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Risk Analysis of Disease Transmission Between Domestic Sheep and Bighorn Sheep on the Payette National Forest

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Background

In a March 14, 2005 appeal decision on the 2003 Forest Plan for the Payette National Forest (NF), the reviewing officer for the Chief of the Forest Service made the following determinations (USDA Forest Service 2005:page 15):

> "Management direction in the Payette NF LRMP [Land and Resource Management Plan] for the Hells Canyon MA [Management Area] does not adequately provide for habitat to insure the maintenance of a viable bighorn sheep population within the Payette NF (36 CFR 219.19). It also does not adequately protect bighorn sheep populations and habitat in the Hells Canyon NRA (36 CFR 292.48). I find the Payette NF LRMP is not in compliance with NFMA regulations concerning wildlife viability of bighorn sheep, and may not be in compliance with the Hells Canyon NRA Act and its implementing regulations. The Regional Forester's decision to approve revised management direction in the Payette NF LRMP for the Hells Canyon MA is reversed."

The following direction was provided in the appeal decision (USDA Forest Service 2005:page 15):

> "The Regional Forester is instructed to do an analysis of bighorn sheep viability in the Payette NF commensurate with the *concerns and questions* [italics added] discussed above, and amend the SW Idaho Ecogroup FEIS [Final Environmental Impact Statement] accordingly. Changes to the management direction of the Payette NF LRMP for MA #1 (Hells Canyon) and adjacent areas shall be evaluated, and adopted as necessary to ensure bighorn sheep viability. The analysis and evaluation must be extensive enough to support determinations of compliance with applicable law and regulation, specifically the Hells Canyon NRA Act, 36 CFR 219.19, and 36 CFR 292.48."

The "... concerns and questions ..." identified on line 2 of the preceding paragraph refers to the threat to bighorn sheep populations resulting from diseases transmitted from domestic sheep grazed on the Payette NF. This issue was raised in 3 separate appeals to the 2003 Payette Forest Plan (USDA Forest Service 2005:page 10).

Following direction from the Chief's Reviewing Officer, the Payette NF conducted an analysis of the effects of disease transmission from domestic sheep grazed on the Forest to bighorn sheep populations occurring within and near the Payette NF. This report summarizes the results of this analysis.

The analysis was conducted at the spatial scale of the Payette NF, even though direction in the LRMP appeal decision focused on the Hells Canyon Management Area (MA #1). Language in the appeal decision incorrectly states that the 2 bighorn sheep populations on the Payette NF are the Hells Canyon and Snake River populations (USDA Forest Service 2005:page 13). Bighorn sheep populations occur in 2 distinct geographic areas on the Payette NF: Hells Canyon of the Snake River and the Salmon River Mountains (referred to as Salmon River Canyon on page 3-286 of the FEIS for the Southwest Idaho Ecogroup Land and Resource Management Plans). The analysis consists of 3 parts: 1) a review of the scientific literature on disease transmission from domestic sheep to bighorn sheep and the impacts that disease has on bighorn sheep populations; 2) an evaluation of population data available for bighorn populations located within and adjacent to the Payette's boundaries; and 3) an expert panel assessment of risk of disease transmission from each of the Payette's domestic sheep allotments to nearby bighorn sheep populations.

Literature Review

Status of Bighorn Sheep

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. Traditionally, bighorn sheep have been divided into Rocky Mountain bighorn sheep (*Ovis c. canadensis*), California bighorn sheep (*O. c. californiana*), and desert bighorn sheep (*O. c. nelsoni*), but see Wehausen and Ramey (2000).

Bighorn sheep were abundant and widely distributed across the western United States prior to the mid 1800s. The combined effects of overharvest, habitat loss, competition for forage caused by livestock overgrazing, and diseases transmitted by domestic livestock resulted in precipitous declines in abundance and distribution of bighorn sheep during the late 1800s and early 1900s (Goodson 1982, Valdez and Krausman 1999). Rocky Mountain and/or California bighorn sheep were extirpated from eastern Montana, eastern Wyoming, western North and South Dakota, northwestern Nebraska, Oregon, Washington, northern California, New Mexico, and Nevada (Valdez and Krausman 1999:page 21). Desert bighorn populations were extirpated from Texas and the Mexican states of Chihuahua and Coahuila (Valdez and Krausman 1999:page 21). Despite extensive efforts to recover bighorn populations in the western U.S., the total number of bighorn sheep in the U.S. currently is thought to be less than 10% of presettlement numbers. Current distribution of bighorn sheep is less than a third of its presettlement distribution, and most existing populations are relatively isolated and small, composed of fewer than 100 individuals (Berger 1990, Singer et al. 2000c). Over half of existing bighorn populations are the result of translocations (Singer et al. 2000c). Indigenous populations of bighorn sheep in the Peninsular Ranges of southern California and the Sierra Nevada of California are currently listed as endangered under the Endangered Species Act.

Bighorn sheep were abundant in Idaho prior to the 1850s (the following information on California and Rocky Mountain bighorn sheep populations in Idaho was summarized from Smith 1954 and Toweill and Geist 1999). California bighorns occurred in southwest Idaho, separated from Rocky Mountain bighorn populations by the Snake River plains. Similar to other areas throughout the western U.S., large die-offs of California bighorn herds occurred during the late 1800s and early 1900s. California bighorn sheep were extirpated from Idaho by 1940. In 1963 Idaho began reintroducing California bighorns along the East Fork of the Owyhee River. Hundreds of California bighorns were translocated to southwest Idaho between 1980 and 1993. Estimated numbers of California bighorns in Idaho were 90 in 1970; 570 in 1985; 1,240 in 1990; and 1,460 in 1997 (Toweill and Geist 1999:page 137).

Rocky Mountain bighorn sheep were abundant throughout mountainous areas of central Idaho prior to the 1850s. Settlement of Idaho in the mid 1800s led to increased harvest of bighorns, especially following discovery of gold in central Idaho in the 1860s and 1870s. Domestic sheep were brought into parts of Idaho in the 1860s, and historic accounts indicate that major die-offs of bighorns in the Salmon River Mountains began about 1870 (Smith 1954:page 21). Idaho started reintroducing Rocky Mountain bighorn sheep in 1969, and numbers of Rocky Mountain bighorn sheep in Idaho increased to nearly 4,000 sheep by 1989. Estimated numbers of Rocky Mountain bighorns in Idaho decreased from about 3,850 in 1990 to 1,710 in 1998 (Toweill and Geist 1999:page 85). Population declines during the 1990s were primarily the result of disease outbreaks (Toweill and Geist 1999:pages 84-85).

Effects of Disease on Bighorn Populations

Populations of other wild ungulates such as mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) also were significantly reduced during the late 1800s and early 1900s, but their populations have recovered to a much greater extent than have populations of bighorn sheep. Perhaps the most important reason bighorn sheep populations have recovered poorly is that bighorn populations have been negatively affected by disease to a much greater extent than have populations of other wild ungulates such as mule deer and elk (Goodson 1982). Bighorn sheep is a New World species closely related to domestic sheep (*Ovis aries*). 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.

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; 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; 6) there is consensus among wildlife biologists and veterinarians experienced in bighorn sheep management that domestic sheep and bighorn sheep must be kept separated in order to maintain healthy bighorn populations (e.g., Foreyt and Jessup 1982; Goodson 1982; Onderka and Wishart 1988; Foreyt 1989; Desert Bighorn Council Technical Staff 1990; Callan et al. 1991; Cassirer et al. 1996; Martin et al. 1996; USDI Bureau of Land Management 1998; Bunch et al. 1999; Singer et al. 2000a, 2000b, 2000c, 2000d; Monello et al. 2001; Schommer and Woolever 2001; Singer et al. 2001; Dubay et al. 2002; Garde et al. 2005).

There is evidence that domestic goats (*Capra aegagrus hircus*) can transmit *M. haemolytica* to bighorn sheep (Rudolph et al. 2003). Bighorn sheep and domestic sheep are attracted to each other, which greatly increases the potential for close contact and disease transmission. Transmission of *M. haemolytica* requires nose-to-nose contact or transfer of mucus through coughing or sneezing. Currently there is no vaccine available known to prevent bighorn sheep from developing pneumonia. Even if such a vaccine were available, it would be difficult and expensive to vaccinate large numbers of wild bighorns. Bighorn sheep are easily stressed, so much so that they are susceptible to a condition termed "capture myopathy" when handled (Bunch et al. 1999:pages 233-237).

Pneumonia outbreaks frequently result in mortality of many to most individuals within the herd. All age classes of bighorns are typically affected. In addition to high mortality of all age classes during the pneumonia outbreak, lamb survival and thus recruitment typically remains depressed for 2 or more years following the epizootic. Because of these impacts on both survival and recruitment, pneumonia outbreaks can have significant long-term impacts on bighorn sheep populations. 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. Gross et al. (2000) used individual-based simulation models to evaluate the effects of disease on bighorn population dynamics. Results of model simulations were significantly affected by the occurrence of disease. Modeled disease events of moderate and severe intensity resulted in higher 200-year extinction rates than mild disease events, but mild disease events had longer lasting effects on population size (over 2 decades) than did moderate or severe disease events. 200-year extinction rates approached 80% when models incorporated moderate and severe disease events at 15-year frequencies.

Management of Bighorn Sheep Disease Issues

Goodson (1982) listed several examples of past management direction or guidelines taken to reduce the risk of disease transmission from domestic sheep to bighorns. As early as 1954, Colorado Division of Wildlife purchased land in bighorn range at Pikes Peak to prevent domestic sheep grazing, thus reducing potential contact between domestic sheep and bighorns. Goodson (1982) noted that the San Bernardino and Angeles National Forests in California developed a policy against domestic sheep grazing on occupied bighorn range as early as 1967. Goodson (1982) also cited NEPA decisions on the Inyo and San Bernardino National Forests to not convert from cattle to sheep allotments based on concern about the potential for disease transmission between domestic sheep and bighorns. As a result of concern over disease transmission between domestic sheep and bighorn sheep, the Director of Wildlife and Fisheries for the U.S. Forest Service sent a memo to Regional Foresters in western regions in 1981 stating that "... Appropriate caution should be exercised to prevent contact between the species" (Jones 1981 as cited in Goodson 1982).

In 1995 the Wallowa-Whitman National Forest eliminated domestic sheep grazing from 3 active allotments within the Hells Canyon National Recreation Area to reduce threats to bighorn sheep viability posed by disease transmission from domestic sheep (USDA Forest Service 1995a, 1995b). In 2003 the Uinta National Forest in Utah closed 2 vacant sheep allotments due to concern over disease transmission to reintroduced Rocky Mountain bighorn sheep (USDA Forest Service 2003c:page ROD-4).

The Desert Bighorn Council Technical Staff (1990) developed guidelines for management of domestic sheep in the vicinity of desert bighorn habitat. Their recommendations included: 1) no nose-to-nose contact between bighorn and domestic sheep; 2) a minimum of a 13.5-km-wide (8.4 miles) buffer strip between ranges used by domestic sheep and bighorns; 3) trucking of domestic sheep in preference to trailing, and no trailing when domestic ewes are in estrus; and 4) no bighorn reintroductions into areas that have been grazed by domestic sheep during the previous 4 years.

In 1992, the Bureau of Land Management (BLM) issued Instruction Memorandum 92-264, *Guidelines for Domestic Sheep Management in Bighorn Sheep Habitats*, as part of an ongoing effort to restore bighorn sheep populations into historically occupied habitats on public lands (USDI Bureau of Land Management 1992). In 1998, Bureau of Land Management issued Instruction Memorandum No. 98-140, *Revised Guidelines for Management of Domestic Sheep and Goats in Native Wild Sheep Habitats* (USDI Bureau of Land Management 1998). Guidelines included: 1) domestic sheep or goat grazing and trailing should be discouraged in the vicinity of native wild sheep ranges; 2) native wild sheep and domestic sheep or goats should be spatially separated by buffer strips of 13.5 km (8.4 miles) except where topographic features or other barriers minimize contact between native wild sheep and domestic sheep or goats; 3) domestic sheep and goats should be closely managed and carefully herded where necessary to prevent them from straying into native wild sheep areas; 4) trailing of domestic sheep or goats near or through occupied native wild sheep ranges may be permitted when safeguards can be

implemented to prevent physical contact between native wild sheep and domestic sheep or goats; 5) BLM must conduct on-site use compliance during trailing to ensure safeguards are observed; 6) cooperative efforts should be undertaken to quickly notify the permittee and appropriate agency to remove any stray domestic sheep or goats or wild sheep in areas that would allow contact between domestic and wild sheep; 7) native wild sheep should only be reintroduced into areas where domestic sheep or goat grazing is not permitted.

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. Examples are also provided of a bighorn sheep/domestic sheep management strategy for the Wallowa-Whitman NF and forest plan direction on management of bighorn sheep habitat from the White River NF in Colorado.

Wyoming provides an example of a state effort in dealing with domestic sheep/bighorn sheep issues (Wyoming State-wide Bighorn/Domestic Sheep Interaction Working Group 2004). The U.S. Fish and Wildlife Services developed an interagency domestic sheep management strategy to help protect endangered populations of bighorn sheep in California (USDI Fish and Wildlife Services 2001). This strategy was included in the draft recovery plan for Sierra Nevada bighorn sheep (USDI Fish and Wildlife Services 2003:Appendix B) and is currently being revised.

Domestic Sheep Grazing on Payette NF

The sheep industry in Idaho developed more slowly than the cattle industry. There were only about 1,000 domestic sheep in Idaho in 1870, although hundreds of thousands of sheep were trailed across the state from Oregon to the East prior to development of an established sheep industry (Jones 1989). The sheep industry grew tremendously during the 1870s and 1880s, especially following completion of key railroad lines. The Weiser Forest Reserve was established in 1905, and the Idaho Forest Reserve was established in 1908. Both reserves, later called national forests, went through many boundary adjustments until they were consolidated in 1944 to become the Payette National Forest. Similar to many areas throughout the West, huge numbers of sheep were grazed on Payette NF lands during the late 1800s and early 1900s, resulting in severe erosion and significant changes in vegetation structure and composition (Hockaday 1968:pages 53 to 58, Jones 1989). Total number of permitted sheep on Payette NF lands has declined steadily since 1915: 174,445 sheep were permitted in 1915; 132,621 in 1925; 100,606 in 1935; 64,067 in 1945; 49,471 in 1955; 42,330 in 1964; and 19,112 in 2005 (Hockaday 1968:page 56). Currently, domestic sheep are grazed only within the western half of the Payette NF (Figure 1). Historically, sheep were grazed across the entire Forest, including eastern portions of the Forest within the South Fork Salmon River drainage and other areas within what is now classified as the Frank Church River of No Return Wilderness (Jones 1989:pages 28-33). Livestock grazing within the South Fork Salmon River drainage was substantially reduced by the late 1950s, and by 1970 there were no livestock allotments left in the drainage above the confluence with the East Fork of the South Fork Salmon River (Jones 1989:page 30).

Currently, there are 4 permittees who graze domestic sheep on 24 sheep allotments on the Payette NF: 5 allotments on the west side of the Forest and 19 allotments on the east side (Figure 1). Numbers of permitted sheep range from 1,500 dry ewes (on Victor-Loon and North Forth Lick Creek allotments) to 3,100 dry ewes (Smith Mountain allotment) and from 800 ewe/lamb pairs (on Fall/Brush Creek allotment) to 3,100 ewe/lamb pairs (Smith Mountain allotment) (Table 1). The earliest permitted season-on date is April 1 (Surdam allotment) and the latest permitted season-off date is October 15 (Smith Mountain, Vance Creek, Brundage, Bill Hunt, and Jughandle allotments).

Forest-wide goals, objectives, and standards for rangeland resources are found on pages III-44 to III-45 of the 2003 Payette Forest Plan (USDA Forest Service 2003a). Rangeland resources standards on page III-45 are designed to protect forest resources, primarily by restricting certain grazing practices or grazing levels, such as setting maximum forage utilization levels for riparian and upland vegetation cover types. An additional Forest-wide rangeland resource guideline (guideline 0142) is found in Errata #3:

> Within bighorn sheep habitat emphasis areas, close sheep allotments as they become vacant, or convert to cattle where appropriate, to eliminate the risk of disease transmission from domestic to wild sheep. Do not convert cattle allotments to sheep allotments within occupied bighorn sheep habitat.

Additional management direction for rangeland resources is found for each of the 14 management areas on the Payette NF (USDA Forest Service 2003a:pages III-78 to III-274).

Population Status of Bighorn Sheep Populations on the Payette NF

Only Rocky Mountain bighorn sheep occur on the Payette NF (there are no California bighorn populations on the Forest). Currently, Rocky Mountain bighorn sheep populations occur in 2 geographic areas on the Payette NF: Hells Canyon of the Snake River and the Salmon River Mountains (USDA Forest Service 2003b:pages 3-286 to 3-287). Bighorn sheep typically occur in a metapopulation structure, in which discrete local populations interact at some level as a result of limited movements between local populations (Bleich et al. 1996, Singer et al. 2000a). This metapopulation structure is crucial to analyzing the effects of disease transmission on bighorn sheep populations. Interactions among individuals from different populations can have negative effects by facilitating the spread of disease between populations within the metapopulation. These interactions also can have important positive effects by creating opportunities for population augmentation, colonization, and recolonization, as well as enhancing genetic diversity. Bighorn sheep colonization rates have traditionally been thought to be low, but see Schwartz et al. 1986 and Singer et al. 2000a. Bighorn populations in both the Hells Canyon and Salmon River Mountains metapopulations generally move between lower-elevation winter ranges in the canyon bottoms to upper-elevation summer ranges, although considerable variation exists among herds and even among individuals, especially between rams and ewes, within herds. Summer ranges are typically much more expansive than winter ranges.

Hells Canyon Metapopulation

Bighorn sheep were historically abundant in Hells Canyon. There may have been 10,000 or more Rocky Mountain bighorn sheep inhabiting Hells Canyon and surrounding mountains in the early to mid 1800s (Hells Canyon Bighorn Sheep Restoration Committee 2005:Appendix C). Bighorn sheep were extirpated from the area by the mid 1940s due to competition for forage with domestic livestock, diseases carried by domestic sheep, and unregulated hunting (Hells Canyon Bighorn Sheep Restoration Committee 2005:Appendix C). In 1971 efforts began to reintroduce bighorn sheep to Hells Canyon. The Hells Canyon Initiative was started in 1995 as a program to

accelerate restoration of bighorn sheep in Hells Canyon and the surrounding areas of Idaho, Oregon, and Washington. The program was formalized in 1997 with the completion of an interagency memorandum of agreement among the Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, U.S. Forest Service, Bureau of Land Management, and Foundation for North American Wild Sheep. A restoration plan was developed in 1997 (Hells Canyon Bighorn Sheep Restoration Committee 1997) and updated in 2004 (Hells Canyon Bighorn Sheep Restoration Committee 2004). The Hells Canyon bighorn sheep project area encompasses 5,617,062 acres in the Snake River drainage in Washington, Oregon, and Idaho from the mouth of the Clearwater River to the north and Brownlee Reservoir to the south (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 1). The project area is bounded on the east by the hydrologic divide between the Salmon River drainage and Snake River drainage and extends west to the Eagle Cap Wilderness on the Wallowa-Whitman NF in Oregon.

Between 1971 and 2004, 474 bighorn sheep were transplanted into the Hells Canyon area, and 126 bighorns were relocated within the area. The Hells Canyon bighorn sheep metapopulation was estimated at 875 sheep in 2005, a 4% decline from 2004 (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 13). The metapopulation consists of 16 populations or herds. Seven bighorn die-offs have been reported since reintroductions began in 1971. Five of these die-offs were pneumonia (Pasteurellosis) disease outbreaks circumstantially linked to domestic sheep, 1 was a pneumonia outbreak circumstantially linked to a feral goat, and 1 to drought and scabies (*Psoroptes ovis*) (Idaho Department of Fish and Game 2004a:page 4). Despite these die-offs, growth of the metapopulation has been positive since 1971 (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 6).

Between 1997 and 2003, 154 radio-collared bighorns were monitored (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 8). Sixty-one radio-collared bighorns died, and mortality could be determined for 49 of these. Disease (primarily pneumonia) was the most frequent cause of mortality (43%), followed by cougar predation (27%), falls or injuries (22%), and human-caused (harvest, poaching, vehicle collisions: 8%). In addition, 42 dead lambs were collected during summer, and of 29 lambs for which cause of death could be determined, 25 (86%) were determined to have died due to pneumonia.

Bighorn populations located closest to the Payette NF are the McGraw, Sheep Mountain, Upper Hells Canyon, Idaho, and Upper Hells Canyon, Oregon populations (Figure 1). The McGraw population was established with a transplant of 15 bighorns from the Lostine, Oregon population in January, 1999. Sheep were transplanted to McGraw Creek on the Oregon side of Hells Canyon. At the time, biologists thought that the sheep would stay on the Oregon side of Hells Canyon. However, bighorn sheep did cross over to the Idaho side. Bighorn sheep were observed on the Brownlee Dam and swimming across Hells Canyon Reservoir (Vic Coggins, personal communication). Two of the transplanted bighorn rams spent much of the spring and summer of 1999 on the Idaho side within the Smith Mountain sheep allotment on the Payette NF (Coggins et al. 1999). Both of these rams were observed on the ground at Lyne's Saddle within the Smith Mountain sheep allotment on August 12, 1999. Both had nasal discharge and appeared sick: one was coughing and the other sneezing. In an effort to reduce the likelihood of spreading disease to other bighorn sheep, Oregon Department of Fish and Wildlife biologists shot and killed these 2 rams (Coggins 2001, 2002). The following summer in 2000, a sick bighorn ewe found in close proximity to a band of domestic sheep near Sheep Rock in the Smith Mountain allotment was also shot and killed by biologists from Oregon Department of Fish and Wildlife (Coggins 2001, 2002). Necropsy confirmed that this ewe had pneumonia. Bighorn sheep from the McGraw herd began dying during fall of 1999 and winter of 1999/2000, and by 2003 most of the transplanted bighorn sheep in the McGraw herd had died or dispersed to nearby herds (Idaho Department of Fish and Game 2004a:page 39). Necropsies confirmed that the die-off was

caused by pneumonia. The McGraw herd is not currently considered an extant population (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 13).

A total of 42 bighorn sheep were transplanted to Sheep Mountain on the Oregon side of Hells Canyon between 1990 and 1995. The population increased to 70 sheep in 1998. Two of the bighorn sheep from the McGraw population were observed with bighorns from the Sheep Mountain population in July, 1999 (Coggins et al. 1999). A confirmed pneumonia outbreak followed, resulting in loss of over 50% of the population by 2002 (Idaho Department of Fish and Game 2004a:page 46). There were an estimated 25 bighorn sheep in the Sheep Mountain population in 2005 (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 13).

A total of 58 bighorn sheep have been transplanted into the Upper Hells Canyon, Idaho population since the mid 1970s (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 31). This herd grew to an estimated population size of about 90 sheep in the early 1980s. Population size then began declining around 1983 when a pneumonia outbreak began (Vic Coggins, personal communication). Population size declined to very few sheep by 1991 (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 31). There were an estimated 20 bighorn sheep in the Upper Hells Canyon, Idaho population in 2005 (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 13).

The Upper Hells Canyon, Oregon herd received a total of 54 transplanted sheep between 1971 and 1980. Radio-collared bighorn sheep from this population have been detected in the Seven Devils Mountains just west of the Curren Hill allotment near Black Lake and within the Smith Mountain allotment as far south as Limepoint Creek (Coggins 2001). This population has experienced several pneumonia outbreaks (Coggins 2001). Following these pneumonia die-offs, this population grew to about 40 sheep by 1983 when another pneumonia die-off began. Population size declined sharply, and by 1989 only about 10 sheep remained in the population. Since that time, the population has grown to an estimated population size of 35 sheep by 2005 (Hells Canyon Bighorn Sheep Restoration Committee 2005:page 13).

Disease, primarily pneumonia initiated by contact with domestic sheep, has been identified as the key factor limiting bighorn restoration in Hells Canyon (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 24; Hells Canyon Bighorn Sheep Restoration Committee 2005:Appendix C). To date, treatments (including medicated and mineralized feed, vaccination, and culling) have had little success at reducing the effects of disease outbreak in the Hells Canyon bighorn population. Accordingly, research emphasis is being placed on understanding the ecology of disease in Hells Canyon and developing tools to resolve disease issues through preventative and acute management (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 24).

Salmon River Mountains Metapopulation

Unlike the Hells Canyon area, bighorn sheep were not extirpated from the Salmon River Mountains area of central Idaho. Smith (1954:page 40) showed that bighorn sheep occurred along the lower South Fork of the Salmon River, the north side of the Main Salmon River canyon, the Middle Fork of the Salmon River, Panther Creek, and the surrounding mountains in 1952. Rocky Mountain bighorns have been reintroduced to different parts of central Idaho beginning in 1969: Mahogany Creek near Mt. Borah, Blue Dome, Copper Mountains, Birch Creek southwest of Challis, Lost River and Little Lost River Ranges (Toweill and Geist 1999:page 85).

Two bighorn populations currently occur in the Salmon River Mountains primarily within the boundaries of the Payette NF: one in the South Fork Salmon River drainage, and one in the Big Creek drainage (Figure 1). Bighorn populations also occur just north of the Forest along the Main Salmon River and just east of the Forest along the Middle Fork Salmon River.

Big Creek is a major drainage of the Middle Fork Salmon River. The Big Creek population winters along the lower 20 km (12 miles) of the Big Creek drainage (Akenson and Akenson 1992). Population survey data for this herd from 1973 to 1992 is presented in Akenson and Akenson (1992), and survey data from 1989 to 2004 is presented in Idaho Department of Fish and Game (2004b:page 32). Total number of sheep counted increased from approximately 60 in 1973 to 270 by 1989. Bighorn sheep exhibiting signs of pneumonia (coughing, nasal discharge, poor body condition) began to be observed in 1986. Clinical examination and culture samples indicated that pneumonia due to *Mannheimia haemolytica* (formerly *Pasteurella haemolytica*) was a significant cause of summer lamb mortality (Akenson and Akenson 1992). Early summer lamb mortality resulted in declining lamb/ewe ratios from 1986 to 1991. During 1990/1991, an all-age die-off occurred, resulting in a population decline of approximately 50%. Akenson and Akenson (1992) found that lambing areas for bighorn sheep that wintered along lower Big Creek were up to 40 km (25 miles) from winter range, and that bighorn sheep from herds that wintered elsewhere along the Middle Fork Salmon River used some of the same summer range used by Big Creek sheep. They noted how this sharing of summer range could facilitate transfer of disease among different bighorn populations. Survey data indicate that population size for this population has been relatively stable since the early 1990s (Table 2).

Suitable bighorn habitat located throughout most of Unit 27 is considered bighorn sheep summer range (Tom Keegan, personal communication). Survey data for Hunt Areas 27-1, 27-2, and 27-3, which are areas just east of the Payette NF along the Middle Fork Salmon River (Figure 1), show a similar pattern of population decline in 1989/1990 followed by 1 to 2 years of poor recruitment (Table 3). Survey data from Unit 20A along the lower Middle Fork Salmon River (Figure 1) indicate that bighorn recruitment was very low in 1990 and 1991 in this herd, and that population size has been declining gradually since the early 1990s (Table 4). The population decline in this region between 1989 and 1991 has been attributed to a pneumonia outbreak in 1988-1989 (Idaho Department of Fish and Game 2004:page 53). The similar pattern observed in population survey data from different bighorn populations across a large area in the Middle Fork Salmon River drainage provides an example of how nearby populations likely interact and how disease can spread across relatively large areas.

Population survey data for the South Fork Salmon River population was available from 1985 to 2002 (Table 5). Thirty-eight sheep were counted in 1985 and 92 in 1986. Counts were relatively stable between 1989 and 1994 and then declined between 1994 and 1995. The Chicken Complex wildfire burned approximately 108,000 acres in the South Fork Salmon River drainage area during 1994. Approximately 20 burned bighorn sheep carcasses were detected following this fire (Jeff Rohlman, personal communication). In addition to causing direct mortality, this fire likely negatively affected bighorn habitat and forage for the 1994-1995 winter. Total sheep counted declined by 55% between 1994 and 1996. Although vegetation should have recovered extensively since the 1994 fire, total sheep counted in 2002 was still very low (33 sheep). Disease could have been negatively affecting this population during this time period, but no disease testing data is available (Jeff Rohlman, personal communication).

Bighorn populations also occur along the north side of the Main Salmon River (Figure 1). In Units 19 and 20, survey data indicates that bighorn numbers were low in 1981 and increased during the early 1980s (Table 6). In Unit 19, population size declined between 1984 and 1986 and again between 1989 and 1992. Lamb/ewe ratios indicate recruitment was very low in 1991 and 1992 in Unit 19. These survey data suggest that the pneumonia outbreak of 1988-1989 affected bighorn sheep survival in Units 19 and 20. Population declines also occurred between 1986 and 1989, 1992 and 1993, and 1996 and 2001 in Unit 20 (Table 6). Bighorn sheep in Unit 20 may have been negatively affected by wildfires that burned in 2000 (Idaho Department of Fish and Game

2004:page 9). The Allison-Berg domestic sheep allotment on the Nez Perce NF is located adjacent to the range of bighorn sheep along the Salmon River (Figure 1).

Expert Panel Risk Assessment

Introduction

The objective of the expert panel disease transmission risk assessment was to provide decision makers with information about the likelihood of disease transmission from domestic sheep to bighorn sheep for specific sheep allotments on the Payette NF. Wildlife disease ecology is complex, and like many other aspects of wildlife population ecology, characterized by many uncertainties. We know of no quantitative models available to predict likelihood of disease outbreak in bighorn sheep populations due to potential contact with domestic sheep. Because of the complexities associated with trying to develop a spatially explicit disease transmission model relevant to the needs of decision makers on the Payette NF, we chose instead to conduct an expert panel risk assessment to evaluate the risk of disease transmission from domestic sheep to bighorn sheep for each of the Payette's sheep allotments. Methods followed were similar to those used to evaluate EIS alternatives on likelihood of species persistence in the Interior Columbia Basin (Lehmkuhl et al. 1997). Similar expert panel risk assessments were also conducted by the Forest Ecosystem Management Assessment Team (FEMAT) in 1993 (Cleaves 1993, 1994) and during revision of the forest plan on the Tongass NF (Shaw 1999).

Methods

A panel of 6 wildlife biologists, each with considerable knowledge of bighorn sheep biology and management, was convened in New Meadows, Idaho on December 14, 2005. Names of the panelists, their professional affiliations, and descriptions of their bighorn management experience are provided in Appendix 1. Expert judgments were recorded through a process of likelihood voting, using a structured outcome scale (Lehmkuhl et al. 1997:pages 541-548). The outcome scale was composed of 5 possible outcomes. Individual outcomes represented points along a gradient ranging from very low risk to very high risk of disease transmission:

> Outcome 1: Very low risk of disease transmission from domestic sheep in this allotment to bighorns within next 10 years because of very low likelihood of direct contact between domestic sheep and bighorns.
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> Outcome 2: Low risk of disease transmission from domestic sheep in this allotment to bighorns within next 10 years because of low likelihood of direct contact between domestic sheep and bighorns.
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> Outcome 3: Moderate risk of disease transmission from domestic sheep in this allotment to bighorns within next 10 years because of moderate likelihood of direct contact between domestic sheep and bighorns.
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> Outcome 4: High risk of disease transmission from domestic sheep in this allotment to bighorns within next 10 years because of high likelihood of direct contact between domestic sheep and bighorns.
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> Outcome 5: Very high risk of disease transmission from domestic sheep in this allotment to bighorns within next 10 years because of very high likelihood of direct contact between domestic sheep and bighorns.

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

> Direct contact between domestic sheep and bighorn sheep results in a high likelihood of disease transmission to bighorn sheep and disease outbreak in local bighorn herd.

For each allotment, the panelists distributed 100 likelihood points across the 5 outcomes. The panelists could distribute the 100 likelihood points across the 5 outcomes however they wanted. Placing 100 likelihood points on a single outcome indicated much certainty in that outcome. Distributing the 100 points across several outcomes indicated less certainty in any one outcome.

Panelists were provided the following information:

- A table listing allotment name, permittee, class of livestock, permitted number of sheep, permitted season-on date, permitted season-off date, permitted number of livestock and head months.
- A 48 x 36 inch map showing sheep allotments, sheep trailing routes, topography (digital elevation map layer), bighorn sheep population ranges (polygon layer), radio telemetry point locations for Hells Canyon bighorn sheep, point locations of incidental bighorn sheep observations, a GIS-modeled bighorn habitat layer.
- A 48 x 36 inch map showing the distribution of large wildfires on the Payette NF during the past 20 years.

The GIS habitat model was modified from a model developed by Idaho Department of Fish and Game for Hells Canyon (Idaho Department of Fish and Game 2004a:page 31). The Forest Service model used in this analysis is described in Table 7.

Panelists reviewed pertinent maps and discussed disease transmission risk factors relevant for each sheep allotment. Risk factors discussed included: 1) distance between sheep allotment and nearest bighorn sheep populations; 2) amount of GIS-modeled bighorn habitat within the sheep allotment, between the allotment and the nearest bighorn sheep herd, and the relative continuity of that habitat; 3) panelists' first-hand knowledge of the amount and quality of bighorn habitat within the allotment and around the allotment; 4) presence of incidental bighorn sightings within or near the allotment; 5) the level of knowledge about bighorn sheep distribution and movements in the area around the allotment; 6) characteristics of the sheep allotment such as number of permitted sheep and permitted season of use. Following group discussion of risk factors, panelists independently rated risk of disease transmission for each allotment by distributing the 100 likelihood points among the 5 possible outcomes. Consensus was not an objective of the rating process.

Two variables were calculated from the risk rating data: 1) a weighted mean outcome for the risk outcome categories for each allotment, and 2) a standard deviation of the distribution of likelihood points among the 5 outcome classes for each allotment. The weighted mean outcome was calculated by first determining the mean likelihood scores for each allotment. Mean likelihood scores were calculated by summing the likelihood points for each outcome across the 6 panelists and dividing by 6. Weighted mean outcomes were then determined by assigning a value to each of the 5 outcomes (Outcome 1, value = 1; Outcome 2, value = 2; etc.), multiplying the mean likelihood of that outcome by its assigned value, adding these products for all outcomes, and dividing by 100. Because original scoring by panelists was based on categorical data (Outcomes 1, 2, 3, 4, and 5) and to facilitate interpretation, weighted mean outcome, which is a continuous variable, was grouped into 5 categories (Lehmkuhl et al. 1997:page 545):

Outcome 1 (Very Low): 1.00 – 1.49;
Outcome 2 (Low): 1.50 – 2.49;
Outcome 3 (Moderate): 2.50 – 3.49;
Outcome 4 (High): 3.50 – 4.49;
Outcome 5 (Very High): 4.50 – 5.00.

The standard deviation was calculated according to the formula provided by Lehmkuhl et al. (1997:page 546; following discussion with the authors of the original 1997 manuscript, the formula was modified slightly to correct for a typographical error). The standard deviation provides a measure of total variation in how panelists distributed their likelihood points. This total variation consisted of variation in how each panelist spread their 100 likelihood points among the 5 outcomes and variation in scoring among the 6 panelists. The standard deviation is used as a measure of the level of uncertainty associated with the weighted mean outcome for each allotment (Lehmkuhl et al. 1997:page 546). It is used only as a relative measure: a domestic sheep allotment with a greater standard deviation value than another sheep allotment has greater total variation in likelihood scoring, which we interpreted to indicate greater uncertainty about the perceived risk of disease transmission.

Results

One permitted sheep allotment was not included in the expert panel risk assessment. The Surdam On/Off allotment is a very small (158 acres) area on the Payette NF adjacent to private ranch lands (Figure 1). It was left out of the expert panel risk assessment because the facilitator did not know of the existence of the allotment at the time of the December 14, 2005 assessment.

Weighted mean outcomes ranged from 4.97 to 1.22 (Table 8). The weighted mean outcome for 1 of the 23 analyzed allotments fell into the very high risk category, 4 fell into the high risk category, 5 into the moderate risk category, 6 into the low risk category, and 7 into the very low risk category. These results are graphically displayed in Figure 2.

The 1 allotment in the very high risk category was the Smith Mountain allotment. The primary risk factor discussed for the Smith Mountain allotment was its proximity to Hells Canyon bighorn sheep populations. Radio-collared bighorn sheep were detected within the boundaries of the Smith Mountain allotment on 319 occasions between 1997 and 2004 (Hells Canyon Bighorn Sheep Restoration Committee, unpublished data). For sheep allotments on the Payette's west side, an additional map was made showing 6th order hydrologic units, which were used to identify allotment subunits (Figure 3). Panelists were asked if they could identify subunits within any of the west side sheep allotments that did not contribute to the overall risk rating for the allotment. This was done for west side sheep allotments and not east side sheep allotments because there was much greater knowledge of bighorn sheep distribution and movement patterns resulting from radio-telemetry data on bighorn sheep in Hells Canyon dating back to 1997. (Radio-telemetry data has not been collected on bighorn sheep from the 2 bighorn populations located closest to Payette NF east side sheep allotments.) Panelists identified 3 subunits within the Smith Mountain allotment that they thought did not contribute to the allotment's overall risk rating. These 3 subunits correspond to the portions of the following 6th order hydrologic units located within the Smith Mountain allotment: Lick Creek, Lost Creek, and Upper West Fork Weiser River (Figure 3).

The 4 allotments in the high risk category were Marshall Mountain, Curren Hill, Bear Pete, and French Creek (Figure 2). For Curren Hill, risk factors discussed were close proximity to known bighorn range and presence of suitable bighorn habitat within allotment boundaries. Although none of the bighorn telemetry locations was located within the boundaries of the Curren Hill allotment, radio-collared bighorn sheep were detected within 1 to 4 miles of the allotment

boundaries on 22 occasions between 1997 and 2004 (Hells Canyon Bighorn Sheep Restoration Committee, unpublished data).

Risk factors discussed by panelists for Marshall Mountain, Bear Pete, and French Creek allotments were proximity to the Main Salmon River bighorn population and the South Fork Salmon River population, and presence of suitable bighorn habitat within allotment boundaries. The northern-most boundaries of the French Creek, Bear Pete, and Marshall Mountain allotments are located approximately 4 air miles from the mapped range of the Main Salmon River bighorn population, and the eastern-most boundary of the Marshall Mountain allotment is located approximately 8-12 air miles from mapped range of the South Fork Salmon River population (Figures 1 and 2). Panelists discussed habitat as a key risk factor for Marshall Mountain allotment because of the extensive suitable bighorn sheep habitat available within the allotment and between the allotment and the Main Salmon River canyon. Panelists noted that the extensive 2000 Burgdorf Junction wildfire may have opened up a lot of bighorn sheep habitat in this area (Figure 4).

The 5 allotments in the moderate risk category were North Fork Lick Creek, Shorts Bar, Victor-Loon, Lake Fork, and Hershey-Lava. The northern boundary of the Hershey-Lava allotment is located about 5 air miles from the western edge of mapped range for the Main Salmon River bighorn population (Figures 1 and 2). For the Shorts Bar and Hershey-Lava allotments, the primary risk factor discussed by panelists was proximity to the Main Salmon River bighorn population. The northwest corner of the Shorts Bar allotment also is located only about 4 miles from a couple of radio-telemetry locations of bighorn sheep from the Hells Canyon metapopulation located near the confluence of the Little Salmon River and the Main Salmon River near Riggins (Hells Canyon Bighorn Sheep Restoration Committee, unpublished data). For the Victor-Loon, North Fork Lick Creek, and Lake Fork allotments, the primary risk factor discussed was proximity to the South Fork Salmon River bighorn population. Panelists acknowledged uncertainties about the movement patterns and extent of summer range for this bighorn population. A bighorn sheep was observed in the North Fork Lick Creek allotment during the summer of 2005 (Figure 1). It is not known which population this bighorn sheep came from. Domestic sheep do not graze throughout the North Fork Lick Creek allotment; they are only permitted to trail through this allotment.

The 6 allotments in the low risk category were Jughandle, Josephine, Boulder Creek, Twenty Mile, Fall/Brush Creek, and Little French Creek. A bighorn sheep was captured in a wolf trap set by USDA Wildlife Services trappers in the Josephine allotment during the summer of 2005 (Figure 1). It is not known which population this bighorn sheep came from. These allotments were rated as low risk due to their greater distances from bighorn populations and their relative lack of suitable bighorn habitat. – GIS habitat map indicates substantial sheep habitat in this area.

The 7 allotments in the very low risk category were Price Valley, Cougar Creek, Bill Hunt, Brundage, Grassy Mountain, Slab Butte, and Vance Creek. Price Valley is located relatively close to the mapped range of the McGraw bighorn population of Hells Canyon, but panelists discussed its lack of suitable bighorn habitat. The other 6 allotments in this group are located distant from any bighorn population and lack large areas of suitable bighorn habitat. – GIS map shows sheep habitat in some of these allotments

Standard deviations ranged from 1.23 for the Josephine allotment to 0.18 for the Smith Mountain allotment (Table 9). Greater standard deviations reflect greater levels of uncertainty among panelists concerning risk of disease transmission. Allotments were placed into 3 categories based on the distribution of standard deviation values (Table 9). Allotments that had relatively high standard deviations (relatively high levels of uncertainty) were Josephine, Bear Pete, Hershey-Lava, Fall/Brush Creek, Curren Hill, and Boulder Creek. Allotments that had moderate values for standard deviation were North Fork Lick Creek, Shorts Bar, Lake Fork, French Creek,

Price Valley, Jughandle, Victor-Loon, Marshall Mountain, Twenty Mile, and Little French Creek. Allotments that had relatively low standard deviations were Bill Hunt, Brundage, Cougar Creek, Vance Creek, Grassy Mountain, Slab Butte, and Smith Mountain. These results are shown graphically in Figure 5.

Risk of disease transmission posed by existing sheep trailing routes also was discussed by panelists. Panelists considered the Salmon River Driveway, which runs northeast to southwest out of the Smith Mountain sheep allotment (Figure 2), to present a high risk of disease transmission because of its proximity to occupied bighorn sheep range in Hells Canyon. Panelists also commented that the trailing routes along the Main Salmon River and between the Main Salmon River and the Payette's east side sheep allotments presented considerable risk of disease transmission to bighorn sheep. Domestic sheep are trailed along the road on the south side of the Main Salmon River. Sheep are also trailed south into the Shorts Bar, French Creek, Bear Pete, and Marshall Mountain allotments along 4 trailing routes (Figure 2). Panelists considered the risk of disease transmission to be greater for the 2 eastern trailing routes than for the 2 western trailing routes. The eastern-most Carey Creek trailing route was considered to pose the greatest risk.

Panelists also were asked to identify and discuss any factors other than disease transmission that may be negatively affecting bighorn sheep populations within and around the Payette NF. Panelists were asked about habitat loss and fragmentation, habitat degradation due to vegetation succession, negative effects associated with roads, and disturbance from recreational or other forest uses. These factors were discussed, but none was identified as a factor causing substantive negative effects to bighorn sheep habitat or populations on the Payette NF. The effects of wildfire on bighorn sheep habitat were discussed, and panelists acknowledged that wildfire can have short-term negative but longer-term positive effects on bighorn habitat. Bighorn sheep select open habitats, and in some areas in western North America bighorn sheep habitat is being negatively affected by vegetation succession processes resulting from decades of fire suppression (e.g., Wakelyn 1987, Singer et al. 2000a). There have been many large wildfires on the Payette NF during the last 20 years (Figure 4), so this may not be a problem on the Payette. Panelists also discussed positive aspects of the Payette NF as bighorn sheep habitat, such as the vast roadless area in the Frank Church River of No Return Wilderness and the lack of domestic sheep grazing in such a vast area in the eastern half of the Forest.

The issue of disease transmission from domestic goats and llamas was discussed by panelists. Panelists stated that evidence indicates that domestic goats can transmit diseases to bighorn sheep, and an example was cited in which a feral goat was implicated in transmitting Pasteurellosis to bighorn sheep in Hells Canyon (Rudolph et al. 2003). It was stated that llamas may be able to transmit certain diseases to bighorn sheep, but that llamas are not considered to present as much risk of disease transmission as domestic sheep or goats.

At the end of the expert panel risk assessment on December 14, 2005, panelists were asked to discuss issues related to population viability of bighorn sheep on the Payette NF. Panelists commented that it is difficult to ensure viability for the kind of small bighorn populations that occur within the Payette NF's boundaries. Panelists discussed how population viability of wide-ranging species such as bighorn sheep needs to be addressed at spatial scales larger than the Payette NF, and that the metapopulation structure of interacting populations is very important in understanding bighorn sheep population dynamics. Panelists discussed the real and significant impacts that disease, especially pneumonia, has had on population dynamics of bighorn populations in the Hells Canyon and Salmon River Mountains metapopulations in recent history.

Discussion

This analysis was conducted in response to a March 14, 2005 appeal decision on the 2003 Payette Forest Plan. The Chief's Reviewing Officer directed the Regional Forester to do an analysis of bighorn sheep viability in the Payette NF commensurate with the concerns and questions raised in the appeal decision related to potential impacts of disease transmission from domestic sheep grazed on the Forest on bighorn sheep populations. Viability is discussed below in general terms of persistence of the population over some relatively long temporal interval (Gilpin and Soule 1986:page 20). Discussion of "... bighorn sheep viability in the Payette NF...", however, is complicated by the nature of bighorn sheep populations. Traditional population analyses and population viability analyses (PVAs) have been conducted largely in the context of isolated populations (Hanski 1998). Bighorn sheep, however, typically occur within a metapopulation structure (see discussion on page 8). Conducting a viability analysis of bighorn sheep on the Payette NF is complicated by the fact that only small portions of 2 different metapopulations occur within Payette NF boundaries, and a meaningful analysis of population viability can not be done without accounting for metapopulation dynamics.

Four bighorn sheep populations of the Hells Canyon metapopulation have occurred in close proximity to domestic sheep allotments within the Payette's west side since 2000. One of these populations, the McGraw population, is no longer considered extant. Pneumonia outbreaks have occurred in each of these populations in recent history, resulting in substantial mortality of bighorn sheep. Radio-collared bighorn sheep were detected within the Smith Mountain allotment on 319 occasions and within 1 to 4 miles of the Curren Hill allotment on 22 occasions between 1997 and 2004. In attempts to reduce the spread of disease, Oregon Department of Fish and Wildlife biologists have shot and killed 3 bighorn sheep showing symptoms of pneumonia and found in close proximity to domestic sheep within the boundaries of the Smith Mountain allotment. Recruitment of lambs into these populations has also been very low due to repeated pneumonia outbreaks causing high rates of mortality (Frances Cassirer, personal communication).

Should include this in final decision

Mean weighted outcomes calculated from the expert panel risk assessment indicate that panelists considered the Smith Mountain allotment to present a very high risk of disease transmission to bighorn sheep, and the Curren Hill allotment to present a high risk of disease transmission. One piece of information not available to panelists during the December 14 risk assessment is that under current management, domestic ewes are bred on the Curren Hill allotment during late summer/early fall. Having estrous domestic ewes in close proximity to bighorn sheep increases the likelihood of contact between the 2 species because bighorn rams are attracted to estrous domestic ewes (e.g., Desert Bighorn Council 1990, USDI Bureau of Land Management 1998, Singer et al. 2000a). Portions of the Smith Mountain allotment presenting the highest risk of disease transmission include all areas except the southeast part of the allotment. Portions that present substantially less risk than the rest of the allotment are portions within the Lick Creek, Lost Creek, and Upper West Fork Weiser River 6th order hydrologic units because of the lack of suitable bighorn sheep habitat in these subunits and their greater distance from known locations of bighorn sheep. Panelists could not identify any 6th order hydrologic subunits within the Curren Hill allotment that presented a substantially reduced risk of disease transmission. Although the finger on the southeast side of the Curren Hill allotment south of the Rapid River does not constitute a 6th order hydrologic unit, this portion of the allotment is heavily forested and contains no GIS-modeled bighorn habitat. It therefore likely presents low risk of contact between bighorns and domestic sheep, and thus less risk of disease transmission than do portions of the allotment north of the Rapid River. Panelists thought that the Salmon River Driveway (Figure 2) also presented a high risk of disease transmission because of its proximity to occupied bighorn sheep range in Hells Canyon.

The Surdam allotment is a 158-acre Payette NF sheep allotment located adjacent to the permittee's private ranch lands. It is located about 12 miles southeast of the mapped range of the Sheep Mountain bighorn population (Figure 1). Because it was not included in the expert panel risk assessment, risk of disease transmission for this allotment will not be discussed in this report.

One of the 2003 Payette Forest Plan appeal issues was related to consistency between language in the Hells Canyon NRA Act and its implementing regulations (36 CFR 292.48) and maintaining domestic sheep grazing because of the known risks of disease transmission from domestic sheep to bighorn sheep (USDA Forest Service 2005:pages 14 to 15). A 24,857-acre portion of the Hells Canyon NRA occurs within the proclaimed boundaries of the Payette NF (Figure 3). The Hells Canyon NRA is administered by the Wallowa-Whitman NF. However, a 6,567-acre area of the Smith Mountain allotment occurs within the boundaries of the NRA (Figure 3), and livestock grazing within the entire Smith Mountain allotment, including this 6,567-acre area, is administered by the Payette NF. Boundaries of the Curren Hill allotment were changed in 1998, and contrary to what's shown in Figure 3, no part of the Curren Hill allotment now occurs within the boundaries of the NRA.

Despite multiple die-offs caused by disease, the Hells Canyon bighorn sheep metapopulation has shown a positive annual population growth rate since 1971 (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 6). The current population estimate for the entire metapopulation is 875 sheep, spread across 16 populations over an 8,900-square mile tri-state area. Continuing to graze domestic sheep on the Smith Mountain and Curren Hill allotments, or any of the other west side sheep allotments, would likely not threaten the viability of the overall Hells Canyon bighorn sheep metapopulation. This conclusion is based on the following rationale: 1) the vast geographic range of the metapopulation ensures that there are bighorn populations within the metapopulation that are located distant from sheep allotments on the Payette NF; and 2) the metapopulation has exhibited positive annual population growth since 1971, even though domestic sheep grazing throughout the range of the metapopulation was much more extensive during the 1970s, 1980s, and early 1990s than it is currently (Hells Canyon Bighorn Sheep Restoration Committee 2004:page 17). However, continuing to graze domestic sheep on the highest risk portions of the Smith Mountain and Curren Hill allotments would continue to negatively affect bighorn sheep restoration efforts within the Hells Canyon project area and threaten the viability of populations located within the metapopulation's southern range. As long as domestic sheep are grazed on the highest risk portions of the Smith Mountain and Curren Hill allotments, disease-related population impacts will likely continue to preclude the establishment of a viable bighorn sheep population anywhere within the Payette's west side.

Bighorn sheep populations within the Salmon River Mountains metapopulation located nearest to the Payette's east side sheep allotments are the South Fork Salmon River population and the Main Salmon River population in Unit 19. There is evidence that disease has affected both populations in the recent past. Survey data indicate a decline in total sheep counted of 22% between 1989 and 1991 for the South Fork Salmon River population, and a decline of 43% between 1989 and 1992 for the Main Salmon River Unit 19 population (Table 6). Both declines were followed by several years of poor lamb survival, which is typical of pneumonia outbreaks in bighorn sheep. Local wildlife biologists for Idaho Department of Fish and Game believe the survey data reflect the impacts of a disease outbreak, most likely pneumonia, that occurred between 1989 and 1991 (Jay Crenshaw, personal communication; Jeff Rohlman, personal communication).

Mean weighted outcomes resulting from the expert panel risk assessment indicated that panelists considered the Marshall Mountain, Bear Pete, and French Creek sheep allotments to present a high risk of disease transmission, and the Shorts Bar, Hershey-Lava, Victor-Loon, North Fork Lick Creek, and Lake Fork allotments to present moderate risk of disease transmission (Figure 2).

Domestic ewes are bred on the Victor-Loon allotment during late summer/early fall, but panelists did not have this information at the time of the December 14 risk assessment. Standard deviations indicated that levels of uncertainty related to the disease transmission risk ratings were moderate to high for each of these allotments (Figure 5). Relatively high levels of uncertainty for these allotments is not surprising given the uncertainties about movement patterns of bighorn sheep from the Main Salmon River and South Fork Salmon River populations. Unlike populations within the Hells Canyon metapopulation, there is no bighorn sheep radio-telemetry data from either of these 2 populations. There are 2 key questions directly related to likelihood of contact between domestic sheep and bighorn sheep, and thus likelihood of disease transmission: 1) what is the western and southern extent of summer range for the South Fork Salmon River population (mapped range for this population shown in Figure 1 was only estimated by Idaho Department of Fish and Game wildlife biologists based on knowledge of winter range and distribution of suitable habitat); and 2) how frequently do bighorn sheep from the Main Salmon River population cross the Salmon River and interact with domestic sheep in the Payette's east side allotments.

The extent of the South Fork Salmon River population's summer range is especially relevant, given the summer 2005 records of a bighorn sheep in the Josephine allotment and one in the North Fork Lick Creek allotment (Figure 1). It is not known which population either of these bighorn sheep belonged to, or what general route they followed to arrive in these domestic sheep allotments. The farther bighorn sheep from the South Fork Salmon River population move during summer to the west and south of known winter range along the lower South Fork Salmon River, the closer they would be to domestic sheep allotments. However, much of the habitat between the South Fork Salmon River and Payette sheep allotments is heavily forested, and heavily forested areas do not provide bighorn sheep habitat and are believed to serve as partial barriers to bighorn movement (e.g., Singer et al. 2000c). Large rivers also are thought to serve as partial barriers to bighorn movements (Singer et al. 2000c). The Salmon River is a large river with peak flows in May and June. Bighorn sheep, however, are certainly capable of swimming relatively large rivers. Smith (1954) commented that bighorn sheep were frequently observed swimming across the Middle Fork of the Salmon River. Bighorn sheep also have been observed swimming across the Snake River and Hells Canyon Reservoir (Vic Coggins, personal communication). Three bridges cross the Salmon River between Riggins and the South Fork Salmon River (Figure 1), but it is not known whether, or to what extent, bighorn sheep may use any of these bridges. If bighorns frequently crossed the river from the north side to the south, it seems likely that there would be bighorn sightings along the south side of the river, especially downstream of the Vinegar Creek Boat Ramp where detection opportunities are great because of relatively high vehicle and boat traffic. However, bighorn detections along the south side of the Main Salmon River downstream of Warren Creek are rare (Jeff Rohlman, personal communication). The Allison-Berg domestic sheep allotment on the Nez Perce NF would seem to present a substantially greater risk of disease transmission to the Main Salmon River population in Unit 19 than would the Payette NF sheep allotments (Figure 1).

The Salmon River Mountains bighorn sheep metapopulation is very large, ranging across a large part of mountainous central Idaho (Toweill and Geist 1999:page 85). Unlike the Hells Canyon metapopulation, this bighorn sheep metapopulation was not extirpated during the early 1900s. It thus persisted through the period of the late 1800s and early 1900s when domestic sheep grazing was much more extensive than it is currently. The number of domestic sheep currently permitted to graze on the Payette NF is approximately 10% of the number of sheep permitted to graze comparable lands in 1915 (Hockaday 1998:page 56). Up until the 1960s, domestic sheep grazing on the Payette NF extended much farther to the east than it does currently. Since the 1970s when the remaining sheep allotments in the South Fork Salmon River drainage were closed, domestic sheep grazing has not been permitted within a vast 50-mile-wide area of the Payette NF (Figure 1). Continuation of current management of domestic sheep grazing within the

Payette's east side sheep allotments would likely not threaten the viability of the overall Salmon River Mountains bighorn sheep metapopulation. This conclusion is based on the following rationale: 1) the vast geographic range of the metapopulation ensures that there are bighorn populations within the metapopulation that are located distant from sheep allotments on the Payette NF; 2) a vast area approximately 50 miles wide is currently provided within the Payette NF in which no domestic sheep (or cattle) grazing occurs; 3) this metapopulation has persisted through historic times when domestic sheep grazing was much more extensive than it is currently. Continuation of current management of domestic sheep grazing within the Payette's east side sheep allotments would likely not threaten the viability of the Big Creek bighorn population in the Frank Church River of No Return Wilderness. This population is located a considerable distance east of the Payette's sheep allotments, and surveys conducted by Idaho Department of Fish and Game indicate that this population is relatively large and that total numbers of sheep have been relatively stable during the past 13 years (Table 2). The level of threat to the South Fork Salmon River bighorn population posed by current sheep grazing management in the Payette's east side is unknown. The very low population counts for this population in 1996 and 2002 (Table 5) are cause for concern over the status of this population. Much of the decline in the population count between 1994 and 1996 may have been due to effects of the 1994 Chicken Complex fire, but survey data indicate that measurable population recovery had still not occurred by 2002. Idaho Department of Fish and Game plans to conduct aerial surveys of the South Fork Salmon River and Big Creek bighorn populations in February 2006 (Jeff Rohlman, personal communication). There is great uncertainty over the levels of risk posed by the Payette's east side sheep allotments, and these uncertainties will unlikely be reduced until movement patterns and distribution of bighorn sheep from the Main Salmon River and South Fork Salmon River populations are better understood.

Conclusions

Although important aspects of bighorn sheep disease ecology are still poorly understood, the scientific literature indicates that: 1) when in close contact, domestic sheep commonly transmit diseases to bighorn sheep; 2) some of these diseases (e.g., Pasteurellosis or pneumonia) result in mortality of large portions of bighorn sheep herds and cause depressed recruitment for years, and thus have significant impacts on bighorn sheep population dynamics; and 3) bighorn sheep and domestic sheep must be kept separated if one of the management goals is to maintain viable populations of bighorn sheep. Two factors complicate management of domestic sheep and bighorn sheep when the 2 species occur in close proximity: 1) bighorn sheep and domestic sheep are attracted to each other, greatly increasing the likelihood of close contact between the 2 species; and 2) when herding large bands of domestic sheep, it is difficult to prevent small groups of domestic sheep from occasionally straying from the herd and thus becoming, at least temporarily, an unmanaged source of disease transmission to nearby bighorn sheep.

Ranges of 2 bighorn sheep metapopulations overlap the Payette NF. Research conducted under the 1997 Hells Canyon Initiative indicates that bighorn sheep from populations at the southern end of the metapopulation's range commonly occur within the boundaries of the Payette's Smith Mountain domestic sheep allotment. Strong circumstantial evidence indicates that at least some of these bighorn sheep contracted pneumonia from domestic sheep on the Smith Mountain allotment, and that pneumonia resulted in substantial mortality of bighorn sheep in at least 2 populations (Sheep Mountain and McGraw populations). Bighorn sheep also have been commonly detected within 1 to 4 miles of the Payette's Curren Hill sheep allotment. Results of the expert panel risk assessment indicated that panelists considered the Smith Mountain allotment to present a very high risk of disease transmission to bighorn sheep and the Curren Hill allotment to present a high risk of disease transmission. Continuing to graze domestic sheep on the highest risk portions of the Smith Mountain and Curren Hill allotments would likely not threaten the viability of the overall Hells Canyon bighorn sheep metapopulation but would likely

threaten the viability of bighorn sheep populations occurring within the metapopulation's southern range. As long as domestic sheep are grazed on the highest risk portions of the Smith Mountain and Curren Hill allotments, disease-related population impacts will likely continue to preclude the establishment of a viable bighorn sheep population anywhere within the Payette's west side.

The Payette NF provides vast areas of suitable bighorn sheep habitat in the Frank Church River of No Return Wilderness in the Salmon River Mountains. Unlike so many areas across the western U.S., these native bighorns were never extirpated and thus provide a significant genetic and population resource. The Payette NF provides a swath of wildlife habitat approximately 50 miles wide in which no domestic sheep, or cattle, grazing occurs. Bighorn sheep populations have persisted within and adjacent to Payette NF boundaries in the Salmon River Mountains despite the fact that domestic sheep grazing was much more extensive during the late 1800s to early 1900s than it is today. However, existing sheep allotments within the Payette NF's east side certainly present some level of disease-transmission risk to Salmon River Mountains bighorn sheep as evidenced by: 1) the relative close proximity of some of these allotments to a bighorn sheep population in the South Fork Salmon River drainage and a population along the Main Salmon River in Unit 19 and past disease-related declines in both of these populations; 2) expert panelists rated risk of disease transmission as high for 3 of the east side allotments and moderate for 5 of the east side allotments; and 3) recent observations of a bighorn sheep in the Josephine allotment and another in the North Fork Lick Creek allotment. Management of the domestic sheep disease transmission issue in the Payette NF's east side, however, is greatly complicated by lack of information on distribution and movement patterns of bighorn sheep from nearby bighorn populations. Continuation of current sheep grazing management on east side sheep allotments would likely not threaten the viability of the extensive Salmon River Mountains bighorn sheep metapopulation, nor would continuation of current sheep grazing management on the Payette likely threaten the viability of the Big Creek bighorn population or the Main Salmon River bighorn population. The small number of bighorn sheep counted in the South Fork Salmon River population during the last 2 Idaho Department of Fish and Game surveys (33 total sheep in 1996 and 33 total sheep in 2002) justify concern over viability of this population. However, lack of information about the current disease status within this population and lack of information on movements of these sheep on their summer range when domestic sheep are on the east side allotments make it extremely difficult to assess the level of risk posed by east side sheep allotments to the South Fork Salmon River bighorn sheep population.

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Table 1. Permit Information for Payette National Forest Sheep Allotments.

Allotment	Class	Permitted Number	Season On	Season Off	Head Months
Smith Mountain	Ewe/lambs	1200	5/16	8/10	3432
	Dry Ewes	1200	8/17	10/15	2367
	Ewe/lambs	1900	6/18	8/10	3373
	Dry Ewes	1900	8/17	10/15	3748
Curren Hill	Dry Ewes	1925	9/1	9/30	1899
Boulder Creek	Ewe/lambs	1000	6/16	8/31	2532
Price Valley	Ewe/lambs	895	6/16	8/31	2266
Surdam	Ewe/lambs	1900	4/1	6/30	284
Shorts Bar	Dry Ewes	1600	9/20	10/7	907
Hershey-Lava	Ewe/lambs	1333	7/10	9/15	2980
French Creek	Ewe/lambs	833	7/7	10/7	2547
Bear Pete	Ewe/lambs	833	7/7	10/7	2547
Marshall Mtn	Ewe/lambs	834	7/7	10/7	2550
Vance Creek	Dry Ewes	2666	9/15	10/15	2717
Little French Creek	Dry Ewes	1333	7/10	7/20	444
Josephine	Ewe/lambs	1333	7/10	9/15	2980
Victor-Loon	Dry Ewes	1500	8/26	10/10	2268
Grassy Mtn	Ewe/lambs	1333	7/10	9/15	2980
Slab Butte	Ewe/lambs	1333	7/10	9/15	2980
Cougar Creek	Ewe/lambs	1333	7/10	9/15	2980
Twenty Mile	Ewe/lambs	1333	7/10	9/15	2980
Brundage	Dry Ewes	2666	9/15	10/15	2717
Bill Hunt	Dry Ewes	2666	9/15	10/15	2717
Fall/Brush Creek	Ewe/lambs	800	7/1	8/25	1473
North Fork Lick Creek	Dry Ewes	1500	8/25	8/25	50
Lake Fork	Ewe/lambs	817	7/1	8/25	1504
Jughandle	Dry Ewes	2000	7/10	10/15	6444

Table 2. Numbers of bighorn sheep counted during winter population surveys in the Big Creek Drainage in Unit 26 (Idaho Department of Fish and Game 2004: page 32). Survey data is presented only for years with complete counts.

Year	Lambs	Ewes	Rams	Lambs/ 100 Ewes	Total Sheep
1989	28	180	72	16	270
1991	4	93	39	4	136
1992	26	91	48	29	165
1993	22	108	35	20	165
1995	10	95	22	11	131
1996	11	99	28	11	138
1999	23	88	35	26	146
2002	26	86	23	30	135
2004	23	90	31	26	144

47% decline

Table 3. Numbers of bighorn sheep counted during winter population surveys along the Middle Fork Salmon River in Hunt Areas 27-1, 27-2, and 27-3 (Idaho Department of Fish and Game 2004: page 54). Survey data is presented only for years with complete counts.

Year	Lambs	Ewes	Rams	Lambs/ 100 Ewes	Total Sheep
Hunt Area 27-1					
1989	39	77	56	51	172
1991	3	108	42	3	153
1993	14	90	25	16	129
1999	14	56	33	25	103
2001	13	80	23	16	116
2004	24	100	39	24	163
Hunt Area 27-2					
1989	19	57	57	33	133
1990	5	43	27	12	75
1991	2	60	11	3	73
1993	2	36	16	6	54
1999	16	54	21	30	91
2004	9	44	14	21	67
Hunt Area 27-3					
1989	35	80	39	44	154
1991	7	88	28	8	123
1993	17	62	30	27	109
1999	12	67	23	18	102
2004	13	57	28	23	98

Totals

1989 - 459 + 116 = 575

2004 - 328 + 36 = 364

} 37% decline

29% decline

Table 4. Numbers of bighorn sheep counted during winter population surveys along the lower Middle Fork Salmon River in Unit 20A (Idaho Department of Fish and Game 2004: page 32). Survey data is presented only for years with complete counts.

Year	Lambs	Ewes	Rams	Lambs/ 100 Ewes	Total Sheep
1989	13	76	27	17	116
1991	3	72	30	4	105
1992	7	80	29	9	116
1993	10	62	22	16	94
1994	11	63	19	18	93
1995	11	53	19	21	83
1996	6	38	14	16	58
1999	11	35	5	31	51
2002	14	35	9	40	58
2004	8	21	7	38	36

Table 5. Numbers of bighorn sheep counted during winter population surveys in the South Fork Salmon River drainage (Idaho Department of Fish and Game, unpublished data). Survey data is presented only for years with complete counts.

Year	Lambs	Ewes	Rams	Lambs/ 100 Ewes	Total Sheep
1985	4	22	12	18	38
1986	19	57	14	33	92
1989	12	50	15	24	77
1991	5	33	22	15	60
1992	5	49	15	10	69
1993	13	51	14	25	78
1994	10	50	14	20	74
1995	9	44	5	20	58
1996	3	24	6	13	33
2002	6	23	4	26	33

n. of Salmon

Table 6. Summary of bighorn sheep winter population survey data for Units 19 and 20 along the Main Salmon River (Idaho Department of Fish and Game 2004: page 17). Survey data is presented only for years with complete counts.

Year	Lambs	Ewes	Rams	Lambs/ 100 Ewes	Total Sheep
Unit 19					
1981	9	44	3	21	56
1982	14	76	10	18	100
1983	31	95	10	33	136
1984	25	92	5	27	122
1986	9	69	11	13	89
1987	20	68	2	29	90
1989	20	63	8	32	91
1992	2	38	12	5	52
1993	0	40	20	0	60
1996	14	32	10	45	56
2001	13	28	12	46	53
Unit 20					
1981	3	12	11	25	26
1982	19	78	32	24	129
1983	13	83	37	16	133
1984	29	107	41	27	177
1986	31	132	67	24	230
1987	25	113	69	22	207
1989	26	94	32	28	152
1992	13	68	25	19	106
1993[a]	7	53	6	13	66
1994	11	49	27	22	87
1996	7	51	20	14	78
2001[b]	6	22	23	27	51

61% ↓

78% ↓

[a] The 1993 survey was conducted in May. All other surveys were conducted in January and February coincident with elk surveys.
[b] Includes sightability estimates with 90% bounds.

Table 7. Description of GIS bighorn sheep habitat model. Model was modified from Hells Canyon bighorn sheep habitat model developed by Hells Canyon Bighorn Sheep Restoration Committee.

Habitat Component	Criteria	Source
Escape Terrain		
Slope	Areas with slopes between 31° and 85°	Hells Canyon Bighorn Restoration Committee 2004: page 4
Buffer	300 m or land areas ≤1000 m wide bounded on ≥2 sides by escape terrain (500 m)	Hells Canyon Bighorn Restoration Committee 2004: page 4
Minimum area	1.6 ha	Hells Canyon Bighorn Restoration Committee 2004: page 4
Horizontal Visibility		
Habitat types	upland grasslands, altered grasslands, mountain mahogany, bitterbrush, shadscale, exposed rock, barren areas, snow fields, all forest cover types with ≤10% canopy cover (determined from Landsat satellite imagery)	USDA Forest Service 1997

Table 8. Mean likelihood scores, weighted mean outcome, and standard deviation (S.D.) from expert-panel assessment of disease transmission risk for 23 sheep allotments on the Payette National Forest. Sorted by value of weighted mean outcome.

Allotment	Risk of Disease Transmission					Weighted Mean Outcome	S.D.
	Very Low	Low	Moderate	High	Very High		
	1	2	3	4	5		
Smith Mountain	0.0	0.0	0.0	3.3	96.7	4.97 VH	0.18
Marshall Mountain	0.0	0.0	16.7	40.0	43.3	4.27 H	0.73
Curren Hill	1.7	10.8	17.5	39.2	30.8	3.87 H	1.03
Bear Pete	3.3	16.7	21.7	25.0	33.3	3.68 H	1.19
French Creek	0.0	14.2	38.3	30.8	16.7	3.50 H	0.93
N. Fork Lick Creek	0.0	43.3	33.3	15.0	8.3	2.88 M	0.95
Shorts Bar	6.7	30.0	41.7	16.7	5.0	2.83 M	0.95
Victor-Loon	0.0	48.3	36.7	11.7	3.3	2.70 M	0.80
Lake Fork	8.3	46.7	28.3	13.3	3.3	2.57 M	0.94
Hershey-Lava	23.3	26.7	28.3	15.0	6.7	2.55 M	1.19
Jughandle	21.7	41.7	30.0	6.7	0.0	2.22 L	0.86
Josephine	39.2	33.3	12.5	6.7	8.3	2.12 L	1.23
Boulder Creek	48.3	33.3	10.0	5.0	3.3	1.82 L	1.03
Twenty Mile	50.0	40.8	7.5	1.7	0.0	1.61 L	0.70
Fall/Brush Creek	71.7	12.5	5.8	5.0	5.0	1.59 L	1.12
Little French Creek	56.7	33.3	10.0	0.0	0.0	1.53 L	0.67
Price Valley	78.3	10.0	6.7	3.3	1.7	1.40 VL	0.88
Cougar Creek	66.7	28.3	5.0	0.0	0.0	1.38 VL	0.58
Brundage	82.5	12.5	3.3	1.7	0.0	1.24 VL	0.59
Bill Hunt	82.5	12.5	3.3	1.7	0.0	1.24 VL	0.59
Vance Creek	80.0	18.3	1.7	0.0	0.0	1.22 VL	0.45
Grassy Mountain	78.3	21.7	0.0	0.0	0.0	1.22 VL	0.41
Slab Butte	78.3	21.7	0.0	0.0	0.0	1.22 VL	0.41

Table 9. Mean likelihood scores, weighted mean outcome, and standard deviation (S.D.) from expert-panel assessment of disease transmission risk for 23 sheep allotments on the Payette National Forest. Sorted by value of standard deviation.

Allotment	Risk of Disease Transmission					Weighted Mean Outcome	S.D.
	Very Low	Low	Moderate	High	Very High		
	1	2	3	4	5		
Josephine	39.2	33.3	12.5	6.7	8.3	2.12	1.23
Bear Pete	3.3	16.7	21.7	25.0	33.3	3.68	1.19
Hershey-Lava	23.3	26.7	28.3	15.0	6.7	2.55	1.19
Fall/Brush Creek	71.7	12.5	5.8	5.0	5.0	1.59	1.12
Curren Hill	1.7	10.8	17.5	39.2	30.8	3.87	1.03
Boulder Creek	48.3	33.3	10.0	5.0	3.3	1.82	1.03
N. Fork Lick Creek	0.0	43.3	33.3	15.0	8.3	2.88	0.95
Shorts Bar	6.7	30.0	41.7	16.7	5.0	2.83	0.95
Lake Fork	8.3	46.7	28.3	13.3	3.3	2.57	0.94
French Creek	0.0	14.2	38.3	30.8	16.7	3.50	0.93
Price Valley	78.3	10.0	6.7	3.3	1.7	1.40	0.88
Jughandle	21.7	41.7	30.0	6.7	0.0	2.22	0.86
Victor-Loon	0.0	48.3	36.7	11.7	3.3	2.70	0.80
Marshall Mountain	0.0	0.0	16.7	40.0	43.3	4.27	0.73
Twenty Mile	50.0	40.8	7.5	1.7	0.0	1.61	0.70
Little French Creek	56.7	33.3	10.0	0.0	0.0	1.53	0.67
Brundage	82.5	12.5	3.3	1.7	0.0	1.24	0.59
Bill Hunt	82.5	12.5	3.3	1.7	0.0	1.24	0.59
Cougar Creek	66.7	28.3	5.0	0.0	0.0	1.38	0.58
Vance Creek	80.0	18.3	1.7	0.0	0.0	1.22	0.45
Grassy Mountain	78.3	21.7	0.0	0.0	0.0	1.22	0.41
Slab Butte	78.3	21.7	0.0	0.0	0.0	1.22	0.41
Smith Mountain	0.0	0.0	0.0	3.3	96.7	4.97	0.18

D-why not sheep on S. side of Salmon from Riggins → S. Fk?

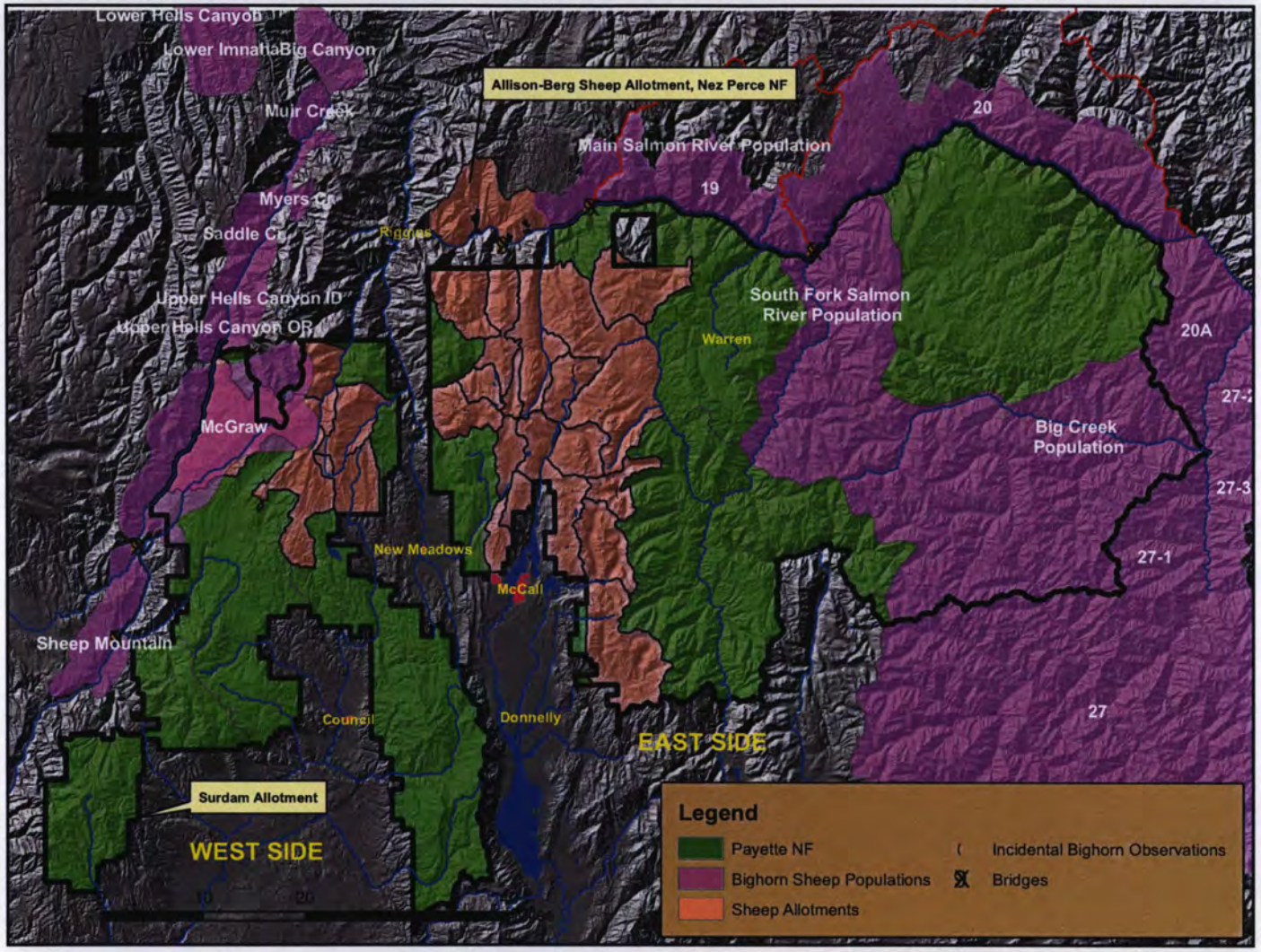

Figure 1. Ranges of bighorn sheep populations in the vicinity of the Payette National Forest. Ranges of Hells Canyon bighorn sheep populations (west side of map) were delineated by Hells Canyon Bighorn Sheep Restoration Committee (2004: page 3). Ranges of bighorn populations in Salmon River Mountains (east side of map) were estimated by wildlife biologists from Idaho Department of Fish and Game based on knowledge of winter range and distribution of suitable habitat.

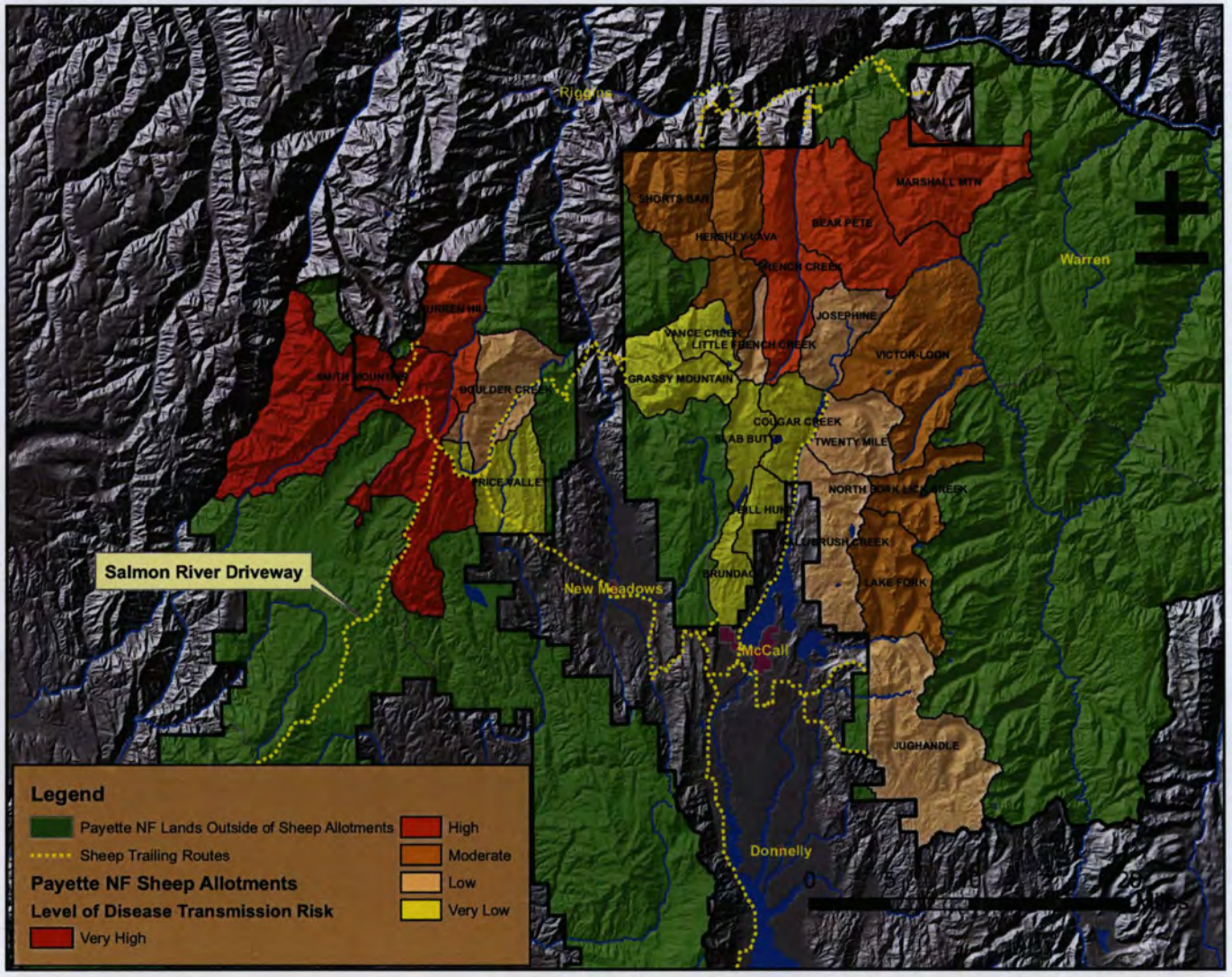

Figure 2. Category of risk of disease transmission from domestic sheep to bighorn sheep on the Payette National Forest. Categories were determined by value of weighted mean outcome of expert panel risk assessment data (Table 8)

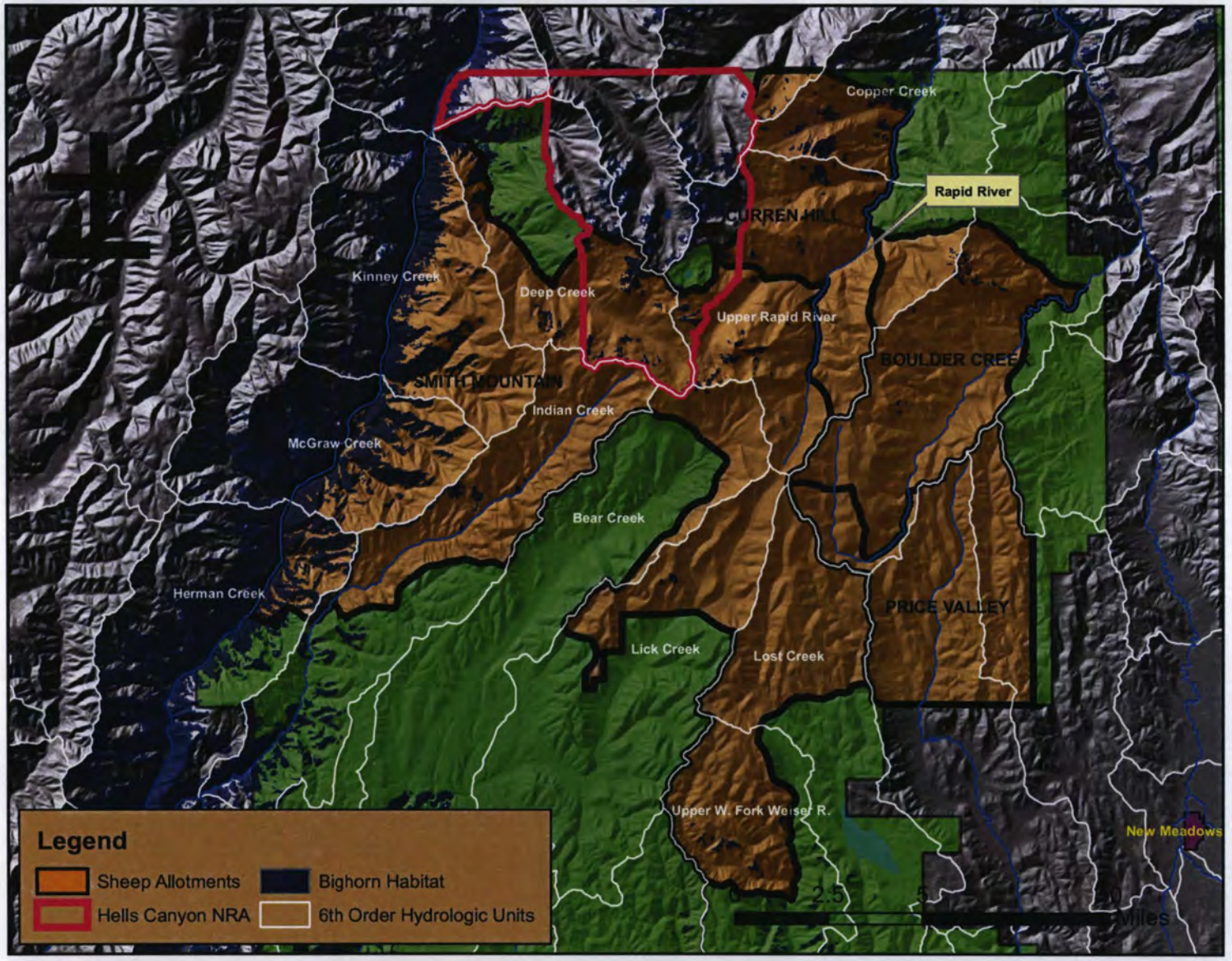

Figure 3. Smith Mountain, Curren Hill, Boulder Creek, and Price Valley domestic sheep allotments on the west side of the Payette National Forest. Bighorn habitat was estimated from GIS model. Portion of Hells Canyon NRA located within the proclaimed boundaries of the Payette National Forest is shown.

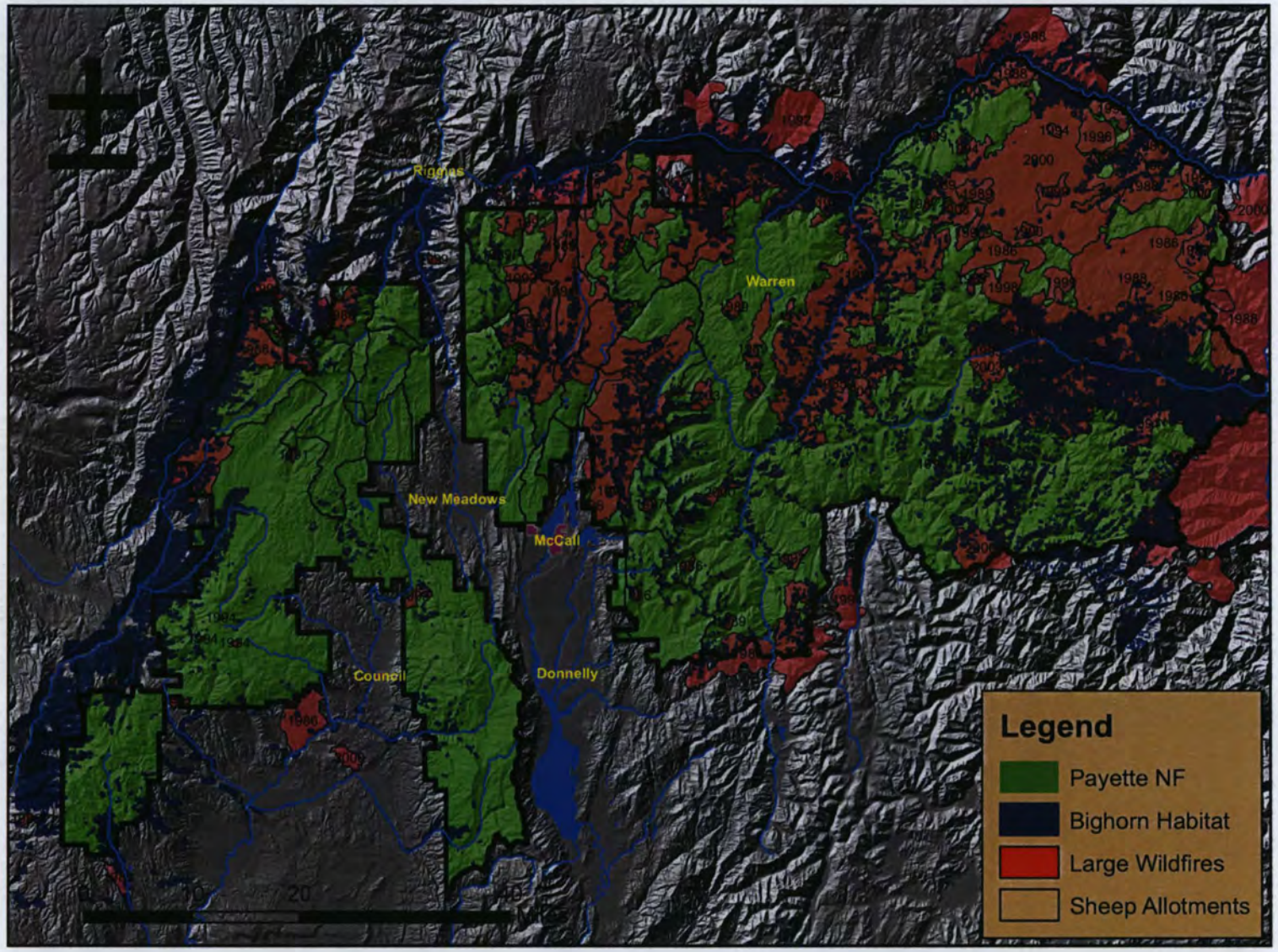

Figure 4. Bighorn sheep habitat and large wildfires on the Payette National Forest. Bighorn habitat was estimated from GIS model. Wildfires larger than 200 acres that have occurred since 1985 are shown. Dates are year wildfire occurred.

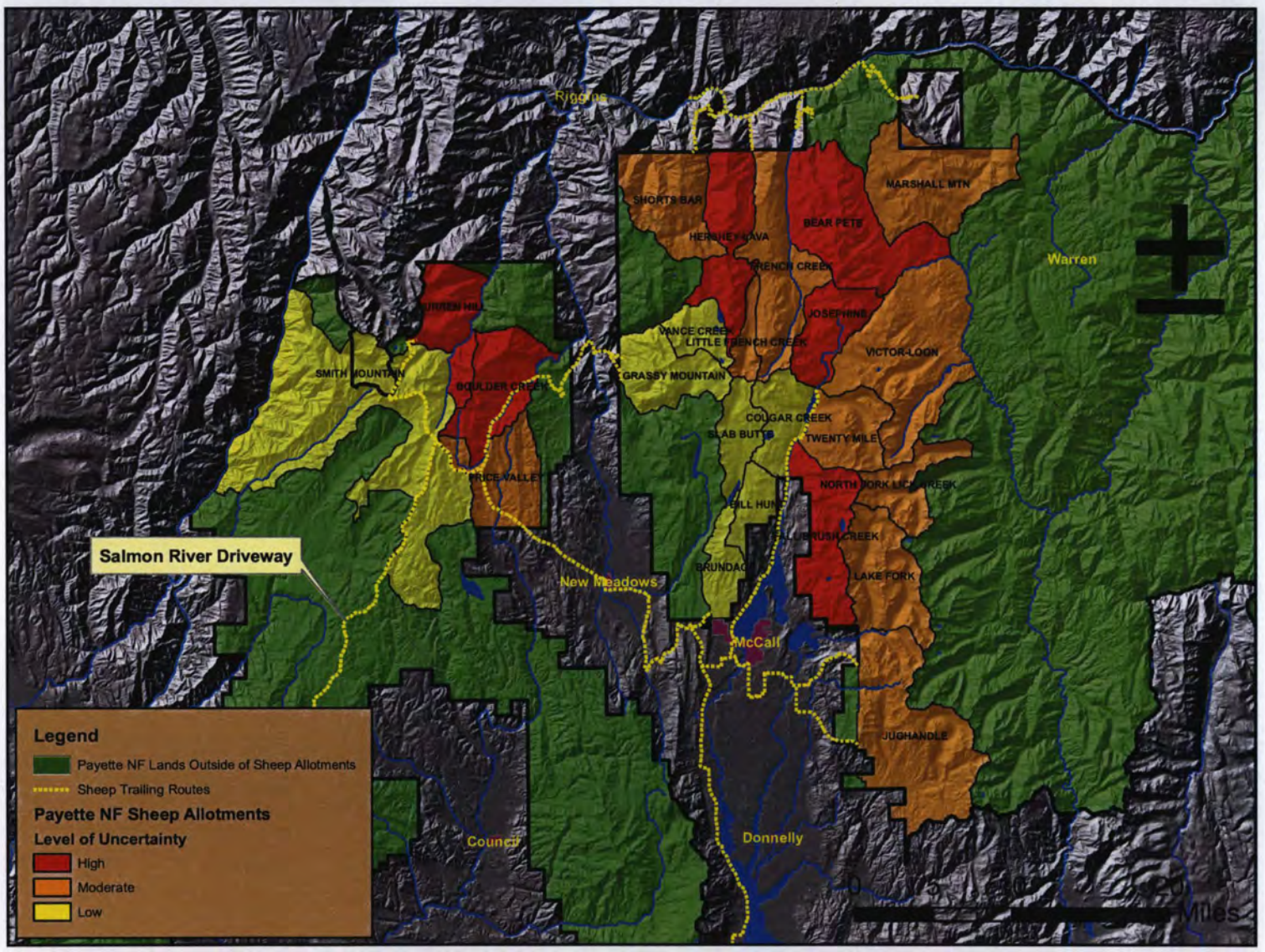

Figure 5. Category of uncertainty associated with risk of disease transmission from domestic sheep to bighorn sheep on the Payette National Forest. Categories were determined by standard deviation value associated with the weighted mean outcome score (Table).

Appendix 1. Panelists who served on the expert panel risk assessment held in New Meadows, Idaho, on December 14, 2005.

Panelist	Title	Organization	Experience
Vic Coggins	District Wildlife Biologist	Oregon Department of Fish and Wildlife, Enterprise, OR	35 years of professional experience with bighorn sheep management.
Jay Crenshaw	Regional Wildlife Manager	Idaho Department of Fish and Game, Lewiston, ID	12 years of professional experience with bighorn sheep management.
Clint McCarthy	Regional Wildlife Ecologist	U.S. Forest Service, Intermountain Regional Office, Ogden, UT	20 years of professional experience with bighorn sheep management.
Jeff Rohlman	Regional Wildlife Manager	Idaho Department of Fish and Game, McCall, ID	20 years of professional experience with bighorn sheep management.
Tim Schommer	National Bighorn Sheep Biologist	U.S. Forest Service, Wallowa-Whitman NF, Baker City, OR	26 years of professional experience with bighorn sheep management.
Dale Toweill	Wildlife Program Coordinator	Idaho Department of Fish and Game, Boise, ID	22 years of professional experience with bighorn sheep management. Currently supervises Idaho statewide bighorn sheep management program. Author of 2 books on wild sheep.

① - Literature Review

② - Scope
- subject
- geographic area

③ - risk categories
- habitat ?
- transmission among metapops - bighorn → bighorn
- historic levels of sheep grazing did not impact sheep

④ - missing information should be included in analysis.
- allotment
- breeding allotments
- trailing routes