

Risk Analysis of Disease Transmission between Domestic Sheep and Goats and Rocky Mountain Bighorn Sheep

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Background

In 2009, after receiving comments to forest plan revision from the Wyoming Game and Fish Department (WGFD) about the health of bighorn sheep and the risk of disease transmission from domestic goats, the Shoshone National Forest initiated public scoping to gather information on recreational pack goat use in core native bighorn sheep range. While action on this proposal was delayed, in December 2010, presentations of a proposed temporary closure to domestic goats were made to the Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group and Fremont County Commissioners. In 2011, the Shoshone staff met with the North American Pack Goat Association to discuss options to a temporary closure.

On November 4, 2011, Shoshone Supervisor Joe Alexander signed a temporary closure order restricting domestic goat use on four of five ranger districts until a bighorn sheep viability and risk assessment could be completed during forest plan revision.

In an August 19, 2011 Washington Office letter from the Deputy Chief, National Forest System, direction was provided on the preparation of viability analysis for bighorn sheep commensurate with the complexity of the proposed action, when decisions are made requiring National Environmental Policy Act (NEPA) analysis.

Following direction from the Deputy Chief, the Shoshone staff conducted an analysis of the effects of disease transmission from domestic sheep and goats on the Forest to bighorn sheep populations occurring within and near the Shoshone.

The analysis was conducted at the spatial scale of the Shoshone and consists of four parts: (1) a review of the scientific literature on disease transmission from domestic sheep and goats to bighorn sheep and the impacts that disease has on bighorn sheep populations; (2) an evaluation of domestic sheep and goat use on the Shoshone; (3) an evaluation of population data available for bighorn populations located within and adjacent to the Shoshone's boundaries; and (4) and an assessment of risk of disease for each of the Shoshone's bighorn sheep herds from domestic sheep and goats use on the Forest.

The level of analysis completed for this risk assessment is commensurate with the complexity of the proposed action (separation between domestic sheep and goats from bighorn sheep in core native bighorn sheep habitat) and the risk of disease transmission on the Shoshone.

Bighorn Sheep Distribution and Abundance

Two species of mountain sheep occur in North America: thinhorn sheep (*Ovis dalli*) and bighorn sheep (*O. canadensis*). Dall's sheep (*O. d. dalli*) occur in Alaska and northwestern Canada, and Stone's sheep (*O. d. stonei*) occur in northwestern Canada. Bighorn sheep occur in western North America from British Columbia and Alberta to northwestern Mexico.

Bighorn sheep were abundant and widely distributed across the western United States prior to the mid-1800s. By 1950, bighorns were extirpated from a large portion of their range. Most extant populations of bighorn sheep consist of fewer than 100 individuals occurring in a fragmented distribution across the landscape (Singer et al. 2000c). Over half of existing bighorn populations are the result of translocations (Singer et al. 2000c).

Rocky Mountain bighorn sheep (*O. c. canadensis*) are native to Wyoming. Historically, bighorns ranged across most of the state within suitable habitat. Today, bighorns are primarily located in northwestern Wyoming with multiple re-introduced populations scattered across the state.

Northwestern Wyoming contains eight core native bighorn sheep herds in the Absaroka, Teton, Gros Ventre, and Wind River Ranges (WGFD 2010a). Core native herds are those herds that have never been extirpated and re-populated with transplanted bighorn sheep (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004). These are Wyoming's largest bighorn sheep populations and are the highest priority areas for bighorn sheep management in Wyoming (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004). Core native herds include the Clarks Fork, Trout Peak, Wapiti Ridge, Younts Peak, Francis Peak, Targhee, Jackson and Whiskey Mountain Herds. Seven other bighorn sheep herds have been either augmented or re-established through transplants in the Wyoming, Snowy, and Sierra Madre Ranges, Laramie Peak, along the Lander Front, in the Seminoe/Ferris Mountains, and on the west slope of the Bighorn Mountains (WGFD 2010a). In 2008, the estimated statewide population (outside of Yellowstone National Park) was 6,035 (population objective = 8,735) (WGFD 2010a). The core native herds in northwestern Wyoming account for over 90 percent of the statewide total of bighorn sheep.

Two core native herds have suffered significant die-offs in the past due to pneumonia. The Jackson Herd (Bridger-Teton National Forest) experienced a significant die-off in 2002 and the Whiskey Mountain Herd (Shoshone National Forest) have suffered through several outbreaks (WGFD 2011).

Literature Review

One of the most current literature reviews of disease transmission between domestic animals and bighorn sheep was compiled on the Payette National Forest in preparation of their forest plan amendment for domestic sheep and goat grazing in bighorn sheep habitat (USDA Forest Service 2010). In preparation for the Shoshone's risk assessment pertinent information was extracted from the Payette's risk assessment and brought forward into this risk assessment.

Effects of Disease on Bighorn Populations

An extensive body of scientific literature on the effects of disease on bighorn populations has accumulated. The literature indicates the following: (1) numerous examples of bighorn die-offs due to disease have been documented; (2) bighorn die-offs were documented as early as the mid 1800s and have been documented in every state in the western U.S.; (3) bighorn die-offs typically follow known or suspected contact with domestic sheep or goats; (4) under experimental conditions, clinically healthy bighorn sheep have developed pneumonia and died within days to weeks following contact with clinically healthy domestic sheep; (5) a variety of diseases and pathogens have been implicated in die-offs, but most commonly the disease implicated in the die-off is bacterial pneumonia (Pasteurellosis) caused by *Mannheimia haemolytica* (formerly *Pasteurella haemolytica*) or other species of closely related *Pasteurella* bacteria; and (6) there is consensus among wildlife biologists and veterinarians experienced in bighorn sheep management that domestic sheep and goats and bighorn sheep must be kept separated in order to maintain healthy bighorn populations (Foreyt 1989; Garde et al. 2005; Martin et al. 1996; Monello et al. 2001; Schommer and Woolever 2001; Singer et al. 2000a, 2000b, 2000c, 2000d; Singer et al. 2001).

Free-ranging bighorn sheep are susceptible to many diseases and declines of bighorn sheep populations throughout much of West have been a result of disease (Valdez and Krausman 1999). A long history of large-scale, rapid, all-age die-offs in bighorn sheep has been documented across Canada and the United States, many presumed associated with domestic animal contact (Shackleton 1999). The resistance of bighorn sheep to disease organisms is reduced as a result of stressors including nutrition, overcrowding on limited range, loss of escape cover, harassment by dogs, encroachment by humans, heavy snowfall, and other weather stresses (Bunch et al. 1999).

Native bighorn sheep are very susceptible to pneumonia and particularly to pasteurellosis, often a respiratory disease most commonly caused by bacteria in the family *Pasteurellaceae*. In contrast to most other wild and domesticated mammal species, bighorn sheep are notable in their extreme susceptibility to some strains of *Pasteurellaceae* (Miller 2001). In bighorn sheep, pasteurellosis frequently results in both all-age die-offs and persistent high rates of pneumonia in lambs, followed by several years of low lamb survival (Cassirer and Sinclair 2007; Coggins 1988; Coggins and Matthews 1990; Foreyt 1990; George et al. 2008). It has been speculated that once *Pasteurella* spp. have been introduced to bighorn sheep populations, they may become endemic and continue cycling for decades (Miller et al. 1991; Hobbs and Miller 1992, Miller et al. 1995). Because of these impacts on both survival and recruitment, pneumonia outbreaks can have significant long-term impacts on bighorn sheep populations (USFS 2006a, USFS 2010).

In some bighorn epidemics, endemic respiratory pathogens including parainfluenza-3 (PI-3) virus, respiratory syncytial viruses (RSV), and *Mycoplasma ovipneumoniae*, as well as lungworms (*Protostrongylus* spp.) are believed to have contributed to disease (Rudolph et al. 2007; Spraker et al. 1986).

Infectious keratoconjunctivitis caused by infection with *Mycoplasma conjunctivae* is an ocular disease that usually causes temporary blindness. This disease affects domestic livestock (Jones 1991) as well as wild ruminants in North America (Thorne 1982; Meagher et al. 1992) and Europe (Degiorgis et al. 2000). In limited instances of discovering this epizootic disease in bighorn sheep, sheep that regained their eyesight or perished were blind for 38 to 44 days (Jansen et al. 2006).

Review of Disease Transmission and Bighorn Sheep

Bighorn sheep are closely related to domestic sheep (*Ovis aries*) but did not evolve with them and thus are vulnerable to many infectious diseases commonly carried by domestic sheep (Jessup and Boyce 1993). Domestic sheep, an Old World species, has likely evolved resistances to important diseases as a result of domestication and intense artificial selection. Because they are so closely related, bighorn sheep are thought to be highly susceptible to diseases carried by domestic sheep (USFS 2010). Although limited knowledge of transmission dynamics exists (Garde et al. 2005) extensive scientific literature supports a relationship between disease in bighorn sheep populations and contact with domestic sheep (USFS 2010). In a pen experiment, transmission of bacterial pneumonia (*Mannheimia haemolytica*) from domestic sheep to bighorn sheep has been unequivocally demonstrated and the resulting pneumonia and death of bighorn sheep (Lawrence et al. 2010). Co-mingling of domestic sheep and bighorn sheep under experimental conditions clearly results in transmission of fatal pneumonia to bighorn sheep.

However, pen experiments cannot by themselves shed light on whether transmission of fatal disease between domestic sheep and bighorn sheep actually occurs in the wild. The literature includes both circumstantial evidence linking bighorn die-offs in the wild to contact with domestic animals, and controlled experiments where healthy bighorn sheep exposed to domestic sheep displayed subsequently high mortality rates (Foreyt 1989, 1990, 1992 a,b; Foreyt et al. 1994; Onderka et al. 1988; Onderka and Wishart 1988; Garde et al. 2005). As previously discussed, while much of the evidence for disease transmission from domestic sheep to free-ranging bighorn sheep is circumstantial, a large literature base has emerged that documents bighorn sheep die-off near domestic sheep (Goodson 1982).

Given the evidence from pen experiments, it is certainly plausible that transmission of pneumophilic bacteria could also occur in the wild. Bighorn sheep and domestic sheep are attracted to each other, particularly during rut, which increases the probability that they will make close contact necessary for disease transmission when they are in the vicinity of one another (Onderka et al. 1988, Foreyt 1989, Ward et al. 1997, Dubay et al. 2002).

Evidence that disease transmission and subsequent die-offs may occur in the wild comes from numerous observations of die-offs following soon after contact of free-ranging bighorn sheep with domestic livestock (e.g. Onderka and Wishart 1984, Coggins 1988, Callan et al. 1991, George et al. 2008, Onderka and Wishart 1984) describe a major die-off of bighorn that began in southeaster British Columbia after bighorn sheep were observed mixing with domestic sheep, and proceeded to spread south over the course of three winters, eventually reaching Glacier Park. Coggins (1988) reports a die-off that killed two-thirds of a herd of 100 animals in the Wallowa Mountains of northeastern Oregon. Almost two months before the outbreak, two bighorn rams and ewe had been observed with a domestic ewe. In December 1997, on Sugarloaf Mountain in Colorado, George et al. (2008) observed a single domestic ram grazing with a group of bighorn sheep, 14 kilometers (km) from the nearest herd of domestic sheep. It was the first and only time during a 10-year study that the authors saw domestic sheep associating with bighorn sheep, and it coincided with the beginning of an outbreak that eventually spread to two additional herds.

These observations and others like them (Martin et al. 1996) are consistent with the hypothesis that disease spread by domestic sheep cause die-offs of bighorn sheep herds, but they are by themselves essentially anecdotal. On the one hand, they don't include definitive evidence that transmission of a fatal pathogen occurred – evidence that is only possible in a carefully controlled experimental setting. On the other hand, they lack generality – even if disease transmission has occurred in one or a few cases, is it really a general phenomenon?

Not all pasteurellosis epidemics in bighorn sheep can be attributed to contact with domestic sheep (USDA FS 2006b). Because some potentially pathogenic *Pasteurellance* and other pathogens are endemic in some wild sheep populations, wildlife managers should examine the implications of interactions between different herds of wild sheep (CAST 2008).

While the body of literature linking disease transmission from domestic goats (*Capra aegagrus hircus*) to bighorn sheep is not as extensive as that of domestic sheep, nonetheless, it does exist. As in domestic and bighorn sheep, strains of *Mannheimia haemolytica* are the organisms most frequently isolated from the lungs of pneumonic domestic goats. *Mannheimia haemolytica* A1 is infrequently isolated from the upper respiratory tract of healthy bighorn sheep, and is thought to act as an opportunistic invader in much the same way as other strains of *Pasteurella* spp. *Mannheimia haemolytica* A2 has been found in the upper respiratory tract of healthy domestic sheep and goats, but has not been isolated from healthy wild sheep (Garde et al. 2005). It is thought that bighorn sheep are infected with *M. haemolytica* A2 through contact with domestic sheep or goats (Foreyt et al. 1996, Martin et al. 1996, Schommer and Woolever 2001). This bacteria has the potential to act as a primary pathogen in bighorn sheep, resulting in all age die-offs (Garde et al. 2005). In addition *pasteurella* spp. were isolated from feral goats and bighorn sheep in the Hells Canyon National Recreation Area. Although the direction of transmission could not be established, evidence suggests transmission of strains from goats to bighorn sheep (Rudolph et al. 2003, Foreyt et al. 2009).

In late 2003 and 2004, the Silver Bell bighorn herd in Arizona was reported with clinical signs of keratoconjunctivitis caused by *Mycoplasma conjunctivae*. This is a highly contagious eye infection common in domestic sheep and goats, and bighorn sheep and mountain goats (Whithear 2001). This ocular disease usually causes temporary blindness, but in advanced stages can lead to permanent blindness (Janovsky et al. 2002). The source of the infection was believed to be direct contact with 4,800 domestic goats released for pasturing purposes into bighorn habitat (Jansen et al. 2006).

In a pen experiment, lungworms (*Muellerius capillaries*) from domestic goats infected bighorn sheep when co-pastured together (Foreyt 2009). Based on the results of this experimental study, bighorn sheep that occupy habitat with domestic goats are at potential risk of acquiring *Muellerius* infections, thus increasing the potential risk of pneumonia (Foreyt 2009). Lungworm larvae deposited in animal feces, are

hosted by several species of land snails and remain in the snail until accidentally ingested by bighorn sheep. Lungworm inhabits the air passages of the lungs and can make wild sheep more susceptible to bacterial pneumonia (Colorado Division of Wildlife 1981).

Mycoplasma conjunctivae, a highly contagious eye infection, and previously discussed in the Silver Bell incident, is also common in domestic goats. This disease is thought to spread via insect vectors or direct contact (Whithear 2001). Infection is characterized by redness of the eyes, squinting, pain, ocular discharge and, in advanced stages, permanent blindness (Janovsky et al. 2002)

Contagious ecthyma, commonly called sore mouth is endemic in domestic herds of sheep, goats, and llamas in western Canada (Fowler 1998, Wenger and Tait 2001). Lesions are usually restricted to the lips and muzzle on domestics while they can cover the entire body of bighorn sheep (Fowler 1998, Merwin and Brundage 2000). The condition can be very painful, interfering with prehension and mastication of food (Samuel et al. 1975), and resulting in loss of body condition (Fowler 1998, Kimberling 1988). Although bighorn lambs can be impacted the most by this disease, it appears that contagious ecthyma rarely leads to population declines (Clark et al. 1993a, L'Heureux et al. 1996). Contagious ecthyma was reported from the Silver Bell bighorn sheep herd incident previously discussed. The bighorns initially suffered from keratoconjunctivitis, which was followed by a large-scale and severe contagious ecthyma outbreak (Jansen et al. 2006).

What makes bighorn sheep so susceptible to *Pasteurella* spp.? As previously mentioned, bighorn sheep did not co-evolve with the same set of pathogens as domestic sheep (Dubay et al. 2002), and domestic animals have likely been selected for disease resistance (Jessup 1985). Divergences in host-parasite co-evolutionary paths may explain observed differences in defense mechanisms between bighorn and domestic sheep (Silflow et al. 1989). In addition, bighorn sheep immune response cells have a reduced capacity to kill bacteria as compared with domestic sheep immune function (Dubay et al. 2002, Frank et al. 2004 in Schrommer and Woolever 2001). Bighorn sheep and domestic sheep are attracted to each other, which greatly increases the potential for close contact and disease transmission. Developing immunity to pasteurellosis in bighorn sheep is complex and poorly understood (Miller 2001) and vaccines to protect bighorn sheep have proven ineffective (Foreyt 1992a, Foreyt 1998, Foreyt and Silflow 1996). As vaccines and therapeutics for the prevention and control of infection or disease caused by Pasteurellaceae in domestic or wild sheep become available, producers and wildlife managers should seek practical ways to use them (CAST 2008). Most recently in a penned experiment, four bighorn sheep repeatedly immunized with multivalent *Mannheimia-Bibersteinia* vaccine protected them from induced *Mannheimia haemolytica* pneumonia, while four nonvaccinated control bighorn sheep died within 48 hours of being infected (Subramaniam et al. 2011). While repeated vaccination is not practical in the wild, a vaccine deliverable through feed or water may be one step closer to fruition. In some instances where these approaches are not effective, one species or the other may need to be given management priority in, or excluded from a particular range (WAFWA 2010).

Analyses Correlating Bighorn Population Performance with Distance from Domestic Sheep

The few attempts to quantitatively test whether contact with domestic sheep poses a general risk of die-off or extirpation of bighorn sheep populations have examined the correlation between population performance and distance from domestic sheep. Monello et al. (2001) analyzed population records of 99 bighorn sheep herds ranging from the southwestern United States to Alaska, in an investigation designed to discover the ecological correlates of pneumonia epizootics. They found that bighorn sheep populations that had suffered a pneumonia-induced-die-off were located on average significantly closer to

domestic sheep allotments (24.1 ± 11.5 km) than either those that had not suffered a die-off (39.6 ± 8.5 km) or those that had suffered a die-off not induced by pneumonia.

Singer et al. (2000d) analyzed factors contributing to the success of 100 translocations of bighorn sheep in six western states, and found that the 30 unsuccessful translocations were on average significantly closer to domestic sheep ($6 \pm$ km) than either modestly successful or successful translocations. Finally, based on an analysis of 24 herds, Singer et al. (2001) found that the persistence of bighorn sheep populations was significantly correlated with the presence of domestic sheep: populations located closer to domestic sheep were smaller and had lower population growth rates than bighorn populations located farther from domestic sheep.

While these analyses indicate that bighorn sheep populations perform more poorly when they are closer to domestic sheep, they typically don't even include observations of contact, let alone the transmission of a pathogen from domestic sheep to bighorn sheep (USDA Forest Service 2010).

Management of Bighorn Sheep Disease Issues

Schommer and Woolever (2001) presented guidelines for and examples of management solutions to domestic sheep/bighorn sheep conflicts. They provided examples of different management actions to reduce or eliminate the risk of disease transmission from domestic sheep: conversion of sheep allotments to cattle allotments, moving domestic sheep to another allotment or dropping pastures from sheep allotments, trucking versus trailing sheep, changing rotations or season of use, more intensive efforts to herd sheep and gather strays. Schommer and Woolever (2001) recommended (1) using a collaborative approach to develop solutions; (2) developing strategies to keep domestic sheep and bighorn sheep separated *at all times*; (3) developing site-specific solutions for each bighorn sheep herd; (4) developing management strategies when the situation is complex; and (5) maintaining flexibility and opportunities for the livestock industry by leaving vacant allotments open when they are not in conflict with other resource uses. Given the limitations of today's tools, the most practical approaches identified thus far for minimizing the risk of disease involve simply preventing interspecies interactions that could result in respiratory pathogen transmission between domestic sheep and goats and wild sheep (WAFWA 2010).

Singer et al. (2001) evaluated correlations between population persistence of 24 translocated bighorn sheep populations and several variables, including distance to domestic sheep. Persistence of bighorn populations was significantly correlated with the presence of domestic sheep: bighorn populations located closer to domestic sheep had smaller population sizes and lower population growth rates than bighorn populations located farther from domestic sheep. In a different study, Singer et al. (2000b) analyzed factors that contributed to the success of 100 bighorn translocations within 6 western states between 1923 and 1997. Sites where translocations were unsuccessful were located significantly closer to domestic sheep than were sites where translocations were successful.

Wyoming provides an example of a cooperative state effort in dealing with domestic sheep/bighorn sheep issues and management recommendations (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004a). This Working Group that included the U.S. Forest Service was initiated in 2000 in response to the escalating conflict and confrontation between concerned publics of bighorn sheep and domestic sheep. They met and developed a statewide approach to developing collaborative recommendations and actions culminating in a final report in 2004. Among other things, statewide bighorn sheep management areas were mapped and delineated into core native herds, cooperative review areas and bighorn sheep non-emphasis areas. It was agreed that core native herds were the highest priority areas for bighorn sheep, where all efforts would be made to prevent contact between bighorn and domestic sheep. Cooperative review areas are suitable bighorn sheep range where proposed changes in bighorn sheep management or domestic sheep use will be cooperatively evaluated. Bighorn sheep non-

emphasis areas are where no effort will be made to prioritize/emphasize bighorn sheep unless agreed to by the Working Group. Among the recommendations made by the Working Group, a focus was the need to minimize the risk of disease transmission, and to optimize preventive medical and management procedures to ensure healthy populations of bighorn and domestic sheep. (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004a).

Concerns over the use of pack goats within Dall's sheep range (Garde et al. 2005) would be similar to concerns for their use within occupied bighorn sheep range. Wildlife specialists and veterinarians in the Northwest Territories, Canada, recommended no domestic goat use as pack animals in the vicinity of Dall's sheep ranges (Garde et al. 2005). The Western Association of Fish and Wildlife Agencies (WAFWA 2010) recommends prohibiting the use of domestic sheep and goats as pack animals by hunters, anglers, and other recreational or commercial users that travel in identified wild sheep habitat. In addition, where legislation or regulations are not already in place, an effective outreach and public education program should be implemented, to inform potential users of the risks associated with that activity and recommend that individuals not use domestic sheep or goats as pack animals in occupied wild sheep habitat.

Most recently, the Payette National Forest amended its 2003 Forest Plan by reducing suitable domestic sheep and goat grazing lands that had the potential to impact bighorn sheep (USDA Forest Service 2010). This decision provided for a level of risk for long-term management of domestic sheep and goat grazing on the Forest while providing for bighorn sheep populations.

Domestic Sheep Grazing and Domestic Goat Use on the Shoshone National Forest

Domestic Sheep Grazing

The sheep industry started in southern Wyoming in the 1870s. By 1910, there were about 5.5 million domestic sheep in Wyoming. Today, there may be 10 percent of that number in the state.

On the Shoshone National Forest, domestic sheep grazing was at its highest point in the early 1900s and has been on a steady decline. The initial decline in sheep numbers was primarily due to stocking rate adjustments that reflected a more sustainable use of the range land. Within the past 10 years, all the commercial sheep grazing permits except for one permit have been removed on the Shoshone. This was primarily due to an increase in predator/livestock conflicts and willingness of domestic sheep grazing permittees to move out of the allotments, which benefited bighorn sheep (Woolever, personal communication, 2011). Currently, domestic sheep graze about 2 percent of the area projected in the 1986 Shoshone Forest Plan.

Three allotments (Table 1) on the southern end of the Forest make up the extent of domestic sheep grazing on the Shoshone. Two allotments, with a total of 1,150 ewe/lambs, are active and one allotment is vacant. No domestic sheep grazing occurs within core native bighorn sheep range, but there is currently some recreational domestic goat packing.

Table 1. Domestic sheep grazing allotments on the Shoshone National Forest

Allotment	Stocking Rate	Grazing Dates	Allotment Status
Atlantic City	1,000 ewe/lamb	7/16 – 8/25	Vacant
Pine-Willow	1,150 ewe/lamb ¹	7/20 – 8/15	Active
Slate Creek	1,150 ewe/lamb ¹	8/16 – 9/10	Active

¹ Pine-Willow and Slate Creek domestic sheep are the same sheep.

Domestic Goat Use

There are no active commercial domestic goat allotments on the Shoshone. There is a distinction in the use of domestic goats for packing versus use of goats on grazing allotments. The use of domestic goats as pack animals in most cases is a different use than a grazing allotment due to the amount of control that can be placed on the pack goats. Pack goats can be tethered at night to prevent straying and tied together during the day when trailing. Health certifications are more economically attainable for pack goats versus domestic sheep or goat herds and can be kept insight when in bighorn sheep habitat. Of course this all depends upon the pack goat user and the efficacy of these and other best management practices.

Recently, pack goat use for back country trips into the Wind River Range has become popular. The primary destinations for goat pack trips have been in the Fitzpatrick Wilderness. Specific trails in this area have recently been identified by goat packing enthusiasts (North American Packgoat Assoc. 2011) for pack goat use. A total of about 38 miles of trail would be used within the wilderness. Of these trails, about 33 miles of trail are within currently occupied bighorn sheep habitat within the Whiskey Mountain herd range (Figure 1). The remaining trail on the Shoshone is just south of this herds range. Additional goat pack trail use is proposed on the adjacent Bridger-Teton National Forest, but outside of currently occupied bighorn sheep habitat.

On November 14, 2011, a Shoshone National Forest temporary area closure order was signed and implemented restricting domestic goat use on the Clarks Fork, Wapiti, Greybull and Wind River Ranger Districts. During this temporary closure, domestic goat use is only allowed on the Washakie Ranger District out of Lander, WY. This closure was implemented in response to concern over the potential risk of disease transmission and contact between pack goats and bighorn sheep in core native habitat (USDA Forest Service 2011).

Population Status of Bighorn Sheep Populations on the Shoshone

The Shoshone National Forest has the largest number of bighorn sheep of any forest within National Forest System lands, with over 4,000 of the estimated 6,000 bighorn sheep in Wyoming, occurring on the Shoshone. Five of the six core native herds on the Shoshone are not isolated from one another, (the Whiskey Mountain herd being the exception) and natural interchange between adjacent herds is thought to be greater than 10 percent. If interchange falls below the 10 percent threshold, WGFD considers the relevant herd units to be isolated from one another and functioning as discrete biological herds. WGFD recognizes the importance of maintaining connectivity between these herds so that they continue to function as an effective metapopulation. While the Whiskey Mountain herd has historically contained a large number of bighorn sheep, the level of individual interchange with other herd units is low. The Highway 26 corridor, which is the dividing line between the Whiskey Mountain herd and herds to the north, consists of fairly unsuitable bighorn sheep habitat, which limits interchange (Beecham et al. 2007).

Only Rocky Mountain bighorn sheep occur on the Shoshone National Forest, and the Forest is occupied by six of the eight core native bighorn sheep herds in Wyoming. These core native herds include: Francis Peak, Younts Peak, Whiskey Mountain, Trout Peak, Wapiti Ridge, and Clark's Fork. These core native herds currently occupy 67 percent (1.65 million acres) of the Shoshone (Figure 2).

A small portion of the Washakie Ranger District is occupied by the Temple Peak herd. This herd is not a core native herd. It is classified as a remnant herd by the WGFD. The Temple Peak herd is also considered a transplant herd and is managed within a "Cooperative Review Area" (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004). Cooperative Review Areas are areas of suitable bighorn sheep range where proposed changes in bighorn sheep management or domestic sheep use will be cooperatively evaluated. Most suitable bighorn sheep range in Wyoming not addressed in the

core native herds or non-emphasis areas is in the Cooperative Review category (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004).

An additional remnant bighorn sheep herd occurs on the adjacent Wind River Indian Reservation in the South Fork Little Wind River watershed. This herd consists of about 25 sheep. Their current occupied range does not include the Shoshone National Forest

For this analysis of the population status of bighorn sheep, a map was developed collaboratively by Wyoming Game and Fish Department, U.S. Forest Service and Bureau of Land Management (BLM) wildlife biologists (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft). This map displays occupied bighorn habitat along with active and vacant domestic sheep/ goat allotments.

Francs Peak Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone National Forest and the Wind River Indian Reservation within the Absaroka and Owl Creek mountain ranges. This herd includes WGFD Hunt Areas 5 (Francs Peak) and 22 (Dubois Badlands), as well as the Owl Creek Mountains in the northern portion of the Wind River Indian Reservation (Beecham et al. 2007).

The population objective for this herd is 1,360 sheep. Current model estimates put the population at 1,400 sheep, or near objective (WGFD 2010b). This sheep herd is considered very healthy and the population has remained stable for the past 6 years. Based on a 10-year average, post-season lamb ratios averaged 29:100, while ram ratios averaged 48:100 (WGFD 2010b).

No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on public lands to the Francs Peak Herd is approximately 3.2 km (2 miles) to the east on BLM lands. Because of the concern of disease transmission, five bighorn sheep ewes were removed from the population upon grazing on private land used by domestic sheep (WGFD, personal communication 2012b). Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 112.7 km (70 miles) south of the Francs Peak Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

No pack goat use occurs within this core native herd range.

Younts Peak Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone and Bridger-Teton National Forests, primarily within the Absaroka Mountain Range. This herd includes WGFD Hunt Area 4. Younts Peak is the most remote bighorn sheep herd in Wyoming (Beecham et al. 2007). They are non-migratory and reside year-round on high-elevation ridges (WGFD 2009a). This makes them prone to periodic high mortality losses due to severe winter weather.

The population for this herd is estimated to be at the objective of 900 sheep. The March 2010, lamb:100 ewe ratio was 21:100, and ram:100 ewe ratio was 30:100. The lamb:ewe ratio was below the 5-year (2005-2009) average of 29:100 for this herd, as was the ram:ewe ratio that averages 52:100 for this herd (WGFD 2010b). No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on public lands to the Younts Peak Herd is approximately 41.8 km (26 miles) east on BLM lands. Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 136.8 km (85 miles) southeast of the Younts Peak Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

No pack goat use occurs within this core native herd range.

Whiskey Mountain Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone and Bridger-Teton National Forest's and the Wind River Indian Reservation within the Wind River Mountain Range. This herd includes WGFD Hunt Areas 8, 9, 10, and 23 (Beecham et al. 2007).

The population objective for this herd is 1,350 sheep. After a disease related die-off in 1991, the population has yet to recover and has been in a decline for the past 20 years. Current population estimate is about 634 sheep (WGFD 2010c). In 2009, the lamb:ewe ratio of 30:100 was the highest observed in the past 20 years (WGFD 2009b). In 2010, the ratio was 21:100 lamb:ewes. The ram:ewe ratio for this herd has been more stable. In 2010, the ratio was 30:100, below the 2005-2009 average of 35:100 (WGFD 2010c).

It is suggested that the high concentration of wintering sheep contributed to the severity and lasting impacts of the pneumonia outbreak in 1991. As a result, it's been suggested that the Whiskey Mountain Bighorn Sheep Technical Committee review the population objective for this herd to try to avoid the scenario that occurred in 1991 (WGFD 2009b).

In 2010, WGFD personnel spent a significant amount of time observing sheep in early fall as they arrived on winter range. Many lambs were observed coughing violently and showing symptoms of pneumonia. Eleven sheep were euthanized throughout the fall and examined at the state vet lab to document the presence of disease. Examinations revealed *Mycoplasma ovipneumoniae* in all the sheep that had been seen coughing violently. It appears likely persistent, low, annual recruitment in this population can be traced to chronic bacterial infection resulting in significant lamb mortality as sheep migrate onto winter range in the fall. Despite low recruitment, the population is declining very slowly and it appears a small increase in lamb recruitment will stabilize this population. Unfortunately, managers do not have any effective tools to mitigate the persistent presence of bacterial pneumonia that is impacting lambs annually (WGFD 2010b).

No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on public lands to the Whiskey Mountain Herd is approximately 9.7 km (6 miles) west on the Bridger-Teton National Forest. Four domestic sheep were removed (shot) in Hunt Area 8 that had strayed onto core native bighorn sheep habitat on the Bridger-Teton National Forest due to concerns over disease transmission (WGFD, personal communication 2012b). Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 80.5 km (50 miles) southeast of the Whiskey Mountain Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

Pack goat use occurs within occupied habitat of this core native herd. The only pack goat outfitter to operate in this area was bought out in 2007.

Trout Peak Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone National Forest within the Absaroka Mountain Range. Sheep move between this herd unit and Yellowstone National Park (Beecham et al. 2007). This herd includes WGFD Hunt Area 2.

The population objective for the Trout Peak herd is 750. The present population is estimated to be about 650 sheep (WGFD 2010b). The lamb:ewe ratios were average for this herd in 2007 (30:100) and 2009 (29:100), but were low in 2008 (19:100). The ram:ewe ratios were average for this herd in 2007 (30:100) and 2009 (33:100), but were substantially higher in 2008 (65:100) (WGFD 2009a). No ratio data exists for 2010. No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on

public lands to the Trout Peak Herd is approximately 19.3 km (12 miles) east on Bureau of Land Management lands. Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 220.8 km (138 miles) south of the Trout Peak Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

No pack goat use occurs within this core native herd range.

Wapiti Ridge Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone and Bridger-Teton N.F's within the Absaroka Mountain Range. Sheep move between this herd unit and Yellowstone National Park (Beecham et al. 2007). This herd includes WGFD Hunt Area 3.

The population objective for the Wapiti Ridge herd is 1,000 sheep with the present population about the same (WGFD 2010b). In 2010, the lamb:ewe ratio was 22:100 which is below the 2000-2009 average of 30:100. The ram:ewe ratios were average in 2008 (40:100), but were slightly below average (38:100) in 2009 and 2010 at 32:100 rams:ewes (WGFD 2009a, WGFD 2010b). No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on public lands to the Wapiti Ridge Herd is approximately 29.0 km (18 miles) east on Bureau of Land Management lands. Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 179.2 km (112 miles) south of the Wapiti Ridge Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

No pack goat use occurs within this core native herd range.

Clark's Fork Bighorn Sheep Herd

This core native herd occupies portions of the Shoshone National Forest and the Gallatin and Custer National Forests in Montana. They range across the Absaroka Mountain Range and the Beartooth Plateau. Sheep from this herd, primarily rams, move in and out of Yellowstone National Park. This herd includes WGFD Hunt Area 1 (Beecham et al. 2007).

The population objective for the Clark's Fork herd is 500 with the present population about the same (WGFD 2010b). The lamb:ewe ratio of 32:100 in 2009, was one of the lowest recorded for this herd. This may have been caused by the cool, wet conditions during the lambing season in 2009. The ram:ewe ratio of 42:100 was lower than recent surveys in 2005 and 2006, but still within the range seen from 2003-2006 (WGFD 2009a). No ratio data exists for 2010. No domestic sheep grazing occurs within this herd unit. Closest domestic sheep/goat grazing on public lands to the Clark's Fork Herd is approximately 20.9 km (13 miles) east on BLM lands. Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 240.0 km (150 miles) south of the Clark's Fork Herd (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).

No pack goat use occurs within this core native herd range.

Temple Peak Bighorn Sheep Herd

This cooperative review herd is an indigenous population of the Bridger-Teton and Shoshone National Forests. This herd currently occupies a very small portion of the Shoshone along the Lander Front in the southern end of the Wind River Range. The distribution of bighorns with this unit is scattered, with known wintering areas in the North Fork of the Popo Agie River, Sinks Canyon, and the Little Popo Agie River. This herd includes WGFD Hunt Area 11 (Beecham et al. 2007). This herd no longer has a hunt area assigned to it and is not discussed in the WGFD 2010 Annual Big Game Herd Unit Reports.

This herd experienced an all-age pneumonia die-off in 1992 and has never recovered (WGFD 2006). The current population is suspected to be about 25 sheep. The population objective is 250 sheep. Singer et al. (2001) identified bighorn sheep populations that fall below 30 sheep as “quasi-extirpation” meaning that the population is unlikely to ever recover. This quasi-extirpation herd is likely to eventually go extinct. Due to the low population, no population data is currently being collected by the WGFD.

Domestic sheep grazing occurs on both the Shoshone and Bridger-Teton National Forests within this herd’s historic summer range, but not within currently occupied herd range. Suitable bighorn sheep habitat within these domestic sheep allotments on the Shoshone is very limited as a vast majority of the land is forested and within occupied habitat of gray wolves. In addition, a large portion of the land between these allotments and the bighorn sheep occupied habitat is forested. This herd’s current occupied range is very confined, suggesting that they no longer are a migratory herd or have little, if any interchange with bighorns in the Whiskey Mountain or Wind River Indian Reservation populations (Beecham et al. 2007).

Closest domestic sheep/goat grazing on public lands to the Temple Peak Herd is approximately 9.7 km (6 miles) east on Bureau of Land Management lands. Closest domestic sheep/goat grazing on the Shoshone National Forest is approximately 28.9 km (18 miles) southeast of the Temple Peak Herd (Wyoming: Domestic Sheep and Bighorn Sheep Distribution 2011). Closest domestic sheep/goat grazing on the Bridger-Teton National Forest to the Temple Peak Herd is approximately 3.2 km (2 miles) west. To reduce the risk of transmission, at least one bighorn sheep ram was removed after it made a foray onto private land.

Pack goat use occurs within occupied habitat of this cooperative review herd. The only pack goat outfitter to operate in this area was bought out in 2007.

Assessment of Risk

Shoshone National Forest Disease Risk from Domestic Sheep and Goats

Methods

Utilizing existing bighorn sheep herd information and existing domestic sheep and goat (including pack goat) use, a qualitative analysis was prepared to determine the likelihood of disease transmission from domestic sheep and goats (including pack goats) to bighorn sheep for the specific bighorn sheep herds. The complexity of this issue on the Shoshone National Forest is lower than other forests in the western United States due to the limited amount of domestic sheep and goat use in occupied bighorn habitat. However, there is some pack goat use that does occur and needs to be addressed.

Wildlife biologists from the Wyoming Game and Fish Department with considerable knowledge of bighorn sheep biology and management along with Shoshone land managers assisted in this risk assessment (WGFD, personal communication 2012b). Because of the lack of quantitative models available to predict likelihood of disease outbreak in bighorn sheep populations due to potential contact with domestic sheep or goats (including pack goats), the same basic outcomes, with the addition of domestic pack goats, identified by the Payette National Forest (USDA Forest Service 2006a) and used in the Payette’s risk assessment, are utilized in this risk assessment.

The outcome scale was composed of five possible outcomes. Individual outcomes represented ranged from very low risk to very high risk of disease transmission (USDA Forest Service 2006a):

Outcome 1: Very low risk of disease transmission from domestic sheep or goats (including pack goats) in this bighorn sheep herd within next 10 years because of very low likelihood of direct contact between domestic sheep or goats (including pack goats) and bighorns.

Outcome 2: Low risk of disease transmission from domestic sheep or goats (including pack goats) in this bighorn sheep herd within next 10 years because of low likelihood of direct contact between domestic sheep or goats (including pack goats) and bighorns.

Outcome 3: Moderate risk of disease transmission from domestic sheep or goats (including pack goats) in this bighorn sheep herd within next 10 years because of moderate likelihood of direct contact between domestic sheep or goats (including pack goats) and bighorns.

Outcome 4: High risk of disease transmission from domestic sheep or goats (including pack goats) in this bighorn sheep herd within next 10 years because of high likelihood of direct contact between domestic sheep or goats (including pack goats) and bighorns.

Outcome 5: Very high risk of disease transmission from domestic sheep or goats (including pack goats) in this bighorn sheep herd within next 10 years because of very high likelihood of direct contact between domestic sheep or goats (including pack goats) and bighorns.

The principal assumption for rating disease transmission risk was the following:

Direct contact between domestic sheep or goats (including pack goats) and bighorn sheep results in a high likelihood of disease transmission to bighorn sheep and disease outbreak in local bighorn sheep herds.

Members of this risk assessment team were provided:

- A table listing domestic sheep allotment name, allotment status, class of livestock, permitted number of sheep, permitted season on date and permitted season-off date.
- An 18 x 24 inch map showing domestic sheep allotments, sheep trailing routes and bighorn sheep occupied habitat (Wyoming Bighorn Sheep Occupied Habitat and Domestic Sheep Grazing Allotments Map, February 29, 2012 draft).
- An 8 ½ x 11 inch map of the popular domestic pack goat trails.

Members reviewed the pertinent maps and discussed disease transmission risk factors relevant for each bighorn sheep herd.

Risk assessment by herd unit from domestic sheep and goats

Clark's Fork, Trout Peak, Wapiti Ridge, Younts Peak and Francs Peak herd units

None of these core native bighorn sheep populations have occurred close (within 112 km) to domestic sheep allotments on the Shoshone in recent history. All domestic sheep allotments within these herd units on the Shoshone have been closed or converted to cattle due to livestock depredation by grizzly bears and/or willingness of a grazing permittees to move to other allotments. Although the foray distance for bighorn rams on the Shoshone is not known, the data compiled by the Payette National Forest (USFS 2006a) could be used to represent the potential foray distance on the Shoshone. They found that most sheep forayed from 0-26 km outside of their core home range with the longest foray being 35 km. No occupied habitat for core native herds occurs within 35 km of domestic sheep allotments on the Shoshone. In addition, no pack goat use occurs within these bighorn sheep herd's occupied habitat. The disease transmission risk is **Very Low** from domestic sheep and goats, including pack goats.

As a result of domestic sheep grazing on adjacent BLM land, risk is Very Low except for the Francs Peak herd. Because of domestic sheep grazing occurring in Owl Creek, risk of disease is considered to be Low to the Francs Peak herd. Present day risk from private land is Moderate due to the unknowns that could occur.

Whiskey Mountain herd unit

This core native bighorn sheep population has not occurred close (within 75 km) to domestic sheep allotments on the Shoshone in recent history. As stated earlier, these domestic sheep allotments likely provide very limited suitable habitat because they are mostly forested and occupied by gray wolves, utilizing the forested habitat in pursuit of prey. This would reduce the likelihood of foraging bighorn sheep utilizing these allotments. A pneumonia outbreak of unknown/undetermined origin last occurred in the Whiskey Mountain herd in 1991. Sick bighorn sheep were last observed on winter range in this herd in 2010. No known pneumonia outbreaks have occurred in the other core native herds on the Shoshone.

The disease transmission risk from domestic sheep to this core native bighorn sheep herds is **Very Low** due to livestock grazing on the Shoshone.

Goat packing occurs within occupied habitat of this core native herd (Figure 1). A portion of the trails used for goat packing are within and adjacent to occupied bighorn sheep habitat consisting of rocky escape cover and open alpine meadows (Figure 4). These trails are in spring/summer/fall and winter/year-long bighorn sheep habitat. Therefore, there would be spatial and temporal overlap between goat packing and bighorn sheep. This increases the opportunities for contact between bighorn sheep and pack goats, thus increasing the potential risk of disease transmission. Due to the lack of sufficient literature about disease transmission from domestic goats to bighorn sheep, and unproven best management practices including diagnostic tests on pack goats, the risk of disease transmission as a result of activities on the Shoshone is increased from Very Low to **Low**. Currently, no other core native bighorn sheep herds on the Shoshone have known goat packing use within occupied habitat or adjacent to occupied habitat

Bighorn sheep from the Whiskey Mountain herd have made forays to active domestic sheep allotments on the Bridger-Teton National Forest. Because of these forays and documented domestic sheep in core native habitat on the Bridger-Teton, the risk of disease transmission to this herd is Low to Moderate.

As a result of allotments closed to domestic sheep grazing on adjacent BLM land, risk is Very Low. Present day risk from private land is Moderate due to the unknowns that could occur.

Temple Peak herd unit

The closest portion of the remnant Temple Peak herd is about 28.9 km from the domestic sheep allotments on the Shoshone. The remnant South Fork Little Wind River herd on the Wind River Indian Reservation is about 33 km from the allotments. Both bighorn sheep herds are at population levels considered to be quasi-extirpation (fewer than 30 sheep) which will likely result in eventual herd extinction regardless of any potential threat from domestic sheep. WGFD has determined the Temple Peak herd (a Cooperative Review herd) is not going to be supplemented or encouraged to expand until domestic sheep allotments on the adjacent Bridger-Teton National Forest are addressed (WGFD, personal communication 2012a).

As stated earlier, these domestic sheep allotments likely provide very limited suitable habitat because they are mostly forested. In addition, there is a high amount of the landscape between currently occupied habitat for these two herds and the allotments that is forested. Low numbers of bighorn sheep also decrease the chance of interaction with domestic sheep allotments on the Shoshone. All of these factors would reduce the likelihood of foraging bighorn sheep utilizing these allotments on the Shoshone.

The disease transmission risk from domestic sheep to this cooperative review bighorn sheep herd is **Very Low** due to livestock grazing on the Shoshone.

Goat packing occurs within occupied habitat of this cooperative review herd. Portions of trails used for goat packing are within and adjacent to occupied bighorn sheep habitat consisting of rocky escape cover and open alpine meadows. These trails are in spring/summer/fall and winter/year-long bighorn sheep habitat. Therefore, there would be spatial and temporal overlap between goat packing and bighorn sheep. This increases the opportunities for contact between bighorn sheep and pack goats, thus increasing the potential risk of disease transmission. Due to the lack of sufficient literature about disease transmission from domestic goats to bighorn sheep, and unproven best management practices including diagnostic tests on pack goats, the risk of disease transmission as a result of activities on the Shoshone is increased from Very Low to **Low**.

Bighorn sheep from the Temple Peak herd have made intermittent forays to active domestic sheep allotments on the Bridger-Teton National Forest. In addition, due to the unknowns that can occur from domestic sheep grazing on private land and the Wind River Reservation, the risk of disease transmission to this herd is increased from Very Low to Low to Moderate.

Summary of Conclusions

All core native bighorn sheep herds on the Shoshone National Forest are at **Very Low** risk from domestic sheep due to the distance their occupied habitat is from domestic sheep allotments on the Forest. No further conservation measures are needed related to domestic sheep grazing and bighorn sheep. The Shoshone will continue to provide a vast amount of bighorn sheep habitat for these core native herds into the future.

The Temple Peak herd will continue to be managed within the “Cooperative Review Area” as a remnant herd. Any change in management of this herd would be cooperatively agreed upon by the Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004a).

Although scientific literature is limited specifically for the risk of disease transmission between domestic goats (including pack goats) and bighorn sheep, some information is available (Rudolph et al. 2003, Jansen et al. 2006, Foreyt et al. 2009). Until further scientific information is available to prove otherwise, the risk to bighorn sheep is far too great to allow domestic goat use within core native bighorn sheep habitat (WGFD 2012b, personal communication). Even one disease transmission event could be catastrophic to a bighorn sheep herd, as discussed earlier in the disease risk from domestic sheep and goats to bighorn sheep. The risk assessment team all agreed that any change from Very Low (even to **Low**) was not an acceptable risk in core native bighorn sheep habitat.

Conservation Measures and Recommendations

1. Close all occupied core native bighorn sheep habitat and the area within 26 km of the occupied core native habitat to domestic goat (includes pack goat) use. This is needed to protect core native bighorn sheep herds from the potential for contact with domestic goats. The closure for the 26 km buffer is to protect foraging bighorn sheep from coming into contact with domestic goats. This measure effectively closes the entire Shoshone National Forest, except the Washakie Ranger District to domestic goat use, including pack goats.

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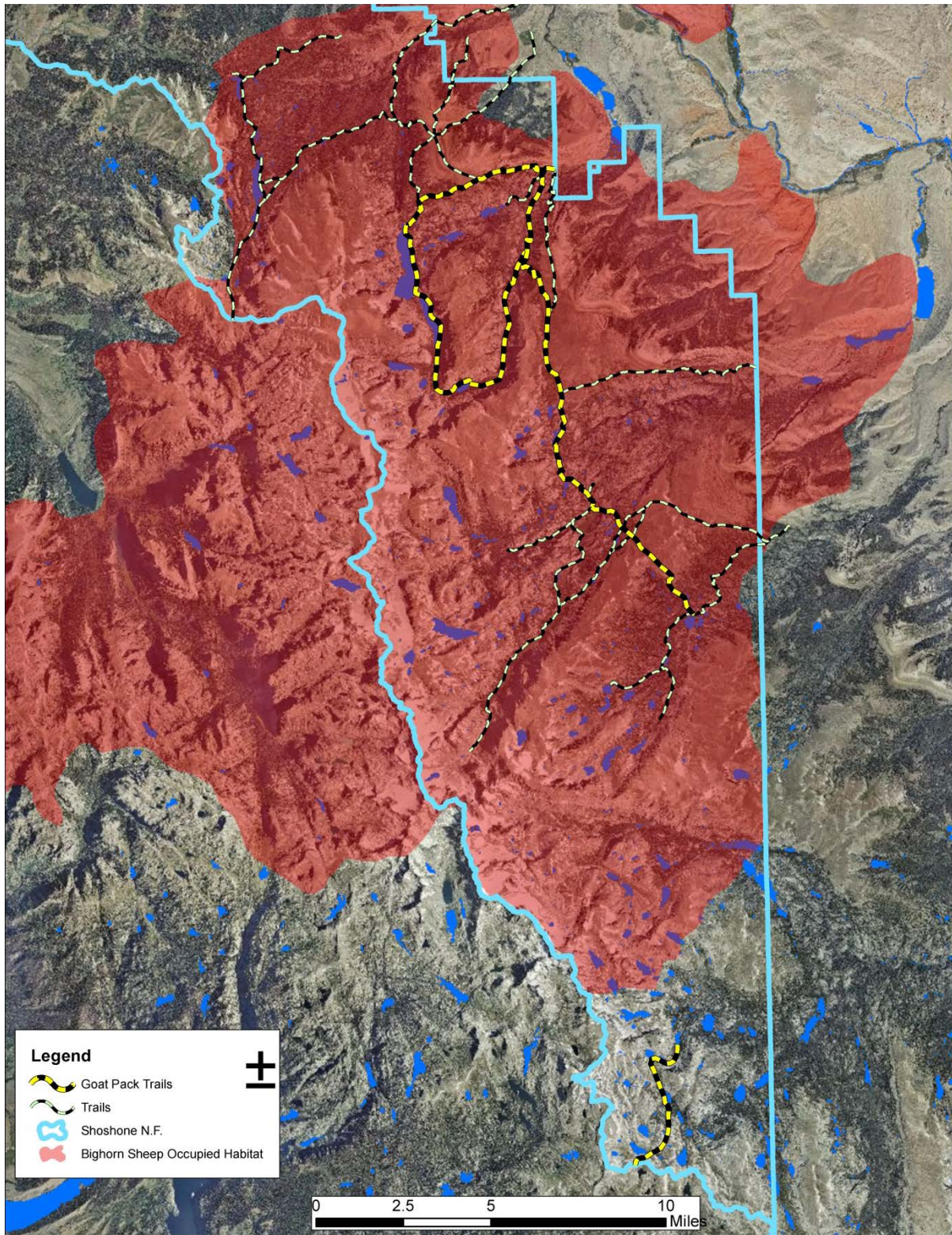


Figure 1. Goat packing trails within the Whiskey Mountain bighorn sheep herd's occupied habitat

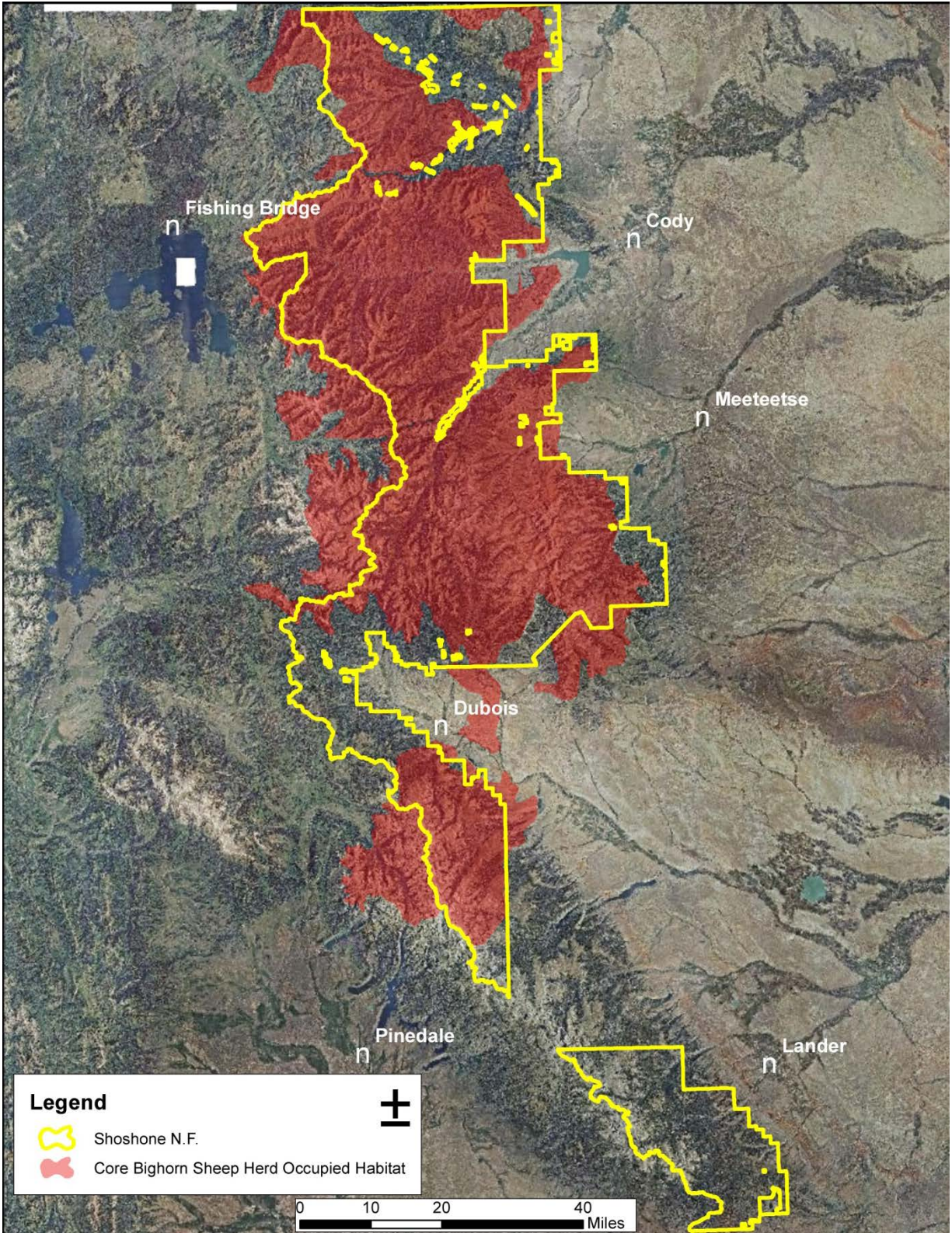


Figure 2. Core native bighorn sheep herd's occupied habitat on the Shoshone National Forest

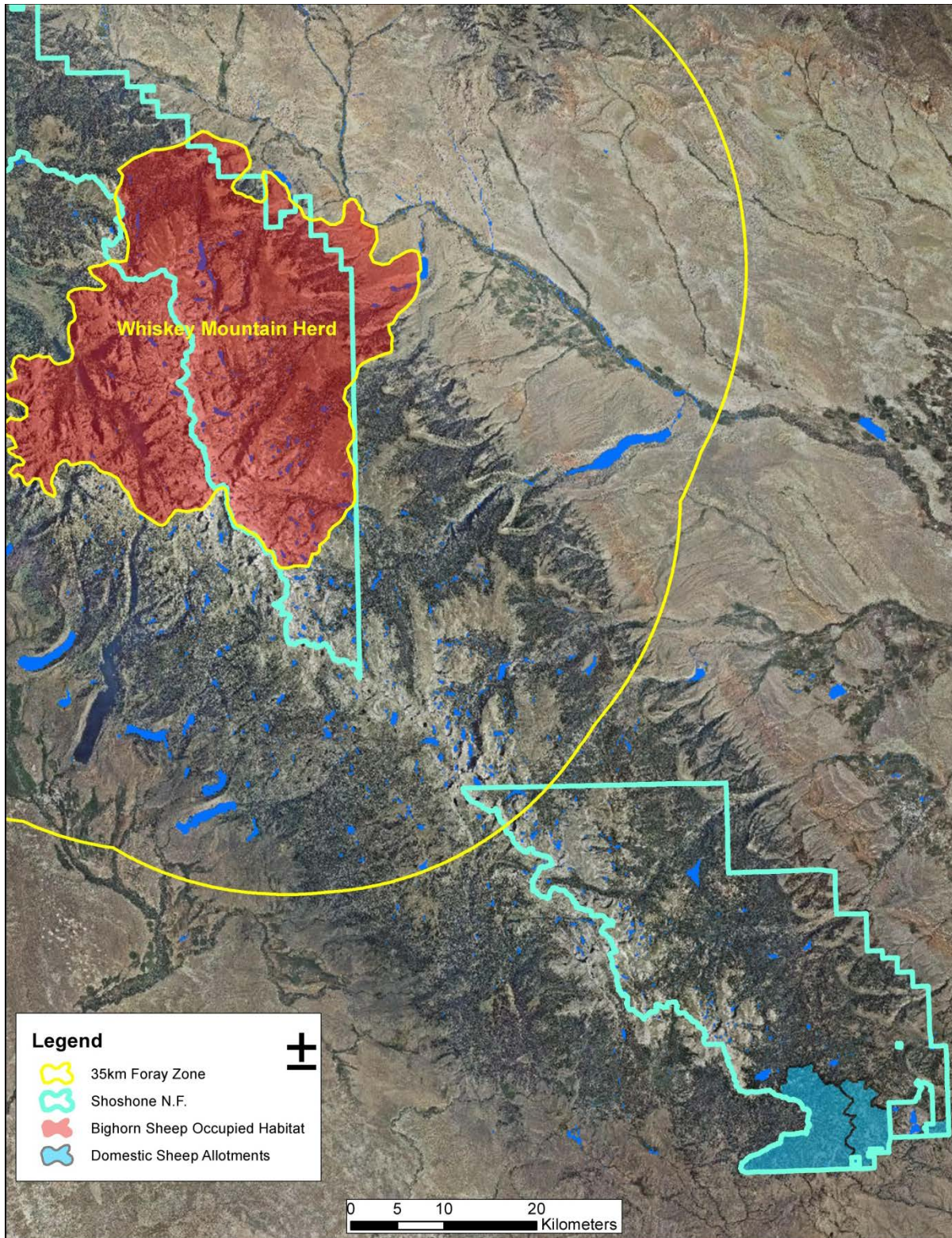


Figure 3. Whiskey Mountain bighorn sheep herd and domestic sheep grazing allotments on the Shoshone National Forest

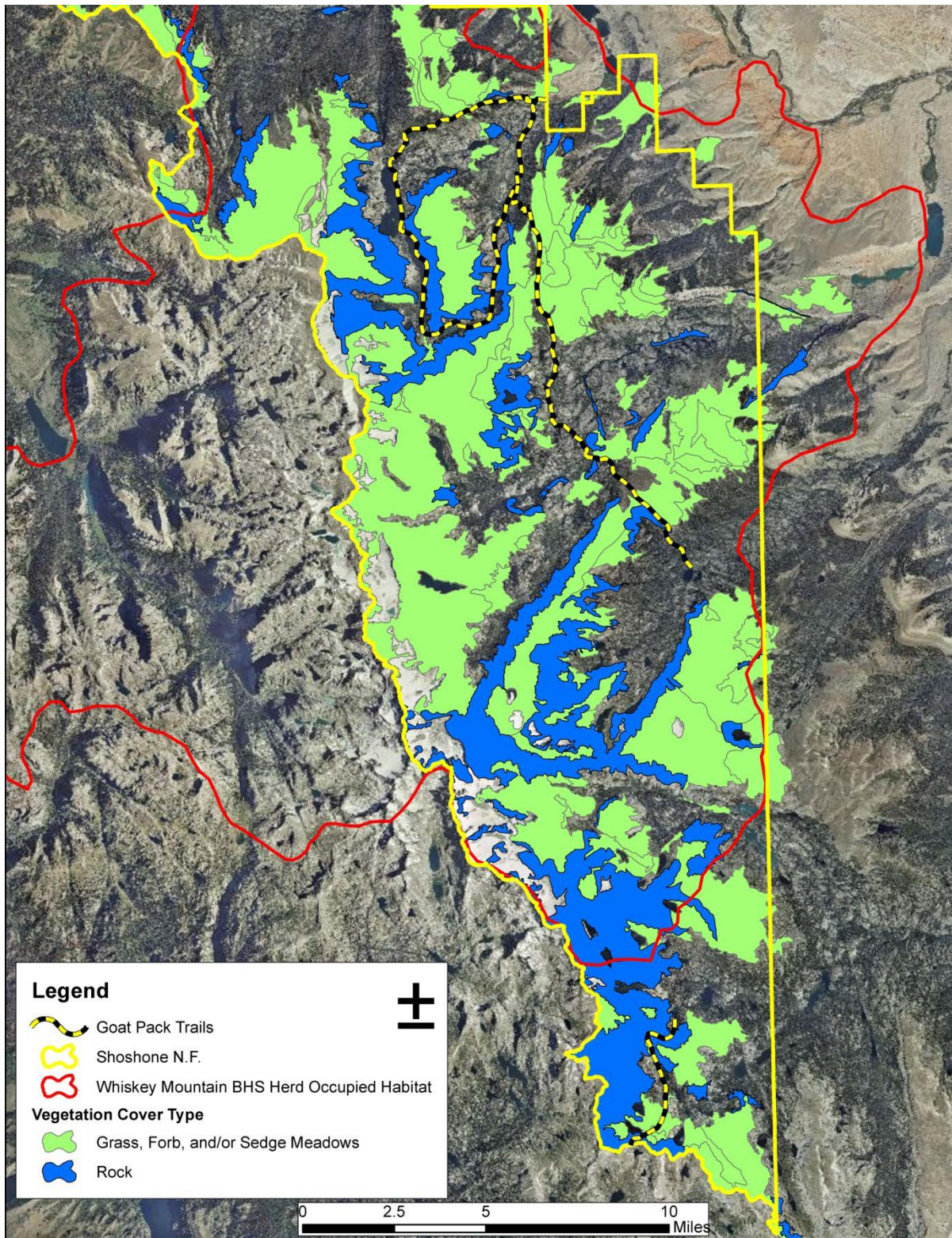


Figure 4. Potentially suitable bighorn sheep habitat and goat packing trails within the Whiskey Mountain bighorn sheep herd's occupied habitat