zones

There are a number of private farm and range flocks surrounding the Forest. If bighorns move down into these domestic sheep, it is important that ODF&W biologists are contacted as quickly as possible. ODF&W will take the lead in organizing a public education process that will make the public more aware of the potential for bighorn/domestic sheep disease transmission.

The proximity of private farm flocks to potential bighorn transplant sites on the WWNF will be considered by both agencies in the decision process for future bighorn transplants. If there's a high probability of physical contact between domestic and wild sheep, it may be the best decision to not transplant bighorns in that area.

APPENDIX A

Locations of Potential Reintroductions/Supplements

Map Letter	Zone	Location		State	Priority
A	1	Bear Ridge	Reintro	ODFW	High
B	1	Table Mountain	Supp	ODFW	High
C	1	Cache Creek	Reintro	ODFW	High
D	1	Deadhorse Ridge	Supp	ODFW	High
E	2	Deep Creek	Reintro	ODFW	High
F	2	Tryon Creek	Reintro	ODFW	High
G	2	Pumpkin Creek	Reintro	ODFW	High
H	2	Sheep Divide	Reintro	ODFW	High
I	2	Devils Gulch	Reintro	ODFW	Moderate
J	3	Minam	Supp	ODFW	High
K	3	Cornucopia	Reintro	ODFW	Low
L	4	Sand Creek	Reintro	ODFW	Low
M	4	Battle Creek	Supp	ODFW	Low
N	4	Spring Creek	Reintro	ODFW	Low
O	5	Mud Creek	Reintro	ODFW	Low
P	6	Grande Ronde	Supp	ODFW	Low
Q	7	Granite Creek	Supp	IDFG	Moderate
R	7	Bernard Creek	Supp	IDFG	Moderate
S	7	Sheep Creek	Supp	IDFG	Moderate
T	8	Rock Creek	Reintro	ODFW	Moderate

ODFW - Oregon Department of Fish and Wildlife
IDFG - Idaho Department of Fish and Game
Reintro - Reintroduction of new herds
Supp - Supplement existing herds

APPENDIX B

STATUS OF DOMESTIC SHEEP ALLOTMENTS

Active Domestic Sheep Allotments

Sheep Creek - HCNRA (Idaho portion)

Temperance-Snake - HCNRA

Mud Duck - HCNRA and Eagle Cap RD's

Spring Creek – La Grande RD

McCarty – La Grande RD

Mud Creek (dual use) - Wallowa Valley RD

Davis Creek (dual use) - Wallowa Valley RD

Vacant Domestic Sheep Allotments

Big Canyon - HCNRA (Idaho)

Canyon - HCNRA

Minam River - Eagle Cap RD

Standley-Huckleberry - Eagle Cap RD

Huckleberry - Eagle Cap RD

Sheep Rock - Pine RD

Chicken Hill – La Grande RD

Indian Crane - Baker RD

APPENDIX C

Status of Bighorn Sheep Herds
on or Near the WWNF
September 1991

Herd Name	Management Unit	Population #'s	Population Trends	
Lostine	Minam	45	Slowly increasing	App
Lower Imnaha	Snake River	100	Increasing	App
Upper Hells Canyon	Snake River	5-10	Static	App
Cherry Creek	Chesnimnus	30	Slowly Increasing	Non
Bear/Minam	Minam	40	Increasing	App
Upper Joseph Creek	Sled Sps/Ches	30	Increasing	Non
Lower Joseph Creek	Sled Springs	10-15	Summer range for Wash	XXX
Granite/Three Crks	18	40-50	Declining	App
Sheep Mountain	Pine Creek	30	Slowly Increasing	XXX
Hooker Gulch	Sumpter	35	Slowly Increasing	XXX

App - Release was approved through the environmental assessment process
Non - Not approved through the process.
XXX - On private, state, and/or BLM land

APPENDIX D

LIST OF PERTINENT BIGHORN SHEEP DOCUMENTS

1. Cooperative Management Agreement - Supplemental Release of Bighorn Sheep Snake River 12/14/89.

2. Guidelines for Bighorn/Domestic Sheep Management on the WWNF. 1988.

3. Bighorn Sheep Management Plan written by ODFW. 1986

4. Environmental Assessment for Lower Minam Area Bighorn Sheep Reintroduction 9/10/85.

5. "Whitepaper" - Guidelines for bighorn sheep/domestic sheep management on the Wallowa-Whitman National Forest. 1981

6. Environmental Assessment and Memorandum of Understanding for Reintroduction of Bighorn Sheep in the Imnaha River Drainage 1/2/79.

7. Memorandum of Understanding for Transplant of 20 Bighorns to Black Mountains 1/10/78.

8. Addendum to Environmental Assessment for Reintroduction of Bighorns into Bear Creek 12/28/83.

9. Memorandum of Understanding for Transplant of 25 Bighorns from Lostine River to Bear Creek 12/23/76.

10. Memorandum of Understanding for Reintroduction of 20 Bighorns to Sheep Creek Divide 7/10/86.

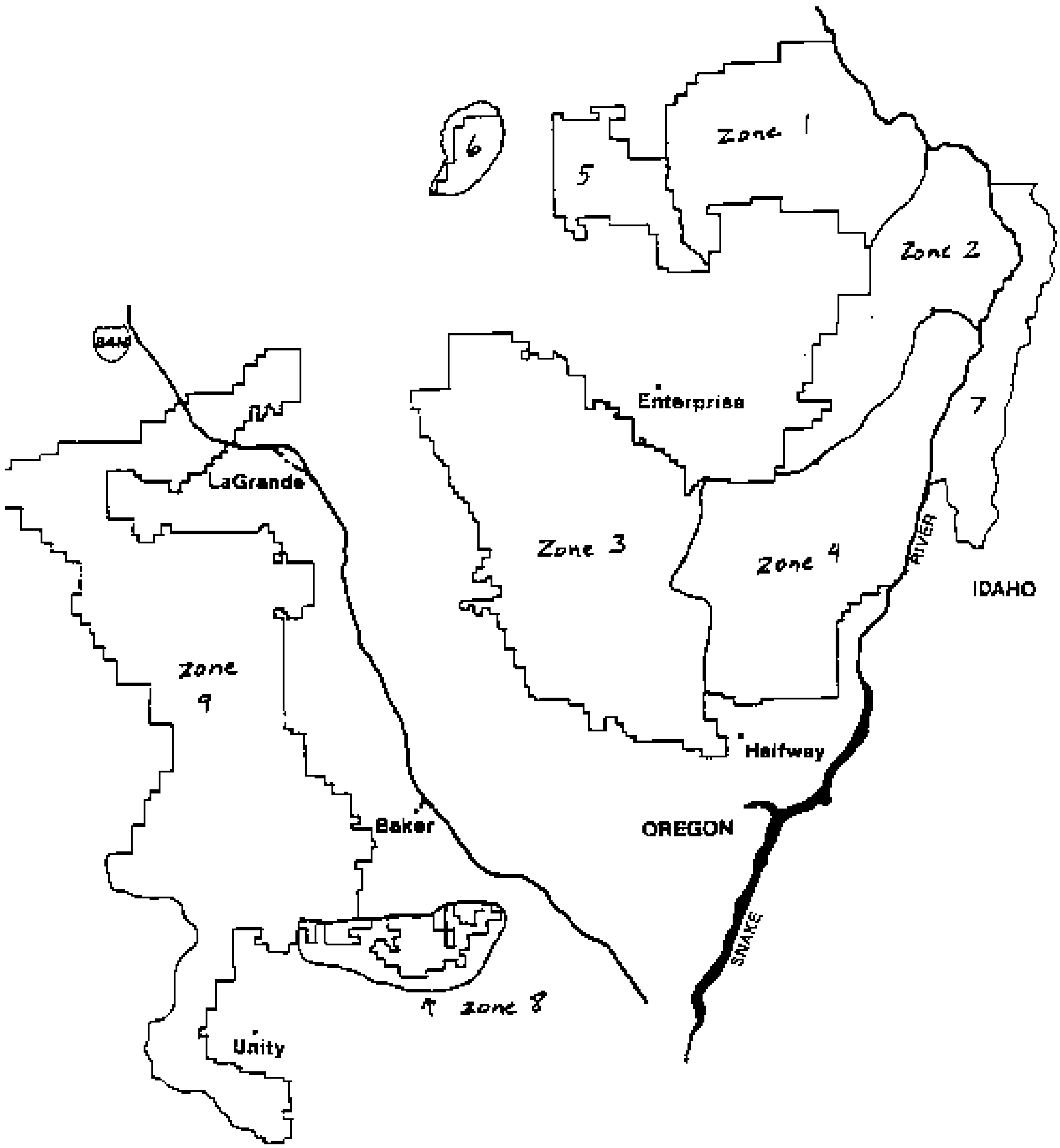
11. Environmental Assessment for Bighorn Reintroduction on Snake River 1/20/76.

12. Multiple Use Survey Report for Bighorn Sheep Transplants 1/70.

13. Lostine River Biological Unit Management Plan 11/10/71.

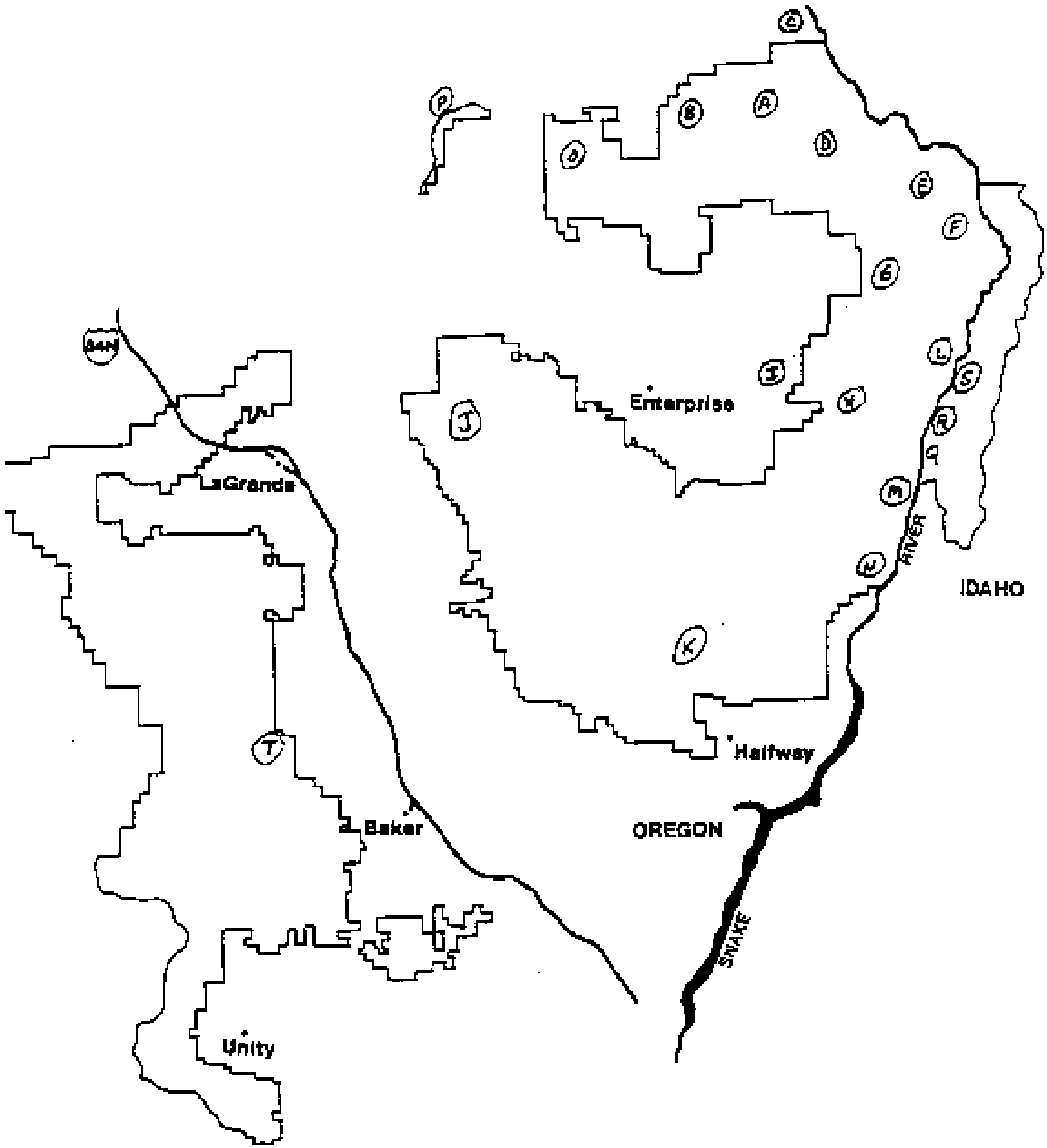
APPENDIX E

BIGHORN/DOMESTIC SHEEP MANAGEMENT ZONES



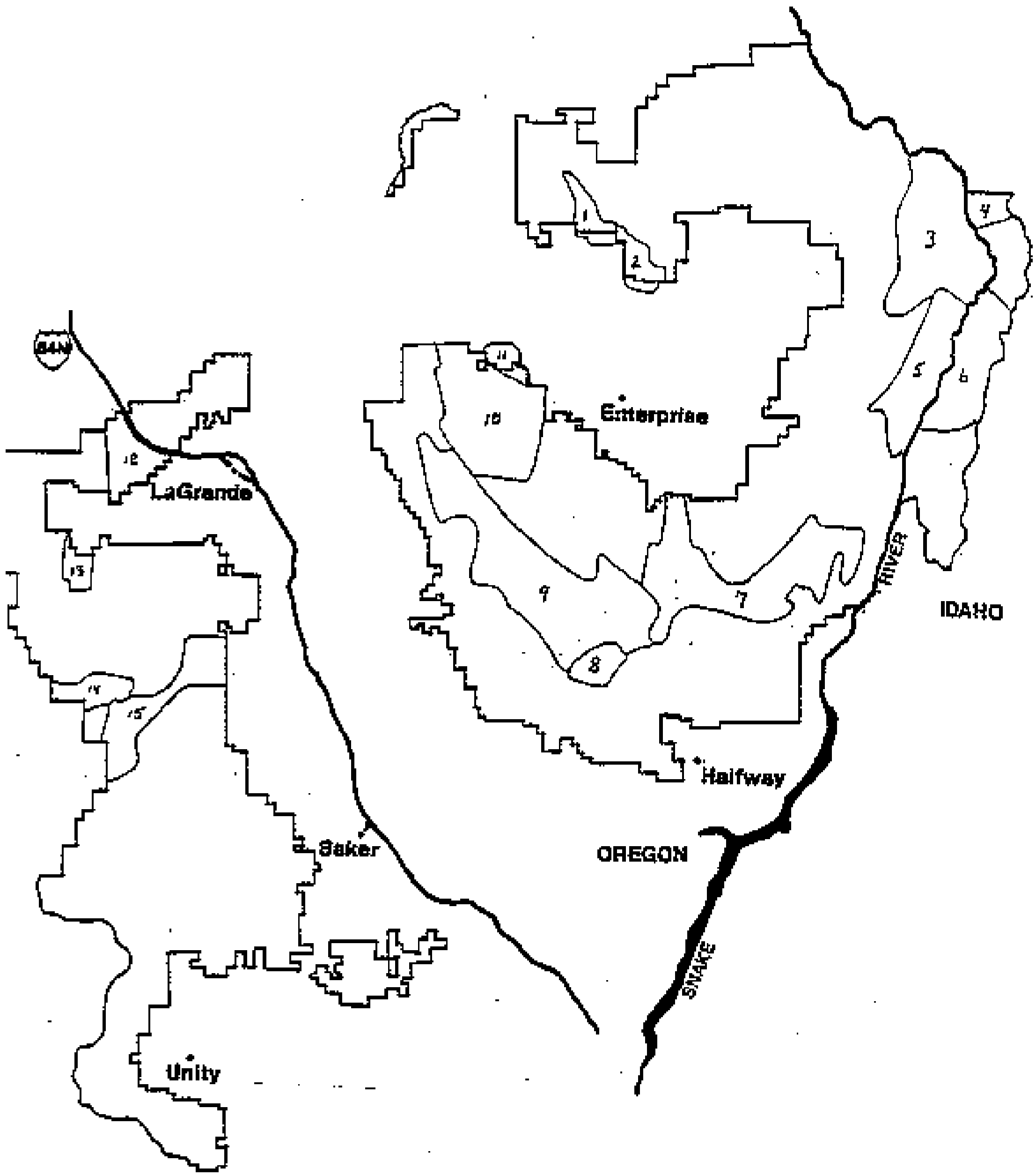
APPENDIX F

POTENTIAL REINTRODUCTION



APPENDIX G

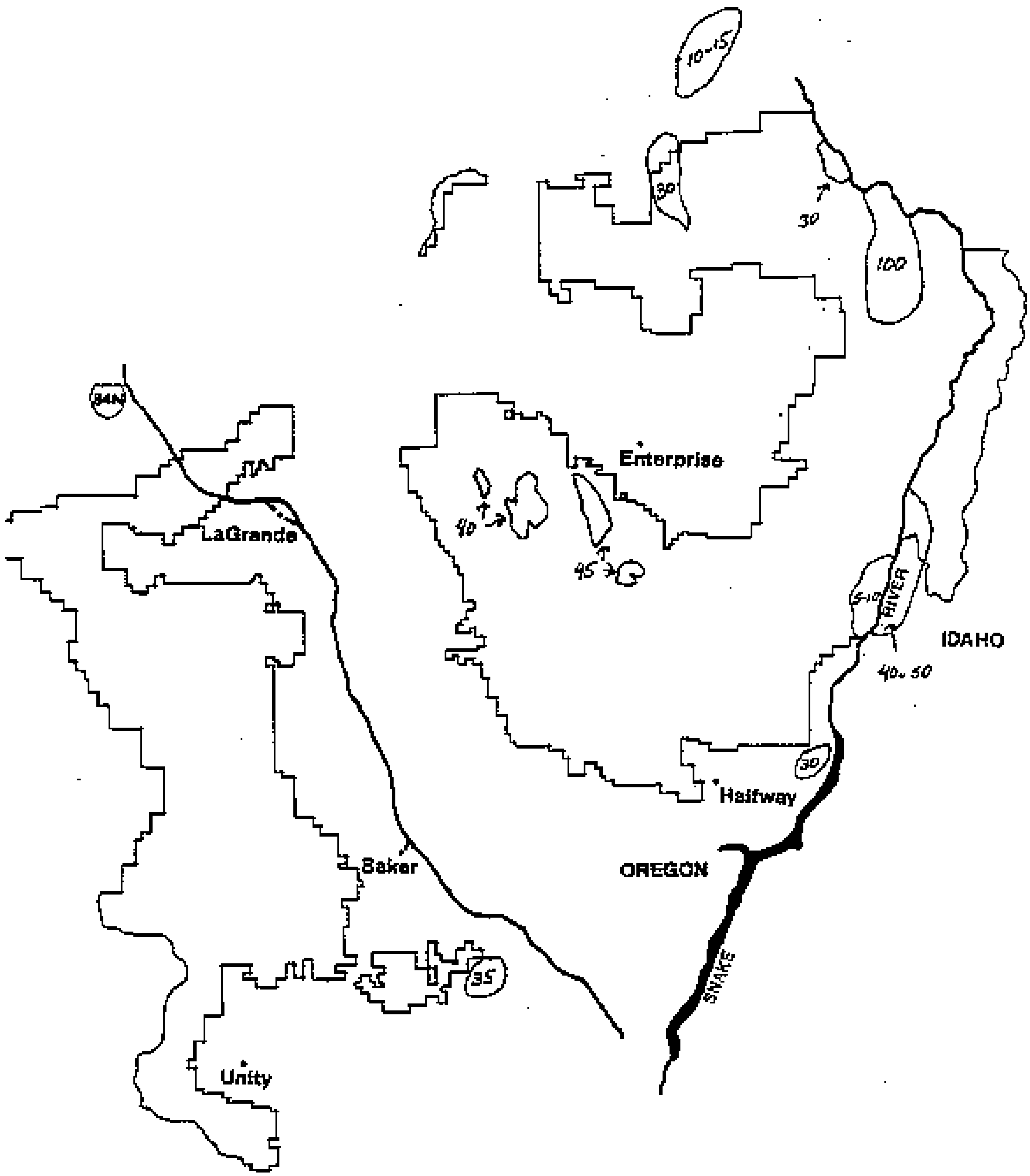
DOMESTIC SHEEP ALLOTMENTS



DOMESTIC SHEEP ALLOTMENTS	
1. MUD CREEK	8. SHEEP ROCK (V)
2. DAVIS CREEK	9. MINAM RIVER (V)
3. CANYON (V)	10. STANDLEY
4. BIG CANYON (V)	11. HUCKLEBERRY (V)
5. TEMPERANCE-SNAKE	12. SPRING CREEK
6. SHEEP CREEK	13. MCCARTY
7. MUD DUCK	14. CHICKEN HILL (V)
	15. INDIAN CRANE (V)

APPENDIX H

BIGHORN HERD LOCATIONS AND SIZES



LIST OF THOSE RESPONDING TO BIGHORN/DOMESTIC
SHEEP MANAGEMENT STRATEGY

August 1991

1. Jon Vanderheyden
2. Ed Watters
3. BLM Baker Office
4. Hells Canyon Preservation Council
5. Idaho Department of Fish and Game
6. Umatilla National Forest
7. Art Seamans
8. Paul Morehead
9. Skye Krebs

APPENDIX B

5.42 Bighorn Sheep Habitat

Theme

Management emphasis is to provide adequate amounts of quality forage, cover, escape terrain, and solitude for bighorn sheep and other species, while allowing vegetative manipulation that provides other multiple-use resources.

Management area description

These areas provide habitat for established bighorn sheep herds on the Forest. To ensure bighorn sheep viability, maintaining and improving the habitat upon which bighorn sheep depend is emphasized. Much of the area contains cliffs, rocky points, and benches intermixed with grass, forb, and shrub communities. Forested stands may also be present.

Desired condition

Herd objectives are established in cooperation with the Colorado Division of Wildlife. Interpretive opportunities are provided in established viewing areas.

Vegetation is managed to provide healthy plant communities with a variety of species present for food and cover. Natural and created openings or meadows of various sizes and shapes occur. Prescribed natural fire and management-ignited fire plans are developed in support of habitat improvement.

The recreation opportunity spectrum (ROS) for this management area is primitive, semi-primitive non-motorized, semi-primitive motorized, roaded natural, or rural year-round. For the ROS designation of a particular area, see the ROS maps in Appendix XX. Scenery is managed to provide a range of scenic integrity objectives from moderate to high as shown on the Scenic Integrity Objective maps in Appendix XX.

Standards and guidelines

INFRASTRUCTURE

Standard **1.** Over-the-snow vehicle use is restricted to designated routes.

MINERAL AND ENERGY RESOURCES

Guideline **1.** These areas are available for oil and gas leasing with controlled surface use or timing restrictions.

RANGE

Standards

1. Grazing strategies will be implemented to meet bighorn sheep habitat objectives.

2. Grazing by domestic sheep is prohibited unless adequate temporal or spatial separation can be demonstrated.

RECREATION

Guidelines

1. Recreation activities that disturb bighorn sheep should be restricted.

2. Provide interpretive opportunities in established viewing areas.

VEGETATION MANAGEMENT

Standards

1. These areas are not part of the suitable timber land base.

2. Vegetation management practices will be used to maintain or improve bighorn sheep habitat.

APPENDIX C

BIGHORN SHEEP
HERD UNIT REVIEW

Targhee (Area 6) (BHS106) **Revision Date: 4/17/98**

Estimated Population: 100 (post season 1997)

Population Objective: 125

Most Recent Hunting Regulations: 4 licenses, 3/4 curl ram

Current WGFD Managers: Doug Brimeyer, Steve Kilpatrick, Doug Crawford

JCR Responsibility: Doug Brimeyer

Other Contacts: Mary Oshner (USFS), Garvice Roby (WGFD-Ret.), Steve Cain (NPS)

Previous Studies: Steve Cain (NPS Reports)
N. Fitzsimmons & S. Buskirk (1992)
Mike Whitfield (1984)

Problems:

Habitat - Limited winter range, lack of fire
Domestic Sheep - Buffer zone only 3 miles (enough?)
Predation -
Genetics - Isolated population
Disease -
Migration -
Herbivore Competition -
Recreation/Development Encroachment -
Poor/Inconsistent Classification Data -
Hunting Related - Variable harvest due to land status (Grand Teton National Park)
Other - High natural mortalities (GTNP)

Jackson (Area 7) (BHS107) — Revision Date: 4/17/98

Population Estimate: 530 (post season 1997)

Population Objective: 500

Most Recent Hunting Regulations: 20 licenses any sheep

Current WGFD Managers: Doug Brimeyer, Gary Fralick, Doug Crawford, Dallas Jenkins

JCR Responsibility: Doug Brimeyer

Other Contacts: Adrian Villaruz (USFS), Garvice Roby (WGFD-Ret.)

Previous Studies:

Honess and Frost (1942)
Les McCann (1956)
Buechner (1960)

Transplant History:

1934 Transplant - 20 sheep trapped in Flat Creek, released in Bighorn Mountains - Hurley (1996)
1980 Transplant - 14 sheep released at Stinking Springs - Roby (1980)
these sheep were destined for Darby Mtn., but weather conditions precluded their release there, so they were turned out at Stinking Springs
- 11 sheep were released on Flat Creek

Total - 25 sheep released into herd unit

Problems:

Habitat - Habitat conditions (Willow Creek), lack of fire
Domestic Sheep - Yes, potential for contact on south end of herd unit
Predation -
Genetics - Scattered, isolated populations
Disease - Scabies at Camp Creek
Migration -
Herbivore Competition - Elk competition
Recreation/Development Encroachment - Snow machine disturbance
Encroachment on winter range - Stinking Springs
Poor/Inconsistent Classification Data -
Hunting Related -
Other - Recent overwinter mortality

Wapiti Ridge (Area 3) (BHS203) Revision Date: 4/17/98

Population Estimate: 925 (post season 1997)

Population Objective: 1000

Most Recent Hunting Regulations: 44 licenses, 3/4 curl ram

Current WGFD Managers: Larry Roop, Craig Sax, Tim Fagan

JCR Responsibility: Larry Roop

Other Contacts: Dave Henry, Bernie Spanogle (USFS), Kevin Hurley, Scott Smith, Doug McWhirter (WGFD)

Previous Studies: Hurley (1985)
Smith (1988)
McWhirter (1993)

Problems:

Habitat - Private land issues - winter range - reliance on improved meadows, valley, ranch
Fenced in holdings in USFS - Land exchange
CRM - Upper South Fork - USFS initiated
Weed problems on winter range - "toadflax"
Tremendous habitat opportunities - limber pine/juniper, S. Fork side - some on N. Fork, but limited.
Conifer encroachment

Domestic Sheep - Potential for domestic sheep on private lands - easement potential?

Predation - Predation - wolves - Upper South Fork

Genetics –

Disease - Disease – scabies

Migration –

Herbivore Competition - Elk numbers?? South Fork
Livestock issues - Ishawooa Hills

Recreation/Development Encroachment - Winter range encroachment - Recreation (ice climbing, photographers, wildlife viewers)

Worth The Watching - Lots of interest- High profile

Poor/Inconsistent Classification Data –

Hunting Related –

Other - Prospects for trapping - up to 80 sheep

Francs Peak (Area 5, 22) (BHS205) Revision Date: 4/17/98

Population Estimate: 1430 (post season 1997)
Three components: Area 5, Badlands (Area 22), Owl Creek Mountains/ Wind River Indian Reservation (OCM/WRIR)

Population Objective: 1360

Most Recent Hunting Regulations: Area 5-60 licenses any ram, Area 22-4 licenses 3/4 curl ram, OCM/WRIR-8 licenses any ram

Current WGFD Managers: ColeThompson, Pat Hnilicka, Tim Fuchs, Jerry Longobardi, Kevin Hurley, Tim Fagan

JCR Responsibility: Kevin Hurley

Other Contacts: USFWS - Dave Skates, Jeff Kimber, USFS - Joe Hicks, Mark Hinschberger, Dave Henry
BLM - Sue Oberlie, Tim Stephens, Marian Atkins, Kathy Firchow (formerly USFWS)

Previous Studies: Hurley/Firchow (1994)
Smith (1981)

Transplant History:

1970 Transplant - 23 sheep released at Castle Creek -WGFD (1976), Oudin (1996), Hurley (1996)
1973 Transplant - 17 sheep released at the Dennison Place - WGFD (1976), Hurley (1996)
1995 Transplant - 43 sheep released in Wind River Canyon - USFWS (1996), Hurley (1996)

Total - 83 sheep released into herd unit

Problems: Hunt Area 5

- **Habitat -** Habitat opportunity - on and off USFS - on Inberg-Roy WHMA
- **Domestic Sheep -** Livestock - 6 "vacant" domestic sheep allotment - USFS looking to fill these?
- **Predation -** Predation -future? - wolves/ no escape cover (Dennison) Little escape cover on Black Mountain, better escape cover higher
- **Genetics** –
- **Disease -** Disease - minor, scabies
- **Migration** - Reservation - Unoccupied habitat - 40 mile migration lost - from Wind River Canyon to Owl Creek Mtns.
- **Herbivore Competition -** Wild horses on sheep winter range (WRIR)
- **Recreation/Development Encroachment** –
- **Poor/Inconsistent Classification Data** –
- **Hunting Related** –
- **Other -** Unoccupied habitat - 50's-60's - thousands of domestic sheep, slowly coming back in these areas, Reintroduction potential

Problems: Hunt Area 22 (Badlands)

- **Habitat -** Habitat improvement potential high - Wiggins Fork to Badlands
  Private meadows
- **Domestic Sheep -**
- **Predation -**
- **Genetics -**

Whiskey Mountain (Area 8, 9, 10, 23) (BHS609) Revision Date: 4/17/98

Population Estimate: 950 (post season 1997)

Population Objective: 1350

Most Recent Hunting Regulations: Area 8-4 licenses any ram, Area 9-8 licenses 3/4 curl ram, Area 10-16 licenses 3/4 curl ram, Area 23-8 licenses any ram

Current WGFD Managers: Pat Hnilicka, Cole Thompson, Bob Yates, Doug McWhirter, Duke Early, Dan Stroud

JCR Responsibility: Pat Hnilicka

Other Contacts: Mark Hinschberger, Barb Franklin (USFS), Sue Oberlie (BLM)

Previous Studies: Thorne et al. (1976)
Thorne et al. (1984)
Ryder et al. (1992)
Ryder et al. (1994)
Corruthers GIS Study (date?)
Hnilicka et al. (1997)

Transplant History:

1,894 sheep have been trapped on Whiskey Mountain winter ranges for relocation elsewhere (1949-1995)
1,878 sheep were released at their respective destinations
99.2% survival for all sheep relocation efforts spanning a 46-year period

1,489 were released in Wyoming, 389 were released in other states - Hurley (1996)

Problems:

Habitat - Forage quality?
Mineral quality?
Heavy forage use on portions of winter range (90%+ on some preferred sites)
Very limited winter range in Upper Green River
Some resident (year-round) use by sheep on Torrey Rim and Torrey Creek

Domestic Sheep - Domestics on Pinedale side, particularly Baldy Lake & North Fork Allotments

Predation -

Genetics -

Disease - Chronic Disease? Pasturella trehelosi present as of 3/97 in 5 of 9 ewes tested

Migration -

Herbivore Competition - Elk Competition

Recreation/Development Encroachment - Recreation - dogs/people

Poor/Inconsistent Classification Data -

Hunting Related -

Other - Poor lamb production (6th year), resulting in declining population
Tenuous access across Wind River Indian Reservation to portions of winter range (Red Creek)

Temple Peak (Area 11) (BHS610)	Revision Date: 4/17/98

Population Estimate: 35 (excluding WRIR) (post season 1997)

Population Objective: 250

Most Recent Hunting Regulations: CLOSED

Current WGFD Managers: Tom Ryder, Bob Trebelcock, Chuck Clarke, Doug McWhirter, Tom Christiansen,
Allan Round, Dan Stroud, Dennis Almquist

JCR Responsibility: Tom Ryder

Other Contacts: Bob Lanka, John Emmerich (WGFD), Ken Persson (WGFD-ret.), Jack Welch (BLM-ret.),
Barb Franklin (USFS)

Previous Studies: Smith (1981)
Deibert (1994)
Firchow (1995)
Ryder and Lanka (1997)

Transplant History:

1964 Transplant - 21 sheep released in Sinks Canyon - Ryder & Lanka (1996)
1965 Transplant - 20 sheep released in Sinks Canyon - Ryder & Lanka (1996)
1966 Transplant - 18 sheep released in Sinks Canyon - Ryder & Lanka (1996)
1971 Transplant - 13 sheep released in Cherry Creek - Ryder & Lanka (1996)
1973 Transplant - 39 sheep released in Cherry Creek - Ryder & Lanka (1996)
1987 Transplant - 77 sheep released in Sinks Canyon & N. Fk. Popo Agie - Ryder & Lanka (1996)
1988 Transplant - 47 sheep released in S. Fk. Little Wind River - Firchow (1995)
1993 Transplant - 42 sheep released in S. Fk. Little Wind River - Firchow (1995)

Total - 277 sheep released into herd unit (including WRIR) - summarized in Hurley (1996)

Problems:
Habitat - Lack of Fire
Domestic Sheep - Past exposure to domestics on winter range
Real potential of co-mingling on summer range west of Continental Divide
Predation -
Genetics -
Disease -
Migration - Interrupted migration corridors - conifers
Herbivore Competition -
Recreation/Development Encroachment - Recreation - (Sinks Canyon/N. Fork/Cherry

Crk)

Poor/Inconsistent Classification Data - Data difficult to obtain - inconsistent
Hunting Related -
Other -

APPENDIX D

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:72-77.

LITERATURE REVIEW REGARDING THE COMPATIBILITY BETWEEN BIGHORN AND DOMESTIC SHEEP

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Abstract: A literature review was conducted regarding the compatibility of bighorn sheep and domestic sheep. In both fenced studies and free ranging herds, most contact between bighorn sheep and domestic sheep has resulted in pneumonia in bighorns and the deaths of all or most bighorns while domestic sheep remained healthy. Published research has shown that *Pasteurella haemolytica* (usually biotype A, serotype 2) is the major pathogen responsible for the death of bighorn sheep after contact with domestic sheep. DNA fingerprinting has proven the transfer of *Pasteurella* spp. between bighorn and domestic sheep under both controlled "experimental" and range conditions. No studies reported any bighorn herds, fenced or free ranging, that have come into contact with domestic sheep and remained healthy. No vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *Pasteurella.* With the current information, almost all wildlife professionals, wildlife veterinarians and researchers have concluded that bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other, because of the potential adverse effect from disease on bighorn sheep.

BACKGROUND

This is an updated report and literature review of information pertaining to the compatibility of bighorn and domestic sheep. The original review was requested by Regional Forester, John Lowe in 1993, with the content to be used as the basis for future decisions for the management of bighorn sheep and domestic sheep within the boundaries of Hells Canyon National Recreation Area, on the Wallowa-Whitman National Forest.

Current bighorn sheep numbers in the western United States have been estimated to be less than 1% of what they were prior to presettlement (Goodson 1982). Rocky mountain bighorn sheep (*Ovis canadensis canadensis)* were native to much of the mountain and canyon country which currently comprises a large proportion of the Wallowa-Whitman National Forest in Northeast Oregon and western Idaho. Specifically, historical accounts indicate that bighorns were numerous in the drainages in and around the Wallowa Mountains (Bailey 1936), the lower Imnaha River, Snake River, Grande Ronde River, Elkhorn Mountains, Powder River, and Joseph Canyon. The last Rocky Mountain bighorn sheep were gone from northeastern Oregon by 1945 (Oregon's Bighorn Sheep Management Plan 1992). Current numbers of Rocky Mountain bighorn sheep in the Hells Canyon National Recreation Area are also a fraction of what they were historically. Archaeological studies indicate wild sheep were a significant ungulate food item for Native Americans (USDA Forest Service Report 1991).

Following enormous population declines in the United States in the late 1800s and early 1900s, bighorn populations did not recover, in contrast to many other wildlife species. Bighorns have demonstrated less tolerance than other native North American ungulates to poor range conditions, interspecific competition, over hunting, and stress caused by loss of habitat (Desert Bighorn Council 1990). Most important, they have shown a much greater susceptibility to diseases (Goodson 1982).

In the last century wild sheep numbers have declined, their populations suffering from a wide variety of diseases, some that they have contracted from domestic sheep (Geist 1971). Some of these include scabies, chronic frontal sinusitis, internal nematode parasites, pneumophilic bacteria, footrot, parainfluenza III virus, bluetongue virus, and contagious ecthyma (Desert Bighorn Council 1990). Documented bighorn die-offs were recorded as early as the mid-1800s and have continued up to the present (Table 1) (Goodson 1982, Foreyt and Jessup 1982, Coggins 1988, Onderka et al. 1988, Foreyt 1989, Desert Bighorn Council 1990, Foreyt 1990, Callan et al. 1991, Hunter 1993, Foreyt 1993, Foreyt et al. 1994). Bighorn sheep die-offs have occurred in every state in the western United States. In recent years biologists and researchers have suspected that even casual contact between bighorn sheep and domestic sheep may lead to respiratory disease and fatal pneumonia in the bighorns (Onderka and Wishart 1988). The role of domestic sheep in the epizootiology of bighorn sheep pneumonia is an important issue in multiple use management (Foreyt et al. 1994).

FINDINGS

There is strong evidence (Table 1) that the presence of domestic sheep with bighorn sheep caused the loss of part or all of the affected bighorn sheep population. The lack of compatibility between domestic sheep and bighorn sheep is evidenced by the fact that no bighorn populations exist anywhere in the state of Nevada where domestic sheep are currently being grazed (McQuivey 1978). Goodson (1982) reported that no bighorn sheep herds, that occurred with domestic sheep on their ranges were increasing except those on ranges where use by domestic sheep has been significantly reduced. With the information currently available, most wildlife professionals, wildlife veterinarians and researchers have concluded that bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other, because of the potential adverse effect on the bighorn sheep (Jessup 1980, Foreyt and Jessup 1982, Goodson 1982, Jessup 1982, Kistner 1982, Wishart 1983, Coggins 1988, Jessup 1988, Onderka et al. 1988, Foreyt 1989, Foreyt 1990, Desert Bighorn Council 1990, Callan et al. 1991, Coggins and Matthews 1992, Foreyt 1992, USDI BLM Technical Committee 1992, Ward 1993, Foreyt et al. 1994, Foreyt 1994, Pybus et al. 1994, Hunter 1995, Foreyt 1995, University of Idaho 1995).

Of the numerous pathogens affecting bighorn sheep, *Pasteurella haemolytica* is the most important respiratory pathogen of bighorn sheep, and *Pasteurella multocida* may also be important in the pneumonia complex (Foreyt 1993).

Based on experimental data, bighorn sheep are more susceptible to fatal pneumonia than are domestic sheep. Based on all published experimental data, bighorn sheep die after close association with domestic sheep (Foreyt 1993).

Bighorn sheep are highly susceptible to domestic sheep strains of *Pasteurella spp.* while domestic sheep are refractory to bighorn sheep strains (Onderka 1986). Bighorn sheep die after inoculation with specific "strains" of *P. haemolytica* of "healthy" domestic sheep origin (Onderka et al. 1988, Foreyt et al. 1994). Biotype T strains of *P. haemolytica* (*P. treahola*) are found predominately in bighorns and other wild ruminants, biotype A strains of *P. haemolytica* are found predominately in domestic sheep (Foreyt 1993). In a study at the University of Idaho, Biotypes A, T and 3 were isolated from both bighorn and domestic sheep. In culture positive individuals, biotype T organisms were isolated from 76% of the bighorns and 21% of the domestic sheep, while biotype A organisms were isolated from 30% of the bighorns and 75% of the domestic sheep (Ward et al. 1990). There are many serotypes (10-20 or more) of *P. haemolytica* found in both bighorn and domestic sheep. There are many DNA types (50-100 or more) of P. haemolytica in bighorns and domestics. Different DNA types are present within a serotype and different serotypes are within a ribotype. Most *P. haemolytica* serotypes and DNA types look the same on agar, multiple colonies have to be typed from each animal. Multiple biotypes and serotypes can be isolated from the same animal. Tonsillar (pharyngeal) samples yield the highest isolation rate of *P. haemolytica*, nasal swabs have limited value except for the fact that healthy bighorn sheep rarely have *P. haemolytica* detected by nasal swabs. *P. haemolytica* survives for less than 24 hours in the environment, survival on dead animals and on many swabs, placed in medium, is often less than 24 hours, but tends to be longer on swabs. For the highest isolation rates of *P. haemolytica*, special steps must be taken to assure good sampling and preservation of samples.

Studies at Washington State University, one in Edmondton, Canada, and one at the Caine Veterinary Center, Boise, Idaho, have shown that specific types of *Pasteurella haemolytica* and *P. multocida* can be directly transmitted to bighorn sheep from domestic sheep (Onderka and Wishart 1988, Foreyt 1989, Foreyt 1990, Foreyt 1992, Hunter IDFG Letter Dated October 14, 1993) Table 1.

Foreyt et al. 1994 published the results of a study where DNA fingerprinting was used to pinpoint the origin of bacteria that lead to the death of bighorn sheep. Identified was the specific DNA type that caused the death of the bighorn sheep. The DNA type originated in the domestic sheep and had not been present in bighorn sheep before they were inoculated. The bacteria was *Pasteurella haemolytica* (biotype A, serotype 2).

In wild situations, domestic sheep and bighorn sheep association often results in death of the bighorns and does not affect the domestics. Often this is based on circumstantial evidence, because direct disease transmission is difficult to substantiate under field conditions. The finding of a shared *Pasteurella* spp. (by DNA fingerprinting) between feral domestic sheep and bighorn sheep in a Nevada study suggests the Pasteurella spp. can be transmitted between the bighorn and domestic sheep under range conditions (Hunter 1995, Hunter 1996 personal communication). Deaths occur in bighorns after association with domestic sheep because strains of *P. haemolytica* that are nonpathogentic in domestic sheep are transmitted from domestic sheep to bighorns resulting in pneumonia and death of the bighorns (Foreyt 1993, Foreyt et al. 1994).

When bighorn sheep experience a pneumonia episode, all age mortality often occurs. Lambs that are born into these populations generally experience low survival rates for approximately 3 to 5 years or more after the initial pneumonia (Foreyt 1990, Coggins and Matthews 1992, Ward et al. 1992, Foreyt 1995, Hunter 1995). Observations of bighorn sheep have provided evidence that pneumonia associated *Pasteurella* infections may contribute to the high lamb mortality (Jaworski et al. 1993).

Essentially all ungulates carry some strains of *P. haemolytica* (Foreyt 1995). Experimentally, elk, deer, mountain goat, cattle, llama and domestic goat association with bighorn sheep did not result in pneumonia in bighorns (Foreyt 1992, Foreyt 1993, Foreyt 1994). Evaluation of samples from Idaho and Alaska bighorn sheep has conclusively demonstrated that free roaming bighorn sheep which have not had contact with domestic sheep are not free of *P. haemolytica* (Ward 1990, Heimer et al. 1992). There are isolates of *P. haemolytica* in some domestic sheep that are not lethal in bighorn sheep (Foreyt -1993).

There are bighorn sheep die-offs due to pneumonia that have occurred without any association with domestic sheep (Goodson 1982, Onderka and Wishart 1984, Foreyt 1989, Ward 1993 and Ryder et al. 1994). Researchers agree that there are five primary factors that cause pneumonia in bighorn sheep. These are: 1) the presence of bacteria such as *P. haemolytica* and *P. multocida*, types indigenous to bighorn sheep, which with other factors can predispose bighorns to pneumonia, 2) the presence of stress, examples include: depleted forage or human disturbance, 3) the presence of lungworms, 4) the presence of viruses, and 5) exposure to a virulent strain of *P. haemolytica* from domestic sheep. Research indicates that the first four factors are relatively common at times for bighorn sheep (Foreyt 1995).

Bighorn sheep, in particular young rams, have a propensity to travel outside their home range. Domestic sheep in rugged terrain have a tendency to stray from the main flock. Because of both behaviors, buffers between the two species, unless very large, have often failed.

Although attempts have been made, no effective vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *P. haemolytica* (Foreyt 1995).

CONCLUSIONS

1) In both fenced studies and free ranging herds, most contact between bighorn sheep and domestic sheep has resulted in pneumonia in bighorns and the deaths of all or most bighorns while domestic sheep remained healthy.

2) Thirteen fenced studies, some of which were circumstantial evidence, in six states or provinces resulted in: 9 cases where all bighorns died from pneumonia, while from 50% to 83% were lost in the other 4 studies.

3) Additionally, 18 incidents involving free ranging bighorns in 8 states or provinces linked contact with domestic sheep to bighorn die-offs (Table 1).

4) DNA fingerprinting have proven the transfer of *Pasteurella* spp. between bighorn and domestic sheep under both controlled "experimental" and range conditions.

5) No studies reported any bighorn herds, fenced or free ranging, that have come into contact with domestic sheep and remained healthy.

6) Published research has shown that *Pasteurella haemolytica* (usually biotype A, serotype 2) is the major pathogen responsible for the death of bighorn sheep after contact with domestic sheep.

7) No vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *Pasteurella* spp.

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Table 1. Bighorn declines and die-offs believed to have resulted from contacts with domestic sheep.

Location	Cause of die-off	Results	Year(s)	Source
Sun River, Mont.	Unknown	>70 died	1910-35	Goodson (1982)*
Upper Rock Ck., Mont.	Unknown	All died	1965-70s	Goodson (1982)*
Thompson Falls, Mont.	Unknown	All died	1940-60	Goodson (1982)*
Kootenay Natl. Pk. BC., Can.	Pneumonia		1939	Goodson (1982)*
Bull River, BC., Can.	Pneumonia	96% died	1965	Brandy (1968) in Goodson (1982)*
MacQuire Creek, BC., Can.	Pneumonia		1981-82	Davidson in Goodson (1982)*
Lava Beds Natl. Mon., Cal***	Pneumonia	All died	1980	Blaisdell (1982)* and Hunt (1980)
Mormon Mtns., Nev.	Pneumonia	50% died	1980	Jessup (1981)*
Dinosaur Natl. Mon., Colo.	Unknown	All died	1950	Barmore (1962) in Goodson (1982)*
Rock Ck., Mont.	Unknown	8 left	1900-20	Goodson (1982)*
Rocky Mtn. Natl. Pk., Colo.	Pneumonia	All died	1917-30	Packard (1939a), (1939b) in Goodson (1982)*
Methow Game Range, Wash.***	Pneumonia	13 of 14 died	1979-81	Foreyt and Jessup (1982)*
Warner Mtn., Cal.	Pneumonia	All died	1988	Weaver (1988)*
Latir Parks, N.M.	Pneumonia	All died	1978-82	Sandoval (1988)*
Utah St. Univ., Utah**	Pneumonia	All died	1970s	Spillett in Goodson (1982)*
Univ. BC., Can**	Pneumonia	All died	1970s	Herbert in Goodson (1982)*
Colorado St. Univ., Colo.**	Pneumonia	All died	1970s	Hibler in Goodson (1982)*
Lostine, Or.	Pneumonia	70% died	1986	Coggins (1988)
Utah St. Univ., Utah**	Pneumonia	4 of 5 died	1988	T.D. Bunch (Utah St. Univ. Pers. Comm)*
Sheep River Alberta, Can.**	Pneumonia	2 of 2 died	1988	Onderka (1988)
Wash. St. Univ., Wash.**	Pneumonia	6 of 6 died	1989	Foreyt (1989)
Wash. St. Univ., Wash.**	Pneumonia	2 of 2 died	1990	Foreyt (1990)
Utah St. Univ., Utah**	Pneumonia	5 of 5 died	1991	Callan (1991)
Wash. St. Univ., Wash.**	Pneumonia	2 of 2 died	1991	Foreyt (1991)
Wash. St. Univ., Wash.**	Pneumonia	5 of 6 died	1992	Foreyt (1992) `
Caine Vet. Cnt., Boise, ID**	Pneumonia	2 of 4 died	1993	Hunter (1993) (IDFG pers. Comm.)
East Range, Nev.	Unknown	85 died	1992-93	Hunter (1993) (IDFG pers. Comm.)
Desatoya Range, Nev.	Pneumonia		1992-93	Tanner (1993) (NDW pers. Comm.)
Tollgate Ram	Pneumonia	died	1994	Hunter (1996) (pers. Comm.)
Hells Canyon Ram (BR95014)	Pneumonia	died	1995	Hunter (1995)

* From Desert Bighorn Council 1990
** University Controlled Conditions
*** Large Pen or Paddock

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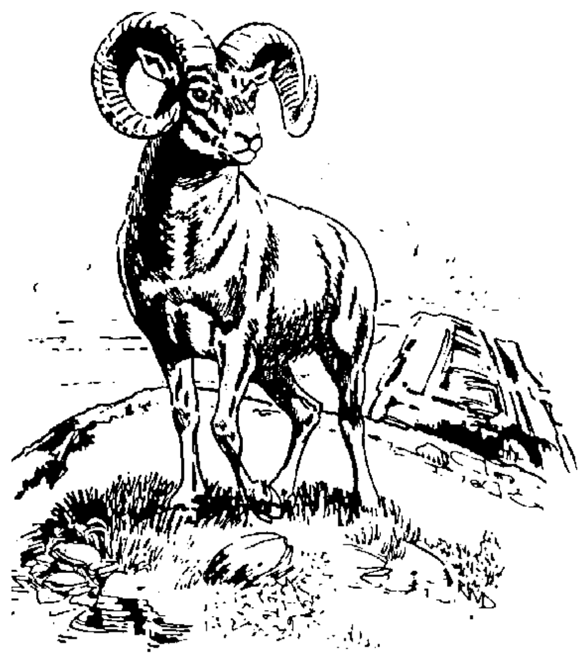
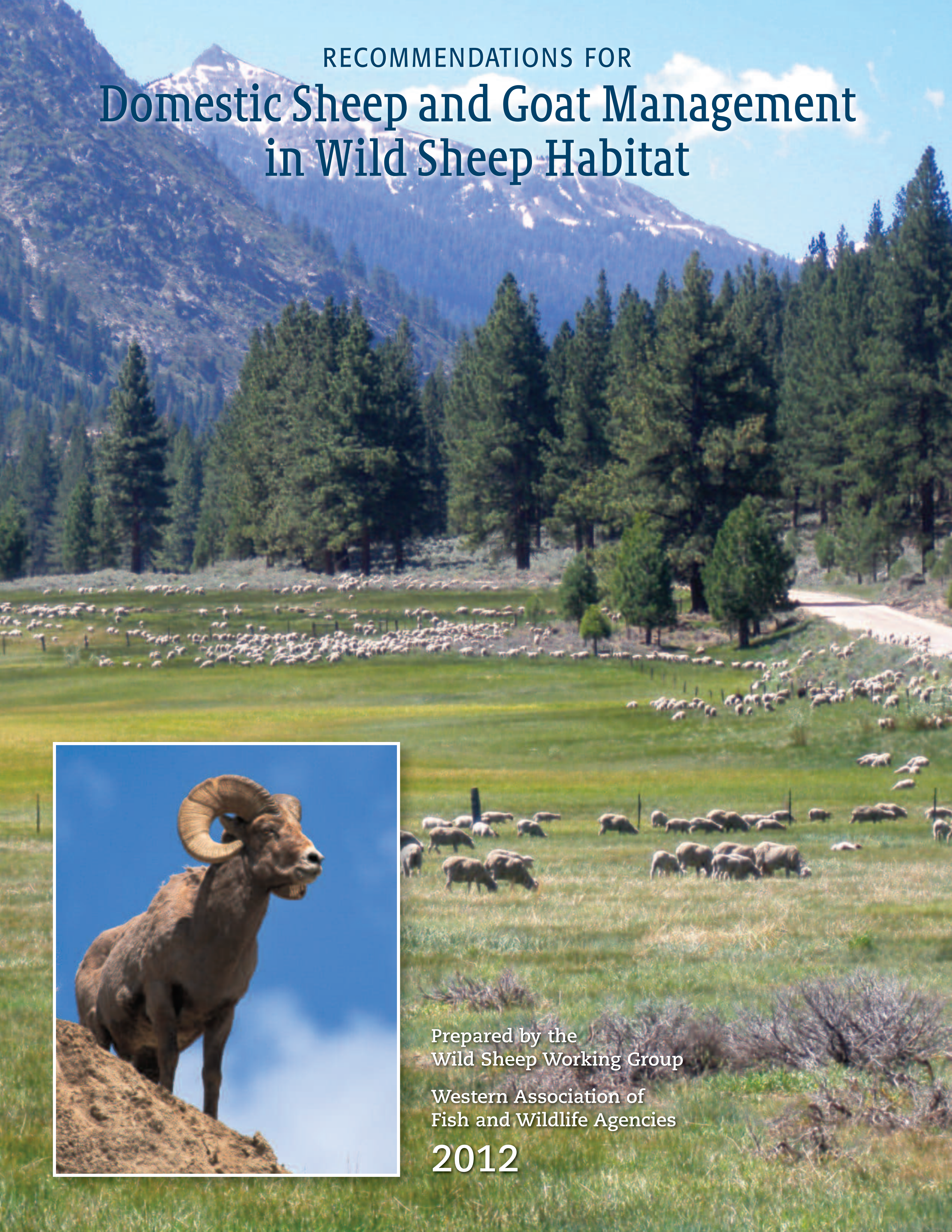


EXHIBIT 7

RECOMMENDATIONS FOR

Domestic Sheep and Goat Management in Wild Sheep Habitat



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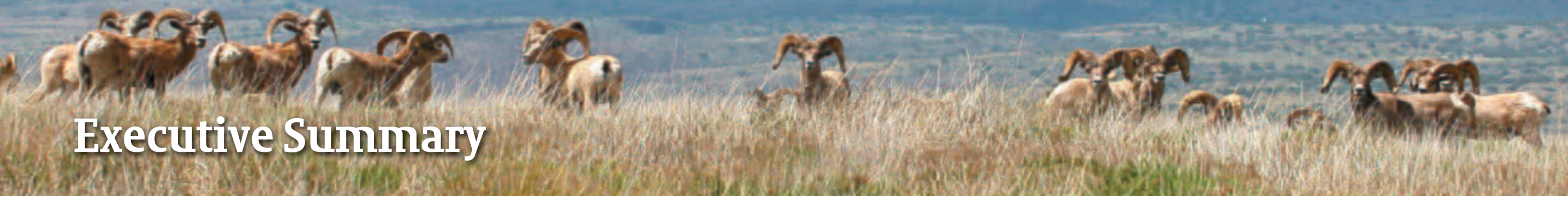


Executive Summary

Although the risk of disease transmission from domestic sheep or goats to wild sheep is widely recognized, a unified set of management recommendations for minimizing this risk has not been adopted by responsible agencies. These Western Association of Fish and Wildlife Agencies (WAFWA) recommendations were produced to help state, provincial, and territorial wild sheep managers, federal/crown land management agencies, private landowners and others take appropriate steps to eliminate range overlap, and thereby, reduce opportunities for transmission of pathogens to wild sheep.

Transmission of *Mannheimia haemolytica* from domestic sheep to bighorn sheep was irrefutably demonstrated by Lawrence et al. (2010) and provides justification sufficient for preventing range overlap and potential association of domestic sheep and goats with wild sheep. The higher the conservation value of a wild sheep population (e.g., federally or state listed, "sensitive species" status, native herds, transplant source stock, herds in areas with no history of domestic livestock presence), the more aggressive and comprehensive wild sheep and domestic sheep or goat separation management strategies should be.


Photo by: David Wetzel (Texas Bighorn Society)


Photo by:Tom Carlsen (MDFWP)

Practical solutions will be difficult, if not impossible to achieve until the risk of disease transmission from domestic sheep or goats to wild sheep is acknowledged by those responsible for wildlife and agricultural management. All parties benefit when risk is assessed and actively managed to minimize the potential for transmission of pathogens. The recommendations contained within this report are intended to help achieve that objective to benefit all sectors and are summarized as follows:

WAFWA agencies should:
(1) assess wild sheep conservation value/status and complete risk assessments of interspecies contact in a meta-population context; (2) remove wild sheep that have likely associated with domestic sheep or goats and develop a policy to promptly respond to wild sheep wandering from occupied wild sheep ranges; (3) thoroughly explore demographic consequences of translocations and conduct appropriate analyses of habitat suitability and risk of disease transfer prior to implementing any translocations; (4) coordinate with other agencies, land owners and stakeholders regarding management of domestic sheep or goats on or near ranges occupied by wild sheep; (5) fully consider the risk of disease transmission when issuing or commenting on permits/regulations associated with private lands used for domestic production; and (6) develop educational materials and outreach programs to interpret the risk of association between wild sheep and domestic sheep or goats.

Land management agencies should:
(1) reduce risk of association by eliminating overlap of domestic sheep or goat allotments or grazing permits/tenures within wild sheep habitat; (2) ensure that annual operating instructions or their equivalent include measures to minimize domestic association with wild sheep and confirm appropriate methods to remove stray domestic sheep or goats; and (3) manage wild sheep habitat to promote healthy populations in areas without domestic sheep or goats.

Wild sheep conservation organizations should:
(1) assist with educational/extension efforts to all parties; (2) negotiate alternatives and incentives for domestic sheep or goat grazers on public land to find alternatives to wild sheep habitat; and (3) advocate for and support research concerning disease and risk associated with domestic sheep and goats in proximity to wild sheep.

Domestic sheep and goat permittees/owners should:
(1) implement best management practices (BMPs) to prevent straying by domestic sheep or goats; and (2) establish protocols to respond to straying.

Private landowners should:
(1) educate themselves and work with wild sheep managers and advocates to support effective separation through a variety of site-specific mitigation measures; and (2) promptly report the potential or actual association between domestic sheep or goats and wild sheep.

Introduction

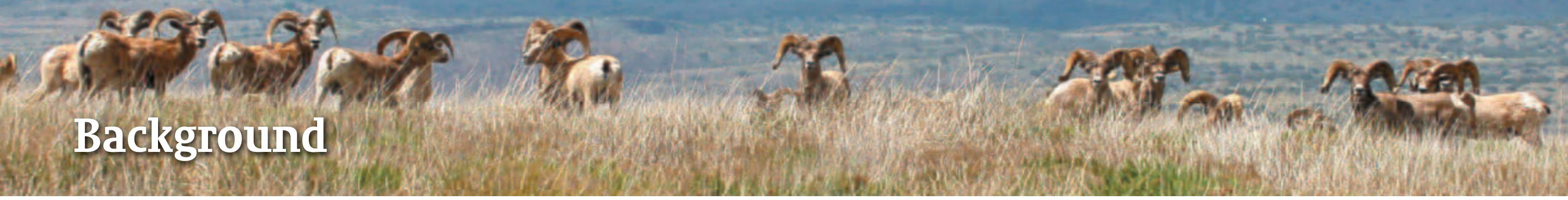
In January 2007, the Western Association of Fish and Wildlife Agencies (WAFWA), comprised of 23 state and provincial wildlife agencies from the western United States (U.S.) and western Canada, established a Wild Sheep Working Group (WSWG) to develop a report titled, "Recommendations for Domestic Sheep and Goat Management in Wild Sheep Habitat" (WAFWA 2007). Unanimously endorsed by WAFWA Directors in July 2007, that report provided recommendations to which state, provincial and federal agencies could tier their management actions. In August 2007, the report was forwarded to the heads of the U.S. Forest Service (USFS), Bureau of Land Management (BLM), National Park Service, U.S. Fish and Wildlife Service, Bureau of Reclamation, and Department of Defense. In July 2010, the report was revised (WAFWA 2010c) and has represented the official position of WAFWA on the management of domestic sheep and goats and wild sheep.

Scientific literature that has become available since July 2010 has been incorporated into this document to ensure that the recommendations contained herein remain current and robust, but the basic purpose, scope, and principles of the document remain unchanged. Additional editorial modifications are intended to improve the readability of the document. Information contained in this report is provided to assist BLM and USFS leadership with development of a unified policy addressing the grazing of domestic sheep or goats in wild sheep habitat on lands under the administration of those agencies. In addition, this document is intended to assist state, provincial, and territorial wild sheep managers, federal/crown land management agencies, private landowners and others take appropriate steps to eliminate range overlap, and thereby, reduce opportunities for transmission of pathogens to wild sheep. This revision was approved by the WAFWA Directors March 29, 2012, and supersedes all previous versions.

Photo by: Earl Nottingham (TPWD)

Photo by: Dr. Peri Wolff (NDOW)

In this paper we do not review and synthesize all available literature or evidence pertaining to the issue of disease transmission among bighorn sheep and domestic sheep and goats. We do, however, include relevant citations, results, literature, or analyses published since completion of our previous reports (WAFWA 2007, 2010c). We provide reasonable and logical recommendations based on the best available information to help achieve effective separation between wild sheep and domestic sheep or goats. We recognize it is impossible to achieve zero risk of contact or disease transmission; however, we also recognize there are many ways to reduce the probability of association between these species and, thereby, lower the overall risk of epizootics occurring in populations of wild sheep.



Background

Photo by: David Wetzel (Texas Bighorn Society)

Photo by: Mike Pittman (TPWD)

Photo by: Brett Wiedmann (NDGFD)

Background

Throughout substantial portions of their range, bighorn sheep (*Ovis canadensis*) experience periods when populations are depressed; those episodes generally are associated with epizootics of respiratory disease (Ryder et al.1994). Diseases have contributed to the decline of bighorn sheep populations in much of western North America (Beecham et al. 2007, CAST 2008) and many native herds declined to less than 10% of historical size. According to historical accounts, such declines coincided with the advent of domestic livestock grazing on ranges occupied by bighorn sheep (Warren 1910, Grinnell 1928, Schillinger 1937, Honess and Frost 1942, CAST 2008). Epizootics among native bighorn herds were reported in various locations following European settlement and establishment of domestic livestock grazing throughout the central and southern Rocky Mountains. These observations may reflect the introduction of novel bacterial pathogens (including some strains of *Pasteurella [Mannheimia]* spp.) to naïve bighorn populations beginning in the late 1800s (Grinnell 1928, Skinner 1928, Marsh 1938, Honess and Frost 1942, Miller 2001).

Over the past 30 years, increasing evidence has underscored the potential risk of disease transmission from domestic sheep or goats to wild sheep (McQuivey 1978, Hunt 1980, Jessup 1982, Foreyt and Jessup 1982, Goodson 1982, Onderka and Wishart 1984, Jessup 1985, Black et al.1988, Coggins 1988, Festa-Bianchet 1988, Onderka and Wishart 1988, Onderka et al.1988, Schwantje 1988, Callan et al.1991, Coggins and Matthews 1992, Foreyt 1994, Foreyt et al. 1994, Cassirer et al.1996, Foreyt and Lagerquist 1996, Martin et al. 1996, Coggins 2002, Rudolph et al. 2003, Jenkins et al. 2007, Rudolph et al. 2007, George et al. 2008, Jeffress 2008, Lawrence et al. 2010). Moreover, a number of recent risk assessments and reviews (Beecham et al. 2007, CAST 2008, Baumer et al. 2009, USAHA 2009, WAFWA 2009, Croft et al. 2010, USDA Forest Service 2010a, b; Wehausen et al. 2011), conservation management strategies or plans (Colorado Division of Wildlife 2009, Montana Department of Fish, Wildlife, and Parks 2009), modeling exercises (Clifford et al. 2009, Cahn et al. 2011), and many wildlife biologists and wildlife veterinarians (Gross et al. 2000, Singer et al. 2000, Dubay et al. 2002, Epps et al. 2004, Garde et al. 2005, Jansen et al. 2006, Foreyt et al. 2009) have focused on risks associated with contact between wild sheep and domestic sheep or goats. Many of the aforementioned investigators and participants in workshops conducted throughout the western US (California, Arizona, Utah, and Idaho),

have recommended temporal or spatial separation of domestic sheep or goats from wild sheep to reduce the potential for disease in the latter.

Disease Transmission

Although domestic animals have been selected for their ability to live at high densities and for their resilience to infectious diseases (Diamond 1997), two-way transmission of certain diseases (e.g., paratuberculosis, some enteric pathogens and parasites) between wild sheep and domestic sheep or goats in shared habitats can occur (Garde et al. 2005). However, the most important and ecologically significant transmission in this context is from domestic sheep or goats to wild sheep.

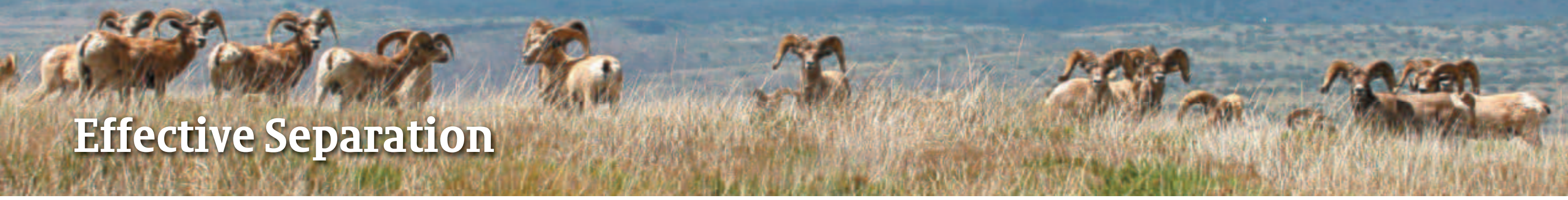
Winter 2009-2010 bighorn sheep pneumonia die-offs (totaling an estimated 880 bighorns) in Montana, Nevada, Washington, Utah, and Wyoming have reduced bighorn numbers in at least 9 herds, either through direct mortality or agency removal (i.e., "culling") of bighorn sheep exhibiting symptoms of respiratory infections (Edwards et al. 2010, WAFWA 2010b). Domestic sheep and goats were known to occur within or near occupied bighorn sheep ranges and within normal bighorn movement zones, and association between wild sheep and domestic sheep or goats is known to have preceded at least one of these die-offs, was likely in 2 others, and was possible in 4 more (WAFWA 2010b).

Die-offs of wild sheep populations and individual animals have occurred in the absence of reported association with domestic sheep or goats (Aune et al. 1998, UC-Davis 2007). However, when contact between wild sheep and domestic sheep or goats has been documented, the pattern and severity of die-off is typically greater than when otherwise is the case (Onderka and Wishart 1984, Martin et al. 1996, Aune et al. 1998, George et al. 2008).

It is generally acknowledged (Garde et al. 2005, CAST 2008) that thinhorn sheep (*Ovis dalli* spp.) in Alaska and northwestern Canada are likely naïve to exposure to many organisms commonly 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 infectious organisms are clearly understood, it is essential that no association occurs between thinhorn sheep and domestic sheep or goats.


Photo by: Donny Martorello (WDFW)


Photo by: Ernie Finch



Effective Separation

WAFWA defines “Effective Separation” as spatial or temporal separation between wild sheep and domestic sheep or goats to minimize the potential for association and the probability of transmission of diseases between species. WAFWA advocates that effective separation should be a primary management goal of state, provincial, territorial and federal agencies responsible for the conservation of wild sheep, based on evidence that domestic sheep or goats can transfer pathogens to wild sheep. Literature (reviewed by Wehausen et al. 2011) and experimental evidence (Lawrence et al. 2010) support the goal that domestic sheep or goats should not concurrently occupy areas where conservation of wild sheep is a clearly stated management goal.


Photo by: John Kanta (SDGFP)

Effective separation does not necessarily require removal of domestic sheep or goats in all situations. However, the option of removing domestic sheep or goats should be included in an array of alternatives available to address this issue. In fact, some collaborative working groups (USAHA 2009) have recommended domestic goats not be allowed to graze in occupied bighorn sheep habitat because of their gregarious nature and tendency to wander. We are aware of the continuing debate and discussion (CAST 2008, USAHA 2009) between wildlife advocates and some domestic sheep or goat industry proponents and resource managers regarding the credibility or scientific merit of past findings; that debate is founded largely on criticisms of experimental design or rigor, and limitations of drawing inferences about natural disease events when compared to controlled experiments in confined settings. However, it is WAFWA’s collective opinion that enough is known about potential pathogen transmission from domestic sheep or goats to wild sheep that efforts toward achieving effective separation are necessary and warranted.


Photo by: Ted Borda (Borda Land & Sheep Company)

Reducing risk of disease transmission on the landscape by minimizing or preventing association between wild and domestic sheep or goats is a key management strategy for WAFWA agencies (e.g., Colorado Division of Wildlife 2009, Montana Department of Fish, Wildlife and Parks 2009). Legislation in Utah (House Bill 240 Supplement, 2009), Wyoming (Senate Enrolled Act No. 30, 2009) and Idaho (Senate Bill 1232 amended, 2009) provides direction, authority and responsibilities for addressing feral or stray livestock that pose a disease transmission risk. Further, recent court rulings (e.g., U.S. District Court, Idaho Case 09-0507-BLW) have mandated separation between domestic sheep or goats and bighorn sheep, including mandatory non-use of grazing allotments where effective separation could not be assured.


Photo by: Ted Borda (Borda Land & Sheep Company)

Effective Separation

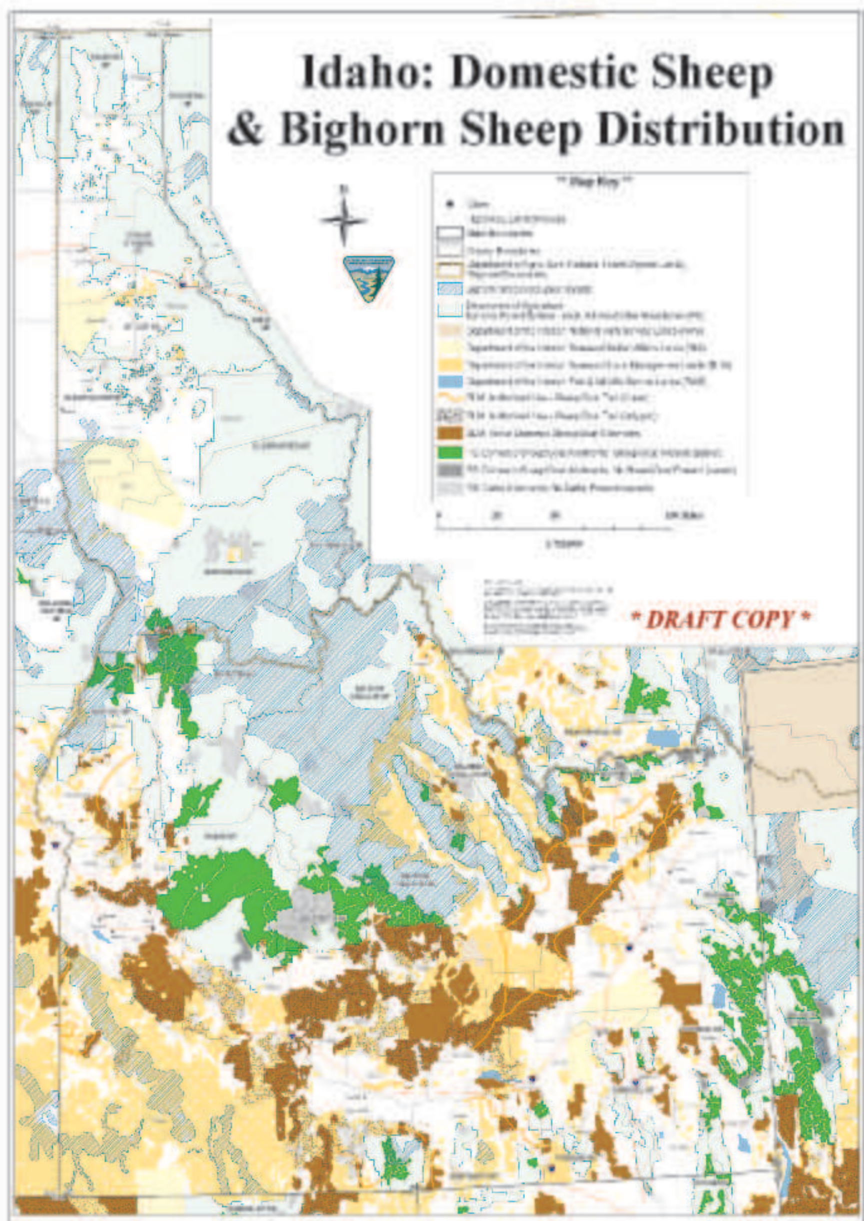
Principal federal land management agencies in the western U.S., BLM and USFS, continue to review, revise, and update policies on the management of domestic sheep or goats in wild sheep habitat (USDI BLM 1992, 1998, 2010; USDA Forest Service 2009). Additionally, several administrative units of the USFS (Northern Region, Rocky Mountain Region, Southwest Region, Intermountain Region, and the Pacific Southwest Region) have designated bighorn sheep as a "Sensitive Species," thereby mandating special management emphasis. This includes: thorough reviews and analyses of management actions that could affect populations of bighorn sheep or their habitat to ensure their viability and to preclude demographic trends that would result in the need for Federal listing.

An interagency GIS-based decision-support tool and GIS coverage maps that overlay current bighorn sheep distribution with vacant and active domestic sheep or goat grazing allotments and trailing routes were finalized for 14 western states (WAFWA 2010a). These maps identify areas where association between domestic sheep or goats and bighorn sheep could occur on, or adjacent to, lands managed by BLM or USFS, and also identify areas that could provide spatial separation. The maps further provide a context for national policy development, and help identify situations where proactive management is necessary to minimize risk of association. Although risk of disease transmission from domestic sheep or goats to wild sheep is widely acknowledged by wildlife and land management agencies, a unified set of management guidelines for minimizing this risk has not yet been adopted.

In some cases, results of contact between domestic sheep or goats and wild sheep have been severe enough to endanger entire populations of the latter. In Idaho, legislation (Senate Bill 1232 amended, May 2009) mandated collaboration between the Idaho Department of Fish and Game and domestic sheep grazing permittees that identified BMPs to achieve effective separation between domestic sheep and wild sheep on both public and private lands. In specific situations, implementation of BMPs could lead to a reduced risk of association. In particular, BMPs implemented in open, gentle terrain where domestic sheep or goats can be easily controlled and monitored can reduce risk of association (Schommer 2009). Nevertheless, BMPs that work in one situation may not work in other situations (Schommer 2009).

Consequently, we recommend that managers take appropriate steps to minimize opportunities for association and, thereby, the potential for disease transmission in all situations.

Photo by: Bighorn Institute



Provided by: Chans O'Brien (USFS)

Photo by: Rebecca Barboza (CDFG)

Photo by: Larry Kruckenberg

Management Recommendations

The recommendations that follow can be applied to state, provincial, and territorial wildlife agencies, federal/crown land management agencies, wild sheep conservation organizations, domestic sheep or goat producers or permittees, and private landowners, and have been strategically assigned to logical categories. It is imperative, however, that readers recognize these recommendations typically apply to multiple parties, and that they further recognize that a multi-disciplinary and collaborative approach will produce the best outcomes, both for wild sheep and for producers or permittees. Definitions of various terms used throughout this document are provided in Appendix A.

Although these recommendations have been developed by a working group largely comprised of wildlife agency personnel, cooperation between numerous concerned parties is critically important to deriving on-the-ground solutions (USAHA 2009, Wild Sheep Foundation 2011). Among these are state, provincial, and territorial wildlife agencies; federal/crown land management agencies; First Nation or tribal representatives; domestic sheep or goat producers or grazing permittees; agricultural industry representatives; wild sheep conservation organizations; environmental groups; academic institutions; and interested individuals. As a result of information contained herein, it is our hope that collaborative discussions will occur and that those discussions yield results in the form of innovative and collaborative site-specific delivery of programs such as the British Columbia Wild/Domestic Sheep Separation Program and the Wyoming Statewide Domestic Sheep/Bighorn Sheep Interaction Working Group.

Many anthropogenic and environmental factors (CAST 2008) influence the demographics and viability of wild sheep populations. Some factors affecting wild sheep population performance can be managed while others cannot. Nevertheless, the guiding principle of our effort has been "to seek effective separation" between wild sheep and domestic sheep or goats. There is no "one size fits all" risk assessment of respiratory disease transmission between wild sheep and domestic sheep or goats. However, a comprehensive risk assessment (qualitative and quantitative) is a critically important component for managing the potential for disease transmission.

We recommend that wild sheep managers design and implement management strategies by taking the first step of assessing and prioritizing conservation value and relative importance of wild sheep populations. The greater the conservation value and the greater the risk of association with domestic sheep or goats, the more aggressive and comprehensive a strategy to ensure effective separation should be. To ensure that is the case, we offer the following:

Management Recommendations

RECOMMENDATIONS TO WAFWA AGENCIES

■ Historic and suitable but currently unoccupied wild sheep range should be identified, evaluated, and compared against currently-occupied wild sheep distribution and existing or potential areas where domestic sheep or goats may occur.

■ Risk assessments should be completed at least once per decade (more often if warranted) for existing and potential wild sheep habitat. These assessments should specifically identify where and to what extent wild sheep could interface with domestic sheep or goats, and the level of risk within those areas.

■ Following completion of site or herd-specific risk assessments, any translocations, population augmentations, or other restoration and management strategies for wild sheep should minimize the likelihood of association between wild sheep and domestic sheep or goats. Agencies should:

- Avoid translocations of wild sheep into areas with no reasonable likelihood of effective separation from domestic sheep or goats.
- Re-evaluate planned translocations of wild sheep to historical ranges as potential conflicts, landscape conditions, and habitat suitability change.
- Recognize that augmentation of a wild sheep herd from discrete source populations poses a risk of pathogen transfer (CAST 2008) and thus, only use source stock verified as healthy through a proper health assessment (WAFWA 2009) for translocations. Source herds should have extensive health histories and be regularly monitored to evaluate herd health. Wild sheep managers should evaluate tradeoffs between anticipated benefits such as demographic, behavioral and genetic interchange, and the potential consequences of mixing wild sheep from various source herds.
- Develop and employ mapping or modeling technology as well as ground based land use reviews prior to translocations to compare wild sheep distribution and movements with distribution of domestic sheep or goats. If a translocation is implemented and association with domestic sheep or goats occurs, or is likely to occur beyond an identified timeframe or pre-determined geographic area, domestic sheep or goat producers should be held harmless.

■ The higher the risk of association between wild sheep and domestic sheep or goats, the more intensively wild sheep herds should be monitored and managed. This is particularly important when considering “new” vs. “augmented” wild sheep populations.

- Site-specific protocols should be developed when association with domestic sheep or goats is probable. For example, decisions concerning percentage of translocated wild sheep that must be radio-collared

Photo by: Mike Cox (NDOW)

Photo by: Chase Fountain (TPWD)

for achieving desired monitoring intensities should in part, be based upon the subsequent level of risk of association with domestic sheep or goats.

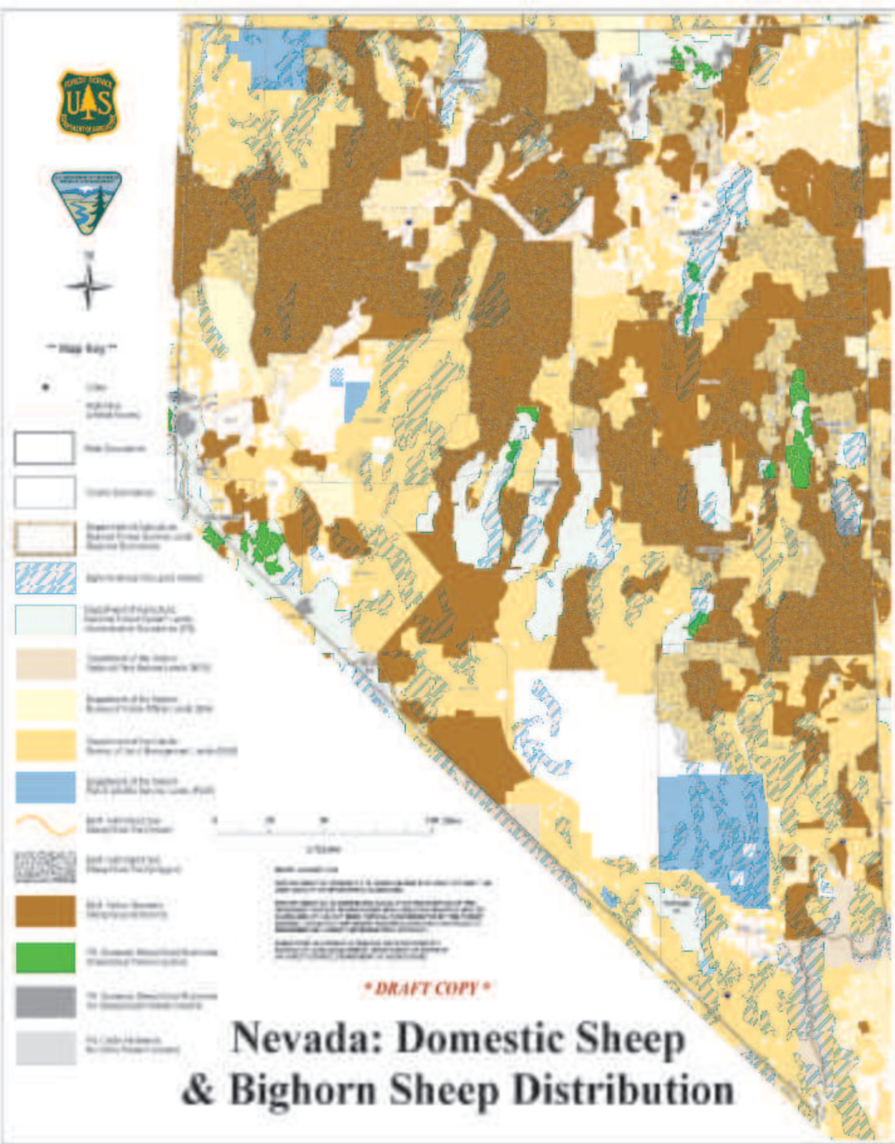
- Intensive monitoring provides a mechanism for determining proximity of wild sheep to domestic sheep or goats and for evaluating post-release habitat use and movements.
- Budgets for wild sheep translocation projects should include adequate funding for long-term monitoring.

■ Wild sheep managers should identify, analyze, and evaluate the implications of connectivity and movement corridors between largely insular herds comprising a meta-population against opportunities for increased association with domestic sheep or goats. Analyses should include distribution and continuity (Mack 2008) among populations of wild sheep and the anticipated frequency of movement among or within wild sheep range. In doing so, the benefits of genetic interchange and its resultant implications for population viability, must be weighed against the risks of disease transmission (Bleich et al. 1990), especially if dispersing or wandering wild sheep could travel across domestic sheep or goat grazing allotments or trailing routes, private land holdings or other areas where the potential transfer of endemic pathogens from an infected wild herd to a naïve herd could occur.

■ Removal of wild sheep known, or suspected to have closely associated with domestic sheep or goats is considered to be an effective management tool. Atypical movements by wild sheep can heighten risk of association with domestic sheep or goats. Additional measures to achieve effective separation should be implemented if such association occurs. However, removal of wild sheep from occupied, normally-anticipated wild sheep range is not always the best management option. Continuous risk of association exists during active grazing seasons when domestic sheep or goats are grazed within normally-anticipated wild sheep range. Thus, removal of individual wild sheep is an ineffective method for maintaining separation, and has potentially negative consequences for population viability. Removal of wild sheep should occur only after critical evaluation and further implementation of measures designed to minimize association and enhance effective separation.

■ Wild sheep populations should have pre-determined population objectives, and should be managed at agreed-upon densities to minimize the potential for dispersal. Because some dispersal occurs regardless of population density, some risk of association is always present if domestic sheep or goats are within range of dispersing wild sheep.

■ Agencies should develop a written protocol to be implemented when association between wild sheep and domestic sheep or goats is confirmed. Notification requirements, appropriate response and post-contact monitoring options for both domestic sheep and goats and dispersing or wandering wild sheep should be included. Moreover, wildlife agencies should collaborate with agricultural agencies, land management agencies, producers and permittees, grazing industry representatives,



Provided by: Chans O'Brien (USFS)

and wild sheep advocates to develop an effective, efficient, and legal protocol to be implemented when feral or abandoned domestic sheep or goats threaten to associate with wild sheep but for which no owner can be identified. Written protocol examples are provided in Appendix B (British Columbia Fish, Wildlife and Habitat Management Branch) and Appendix C (Wyoming Game and Fish Department).

■ Wildlife agencies should develop databases as a system to report, record, and summarize association between wild sheep and domestic sheep or goats and its outcome; the WAFWA WSWG website (http://www.wafwa.org/html/wswg.shtml) would be a logical host. Further, wildlife managers and federal/crown land managers should encourage prompt reporting by the public of observed proximity between wild sheep and domestic sheep or goats.

■ Wild sheep managers should coordinate with local weed or pest management districts, or other applicable agencies or organizations involved with weed or vegetation management, to preclude the use of domestic sheep or goats for noxious weed or vegetation control in areas where association with wild sheep is likely to occur. Agencies should provide educational information and offer assistance to such districts regarding disease risks associated with domestic sheep or goats. Specific guidelines (Pybus et al. 1994) have already been developed and implemented in British Columbia, and are available at: http://www.for.gov.bc.ca/hfp/publications/00006/.

■ Specific protocols for sampling, testing prior to translocation, and responding to disease outbreaks should be developed and standardized to the extent practical across state and federal jurisdictions. Several capture and disease-testing protocols have been developed and are available to wild sheep managers (Foster 2004, UC-Davis 2007, WAFWA 2009). Protocols should be reviewed and updated as necessary by the WAFWA Wildlife Health Committee (WHC) and presented to WAFWA Directors for endorsement. Once endorsed, agencies should implement the protocols, and the WHC should lead an effort to further refine and ensure implementation of said protocols.

■ Agencies should coordinate and pool resources to support the ongoing laboratory detection and interpretation of important diseases of wild sheep. Furthermore, wild sheep managers should support data sharing and development and use of standardized protocols (WAFWA 2009). Interagency communication between wildlife disease experts such as the WAFWA Wildlife Health Committee (WHC) should be encouraged to enhance strategies for monitoring, managing and improving health of wild sheep populations through cooperative efforts.

■ Wild sheep management agencies should develop educational materials and outreach programs to identify and interpret the risk of association between wild sheep and domestic sheep or goats for producer groups, owners of small and large farm flocks, animals used for packing and 4-H animals. In some cases, regulation may be necessary to maintain separation.

RECOMMENDATIONS TO BLM, USFS, PARKS, PROTECTED AREAS AND OTHER APPLICABLE LAND MANAGEMENT AGENCIES

■ Joint federal land management agency guidelines on management of domestic sheep or goats in wild sheep habitat should be developed and included in broad agency policy documents. Guidelines should be based on the need to minimize risk of association and provide effective separation between domestic sheep or goats and wild sheep.

Photo by: Todd Nordeen (NGPC)

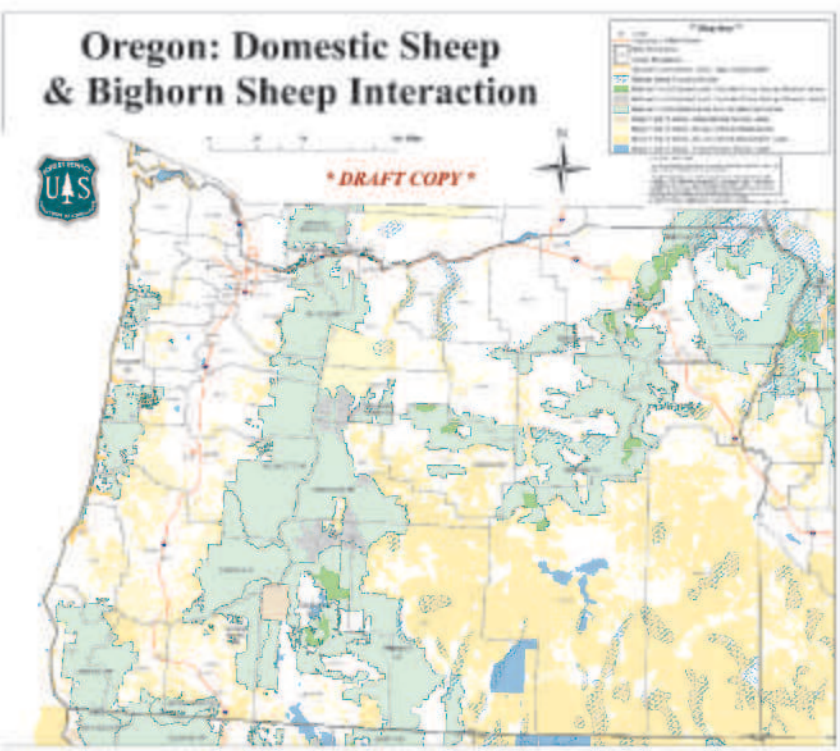
Photo by: Debra Hamilton (CDFG)

Management Recommendations

Approved guidelines should not include an automatic "sunset" provision or expiration date but, if there is a maximum longevity (i.e., a "sunset clause") specified by federal policy and if appropriate and timely review cannot be completed, guidelines should remain in effect, rather than becoming obsolete, until any mandated review can be completed.

■ The use of domestic sheep or goats as pack animals by persons that travel in identified wild sheep habitat should be prohibited by the appropriate management agency (e.g., USDA Forest Service 2011). 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.

Photo by: Ted Borda (Borda Land & Sheep Company)



Provided by: Chans O'Brien (USFS)

■ Land management agencies that regulate or are responsible for domestic sheep or goat grazing allotments, trailing routes, vegetation management, use as pack stock, or any other uses involving domestic sheep or goats should only authorize such use(s) outside of occupied wild sheep range.

■ Land management agencies should require immediate notification by permittees and their herders of association between wild sheep and domestic sheep or goats and in no case should it be more than within 24 hours of any such event. Notification procedures, including phone numbers and contact information for permittees and use of satellite phones in backcountry settings, should be outlined in Annual Operating Instructions for grazing allotments and trailing permits, and should include consequences for failure to report.

■ Land management agencies should map active and inactive domestic sheep or goat grazing allotments and trailing routes, including information on dates of use and contact information for responsible grazing or trailing permittees.

■ Land management agencies must ensure that advance written instructions (such as USFS Annual Operating Instructions) exist, and that they address management, retrieval, and disposition of domestic sheep or goats present on public lands prior to or after permitted grazing or trailing dates.

■ Land management agencies should work collaboratively with state, provincial, and territorial wildlife and agricultural interests to develop written agreements that address management, retrieval, and disposition of domestic sheep or goats occupying public lands where there is no permitted use. Such agreements should also address the presence of feral sheep or goats and other exotic ungulates, especially ovines such as aoudad, red sheep, urial, or argali that are detected on public lands.

■ Land management agencies should review domestic sheep allotment boundaries or other use areas, such as trailing routes, and reconfigure boundaries or routes to avoid or minimize overlap with occupied wild sheep habitat. Techniques available to accomplish this include the use of geographic or topographic

barriers that enhance species separation, and temporal or spatial separation resulting from implementation of novel domestic sheep or goat grazing management strategies.

■ Land management agencies should undertake habitat enhancements that improve wild sheep habitat outside allotment boundaries in an effort to attract wild sheep away from domestic sheep allotments.

■ Land management agencies should undertake water developments to divert wild sheep away from domestic sheep allotments or domestic sheep or goats away from areas used by wild sheep.

■ Land management agencies should ensure that Annual Operating Instructions require careful management and vigilant herding to minimize potential association between wild sheep and stray domestic sheep or goats. A count-on, count-off inventory of domestic sheep or goats must be required as a condition of operation with follow-up provisions to account for missing livestock.

■ In areas of high risk of association, trucking should be required to minimize risks associated with trailing. Trucking of domestic sheep or goats is preferred to trailing because there is less chance of straying and, thereby, less likelihood of association with wild sheep, particularly when domestic sheep are in estrus.

■ Land management agencies should require marking of all permitted domestic sheep and goats to provide for rapid ownership identification of stray animals.

■ In the event of trailing, on-site compliance monitoring to minimize strays must be conducted by the permittee or the land management agency.

■ Land use or resource management plans should explicitly address the potential for domestic sheep or goats to associate with wild sheep. Land use plans should evaluate the suitability of permitting activities involving domestic sheep or goats, and determine the best course of action with respect to wild sheep conservation. Plans should also identify general areas of public land where domestic sheep or goats cannot be permitted for weed control, commercial grazing, recreational packing, vegetation management, or other uses.

■ Land management agencies should coordinate with appropriate entities involved in weed control programs that use domestic sheep or goats on public or Crown lands (Pybus et al. 1994), adjoining private lands, or state, provincial, and territorial wildlife habitat management areas to minimize risk of association between domestic sheep or goats and wild sheep.

■ Within occupied or suitable wild sheep habitat, where topography, vegetation, and other parameters allow, conversions of allotments from domestic sheep or goats to types of domestic livestock that pose a lower risk of disease transmission to wild sheep should be implemented.

■ Within suitable, historic wild sheep habitat not currently occupied by wild sheep, agencies should not convert cattle grazing allotments to domestic sheep or goat grazing, or allow trailing if restoration of wild sheep populations is an agency goal.

Photo by: AZGFD

Photo by: Justin Binfet (WGFD)

Management Recommendations

■ Under emergency conditions, stocking of allotments not currently under permit to domestic sheep or goats should be permitted only after an adequate risk assessment has been completed. Any such assessment must include appropriate documentation and the conclusion that effective separation can be assured, and can be accomplished via project-level NEPA analysis.

■ Land management agencies should incorporate state, provincial, or territorial wild sheep management plans either in, or as supplements to, federal resource or land use management plans, and collaborate with wildlife agencies to ensure comprehensive risk assessments (Clifford et al. 2009, USDA Forest Service 2010a, b) of domestic sheep or goat grazing allotments or trailing routes in wild sheep habitat are thorough and complete. To accomplish this objective, training adequate to allow the preparation of such assessments must be provided.

Photo by: Mike Cox (NDOW)

■ Where mandatory buffer zones (frequently cited as a minimum of 9 airline miles [14.5 km]) between domestic sheep or goats and wild sheep have been used to minimize association, it should be recognized that buffer zones apply to herds or populations of wild sheep, rather than individual wandering wild sheep. In some cases, buffer zones have been effective in reducing association between wild sheep and domestic sheep or goats. However, in contiguous wild sheep habitat where movements by wild sheep have the potential to exceed *a priori* expectations, buffer zones may not be effective or practical (Schommer and Woolever 2001).

■ Topographic features or other natural or man-made barriers (e.g., fenced, interstate highways) can be effective in minimizing association between wild sheep and domestic sheep or goats. Site-specific risk assessments should be completed to evaluate the efficacy of using natural barriers, defined buffer zones, or other actions to minimize risk of contact. Given the wide range of circumstances that exists across jurisdictions, buffer zones may not be needed in all situations. Conversely, buffer zones should not be precluded as an effective method to address potential association between wild sheep and domestic sheep or goats.

■ Land management agencies, in collaboration with jurisdictional domestic sheep or goat health agencies, should work with producers and permittees to prevent turnout or use of sick or diseased domestic sheep or goats on grazing allotments and trailing routes. Sick or diseased domestic sheep or goats can increase risk of association with wild sheep because they likely are less able to keep up with their bands and are more prone to straying. Sick or diseased animals observed on the range should be reported to land management agency personnel immediately, and inter-agency coordination to address the situation should promptly occur. Further, responsible agencies must require that domestic sheep or goats are in good health before being turned out. For example, Alberta and British Columbia have developed health certification protocols (Pybus et al. 1994) that must be complied with before domestic sheep are turned out for vegetation management in conifer regeneration efforts (available at: http://www.for.gov.bc.ca/hfp/publications/00006/). We emphasize that the higher the risk of association between domestic sheep or goats with wild sheep, the higher the certainty of domestic animal health should be. Further, it must be recognized that even clinically healthy domestic sheep or goats can still carry pathogens that are transmissible to wild sheep, and thus, pose a significant risk to wild sheep.

Photo by: Todd Nordeen (NGPC)

Management Recommendations

■ Proportional to risk of association between domestic sheep or goats and wild sheep, land management agencies should work with stakeholders to implement a variety of management practices. Examples include: herders, dogs or other guarding animals trained to repel animals foreign to domestic sheep bands or goat flocks (wandering wild sheep or various predators), regular counts, removal of sick animals, confinement of domestic sheep or goats at night, adequate fencing configurations, covenants, allotment retirements, conversion of class of livestock, trucking versus trailing, and others. Effectiveness of management practices designed to reduce risk of association are not proven (Baumer et al. 2009, Schommer 2009) and therefore should not be solely relied upon to achieve effective separation. Such practices could however, help achieve separation when applied outside of occupied wild sheep range or connected and potentially mitigate impacts associated with straying domestic sheep or goats, or wandering wild sheep.

■ Land management agencies and wildlife agencies should cooperatively manage for quality wild sheep habitat and routinely monitor habitat to detect changes in condition.

■ In areas where association between wild sheep and domestic sheep or goats is likely, land management agencies should post advisory signs at trailheads, campgrounds, and other high-use areas that are designed to educate visitors about the issue of interaction and to encourage prompt reporting of association of wild sheep with domestic sheep or goats. Agencies should also ensure that individuals keep dogs under immediate voice control or on leash to prevent scattering of domestic sheep or goats in permitted areas, or disturbances to wild sheep.

■ Land management agencies should clearly define the processes, protocols, and timelines for short-term or emergency management actions when intervention is needed to minimize risk of association between wild sheep and domestic sheep or goats.

■ Land management agencies should develop programs to foster and recognize the benefits of compliance, cooperation, and cost-sharing in efforts to prevent commingling of wild sheep and domestic sheep or goats on shared ranges.

■ In collaboration with wild sheep management agencies, land management agencies should investigate and implement an option to allow the permittee or producer, or appropriate agency representatives, to remove commingling wild sheep and, where not already established, develop or clarify legal authority for removing stray domestic sheep from public lands by lethal means.

■ Risk assessment should be conducted on an appropriate geographic scale regardless of jurisdictional boundaries. Recognizing the limits of regulatory authority, land management agencies should consider private in-holdings and adjacent private lands when conducting risk assessments.

■ Land management agencies should closely evaluate timing of permitted domestic sheep or goat grazing or trailing activities to reduce risk of disease transmission. For example, grazing estrous domestic females heightens

Photo by: Robin Fehlau (BLM)


Photo by: Stephanie Steinhoff (CPW)

attraction and increases the probability of association between wild sheep and domestic sheep, and should be eliminated where benefits can be accrued.

■ In areas of high risk of association between wild sheep and domestic sheep or goats, agencies and permittees should ensure enhanced monitoring of grazing and trailing patterns using global positioning system (GPS) collars or other technology that provide detailed data on movements and grazing patterns. While enhanced monitoring will not reduce risk of association, it is vital for development of meaningful risk assessments and to ensure appropriate management recommendations are taken to achieve effective separation.


Photo by: Mike Cox (NDOW)


Photo by: Helen Schwantje (BC FLNRO)

RECOMMENDATIONS TO WILD SHEEP AND OTHER CONSERVATION ORGANIZATIONS

■ Recognize and support efforts of wild sheep management agencies and industry leaders in maintaining effective separation.

■ Assist wildlife and land management agencies with development of informational brochures and other materials that identify and explain risk of association between wild sheep and domestic sheep or goats.

■ Assist wildlife and land management agencies with educational efforts regarding risks associated with the use of domestic sheep or goats as pack animals in wild sheep habitat. If use is authorized, encourage participants to closely control, tether, and night-pen their pack stock. Encourage prompt reporting of association between wild sheep and domestic sheep or goats, and promote a reporting system for monitoring association between wild sheep and domestic sheep or goats.

■ Maintain or establish open lines of communication with domestic sheep or goat producers and industry organizations to reduce polarization. Jointly organized and cooperatively-funded workshops on risk assessment, identification of practical strategies to achieve effective separation, development and distribution of pamphlets or brochures, and public speaking opportunities are tangible examples of collaborative, multi-disciplinary approaches to address potential disease transmission.

■ Continue to negotiate alternatives or incentives for domestic sheep or goat permittees to shift their operations to grazing allotments outside of wild sheep habitat. Advocate that permittees convert to a different class of livestock with lower risk of disease transmission or waive permitted domestic sheep or goat use in areas where risk assessment indicates high potential for association with wild sheep.

■ Encourage and support development and funding of cooperative research, and encourage agencies and conservation groups to commit resources necessary to maintain wild sheep populations.

SUGGESTED MANAGEMENT PRACTICES FOR DOMESTIC SHEEP AND GOAT PERMITTEES

The following suggestions are based largely on recommendations provided by CAST (2008), Baumer et al. (2009), or USAHA (2009), and are intended to provide a responsible and common-sense approach for reducing risk of association. However, there is no science-based evidence or evaluation that assesses the effectiveness of these actions to reduce risk or enhance separation (Schommer 2009).

Management Recommendations

■ Implement the following reporting and record keeping procedures or use an existing standard such as the BC (Appendix B) or Wyoming (Appendix C) models:

- Require prompt, accurate reporting by herders working on domestic sheep or goat grazing allotments where association of wild sheep with domestic sheep or goats is possible.
- Support fluency in English or translators for foreign herders in order to facilitate accurate reporting.
- Require sheepherders to use cellular or satellite phones or two-way radios, and location equipment such as GPS receivers to report and record grazing movements and encounters with wild sheep. Seek cost-sharing partnerships for providing communications equipment when an operator changes grazing management practices for the sole purpose of minimizing domestic sheep association with wild sheep. Partnerships could include wildlife management agencies, federal land managers, or private organizations.
- Require herders to record GPS locations, counts, losses and other information in a log book.

■ Place only experienced, informed and responsible sheepherders on allotments located near wild sheep habitat.

■ Ensure that all domestics are individually marked and traceable to source flocks.

■ Conduct full counts when trailing, immediately any time scattering occurs and regularly during general grazing.

■ Develop agreements between permittees and wildlife agencies that provide for locating and reacquiring all stray domestic sheep, either dead or alive. In the event of missing domestic sheep, a comprehensive search should be initiated immediately and the land manager and state wildlife agency must be notified of missing and subsequent recovery of animals.

■ Develop a detection and response protocol that includes:

- Reporting of wild sheep and domestic sheep associations (animal counts and GPS location) to the appropriate wildlife agency.
- Reporting of stray or missing domestic sheep to the land management agency who will, in turn, report that information to the wildlife agency.
- Removal of stray domestic sheep by the permittee, land manager or wildlife agency personnel.
- Removal of individual commingling wild sheep by wildlife agency personnel.
- Collection of standardized diagnostic samples from stray domestic sheep or commingling wild sheep.

■ Utilize the following trailing procedures:

- Conduct full counts when moving on and off each allotment/grazing site.
- Truck domestic sheep through "driveway" areas that pass through occupied wild sheep habitat.
- Truck in water (if needed) to reduce straying.
- Immediately remove animals unable to stay with the flock/herd and move them to a base property.
- Avoid trailing more than 5 miles per day and stop trailing when sheep or lambs show signs of fatigue. Provide for a "babysitter" or removal of lagging sheep when trailing.
- In the event that all animals cannot be accounted for, the permittee must advise the responsible agency and initiate efforts to locate missing animals and implement removal protocol as necessary.

■ Sick domestic sheep should be removed from allotments immediately and must never be abandoned.

Photo by: Mike Pittman (TPWD)

Photo by: Aaron Reid (BC FLNRO)

Management Recommendations

■ Select herder's camp, nighttime bedding ground, and midday bedding ground locations that maintain communication between guard dogs and herding dogs by smell, sound (barking) and sight, and to take advantage of differences in the sleep cycles of guard dog and herding dogs. Place mature and effective guard dogs and herding dogs with domestic sheep (at least 2 of each per 1000 animals) and do not use female dogs in heat.

■ If grazing on federal lands, comply with established "bed ground" standards. Where conditions permit, construct temporary electric or boundary fences to ensure that domestic sheep remain within selected bedding grounds.

SUGGESTED MANAGEMENT PRACTICES ON PRIVATE LANDS

■ Recognize that domestic sheep or goat farming on private lands can influence wild sheep population viability on adjacent public or other private lands.

■ Report any observed association between wild sheep and domestic sheep or goats on or near private land to the appropriate wildlife conservation agency.

■ Cooperate with wildlife agencies in reporting and removing feral sheep or goats and other exotic bovine ungulates such as aoudad, red sheep, urial, or argali that are detected within or near wild sheep habitat.

■ Participate in cooperative educational efforts to enhance understanding of the issues of disease transmission between domestic sheep or goats and wild sheep.

■ Do not release or leave unattended domestic sheep or goats in areas where they may seek, or be sought, by wild sheep.

■ Cooperate with appropriate agencies, agricultural and producer associations, conservation organizations, and other interested stakeholders to develop effective, comprehensive risk management approaches to help ensure effective separation between wild sheep and domestic sheep or goats, consistent with private property rights in and near wild sheep habitat.

- Possible approaches include, but are not limited to, changing species or class of livestock, purchase of land or the domestic sheep or goats, use of methods to ensure physical separation, or development of conservation incentives, bylaws, covenants, or legislation.

■ Consider partnerships with non-governmental organizations and wild sheep advocate groups for cost sharing on risk management/mitigation strategies such as fencing, or other domestic sheep or goat management actions that reduce risk of disease transmission from private flocks to wild sheep.

■ Support "effective separation" fencing standards that are designed to prevent nose-to-nose contact and aerosol transmission through adequate physical distance, in order to reduce transmission of respiratory disease agents. Examples include: electric outrigger fences (2 feet from page (woven) wire fencing) and double fencing (two page-wire fences with a minimum spacing of at least 10 feet). A combination of fencing methods with or without the use of effective livestock guardian dogs may be most effective to ensure that wild sheep do not physically contact domestic sheep or goats on private land.

■ Participate in or support cooperative research to enhance understanding and test mitigation protocols for disease risk management.

■ Carefully consider the consequences of using domestic sheep or goats for weed control on private lands where association with wild sheep could occur. Work with agencies to develop alternative weed management strategies to reduce risk of association, while adequately managing weed problems.

Photo by: David Wetzel (Texas Bighorn Society)

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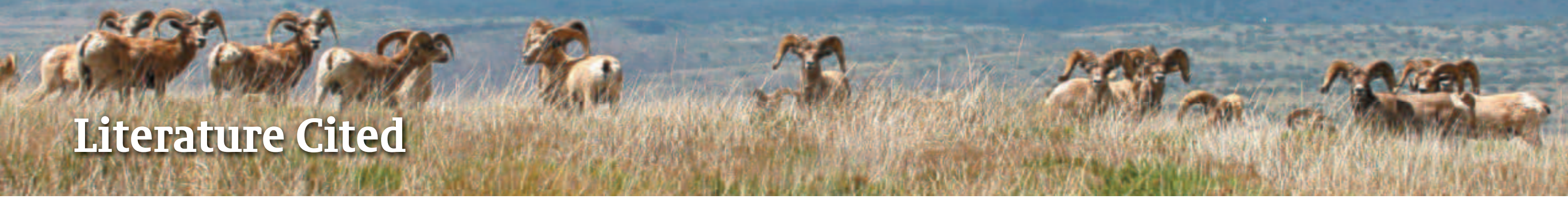

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Appendix A

Glossary of Terms

Allotment: A portion of a landscape where livestock grazing of a plant community is prescribed according to a specific land use plan or legally defined regulatory authority.

Annual Operating Instructions: Specific language included in a term grazing or trailing permit file; reviewed each year with the permittee, prior to turnout of livestock on a grazing allotment or trailing route.

Association: Close proximity between wild sheep and domestic sheep or goats, potentially leading to direct physical contact and potential disease transmission.

Augment: To intentionally introduce wild sheep from one or more source populations into another existing wild sheep population, to enhance the recipient population demographically or genetically.

Buffer zone: A defined and delineated space on a landscape established by wildlife managers to reduce association and the potential for disease transmission between wild and domestic sheep or goats across that geographic space.

Bighorn sheep: A member of the species *Ovis canadensis* found throughout the mountains of western North America from the Peace River in Canada to northern Mexico and east to the Badlands of the Dakotas.

Contact: Direct contact between body parts of two animals during which a disease might be transmitted from one to another. In this document, "contact" typically refers to nose-to-nose or face-to-face interactions that may lead to the transmission of respiratory disease via secretions or aerosols. Synonymous with "Interaction."

Connectivity: Creating or maintaining networks of habitat that connect fragmented habitats, thus linking population segments of wildlife. Connectivity allows gene flow and enhances long-term species survival.

Conservation Incentives: In direct contrast to regulation-based conservation, incentive-based conservation provides economic, management or esthetic benefits to individuals or corporations to encourage them to conduct management activities that have positive conservation consequence to wildlife or wildlife habitat. Examples are: private land conservation easements, direct lease agreements for grazing rights for conservation purposes, or a trade/exchange of equal value grazing rights among various partners to minimize wildlife-domestic livestock conflict.

Die-off: A large-scale mortality event that impacts many animals from a population and may have significant demographic consequence for the long-term persistence of that population. In this report, such mortality events are usually caused by respiratory disease epidemics involving bacterial or other pathogens alone or in various combinations.

Disease: The word disease means literally "free of ease." Disease is any impairment that modifies or interferes with normal functions of an animal, including responses to environmental factors such as nutrition, toxicants, and climate. Typically, disease involves transmission of, and exposure to, some infectious agent but it may involve non-infectious causes such as congenital defects.

Dispersal: The process whereby individuals leave one habitat or landscape to seek another habitat or landscape in which to live.

Double fencing: Two fences running parallel around a landscape or pasture to prevent contact between animals across the fence line, designed to inhibit disease transmission.

Effective separation: Spatial or temporal separation between wild sheep and domestic sheep or goats, resulting in minimal risk of contact and subsequent transmission of respiratory disease between animal groups.

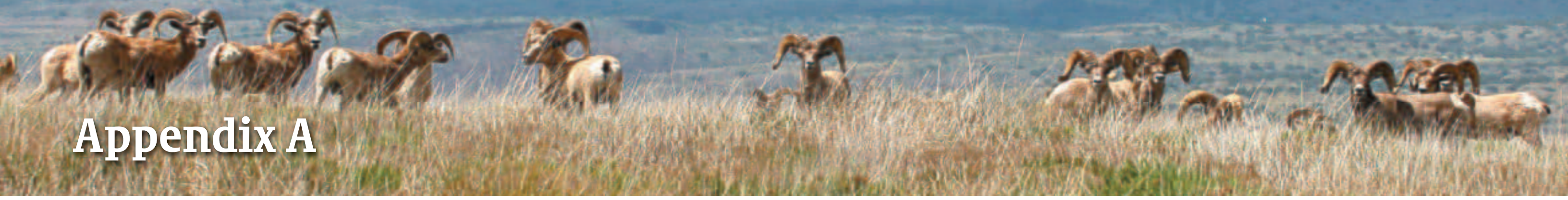
Feral: An animal of a domestic species that resides in a non-domestic setting and is not presently owned or controlled.

Historic habitat: Based on historic records, landscape that was previously occupied by bighorn sheep and thought to have provided necessary requirements to sustain a wild sheep population through time.

Interaction: Direct contact between body parts of two animals during which a pathogen might be transmitted from one to another. In this document, "interaction" typically refers to nose-to-nose or face-to-face interaction that may lead to the transmission of respiratory disease via secretions or aerosols. Synonymous with "Contact".

Metapopulation: An assemblage of populations, or a system of local populations (demes) connected by movement of individuals (dispersal) among various population segments.

Movement corridor: Routes that facilitate movement of animals between habitat fragments.



Appendix A

Occupied habitat/range: Suitable habitat in which a wild sheep population currently exists.

Preferred: A specific management action that *should* be chosen over another, whenever possible:
Radio collars: Transmitters fitted on neckband material to monitor animal locations.

Global Positioning System (GPS): A radio transmitter fitted on neckband material linked with orbiting satellites; animal locations can be precisely triangulated from space, with the location data then electronically stored in a memory chip or transmitted by various methods for data retrieval.

Very High Frequency (VHF): A radio transmitter fitted to neckband material transmitting in the Very High Frequency range that can be located from the ground or aircraft using a telemetry receiver.

Removal: Physical extraction of domestic sheep or goats, or wild sheep, to eliminate (permanently or temporarily) occupancy of that range or habitat.

Risk/Risk Assessment/Risk Management: In this context, evaluation of the probability that a wild sheep population could experience a disease event with subsequent demographic impacts. Identification of what factors might contribute to the probability of a disease event. Management actions taken to reduce the probability of exposure and/or infection among or between animals. Examples of risk management include separation of infected and non-infected animals, treatment of infected individuals, vaccination, manipulations of the host environment, or manipulations of the host population.

- Qualitative Risk Assessment: Interpretation and analysis of factors that cannot necessarily be measured.

- Quantitative Risk Assessment: Use of tangible data and measurements.

Spatial separation: A defined physical distance between animal populations.

Stray: A domestic sheep or goat physically separated from its flock or band.

Stressor: A specific action or condition that causes an animal to experience stress and the subsequent physiological results of that stress.

Suitable habitat: Landscape that has all necessary habitat requirements to sustain a wild sheep population through time.
Temporal separation: Segregating animal populations over time to prevent association, such that they may occupy the same physical space but at different times.

Thinhorn sheep: A member of the species *Ovis dalli* occurring in Alaska, Yukon Territory, Northwest Territories, and northern British Columbia.

Transmission: The physical transfer (direct or indirect mechanisms) of a disease agent from one animal to another, either within an animal population or between animal populations. In some instances, transmission can lead to full expression of disease in individuals or populations.

Transplant: An intentional movement of wild sheep from a source population to other suitable wild sheep habitat, either currently occupied or not. (Also called “translocation” in some documents.)

Trailing: The planned ambulatory movement of domestic sheep or goats across a landscape or within a corridor to reach a destination where grazing or use will be allowed.

Unoccupied habitat/range: Suitable habitat in which a wild sheep population does not currently exist.

Viability: The demographic and genetic status of an animal population whereby long-term persistence is likely.

Wandering Wild Sheep: Wild sheep, primarily but not always young, sexually-mature rams, occasionally traveling outside of normally anticipated or expected wild sheep range and adjacent habitat. Removal of wandering wild sheep typically does not have population-level implications for wild sheep. Conversely, failure to respond to wandering wild sheep may result in significant, adverse population-level impacts.

Appendix B

British Columbia Domestic-Wild Sheep Separation Project Contact Protocol

The following protocols outline ***the steps to be taken when reports of wild sheep contact with domestic sheep are received by the Ministry of Environment*** in one of several ways:

1. Regular report from public to regional office (Conservation Officer Service or Wildlife Section):

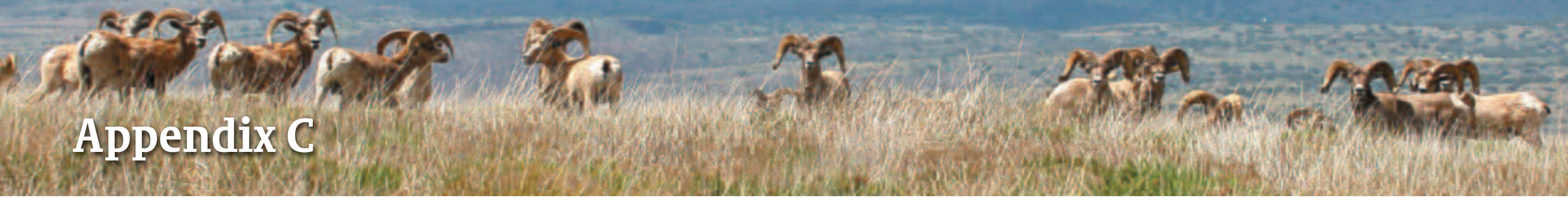
- Contact reported to Regional office.
- Assessment of situation by sheep biologist and COS, in consultation with wildlife veterinarian
- If close contact is confirmed and is considered a high risk situation, consider the following options:
  - a. Kill bighorn and save carcass – sample bighorn and/or domestics in consultation with wildlife veterinarian
  - b. Continue to monitor bighorn herd in area – observe and record general signs of health
  - c. Do nothing – but keep records
- If contact is unsubstantiated/considered low risk, continue to monitor bighorn herd in area, alert and encourage mitigation measures with domestic producers in area to ensure separation.

2. Regular report from public to Call Line.

- Contact reported to Call Line; Call Line staff forwards to regional COS.
- Assessment of situation by COS and sheep biologist, in consultation with wildlife veterinarian
- If close contact is confirmed and is considered a high risk situation, consider the following options:
  - a. Kill bighorn and save carcass – sample bighorn and/or domestics in consultation with wildlife veterinarian
  - b. Continue to monitor bighorn herd in area – observe and record general signs of health
  - c. Do nothing – but keep records
- If contact is unsubstantiated/considered low risk, continue to monitor bighorn herd in area, alert and encourage mitigation measures with domestic producers in area to ensure separation.

3. Out of hours call from public to Call Line.

- Contact reported to Call Line; Call Line staff forwards to regional COS officer-on-call.
- Assessment of situation by COS officer-on-call – contacts sheep biologist and wildlife veterinarian, if possible for consultation
- If sheep biologist and wildlife veterinarian cannot be contacted, biologist and veterinarian will support COS decision and action. COS will inform sheep biologist and wildlife veterinarian by email of the situation and action taken.
- If close contact is confirmed and is considered a high risk situation, consider the following options:
  - a. Kill bighorn and save carcass – sample bighorn and/or domestics in consultation with wildlife veterinarian
  - b. Continue to monitor bighorn herd in area – observe and record general signs of health
  - c. Do nothing – but keep records
- If contact is unsubstantiated/considered low risk, continue to monitor bighorn herd in area, alert and encourage mitigation measures with domestic producers in area to ensure separation.



Appendix C

Wyoming Game and Fish Department

5400 Bishop Blvd. Cheyenne, WY 82006

Phone: (307) 777-4600 Fax: (307) 777-4610

Web site: http://gf.state.wy.us

MEMORANDUM

TO: Wildlife Division Employees

FROM: Jay Lawson, Chief, Wildlife Division

COPY TO: Terry Cleveland, Gregg Arthur, File

SUBJECT: **PROTOCOL FOR HANDLING THE COMMINGLING OF BIGHORN SHEEP AND DOMESTIC SHEEP/GOATS**

Due to the threat of disease transmission and subsequent bighorn sheep die-offs, the following protocol should be followed.

Wandering Bighorn Sheep:
Where there is known, suspected, or likely contact by a wandering bighorn sheep with domestic sheep/goats:

- If possible, that bighorn(s) should be live-captured and transported (one-way) to our Sybille Research Unit.
- If that bighorn(s) cannot be live-captured, that bighorn(s) should be lethally removed (per authority of Chapter 56) and, if possible, transported (either whole or samples) to our Sybille Unit or our WGFD Lab in Laramie.

Stray Domestic Sheep/Goat:
Where there is known, suspected, or likely contact by a stray domestic sheep/goat with bighorn sheep:

- The owner of such livestock should be notified and asked to remove the stray sheep/goat to eliminate the threat of disease transmission; however, it will be the owner's prerogative to determine what course of action should be taken.

Reporting:
All documented commingling and any actions taken must be reported to the employee's immediate supervisor, Wildlife Administration as well as the Bighorn Sheep Working Group Chairman, presently Kevin Hurley.

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Dallas Safari Club

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Foundation for North American Wild Sheep

Wild Sheep Foundation Midwest Chapter

Nevada Bighorns Unlimited

Texas Bighorn Society

Texas Parks & Wildlife Foundation

Utah Foundation for North American Wild Sheep

Wild Sheep Society of BC

Wild Sheep foundation

Wyoming Wild Sheep Foundation

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Alberta Fish & Wildlife Division

Arizona Game & Fish Department

British Columbia Ministry of Forests, Lands and Natural Resources Operations

California Department of Fish & Game

Colorado Parks and Wildlife

Hawaii Division of Forestry and Wildlife

Idaho Department of Fish & Game

Kansas Department of Fish and Parks

Montana Department of Fish, Wildlife and Parks

Nebraska Game & Parks Commission

Nevada Department of Wildlife

New Mexico Department of Game & Fish

North Dakota Game and Fish Department

Oklahoma Department of Wildlife Conservation

Oregon Department of Fish & Wildlife

Saskatchewan Ministry of Environment, Fish, Wildlife, and Biodiversity Branch

South Dakota Department of Game, Fish and Parks

Texas Parks and Wildlife Department

Utah Division of Wildlife Resources

Washington Department of Fish and Wildlife

Government of Yukon Department of Environment

Wyoming Game and Fish Department

EXHIBIT 8

Population response of reintroduced bighorn sheep after observed commingling with domestic sheep

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ORIGINAL PAPER

Population response of reintroduced bighorn sheep after observed commingling with domestic sheep

Justin M. Shannon · Jericho C. Whiting · Randy T. Larsen · Daniel D. Olson · Jerran T. Flinders · Tom S. Smith · R. Terry Bowyer

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Abstract Bighorn sheep (*Ovis canadensis*) often die from respiratory disease after commingling with domestic sheep. From 2000 to 2009, we observed commingling between domestic and reintroduced bighorn sheep in 3 populations in UT, USA. We investigated how commingling affected survival of radio-collared female bighorns that were released initially (founder) and those that were subsequently released (augmented). We predicted that the proportion of young surviving to their first winter and population growth would be lower after observed commingling with domestic sheep. We observed groups of bighorns year-round on 2,712 occasions and commingling between domestic sheep and bighorns in 6 instances. On Mount Timpanogos, survival rates were best modeled as constant for females ($n=57$) before and after observed commingling with domestic sheep. Survival rates of female bighorns, however, decreased significantly in Rock Canyon ($n=21$) and on Mount Nebo ($n=22$) for founder, but not augmented bighorns after observed commingling with domestic sheep. Also, the proportion of young surviving to their first winter was almost 3 times lower and population growth was reduced for bighorns after observed commingling with domestic sheep in Rock Canyon and on Mount Nebo. Commingling between domestic and bighorn sheep reduced population parameters in 2 of 3 bighorn populations we studied; however, on Mount Timpanogos, interactions between those 2 species were not fatal for radio-collared female bighorns. Wildlife biologists should manage for spatial separation of these 2 species and consider the location of hobby farms and trailing operations of domestic sheep near release sites for bighorns.

Communicated by H. Kierdorf

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Keywords Domestic sheep · *Ovis canadensis* · Reintroductions · Respiratory disease · Translocations

Introduction

Bighorn sheep (*Ovis canadensis*) historically occupied much of the western USA (Buechner 1960; Valdez and Krausman 1999; Krausman and Bowyer 2003); however, populations of those mammals have declined drastically since the latter part of the nineteenth century (Geist 1971; Valdez and Krausman 1999). Historical declines have been attributed to overharvesting, habitat loss, competition with domestic livestock, and disease (Smith et al. 1988; Wehausen et al. 2011). Of those factors, pneumonia epizootics have plagued populations of bighorns for the past century (Grinnell 1928; Wehausen et al. 2011). Disease epizootics in bighorn populations appeared to follow the establishment of grazing by domestic livestock after European settlement (George et al.

2008; Wehausen et al. 2011). Respiratory disease may include multiple infectious agents, such as bacteria (primarily *Mycoplasma ovipneumoniae*, as well as *Pasteurella multocida*, *Mannheimia haemolytica*, and *Bibersteinia trehalosi*) (Dassanayake et al. 2010; Besser et al. 2012a, b, 2013), and potentially other stressors, such as drought and the proximity of the bighorn population to carrying capacity (Monello et al. 2001; George et al. 2008). Fatal respiratory disease poses 1 of the greatest threats to remaining populations of bighorn sheep in North America (McClintock and White 2007; Besser et al. 2012b).

Over the past 30 years, experimental research in enclosures has been extensive concerning the transmission of fatal respiratory disease when domestic sheep commingle with bighorn sheep (Foreyt and Jessup 1982; Onderka and Wishart 1988; Wehausen et al. 2011; Besser et al. 2012a). Additionally, die-offs in free-ranging herds of bighorns have been documented after suspected and observed contact with domestic sheep (Martin et al. 1996; Monello et al. 2001; Cassaigne et al. 2010); however, commingling between bighorns and domestic sheep has been difficult to observe in the wild prior to die-offs. Epizootics of respiratory disease can suppress populations of bighorn sheep by reducing survival of adult animals (Cassirer and Sinclair 2007; George et al. 2008) and decreasing survival of young, especially during summer (Monello et al. 2001; Cassirer and Sinclair 2007; George et al. 2008; Cassirer et al. 2013). Those factors produce lingering effects that can hinder population growth for many years after contact (Martin et al. 1996; Monello et al. 2001; Cassirer and Sinclair 2007). Although research has documented increased bighorn mortality shortly after exposure to domestic sheep in an experimental setting, the etiology of pneumonia epizootics in the wild is less certain (Besser et al. 2012b, 2013).

Reintroductions of bighorn sheep are an important management tool for conserving these unique mammals (Bleich et al. 1990; Whiting et al. 2010b), and this method often is used by biologists to reestablish populations (Bleich et al. 1990; Krausman 2000). Despite efforts to restore populations of bighorn sheep, many reintroductions have experienced low rates of success, because of predation (Rominger et al. 2004), habitat suitability (Smith et al. 1991), and disease (Singer et al. 2000a). Previous research indicates that reintroduced populations of bighorns may be more likely to experience problems with respiratory disease than native populations, especially when releases occur in areas of proximity to domestic sheep (Gross et al. 2000; Singer et al. 2000a; Monello et al. 2001). In some areas, disease may have been a major factor in limiting the establishment of populations of reintroduced bighorn sheep (Gross et al. 2000; Singer et al. 2000a; Shannon et al. 2008). Indeed, much remains to be learned about the implications of respiratory disease and its effects on the restoration and management of bighorn sheep (Monello et al. 2001; Wehausen et al. 2011; Plowright et al. 2013).

Mechanisms and causal agents leading to pneumonia epizootics in bighorn sheep after contact with domestic sheep are not completely understood (Wehausen et al. 2011; Besser et al. 2013). Much debate still exists about this controversial topic; therefore, long-term studies are needed documenting population dynamics of bighorns before and after such events occur to understand the implications of respiratory disease on the conservation of bighorn populations (George et al. 2008). We monitored 3 reintroduced populations of bighorns year-round in northern UT, USA from 2000 to 2009. During that time, we observed domestic sheep commingling with bighorns in each population. Those commingling events provided us with a rare, post hoc test in a natural setting regarding the effect of interactions of domestic sheep on population parameters of reintroduced bighorn sheep. We used Program MARK to test hypotheses (White and Burnham 1999) regarding survival of radio-collared female bighorns that were released initially (founder animals) and those that were subsequently released (augmented animals). Specifically, we evaluated the influence of augmentation and observed commingling with domestic sheep, as well as environmental, seasonal, and year effects on survival of radio-marked bighorns. We also predicted that the proportion of young surviving to their first winter and population growth for those bighorns would be substantially lower after observed commingling with domestic sheep. The results of our study provide a greater understanding of the implications of respiratory disease on the conservation, restoration, and management of populations of bighorn sheep in the western USA.

Materials and methods

Study area

We studied 3 populations (Mount Timpanogos, Rock Canyon, and Mount Nebo) of Rocky Mountain bighorn sheep (*O. canadensis canadensis*) that were reintroduced into UT, USA (Fig. 1). Those populations occupied the Uinta National Forest of the Wasatch Mountains, which are oriented north to south with a large urban interface (>500,000 people) to the west (Whiting et al. 2008). Elevation in those areas ranged from 1,388 to 3,636 m (Whiting et al. 2008). Mean summer temperature was 19 °C, and mean winter temperature was 3 °C (Whiting et al. 2011). Mean annual rainfall was 51 cm, and the mean yearly snowfall was 145 cm. Those areas were similar in environmental conditions, topography, and flora. Generalized vegetative zones descending in elevation were alpine, conifer, aspen (*Populus tremuloides*), maple (*Acer* spp.), juniper (*Juniperus* spp.), mountain brush, big sagebrush (*Artemisia tridentata* ssp.), forbs, and grasses (Whiting et al. 2008). Forage species used by bighorns in those areas

Fig. 1 Locations of study areas in which we observed commingling between domestic and bighorn sheep in UT, USA, from 2000 to 2009. *Dark lines* traversing the state are major highways

included bluebunch wheatgrass (*Elymus spicatus*), spike fescue (*Lecopoa kingii*), Sandberg's bluegrass (*Poa secunda*), shortstem buckwheat (*Eriogonum brevicaule*), and littlecup penstemon (*Penstemon sepalulus*) (Whiting et al. 2010b). In all of our study areas, grazing allotments for domestic sheep and goats were retired, or converted to cattle allotments, through the local United States Forest Service Office prior to bighorn sheep being released; therefore, no legal grazing by domestic sheep or goats occurred in our study areas.

Capture and observations of bighorn sheep

From 2000 to 2007, 157 bighorn sheep were captured and released into the 3 study areas (Fig. 1, Table 1). Ninety-four females were equipped with VHF radio collars at the time of release (Table 1), and 12 additional females were collared periodically throughout the study. To help identify groups (founder or augmented), bighorns released in all study areas in 2007 were marked with 2, colored ear tags. Wildlife biologists from the Utah Division of Wildlife Resources (UDWR) used care when capturing, handling, translocating, and attaching radio-transmitting collars and ear tags to bighorns (Sikes et al. 2011). We arbitrarily considered bighorn sheep released from 2000 to 2002 on Mount Timpanogos as founder animals and those released in 2007 as augmented bighorns (Table 1). After the release of bighorn sheep from Hinton, Alberta, Canada, on Mount Timpanogos in 2001, 3 of those 10 bighorns died within 5 months, and 5 individuals (1 male and 4 females) were removed by employees of the UDWR because of suspected disease, although we never observed those bighorns commingling with domestic sheep. We considered animals released in Rock Canyon (2001) and on Mount Nebo (2004) as founder animals and those released in 2007 as augmented bighorns (Table 1). Each release of augmented bighorns occurred in areas used by founder animals, and augmented and founder bighorns intermixed during 29 % of our sightings (n=1,401 observations) after January 2007.

Table 1 Locations, years of capture, source areas, and demographic information for populations of bighorn sheep released in northern UT, USA

Release site and date	Source area	Males	Females	Young	Total	% females collared
Mount Timpanogos						
January 2000[a]	Rattlesnake Canyon, UT	6	16	3	25	81
January 2001[a]	Hinton, Alberta, Canada	2	8	0	10	100
February 2002[a]	Sula, MT	2	6	1	9	67
January 2007	Sula, MT	0	20	0	20	70
March 2007	Alamosa, CO	1	17	0	18	100
Rock Canyon						
January 2001[a]	Hinton, Alberta, Canada	4	15	3	22	67
January 2007	Sula, MT	0	5	0	5	60
January 2007	Augusta, MT	0	5	0	5	60
Mount Nebo						
December 2004[a]	Augusta, MT	2	13	3	18	69
January 2007	Augusta, MT	3	22	0	25	59

[a] We considered bighorns from these releases as founder animals

We located bighorn sheep with transmitting radio collars using radiotelemetry equipment, binoculars, and spotting scopes year-round from 2000 to 2009. We observed groups of those ungulates an average of 24 occurrences each month. During that time, near Rock Canyon, we observed 1 domestic sheep along the urban interface 5 years before our first observed commingling between bighorn and domestic sheep. That domestic sheep was removed by wildlife biologists from the UDWR 12 days after being observed. We also observed 3 domestic sheep in an area near Rock Canyon 1 month before our observed first commingling between bighorn and domestic sheep. Those domestic animals were removed by wildlife biologists from the UDWR the day that they were observed. Additionally, in an area near Rock Canyon, we observed 6 domestic goats 1 month before our first observed commingling between bighorn and domestic sheep. All 6 of those goats were removed the day that they were observed. Because we did not observe commingling between domestic sheep or goats and bighorn sheep during all of those observations, it is tenuous to infer that transmission of pathogens occurred; therefore, for our analyses, we only used sightings of domestic sheep commingling with bighorns (i.e., the 2 species were within 20 m of each other and moved as a group) that were observed by at least 1 of the authors of this paper, wildlife biologists from the UDWR, or in 1 instance, a local law enforcement officer.

Survival analyses

We estimated monthly and annual survival rates (s) using known-fate models in Program MARK version 5.1 (White and Burnham 1999). We used model selection (Burnham and Anderson 2002) to evaluate support for survival models of radio-collared female bighorn sheep before and after the date of augmentations of bighorns and before and after the date of observed commingling with domestic sheep. We only tested for effects of source population of augmented bighorns on survival of collared females in 1 of our study areas (Mount Timpanogos). We were not able to test for the effects of source population of augmented bighorns in Rock Canyon, because there were too few collared females (3 from each release) to do such. We were not able to test for the effect of source population of augmented bighorns in models for Mount Nebo, because all bighorns in that area were from the same source population (Augusta, MT). We also tested for effect of group, which included founder or augmented individuals, on survival of females. To test for differences in survival of collared females in relation to weather (i.e., drought or inclement weather), we evaluated support for season—birthing (1 April to 31 July), summer and autumn (1 August to 30 September), and winter (1 October to 31 March) (Cassirer and Sinclair 2007; George et al. 2008)—and year effects. Some of those models included 4-, 8-, or 12-month linear or quadratic decreases in survival following commingling with domestic sheep (George et al. 2008). Those trend models allowed us to capture the possibility of acute, chronic, or recovery of survival rates following observed comingling with domestic sheep. We followed protocols for standard model selection and constructed a list of biological meaningful *a priori* candidate models for each population (Anderson and Burnham 2002; Burnham and Anderson 2002; Arnold 2010). Separate analyses for each population simplified our analyses and allowed us to evaluate support for models in relation to when augmentation of bighorn sheep occurred or when domestic sheep were observed comingling with bighorns in each population. We formatted encounter histories (live, dead, or censored) for each collared female bighorn by month. For our analyses, we only used collared females that were alive for

>1 month after release (Cassirer et al. 2013). We censored 9 bighorns on Mount Timpanogos (4 that were shot by wildlife biologists because of suspected disease in 2001 and 5 individuals because the battery on the radio collars failed) and 2 bighorns in Rock Canyon because of radio-collar failures.

We based model selection on the minimization of Akaike's information criterion (Akaike 1973) corrected for small sample size (AIC_c) (Lebreton et al. 1992) and AIC_c weights (w_i) (Buckland et al. 1997; Burnham and Anderson 2002). When model selection uncertainty occurred (competing models with >5 % AIC_c weight), we calculated model-averaged estimates (Burnham and Anderson 2002) of annual survival by adjusting time intervals to equal 1/12th of a year. To evaluate effect sizes, we examined overlap in 95 % confidence intervals (CI) associated with survival estimates. For survival analyses, we considered bighorn sheep released from 2000 to 2002 on Mount Timpanogos as founder animals and those released in 2007 as augmented bighorns (Table 1). We also considered animals released in Rock Canyon (2001) and on Mount Nebo (2004) as founder animals and those released in 2007 as augmented bighorns (Table 1).

We calculated an index of the survival of young bighorn sheep to their first winter for Rock Canyon and Mount Nebo and then compared that value before and after the first observed commingling event with domestic sheep. We could not compare that value on Mount Timpanogos, because our first observed commingling event between domestic and bighorn sheep occurred in August 2000, only 8 months after the first group of bighorns was released in that area (Table 1). That value included survival of young from collared and uncollared females, because we could not identify individual young. For this analysis, we first relocated collared and uncollared female bighorns throughout the birthing season to record birthdates and determine the number of young born in each population during that season. This method, which has been well established for these populations, provided a total number of young born in the sampling year. Data regarding the number of young born in all areas from 2000 to 2007 were adapted from Whiting et al. (2008, 2010b, 2011, 2012). Second, during winter (1 October to 31 March), bighorn sheep used areas of low elevation, which facilitated their relocation. We searched those areas and tallied the highest count of young observed across that season of the same year (Jorgenson 1992; Roy and Irby 1994). We then compared that value with the number of young born the previous spring to calculate an index of the proportion of neonates that survived to their first winter in each year (Clutton-Brock et al. 1987; Whiting et al. 2011). We did not partition data by year because of small sample sizes. Data concerning the number of young surviving to their first winter on Mount Timpanogos and in Rock Canyon from 2000 to 2006 were adapted from Whiting et al. (2010b, 2011). We used the two-sample *Z* test for proportions, which allows sampling with replacement (Remington and Schork 1970), to investigate the prediction that the proportion of young surviving to their first winter was reduced in Rock Canyon and on Mount Nebo after first observed commingling with domestic sheep. Others methods, such as age ratios, were considered more problematic than the method we used, because of the double variable nature of ratios (Bowyer et al. 2013).

To document an index of population growth before and after observed commingling between domestic and bighorn sheep from 2000 to 2009 in each area, we relocated bighorns during winter as described previously and tallied the highest population count of all bighorns observed during that season. Data from counts have been used as an index of population size (Slade and Blair 2000). We then calculated the annual growth rate (λ) (Monello et al. 2001) of bighorn sheep in Rock Canyon and on Mount Nebo for each year. We then averaged that value before and after the first observed commingling between domestic and bighorn sheep in those 2 areas. We could not compare annual growth rates of bighorn sheep on Mount Timpanogos, because our first observed commingling event between domestic and bighorn sheep occurred in August 2000, 8 months after the first group of bighorns was released in that area.

Results

From 2000 to 2009, we observed groups of bighorn sheep year-round on 2,712 occasions (Mount Timpanogos = 1,549, Rock Canyon = 797, and Mount Nebo = 366). On Mount Timpanogos, we observed 2 domestic sheep with 6 founder bighorns (2 females, 1 yearling, and 3 young) in August 2000 and 1 domestic sheep with 16 augmented bighorns (1 male, 13 females, and 2 young) in November 2008. In Rock Canyon, we sighted 1 domestic sheep with 4 bighorns (1 founder male, 2 founder females, and 1 augmented female) in November 2007. On Mount Nebo, we observed 1 domestic sheep with 3 founder bighorns (1 male, 1 female, and 1 young) in November 2006, 4 domestic sheep with 5 bighorns (females and young, most likely founders) in March 2007, and 4 domestic sheep with 2 founder females in February 2008. Observations of domestic sheep commingled with bighorns, in bighorn habitat, accounted for 0.2 % of all sightings of bighorn sheep, indicating that observing such events was rare. We observed no other commingling of bighorn sheep with any other domestic ungulates during our study.

Throughout the study, we calculated survival rates for 100 female bighorns that were radio-collared: 28 founder and 29 augmented bighorn sheep on Mount Timpanogos, 15 founder and 6 augmented individuals in Rock Canyon, and 9 founder and 13 augmented bighorns on Mount Nebo. In Rock Canyon, all founder females that were radio-collared (n=6) died within 8 months after observed commingling with domestic sheep compared with 1 of 4 augmented females that were radio-collared. Similarly on Mount Nebo, 7 of 8 founder females that were radio-collared died within 8 months after commingling with domestic sheep in March 2007 compared with 2 of 13 augmented females that were radio-collared.

On Mount Timpanogos, the top model was the null model indicating constant monthly survival, but significant model selection uncertainty occurred with 5 other competing models receiving >5 % AIC_c weight (Table 2). Those models included group (difference in survivorship between founder and augmented bighorns), commingling events, season, and linear trend models for which survival varied in relation to commingling events (Table 2). Top models for Rock Canyon and Mount Nebo, however, indicated that variation in monthly survival rates was best modeled based on timing of observed commingling with domestic sheep, but with different estimated survival rates for augmented versus founder bighorns (Table 2). These top models were similar and accounted for almost all of the AIC_c weights, with no other models receiving >5 % model weight (Table 2).

Average annual survival (±95 % CI) for radio-collared female bighorns on Mount Timpanogos was estimated at 0.83 (0.68 to 0.92) before observed contact with domestic sheep in August 2000 and 0.83 (0.74 to 0.89) after that observed commingling (Fig. 2). Before commingling in November 2008, the estimated average annual survival rate of founder female bighorns was again 0.83 (0.74 to 0.89) compared with 0.81 (0.70 to 0.89) for augmented bighorns. Following commingling in November 2008, the estimated average annual survival rate for founder female bighorns on Mount Timpanogos was 0.82 (0.71 to 0.90) compared with 0.77 (0.59 to 0.89) for augmented bighorns (Fig. 2).

Average annual survival (±95 % CI) for all female bighorn sheep that were radio-collared in Rock Canyon was estimated at 0.84 (0.72 to 0.91) before observed contact with domestic sheep and 0.38 (0.17 to 0.64) after contact. For founder

Table 2 Results of model selection (AIC_c and ΔAIC_c), model weights (w_i), number of estimated parameters (K), and deviance for models (AIC_c weight >1 %) of bighorn sheep survival in relation to observed commingling with domestic sheep, as well as season, group (founder or augmented), and monthly trend effects in 3 populations in UT, USA, from 2000 to 2009

Model structure	AIC_c	ΔAIC_c	w_i	K	Deviance
Mount Timpanogos					
s(.)	315.32	0.00	0.20	1	125.36
s(group)	317.11	1.79	0.08	3	123.14
s(1st observed comingling)	317.13	1.82	0.08	2	125.17
s(group + 12-month linear trend, 1st observed comingling)	317.24	1.92	0.08	4	121.26
s(2nd observed comingling)	317.28	1.97	0.07	2	125.32
s(group + 4-month linear trend, 2nd observed comingling)	317.57	2.25	0.06	2	121.59
s(2nd observed comingling)	318.18	2.86	0.05	4	122.20
s(group + 8-month linear trend, 1st observed comingling)	318.40	3.08	0.04	4	122.42
s(group + 8-month linear trend, 2nd observed comingling)	318.54	3.22	0.04	4	122.56
s(group + 8-month quadratic trend, 1st observed comingling)	318.77	3.45	0.04	4	122.79
s(group + 4-month quadratic trend, 1st observed comingling)	318.84	3.52	0.03	4	122.86
s(group + 4-month linear trend, 1st observed comingling)	318.85	3.53	0.03	4	122.87
s(group + 4-month quadratic trend, 2nd observed comingling)	318.87	3.55	0.03	4	122.89
s(constant survival before 1st observed comingling, different survival by group post commingling)	318.97	3.65	0.03	4	122.99
s(group + 12-month linear trend, 2nd observed comingling)	319.00	3.69	0.03	4	123.03
s(season)	319.04	3.72	0.03	3	125.07
s(different survival by group before and after 1st comingling)	319.06	3.74	0.03	4	123.08
s(season*group)	320.25	4.94	0.02	9	114.20
Rock Canyon					
s(constant survival before commingling, different survival by group post commingling)	147.39	0.00	0.52	3	67.44
s(different survival by group before and after commingling)	147.74	0.35	0.44	4	65.77
Mount Nebo					
s(constant survival before 2nd commingling, different survival by group post commingling)	106.82	0.00	0.70	3	43.90
s(different survival by group before and after 2nd commingling)	108.62	1.80	0.28	4	43.68
s(constant survival before augmentation, different survival by group after augmentation)	114.47	7.65	0.02	3	51.56

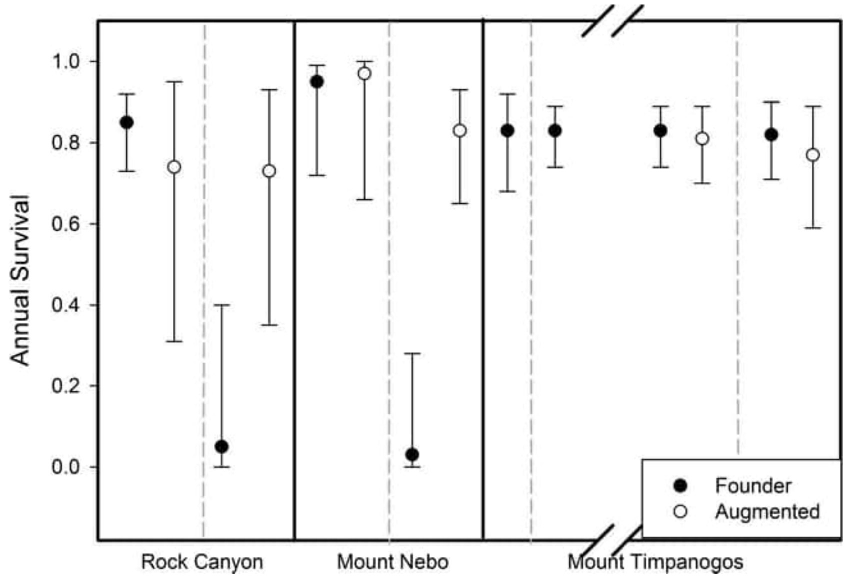

Fig. 2 Average annual survival rates of female bighorn sheep that were radio-collared in Rock Canyon, on Mount Nebo, and on Mount Timpanogos in UT, USA, from 2000 to 2009. *Dashed-vertical lines* represent observed commingling events between domestic and bighorn sheep during November 2007 in Rock Canyon and March 2007 (second commingling event) on Mount Nebo, as well as August 2000 (*left line*) and November 2008 (*right line*) on Mount Timpanogos

bighorns, an estimate of average annual survival in Rock Canyon was 0.85 (0.73 to 0.92) before observed contact with domestic sheep and 0.05 (0.00 to 0.40) after contact (Fig. 2). Annual survival rates for augmented female bighorns in Rock Canyon were 0.74 (0.31 to 0.95) before observed contact with domestic sheep and 0.73 (0.35 to 0.93) following observed commingling (Fig. 2). For Mount Nebo, supported models indicated that the second commingling event (March 2007) influenced survival rates of collared bighorn sheep (Table 2); therefore, we report annual survival rates of female bighorn sheep in relation to that event. On Mount Nebo, the average annual survival for all radio-collared female bighorns was estimated at 0.95 (0.73 to 0.99) before observed contact with domestic sheep and 0.64 (0.48 to 0.78) after contact. For founder bighorns, the estimated average annual survival rates on Mount Nebo were 0.95 (0.72 to 0.99) before observed commingling with domestic sheep and 0.03 (0.00 to 0.28) after commingling (Fig. 2). For augmented bighorns on Mount Nebo, the annual survival rates were estimated at 0.97 (0.66 to 1.00) before observed commingling with domestic sheep and 0.83 (0.65 to 0.93) afterward (Fig. 2).

We observed 1,313 groups of bighorn sheep during the birthing period on Mount Timpanogos (n=726), in Rock Canyon (n=398), and on Mount Nebo (n=189). Across all years and during the birthing season, we recorded 151 young born on Mount Timpanogos and 74 young born in Rock Canyon before and 26 young born after observed commingling between domestic and bighorn sheep; and on Mount Nebo, we recorded 10 young born before and 46 young born after observed commingling with domestic sheep. To assess survival of young to their first winter, we observed 964 groups of bighorn sheep on Mount Timpanogos (n=568), in Rock Canyon (n=277), and on Mount Nebo (n=119) during that season. Survivorship of young to their first winter was 34 % on Mount Timpanogos during the study. Survivorship of young to their first winter was almost 3 times higher in Rock Canyon (Z=5.01, P<0.001) and Mount Nebo (Z=3.62, P<0.001) before observed commingling with domestic sheep (Fig. 3).

Average annual growth rate (λ), indexed from changes in population size, of bighorns on Mount Timpanogos from 2000 to 2009 was estimated at 1.11 (Fig. 4), whereas the growth rate in Rock Canyon was estimated at 1.12 before observed contact with domestic sheep and 0.44 after commingling (Fig. 4). On Mount Nebo, λ for bighorns was estimated at 1.87 before and 0.73 after observed commingling with domestic sheep (Fig. 4).

Discussion

Effects of commingling

Long-term studies documenting population dynamics of bighorn sheep in the wild before and after epizootics of respiratory disease are difficult to conduct, but are needed to better understand implications of fatal pneumonia on the conservation of bighorns (George et al. 2008). We observed commingling between domestic and bighorn sheep in 3 populations of reintroduced bighorns. Although we were unable to collect immunological data or identify the etiological agent that caused die-offs, which is difficult to do in the wild (sensu Plowright et al. 2013), the best models indicated a decrease in survival rates of collared female bighorns in Rock Canyon and on Mount Nebo after observed commingling with domestic sheep. Similar outcomes have been documented in other studies (Cassirer and Sinclair 2007; George et al. 2008). Survival rates for collared female bighorns on Mount

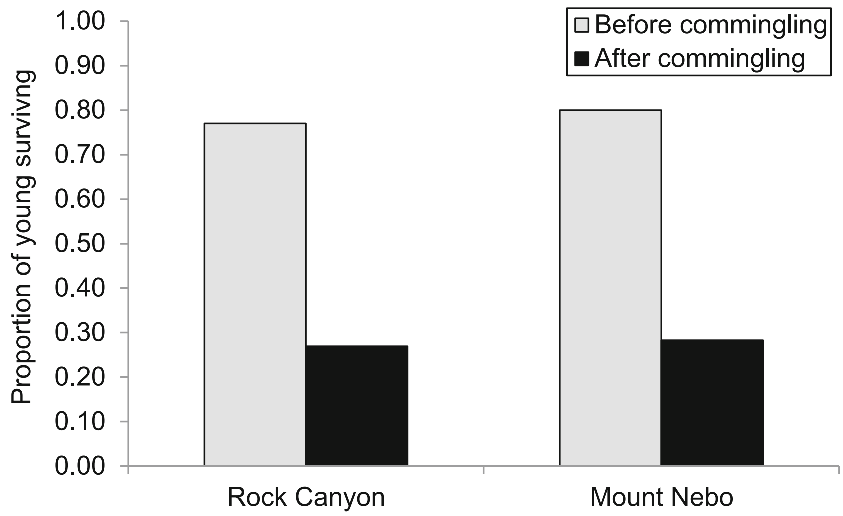

Fig. 3 Proportion of young surviving to their first winter in 2 populations of bighorn sheep before and after observed commingling with domestic sheep in UT, USA, from 2001 to 2009 in Rock Canyon and from 2005 to 2009 on Mount Nebo

Timpanogos were similar to survival rates of collared females in Rock Canyon and on Mount Nebo before observed commingling with domestic sheep. Additionally, on Mount Timpanogos, survival rates remained constant after 2 occasions of commingling with domestic sheep, indicating that not all interactions between domestic and bighorn sheep were detrimental to collared female bighorns in that population. We hypothesize that domestic sheep that interacted with bighorns on Mount Timpanogos were not carriers of pathogens that produced respiratory disease (Besser et al. 2012a), that pathogens were not transferred, or did not lead to fatal pneumonia in collared female bighorns (Wehausen et al. 2011).

Survival rates of founder versus augmented females

We also documented decreases in survival rates of female bighorn sheep that were considered founder (from original releases) in Rock Canyon and on Mount Nebo after observed commingling with domestic sheep. This outcome was noteworthy, because stress of translocation may increase the susceptibility of augmented bighorn sheep to disease (Weiser et al. 2009). The mechanisms leading to outbreaks of epizootic disease in bighorns after contact with domestic sheep in the wild are complex and may differ from the results of controlled pen studies (Wehausen et al. 2011). On Mount Nebo, all bighorns came from the same source herd and releases were separated by just over 2 years; however, survival rates of founder females in that population, as well as in Rock Canyon, were much lower than survival rates of augmented bighorns after observed commingling with domestic sheep. Additionally, on Mount Nebo, had we not evaluated for models including group (founder or augmented), the overall effect of observed commingling would have been difficult to detect, because of overlapping confidence intervals in survival rates of founder and augmented females in that population. We hypothesize that founder animals had a weaker innate immune response, that augmented bighorns had some level of resistance to pathogens, or that the transfer of pathogens or predisposing factors to disease differed between founder and augmented animals (Wehausen et al. 2011; Besser et al. 2012a; Plowright et al. 2013). Indeed, some female bighorn sheep may be chronic carriers of disease, but may not be infected by such maladies (Besser et al. 2013; Cassirer et al. 2013; Plowright et al. 2013). These ideas, however, deserve further experimental testing.

Augmentations of bighorn sheep have been a common management practice for this species for almost 100 years (Singer et al. 2000a). Reintroduced populations of bighorns, however, may be more likely to experience problems with respiratory disease than native populations, especially when releases occur in areas of proximity to domestic sheep (Gross et al. 2000; Singer et al. 2000a; Monello et al. 2001). Decreased survival rates of founder female bighorns in Rock Canyon and on Mount Nebo could have been caused by augmented bighorns that were carrying pathogens when they were released. Such an idea has been forwarded as a potential to spread disease to founder bighorn sheep (Wild Sheep Working Group 2012). Our models, however, did not support this idea. Indeed, no models that included variation in survival rates related to the timing of augmentation received >5 % AIC_c weight. Additionally, in Rock Canyon, survival rates of founder bighorns did not decrease until 11 months after augmentation and within 1 month following observed commingling with domestic sheep. If augmented bighorns were carriers of disease, we would have predicted that founder animals in Rock Canyon and on Mount Nebo would have died during the most stressful time of the year and when increased social interactions occur (i.e., winter to early spring following release) (Cassirer and Sinclair 2007; Cassirer et al. 2013).

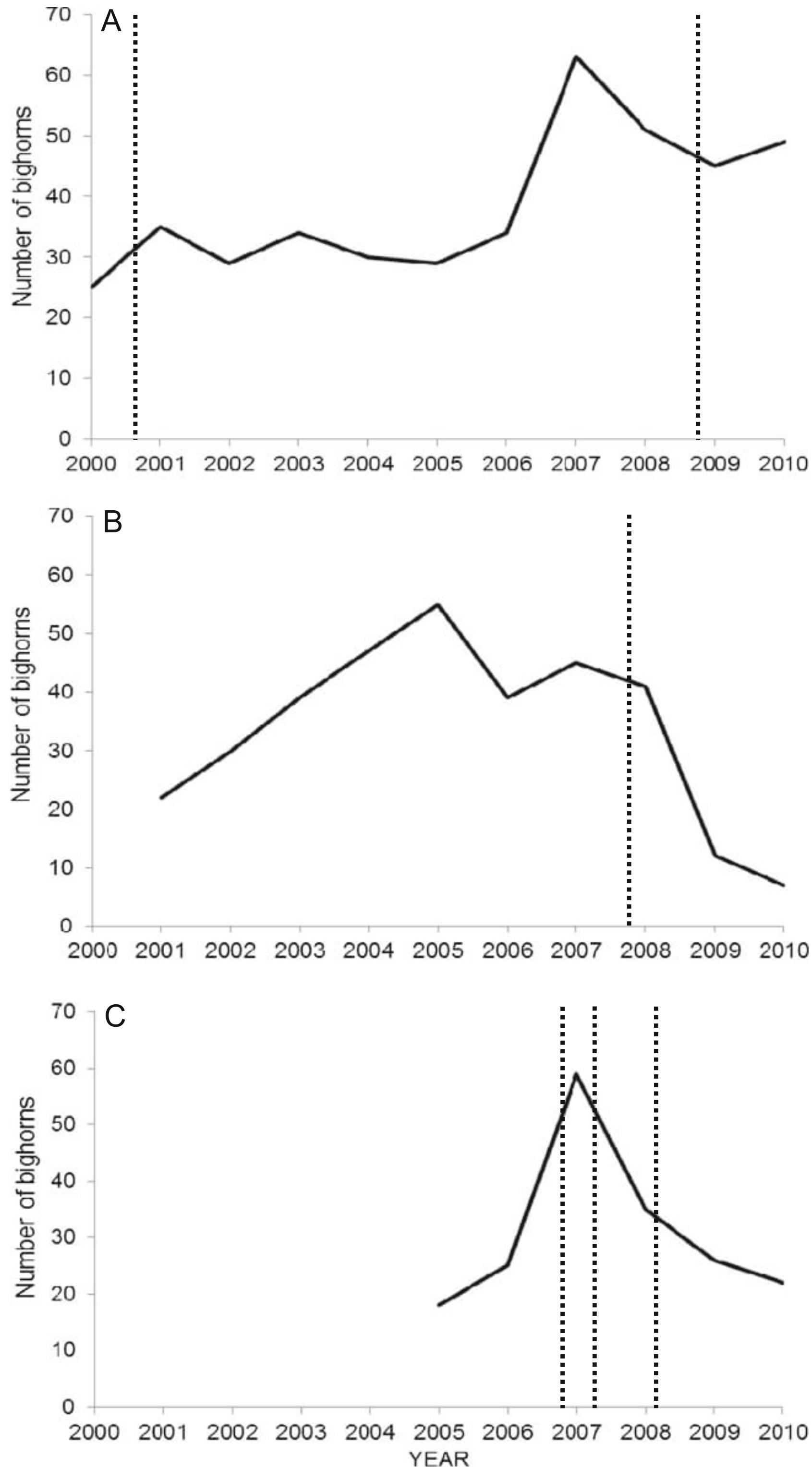

Fig. 4 Number of Rocky Mountain bighorn sheep counted on Mount Timpanogos (**a**), Rock Canyon (**b**), and Mount Nebo (**c**) during winter surveys in UT, USA. *Dashed-vertical lines* represent approximate dates of observed commingling events between domestic and bighorn sheep. Augmentations in all study areas in 2007 contributed to population growth (Table 1)

Survivorship of young

Quantifying survivorship of young bighorn sheep before and after contact with domestic sheep is a valuable way to document potential effects of commingling between those species (Monello et al. 2001; Cassirer and Sinclair 2007; George et al. 2008). In our study, we predicted that the proportion of young surviving to their first winter would be substantially lower after observed commingling with domestic sheep. This prediction was supported in areas (Rock Canyon and Mount

Nebo) in which we could compare survivorship of young before and after observed commingling between domestic and bighorn sheep. Those results were similar to other studies that documented a decrease in survival of young bighorns following suspected outbreaks of disease (Cassirer and Sinclair 2007; Cassirer et al. 2013; Plowright et al. 2013). Respiratory disease likely affected the survivorship of young for all female bighorns (founder and augmented) in Rock Canyon and Mount Nebo, even though survival rates of augmented females that were collared did not decrease in those populations. Indeed, young bighorns may die from the effects of respiratory disease even when adult females do not (Cassirer and Sinclair 2007; Cassirer et al. 2013; Plowright et al. 2013).

Although we could not compare survivorship of young before and after commingling on Mount Timpanogos, because those domestic and wild ungulates were first observed commingling 8 months after the initial release of bighorns, noteworthy patterns emerged in that population. Survivorship of young (n=93) was 40 % from 2000 to 2008. This low value, however, could have been partially attributed to young being born late in some of those years (Whiting et al. 2011), or potential effects of commingling with domestic sheep. After observed comingling with domestic sheep in November 2008 on Mount Timpanogos, survivorship of young (n=58) to their first winter was 26 %, similar to the survivorship values we observed in Rock Canyon and on Mount Nebo after observed commingling with domestic sheep. Once again, those young bighorns may have died from the effects of respiratory disease even when collared females did not (Cassirer and Sinclair 2007; Cassirer et al. 2013; Plowright et al. 2013). After observed die-offs, survivorship of young can be reduced for >5 years (Monello et al. 2001), which could have lingering effects on the establishment of reintroduced populations. We hypothesize that these lingering effects will continue to hinder population growth of bighorns in our study areas.

Population growth

Quantifying changes in population growth before and after commingling of domestic and bighorn sheep is a valuable way to detect the consequences of such interactions (Monello et al. 2001; Cassirer and Sinclair 2007). In Rock Canyon and on Mount Nebo, although not tested statistically, a general pattern emerged indicating decreases in estimated population growth rates after observed commingling of domestic and bighorn sheep, similar to the results reported in other studies (Monello et al. 2001; Cassirer and Sinclair 2007). Another study used information from at least 2 years prior and 2 years after die-offs to compare rates of population growth in bighorns (Monello et al. 2001). We documented long-term survival of collared females (almost 7 years in Rock Canyon) before observed commingling with domestic sheep, which provided a clear picture of the effects of such commingling on population growth of bighorns in that study area.

Density dependence

Density-dependent factors may predispose bighorn sheep to fatal respiratory disease (Monello et al. 2001). Across North America, almost 88 % of pneumonia epizootics in bighorns occurred within 3 years of peak population numbers (Monello et al. 2001). Our study populations were recently reintroduced and consisted of a low number of individuals in each population. Additionally, females in those populations exhibited high pregnancy rates (Whiting et al. 2008, 2010a, 2011) and high survival of young to first winter before contact with domestic sheep, which indicate that those populations were most likely not influenced strongly by density-dependent factors (Martin and Festa-Bianchet 2010).

Proximity of domestic sheep

Fatal respiratory disease can be transmitted to bighorn sheep by male bighorns wandering, contacting domestic sheep, and then returning and infecting other bighorn sheep (Besser et al. 2013), or by overlap of domestic sheep grazing allotments with areas used by bighorn sheep (Carpenter et al. 2014). Domestic sheep we observed most likely were stray animals from trailing operations or from hobby farms of residents who lived along a heavily populated urban interface. For example, in 2003, adjacent to our study areas along the Wasatch Front, we observed as many as 8 flocks of domestic sheep in small backyard pastures within 10 km of areas occupied by bighorns. Also, near Mount Nebo, road corridors that were within 6 km of areas occupied by bighorns were used to move domestic sheep from summer to wintering areas, much closer than the buffer of 20 km recommended to separate domestic and bighorn sheep (Smith et al. 1991; Singer et al. 2000a). The close proximity of bighorns to domestic sheep along the urban interface in our study areas may continue to be problematic, because of the behavioral attraction between these species (Etchberger et al. 1989; Turner et al. 2004; Wehausen et al. 2011). Indeed, in many areas where the urban interface encroaches on habitat of bighorn sheep, infectious diseases will become an increasingly important issue for the conservation of bighorns (Etchberger et al. 1989; Turner et al. 2004)—especially as the likelihood of interactions increases between wildlife and domestic species in those areas (Smith et al. 2009).

Management implications

The conservation of bighorn sheep populations remains an important issue across much of western North America

(Buechner 1960; Monello et al. 2001). Diseases of domestic sheep have long posed concerns for the conservation of bighorn sheep (Buechner 1960; Wehausen et al. 2011), especially for small, reintroduced populations (Gross et al. 2000; Singer et al. 2000b; Cassaigne et al. 2010). Additional information regarding the effects of respiratory disease on population growth in reintroduced bighorns is a pressing need for the conservation of these mammals (Monello et al. 2001), especially because much debate still exists about this controversial topic. In Rock Canyon and on Mount Nebo, we documented reductions in survival rates of founder female bighorns, survivorship of young, and population growth of bighorns after observed commingling with domestic sheep. Nonetheless, on Mount Timpanogos, survival rates remained constant for female bighorn sheep before and after observed commingling with domestic sheep, indicating that not all contact with domestic sheep resulted in die-offs of collared female bighorns. As well as understanding the proximity of release areas to domestic grazing allotments, we recommend that biologists consider hobby farms and trailing operations of domestic sheep in locations adjacent to translocation areas prior to releasing bighorn sheep. Also, if management of bighorn populations is the goal, we recommend spatial and temporal separation of bighorn and domestic sheep wherever possible (Martin et al. 1996; Schommer and Woolever 2008; Wehausen et al. 2011; Besser et al. 2013).

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EXHIBIT 9

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UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF WASHINGTON

WILDEARTH GUARDIANS, and WESTERN WATERSHEDS PROJECT, Plaintiffs, v. KRISTIN BAIL, Okanogan-Wenatchee National Forest, Forest Supervisor, and U.S. FOREST SERVICE, Defendants, S. MARTINEZ LIVESTOCK, a Washington Corporation, Defendant-Intervenor.	No. 2:20-cv-00440-RMP **DECLARATION OF DR. THOMAS BESSER IN SUPPORT OF PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION**

I, Thomas Besser, with full knowledge of the penalties of perjury, declare as follows:

1. I have been a Professor and infectious disease researcher in the Department of Veterinary Microbiology and Pathology, College of Veterinary Medicine, and the Washington Animal Disease Diagnostic Laboratory at Washington State University, Pullman, Washington since 1986. Upon my retirement in September 2019, I became Professor Emeritus.

2. I have been asked by Plaintiffs in this litigation to provide my expert opinion on disease transmission from domestic sheep to bighorn sheep and scientific issues relevant for making management decisions where conflicts exist.

I. Professional Qualifications and Experience.

3. I have over thirty-five years of experience researching the epidemiology and ecology of infectious diseases caused by pathogens across host species. My CV is attached as Exhibit A.

4. I hold a Bachelor of Science degree in Zoology from the University of Wisconsin (1973), a Doctor of Veterinary Medicine degree from the University of Minnesota (1981), and a PhD in Veterinary Science from Washington State University (1986).

5. I have held appointments in the Washington Animal Disease Diagnostic Laboratory throughout my career at WSU: Bacteriology Section Supervisor (1986-2000, during which time I founded the Combined Diagnostic

Microbiology / Infectious Diseases PhD program), Director of Laboratory Services (2000-2004), Molecular Diagnostics Supervisor (2004-2008). Since 2008 I provided consultation on issues related to public health/food safety and wildlife diseases. I was Director of the WSU College of Veterinary Medicine's Immunology and Infectious Diseases graduate studies program (2013-2019). I was an adjunct professor in the Paul G. Allen School for Global Animal Health. In 2016, I was appointed to serve as the WSU/WSF Rocky Crate Endowed Chair in wild sheep disease research, which I held until my retirement.

6. I am a member of the American College of Veterinary Microbiologists and served on their Board of Governors from 2009 to 2012. I am also a member of the American Society for Microbiology, and served as a member of its Applied and Environmental Microbiology Editorial Board from 2008 to 2010.

7. I have received honors for my work from the University of Minnesota, Washington State University, the Washington State Academy of Sciences, and the American Association for the Advancement of Science, and I was a Fulbright Research Fellow at the University of Edinburgh in 2000-2001.

8. I have been conducting research in the fields of veterinary immunology, epidemiology, and microbiology since 1982. One of my primary research focus areas since 2005 has been epidemic pneumonia in bighorn sheep,

including the cause, prevention, and management of this disease through laboratory and field-based microbiological and epidemiological studies.

9. Specifically, my wild sheep research has focused on clarifying the cause of bighorn sheep epizootic pneumonia in order to improve the prevention and management of this disease. In 2009, I joined the Bighorn Sheep Disease Research Consortium, an association of experts studying many aspects of bighorn sheep pneumonia, including transmission, immunity, microbial etiology, connectivity and habitat modeling, pneumonia disease dynamics, and chronic carriage. As a member of this consortium and in my roles as a research microbiologist in the Department of Veterinary Microbiology and Pathology and a diagnostician at the Washington Animal Disease Diagnostic Laboratory, I studied the role of *M. ovipneumoniae* in causing the pneumonia outbreaks that follow its introduction into previously healthy bighorn sheep populations, the persistence of this agent (and the disease it causes) in bighorn sheep populations after it is introduced, and methods to clear the agent from infected bighorn sheep populations to improve their health and productivity. I have also worked on the health and productivity costs of *M. ovipneumoniae* in domestic sheep reservoir, and developed methods to eliminate this pathogen from domestic sheep operations.

10. I served as principal investigator of numerous individual and collaborative research projects looking at disease transmission to bighorn sheep

totaling over $700,000 since 2013. The funding sources for these projects included the U.S. Forest Service, the Idaho Wildlife Disease Research Oversight Committee, the Idaho Department of Fish and Game, the Washington Department of Fish and Wildlife, the Hells Canyon Initiative of Washington, Oregon, and Idaho, and both the national and numerous state chapters of the Wild Sheep Foundation.

11. I have published 361 research papers and 11 book chapters on various infectious disease, immunology, and diagnostic methods topics, including 25 papers on the diagnosis, pathophysiology, epidemiology, management, and control of bighorn sheep pneumonia. The bighorn sheep pneumonia papers where I served as first or senior author included[1]:

Association of Mycoplasma ovipneumoniae *infection with population limiting respiratory disease in free-ranging Rocky Mountain Bighorn Sheep* (Ovis canadensis canadensis) (2008).

Causes of Pneumonia Epizootics among Bighorn Sheep, Western United States, 2008-2010 (2012).

Survival of Bighorn Sheep Commingled with Domestic Sheep in the Absence of Mycoplasma ovipneumoniae (2012).

Bighorn sheep pneumonia: Sorting out the cause of a polymicrobial disease (2013).
Epizootic pneumonia of bighorn sheep following experimental exposure to Mycoplasma ovipneumoniae (2014).

[1] The full citations for these papers are found in my CV, attached to this declaration.

Immunogenicity of a Mycoplasma ovipneumoniae *bacteria for domestic sheep* (Ovis aries) (2014).

Comparison of two bacterial transport media for culture of tonsillar swab from bighorn sheep and mountain goats (2016).

Concordance in Diagnostic Testing for Respiratory Pathogens of Bighorn Sheep (2016).

Exposure of bighorn sheep to domestic goats colonized with Mycoplasma ovipneumoniae *induces sub-lethal pneumonia*. (2017).

Evidence for strain-specific immunity to pneumonia in bighorn sheep (2017).

Pneumonia in bighorn sheep: Risk and resilience. (2018).

A pilot study of the effects of Mycoplasma ovipneumoniae *exposure on domestic lamb growth and performance* (2019).

Risk factors and productivity losses associated with Mycoplasma ovipneumoniae *infection in United States domestic sheep operations* (2019).

Comparison of three methods of enumeration for Mycoplasma ovipneumoniae (2019).

Genetic structure of Mycoplasma ovipneumoniae *informs pathogen spillover dynamics between domestic and wild Caprinae in the western United States* (2019).

12. In addition, I contributed to other papers on bighorn sheep pneumonia as a co-author, which included:

Mycoplasma ovipneumoniae *can predispose bighorn sheep to fatal* Mannheimia haemolytica *pneumonia* (2010).

Use of exposure history to identify patterns of immunity to pneumonia in bighorn sheep (Ovis canadensis) (2013).

Pneumonia in Bighorn Sheep: Testing the Super-Spreader Hypothesis. (2015).

Age-specific infectious period shapes dynamics of pneumonia in bighorn sheep. (2017).

Detection of Mycoplasma ovipneumoniae *in Pneumonic Mountain Goat (*Oreamnos americanus*) Kids*. (2018).

Epidemic growth rates and host movement patterns shape management performance for pathogen spillover at the wildlife-livestock interface (2019).

Removal of chronic Mycoplasma ovipneumoniae *carrier ewes eliminates pneumonia in a bighorn sheep population.* (2020).

Restoration of a bighorn sheep population impeded by Mycoplasma ovipneumoniae *exposure.* (2020).

Previously Unrecognized Exposure of Desert Bighorn Sheep (Ovis canadensis nelsoni) to Mycoplasma ovipneumoniae *in the California Mojave Desert.* (2021).

13. I have given numerous presentations on bighorn sheep pneumonia and *Mycoplasma ovipneumoniae* at conferences, institutions of higher education, symposiums, colloquiums, workshops, and consortia both nationally and internationally. These include addresses presented at the following:

University of California (Davis CA, 2007).

Research Symposium: "Respiratory Disease in Wild and Domestic Sheep" hosted by the Association of State Wildlife Agencies (Salt Lake City, 2008).

Idaho collaborative working group on bighorn – domestic sheep (Boise, 2009).

WA/OR/ID Bighorn Sheep Disease Consortium (various, 2010, 2016, 2019).

Association for Veterinary Epidemiology and Preventive Medicine (Chicago, 2011).

Northern Wild Sheep and Goat Council (various, 2012, 2016, 2018, 2020).

Wild Sheep Working Group of the Western Association of Fish & Wildlife Agencies (Reno, 2013, 2015, 2019, 2020).

Wild Sheep Society of British Columbia (Cranbrook, 2013).

The Wildlife Society symposium on wildlife diseases (Charlotte, 2015).

Wallowa Whitman National Forest (Pendleton, 2015).

Okanagan Wenatchee National Forest (Ellensburg, 2016).

Oregon State University College of Veterinary Medicine (Corvallis, 2016).

Challis Sheep Producers (Challis, 2016, 2019).

University of Idaho Sheep Center Industry Advisory Board (Moscow, 2016).

Desert Bighorn Council (Borrego Springs, 2017).

American Society for Microbiology (New Orleans, 2017).

Midwest Wild Sheep Foundation chapter meeting (Minneapolis, 2017).

Wild Sheep Foundation Chapters and Affiliates (2017, 2018).

Ellensburg Sheep Producers (Ellensburg, 2018).

Desert Tortoise Council (Las Vegas, 2018).

Colorado Collaborative (Denver, 2019).

Montana WSF/DS collaborative meeting (Helena MT, February 2017).

Future Farmers of America state meetings in Washington and Idaho (Pullman WA and Moscow ID, 2018).

Hells Canyon area sheep and goat producers (Asotin, 2019).

NAPGA/WSF meeting on the Shoshone National Forest pack goat access issue (Spokane, August 2018).

14. I have also provided scientific opinions to the U.S. Forest Service in its development of management plans to reduce the risk of disease transmission from domestic sheep to bighorn sheep. These included a 2009 presentation to the agency that discussed transmission of pneumonia from domestic sheep to bighorn sheep, and a 2010 letter to the Payette National Forest explaining recent scientific research showing transmission of respiratory pathogens from domestic sheep to bighorn sheep.

II. Relevant Scientific Studies on Bighorn Sheep Disease.

15. My work on bighorn sheep pneumonia first addressed the question: What infection(s) cause bighorn sheep pneumonia outbreaks? Earlier work had identified many candidate pathogens that were found in bighorn sheep with pneumonia but had not clarified which infections caused the disease. My work targeting the cause of bighorn pneumonia resulted in two key papers.

16. First, in the paper, "Causes of pneumonia epizootics among bighorn sheep, Western United States, 2008-2010", we showed that the bacterium *Mycoplasma ovipneumoniae* was detected in nearly all bighorn sheep tested from eight different herds affected by pneumonia outbreaks but not found in the bighorn

sheep from the control healthy herds studied. No other pathogens had similarly high infection rates in pneumonic herds. Furthermore, our work identified single genetic strain types of *M. ovipneumoniae* involved within each outbreak. Many bacterial species exhibit minor changes in their DNA sequence as they evolve, and *M. ovipneumoniae* is more variable than most. This high variability provides a tool to researchers studying *M. ovipneumoniae* infections, because when it is directly transmitted from animal to animal, there is insufficient time for it to evolve and the DNA strain types match exactly, whereas when acquired from different sources differences in DNA sequences are expected. Therefore, the single strain types detected within outbreaks provide direct evidence that *M. ovipneumoniae* had spread directly from animal to animal as expected for the 'primary' pathogen driving the disease; none of the other candidate bacterial pathogen species showed this definite pattern of animal-to-animal spread.

17. Second, in the paper "Bighorn sheep pneumonia: sorting out the cause of a polymicrobial disease", we compared all the major candidate bighorn sheep pneumonia pathogens for how well they fit widely accepted epidemiological 'causal criteria', a powerful method to clarify complex questions of disease causality. The data summarized in this paper provided very strong support for *M. ovipneumoniae* as the causal agent of bighorn sheep epizootic pneumonia, while providing weak or no support for a causal role for all other candidate pathogens.

We now know that *M. ovipneumoniae* is the pathogen that triggers fatal bighorn sheep epizootic pneumonia outbreaks across the range of the species.

18. The genetic (DNA sequence-based) strain typing method described earlier also provided an explanation for a very important pattern that occurs repeatedly in bighorn sheep pneumonia: When previously healthy bighorn sheep herds first experience a pneumonia outbreak, the disease typically affects all age classes from lambs through adult animals. After these 'all-ages outbreaks' have waned, the surviving adults appear to recover to good health and have relatively normal life expectancies. However, for a period of years to decades afterwards, a different pattern of disease emerges, in which most or all lambs annually develop pneumonia, a pattern referred to as 'lamb pneumonia'.

19. Strain typing revealed that lamb pneumonia cases were infected by the same *M. ovipneumoniae* strain that had been introduced to trigger the earlier all-ages outbreak: A subset of the surviving, apparently healthy ewes continue to carry the outbreak strain in their noses and these chronic nasal carrier ewes serve as a source of the infection to lambs each year. The lamb infection quickly spreads to all lambs in the population, often triggering near 100% mortality before they reach 6 months of age. Herds affected by the lamb pneumonia pattern stagnate or decline in population numbers due to the lack of recruitment (sufficient lambs surviving the first year of life to replace normal adult death rates).

20. Another important aspect of bighorn sheep pneumonia is the spread of disease across metapopulations (groups of populations that are largely independent, but that are connected by occasional animal movements). A metapopulation structure generally adds greatly to the resilience of species like bighorn sheep, since local adverse events affecting one population are countered by animal movements from the other populations within the metapopulation. However, diseases like bighorn sheep pneumonia illustrate the downside of the metapopulation structure: if the animal moving between populations happens to be a chronic carrier of *M. ovipneumoniae,* it can trigger additional outbreaks across the metapopulation.

21. This pattern was clearly documented in the Hells Canyon metapopulation across the borders of Idaho, Washington, and Oregon: after the initial introduction of *M. ovipneumoniae* into northern Hells Canyon in 1995, 14 other populations in the metapopulation experienced disease from the same *M. ovipneumoniae* strain type between 1996 and 2013, due to movements of infected bighorn sheep through the canyon. From this and other examples, it is now clear that introduction of *M. ovipneumoniae* into one bighorn sheep population can trigger disease events in many other populations across long time periods.

22. Once the key role of *M. ovipneumoniae* in bighorn sheep pneumonia was clarified, the logical next question to address was: What is the source of *M.*

ovipneumoniae that infect bighorn sheep to trigger pneumonia outbreaks? We had previously shown that healthy bighorn herds (that is, those with no evidence of pneumonia) were free of this pathogen, based on both highly sensitive nasal swab PCR tests and on blood tests that indicated lack of previous exposure or infection. When some of those healthy, *M. ovipneumoniae*-negative herds subsequently experienced fatal pneumonia outbreaks, *M. ovipneumoniae* were invariably present, showing that the herd had recently become infected.

23. Using genetic strain typing of *M. ovipneumoniae*, we were able to demonstrate that some of those outbreaks were caused by *M. ovipneumoniae* known to be carried by other bighorn sheep herds within the metapopulation, and we concluded that those outbreaks resulted from infections carried by infected bighorn sheep from the source infected herd. However, most new bighorn sheep pneumonia outbreaks were caused by *M. ovipneumoniae* strains that were not carried by any bighorn herds within the region, and we concluded that these outbreaks resulted from contacts with other infected animal sources.

24. The most frequent and widespread *M. ovipneumoniae* infected animal sources are domestic sheep and domestic goats. *M. ovipneumoniae* was first discovered and characterized in domestic sheep, and subsequently it has been recognized as infecting and causing respiratory disease in both sheep and goats globally. *M. ovipneumoniae* is extremely common in domestic sheep: the USDA

National Animal Health Monitoring Service Sheep 2011 project, a national survey of domestic sheep operations, detected *M. ovipneumoniae* infections in approximately 90% of domestic sheep operations sampled, including in all operations larger than 500 head involved in the study.

25. We investigated the ability of *M. ovipneumoniae* carried by domestic sheep to cause bighorn sheep disease in the paper "Epizootic pneumonia of bighorn sheep following experimental exposure to *Mycoplasma ovipneumoniae"*, where we showed that *M. ovipneumoniae* carried by apparently healthy domestic sheep can infect and induce severe pneumonia in previously healthy bighorn sheep. These experiments also showed that domestic and bighorn sheep in proximity interacted readily, for example at feedbunks, water supplies, and bedding areas, including nose-to-nose contacts, such that direct contact transmission would be possible.

26. While *M. ovipneumoniae* has recently been reported in species other than sheep and goats (Caprinae), neither its ability to persist in these hosts for long periods of time, nor the ability of these non-Caprinae hosts to transmit the pathogen to bighorn sheep has been demonstrated, and the low carriage prevalence and the low genetic diversity of *M. ovipneumoniae* in non-Caprinae hosts are not consistent with them representing a separate reservoir for bighorn sheep infection. Together, these data show that domestic sheep, if present on the landscape

occupied by bighorn sheep, carry *M. ovipneumoniae* that represents a large risk for bighorn sheep infection and resulting pneumonia outbreaks. Domestic goats also pose a definite risk to bighorn sheep due to their *M. ovipneumoniae* reservoir status, although limited current data shows that goat sources tend to cause less severe and less persistent bighorn disease. In contrast, non-Caprinae species have not yet been shown to present any risk of transmitting *M. ovipneumoniae* to bighorn sheep.

27. *M. ovipneumoniae* infections from different sources can be identified and distinguished based on variation within their DNA sequences, as mentioned earlier. The DNA sequence-based molecular strain typing method (Multi-Locus Strain Typing, MLST) we developed for *M. ovipneumoniae* can be used to track spread of specific strains within and between bighorn sheep populations, and to identify potential sources of strains responsible for new bighorn pneumonia epizootics.

28. This method was first published in the paper entitled "Evidence for strain-specific immunity to pneumonia in bighorn sheep", which determined "…that introduction of a new genotype (strain) of *M. ovipneumoniae* into a chronically infected bighorn sheep population in the Hells Canyon region of Washington and Oregon was accompanied by adult morbidity (100%) and pneumonia-induced mortality (33%) similar to that reported in epizootics

following exposure of naïve bighorn sheep. This suggests an immune mismatch occurred that led to ineffective cross-strain protection." In this example, more than ten years after a severe pneumonia outbreak, the Black Butte bighorn herd exhibited the common 'lamb pneumonia' pattern where the ewes that survived the outbreak had recovered to apparent good health and a normal life expectancy, but included chronic nasal carriers of the original outbreak strain that when transmitted to lambs resulted in annual high lamb pneumonia mortality.

29. In this paper we documented introduction of a new *M. ovipneumoniae* strain that triggered a dramatic change in the pattern of disease: all adult ewes developed signs of pneumonia (morbidity) and 30% died (mortality). The lambs again experienced a fatal pneumonia outbreak, primarily triggered by lung infections with the newly introduced *M. ovipneumoniae* strain. The finding of lack of cross-strain immunity has since been repeated elsewhere, confirming that the limited immunity that bighorn sheep may develop to a strain of *M. ovipneumoniae* with which they have been infected for years fails to consistently protect them from genetically novel strains that they may encounter.

30. The MLST method was subsequently used for a much larger study of *M. ovipneumoniae* strain types that was published in the paper entitled "Genetic structure of Mycoplasma ovipneumoniae informs pathogen spillover dynamics between domestic and wild Caprinae in the western United States". That paper

concluded: "The genetic data identify domestic sheep as an infection reservoir with multiple and ongoing spillovers to bighorn sheep. Domestic goats are also a source of infection to bighorn sheep, but dynamics of spillover appear to differ from domestic sheep. Strain-sharing across bighorn sheep populations and between wild hosts suggests that, following spillover, pathogen persistence and host movements also contribute to pathogen spread. The ability for *M. ovipneumoniae* to persist and maintain virulence in the absence of spillover is unclear." In this context, 'spillover' refers to infections acquired by a susceptible host species (here, bighorn sheep) from an infected source of a different species (here, domestic sheep or goats).

31. The domestic sheep sampled in this study carried a very large diversity of *M. ovipneumoniae* strains, whereas the infected bighorn sheep herds typically carried only one or two strains. This diversity of strains within domestic sheep likely adds considerably to the risk posed by domestic sheep-bighorn sheep contacts due to the high likelihood that a genetic strain to which the bighorn sheep are not immune will be encountered. A final interesting finding from this study was that strains of *M. ovipneumoniae* carried by domestic sheep were clearly distinguishable from strains carried by domestic goats, indicating that the strain type analysis could indicate the likely source host of this pathogen.

III. Scientific Explanation of Risks to Bighorn Sheep from Domestic Sheep.

32. Bighorn sheep pneumonia occurs when *M. ovipneumoniae* infection is acquired by a susceptible bighorn sheep host following direct or close contact with another animal infected with viable *M. ovipneumoniae*. *M. ovipneumoniae* is unable to survive in the environment for more than a few minutes, so to become infected a susceptible animal must either directly contact the infected host (nose-to-nose contact) or be contacted by respiratory droplets within seconds after they are shed by the infected host (for example, immediately after the host coughs or sneezes).

33. Pathogen transmission is not visible, and its detection requires use of specific diagnostic tests; newly infected animals don’t exhibit signs of the disease until after the incubation period. For *M. ovipneumoniae,* transmission is detectable by realtime PCR tests as soon as 24 hours after infection, but its relatively long incubation period means that a week or more must elapse before the newly infected animal begins exhibiting disease signs (nasal discharge, coughing, etc.). Death from pneumonia may occur from a few weeks to several months after pathogen transmission.

34. The delays between infection and disease onset, and between disease onset and death, make it impossible to identify the specific moment of transmission or the specific animals involved in a *M. ovipneumoniae* transmission event.

However, the MLST strain typing method that we have developed for *M. ovipneumoniae* offers an alternative method to determine the source when this pathogen is newly introduced into bighorn sheep, since finding that MLST strain in a host within or near the bighorn sheep range strongly suggests that the strain was transmitted from that source.

35. For example, given a new pneumonia outbreak in which *M. ovipneumoniae* is detected, the strain can be compared to *M. ovipneumoniae* strains found in potential sources in the region. If no regional bighorn herds carry the strain, then the source must be an infected individual of some other animal host. Potential source animals/herds can then be systematically screened for the outbreak strain. Using these methods, we have successfully identified the sources of *M. ovipneumoniae* strains that were transmitted from domestic sheep and domestic goats, under range conditions, that resulted in bighorn sheep pneumonia outbreaks. This approach offers good potential to clarify the pathogen sources that cause bighorn sheep pneumonia outbreaks; however, it is laborious, time-consuming, and expensive, and dependent on the willingness of the owners of potential pathogen sources to permit sampling and typing of the strains of *M. ovipneumoniae* carried by their animals.

36. *M. ovipneumoniae* induces disease indirectly; the infection damages the muco-ciliary clearance defense mechanisms that normally clears small numbers

of inhaled bacteria from the mouth and throat. In the presence of *M. ovipneumoniae* infection, these inhaled bacteria are not cleared but instead infect and multiply in the lung tissues and airways, and it is these multiple secondary infections that cause severe disease or death. The severity and course of the disease within an individual infected bighorn sheep result from the extent, diversity, and virulence of the secondary infections that occur, and these vary from animal to animal.

37. As discussed above, bighorn sheep that do not die during a pneumonia outbreak return to apparent good health over the subsequent months but may carry *M. ovipneumoniae* for long periods in their nasal passages. In some herds these persistently shedding individuals serve as a source of infection to lambs born in subsequent years, triggering annual pneumonia outbreaks that may kill a high percentage of the lambs for years or even decades after the initial outbreak. It is now clear that such recurrent lamb pneumonia outbreaks may threaten extirpation of the affected bighorn sheep herds, as the herds are unable to produce enough offspring to recover from the disease event. In addition, carriers of *M. ovipneumoniae* may infect other bighorn herds during movements within metapopulations.

38. After decades of research to clarify this complex disease, the risk posed by pneumonia outbreaks to bighorn sheep populations is now recognized to

flow directly from the infection of the bighorn sheep population with *M. ovipneumoniae* from another animal host. Such infections are relatively infrequent, as a series of uncommon events must occur for pathogen spillover to occur. However, if sources of infection are prevalent within or near the bighorn home ranges, the risk of infection is cumulative across years. When I began studying bighorn sheep pneumonia, the three bighorn herds in the Yakima WA area (Umtanum, Tieton, and Cleman Mountain) were all free of *M. ovipneumoniae* and lacked evidence of significant respiratory disease. Since then, Umtanum was infected with *M. ovipneumoniae* in 2009, Tieton in 2013, and Cleman Mountain in 2020.

39. These outbreaks differed in their severity, and each was associated with a different genetic strain type of *M. ovipneumoniae.* All three of the outbreak-associated strain types belonged to the group of strain types typically detected in domestic sheep, rather than domestic goats. None of the *M. ovipneumoniae* genetic strain types associated with these outbreaks had previously been detected in any bighorn sheep population anywhere in western North America, ruling out bighorn sheep to bighorn sheep transmission as the source of infection of these herds. Together, these three outbreaks indicate a high regional risk of spillover *M. ovipneumoniae* transmission to bighorn sheep, suggesting that increased efforts to

remove sources of this pathogen will be required to permit recovery of these regional bighorn sheep populations.

40. In conclusion, over the last decade the science around pneumonia infections of bighorn sheep has evolved significantly. It has established that *M. ovipneumoniae* is the agent that causes respiratory disease episodes in bighorn populations, and that many strains of *M. ovipneumoniae* exist such that infection with one strain will not prevent future infection by another strain. Domestic sheep carry many strains of *M. ovipneumoniae* and together with domestic goats are the most likely source of transmission to bighorn sheep. Because of the potential for a significant die-off within an infected bighorn herd, spread of disease to other herds, and long-lasting impacts on lamb recruitment within infected populations, the consequences of *M. ovipneumoniae* transmission from a domestic sheep to a bighorn sheep are severe. Such consequences are evident in the three Yakima area bighorn herds, which all have experienced infection of *M. ovipneumoniae* from domestic sheep and could experience further disease impacts from future transmission from domestic sheep or goats within or near their home ranges.

Pursuant to 28 U.S.C. § 1746, I declare under penalty of perjury that the foregoing is true and correct.

Signed this 26th day of February 2021 in Moscow, Idaho.

[signature]

Thomas Besser

EXHIBIT 10

Evidence for strain-specific immunity to pneumonia in bighorn sheep: Immunity in Bighorn Sheep

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Research Article

Evidence for Strain-Specific Immunity to Pneumonia in Bighorn Sheep

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ABSTRACT Transmission of pathogens commonly carried by domestic sheep and goats poses a serious threat to bighorn sheep (*Ovis canadensis*) populations. All-age pneumonia die-offs usually ensue, followed by asymptomatic carriage of *Mycoplasma ovipneumoniae* by some of the survivors. Lambs born into these chronically infected populations often succumb to pneumonia, but adults are usually healthy. Surprisingly, we found that introduction of a new genotype (strain) of *M. ovipneumoniae* into a chronically infected bighorn sheep population in the Hells Canyon region of Washington and Oregon was accompanied by adult morbidity (100%) and pneumonia-induced mortality (33%) similar to that reported in epizootics following exposure of naïve bighorn sheep. This suggests an immune mismatch occurred that led to ineffective cross-strain protection. To understand the broader context surrounding this event, we conducted a retrospective analysis of *M. ovipneumoniae* strains detected in 14 interconnected populations in Hells Canyon over nearly 3 decades. We used multi-locus sequence typing of DNA extracts from 123 upper respiratory tract and fresh, frozen, and formalin-fixed lung samples to identify 5 distinct strains of *M. ovipneumoniae* associated with all-age disease outbreaks between 1986 and 2014, a pattern consistent with repeated transmission events (spillover) from reservoir hosts. Phylogenetic analysis showed that the strain associated with the outbreak observed in this study was likely of domestic goat origin, whereas strains from other recent disease outbreaks probably originated in domestic sheep. Some strains persisted and spread across populations, whereas others faded out or were replaced. Lack of cross-strain immunity in the face of recurrent spillovers from reservoir hosts may account for a significant proportion of the disease outbreaks in bighorn sheep that continue to happen regularly despite a century of exposure to domestic sheep and goats. Strain-specific immunity could also complicate efforts to develop vaccines. The results of our study support existing management direction to prevent contacts that could lead to pathogen transmission from domestic small ruminants to wild sheep, even if the wild sheep have previously been exposed. Our data also show that under current management, spillover is continuing to occur, suggesting that enhanced efforts are indicated to avoid introducing new strains of *M. ovipneumoniae* into wild sheep populations. We recommend looking for new management approaches, such as clearing *M. ovipneumoniae* infection from domestic animal reservoirs in bighorn sheep range, and placing greater emphasis on existing strategies to elicit more active cooperation by the public and to increase vigilance on the part of resource managers.

KEY WORDS bighorn sheep, disease ecology, Hells Canyon, livestock-wildlife interface, molecular epidemiology, multi-locus sequence typing, *Mycoplasma ovipneumoniae*, *Ovis canadensis*.

Pneumonia in bighorn sheep (*Ovis canadensis*) is a population-limiting disease associated with transmission of pathogens from domestic sheep and goats (Foreyt and Jessup 1982, Besser et al. 2013, Cassirer et al. 2013). As with many other wildlife diseases, a lack of comprehensive, system-specific information hampers disease management (Besser et al. 2013, Joseph et al. 2013). Limiting contact with domestic sheep and goats is the primary strategy for preventing disease emergence in bighorn sheep (Western Association of Fish and Wildlife Agencies Wild Sheep Working Group 2012, The Wildlife Society 2015). Although currently the best management option available, implementation is politically and logistically difficult because of the natural movements of wild animals, unregulated presence of domestic sheep and goats on private lands, and concerns by the livestock industry about losing access to public grazing allotments. Reliable knowledge about health

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threats and potential solutions will help wildlife and land managers make appropriate risk management decisions that will succeed in resolving the problem of pneumonia in bighorn sheep.

Based on the hypothesis that *Mannheimia haemolytica* expressing leukotoxin is the key causal pathogen, researchers have tested numerous vaccines to boost immunity to disease in bighorn sheep. However, so far no vaccine has protected wild sheep commingled with domestic sheep or goats in captive settings or shown potential for efficacy in free-ranging animals (Callan et al. 1991, Kraabel et al. 1998, Cassirer et al. 2001, Subramaniam et al. 2011, Sirochman et al. 2012). There may be several reasons for the elusiveness of an effective vaccine. First, there is a basic question as to the role of *M. haemolytica* in the disease (Besser et al. 2013) and second there are significant technical difficulties associated with vaccine development and application. Experimental challenge with leukotoxin-positive *M. haemolytica*, a well-described respiratory pathogen in domestic ruminants, is lethal to bighorn sheep in captivity (Foreyt et al. 1994, Dassanayake et al. 2009). However, *M. haemolytica* is only weakly associated with pneumonia epizootics in free-ranging bighorn sheep populations (Besser et al. 2012*b*). The pathology, microbiology, and the course of disease experimentally induced with *M. haemolytica* also do not match observations from the field (Besser et al. 2014). Recently, application of sensitive molecular diagnostic techniques on high quality samples led to identification of *Mycoplasma ovipneumoniae*, a previously overlooked bacterium, as the pathogen most strongly supported as a primary causal agent of pneumonia in bighorn sheep (Besser et al. 2008, 2012*a*, *b*).

M. ovipneumoniae is host-specific to Caprinae, and is frequently carried asymptomatically by domestic sheep and goats (Martin and Aitken 2000). When introduced into naïve bighorn sheep populations, outbreaks of polymicrobial pneumonia ensue, sometimes resulting in high mortality in all age classes (Besser et al. 2008, 2014). After all-age pneumonia outbreaks, surviving adults usually maintain good health and normal life spans, although some individuals chronically carry *M. ovipneumoniae* in their upper respiratory tract (Besser et al. 2013). Both carriers and non-carriers are resistant to disease although this protection fails to prevent epizootics in lambs (Plowright et al. 2013, Manlove et al. 2016).

M. ovipneumoniae is also associated with mild and transient respiratory disease, usually in juveniles, in its normal domestic sheep and goat hosts (DaMassa et al. 1992, Martin and Aitken 2000). However, several investigators have reported that *M. ovipneumoniae* infections in domestic sheep and goats can cause severe pneumonia, particularly when multiple strains are present (Parham et al. 2006, Rifatbegović et al. 2011). This could be linked to a strain-specific immune response that fails to provide universal protection. Many pathogens are able to evade host immune responses by expressing a diversity of surface-exposed targets for neutralizing antibodies. From influenza virus to *Mycoplasma* spp., antigenic variation within and across strains enables immune escape by pathogens and also complicates development of vaccines (Citti et al. 2010, Vink et al. 2012, Quiñones-Parra et al. 2014).

We documented the effects of invasion of a novel strain of *M. ovipneumoniae* into a group of free-ranging bighorn sheep that had harbored adult carriers for nearly 20 years following an all-age pneumonia outbreak (Cassirer et al. 1996, Plowright et al. 2013). Our expectation was that these adults were immune to the pathogen and that invasion of a new strain would not cause disease.

STUDY AREA

We conducted this study near Heller Bar at the mouth of the Grande Ronde River in Asotin County, Washington, USA (46.079° N, −116.986° W). The area was located in low elevation (250–1,250 m) canyon grasslands and cliffs along the breaks of the Grande Ronde and Snake Rivers on the northern edge of Hells Canyon. Summers were hot ($\bar{x}$ highs in Jul and Aug = 26–32° C) and winters were mild ($\bar{x}$ lows in Dec and Jan = −2 to 2° C). Average annual precipitation was 31 cm. July and August were the driest months and peak precipitation occurred in May. Plant associations were dominated by perennial bunchgrass (*Pseudoroegneria spicata* and *Festuca idahoensis*) communities, with deciduous riparian shrub stringers and upland shrub-fields. Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) stands occurred on northerly aspects. In addition to bighorn sheep, common ungulates in the study area included mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and elk (*Cervus elaphus*). Potential predators of bighorn sheep included cougars (*Felis concolor*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), wolves (*C. lupus*), and black bears (*Ursus americanus*). Over 50% of the area was publicly owned and managed by federal and state agencies chiefly for wildlife, recreation, and seasonal (spring) cattle grazing. A low density, unincorporated rural community was scattered on adjoining private rangelands at the mouth of the Grande Ronde River and along the adjacent Snake River.

Following extirpation in the early 1900s, the Washington Department of Fish and Wildlife reintroduced bighorn sheep to the Joseph Creek Wildlife Area near Heller Bar. Between 1977 and 1989, 39 sheep were translocated from Washington, Oregon, and Montana to establish the Black Butte population (Johnson 1995). This became one of 16 interconnected populations that comprise the Hells Canyon bighorn sheep metapopulation. The Black Butte population increased to approximately 215 animals before a pneumonia outbreak occurred in 1995; 70% of the sheep died or were transferred to captivity in an attempt to stop the epidemic (Cassirer et al. 1996). The source of the outbreak was thought to be domestic sheep or goats on private lands within the Black Butte bighorn sheep population range (Rudolph et al. 2003). The population never recovered because of chronically low recruitment due to pneumonia-induced mortality in lambs (Plowright et al. 2013). By 2013, only 36 bighorn sheep were observed in surveys, and the population was estimated at 45 (Cassirer et al. 2013, Washington Department of Fish and Wildlife, unpublished data). Three spatially distinct female groups occur in the population: Heller Bar, Shumaker, and Joseph Canyon. The groups are connected by movements of males, but we observed no female interactions across groups during this study. The Heller Bar female group was most accessible from the road and was the subject of this investigation.

METHODS

Observations

We monitored the Heller Bar female group during 2013 and 2014 as part of a study of contact patterns and lamb survival. We could individually identify 4 (31%) and 11 (85%) of the 13 adult females in 2013 and 2014, respectively, by numbered ear tags and color-coded and numbered very high frequency (VHF) radio-collars. One unmarked female was missing a horn, so all 13 sheep were individually identifiable in 2014. We located marked animals from the ground by radio-telemetry and then observed them through binoculars and a spotting scope. We conducted frequent and intensive observations between 1 May and 16 July to document productivity and neonatal survival (2013 median observation interval = 4 days, median duration of each observation = 3 hr; 2014 median observation interval = 1.5 days, median duration = 2 hr). Frequency of observation from 17 July through 26 August was every 10 days in 2013 and every 5 days in 2014, and from 26 August through the first week in October we observed the sheep once a month in 2013 and every 10 days in 2014. Median duration of observations from 17 July through October was 1 hour in both years. At each observation we recorded female and lamb health and behavior. Animals observed with nasal discharge, droopy ears, head shaking, or lethargy received a clinical score of 1, and animals observed coughing received a clinical score of 2. Sheep with no evidence of disease received a clinical score of 0.

Radio-collars on adults were equipped with a switch that triggered a fast pulse mortality signal if no movement was detected for 4 hours. We conducted site investigations, and where possible, retrieved carcasses whole when mortalities were detected. Where this was not possible, we conducted field necropsies and collected the head, the respiratory tract, and grossly abnormal tissues when available. We detected lamb mortalities through observation and retrieved whole dead lambs when autolysis was not too advanced for diagnostic testing (Cassirer and Sinclair 2007). We assigned lamb mortality dates as the midpoint between the last live observation and either the date when the carcass was found, or the date when the dam was first observed without a lamb if no carcass was located. We assumed a female had lost her lamb when it was found dead or when the number of lambs declined and she was never again observed with a lamb that year. All cadavers and tissues were submitted to the Washington Animal Disease and Diagnostic Laboratory (WADDL; Pullman, WA, USA) for analysis.

Health Sampling

We captured and sampled females in February ($n = 11$ of 13) and July ($n = 2$ of 11) 2014. In October 2014, we resampled all 8 remaining sheep when we transferred them to captivity. We conducted captures via helicopter netgun and by darting from the ground with chemical immobilizing agents. All capture and handling followed animal care protocols approved by the Washington Department of Fish and Wildlife. Sampling entailed collecting throat swabs and placing them in buffered glycerol or Port-a-cul transport media (Becton, Dickinson, and Company, Franklin Lakes, NJ, USA, #220144, #221606) for aerobic culture to detect Pasteurellaceae, swabbing nasal passages and placing swabs in mycoplasma broth (#102, Hardy Diagnostics, Santa Maria, CA, USA) for culture enrichment and polymerase chain reaction (PCR) detection of *M. ovipneumoniae* (Ziegler et al. 2014), and collection of serum for detection of antibodies to *M. ovipneumoniae* (competitive enzyme-linked immunosorbent assay [ELISA]), bovine respiratory syncytial virus (virus neutralization [VN]), bovine virus diarrhea (VN), infectious bovine rhinotracheitis (VN), and bovine parainfluenza-3 (PI-3, VN). Diagnostic testing on the above samples was conducted by WADDL.

We also collected upper respiratory washes by flushing nasal passages with 50 ml of phosphate-buffered saline and swabbed the oropharynx. We kept samples cool and processed them within 48 hours of collection, or stored them at -20° C. We extracted DNA (DNeasy, Qiagen, Redwood City, CA, USA) from swabs, from 10-ml aliquots of nasal wash, and from lung tissues of animals that died during the study as well as 2 pneumonic lambs that died in adjacent populations in 2013 to test for presence of pneumonia agents. We used a multiplex PCR to detect Pasteurellaceae including *Bibersteinia trehalosi*, *Pasteurella multocida*, and *Mannheimia* spp. (Besser et al. 2012*b*) and performed PCR for *lktA*, the gene encoding leukotoxin A, the major virulence factor of *Mannheimia* spp. and *B. trehalosi* (Walsh et al. 2016). If an agent was detected by either PCR or culture on any sample, we classified the animal as positive for that agent.

Strain Typing

Health of the Hells Canyon bighorn sheep metapopulation has been intensively monitored since the 1995 pneumonia outbreak in the Black Butte population, and intermittently prior to this. Therefore, we had access to fixed, frozen, and fresh lung tissue and swab samples collected from 1995–2015 in the Heller Bar female group and from 1986–2015 in adjacent female groups and populations. We extracted DNA from a subset of these sources to detect and strain type *M. ovipneumoniae* within the study population and the metapopulation through time. Detection was based on conventional (McAuliffe et al. 2003) and realtime (Ziegler et al. 2014) PCR.

We used multi-locus sequence typing (MLST) to characterize strains using partial DNA sequences of the 16S-23S intergenic spacer region (IGS), the small ribosomal subunit (16S), and the genes encoding RNA polymerase B (*rpoB*) and gyrase B (*gyrB*). We amplified these targets with PCR using a suite of existing and newly developed primers (Table 1). Because of the high degree of DNA sequence

Table 1. Oligonucleotide primers for polymerase chain reactions (PCR) used to amplify *Mycoplasma ovipneumoniae* multi-locus sequence typing (MLST) targets. Nesting refers to external and internal primer sets used for nested PCR reactions for amplification of the MLST loci, IGS, *rpoB*, and *gyrB,* when amplification from the default (internal) primers produced insufficient DNA template for sequencing.

Target[a]	Nesting	Oligonucleotide primer sequence	Reference
LM-F		TGAACGGAATATGTTAGCTT	McAuliffe et al. (2003)
LM-R		GACTTCATCCTGCACTCTGT	McAuliffe et al. (2003)
Ex-IGS-F	External	GTTAACCTCGGAGACCATTG	This paper
Ex-IGS-R	External	GTTTGCTAGGTTGGGTTTCC	This paper
IGS-F	Internal	GGAACACCTCCTTTCTACGG	Besser et al. (2012*b*)
IGS-R	Internal	CCAAGGCATCCACCAAATAC	Besser et al. (2012*b*)
Ex- *rpoB* –F	External	AGTTATCACAATTTATGGATCAAA	This paper
Ex- *rpoB* –R	External	GCTCAAAGTTCCATTTCNCCGAA	This paper
rpoB –F	Internal	TCGGCTTCAGCAATTCCTTTCTT	This paper
rpoB –R	Internal	TCGGCTGTTGGGTTGTCTTCTC	This paper
Ex- *gyrB* –F	External	AAAACGWCCAGGKATGTATATTGG	This paper
Ex- *gyrB* –R	External	GGATCCATTGTTGTTTCTCATAATTG	This paper
gyrB –F	Internal	GGGTCAAACAAAAGCAAAACTAAA	This paper
gyrB –R	Internal	ACGGAATAAAAATGTCAAAAGTAA	This paper

[a] LM = small ribosomal subunit (16S) gene, IGS = 16S-23S intergenic spacer, *rpoB* = β subunit of RNA polymerase gene, *gyrB* = gyrase B gene, F = Forward, R = Reverse.

variation in *M. ovipneumoniae*, the biggest challenge in developing this ensemble of loci was identification of targets with sufficiently conserved primer binding site sequences to enable consistent PCR amplification for subsequent sequencing. The loci selected for this study each exhibited extensive sequence polymorphism and together provide a highly discriminatory test. We typed the concatenated sequences using multi-locus sequence analysis because of the large numbers and diversity of the alleles detected at each target locus. We aligned sequences using Clustal Omega (http://www.ebi.ac.uk/Tools/msa/clustalo/, accessed 06 Sep 2016). We report sequence divergence as the percentage non-identity.

All PCR protocols included a preliminary dissociation phase (95° C, 15 min), amplification, and a final extension phase (72° C, 7 min). We amplified the 16S target using 35 cycles of 30 seconds each of dissociation (95° C), annealing (58° C), and extension (72° C). We amplified the IGS target using 35 cycles of dissociation (95° C, 1 min), annealing (52° C, 2 min), and extension (72° C, 2 min). For nested IGS amplification, the parameters for the external primers were identical except that the annealing temperature was 54° C. For *rpoB* and *gyrB*, we used inner and nested reactions with identical amplification conditions: dissociation (95° C, 1 min), annealing (50° C, 1 min), and extension (72° C, 2 min). We treated the extracts with alkaline phosphatase and exonuclease I (FastAP and ExoI, ThermoFisher Scientific, Waltham, MA, USA) according to the manufacturer's instructions. We submitted extracts to Amplicon Express (Pullman, WA, USA) to determine forward and reverse DNA sequences using the same primers used for PCR amplification. Representative sequences of all 4 target loci for the gentoypes herein are available in Genbank: strain 393 (KU986495, KU986500, KU986503, KU986506, representing IGS, 16S, *rpoB*, and *gyrB*), strain 404 (KU986496, KU986501, KU986504, KU986507), strain 415 (KU986494, KU986499, KU986502, KU986505), strain 402 (KU986493, KU986498, representing IGS and 16S), and strain 419 (KU986492, KU986497).

Statistical Analysis

We used a Kaplan–Meier staggered entry estimator and a Cox proportional hazard model to analyze survival of females and lambs. We fit trend lines to 7-day moving averages of clinical scores using a lowess smoothing factor derived from locally weighted moving mean scores spanning 25% of the full dataset (2–3 weeks). We used a Fisher's exact test to analyze prevalence of pneumonia agents before, during, and after the outbreak and to compare agents present in adult and lamb mortalities. We used a Kruskal–Wallis rank-sum test to determine whether neutralizing titers to PI-3 differed before, during, and after the outbreak. We used a 1-way analysis of variance (ANOVA) and Tukey contrasts to test for differences in serologic antibody titers to *M. ovipneumoniae* over the course of the outbreak and a 2-sided *t*-test to compare pre-outbreak antibody titers to *M. ovipneumoniae* in animals that died and those that survived. We used a Wilcoxon rank sum test with continuity correction to analyze duration of clinical signs. We conducted analyses with package survival (Therneau 2015), and stats and base packages in R (R Core Team 2015).

RESULTS

Survival and Clinical Signs of Disease

In 2013, we observed all marked females with lambs, and median parturition date was 18 May (range = 5–20 May). In 2014, we observed 10 of 13 females with live lambs and median parturition date was 8 May (range = 27 Apr–17 May). One marked female and her lamb died, presumably of dystocia, on 16 May 2014 (e5 and L5, Fig. 1a), 1 marked female was observed with a dead 2-day old lamb (e10, Fig. 1a), and 1 unmarked female appeared to be pregnant but was never observed with a lamb (e22, Fig. 1a).

We observed clinical signs of pneumonia in lambs starting 1 June in 2013 and 26 May in 2014. Symptoms continued until the day the last lamb died, which was 30 June in 2013, and 2 July in 2014 (Fig. 1). Median lamb mortality date was 28 June in 2013 and 24 June in 2014, at a median age

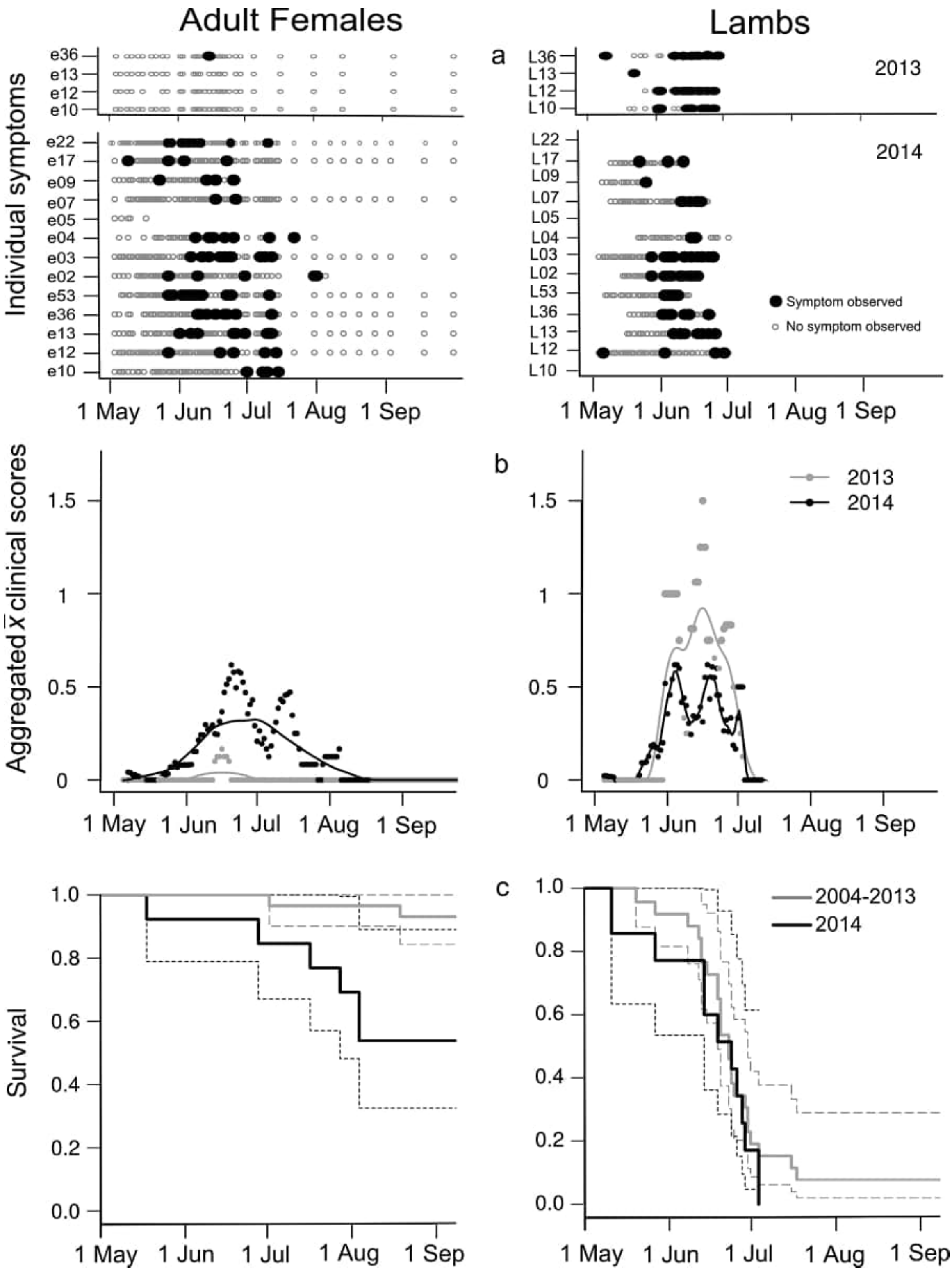

Figure 1. Clinical signs of pneumonia and survival of bighorn sheep in the Black Butte, Washington population during summers 2013 ($n = 4$ adult F and 4 lambs) and 2014 ($n = 13$ adult F and 10 lambs). (a) Time series of field observations of pneumonia symptoms in adult females (e) and their lambs (L). Observations ending prior to September indicate individual died. (b) Smoothed average daily clinical scores for adult females and lambs. (c) Adult female and lamb survival between May and October 2014 and survival between May and October during the 10 previous years, 2004–2013 (Kaplan–Meier curves and 90% CIs).

of 40 and 44 days, respectively. All lambs died both years and there were no differences in lamb survival curves between years (log $\text{rank}_1 = 0.01$, $P = 0.92$) or between 2014 and the previous 10 years (Fig. 1c). We submitted 11 lambs for necropsy (6 in 2013 and 5 in 2014). With the exception of 1 lamb that died at approximately 2 days of age in 2014 (L10, Fig. 1a), all lambs presented characteristic lesions of bighorn lamb respiratory disease, including moderate to

Table 2. Prevalence of *Mannheimia* spp. (Mh), *Bibersteinia trehalosi* (Bt), *Pasteurella multocida* (Pm), Pasteurellaceae leukotoxin encoding gene (*Lkt*A), and *Mycoplasma ovipneumoniae* (*Movi*) in asymptomatic bighorn sheep females (F) sampled before and after a pneumonia outbreak, symptomatic females during the outbreak, and in the lungs of pneumonic females that died in the Black Butte population and pneumonic lambs that died in Black Butte, (10) and adjacent populations (2), Washington and Oregon, USA.

Agent	F before ($n = 11$)	F during (symptomatic) ($n = 2$)	F pneumonia mortalities ($n = 3$)	Lamb pneumonia mortalities ($n = 12$)	F after ($n = 8$)
Mh	0.91	1.00	0.00	0.70	0.75
Bt	0.82	1.00	1.00	0.80	1.00
Pm	0.73	1.00	1.00	0.10	1.00
*Lkt*A	0.27	0.50	0.33	0.50	0.38
Movi	0.09	1.00	1.00	1.00	0.13

severe, subacute to chronic bronchopneumonia and otitis media.

Median age at first observation of clinical signs in lambs was 20 days (range: 7–35), median duration of clinical signs was 22 days (range: 1–59), and median age at death was 42 days (range: 22–66). Assuming that lambs were infected by 4 days of age and lung lesions were present by 10 days of age (Besser et al. 2008), we estimated a median latent period of 16 days (range: 3–31) between infection and first observation of disease symptoms in lambs and a median infection period of 38 days (range: 18–62) prior to death.

In adults, the only evidence of possible respiratory disease in 2013 was a single observation of coughing on 14 June, and all adults survived. In 2014, we observed clinical signs of pneumonia in adults starting in May. By June, all adults exhibited symptoms of pneumonia including severe prolonged coughing (Fig. 1a and b). Five adult females (38%) died between May and August 2014 (difference between summers, log $\text{rank}_1 = 5.98$, $P = 0.01$) and the hazard of an adult female dying in the summer of 2014 was 6.83 times higher ($\text{SE} = 0.83$, $P = 0.02$) than in any of the previous 10 summers (2004–2013, Fig. 1c). We did not observe pneumonia symptoms prior to the first adult death on 16 May 2014. Subsequent mortalities followed observation of clinical signs of pneumonia and occurred on 26 June, 18 July, 27 July, and 3 August (Fig. 1a). Median duration of clinical signs was 36 days (range = 18–81 days), which was longer than observed in lambs (median = 22 days, range = 1–59, $W = 136.5$, $P < 0.001$). Duration of clinical signs did not differ between adults that died and those that survived (Fig. 1a, Wilcoxon rank sum $W = 20$, $P = 1.0$). We submitted samples to WADDL from all (4 of 5) mortalities where sufficient tissues were available for diagnosis. No gross or histological evidence of respiratory disease was found in the female that died on 16 May, although evaluation of tissues at WADDL was limited because of autolysis. The 3 adult females submitted for necropsy between late June and early August were diagnosed with chronic, moderate to severe bronchopneumonia. The survivors appeared to make a full recovery with no evidence of ongoing disease.

Microbiology and Immune Responses

M. ovipneumoniae was the only pneumonia agent detected more frequently in the lungs of adults that died of pneumonia than in the upper respiratory tract of healthy adults before and after the outbreak ($\chi_1^2 = 26.66$, $P < 0.001$; Table 2). Prevalence of other suspected pneumonia agents in the upper respiratory tract of symptomatic adults sampled during the outbreak was similar to that detected in the lungs of adults that died of pneumonia except that *Mannheimia* spp. were detected in the upper respiratory tract of live adults but not in the lungs of adults that died. We found no differences in prevalence of pneumonia agents present in upper respiratory tract samples collected before and after the outbreak ($\chi_1^2 < 2.6$, $P > 0.2$) or in the lungs of lambs that died in 2013 and 2014 ($\chi_1^2 < 0.39$, $P > 0.5$). Detection of *Mannheimia* spp. was more common in lamb mortalities than in adult mortalities ($\chi_1^2 = 4.55$, $P = 0.07$), and *P. multocida* was more frequently detected in the lungs of dead adults than lambs ($\chi_1^2 = 8.78$, $P = 0.01$; Table 2).

We detected serologic evidence of exposure to PI-3 (VN titer ≥ 4) and *M. ovipneumoniae* (ELISA inhibition > 50%) in adults before, during, and after the 2014 pneumonia outbreak. We did not detect evidence of exposure to other respiratory viruses during the study. Average *M. ovipneumoniae* ELISA percent inhibition (%I) values prior to the outbreak (69%) increased significantly to 89%I and 82%I during and after the disease event, respectively ($F_{2,18} = 4.811$, $P = 0.02$; Fig. 2a). Individuals that died during the outbreak had higher *M. ovipneumoniae* ELISA % I values prior to the outbreak ($\bar{x} = 79\%$) than those that survived ($\bar{x} = 59\%$, $t_{7.5} = 3.02$, $P = 0.02$; Fig. 2b). Median PI-3 titers of 256 ($\log_2 7.7$) did not change significantly over the course of the outbreak ($\chi^2_2 = 4.55$, $P = 0.23$).

Strain Typing

We genotyped *M. ovipneumoniae* from all Heller Bar bighorn sheep where it was detected in 2013 ($n = 7$) and 2014 ($n = 11$). We found a single strain in 2013 based on identical DNA sequences of each of the 4 MLST loci, and that strain was also detected in the first lamb to die of pneumonia in 2014. All subsequent detections of *M. ovipneumoniae* differed from the 2013 strain at 3 MLST loci. The IGS sequences differed by 32 single nucleotide polymorphisms (SNP) and 3 base insertions or deletions (indels, 8.7% divergent), *rpoB* by 16 SNP (2.8% divergent) and *gyrB* by 16 SNP (4% divergent). The 16S sequences did not differ between strains.

We report strain differences by IGS sequences because we were unable to amplify *rpoB* and *gyrB* from DNA extracted

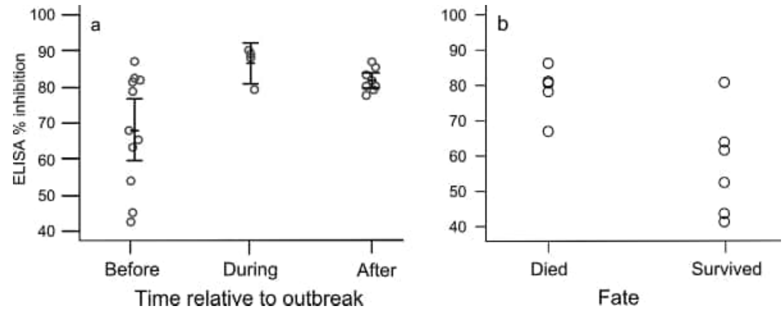

Figure 2. Serologic titers (competitive enzyme-linked immunosorbent assay [ELISA]) to *Mycoplasma ovipneumoniae* in bighorn sheep in Black Butte, Washington, February–October 2014. (a) Mean and 90% confidence intervals before, during, and after a pneumonia outbreak. (b) Antibody titer levels before the outbreak in adults that survived ($\bar{x} = 59\%$) and those that died ($\bar{x} = 79\%$).

from formalin-fixed, paraffin-embedded lung tissues, the only specimens available prior to 2006. Because each of these strains differed by indels in IGS, the strains are conveniently designated by their differing IGS lengths. The 2013 Black Butte strain, IGS 404, has been detected in this population since the 1995 pneumonia outbreak (Fig. 3b). The 2014 strain, IGS 393, had never previously been detected in this population or any other bighorn sheep population in Hells Canyon or elsewhere in the western United States (among >700 other isolates that have been IGS typed).

In October 2014, we removed survivors from the Heller Bar female group in an attempt to prevent further spread of this strain. Nonetheless, 1 month after the removal, we detected the IGS 393 strain type in an adult male removed from the town of Asotin, Washington and we detected it again 4 months later in a 9-month-old lamb in the Shumaker female group, located between the Joseph and Heller Bar

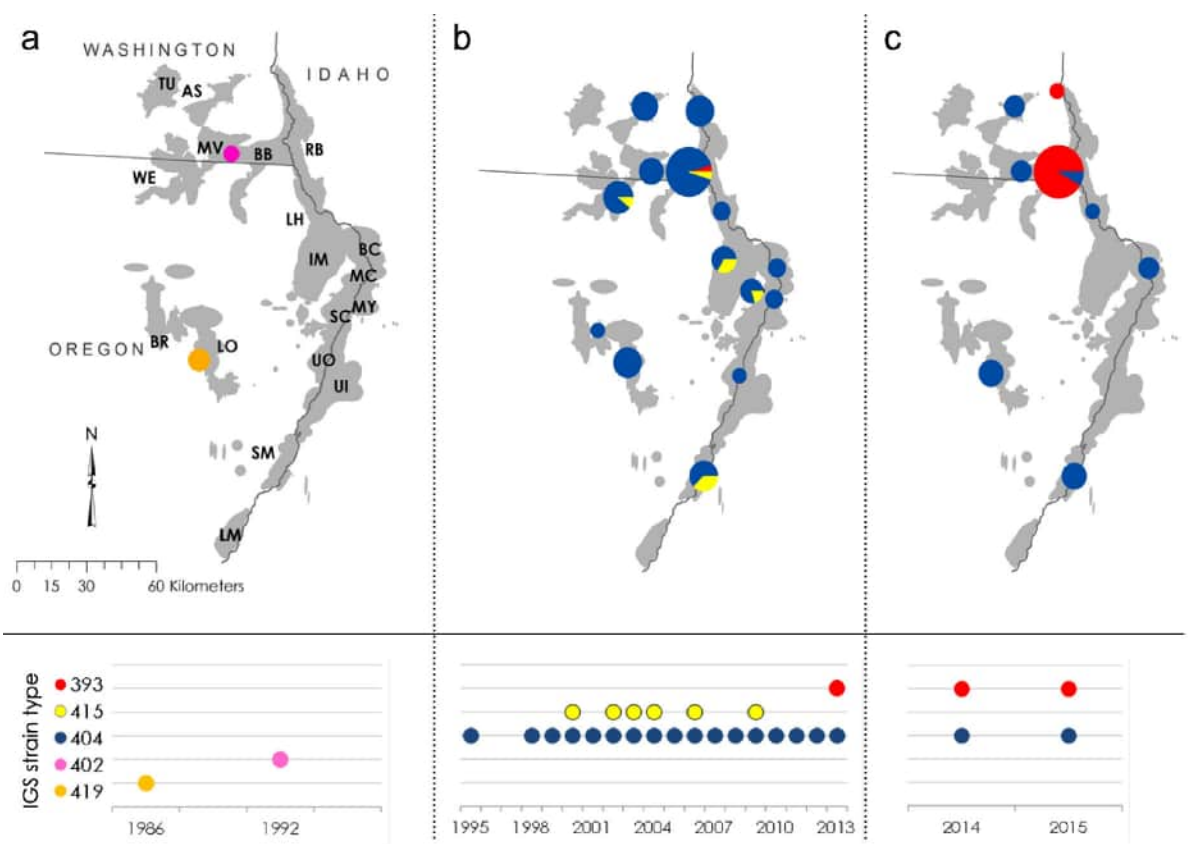

Figure 3. Spatiotemporal distribution of the 16S-23S intergenic spacer (IGS) genotypes of *Mycoplasma ovipneumoniae* in the Hells Canyon bighorn sheep metapopulation in Washington, Oregon, and Idaho, USA in (a) 1986 and 1992 (b) 1995–2013; and (c) 2014–2015. Each colored marker represents one strain type, pie charts display strain types within populations and are scaled by sample size. Pie charts containing >1 color indicate that 2 strain types were present in a population during that time interval but not necessarily detected in the same year. Gray shaded polygons denote bighorn sheep populations: AS = Asotin, BB = Black Butte, BC = Big Canyon, BR = Bear Creek, IM = Imnaha, LH = Lower Hells Canyon, LM = Lookout Mountain, MU = Muir, MV = Mountain View, MY = Myers Creek, RB = Redbird, SM = Sheep Mountain, TU = Tucannon, UO = Upper Hells Canyon, Oregon, UI = Upper Hells Canyon Idaho.

groups in the Black Butte population. Retrospective analysis revealed that this strain was present in the lungs of a male that died of pneumonia in the Joseph Creek group in December 2013, representing the index case of disease associated with the IGS 393 strain type. The IGS 393 strain has not been detected in any surrounding populations, which remain carriers of the original IGS 404 strain (Fig. 3c).

Two other strains were detected in specimens obtained during or after disease outbreaks in other Hells Canyon populations (Coggins 1988, Foreyt et al. 1990), and have not been detected since. These samples were from the Lostine population in 1986–1987 (IGS 419) and the Mountain View population in 1992 (IGS 402; Fig. 3a). A third strain (IGS 415) associated with a pneumonia outbreak in the Sheep Mountain population in 2000 was apparently replaced by the IGS 404 strain by 2006 based on samples typed from 2006 and 2015 in that population. The IGS 415 strain was subsequently infrequently detected in 4 other populations between 2003 and 2009 and has not been found since then (Fig. 3b).

Sequence divergence among the 3 recently detected strains where all 4 genes could be analyzed (i.e., IGS 393, 404, and 415) was between 9% and 10%. These strains were well dispersed across 20 genotypes of *M. ovipneumoniae* collected from 9 domestic sheep flocks in the western United States and Australia and 10 domestic goat flocks in the western United States and China. The IGS 404 and 415 types, first identified in the Black Butte and Sheep Mountain populations, respectively, were more closely related to the domestic sheep lineage, whereas the IGS 393 type detected in the Black Butte population in 2013 and 2014 clustered with the domestic goat clade (Fig. 4).

DISCUSSION

This is the first study to report on an all-age pneumonia outbreak in an intensively sampled population of free-ranging bighorn sheep with health, survival, and observational data collected before, during, and after the disease event. The collection and analysis of this information, employing recently developed molecular methods for pathogen detection and genotyping, allowed us to attribute severe disease in a bighorn sheep population with long-standing *M. ovipneumoniae* carriage to introduction of a novel strain of *M. ovipneumoniae*. This conclusion is supported by the detection of the never before recorded IGS 393 strain in the pneumonic lungs of adults that died, and in the upper respiratory tract of adults with clinical signs during the outbreak. We also observed a significant increase in antibody titers to *M. ovipneumoniae* during the outbreak denoting an active immune challenge and we documented that previous exposure and ongoing carriage of the *M. ovipneumoniae* IGS 404 strain was not protective against disease. To the contrary, lower survival of adults with higher serologic titers prior to the disease outbreak could reflect a harmful autoimmune reaction associated with antibody response to *M. ovipneumoniae* in bighorn sheep as has been suggested for domestic sheep (Niang et al. 1998*a*). Strain-specific immunity, as measured by serologic antibody inhibition of *M. ovipneumoniae*, was similarly reported by Alley et al. (1999) for domestic sheep.

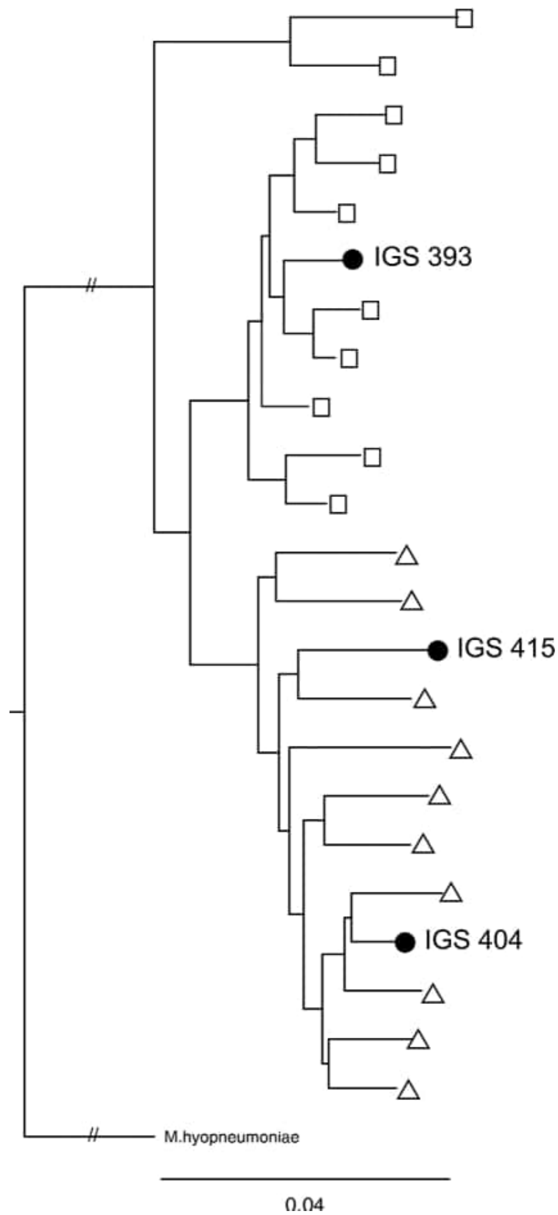

Figure 4. Phylogeny of 3 bighorn sheep strains of *Mycoplasma ovipneumoniae*, Hells Canyon, Washington, Oregon, and Idaho, USA, and randomly selected strains from domestic sheep (triangles) and domestic goats (squares), 1975–2015. Domestic sheep and goats appear to host divergent lineages of *M. ovipneumoniae* and the samples from bighorn sheep clustered with either the domestic sheep or domestic goat lineages. Neighbor-joining tree of concatenated partial 16S, 16S-23S intergenic spacer region (IGS), *rpoB*, and *gyrB* DNA sequences is rooted with homologous sequences from *M. hyopneumoniae.* Branch lengths are scaled by proportion non-identity (scale bar). Domestic sheep samples are from Washington, Oregon, Idaho, Nevada, Colorado, California, and an ATCC type strain from Australia. Domestic goat samples are from Washington, Idaho, California, and China (Yang et al. 2011, 2014).

Adult mortality associated with this strain introduction was within the range previously observed during pneumonia outbreaks in naïve animals in this metapopulation (28–42%; Cassirer et al. 2013). Lamb mortality followed an identical time course regardless of strain, consistent with a lack of protective immunity in neonates. The timing of the onset of clinical signs following infection in lambs (latent period) was similar to that reported in experimental challenge of adults (Besser et al. 2014). However, disease progression in lambs was more rapid and severe than observed in free-ranging adults in this study or in experimental exposure of naïve adults in captivity (Besser et al. 2014).

Although pneumonia in bighorn sheep is a polymicrobial disease, pathogens other than *M. ovipneumoniae*, including *lkt*A positive *Pasteurellaceae* and respiratory viruses, were either not detected or showed no association with disease. Whereas *M. ovipneumoniae* was present in all pneumonic adults and lambs, prevalence of *Pasteurellaceae* varied between age classes. This could be due to conditions associated with growth of an opportunistic pathogen or to other factors. Sample sizes were too small to draw broader inference. Anaerobic bacteria, not tested in this study, are a large component of the microbiome in pneumonic bighorn sheep lung tissue and may also play a larger role as secondary pathogens than previously suspected (Besser et al. 2008).

The novel strain of *M. ovipneumoniae* detected in this study differed from the resident strain by 52 independent genetic mutations on 4 loci. This unique strain was not a variant of a resident strain and had never before been detected in over 700 samples strain-typed from Hells Canyon and other bighorn sheep populations. Therefore, the most likely source of this Caprinae-specific pathogen was a domestic sheep or goat. Phlyogenetic analysis indicated that this strain was most likely of domestic goat origin.

This strain introduction likely occurred from a domestic goat on or from private lands within bighorn sheep range despite substantial efforts by wildlife managers and nongovernmental organizations to prevent contact. Management strategies included distributing educational material to flock owners and the general public, purchasing and removing a domestic sheep flock, and removing individual bighorn or domestic sheep and goats when they were at risk of contact. Our retrospective analysis showed that unique strains of *M. ovipneumoniae* were associated with 4 other epidemiologically unrelated all-age pneumonia outbreaks in Hells Canyon, as would be expected from similar spillover events. Two of these historical strains (IGS 402 and 419) apparently remained localized, one spread and subsequently disappeared (IGS 415), whereas the fourth (IGS 404) has persisted and proliferated over a span of $\geq$20 years. It is not clear why some strains of *M. ovipneumoniae* persist and others apparently do not. The IGS 404 strain may have driven fade-out of other extant strains when it spread, as introduction of the IGS 393 strain did in this study. Strain replacement might occur when the carrier host immune response is cross-reactive but protection is strain-specific. Under these conditions a new strain could have a competitive advantage and exclude the original strain.

Although evidence suggests that this epizootic was caused by introduction of a novel *M. ovipneumoniae* strain, it is also possible that pneumonia outbreaks could be precipitated in carrier bighorn sheep populations if appropriate mutations occur in strains to which resistance has previously been acquired. Mutations in key virulence genes or in genes coding for the *M. ovipneumoniae* capsule, which likely plays a role in adherence to host cells and in evading antibody recognition (Niang et al. 1998*b*, Razin et al. 1998), could cause disease and are unlikely to be detected by our strain-typing method. Another plausible mechanism of pneumonia resurgence would be reintroduction of the same strain of *M. ovipneumoniae* into a population following either pathogen fade-out and waning immunity (Sydenstricker et al. 2005) or recruitment of unexposed susceptible individuals. Finally, other factors may play a role in triggering outbreaks such as pathogen dose, host contact patterns, immunocompetence, and invasion of secondary pathogens. Identifying the conditions most frequently associated with pneumonia outbreaks in previously exposed populations and a wider investigation of the genetic diversity and host-specificity of *M. ovipneumoniae* strains would provide valuable insights into the adaptive immune response in bighorn sheep and the ecology of this disease.

MANAGEMENT IMPLICATIONS

Lack of cross-strain immunity to *M. ovipneumoniae* could be one explanation for the regular occurrence of pneumonia epizootics in bighorn sheep populations over a century after initial contact with domestic sheep. Single strain infection in bighorn sheep populations contrasts with *M. ovipneumoniae* carriage in domestic sheep where numerous strains typically coexist within a flock (Alley et al. 1999, Harvey et al. 2007). In the absence of cross-strain immunity, these flocks may serve as a constant source of novel strains capable of causing disease in bighorn sheep. Although vaccination could potentially reduce pathogen burden or prevalence within bighorn sheep populations, it is not clear that a vaccine would protect bighorn sheep from severe disease if exposed to new strains. Our results instead support preventing spillover as a primary strategy for managing disease in bighorn sheep. This could be accomplished by maintaining separation between bighorn sheep and domestic sheep and goats, by clearing *M. ovipneumoniae* infection from domestic hosts, and by exercising caution to avoid mixing *M. ovipneumoniae* strains among bighorn sheep populations during translocations. The management strategies implemented near the bighorn sheep in this study were apparently unsuccessful in preventing transmission, underscoring the difficulty of maintaining separation. New approaches, more active cooperation by the public, and greater vigilance on the part of resource managers may be key to preventing pneumonia outbreaks in bighorn sheep.

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