Idaho
Bighorn Sheep Management Plan
2022–2027

Prepared by IDAHO DEPARTMENT OF FISH AND GAME
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EXECUTIVE SUMMARY

The Idaho Department of Fish and Game (IDFG) was established to preserve, protect, perpetuate, and manage fish and wildlife in the state. Statewide species planning documents provide an overview of current status and set statewide management direction to help fulfill that mission. The most recent bighorn sheep management plan was completed in 2010 and this plan updates that document.

This plan was developed by IDFG personnel using the best biological information available. Public input was solicited during development of the plan and professionals from other jurisdictions were also consulted. The document provides an overview of current and historical bighorn sheep distribution and abundance statewide. It also describes the current extent of potential habitat and discusses management issues including disease, predation, and hunting. Future statewide management direction is identified in the context of these issues.

In Idaho, bighorn sheep exist in both small, isolated populations and in interconnected metapopulations. For management purposes, these populations and metapopulations have been divided into 21 Population Management Units (PMUs). Currently, an estimated 2,950 bighorn sheep occupy about 15.5% of the state. They are distributed from north-central Idaho to the southern border but are restricted to rugged canyon and mountain terrain and adjacent habitats within this area. Bighorn sheep often select habitats that provide forage, water, and steep open terrain where they can evade predators. Habitat modeling indicates approximately 35,000 km^2 of potential bighorn sheep habitat in the state, of which about one half (17,246 km^2) is within PMUs.

In south-central and southwestern Idaho about 450 California bighorn sheep occur in 5 PMUs. Bighorn sheep were completely extirpated from this part of the state, and current populations are the result of 11 translocations from outside Idaho and 18 in-state translocations between 1963 and 2004. Rocky

Mountain bighorn sheep (approximately 2,500 animals) occur in 16 PMUs in central and southeastern Idaho. Eighteen out-of-state translocations and 17 in-state translocations were conducted between 1975 and 2005 to restore Rocky Mountain bighorn sheep populations to historically occupied habitat. Translocations have successfully expanded the distribution of bighorn sheep, but most of the largest populations are still native Rocky Mountain bighorn sheep that were never extirpated in the Salmon River drainage. The primary limiting factor is disease, although other factors including habitat, genetics, climate change, predation, and hunting can also be important.

Idaho bighorn sheep are managed as populations largely defined by phenotype (e.g., physical characteristics of California and Rocky Mountain bighorn sheep), topographic boundaries, and best available knowledge of movements and spatial distribution. Genetic markers are another source of biological information that can improve or support ecologically-based delineation of population structure for management. Genetic diversity can also affect fitness and the ability to adapt to changing environmental conditions and provides a quantitative measure to assess the effects of management actions and environmental factors. Genetic data from samples collected (blood, horn shavings, and tissue) show that the genetic structure and diversity of Idaho bighorn sheep PMUs has been influenced by a combination of ancestry, population demographics, geography, and management.

Disease was a significant factor associated with the historical decline of bighorn sheep and is a key factor limiting recovery. Pneumonia is the disease that has the most widespread and severe impacts on bighorn sheep population abundance and is triggered by the bacterium *Mycoplasma ovipneumoniae*, commonly referred to as "Movi". Bighorn sheep are vulnerable to Movi organisms carried by healthy domestic sheep and goats and once these organisms are transmitted there is no effective treatment in bighorn sheep. Therefore, the most important management direction to reduce the impact of disease on bighorn sheep populations is to minimize or eliminate contacts between bighorn sheep and domestic sheep and goats that could result in disease transmission. This includes maintaining separation between species and reducing prevalence of infection in domestic and wild sheep and goats. When this strategy fails, a protocol will be followed to remove bighorn sheep that are in contact with domestic flocks and/or stray domestic sheep and goats in contact with bighorn sheep to prevent further disease transmission. IDFG will work with private individuals and public land managers to develop best management practices in areas where interactions are likely to occur to keep the domestic and wild animals separate. IDFG will also collaborate with small flock owners, the pack goat community, and other interested parties to develop and distribute educational materials and develop Movi-free farm flocks. Finally, IDFG will continue to conduct and collaborate on research to better understand and control disease in bighorn sheep, including methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations.

Wildlife managers can also inadvertently facilitate disease transmission through movement of animals. Some disease agents can persist in bighorn sheep populations and mixing populations through translocations poses a risk of infecting naïve animals. In addition, translocating bighorn sheep to areas where they may contact domestic sheep or goats is counterproductive and poses a high risk to bighorn sheep. Therefore, while translocation can be a valuable tool for restoring bighorn sheep populations, IDFG will carefully evaluate the potential risks and benefits of proposed bighorn sheep translocations. When translocations occur, the best, most current, monitoring and health testing protocols will be followed.

Idaho contains abundant habitat for bighorn sheep. However, the quality of that habitat can be diminished by invasive plants, conifer encroachment, roads and urban development, human disturbance (including recreational use), competition with livestock or other wild ungulates, climate change, and other factors. The focus of bighorn sheep habitat management in Idaho is to maintain healthy native plant communities in proximity to rugged escape terrain and to minimize negative effects of human activities. This includes preventing the introduction and spread of invasive plants, minimizing human disturbance, and avoiding management activities that can facilitate introduction and transmission of diseases. Restoration activities in degraded habitats include using fire or logging to reverse conifer encroachment, controlling invasive plants, reducing human disturbance, decreasing the potential for competition with domestic or wild ungulates where appropriate, and maintaining important seasonal habitats, especially those that contribute to climate resiliency. Most bighorn sheep habitat and populations occur on lands managed by the US Forest Service and Bureau of Land Management. However, private landowners, local, county, and state governments can also play an important role in managing habitats for bighorn sheep.

Long-term empirical evidence indicating direct effects of ongoing and projected climate change on bighorn sheep is generally lacking. Indirectly, however, climate affects forage quality and quantity, and these changes may influence bighorn sheep reproduction, recruitment, survival, distribution, and migratory behavior. The ongoing and projected changes in temperature and precipitation in Idaho may both positively and negatively affect bighorn sheep populations. For example, in subalpine and alpine habitats, warmer spring temperatures resulting in earlier spring green-up and shorter winters are associated with higher spring body mass in ewes, which can positively influence lamb summer weight gain and survival. However, warm dry growing seasons that affect forage condition can also negatively influence lamb survival, recruitment, probability of pregnancy, and winter survival for ewes, although the effect on survival may be mitigated by shorter, milder winters. Given the ecological and topographic complexity of bighorn sheep PMUs in Idaho, sufficient availability of cooler microclimates (i.e., climate refugia) may allow populations to persist, and possibly even expand, in seemingly inhospitable areas assuming populations are not impacted by other factors (e.g., disease).

Bighorn sheep have developed successful strategies to elude predators, including gregarious behavior and use of rugged escape terrain. As a result, most predators have difficulty capturing bighorn sheep. For example, wolf predation is generally not a factor for bighorn sheep, probably in part because bighorn sheep can usually outrun wolves in steep terrain. However, mountain lions are more effective predators on bighorn sheep because their hunting strategy is better suited to rugged habitats. While mountain lion predation on bighorn sheep is widespread, it usually does not limit populations. Predation typically only has population-level effects on small bighorn sheep populations that are struggling due to other factors, such as disease or drought. Populations can also be affected if predators, particularly mountain lions, switch to preying on bighorn sheep when their primary prey species (such as deer) decline. Mountain lions can also be effective at preying on newly translocated bighorn sheep. When these situations occur, focused, short term predator removal may be implemented to ensure the long-term survival of bighorn sheep populations.

Bighorn sheep hunting tags are few and highly sought after. Hunters are only able to harvest 1 California and 1 Rocky Mountain sheep in Idaho in their lifetime, and only if they draw these tags. Hunters will likely see few changes in harvest management under the guidelines in this plan. Tag numbers are limited by allowing harvest of no more than 20% of the mature rams in a population. Due to low population densities, hunting ewes is not currently allowed and is unlikely to occur in the foreseeable future. Limited hunting opportunity is maximized by allowing hunters to harvest any ram, allowing them to choose any weapon for their hunt, and not allowing hunting during the breeding season when rams are most vulnerable. Additional ram hunting opportunity could also be offered in populations at high risk for contact with domestic sheep and goats.

Statewide bighorn sheep management direction includes:

- Seek to improve understanding of metapopulation structure and interaction.
- Strive to allow populations to grow to ecologically sustainable densities as determined by habitat and range conditions unless conflicts with other uses of the habitat have been documented that would require management intervention to maintain bighorn sheep at some lower population level.

- Continue to refine efforts to document and model occupied, unoccupied, potential, and suitable bighorn sheep seasonal habitats.
- Continue to emphasize studies and management actions pertinent to resolving bighorn sheep disease issues.
- Conduct research and/or adaptive management in some populations to determine effectiveness and feasibility of using methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.
- Work to reduce risk of disease transmission from small flocks of domestic sheep and goats through outreach, testing animals, and promoting best management practices for healthy, Movi-free flocks.
- Improve understanding of existing and potential effects of changing climates, specifically changes in seasonal temperatures, on bighorn sheep recruitment rates, survival, disease and parasites, distribution, and habitat use.
- Manage for maintaining or increasing genetic diversity in bighorn sheep populations while conserving unique genetic ancestry in native populations.
- Implement the Predator Management Policy when evidence indicates that predation is a major cause for bighorn sheep populations not meeting state management objectives.
- Maximize the likelihood of translocation success at establishing or augmenting bighorn sheep populations.
- Maintain the availability of mature rams by restricting harvest to no more than approximately 20% of the Class III and IV rams observed during the most recent survey or believed present based on the best judgment of the individual Regional Wildlife Manager (as some surveys may not be completed due to weather or other external influences).

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INTRODUCTION

Historically, bighorn sheep (see Appendix B for scientific names) ranged widely in Idaho (Figure 1) and archeological evidence suggests the species was important to Native Americans for subsistence, tools, and ceremonial purposes for ≥7,000 years (Demarchi et al. 2000).

Archaeological evidence and reports by early explorers indicate that bighorn sheep were widely distributed and abundant in Idaho until the late 1800s (Smith 1954, Buechner 1960). Early Idaho settlers and explorers reported seeing thousands of bighorn sheep in their historical range (Merriam 1891, Seton 1929, Smith 1954). As occurred throughout the west, drastic population declines followed the arrival of homesteaders and other settlers in the late 1800s and early 1900s. By 1920, the Idaho bighorn sheep population was estimated at 1,000 animals, mostly within the Salmon River drainage (Smith 1954). In 1925, the last bighorn sheep in Hells Canyon was reported killed and by 1940 bighorn sheep were extirpated from the Owyhee River area, leaving the only remaining populations along the Salmon River (IDFG 1990). The primary factors believed responsible for the decline of bighorn sheep in Idaho were unregulated hunting, competition with domestic livestock for forage, and disease.

Idaho Department of Fish and Game (IDFG) began to restore bighorn sheep populations in the 1960s. Bighorn sheep from British Columbia were translocated to the East Fork Owyhee River drainage in 1963 and bighorn sheep from the Salmon River in central Idaho were translocated to the Lost River Range near Mt. Borah in 1969. Since then, 811 bighorn sheep have been moved into and within Idaho from 6 states and provinces to reestablish populations in historical habitat (Appendix C). The most recent translocation was to the Lost River Range in eastern Idaho in 2005. As a result of restoration efforts, including strict hunting regulations, habitat protection, and translocations of bighorn sheep to historically occupied habitat, numbers increased to about 5,000 animals statewide in 1990. As populations increased, Idaho also contributed 307 bighorn sheep to restoration of populations in other states. However, starting in the late 1980s and continuing at least through the 1990s, population declines in some areas, primarily associated with disease, reduced statewide numbers (Figure 2, Table 1).

Value

Today, bighorn sheep are an important wildlife resource in the state of Idaho. Wildlife and outdoor enthusiasts, hunters, photographers, and others value the opportunity to view bighorn sheep as well as to hunt them as one of Idaho's premier big game species. Although there are no estimates specifically for bighorn sheep, consumptive and nonconsumptive wildlife activities are an important contributor to the economy in Idaho. In 2019, outdoor recreation in Idaho accounted for $2.5 billion of gross domestic product for the state, with $149 million in current-dollar value added from hunting, shooting, and trapping (Bureau of Economic Analysis 2019). The sale and price of resident and non-resident bighorn sheep tags, including special auction and lottery tags, can be attributed directly to bighorn sheep hunting opportunities. Bighorn sheep tag sales for the 2021 season included 94 controlled hunt permits/tags, 1 auction tag, and 1 lottery tag. Resident tags sell for $199.75 (for non-price lock), $166.75 (for price lock) and non-resident tags for $2,626.75. The auction tag sold for $310,000 in 2021 and has averaged $132,500 per year since 2011. The lottery tag raised $172,993 in 2021 and has averaged $89,372 per year since 2011. Indirect income generated from bighorn sheep hunting activities includes funds spent by hunters on travel, food, lodging, outfitters and guides, and possibly taxidermists.

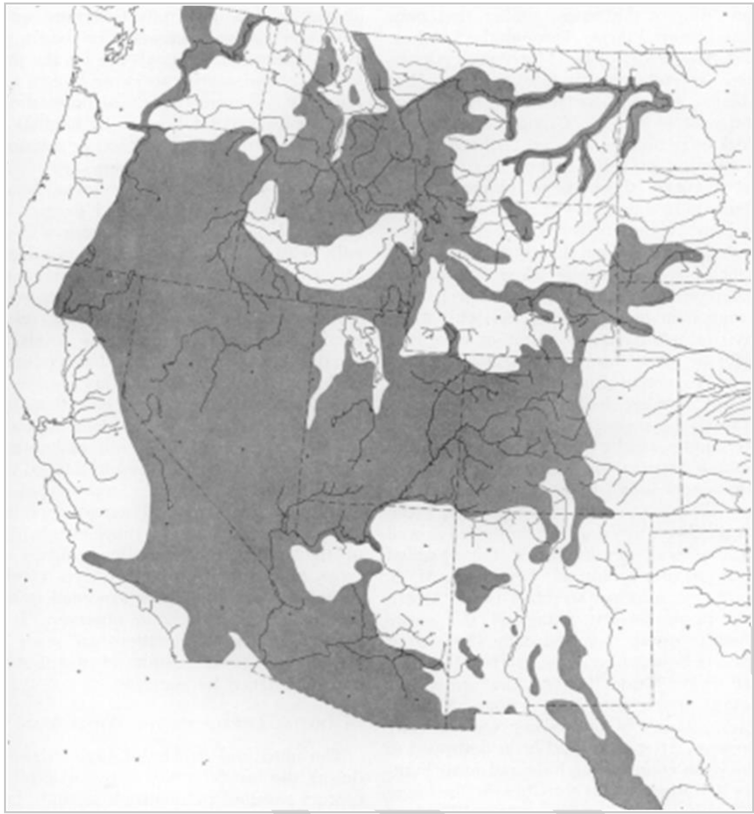


Figure 1. Probable historical distribution of bighorn sheep in the US prior to European settlement (Buechner 1960).

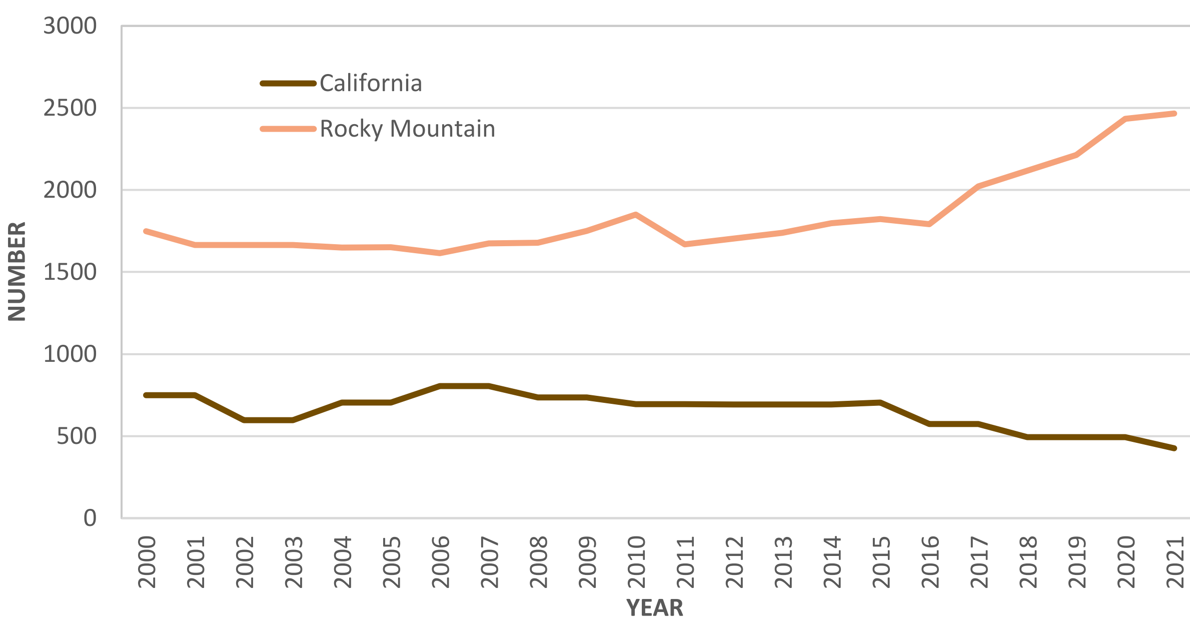


Figure 2. Statewide population estimates of California bighorn sheep and Rocky Mountain bighorn sheep in Idaho, 2000–2021. Statewide estimates are based on the most recent survey in each population management unit which may, or may not, reflect the year of the estimate.

Table 1. Minimum counts and estimates of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep in Idaho by Population Management Unit (PMU) based on the most recent survey.

PMU	Observed					Estimated				Recent Survey
	Ewes	Lambs	Rams	Unc	Total	Ewes	Lambs	Rams	Total	
North Hells Canyon	44	17	40	0	101	78	30	72	180	2020
South Hells Canyon	16	6	20	0	42					2021
Lower Salmon	238	67	121	0	426	298	86	181	565	2019
Selway	-	-	-	-	-					-
Lower Panther-Main Salmon	119	35	63	0	217					2016
Middle Fork Salmon	300	71	138	1	510					2017
Middle Main Salmon	143	36	55	1	235					2016
North Beaverhead	35	21	8	0	64					2016
South Beaverhead	10	3	3	20	33					2016
North Lemhi	57	20	51	0	128					2018
South Lemhi	48	26	36	0	110					2021
Lost River Range	226	72	146	0	444					2020
East Fork Salmon	30	13	20	0	63	34	19	32	85	2019
Pioneers	-	-	-	-	-					-
Lionhead	-	-	-	-	-					-
Palisades	-	-	-	-	-					-
Owyhee Front	16	12	20	0	48					2021
Owyhee River	81	32	27	0	140					2021
Jacks Creek	82	24	33	0	139					2021
Bruneau-Jarbidge	14	9	3	0	26					2021
Jim Sage	40	23	10	0	73					2021

Law and Policies

Idaho Code (36-103) defines the state's wildlife policy and the mission and role of Idaho Fish and Game:

"All wildlife, including all wild animals, wild birds, and fish, within the state of Idaho, is hereby declared to be the property of the state of Idaho. It shall be preserved, protected, perpetuated and managed. It shall be only captured or taken at such times or places, under such conditions, or by such means, or in such manner, as will preserve, protect, and perpetuate such wildlife, and provide for the citizens of this state, and as by law permitted to others, continued supplies of such wildlife for hunting, fishing and trapping."

Through time, the management of wildlife in general, and bighorn sheep in particular, has become increasingly complex. This is evident from the number of specific references to bighorn sheep that have been added to Idaho Code Title 36-106 since 1995. These include mandates associated with translocations and in 2009, a requirement that IDFG develop a plan to ensure a viable, self-sustaining population of bighorn sheep in Idaho and work with domestic sheep producers to develop "Best Management Practices" to help implement a state policy of separation between bighorn and domestic sheep.

Management Planning and Accomplishments

IDFG addressed many of the management directions and strategies in the 2010 management plan. These accomplishments are addressed in the chapters and PMU sections. Below are highlights of accomplishments since 2010.

One statewide strategy from the 2010 plan was to improve our understanding of metapopulation structure and interaction. To accomplish this, IDFG radio-collared and monitored movements of 375 bighorn sheep statewide between 2007 and 2021 (Table 2). These locations, combined with improved habitat modeling, have bettered our understanding of distribution, movements, and habitats used by bighorn sheep. We used these data to refine boundaries of several PMUs across the state (Figure 3) including adding areas now known to be used by bighorn sheep (e.g., Hells Canyon, Middle Fork Salmon, and North Lemhi) and removing areas that exhibit no sheep use and little to no habitat (e.g., Lower Salmon, Lower Panther – Main Salmon).

One management direction identified in the previous plan was to refine efforts at mapping occupied, unoccupied, potential, and suitable bighorn sheep habitat statewide. To accomplish this, we improved data collection (Table 2) and developed ecoregion-specific habitat models. The three ecoregional models were then combined into a single statewide habitat layer, which still reflects habitat use differences across the three ecoregions (Figure 4).

Another management direction was to continue to emphasize studies pertinent to resolving bighorn sheep disease issues with strategies including working to reduce the effects of disease on populations and to maintain close working relationships with universities and other management agencies. Pneumonia is the disease that has the most widespread and severe impacts on bighorn sheep population abundance and is triggered by the bacterium *Mycoplasma ovipneumoniae*, commonly referred to as “Movi”. IDFG led collaborative efforts to develop the test-and-remove management tool now being used in multiple states and jurisdictions to recover stagnant and declining bighorn sheep populations by eliminating bighorn sheep chronically infected with Movi as a strategy to eliminate Movi from the population. The Hells Canyon bighorn sheep have been increasing since the elimination of Movi.

Another management strategy was to collaborate with others to develop treatments for pathogens to prevent transmission of disease among domestic sheep and bighorn sheep. IDFG has been working with livestock owners living near bighorn sheep populations to clear Movi from their small flocks of domestic sheep and herds of domestic goats. Having Movi-free domestic sheep and goats reduces the risk of infecting bighorn sheep with new strains of Movi by reducing Movi on the landscape.

Current Planning Process

In 2021, IDFG assembled a team to update the previous plan to reflect changes since 2010. The current plan provides substantial background information and broad management objectives that will be used to set annual work plan activities and to establish funding priorities.

POPULATION MANAGEMENT

Distribution, Classification, and Population Structure

Bighorn sheep regularly occur from north-central Idaho south to the state boundary. However, within this range, distribution is generally centered on rugged mountains and steep river canyons that are preferred habitat for bighorn sheep. Distribution can be defined as a general delineation of the area regularly or periodically occupied by a species (see Appendix A for Glossary of Terms). Bighorn sheep distribution in Idaho includes both core use areas and space used for movements that does not have sufficient suitable habitat to support persistent populations. Bighorn sheep can and do occasionally travel outside this area and distribution can change over time because of changes in population density, habitat, or other factors. For example, incidental observation in GMUs 1 and 4 in the last 5 years indicate bighorn sheep may be pioneering suitable habitat in these areas.

Mapped bighorn sheep distribution in Idaho includes nearly 35,000 km^2, approximately 15.5% of the state (Figure 3). Not surprisingly, given the rugged nature of the terrain, a disproportionate amount of this area is in federally designated wilderness. Over one-third (35%) of mapped Idaho bighorn sheep distribution is in wilderness while only 10% of Idaho is designated as wilderness.

Idaho refers to bighorn sheep south of Interstate 84 as California bighorn sheep and manages them separately from the Rocky Mountain bighorn sheep in the rest of the state. Although all bighorn sheep in Idaho are considered a single subspecies (Rocky Mountain bighorn sheep, *O. c. canadensis*) based on the most recently accepted taxonomy (Wehausen and Ramey 2000), California and Rocky Mountain bighorn sheep display differences in physical appearance, and they offer different hunting opportunities within the state. California bighorn sheep generally occupy canyon and desert habitat while Rocky Mountain bighorn sheep occupy canyons and rugged mountainous terrain. Approximately 2/3 of the sheep in Idaho are recognized as Rocky Mountain.

Within these designations, bighorn sheep tend to occur in groups of interacting populations, or metapopulations. For management purposes these groups and the area they inhabit are divided into Population Management Units (PMUs) in this plan. This is the level at which many management activities occur. Based on current knowledge of connectivity within and among populations there are 21 PMUs in Idaho. About a quarter of these PMUs (Lower Salmon, Middle Fork Salmon, Middle Main Salmon, Lower Panther – Main Salmon, East Fork) comprise 53% of the statewide population and are considered native (never extirpated). These native populations are primarily found along the Salmon River corridor. The remaining PMUs are reintroduced populations in historical habitat. Population Management Units are described individually in more detail in the last section of the plan.

In most instances PMUs are fairly well defined, but in some cases PMU boundaries are somewhat arbitrary. Interaction among all PMUs is not completely understood. Additional information on population structure and connectivity would be beneficial for population management. Understanding population structure has direct implications for evaluation of population persistence (viability). One statewide strategy from the 2010 plan was to improve our understanding of metapopulation structure and interaction. To accomplish this, IDFG radio-collared and monitored movements of 375 bighorn sheep (228 ewes, 147 rams) across the state between 2007 and 2021. These locations, combined with improved habitat modeling, have improved our understanding of distribution, movements, and habitats used by bighorn sheep. We used these data to refine boundaries of several PMUs across the state including adding areas now known to be used by bighorn sheep (e.g., Hells Canyon, Middle Fork Salmon, and North Lemhi), removing areas that exhibit no sheep use and little to no habitat (e.g., Lower Salmon, Lower Panther – Main Salmon), and splitting PMUs to better reflect sheep movements and distribution (e.g., Hells Canyon). Two PMUs from the 2010 plan no longer exist in the current plan: Tower-Kriley was incorporated into the Lower Panther – Main Salmon PMU and the South Hills PMU was eliminated. Further discussion of PMU boundary adjustments can be found in the PMU descriptions later in the document.

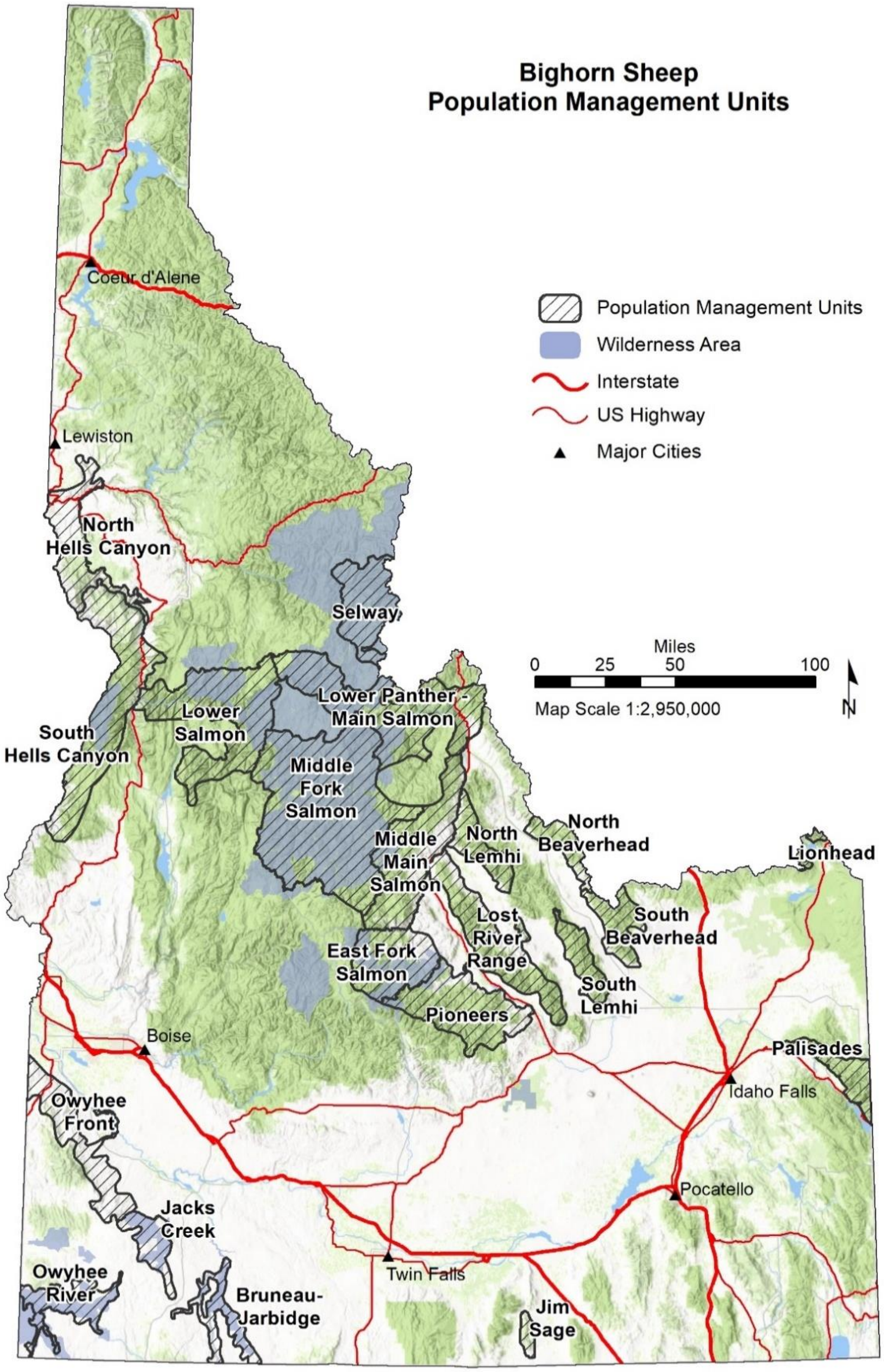


Figure 3. Current distribution of bighorn sheep in Idaho, as defined by Population Management Units (PMU).

Population Monitoring

The goal of a good population monitoring plan is to provide wildlife managers with the information needed to evaluate management goals and make informed decisions. This information should include a minimum known population count and composition data. Surveys should be conducted frequently enough to establish population trends.

Monitoring bighorn sheep in Idaho is difficult as they exist at low to extremely low densities and often in remote, rugged areas including federally designated wilderness. Bighorn sheep generally move between summer and winter home ranges and are a gregarious species that exhibit sexual segregation except during the rut (Geist 1971). This movement between areas of use and sexual segregation can complicate monitoring. Many of Idaho's bighorn sheep populations have not been studied intensely and spatial and temporal habitat use is not well understood. Furthermore, because of hunting seasons for other species, aerial surveys are usually not practical during the rut, when bighorn sheep are typically at their greatest spatial and temporal densities. Timing surveys when bighorn sheep are in smaller, sexually segregated groups increases the likelihood of missing groups, which can impact observed ram:ewe and lamb:ewe ratios as well as the population estimate.

In Idaho, metapopulations span hunt areas, Game Management Units (GMUs), and administrative boundaries. This results in a patchy network of populations of bighorn sheep that may have varied population trends (stable, increasing, or decreasing) across a large area of contiguous habitat that may make up a metapopulation. In many areas this metapopulation structure has not been delineated or is not well understood. This makes it possible for individual populations or parts of individual populations to be missed, affecting survey results.

Challenges associated with monitoring a species that occurs at low density, has a patchy distribution, and exhibits varied population trends will require a different approach than monitoring techniques applied to more common large ungulates. Deploying radio collars on a few individuals in populations where movement patterns are not known may help delineate seasonal ranges. Radio-collared bighorn sheep will also help biologists stratify areas for sheep surveys and provide data for sightability models. Ultimately, this strategy should lead to reducing flight survey hours and generating better population data.

Idaho does not currently survey all populations of bighorn sheep. Survey activities are prioritized in areas where hunts are offered. Most surveys are conducted in a helicopter where a minimum count and demographic information is obtained. The frequency of surveys varies from annually to once every 5 years. Many surveys are conducted during surveys for other species (deer or elk) to save money. This may be cost effective, but likely reduces the quality of the surveys for both species. For example, in 2007 a total of 50 sheep were observed incidentally during an elk survey in GMUs 14 and 19. However, in 2010, 146 sheep were observed in the same area on a survey specifically conducted for bighorn sheep. During this time frame, the bighorn sheep population in this area was thought to be stable. Conducting concurrent surveys also dictates the timing of the survey as most deer and elk surveys are conducted from December through March.

Current factors that affect survey quality are primarily driven by financial limitations (frequency, timing, and conducting a bighorn sheep-only survey), but are also impacted by knowledge of distribution and range. Given the rising cost of aerial surveys, Idaho will have to secure additional funding to maintain the current level of monitoring, much less expand it. Idaho does not currently have a robust sightability model for all bighorn sheep populations. Sightability models are needed to generate bounded population estimates, which can be evaluated to determine statistically significant changes in populations. Since the last plan several sightability models have been created. However, they are population specific, as shown when the Hells Canyon model performed poorly when applied to the Lower Salmon PMU. Additionally, research efforts on test-and-remove have resulted in high numbers of radio-marked bighorn sheep in some populations. In these areas, IDFG has been evaluating a ground-based mark recapture estimate that can allow annual estimates of those populations without the use of helicopters. A similar ground-based mark and resight effort was performed on the East Fork Salmon PMU and resulted in a higher observation rate than aerial-survey and bound-sightability estimates. Ground surveys can reduce the cost and allow annual estimates but are limited by the number of marked individuals in the population (i.e., if there is a 50% detection probability, then 20% of population needs to be marked) and may underestimate ram numbers at some times of the year.

Population Management Directions

Management Direction — Continue to manage Rocky Mountain and California bighorn sheep separately, with Rocky Mountain bighorn sheep north of Interstate 84 and California bighorn sheep south of Interstate 84.

Management Direction — Manage native Rocky Mountain sheep populations as a unique and irreplaceable resource.

> Strategy: No bighorn sheep from outside the 5 native Population Management Units will be released into native populations.

Management Direction — Seek to improve understanding of metapopulation structure and interaction.

> Strategy: Use telemetry, GPS, genetic analysis, and other suitable techniques to study movements, interactions, and gene flow.

Management Direction — Strive to allow populations to grow to ecologically sustainable densities as determined by habitat and range conditions unless conflicts with other uses of the habitat have been documented that would require management intervention to maintain bighorn populations at some lower population level.

Management Direction — Improve the quality of bighorn sheep population data to better evaluate population trend and viability.

Strategy: Develop a monitoring plan for surveys that provides for periodic assessments of population status and distribution.

Strategy: Continue to develop and refine bighorn sheep sightability models for Idaho's differing habitats and terrain.

Strategy: Use radio-collared bighorn sheep to help delineate distribution and increase survey efficiency.

Strategy: Use techniques other than aerial survey when possible, such as radio-collared bighorn sheep and ground observation, to monitor population size, composition, and status.

Strategy: Develop ground count protocols to standardize data collection.

Strategy: In populations where bighorn sheep are marked for research or management efforts, maintain a sample of marked animals post-study to estimate population size using ground counts (where practical and cost effective). For example, if there is a 50% detection probability, then 20% of the population needs to be marked.

HABITAT MANAGEMENT

Habitat, in its simplest sense, is where an animal lives. It includes all the resources an animal needs as part of its daily life: food, water, shelter, and space distributed and arranged appropriately across the landscape. Bighorn sheep are uniquely adapted to exploit specific habitats, and therefore have specialized habitat needs, such as steep, rugged terrain that allows for escape from predators.

In Idaho, bighorn sheep habitat consists of rugged mountains dominating the central part of the state and steep rocky canyons in the south and west. Quality and quantity of bighorn sheep habitat are primary factors potentially limiting the distribution and number of bighorns Idaho can support. Habitat management is therefore a key component of bighorn sheep conservation. Most bighorn sheep habitat in Idaho occurs on lands managed by the US Forest Service (USFS) and Bureau of Land Management (BLM). Long-term success of bighorn sheep management and conservation will depend on close coordination between IDFG and federal and state land management agencies. Although private lands comprise only a small portion of bighorn sheep habitat in Idaho, private landowners, as well as local, county, and state governments, make decisions and conduct activities which may affect bighorn sheep and their habitat.

Understanding the extent and spatial distribution of habitat facilitates management, including developing population goals and prioritizing threats. For bighorn sheep, these threats include conifer encroachment, invasive species, interspecific competition, disease transmission, human recreation, and climate change. Migration habitat and routes, mineral requirements, and water developments are auxiliary issues also important to bighorn sheep habitat management. Each of these threats warrant discussion and specific management objectives to mitigate their effects on the quality and quantity of bighorn sheep habitat. It should be noted, however, that for the foreseeable future, disease risk is the single most important issue driving bighorn sheep management in Idaho.

Mapping of Bighorn Sheep Habitat

Accurate mapping of important habitat is a critical factor in facilitating habitat management. One common process for mapping suitable habitat uses known animal locations and the habitat features recorded at those locations to develop a model that is then applied to a larger geographic area to predict potentially suitable habitat. The resulting model allows biologists to evaluate habitat suitability in areas not currently occupied by a given species, or to identify habitat factors that may play a role in a species success or failure in an area.

Unfortunately, mapping suitable bighorn sheep habitat is neither simple nor static and instead is a dynamic process as habitat conditions change through time. In addition, habitats are generally neither completely suitable nor completely unsuitable, and probability of use varies along a continuum. Therefore, modeling suitable habitat based on features used most frequently may not account for areas that animals use only occasionally, such as migration routes between areas of "suitable habitat." In addition, animals in different geographical regions may use habitat features differently, which may result in a model developed in one area not being applicable to other areas. Ultimately, models may over- and/or under-predict habitat for several reasons and additional assessment is required to strike a balance between these potential errors.

For bighorn sheep, several habitat models have been developed through time. Some are appropriate only to specific locales within Idaho (e.g., Fowles 2002, Fowles and Merrick 2003), whereas others are intended for wider state or region-wide use (Bosworth 2008, USFS 2010). For the previous plan, we assessed the different models available for Idaho and elected to use the USFS (2010) model of summer bighorn sheep habitat. This model was developed using bighorn sheep location data from only the west central (i.e., Payette National Forest) portion of Idaho. Therefore, when compared to actual bighorn sheep locations in other areas of the state, it was apparent that accuracy of the Payette model varied considerably and did not reliably represent habitats used by bighorn sheep in eastern and southern Idaho.

One management direction identified in the previous plan was to refine efforts at mapping occupied, unoccupied, potential, and suitable bighorn sheep habitat statewide. To accomplish this, we increased collection of bighorn sheep locations statewide and improved habitat models. Since 2010 additional location data collection has occurred in most PMUs around the state, most notably in the Hells Canyon, East Fork Salmon, Lost River Range, North and South Lemhi, North and South Beaverhead, and Owyhee River PMUs (Table 2). These recent location data, together with local knowledge, indicate bighorn sheep in western, central, and southern portions of the state exhibit different habitat use characteristics. Because of this, we used ecoregion boundaries to delimit model areas (Figure 4), then combined the 3 ecoregional models into a single statewide habitat layer that still reflects habitat use differences across the state. Models were developed using a subset of location data and several environmental variables likely to influence the distribution of bighorn sheep in a maximum entropy analysis (Maxent 3.4.1; Phillips et al. 2006, Phillips and Dudík 2008, Phillips et al. 2017) (see Appendix D for more information). Modeled potential habitat using this approach included 15.5% (33,602 km^2) of Idaho.

It is important to note that mapped bighorn sheep distribution (i.e., PMU boundaries) does not exhibit perfect correspondence with modeled bighorn sheep habitat. Although most areas within the mapped distribution are modeled as habitat, some areas are not. This may be a result of several factors including bighorn sheep occasionally use areas not typically considered suitable habitat for migratory or dispersal movements, variability in model performance across the state (although this was minimized with the recent ecoregional approach), and a lack of location data (e.g., Lionhead, Middle Fork Salmon, Selway, Palisades, and Pioneers PMUs). Conversely, there is substantial predicted habitat (as determined by the model) well outside current bighorn sheep distribution in areas of known historical distribution (e.g., in the Sawtooth Range, Sublett Range, and Salmon Falls Creek).

Once potential habitat is depicted within a given area, it is possible to calculate potential bighorn sheep population size based on observed bighorn sheep densities in similar areas, given several assumptions. Described densities of bighorn sheep vary widely across North America by location, study, habitat, and other factors, and therefore should only be used as a relative index of the number of bighorn sheep habitat may be able to support in a given area. For example, Smith et al. (1991) suggest densities of 1.9–3.9 bighorn sheep/km^2 should be used in habitat evaluations, but report ranges from <0.4 to >27 bighorn sheep/km^2. Van Dyke (1983) reported a density of 1.9/km^2 for reintroduced herds in southeastern Oregon. In Montana, researchers estimated much higher potential densities on seasonal ranges, such as 9.2–20.4 bighorn sheep/km^2 on modeled winter habitat (Lula et al. 2020), while Stephenson et al. (2020) report much lower densities of 0.1–1.0 bighorn sheep/km^2 in California. These densities may be affected by habitat quality, seasonal movements to more limiting winter habitat, or other factors that limit habitat suitability.

For this plan, we quantified the amount of potential habitat within bighorn sheep distribution and described this by PMU (Table 3). Approximately 51% of modeled habitat is within bighorn sheep distribution; therefore, <8% of Idaho is considered potential habitat for the purposes of developing population objectives. We then used Van Dyke's (1983) recommended density of 1.9 bighorn sheep/km^2 to estimate the total number of bighorn sheep that might be able to occupy this habitat within each PMU (Table 3). This number does not account for local variation in habitat quality or other site-specific factors and should be treated as a relative index to the potential population that could exist based solely on potential habitat. To account for potential conflict with domestic livestock, we removed both private lands and domestic sheep and goat grazing and trailing allotments on public lands from the total available modeled habitat and used the resulting area to calculate the total number of bighorn sheep supportable by the remaining habitat (Table 3). Population estimates derived from densities such as Van Dyke (1983), which is acceptable on relatively spacious summer range, may overestimate numbers for bighorn sheep populations that become more crowded during the winter or if other factors (e.g., competition, invasive plants, fire) reduce the amount of forage available. Because of these factors, efforts at mapping and describing sheep habitat throughout the state need to continually be improved and refined.

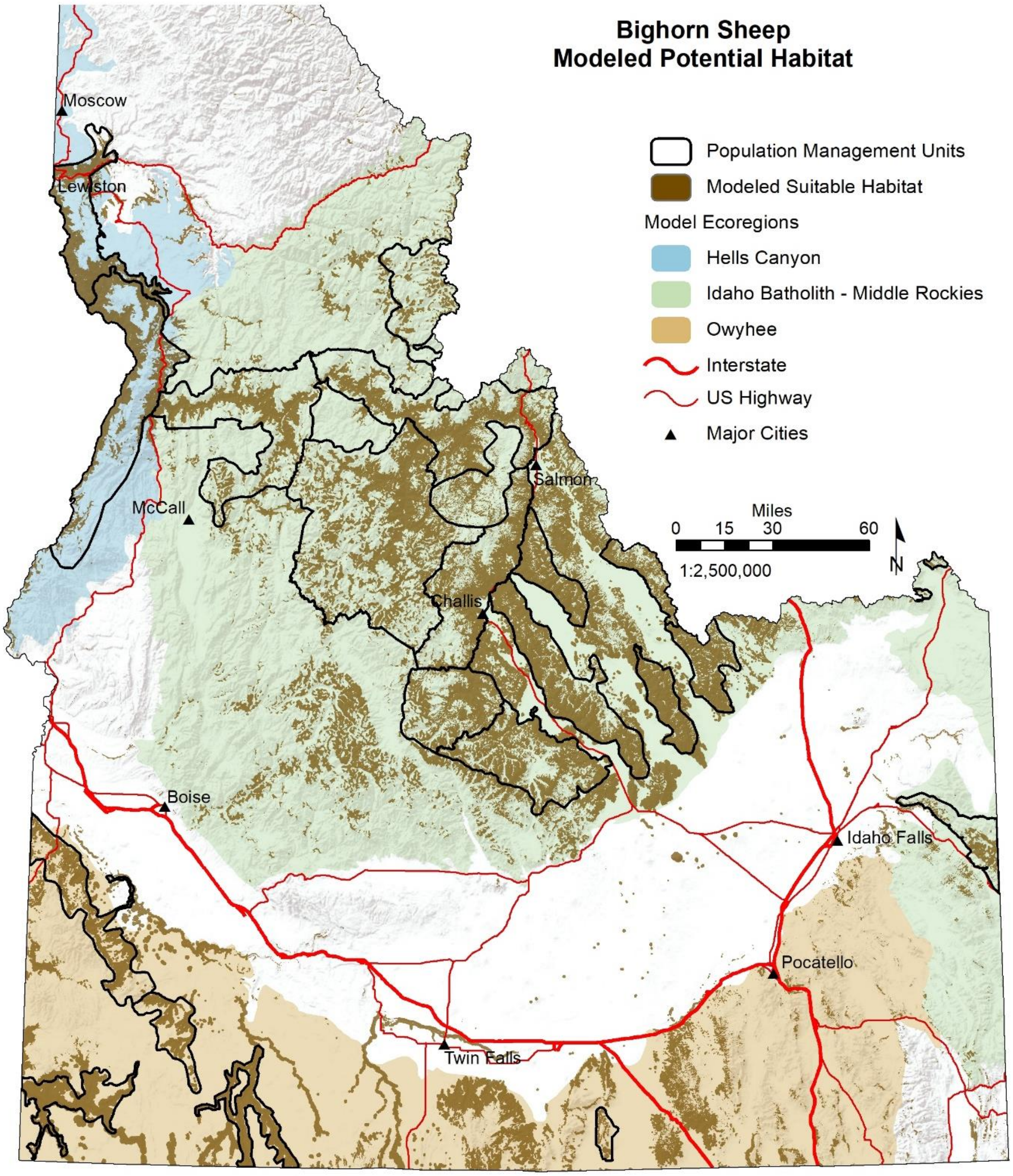


Figure 4. Bighorn sheep modeled potential habitat in Idaho. Independent models were developed for each model ecoregion using maximum entropy analysis and a subset of observations, then combined into a single statewide layer (see Appendix D).

Table 2. Known bighorn sheep locations from radio-collared animals (2007–April 2021, with the number of individual animals in parenthesis), surveys (1986–December 2021), and incidental observations (1932–December 2021) in each Population Management Unit (PMU), Idaho.

Population Management Unit (PMU)	Total Number of Known Locations	Number of Locations From		
		Radio-collared Animals (Number of animals)	Surveys	Incidental Observations
North Hells Canyon	61,191	47,834 (48)	8,733	4,624
South Hells Canyon	16,227	14,099 (28)	529	1,599
Lower Salmon	32,903	32,474 (71)	398	31
Selway	15	0	15	0
Middle Fork Salmon	2,257	1,497 (10)	521	239
Lower Panther-Main Salmon	3,207	2,716 (5)	160	331
North Beaverhead	17,658	17,499 (14)	33	126
South Beaverhead	17,760	17,695 (17)	36	29
North Lemhi	65,925	65,718 (22)	46	161
South Lemhi	38,131	37,826 (14)	154	151
Lost River Range	125,449	124,148 (72)	961	340
East Fork Salmon	118,178	117,802 (54)	132	244
Middle Main Salmon	18,580	17,829 (35)	507	244
Lionhead	2	0	0	2
Owyhee Front	14,467	14,414 (10)	30	23
Owyhee River	68,481	68,079 (45)	362	40
Jacks Creek	1,560	1,250 (2)	266	44
Bruneau-Jarbidge	436	0	397	39
Jim Sage	65	0	58	7
Palisades	5	0	0	4
Pioneers	51	13 (1)	0	38
Outside any PMU	648	96 (32)	404	148
Out of State	7,072	6,358 (17)	100	614
Totals	610,268	587,347	13,843	9,078

Table 3. Predicted bighorn sheep supportable by modeled potential habitat within each Population Management Unit (PMU) based on a density of 1.9 sheep/km² (Van Dyke et al. 1983). Sheep allotments currently considered non-use or partial-use are excluded.

Population Management Unit (PMU)	Total km² of modeled habitat within PMU (A)	Bighorn sheep population supportable by A	Modeled habitat (km²) on private land within A	Modeled habitat (km²) in domestic sheep grazing or trailing allotments within A	Bighorn sheep population supportable by A without private land and allotments
North Hells Canyon	902	1,713	463	0	834
South Hells Canyon	1,319	2,506	610	0	1,347
Lower Salmon	1,130	2,148	69	57	1,907
Selway	347	659	0	0	659
Middle Fork Salmon	2,987	5,675	6	0	5,664
Lower Panther-Main Salmon	1,585	3,012	40	0	2,936
North Beaverhead	390	742	6	0	731
South Beaverhead	635	1,206	8	0	1,191
North Lemhi	676	1,284	23	0	1,241
South Lemhi	605	1,150	2	0	1,146
Lost River Range	1,593	3,026	10	0	3,008
East Fork Salmon	971	1,845	26	0	1,795
Middle Main Salmon	1,370	2,604	62	0	2,487
Lionhead	29	54	0	0	54
Owyhee Front	886	1,683	65	8	1,544
Owyhee River	755	1,434	7	0	1,420
Jacks Creek	345	656	10	0	636
Bruneau-Jarbidge	650	1,234	20	0	1,197
Jim Sage	72	136	3	0	130
Totals	17,246	32,767	1,429	65	29,928

Potential Threats to Bighorn Sheep Habitat

Conifer Encroachment

Bighorn sheep, particularly ewes with lambs, use open habitats with good visibility near rugged escape terrain to detect and evade predators. Encroachment and maturation of forest and tall shrub stands can degrade and fragment habitat (Wakelyn 1987, Brewer et al. 2014) and interfere with migration routes. Stand manipulation via logging, prescribed fire, or wildfire can produce increased bighorn sheep use of treated areas and at least short-term gains in nutrition and population performance (Peek et al. 1979, Smith et al. 1999, Holl et al. 2004, Dibb and Quinn 2008), and may be used to improve migration routes (Dibb et al. 2008).

Invasive Plants

Invasive plants can significantly degrade bighorn habitat by reducing the variety and density of more palatable and nutritious native forage species. In addition, a less diverse plant community may have a more abbreviated period of highly nutritious green forage. Idaho currently has 69 weed species and 4 genera designated as noxious (https://agri.idaho.gov/main/plants/noxious-weeds/). Several of these, such as yellow starthistle, leafy spurge, rush skeletonweed, knapweed, and cheatgrass pose significant threats to bighorn sheep habitat. Land managers should be encouraged to adopt habitat management practices aimed at maintaining healthy native plant communities resistant to weed invasion. IDFG staff should also work closely with land management agencies to ensure that habitat restoration and rehabilitation efforts focus on native species when successful establishment is likely. Where invasive plants have become established, appropriate control measures should be implemented, which may include the use of desirable non-natives to reduce the potential for additional invasions. However, the use of domestic sheep and goats for weed control in bighorn habitat should not be used because of the risk of disease transmission to bighorn sheep (Giacometti et al. 2002, Jansen et al. 2006*a*).

Wildfire

Wildfire has the potential to both benefit and inhibit bighorn sheep habitat depending on fire size, frequency, and severity, as well as location and timing. For example, some fire frequency and severity regimes result in earlier successional stages with more open overstories, reducing conifer encroachment and creating more nutritious forage. Such fires increase visibility and forage accessibility for bighorn sheep and may be particularly beneficial in improving habitat (Clapp and Beck 2016, Donovan et al. 2021). Conversely, repeated large-scale fires may have cumulative detrimental effects, resulting in increased invasive plants (e.g., cheatgrass, knapweed, rush skeletonweed, leafy spurge) and reduced productivity.

The response of bighorn sheep to wildfire appears to be complex, varying by season, sex, and location (e.g., Clapp and Beck 2016, Donovan et al. 2021). Given current trends in fire size, frequency, and severity (Abatzoglou and Williams 2016), as well as projected warmer and drier summers for many PMUs (see Climate section), wildfire may become a greater issue in some areas. Habitat response to fire may be slow, or negative, particularly in semi-arid landscapes with associated droughts, hampering restoration efforts. In addition, the extensive size of wildfires is now often greater than agency capacity to feasibly restore habitats.

Competition

Bighorn sheep frequently share habitat with other wild ungulates and domestic livestock. Other species may limit bighorn sheep populations by competing for resources (often food) and thereby reducing the supply of resources available to bighorns, or by directly interfering with bighorn access to resources. One critical element of competition is that the resource in demand be of limited quantity or quality. For example, 2 individuals or species living in the same area during the same time may consume a similar diet. However, if forage is abundantly available to both, competition may not exist because the resource is not limited. A second critical component of competition is harm to one or both species, such as a negative impact on reproduction, survival, or population growth rate. If no harm occurs to an individual or species, competition is not present. Many studies have documented considerable overlap in resource use between coexisting species, including bighorn sheep; few field studies of wildlife competition have shown actual harm to bighorn sheep. Marshal et al. (2008) demonstrated a negative relationship between wild feral burro abundance and desert bighorn sheep population growth rates, particularly during the driest years. The scarcity of complete evidence for competition does not imply that other species do not compete with bighorns, only that competition is exceedingly difficult to demonstrate in the field.

Interference between bighorn sheep and other species has occasionally been documented. Mountain goats may dominate and displace bighorn sheep (Hobbs et al. 1990, Festa-Bianchet and Côté 2008), while other native ungulates (elk, mule deer, and pronghorn) show no clear dominance pattern over bighorn sheep (Berger 1985). Feral horses and burros are often dominant over bighorn sheep, particularly at water sources (Dunn and Douglas 1982, Berger 1985, Ostermann-Kelm et al. 2008, Stoner et al. 2021), but not always (Seegmiller and Ohmart 1981, Kaweck et al 2018). Wilson (1969) reported bighorn sheep avoidance of cattle in Utah, as did Bissonette and Steinkamp (1996) and Taylor (2001) in Idaho. However, King and Workman (1984) detected no social intolerance between bighorn sheep and cattle, and one study reported a positive association between bighorn sheep and cattle in Alberta (Brown et al. 2010).

In the northerly parts of their range, bighorn sheep are generally considered to subsist primarily on grasses (Geist 1971), whereas the diet of desert bighorn sheep is dominated by browse (Ginnett 1982, King and Workman 1984, Dodd 1986). However, the forage preferences of bighorn sheep are quite elastic, varying considerably depending upon relative species composition available, palatability, and nutrient content of forage available at a particular time. Within a specific area, bighorn sheep may shift seasonally from diets dominated by grasses to ones dominated by browse or forbs (Todd 1975, Wagner and Peek 2006). Given their dietary elasticity, considerable overlap is possible between bighorn sheep diets and those of most other native and introduced grazers, including mule deer, elk, mountain goats, pronghorn, bison, burros, horses, cattle, domestic sheep, and domestic goats (Lawson and Johnson 1982, Shackleton 1985). The effects of dietary overlap and competition may be intensified on shared ranges during winter and when availability of high-quality forage is restricted by forage desiccation. Based on dietary overlap, many authors have inferred forage competition between bighorn sheep and other species, sometimes buttressing the inference with evidence of intense forage utilization or poor range condition (Buechner 1960, Constan 1972, Wilson 1975, Gallizioli 1977).

Bighorn sheep seek out landscapes that offer abundant forage near steep rugged slopes. Generally, this spatially separates bighorn sheep from many other ungulates (Constan 1972, Hudson et al. 1976, Ganskopp and Vavra 1987). Fire in or near bighorn sheep habitat may create nutritious forage that attracts other grazers and intensifies competition (Spowart and Hobbs 1985, Easterly and Jenkins 1991). While dietary overlap and significant competitive potential exists between numerous species and bighorn sheep, few species typically inhabit the same terrain as bighorn sheep and competition typically only occurs on edges of bighorn sheep habitat or during uncharacteristic seasons, such as severe winters when competitive effects may be strongest. In some areas, intensive elk browsing on shrubs such as mountain mahogany can permanently remove virtually all foliage within reach of bighorn sheep. Finally, mountain goats can readily use bighorn sheep habitat and thus may exhibit extensive dietary overlap. However, mountain goats and bighorn sheep are both native to Idaho and coevolved in areas north of the Snake River Plain. Distributions of mountain goats and bighorn sheep in Idaho overlap in the White Cloud, Lemhi, and Beaverhead Mountains; along the Salmon River and several of its tributaries; and in Hells Canyon. In these areas, mountain goat populations are often at low densities and seem to exhibit somewhat different habitat preferences than bighorn sheep. Competitive interactions have not been noted.

Domestic Sheep and Goats

Domestic sheep and goats are grazed throughout portions of bighorn sheep distribution in Idaho. Direct competition with these domestic sheep and goats may result in many of the issues described above. However, the more urgent concern with overlapping populations of bighorn sheep and domestic sheep or goats is the possibility of disease transmission. A more detailed discussion of disease issues can be found in the Health Assessment and Management section. In recent years, IDFG and the Idaho State Department of Agriculture

(ISDA) (IDFG and ISDA 2008) and the Western Association of Fish and Wildlife Agencies (WAFWA) (Wild Sheep Working Group 2012, Brewer et al. 2014) have recommended preventing contact between bighorn sheep and domestic sheep and goats. For this reason, calculations in Table 3 exclude domestic sheep grazing and trailing allotments and private lands from potential bighorn sheep habitat to manage bighorn sheep populations at levels that minimize contact between bighorn sheep and domestic sheep and goats. It is acknowledged that ongoing and future management direction and policy for domestic sheep and goat grazing on public lands (USFS and BLM) may be curtailed to reduce or eliminate risks of disease transmission.

Human Recreation

In recent decades, human population growth, improved access to remote areas, and increases in human recreational activity (e.g., hiking, mountain biking, off-road vehicle use, skiing, snowmobiling, low-altitude aerial activity, rock climbing, trail riding) in and near bighorn sheep habitats have led to more frequent interactions between humans and bighorn sheep. Bighorn sheep can be resilient to human disturbance and recreation under certain circumstances (Jansen et al. 2006*b*, Lowrey and Longshore 2017). When bighorn sheep are exposed to people at predictable locations and times, they may tolerate some level of disturbance (Hicks and Elder 1979, Goodson et al. 1999, Papouchis et al. 2001, Wiedmann and Bleich 2014). Power boaters and river rafters on the Snake and Salmon Rivers frequently see bighorn sheep along the shoreline. Bighorn sheep are commonly seen along the Salmon River Road below Shoup and along Highways 75 and 93 near Challis and Salmon. In these situations, bighorn sheep may tolerate onlookers. However, when bighorn sheep are approached closely, at random times or in irregular locations, even those that are habituated to humans may flee and vacate the area (Papouchis et al. 2001, Wiedmann and Bleich 2014).

Bighorn sheep may respond to human disturbance (including recreational activities) by temporary or permanent abandonment of the area (Wilson et al. 1980, DeForge 1981, Legg 1998, Papouchis et al. 2001, Keller and Bender 2007, Longshore et al. 2013, Lowrey and Longshore 2017). These movements may displace bighorns to less optimal habitats, thereby decreasing foraging efficiency (Horejsi 1976, Hicks and Elder 1979, Legg 1998, Bailey 1999, Courtemanch 2014, Sproat et al. 2020), increasing energy expenditures (MacArthur et al. 1982, Legg 1998), and increasing their risk of predation (DeForge 1981, Papouchis et al. 2001). Human disturbance may also increase stress levels in bighorn sheep (Legg 1998) and lower resistance to disease (Spraker 1977, Foreyt and Jessup 1982, Spraker et al. 1984, Schwantje 1986). Disturbance can also interfere with breeding activities (Legg 1998, Papouchis et al. 2001, Wiedmann and Bleich 2014). The net effect of human disturbance could include decreased survival and reproduction of bighorn sheep (Campbell and Remington 1981, Miller and Smith 1985, Caslick 1993, Papouchis et al. 2001, Keller and Bender 2007). Because fitness of individual bighorn sheep often decreases with increased disturbance levels, it is important to limit potential negative effects of recreation and human disturbance during critical times of the year (e.g., lambing season and on winter range; Boyle and Samson 1985, Papouchis et al. 2001, Courtemanch 2014). Disturbance from human developments and recreational activities along migration routes or near winter range may decrease the already limited habitat available for bighorn sheep (Legg 1998).

Aircraft overflights from helicopter, fixed-wing, or Unmanned Aircraft Vehicle (UAV, “drone”) are a particular form of disturbance with potential to negatively affect bighorn sheep. Unlike many other forms of human activity, bighorn sheep have not been found to habituate to helicopter overflights (Horejsi 1976, MacArthur et al. 1982, Bunch and Workman 1993, Legg 1998). In some places in Idaho, there are frequent US Air Force training exercises in bighorn sheep habitat with flights as low as 100 ft above ground level. Research into the effects of frequent flight activities is limited (Stockwell et al. 1991, Bunch and Workman 1993) and potential effects warrant further investigation. The use of UAVs has increased substantially in recent years by both recreational and vocational users with little knowledge on potential wildlife disturbance (see Mulero-Pázmány et al. 2017, Duporge et al. 2021 for review). Given the growing popularity for employing UAVs in natural resource management (e.g., wildlife monitoring, wildland firefighting, timber surveys, etc.), recent research has focused on identifying potential adverse effects and devising flight practices (e.g., altitude, pattern, timing) that minimize disturbance (e.g., Hodgson and Koh 2016, Duporge et al. 2021). The potential effects of UAVs on bighorn sheep in Idaho is unknown.

Off-road vehicle use, including both non-motorized (e.g., mountain biking) and motorized (e.g.,motorcycles, ATVs, UTVs), has increased in popularity in recent decades (IDPR 2018). This has led to a steady increase in backcountry recreation on both regulated and illegal trails, including in bighorn sheep habitat, and has allowed hunters, photographers, and other recreationists greater access to bighorn sheep habitat that was previously inaccessible or very difficult to access. Increased recreational vehicle presence and volume of human exposure leads to concerns of invasive plant species spreading and disturbance to wildlife, including bighorn sheep. With the upward trajectory in vehicle use, trails previously closed to motorized use have been opened and new trails have been developed. In addition, illegal off-trail motorized use has also increased and has provided access into remote habitats previously considered a safe haven for bighorn sheep and other wildlife species.

Eliminating some of the disturbance associated with human activity may require seasonal or permanent closures of critical bighorn sheep habitats (Goodson et al. 1999). Disturbance may also be minimized by limiting human activities to roads or trails (Papouchis et al. 2001) and requiring that domestic dogs be leashed. The integrity of migration routes should be protected. Special protection during critical periods, such as breeding, lambing, or winter, may be required in some areas to ensure long-term viability of bighorn sheep populations.

Migration Habitat and Routes

Although not all bighorn sheep populations in Idaho exhibit seasonal migrations, many do to make optimal use of plant resources and minimize energy expenditures (Jesmer et al. 2018, Lowrey et al. 2019). Urban development, roads, habitat conversion, and conifer encroachment in bighorn sheep habitat may all have the unintended consequence of interrupting seasonal migration patterns. Disturbance from human developments and recreational activities along migration routes or near winter range may decrease the already limited habitat available for bighorn sheep (Legg 1998, Polfus and Krausman 2012). Where possible, migration habitat and routes should be identified, and efforts should be made to conserve or improve habitats and minimize amounts and types of disturbance within these areas.

Nutrition and Mineral Requirements

Research into bighorn sheep nutrition has generally addressed either forage or mineral requirements. Bighorn sheep are generally grazers with forbs and grasses comprising most of their diets (Van Dyke et al. 1983). Both Rocky Mountain and California bighorn sheep diets have been described as "cosmopolitan" where most available plants are consumed at some time of the year (Shackleton et al. 1999). It is unknown whether selection for individual plant species is driven by nutritive quality or some other factor, and some analyses suggest bighorn sheep graze opportunistically, rather than seeking specific plant species or forage nutrients (Shackleton et al. 1999). However, bighorn sheep may be limited by seasonal forage availability (Goodson et al. 1991*a,b*).

Results of recent research in Idaho (Bilodeau 2021) suggest that summer lamb survival in the Lost River, East Fork Salmon, and Owyhee River bighorn sheep populations was positively related to dam body condition in spring. The link between vital rates and habitat in bighorn sheep is a focus of ongoing investigation.

In addition to forage, bighorn sheep may consume soil or use mineral licks to meet trace mineral requirements. Mineral composition in forage may vary with changing climate conditions (Goodson et al. 1991*a,b*; Hnilicka et al. 2002; McKinney et al. 2006*b*). This variation increases the importance of mineral licks or nutrient-rich soil (Mincher et al. 2008). Specifically, researchers speculated that deficiencies in minerals such as selenium, sodium, potassium, calcium, and magnesium may affect bighorn sheep fitness (Dean et al. 2002, Hnilicka et al. 2002, Mincher et al. 2008). Placement of mineral blocks has alleviated nutrient limitations in some studies (Hnilicka et al. 2002) but may have the same negative impacts as artificial water sources (artificial congregations of animals may promote disease transmission and predation), so such activities should be considered with caution and only if mineral deficiencies have been identified as a primary limiting factor for a bighorn sheep population.

Urban Development

In some areas, urban development near bighorn sheep habitat has been associated with population declines or extirpations (Krausman et al. 2008, Polfus and Krausman 2012). Among the issues associated with urban development near bighorn sheep populations are habitat fragmentation, habitat loss, increased human activity, vehicle collisions, pets, and increased likelihood of parasite and disease transmission from domestic livestock (e.g., hobby farms) (Armentrout and Boyd 1994, Rubin et al. 2002, Krausman et al. 2008). Bleich et al. (2010) theorized that bighorn sheep were more likely to occupy areas with increased distances to roads. This highlights a potential limitation for habitats with increasing abundance of roads and trails for motorized and non-motorized recreation (Lowrey and Longshore 2017). Furthermore, bighorn sheep may habituate to low levels of predictable activity (Polfus and Krausman 2012) and some aspects of developments may even attract bighorn sheep as they seek forage and water resources, thereby bringing animals into closer contact with humans and livestock and creating larger potential for conflict (Rubin et al. 2002, Longshore et al. 2016). Krausman et al. (2008) recommended limiting development near bighorn sheep populations to minimize potential negative effects.

Water Development

Desert bighorn sheep are known to use man-made water developments, particularly during summer months (Broyles 1995, Waddell et al. 2007, Harris et al. 2020) and presence of permanent water has been shown to influence the distribution of desert bighorns (Turner et al. 2004, Bleich et al. 2010, Gedir et al. 2020). Some authors contend that water developments may be important in maintaining small, isolated populations susceptible to threats such as disease, climate change, and habitat fragmentation (Dolan 2006, Whiting et al. 2012). However, there is scant evidence that water developments produce population benefits (Broyles 1995, Krausman and Etcheberger 1995). An experimental removal of water sources in Arizona failed to document negative impacts on desert bighorn sheep, although above average rainfall post-removal complicated conclusions (Cain et al. 2008). Potential adverse aspects of water development include disease transmission, toxic water quality, increased predation risk, and introduction and expansion of nonnative, invasive species (Dolan 2006).

Desert bighorn sheep in the most arid parts of the southwestern US rarely travel more than 2–3 km from permanent surface water during summer months (Turner et al. 2004). Idaho's bighorn sheep occur in comparatively cooler, moister environments with many natural sources of water. Additional water developments in these circumstances will likely produce negligible benefits for bighorn sheep. Water has not been identified as a limiting resource in Idaho, nor is there supportive literature to suggest that water developments benefit Rocky Mountain or California bighorn sheep. However, ongoing and future changes in climate may affect access to water in summer months for some populations in the state.

Because disease risk is a critical management concern for bighorn sheep, proposals that may increase disease risk must carry substantial potential benefits. Man-made water and mineral sources have not been demonstrated to benefit Rocky Mountain or California bighorn sheep, but they may increase predation and disease risks. For these reasons, such developments should be discouraged (Giacometti et al. 2002).

Mining and Energy Development

Few peer-reviewed studies have focused on the effects of mining or energy development on bighorn sheep. However, mining and energy development have the potential to alter habitats and/or influence behavior and cause displacement of bighorn sheep through disruption caused by disturbance. Studies of mining activities in relation to bighorn sheep have been investigated for multiple bighorn sheep populations (Oehler et al. 2005; Jansen et al. 2006*b*, 2009; Bleich et al. 2009; Poole et al. 2013, 2016). Results from these studies varied, with some identifying increased habitat use in mined areas due to early successional vegetation that offered high quality foraging opportunities. However, increases in habitat use were typically seen following a period where bighorn sheep were habituating to mining activities and after vegetation recovery had begun (Oehler et al. 2005, Jansen et al. 2006*b*, Bleich et al. 2009). With bighorn sheep habitat being limited in some areas of Idaho, mineral extraction operations in, or near, bighorn sheep habitat should be minimized where possible, particularly in lambing and wintering habitats.

Similarly, both direct (e.g., disturbance) and indirect effects (e.g., habitat loss and/or fragmentation) of energy development are thought to affect populations in the southwestern US (Lovich and Ennen 2011, Grodsky et al. 2017). Environmental Impact Statements and Biological Opinions for energy development projects in California and Nevada indicate potentially significant disturbances to resident bighorn sheep populations (Aspen Environmental Group 2008, USFWS 2009, BLM 2012) and suggest mitigation measures including alternative siting (to avoid most bighorn sheep habitat), minimizing disturbance during key times (migration, lambing), or temporarily halting activities when bighorn sheep were observed in the vicinity of construction or maintenance activities.

Habitat Management and Restoration

In general, habitat management for bighorn sheep should be directed toward minimizing deleterious human disturbances and maintaining healthy native plant communities in proximity to suitable escape terrain. Where plant community maturation patterns tend toward closed shrub or conifer overstories, logging or fire may be used to produce earlier successional stages with more open overstories favored by bighorn sheep. Emphasis should be on maintaining or improving transitional migration habitat and routes between seasonal ranges. Carefully considered prescribed fire may also be used short-term to improve forage nutrition, to attract bighorns into new areas, or to lure them away from hazardous locations such as highways.

Habitat Management Directions

Management Direction — Engage with land management agencies and other land users and groups to improve the quality and quantity of bighorn sheep habitat throughout Idaho.

> Strategy: Coordinate with land management agencies (USFS, BLM, Idaho Department of Lands, tribes) to promote practices that benefit bighorn sheep habitats, such as invasive plant control, fire and other habitat management practices in areas of significant conifer encroachment, and maintaining important seasonal habitats, especially those that contribute to climate resiliency.
>
> Strategy: Discourage establishment of artificial water sources in bighorn sheep habitat unless bighorns are primarily utilizing habitat $\geq$3 km from a perennial water source. In areas where bighorn sheep spend a significant amount of their time in areas $\geq$3 km from a perennial water source, IDFG staff will evaluate the status of the bighorn sheep population relative to management objectives and assess potential factors limiting the success of that bighorn sheep population prior to considering establishment of artificial water sources.
>
> Strategy: Be involved in restoration and rehabilitation efforts within bighorn sheep habitat to ensure that these efforts focus on restoring native plant communities in proximity to escape terrain and natural water sources.

Management Direction — Work with other land and resource management agencies to ensure that bighorn sheep populations and critical areas of habitat are protected from disturbance (e.g., recreation, urban development, and mining and energy development), or that disturbance is managed to limit or prevent negative impacts during critical periods.

> Strategy: Support investigations into the effects of different types and levels of human activities on bighorn sheep.

> Strategy: In areas where recreation is considered a factor limiting the success of a bighorn sheep population, work with land managers and the public to manage and mitigate the effects associated with recreational activities such as hiking, mountain biking, off-road vehicle use, skiing, snowmobiling, low-altitude aerial activity, rock climbing, or trail riding.

Management Direction — In areas where elk are suspected to compete with bighorn sheep for limited resources, closely monitor both elk and bighorn sheep numbers and adapt management practices to move numbers of both species towards IDFG population objectives.

Management Direction — Continue to refine efforts to document and model occupied, unoccupied, potential, and suitable bighorn sheep seasonal habitats.

> Strategy: Document occurrence and movements, if possible, of bighorn sheep pioneering new areas (such as GMUs 1 and 4) and increase monitoring of areas where new populations appear to be establishing.

> Strategy: Encourage biologists, hunters, and recreationists to record incidental observations of bighorn sheep presence in the Idaho Fish and Wildlife Information System (IFWIS).

> Strategy: Improve collection of bighorn sheep location data focusing more in PMUs that lack information (e.g., Owyhee Front, Jacks Creek, Bruneau-Jarbidge, Jim Sage, Lower Salmon, Middle Fork Salmon, Middle Main Salmon, Lower Panther-Main Salmon) to better assess performance of habitat models applied in those areas.

Strategy: Assess whether additional bighorn sheep location data indicate that seasonal habitat models would improve IDFG's ability to manage bighorn sheep in some or all PMUs.

Strategy: Evaluate bighorn sheep densities in well-understood populations to develop a better local understanding of potential bighorn sheep densities. Where possible, incorporate measures of habitat quality to further understand variation in bighorn sheep densities across the state.

HEALTH ASSESSMENT AND MANAGEMENT

Population health is an essential component of bighorn sheep restoration and management. Historically disease was an important factor contributing to declines and extirpation of bighorn sheep in much of their range and disease continues to limit bighorn sheep numbers today. Not only does disease affect populations directly, risk of disease transmission also affects where and how IDFG manages for bighorn sheep in Idaho.

Bronchopneumonia

Many pathogenic organisms found in bighorn sheep are similar to those in livestock, particularly domestic sheep and goats, and some do not have serious effects on wild sheep populations. However, bighorn sheep differ in important ways from domestic sheep and goats in their responses to bacteria associated with respiratory disease. The disease that has the most widespread and severe impacts on bighorn sheep population abundance is a microbiologically complex pneumonia triggered by the bacterium *Mycoplasma ovipneumoniae*, commonly referred to as "Movi". This pathogen appears to be a necessary agent for initiating most pneumonia outbreaks in free-ranging wild sheep (Besser et al. 2013). The effects of exposure to Movi in bighorn sheep populations are variable and take several forms. Initial exposures are usually accompanied by acute all-age mortality events where, on average, about half the population dies, although mortality rates vary widely between outbreaks (Cassirer et al. 2018). Some survivors of the initial outbreak may become chronically infected and contagious. They can maintain Movi infections for long periods of time within populations of this highly social species. Newborn lambs are unprotected from infection and exposure of young lambs to Movi by chronically infected carrier adults leads to spread through nursery groups, usually causing high rates of mortality restricted to juveniles, especially during summer. In some cases, sporadic low levels of adult mortality are also observed (Besser et al. 2013, Cassirer et al. 2018).

Some populations recover relatively rapidly after initial exposure to Movi (Coggins and Matthews 1992), while others experience decades of low recruitment because of recurring disease epizootics in lambs (Ryder et al. 1992, 1994; Hnilicka et al. 2002; Cassirer and Sinclair 2007). Natural recovery may be associated with cessation of Movi transmission because of death of a carrier (Besser et al. 2021, Spaan et al. 2021) and spatial and social structuring within populations may also limit spread of infection. Overall, the dynamics of initial high rates of mortality in all-ages followed by protracted periods of low recruitment can chronically limit numbers and distribution of bighorn sheep in areas where respiratory disease occurs. Consequently, pneumonia, especially recurring events, impedes management of populations directly by limiting abundance and indirectly by predisposing small, fragmented, surviving populations of bighorn sheep to events unrelated to disease, such as spikes in predation, severe weather events, random loss of genetic diversity, or inbreeding (Berger 1990, Gross et al. 2000, de Castro and Bolker 2005).

Captive inoculation and commingling experiments provide support for Movi as a primary cause of respiratory disease outbreaks in bighorn sheep. Experimental infection of a single captive bighorn sheep with Movi started a pneumonia epizootic in the pen it was in and in an adjacent pen (Besser et al. 2014). Crossover experiments in captivity have shown that pneumonia epizootics in lambs occur in pens with Movi-carrier bighorn ewes, but not in pens without Movi-carrier ewes (Felts 2020, WSU unpubl. data). Finally, clearing Movi from free-ranging bighorn sheep populations by removing carriers has also been associated with improved lamb health and survival (Bernatowicz et al. 2016, Garwood et al. 2020).

Movi is a genetically heterogeneous bacterium with numerous strain types that fall into distinct lineages associated with domestic sheep or goat hosts (Maksimović et al. 2017, Kamath et al. 2019). Movi infections impair ciliary function in respiratory airways, which increases susceptibility to lung infections by secondary pathogens such as Pasteurellaceae, *Fusobacterium* spp. and a multitude of other bacteria (Besser et al. 2008, Dassanayake et al. 2010). These secondary agents can be part of the normal flora, or they may invade along with Movi and the composition of this secondary pathogen community may influence disease severity. For example, experimental exposure to leukotoxinproducing *M. haemolytica,* (a member of Pasteurellaceae commonly present in domestic sheep), at doses that produce no health effects in domestic sheep causes disease and death in bighorn sheep (Foreyt et al. 1994, Dassanayake et al. 2009). On a cellular level, pulmonary macrophages and neutrophils in the blood of bighorn sheep are much more susceptible to destruction by leukotoxin from *M. haemolytica* than those of domestic sheep (Silflow and Foreyt 1994; Silflow et al. 1989, 1991, 1993; Sacco et al. 2006; Herndon et al. 2010). Disease outcomes could also be influenced by tumors that thicken the lining of the paranasal sinuses. These sinus tumors may foster upper respiratory tract infection in some bighorn sheep populations (Fox et al. 2011) and inhibit natural clearance of Movi, which could promote chronic carriage and persistence of Movi and other pathogens (Fox et al. 2015). The roles of Movi strain type and co-infections by known and perhaps as yet unrecognized pathogens on severity and persistence of respiratory disease in wild sheep are not well understood.

Spillover of *Mycoplasma ovipneumoniae* from Domestic Sheep and Goats

In the early 20th century, several naturalists and veterinarians noted catastrophic die-offs following the introduction of domestic sheep into bighorn sheep ranges (Grinnell 1928, Davis and Taylor 1939). Most contemporary reviews have also found proximity to areas grazed by domestic sheep to be associated with an increased risk of pneumonia outbreaks in free-ranging bighorn sheep (Singer et al. 2000*a*, Monello et al. 2001, Sells et al. 2015). In 13 experiments, co-pasturing captive bighorn and domestic sheep has resulted in fatal pneumonia in nearly all bighorn sheep, with no effect on domestic sheep (Shillenger 1937, Wehausen et al. 2011, Besser et al. 2012*a*). On the other hand, 5 of 6 bighorn sheep survived in two captive commingling experiments with domestic sheep in the absence of Movi, showing that the presence (or absence) of this pathogen can determine outcome of contact with domestic sheep (Besser et al. 2012*a*, Kugadas 2014).

Many Mycoplasma species are host-specific and the host range for Movi is generally considered to be Caprinae, including domestic sheep and goats although it has occasionally been detected in other species (Rovani et al. 2019). While accounts of disease transmission to bighorn sheep from domestic goats are less frequent than from domestic sheep, respiratory pathogens that can cause disease in bighorn sheep, including Movi, are regularly detected in apparently healthy domestic goats (Heinse et al. 2016, Drew and Weiser 2017). Transmission of Movi and other bacteria between bighorn sheep and domestic goats has occurred in free-ranging conditions although spillover of Movi is detected less frequently than from domestic sheep (Rudolph et al. 2003, Kamath et al. 2019). No disease or mortality was reported in early experimental commingling of domestic goats with bighorn sheep (Foreyt 1994) though the Movi status of those goats is unknown. More recent commingling experiments produced pneumonia and/or transmission of Movi to bighorn sheep, however epidemic mortality was not observed (Foreyt et al. 2009, Besser et al. 2018).

Limited commingling experiments of bighorn sheep with cattle, horses, mule deer, elk, mountain goats, and llamas of unknown Movi status have not resulted in pneumonia outbreaks in of bighorn sheep (Besser et al. 2012*a*, Foreyt 1992, 1994; Foreyt and Lagerquist 1996). With the exception of mountain goats, which like bighorn sheep, can become infected via spillover (Wolff et al. 2019), Movi is rarely, if ever, detected in these hosts.

Mycoplasma ovipneumoniae in Idaho Bighorn Sheep

Movi is difficult to detect in culture of field samples which is one reason it was not identified as a cause of respiratory disease in wild sheep until a metagenomic study of pneumonia in lambs was conducted in 2006 (Besser et al. 2008). Since then, diagnosticians have consistently detected Movi in all-age pneumonia outbreaks and in persistent infections of populations where pneumonia is mainly restricted to lambs (Besser et al. 2012*b*, Cassirer et al. 2018).

Domestic sheep flocks usually harbor multiple strains of Movi simultaneously (Thirkell et al. 1990; Ionas et al. 1991*a,b*; Parham et al. 2006). In contrast, following spillover, a single strain is typically detected in epizootics in wild sheep and one or occasionally two strains tend to predominate in chronically infected bighorn sheep populations. Bighorn sheep immunity (limited to adults) seems to be restricted to those strains to which they have been exposed (Cassirer et al. 2018).

In Hells Canyon, five genetically distinct strains of Movi were detected in Oregon, Washington, and Idaho from different time periods between 1986 and 2014 by polymerase chain reaction (PCR) analysis of fresh samples and archived lung tissue blocks from cases at the Washington Animal Disease and Diagnostic Laboratory (WADDL). Each strain represented a spillover likely from domestic sheep (n = 4) or goats (n =1) based on Movi genotyping, and the first detection of each strain was associated with an all-age pneumonia outbreak in bighorn sheep. A strain first detected in a 1995 epizootic that started in Washington spread widely and subsequently became the predominant strain throughout the Hells Canyon metapopulation in Idaho, Washington, and Oregon for 20 years (Cassirer et al. 2017).

In 2013, the partners in the Hells Canyon Bighorn Sheep Initiative started an experiment in the Asotin Creek, Washington population to test for and remove chronic Movi carrier ewes, which comprise a small proportion of the population but were thought to have an outsized effect on maintaining infection (Plowright et al. 2017). Two ewes were removed in 2015 and no Movi has been detected in annual testing of the Asotin Creek population since then. No antibodies to Movi, which would indicate exposure, have been detected in sheep born after the removals. Following the success of the initial experiment, testing and removals were continued throughout the metapopulation in Idaho, Oregon, and Washington. As of 2020, Movi was no longer circulating in any Idaho or Washington bighorn sheep population in Hells Canyon (Figure 5).

The earliest known samples available for Movi testing in central Idaho bighorn sheep were from five mortalities submitted to WADDL in 1984. The sheep were diagnosed with bronchopneumonia at the time and, similar to work done in Hells Canyon, Movi was later detected by retrospective PCR analysis of archived tissue blocks fixed in formalin. The genetic type (402) identified in that case matches a strain that is still resident in central and eastern Idaho bighorn sheep populations, over 3 decades later. This strain has also been detected in mountain goats in the East Fork Salmon and Middle Main Salmon PMUs. A second strain detected in archived tissue from a 1988 case of bighorn sheep with pneumonia that died near Salmon does not seem to have persisted, but a different strain (404) has been detected in samples collected from 6 central Idaho populations, 2016 – 2018 (Figure 5).

Bruneau-Jarbidge and Owyhee River are the only California bighorn sheep populations in Idaho where Movi has been detected (Figure 5). Strain type 397 was identified in samples collected from hunter harvested rams in 2016 and 2017 from the Bruneau-Jarbidge. A significant decline in the population was noted in the late 1990s followed by a period of poor recruitment, but the source or type of this decline is unknown. Very limited sampling of hunter harvest has been conducted since 2017 and no Movi has been detected. Movi infection and exposure has been detected in Owyhee populations in Oregon (Spaan et al. 2021), and Movi strain type 398 was detected in one Owyhee River PMU sheep in 2017 and one other sheep tested positive for antibodies in the Owyhee River PMU in 2016, indicating a potential exposure. No evidence of infection or exposure was detected in any other bighorn sheep (n = 61) sampled in 2016 and 2017 or later.

Important questions remain including how Movi persists in populations, when management is logistically feasible, and the optimal methods for selective removal of chronic Movi carriers (i.e., test-and-remove). Test-and-remove efforts show promise for restoration of chronically infected populations in Idaho and elsewhere (Garwood et al. 2020, Almberg et al. 2021). Additional efforts are underway to determine whether this approach is feasible in Idaho bighorn sheep populations outside of Hells Canyon. Another aim of this ongoing work is to develop the least invasive, most efficient approach to clearing pneumonia from free-ranging bighorn sheep populations by gaining information on cofactors associated with Movi persistence and fadeout.

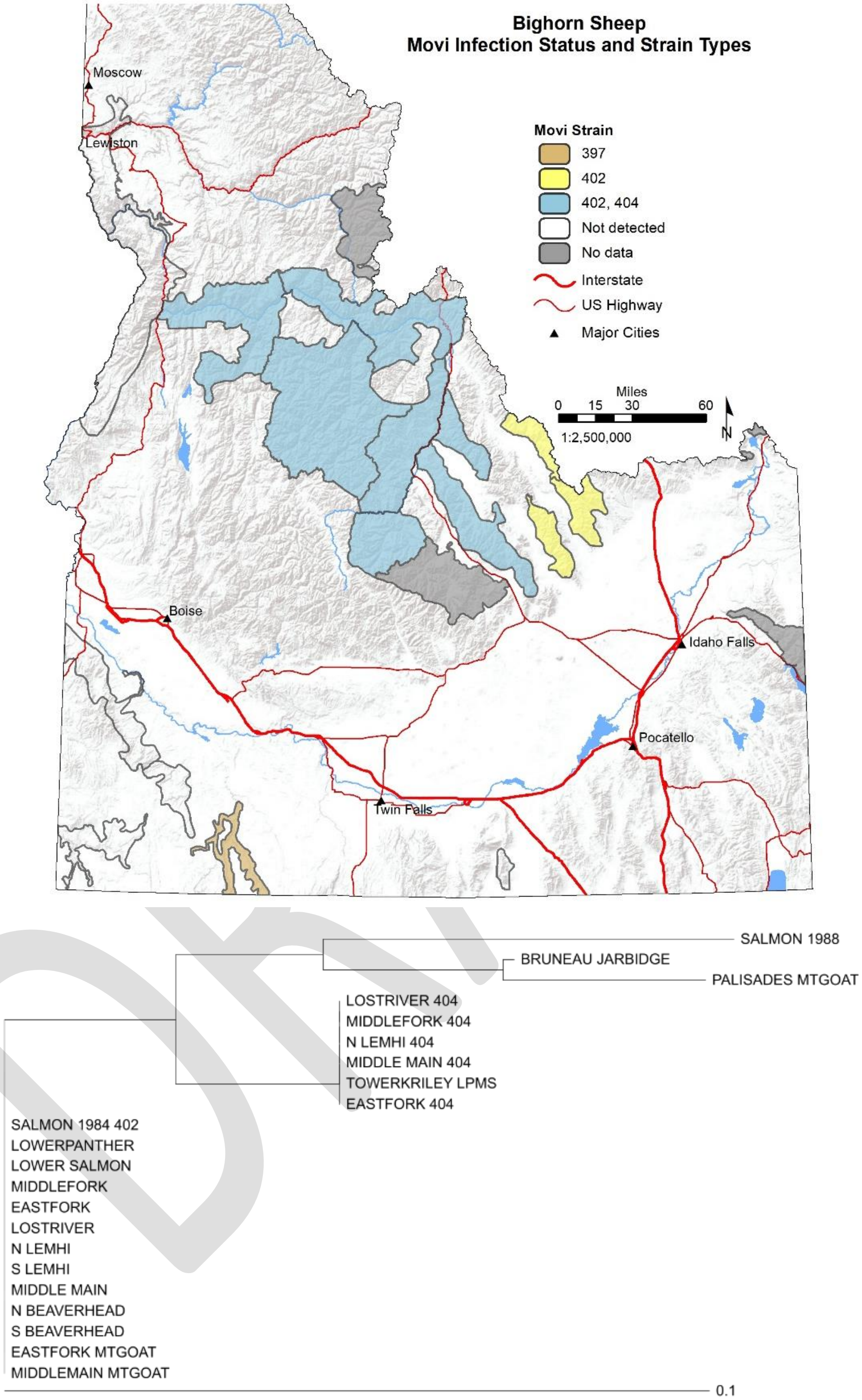


Figure 5. *Mycoplasma ovipneumoniae* (Movi) infection status and current distribution of multi-locus sequence strain types in Idaho bighorn sheep (top), and phylogeny (genetic relatedness) of Movi strains detected in bighorn sheep and mountain goat populations (bottom). Strain types joined by vertical lines are the same. Data from bighorn sheep and mountain goat (MTGOAT) samples collected at capture, natural mortalities, and hunter harvest, 1984 – 2020.

Other Diseases

Numerous pathogens and parasites can affect bighorn sheep health. Morbidity and mortality associated with diseases other than bronchopneumonia tend to be less widespread, severe, and persistent but can have significant detrimental local effects on individuals and populations.

Bacteria

Several infectious keratoconjunctivitis (pink eye) outbreaks have been reported in bighorn sheep associated with *Chlamydia* spp., *Branhamella* spp., or *Mycoplasma conjunctivae* infections (Meagher et al. 1992, Jansen et al. 2006*a*).

Caseous lymphadenitis (*Corynebacterium pseudotuberculosis*) is a chronic contagious disease of domestic sheep and goats, characterized by abscessation of the lymph nodes. It has been reported in a single bighorn sheep case from Utah (Kelly et al. 2018) and has also been recorded in other wild ungulate species, including a case in white-tailed deer in northern Idaho (Stauber et al. 1973). It has not been detected in Idaho bighorn sheep.

Paratuberculosis (Johne's disease) is an incurable, contagious, chronic enteritis of ruminants caused by the bacterium *Mycobacterium avium paratuberculosis*. It is associated with weight loss and diarrhea and can be confirmed through laboratory testing. It has not been detected in Idaho bighorn sheep; however, it has been reported in bighorn sheep from Colorado, Wyoming, and southwestern Alberta (Williams et al. 1979, Williams and Hibler 1982, Forde et al. 2012). While Johne's disease is estimated present in 60–80% of cattle herds, it is a notifiable disease (i.e., must be brought to the attention of ISDA within 48 hours) in domestic sheep and goats in Idaho (ISDA 2021).

Viruses

Contagious ecthyma, caused by a Parapoxvirus (orf), is a relatively common viral disease of domestic ruminants and can affect bighorn sheep and other free-ranging wildlife (Samuel et al. 1975). Contagious ecthyma tends to occur in sporadic outbreaks in which naive animals develop blisters on mucus membranes of the face and mouth. Severe infections can cause morbidity and mortality in lambs due to inability to nurse or feed (Blood 1971, Merwin and Brundige 2000, Douglas 2001).

Bighorn sheep are also susceptible to orbiviruses, including bluetongue and epizootic hemorrhagic disease (Robinson et al. 1967, Castro et al. 1989, Noon et al. 2002).

Exposure to Parainfluenza-3 and Respiratory Syncytial Viruses has been detected in bighorn sheep populations and may be occasionally associated with mostly nonfatal pneumonia (Foreyt and Evermann 1988, Dassanayake et al. 2013).

Macroparasites

Lungworms, *Protostrongylus stilesi* and *P. rushi*, are native lung parasites with a 2-host life cycle that are commonly detected in wild sheep (Uhazy et al. 1973, Robb and Samuel 1990, Rogerson et al. 2008). A lungworm of domestic sheep and goats (*Muellerius capillarus*) has also been reported in bighorn sheep (Ezenwa et al. 2010). Early investigators thought that lungworms, particularly *P. stilesi* were implicated in bronchopneumonia in bighorn sheep, especially in lambs (Marsh 1938, Forrester 1971, Spraker et al. 1984). However infecting lambs with lungworms did not reduce survival (Samson et al. 1987), provision of anthelmintic blocks did not increase lamb survival (Miller et al. 2000, Goldstein et al. 2005), and no consistent associations of lungworm infection with respiratory disease events or lamb survival have been shown in field investigations (Festa-Bianchet 1991*a*, Jones and Worley 1994, Cassirer et al. 1996, Aune et al. 1998). However, lungworm infection is associated with cases of verminous pneumonia in wild sheep (Jenkins et al. 2007).

Some populations of bighorn sheep are infested with mites (*Psoroptes* spp.) that cause psoroptic mange (scabies). Psoroptic mange can have severe individual animal effects and can cause substantial mortality in naïve populations (Welsh and Bunch 1983, Lange et al. 1980, Hering et al. 2021). The mite can be relatively easily transmitted within and among bighorn sheep populations (Lange et al. 1980, Foreyt et al. 1990). Infestation causes lesions including alopecia (hair loss) and thickening of the skin and can lead to secondary skin infections. Extensive crusting and debris accumulation can occur in the ear canals. Infestations can be associated with hypothermia, deafness, and loss of balance, which may increase vulnerability to predation and other sources of mortality (Lange et al. 1980, Foreyt et al. 1990, Boyce and Weisenberger 2005).

Toxoplasma gondii is a parasitic protozoan that infects tissue cells and is prevalent in humans and animals worldwide. Cats (Felidae) are the definitive host. This parasite is recognized as one of the main causes of infective abortion in domestic sheep (Dubey 2009) and has been associated with sporadic cases of encephalitis, abortions, and stillbirths in bighorn sheep (Baszler et al. 2000, WDFW unpubl. data).

Several protozoan parasites of blood cells, including *Babesia* sp. (Goff et al. 1993*a*) and *Anaplasma ovis* (Goff et al. 1993*b*, Jessup et al. 1993) are well documented in bighorn sheep.

Nasal myiasis (parasitic infection) associated with larvae of the nasal botfly *Oestrus ovis,* a widely distributed parasite of domestic sheep and goats has occasionally been reported in bighorn sheep (Capelle 1966). Several gastro-intestinal parasites are also known in bighorn sheep, most of which do not appear to impact individuals or populations (Beckland and Senger 1967, Uhazy and Holmes 1971).

Disease Risk Management

Domestic Sheep and Goats

A National Animal Health Monitoring (NAHMS) survey conducted in 2011 found most domestic sheep flocks (88%) to be positive for Movi carriage as determined by PCR on nasal swabs. Larger operations were more likely to be

Movi positive and all flocks with greater than 500 adult females were positive (USDA Aphis Veterinary Services 2015).

Less extensive surveys of domestic goats reported 44% of herds to be PCR positive on nasal swabs. Larger herds were also more likely to be Movi-positive (Heinse et al. 2016). Unpublished surveys have reported a lower proportion of Movi-positive domestic goat herds (USDA Aphis Veterinary Services 2020). Comprehensive Movi testing of domestic goats was included in a 2019 NAHMS survey but sampling, laboratory testing, and analysis results are not available at this time (USDA Aphis Veterinary Services 2021).

The evidence is clear that introduction of respiratory pathogens, especially Movi, into bighorn sheep populations can have effects that are serious and long lasting. There are no preventive vaccines, and once these pathogens are introduced into free-ranging populations, there is no effective treatment. Current disease management objectives focus on reducing risk of spillover from reservoir populations of domestic sheep and goats and on limiting transmission among bighorn sheep (USFS 2006, CAST 2008, Wild Sheep Working Group 2012). Management strategies include 1. preventing contacts that could lead to transmission and 2. clearing Movi from domestic and wild hosts.

Idaho Code 36-106(e)5(E) requires IDFG to develop Best Management Practices (BMP) agreements with willing domestic sheep permittees who operate on public lands in proximity to bighorn sheep. Recommendations developed by IDFG and ISDA (IDFG and ISDA 2008) and WAFWA (Wild Sheep Working Group 2012) to prevent contact between bighorn sheep and domestic sheep and goats will be followed as appropriate by IDFG in collaboration with other resource management agencies and domestic sheep and goat owners. These recommendations briefly include:

- Identify and map statewide distribution of potential bighorn sheep habitat and existing or potential use areas of domestic sheep and goats.
- Identify and map current documented and potential bighorn sheep use areas.

- Identify and map interface areas with risk of contact among bighorn sheep and domestic sheep and goats.
- Focus population-level disease risk monitoring and management efforts on those bighorn and domestic sheep and goat populations that are in risk of contact.
- Adopt a protocol for managing individual incidents of suspected or known contact between domestic sheep and goats.

Maps of current population distribution and modeled bighorn sheep habitat (Figures 3 and 4) and domestic sheep grazing areas (Figure 6) have been developed and provide a basis to prioritize population and health monitoring and translocation activities (bullet 4 in above list of recommendations). BMP Agreements have or will be developed for bighorn sheep populations that are in risk areas where domestic sheep producers are willing to participate in creating an agreement. These plans should be proactive and focus on preventing interaction between species. Plans should be modified as needed based on changing conditions.

Outreach to Reduce Disease Risk

Nationally the domestic sheep industry is trending towards more, smaller flocks and fewer large operations (Thorne et al. 2021). Domestic goat production for multiple uses is becoming more popular and number of operations has increased over time (USDA Aphis Veterinary Services 2020). The meat goat industry was one of the fastest growing segments of livestock production in the US, particularly in western states and Texas (USDA Aphis Veterinary Services 2012), however more sectors are currently experiencing growth (USDA Aphis Veterinary Services 2020).

Trends towards increasing numbers of sheep and goat operations in rural areas present challenges for preventing disease transmission to bighorn sheep. Use of pack goats is becoming more popular for hiking and hunting, creating a growing risk of pathogen transmission in the backcountry. While avoiding contact remains the safest management strategy for preventing transmission, the identification of Movi as a primary agent for bronchopneumonia may offer some new management options in situations where separation cannot be reliably maintained. Smaller domestic flocks may be uninfected, or have low prevalence of infection, offering the possibility of clearance through treatment should one become available, or by removing infected individuals and maintaining biosecurity measures to prevent reinfection. Management for Movi-free sheep flocks and goat herds may lead to positive outcomes for bighorn sheep and improve domestic flock/herd health and productivity (Manlove et al. 2019). Selective breeding for domestic sheep that resist infection by Movi is another approach currently under investigation with support from the USDA (Mousel et al. 2021). Outreach to owners of small domestic sheep and goat operations aims to prevent transmission by presenting accurate information about disease in bighorn sheep and options for reducing disease risk, including maintaining separation, testing animals for Movi, clearing Movi if the flock or herd is positive, and implementing best management practices to keep domestic sheep flocks and goat herds healthy and Movi-free. Outreach to the public, including hunters, also includes providing accurate information and raising awareness of this issue.

IDFG Response Plan

When proactive management techniques to maintain separation between bighorn sheep and domestic livestock fail and bighorn and domestic sheep or goats are observed to be in contact or likely to come into contact, the following actions may be appropriate:

- Watch and monitor the situation
    - If no contact can be documented, bighorn sheep should be captured, sampled (Appendix E), marked with radio collars and ear tags, held until test results for Movi are received, and, if tests are negative, released in an area where there is low risk of contacting domestic sheep or goats, if such capture is practical and possible.
- Remove bighorn sheep
    - Bighorn sheep observed in contact or in close proximity with domestic sheep or goats should be removed, either lethally or captured alive.

    - If a suitable captive facility has been identified in advance and live capture is possible, the bighorn sheep could be transported to the facility.
    - In the event of lethal removal, the carcass or portions of the carcass will be retrieved as possible, a Big Game Mandatory Report (BGMR) completed, and submitted for complete diagnostic testing, as identified in Appendix E.
    - Prior to any lethal removal actions, Regional Supervisor approval is required
    - Bighorn sheep removed alive from interaction situations will not be released.
- Remove domestic sheep or goats
    - Prior to lethal removal of domestic sheep and goats, permission from the local county sheriff is required. Due to the timely manner these removals require, prior consultation with appropriate sheriff offices is beneficial, especially in cases where the sheriff may not be readily available.
    - After obtaining permission, domestic sheep or goats in contact with bighorn sheep, or loose or stray in or near bighorn sheep habitat, should be immediately removed via capture and/or lethal removal.
    - Efforts to contact and notify any livestock producers that could potentially be the owner of the offending animals is generally required by the county sheriff prior to lethal removal. A contact list of local livestock producers is beneficial and aids in timely response to these situations.

Management actions must be conducted in a timely manner. No removals will be conducted on private land without notification and permission of the landowner.

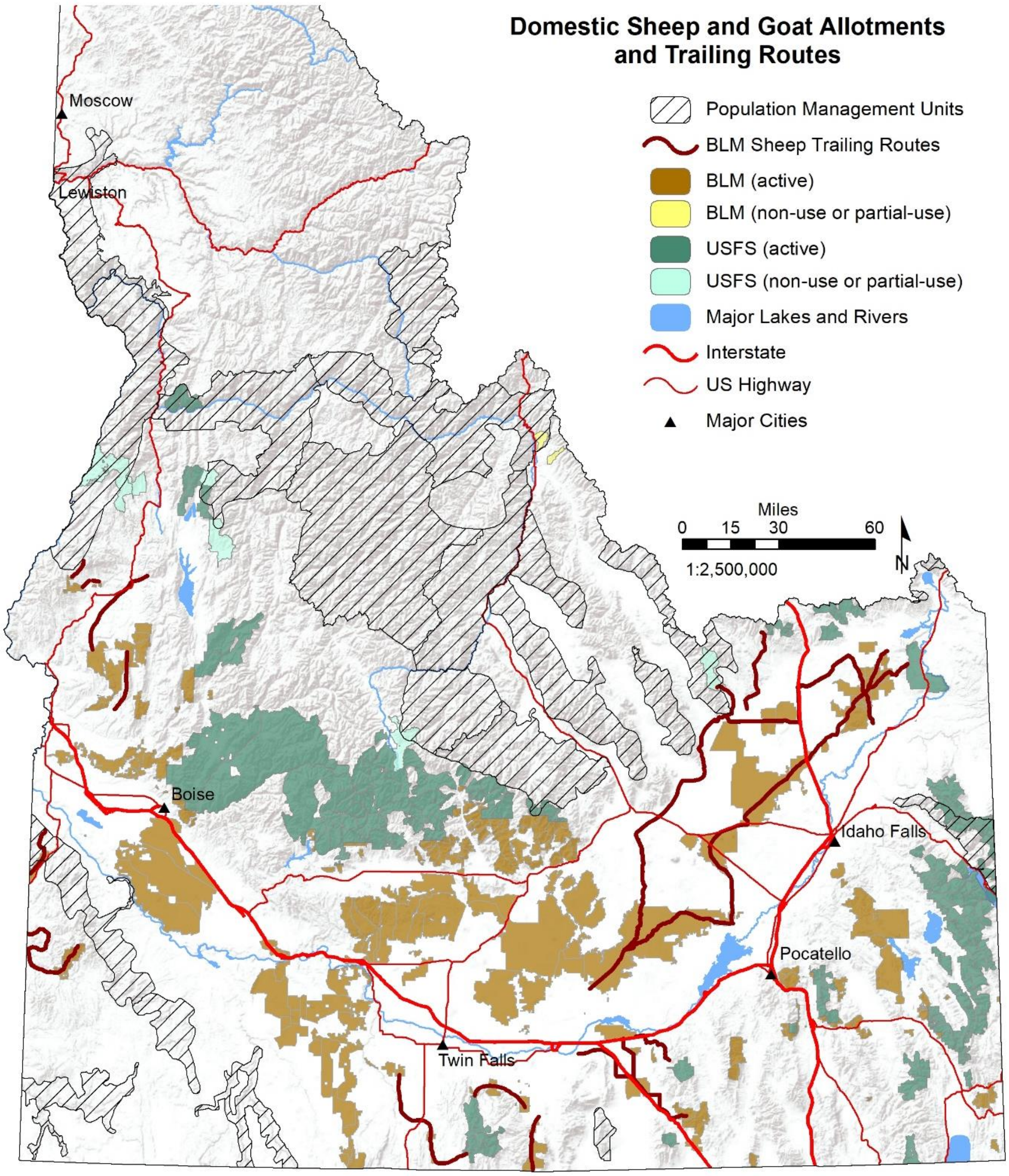


Figure 6. Bighorn sheep distribution and USFS and BLM permitted domestic sheep and goat grazing allotments and trailing routes, Idaho. Allotments currently considered active but non-use or partial-use are identified as such.

Capture and Translocations

Bighorn sheep will be captured using safe, accepted techniques (e.g., Foster 2005; see Appendix E), and animals will be handled to minimize stress and injury to animals and people. Any bighorn sheep that is captured will undergo health screening where possible and animals will not be moved without this information (Appendix E). Bringing together populations with differing health histories poses risks to both resident and translocated individuals. Potential risks and benefits of translocations will be assessed as outlined in the Translocation section. Health screening will be conducted and evaluated for all translocations in advance. Where they overlap, health status of mountain goats will also be assessed, because mountain goats are susceptible to spillover of Movi and transmission can occur between wild sheep and goats (Blanchong et al. 2018, Wolff et al. 2019).

Information Needs

Additional information useful for management includes how to best manage chronic Movi infection via test-and-remove in wild sheep, along with a better understanding of the epidemiology of bronchopneumonia in wild sheep, including factors associated with disease severity and persistence. In areas where populations are healthy and increasing, forecasting how bighorn sheep movements change across the landscape in recovering populations would help to focus management efforts to reduce risk of spillover and spread of pathogens.

Evaluation of the effectiveness of treatments, biosecurity, and animal husbandry practices for establishing and maintaining Movi-free domestic sheep and goat flocks is also essential for outreach and collaboration with the domestic sheep and goat industries to keep bighorn sheep healthy.

Disease Surveillance and Outbreak Investigation

Biological samples will be taken from all animals captured and handled by IDFG personnel whenever possible. Samples need to be collected and handled in an appropriate manner to yield interpretable results that can be applied to management decisions (Appendix E).

The WAFWA Wildlife Health Committee (2014) developed bighorn sheep population health monitoring recommendations for the Wild Sheep Working Group. These recommendations include both field and laboratory monitoring. No standard set of diagnostic samples is recommended. The limitations of some laboratory techniques are discussed, as well as the importance of proper sample collection and handling.

As part of disease surveillance, where possible, bighorn sheep found dead in the field or that die during capture or transport activities should undergo a complete necropsy (Appendix E). Response to a disease outbreak will be evaluated on a case-by-case basis and will include using or, where necessary, developing a standardized protocol for sampling and testing. Where possible, bighorn sheep that are exhibiting signs or symptoms of illness deemed to be potentially detrimental to the population should be promptly removed and disease assessment conducted through necropsy and laboratory tests.

Health Assessment and Management Directions

Management Direction — Continue to emphasize studies and management actions pertinent to resolving bighorn sheep disease issues.

> Strategy: Work to reduce the effects of disease on populations.
>
> Strategy: Conduct research and/or adaptive management in some populations (e.g., South Beaverhead PMU) to determine effectiveness and feasibility of using methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.
>
> Strategy: Initiate research efforts in some populations (e.g., Lower Salmon PMU) to gain more knowledge of how test-and-remove can be used to manage disease in populations with different levels of

management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Strategy: Determine the role rams play in maintaining and spreading Movi infection within and among bighorn sheep populations.

Strategy: Continue to obtain biological samples from all bighorn sheep and mountain goats handled, and from hunter harvest to determine exposure to pathogens, and to maintain individual population health histories of bighorn sheep in Idaho.

Strategy: Conduct investigations of known disease events and their impacts on populations.

Strategy: Continue to maintain close working relationships with universities and other wildlife management agencies to share information on mechanisms of disease development in bighorn sheep and impacts on bighorn sheep populations.

Strategy: Continue to work with the ISDA and appropriate universities to monitor diseases that may potentially affect livestock production in Idaho.

Strategy: Continue to collaborate with others to develop treatments for pathogens to prevent transmission of disease among domestic sheep and bighorn sheep.

Management Direction — Use capture guidelines (Appendix E) to safely capture and handle bighorn sheep.

Management Direction — Continue to manage for spatial or temporal separation between bighorn sheep and domestic sheep and goats, consistent with established Commission policy and WAFWA guidelines (Wild Sheep Working Group 2012).

Strategy: Actively work with interested individual livestock permittees to develop and implement “Best Management Policies” to assist in ensuring physical separation of these species, consistent with Idaho Code.

Strategy: Collaborate with interested parties to develop an education and outreach effort to inform owners of domestic sheep and goats of the risks associated with commingling and recommendations to avoid contact and disease transmission.

Strategy: Record domestic and wild sheep and goat contact incidents and management actions.

Strategy: Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Strategy: Work with appropriate stakeholders to ensure adequate monitoring occurs for maintaining separation.

Strategy: Work with the pack goat community to develop BMPs to protect bighorn sheep.

Management Direction — Work to reduce risk of disease transmission from small flocks of domestic sheep and herds of domestic goats through outreach, testing animals, and promoting best management practices for healthy, Movi-free flocks/herds.

POPULATION GENETIC STRUCTURE AND DIVERSITY

Idaho bighorn sheep are managed as populations largely defined by phenotype (i.e., physical characteristics of California and Rocky Mountain bighorn sheep), topographic boundaries, and best available knowledge of movements and spatial distribution. Genetic markers are another source of biological information that can improve or support ecologically based delineation of population structure for management. Genetic diversity can also affect fitness and the ability to adapt to changing environmental conditions and provides a quantitative measure to assess the effects of management actions and environmental conditions. Genetic markers provide an indication of the degree of isolation or gene flow among populations which can help inform management needs such as delineation of population and hunt area boundaries, translocations, and predictions of pathogen transmission.

Historical declines and extirpations of bighorn sheep populations along with ongoing lack of recovery in many areas have been associated with reductions in natural gene flow and genetic diversity in Idaho and elsewhere. Translocations to restore populations have increased genetic diversity and assisted gene flow in some cases but in others have been associated with genetic bottlenecks and leading to loss of genetic diversity. Genetic data from samples collected (horn shavings, blood, and tissue) show that the genetic structure and diversity of Idaho bighorn sheep PMUs has been influenced by a combination of ancestry, population demographics, geography, and management.

The most distinct genetic differences among Idaho bighorn sheep PMUs are between Rocky Mountain and California bighorn sheep (Figure 7, 8; IDFG unpublished data, Andrews and Waits 2017, Barbosa et al. 2021). These differences are related to geography, demographics, and evolutionary adaptation and are also influenced by management history. Starting in the 1960s, sheep from the Junction population (Chilcotin River) in British Columbia were translocated to vacant habitat to reestablish populations in the Owyhee River and Jacks Creek PMUs. Sheep were later translocated out of the Owyhee

River and Jacks Creek populations to reestablish and supplement other populations including the Bruneau-Jarbidge and Jim Sage PMUs. The Jim Sage PMU was also supplemented with sheep from reintroduced populations in Oregon and Nevada (Appendix C). Initial translocations from a single source population, selected because it was considered to be a phenotypically and genetically distinct subspecies, compounded by second order translocations from reintroduced source populations has shaped the genetic characteristics of Idaho California bighorn sheep populations. Today, California bighorn sheep show low levels of genetic differentiation among PMUs and some California PMUs are not significantly different genetically (Figure 9, Appendix C). Genetic diversity is also lower in California than in Rocky Mountain bighorn sheep populations, again, likely because they were established with low numbers of animals (founder effects) and associated random loss of genotypes (genetic drift) related to reintroduction history (Figure 9; Olson et al. 2013, Barbosa et al. 2021).

Native bighorn sheep populations in the greater Salmon River drainage in central Idaho are managed as five interconnected but genetically differentiated populations. Structure analyses show the most genetic differentiation for the Lower Salmon PMU (Figure 7, 9). The East Fork Salmon PMU also shows relatively high genetic differentiation from other PMUs (Figure 7). Both the Lower Salmon and the East Fork PMUs have lower genetic diversity than other native sheep populations (Figure 10) consistent with the low levels of gene flow detected.

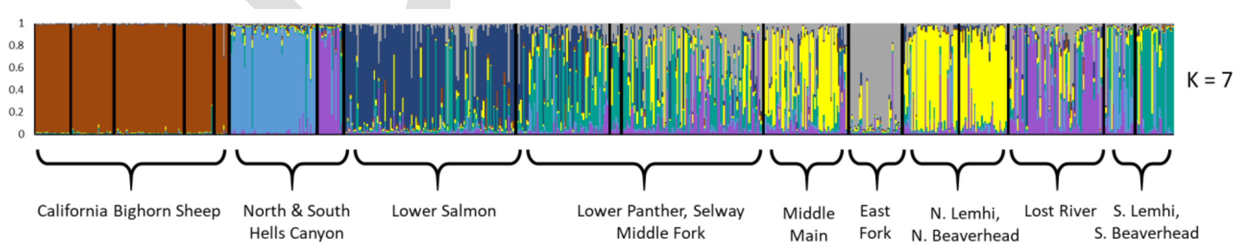


Figure 7. Overview of population genetic structure of Idaho bighorn sheep populations arranged geographically at K = 7 genotypes on analysis of 11 neutral microsatellite loci from 729 bighorn sheep in 17 Idaho populations sampled 2000–2017. Each color represents a different genotype.

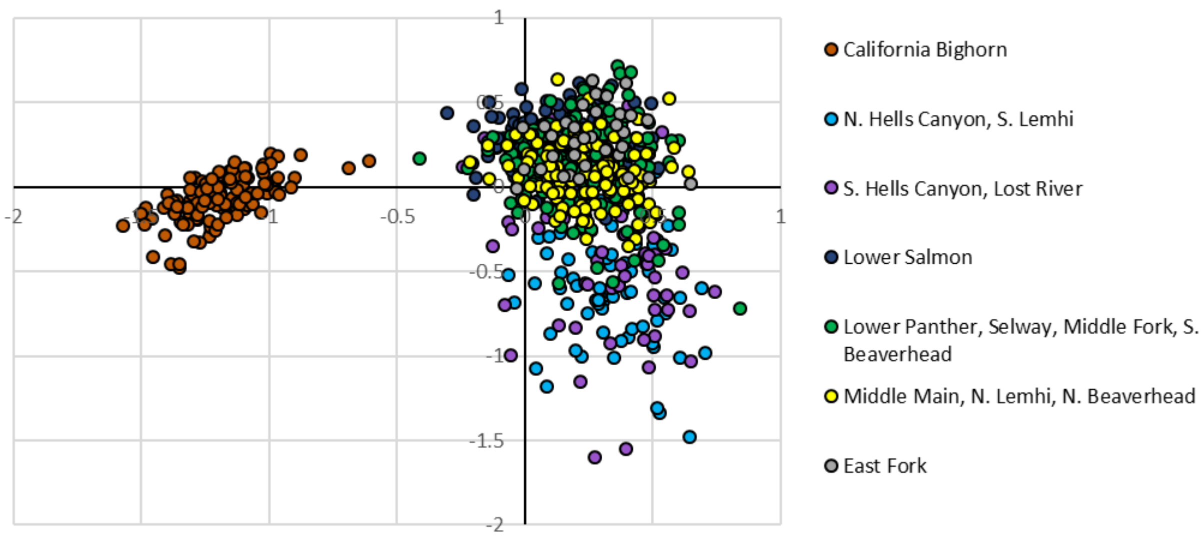


Figure 8. Factorial component analysis of plot of differentiation among 7 bighorn sheep genotypes in Idaho.

	OF	JC	OR	BJ	JS	LS	PS	MF	MMS	EF	S	NHC	SHC	NL	NB	LR	SL
OF																	
JC	0.027																
OR	0.071	0.056															
BJ	0.069	0.062	*0.013*														
JS	0.050	0.040	*0.006*	0.053													
LS	0.249	0.268	0.273	0.237	0.248												
PS	0.241	0.260	0.281	0.233	0.234	0.026											
MF	0.256	0.269	0.291	0.246	0.254	0.039	0.018										
MMS	0.261	0.278	0.309	0.264	0.255	0.057	0.037	0.025									
EF	0.322	0.345	0.391	0.333	0.320	0.094	0.091	0.057	0.054								
S	0.369	0.409	0.436	0.368	0.351	0.061	0.033	0.034	0.067	0.114							
NHC	0.311	0.324	0.356	0.311	0.297	0.110	0.087	0.087	0.062	0.134	0.102						
SHC	0.325	0.344	0.374	0.295	0.294	0.080	0.066	0.059	0.068	0.124	0.061	0.066					
NL	0.288	0.306	0.333	0.276	0.268	0.056	0.037	0.026	*0.006*	0.080	0.056	0.062	0.067				
NB	0.305	0.329	0.350	0.293	0.291	0.054	0.053	0.045	0.040	0.099	0.074	0.105	0.095	0.024			
LR	0.270	0.285	0.308	0.260	0.262	0.050	0.045	0.028	0.021	0.062	0.068	0.075	0.042	0.028	0.044		
SL	0.328	0.347	0.398	0.337	0.303	0.086	0.055	0.055	0.048	0.108	0.067	0.057	0.071	0.060	0.087	0.063	
SB	0.316	0.354	0.375	0.320	0.300	0.119	0.071	0.083	0.100	0.148	0.064	0.137	0.126	0.090	0.097	0.101	0.115

Figure 9. Genetic differentiation (pairwise F*st* values) among Idaho bighorn sheep populations (PMUs). All populations show significant genetic differentiation ($p < 0.05$) except the combinations shaded in yellow with italicized Est values. PMUs are abbreviated as OF–Owyhee Front, JC–Jacks Creek, OR–Owyhee River, BJ–Bruneau-Jarbidge, JS–Jim Sage, LS–Lower Salmon, PS–Lower Panther-Main Salmon, MF–Middle Fork Salmon, MMS-Middle Main Salmon, EF–East Fork Salmon, S–Selway, NHC–North Hells Canyon, SHC-South Hells Canyon, NL–North Lemhi, NB–North Beaverhead, LR–Lost River Range, SL-South Lemhi, SB–South Beaverhead. PMUs not represented include Palisades, Pioneers, and Lionhead.

Genetic data from a collection of bighorn sheep heads from the Lower Salmon and Middle Fork populations dating prior to 1985 obtained by the late John Carrey indicate that genetic diversity (Figure 10) and rates of gene flow in the Lower Salmon PMU have declined, and that some alleles have been lost over time. This is likely due to genetic bottlenecks and population declines associated with pneumonia outbreaks in the 1980s, followed by limited recovery and low population sizes. This scenario is consistent with assessments reported in the Habitat section of this management plan indicating that available habitat could (and once did) support larger populations of native sheep.

Genetic diversity of reintroduced Rocky Mountain bighorn sheep populations in the Lemhi, Beaverhead, and Lost River mountain ranges, and the Hells Canyon PMUs is similar to that in native populations (Figure 10) and genetic structure generally resembles one or more source populations (Appendix C). However, contemporary genetic profiles of reintroduced populations also indicate that some translocations were less successful than others and provide an indication of genetic isolation and gene flow (Figure 11).

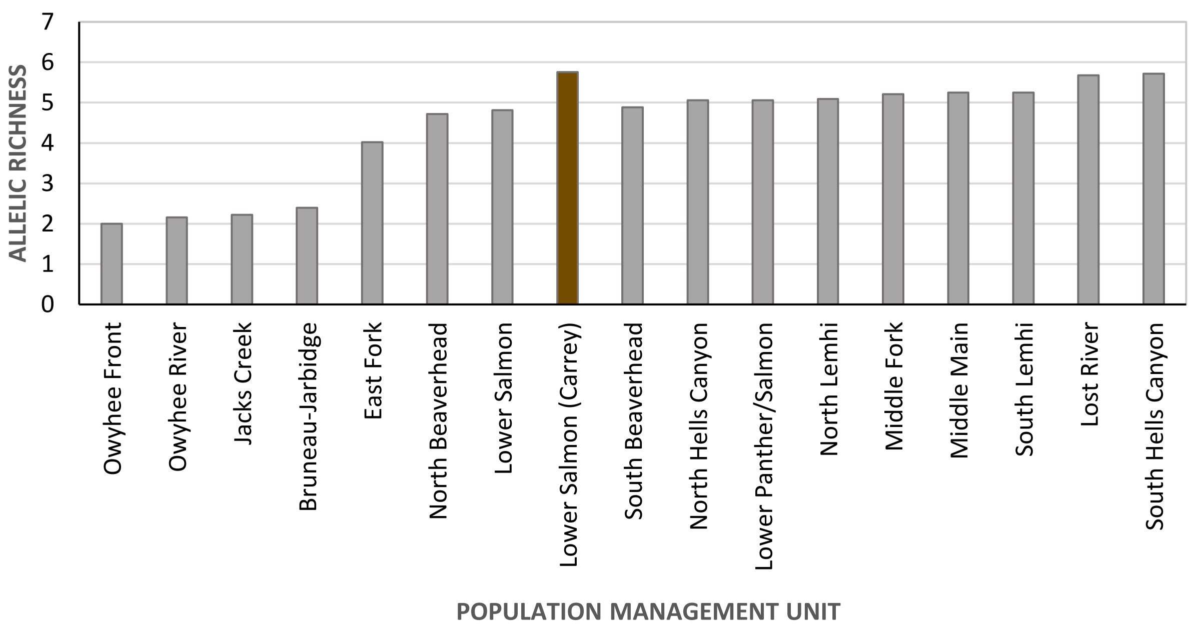


Figure 10. Genetic diversity (allelic richness) of Idaho bighorn sheep from analysis of 11 microsatellite loci from 710 bighorn sheep in 16 Idaho population management units sampled 2000–2017 and samples from the John Carrey collection dated 1923–1985.

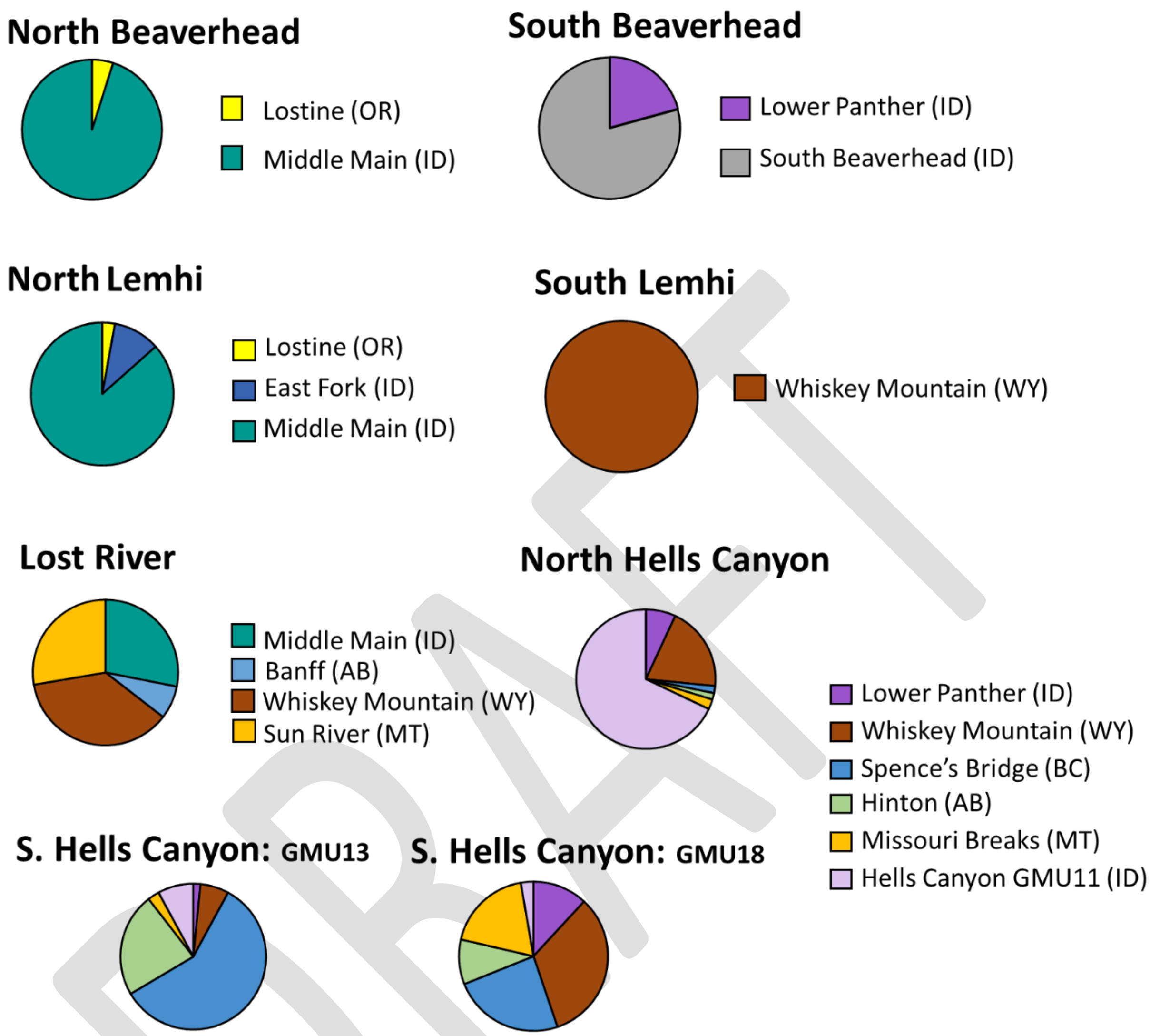


Figure 11. Genetic ancestry of reintroduced Rocky Mountain bighorn sheep populations in Idaho estimated using STRUCTURE Bayesian clustering analysis.

The North and South Hells Canyon PMUs were reestablished from different source populations and are still significantly different genetically, suggesting little if any contemporary gene flow. The North Hells Canyon PMU was reestablished with sheep from Whiskey Mountain, WY and this ancestry is well represented, along with genotypes from an unknown source, possibly from neighboring Washington or Oregon bighorn sheep populations in Hells Canyon. The South Hells Canyon PMU is a mix of largely Spences Bridge, BC and Hinton, AB ancestry along with some Whiskey Mountain and Missouri Breaks, MT origin genotypes, all source populations for this PMU.

The Lost River genotype is a nearly equal mix of three of its sources including the Middle Main Salmon, Sun River, MT, and Whiskey Mountain, WY. Bighorn sheep sampled in Lost River GMUs 50 and 51 have a higher proportion of Whiskey Basin ancestry, some Sun River ancestry, and little evidence of Middle Main Salmon genotypes (not shown). These differences may be a result of greater connectivity with Middle Main Salmon PMU in the northern (GMU37) portion of the Lost River Range PMU.

The North Lemhi population does not differ genetically from the Middle Main Salmon (Figure 9) and the North Beaverhead population also reflects mostly Middle Main Salmon ancestry (Figure 11). Sheep from the Middle Main Salmon were released in both the North Beaverhead and the North Lemhi, although both PMUs were originally established with sheep from the Lostine, OR population. Sheep from the East Fork Salmon were also translocated to the North Lemhi. There is little representation of these translocations in the contemporary genetic profile, suggesting that they did not make a significant contribution to restoration of the North Beaverhead and North Lemhi populations. Genetics of the South Lemhi PMU shows strong resemblance to Whiskey Mountain, WY, which was the sole source population. The South Beaverhead contains ancestry from the Lower Panther–Main Salmon source population and an unknown genotype, which may represent significant genetic drift in this small population.

Population Genetics Management Directions

Management Direction — Manage for maintaining or increasing genetic diversity in bighorn sheep populations while conserving unique genetic ancestry in native populations.

> Strategy: Consider genetic ancestry and diversity when conducting translocations.

Strategy: Collaborate with other states and British Columbia to identify actions to increase genetic diversity in California bighorn sheep populations.

Strategy: Manage for increasing native bighorn sheep populations to minimize further loss of genetic diversity and to maintain gene flow between historically connected PMUs.

CLIMATE

Long-term empirical evidence indicating direct effects of ongoing and projected climate change on bighorn sheep is generally lacking. Indirectly, however, climate affects forage quality and quantity, and these changes may influence bighorn sheep reproduction, recruitment, survival, distribution, and migratory behavior (Goodson et al. 1991*a,b*; Portier et al. 1998, Enk et al. 2001, Blanchard et al. 2003, Butler and Garrott 2012, Butler et al. 2013, Douhard et al. 2018, Renaud et al. 2019, Stephenson et al. 2020, Proffitt et al. 2021). Other potential threats to bighorn sheep populations (see Habitat and Health sections) may also be exacerbated by changes in long-term climate patterns including drought and nutritional status (e.g., Blanchard et al. 2003), landscape disturbance (e.g., invasive plants, fire) (e.g., Clapp and Beck 2016, Donovan et al. 2021), access to water (Gedir et al. 2020), and incidence of disease or parasites (e.g., Aleuy and Kutz 2020, Rivera et al. 2021).

In Idaho, mean annual temperature has increased approximately 0.2 °C (0.4 °F) per decade since 1970 with summer and winter temperatures increasing more than other seasons, extreme heat waves becoming more common, and growing season lengthening (Abatzoglou et al. 2014). Trends in precipitation are more variable but indicate decreases in summer and autumn precipitation and increases in spring and winter precipitation with decreases in the proportion of precipitation falling as snow, particularly at low to middle elevations (Abatzoglou et al. 2014, Klos et al. 2014, Mote et al. 2018, Musselman et al. 2018). For example, >50 years of data from the Reynolds Creek Experimental Watershed and Critical Zone Observatory, an intensively monitored drainage in the middle of the Owyhee Front PMU (see Figure 30), documents a ~2 °C increase in mean annual temperature and a shift from snow- to rain-dominated system, particularly at low and mid-elevations, even with no overall change in total amount of precipitation (Nayak et al. 2010, Seyfried et al. 2018). As a result of these changes, wildlife across Idaho is experiencing changes in several factors including, but not limited to, forage phenology (e.g., timing of green-up, senescence, season length), winter severity (e.g., snow depth, cover, consistency), and drought.

Following current trends, projected changes over the next 50–70 years indicate progressively hotter, drier summers and warmer, wetter winters in the state with greater overall variability (e.g., record cold temperatures even as record highs become increasingly frequent) (Meehl et al. 2009, Rupp et al. 2017). In addition, consecutive years of snow drought will be more common, as will earlier peak snowpack, and an upward elevational shift in snow levels (Catalano et al. 2019, Marshall et al. 2019). Assuming a "business-as-usual" emission scenario (resource concentration pathway [RCP] 8.5), mean annual temperatures in bighorn sheep PMUS are projected to increase 2.9–3.3 °C (5.2–5.9 °F) by mid-century (as compared to 1981–2010 baseline using data from Abatzoglou 2013 and Holden et al. 2015), with mean temperature of the wettest quarter (generally spring) increasing 2.8–5.9 °C (5.0–10.6 °F) and the warmest quarter (generally summer) increasing 3.3–3.6 °C (5.9–6.5 °F) (Table 4). These changes will likely be coupled with slight increases in annual precipitation (4.9 cm, 1.9 in) across all PMUs, with the most variability during the wettest quarter (0.4–27.3 cm, 0.2–10.7 in) and minimal increases during the warmest quarter (0.4–3.9 cm, 0.2–1.5 in). These changes co-occur with a decline in proportion of precipitation falling as snow in all PMUs (2.4–17.2 cm, 0.9–6.8 in), with the most substantial changes occurring in Selway, Palisades, Lionhead, and several Salmon River PMUs (Table 4). However, estimating these trends in Idaho's topographically complex habitats can be challenging due to substantial local variability in both temperature and precipitation (e.g., Ford et al. 2013, Silverman and Maneta 2016, Catalano et al. 2019). Similarly, although model agreement is relatively high with respect to temperature projections, particularly in early and mid-century, models of precipitation projections are much more variable, resulting in less certainty. Further, these estimates represent 30-year averages in climate and not annual, monthly, or daily variability in weather, thus potential effects of annual and seasonal time lags are not incorporated.

These ongoing and projected changes in temperature and precipitation may both positively and negatively affect bighorn sheep populations. In subalpine and alpine habitats, warmer spring temperatures resulting in earlier spring green-up and shorter winters are associated with higher spring body mass in ewes, which can positively influence lamb summer weight gain and survival (Douhard et al. 2018). Warm spring and summer temperatures, coupled with decreased precipitation, can also result in decreased lamb survival and recruitment due to forage changes (Portier et al. 1998, Enk et al. 2001, Butler and Garrott 2012). Summer growing season conditions can influence both probability of pregnancy and winter survival for female bighorn sheep (Proffitt et al. 2021), although the effect on survival may be mitigated by shorter, milder winters (e.g., Douhard et al. 2018). In subalpine and alpine habitats, warm and dry autumns can lead to earlier parturition dates, likely due to forage condition, so much so that median parturition dates in Alberta advanced more than 10 days over 20 years (Renaud et al. 2019). Warm springs can also result in greater mismatch between parturition date and vegetation green-up; however, while greater mismatch resulted in decreased lamb mass at weaning, it did not affect lamb survival (Renaud et al. 2021).

Drought and extended growing seasons in areas of landscape disturbance have increased occurrence of nonnative, invasive plant species which degrade habitat by reducing the variety and density of more palatable and nutritious native forage. Of particular concern for bighorn sheep habitat is the conversion of perennial grass and shrub communities to landscapes dominated by annual grasses and forbs. These changes result in increased fire on the landscape (Abatzoglou and Williams 2016), which may hinder (e.g., through more invasive plants) or benefit (e.g., through increased nutrients and/or reduced conifer and shrub encroachments) bighorn sheep populations. Fires that increase visibility and forage accessibility may be particularly beneficial in improving habitat (Clapp and Beck 2016, Donovan et al. 2021). Increased drought may also increase competition with other ungulates, while mild winters may reduce competition. Although generally not an issue in Idaho, in exceptionally arid landscapes access to surface water may be seasonally important for bighorn sheep (e.g., Bleich et al. 2010, Gedir et al. 2020, Harris et al. 2020). Given projected increases in drought conditions in Idaho, access to water may become more of an issue for some bighorn sheep populations in portions of the state.

Changes in climate patterns across Idaho have also led to more favorable conditions for some diseases and parasites known to infect bighorn sheep, although the magnitude of effects are complex and variable, often depending on many factors including life cycle, alternate or intermediate hosts, and mode/vector of transmission (see Rose et al. 2014, Utaaker and Robertson 2015, Aleuy and Kutz 2020, Rivera et al. 2021, for review). As noted in the Health section, bighorn sheep are susceptible to orbiviruses, including bluetongue and epizootic hemorrhagic disease. These diseases are transmitted by biting midges (*Culicoides* spp., also known as no-see-ums), whose abundance and activity are affected by temperature, precipitation, and wind patterns (Rivera et al. 2021). Increasing drought results in warmer, shallower water sources and exposes fresh mud thought to be ideal for biting midge reproduction (see Pfannenstiel et al. 2015 for review). Drought also tends to congregate animals, increasing host density, potential infection, and spread. Thought to be limited by cold weather, midges (and thus the diseases) were historically restricted between 35 degrees south and 40 degrees north latitude. In recent decades, extensions northward (up to 50 degrees north latitude) in North America and Europe have been attributed to warmer climate patterns (Purse et al. 2005, Rivera et al. 2021) and projections suggest additional expansion in coming decades (Zuliani et al. 2015). Warmer temperatures can also reduce incubation period of the diseases, although extremely high temperatures may decrease survival of biting midges.

The changing climate conditions in Idaho also benefit many macro-parasites common in bighorn sheep including ticks, gastrointestinal nematodes, and lungworms. Warming conditions played a role in the recent expansion of ticks and tick-borne diseases across the US (see Bouchard et al. 2019, Ogden et al. 2021 for review). In the case of the blacklegged deer tick, which transmits bacteria (*Babesia* spp., *Anaplasma ovis*) known to infect bighorn sheep, increasing temperature and humidity results in expanded distributions (latitude and elevation), increased abundance, longer growing seasons, and extended activity patterns (Ogden et al. 2021). Similarly, gastrointestinal nematodes can survive, and thrive, in warmer climates (Aleuy and Kutz 2020).

For example, the abomasal nematode (*Marshallagia marshalli*) not only tolerates extreme temperatures (≤-40 °C [-40 °F] to ≥30 °C [86 °F]) but can hatch directly from egg to 3rd stage infective larvae (skipping larval stages 1 and 2) in warmer temperatures (25–35 °C [77–95 °F]), significantly increasing parasite survival and chance for transmission (Aleuy et al. 2019, Aleuy and Kutz 2020). Although population-level effects of *M. marshalli* on bighorn sheep are unknown, recent research has shown that heavy parasite loads in Dall's sheep can influence lamb sex ratios (Aleuy et al. 2020). Lungworms, another group of parasites common in bighorn sheep, rely on gastropods as an intermediate host. If bighorn sheep congregate at limited water sources during drought, lungworm levels may increase due to increased exposure to infected gastropods (Rogerson et al. 2008). Conversely, extreme weather conditions (e.g., exceeding critical temperature thresholds, extended drought, or flooding) may also reduce survival and pathogen transmission of many macro-parasites in local areas (Aleuy and Kutz 2020, Ogden et al. 2021).

The ability of bighorn sheep to adapt to the ongoing and projected changes in Idaho is uncertain. In general, bighorn sheep are thought to be moderately adaptable and exhibit several attributes typical of species with moderate to high adaptive capacity (Nicotra et al. 2015, Thurman et al. 2020), including being generalist foragers with high dispersal capacity, living in well-dispersed populations across a wide range of abiotic conditions, and displaying great behavioral flexibility. For example, individuals are known to alter behavior to escape heat and drought (e.g., select areas of increased forest canopy cover, northerly aspects, or higher elevation) as well as track plant phenological changes (e.g., through parturition dates), although both adaptive behaviors vary by individual, population, and/or habitat availability (e.g., Renaud et al. 2019, 2021; Gedir et al. 2020). Furthermore, bighorn sheep can survive extended periods in harsh, forage-limited environments by relying on body fat reserves (Stephenson et al. 2020). However, bighorn sheep also demonstrate characteristics indicative of species with lower adaptive capacity, such as low to moderately-low population size, longer generation times, lower reproductive rates, reproductive phenology influenced by seasonal and interannual variation in climate, habitat specialization (i.e., escape terrain), and low to moderate tolerance of humans and human development. These life history characteristics, in addition to reduced genetic diversity in some populations (Barbosa et al. 2021, Genetics section), may prevent rapid adaptation required to match the velocity of climate change.

Given bighorn sheep habitat is still relatively intact across much of Idaho and the opposing effects of longer growing seasons and more extreme weather, bighorn sheep may be able to adapt or shift ranges to provide a buffer to climate changes. However, focusing on the direct effects of climate change on habitat ignores the range of possible ecosystem responses including changes in species interactions such as competition, predation, disease, and human activities that may ultimately have significant impacts on bighorn sheep populations. With the multitude of contributing factors, populations in different areas of Idaho will likely respond differently to changing conditions. For example, studies in Alberta, Montana, Wyoming, and the southwestern US suggest that effects of climate change on bighorn sheep populations, even those in proximity to each other, will not be uniform (Butler et al. 2013, Creech et al. 2020, Proffitt et al. 2021). Given the ecological and topographic complexity of bighorn sheep PMUs in Idaho, sufficient availability of cooler microclimates (i.e., climate refugia) may allow populations to persist, and possibly even expand, in seemingly inhospitable areas assuming populations are not impacted by other factors (e.g., disease).

Climate Management Directions

Management Direction — Improve understanding of existing and potential effects of changing climates, specifically changes in seasonal temperatures, on bighorn sheep recruitment rates, survival, disease and parasites, distribution, and habitat use.

> Strategy: Identify and support collaborative research, standardization of methods, and development of opportunities focused on identifying and understanding changes in climatic conditions that could affect bighorn sheep populations either positively or negatively across a range of ecotypes.

Strategy: Work with researchers to develop climate projections at biologically meaningful scales (e.g., <250 m x 250 m, 15 acres) for projecting future conditions and habitat trends in bighorn sheep PMUs in Idaho.

Strategy: Engage partners in collaborative efforts to address threats to bighorn sheep populations that may be compounded by effects of climate change.

Strategy: Work with land managers to provide or maintain habitat that contributes to climate resiliency.

Table 4. Baseline (1981–2010, B) and projected (2040–2069, P) mean temperature (° C) and precipitation (cm) of the wettest (generally spring) and warmest (generally summer) quarters, and precipitation as snow (PAS, cm) averaged across bighorn sheep population management units.

Population Management Unit	Elevation range (m)	Temperature				Precipitation				PAS	
		Wettest[d]		Warmest		Wettest		Warmest			
		B[a]	P[b]	B	P	B	P	B	P	B[c]	P[c]
North Hells Canyon	218–1,637	18.5	21.8	19.6	23.2	17.4	18.0	16.9	17.4	4.6	1.9
South Hells Canyon	271–2,853	12.2	15.3	18.0	21.6	25.3	26.4	19.9	20.3	18.7	10.2
Lower Salmon	513–2,821	7.8	10.8	15.4	18.9	29.6	31.1	24.6	25.0	39.8	28.8
Selway	676–2,776	4.6	7.4	15.1	18.6	37.7	40.0	29.3	31.3	48.8	31.6
Lower Panther-Main Salmon	752–3,004	12.4	15.9	15.9	19.4	22.7	23.9	21.1	22.6	30.0	21.2
Middle Fork Salmon	888–3,145	6.0	9.3	14.4	17.9	28.5	30.1	24.0	25.1	43.3	32.5
Middle Main Salmon	1,245–3,169	11.2	14.9	15.2	18.7	18.3	19.5	17.3	18.6	23.1	16.0
East Fork Salmon	1,631–3,586	7.1	11.7	13.3	16.7	22.4	23.7	19.9	21.1	37.7	27.6
Pioneers	1,712–3,634	8.9	12.8	13.7	17.1	19.8	21.2	18.6	19.9	35.3	25.6
Lost River Range	1,414–3,844	12.0	15.9	14.3	17.7	19.3	20.9	18.6	20.2	31.5	22.9
North Lemhi	1,295–3,341	14.0	17.6	14.5	17.9	21.7	22.9	19.5	21.4	22.0	14.6
South Lemhi	1,566–3,708	14.2	17.7	14.4	17.9	20.4	22.2	19.9	21.9	30.9	20.8
North Beaverhead	1,727–3,355	13.4	16.9	13.6	17.1	21.0	22.4	19.8	21.9	19.8	12.1
South Beaverhead	1,562–3,471	14.1	17.9	14.6	18.1	20.7	22.1	19.2	21.2	22.8	13.7
Lionhead	2,053–3,173	2.1	7.4	12.2	15.6	38.4	41.2	35.4	39.2	73.8	61.0
Palisades	1,541–3,044	7.3	13.2	16.0	19.3	27.5	29.3	25.5	28.3	37.1	23.0
Owyhee Front	685–2,152	19.3	22.7	20.4	23.9	12.7	13.6	12.6	13.6	5.6	2.0
Owyhee River	1,276–1,869	16.4	20.2	18.6	22.1	10.4	11.0	10.3	11.0	5.6	2.1
Jacks Creek	959–2,044	18.3	21.9	19.5	23.0	14.6	15.8	14.5	15.7	5.6	2.1
Bruneau-Jarbidge	1,010–1,888	18.5	22.4	19.0	22.5	11.2	11.9	11.1	11.8	3.6	1.3
Jim Sage	1,487–2,454	14.6	18.0	18.6	22.1	14.0	14.4	19.9	21.9	10.2	3.9

[a] Baseline temperature data represent mean values at 250 m spatial resolution (Holden et al. 2015).

[b] Projected mid-century values are based on an ensemble of 20 general circulation models (GCM) under a "business-as-usual" emission scenario (representative concentration pathway [RCP] 8.5) (Abatzoglou 2013) superimposed on baseline data.

[c] Baseline PAS data are modeled at 1 km spatial resolution with projected values from an ensemble of 10 GCMs under RCP 8.5 (Wang et al. 2016).

[d] Bioclimatic variables used include mean temperature of the wettest quarter (bio8), mean temperature of the warmest quarter (bio10), precipitation of the wettest quarter (bio16), and precipitation of the warmest quarter (bio18).

PREDATION

While predation can have a profound influence on prey population dynamics in many ecosystems (Rominger 2018), bighorn sheep coevolved with predators in environments inhabited by many species of predators and alternate prey. Predators of bighorn sheep include gray wolf, coyote, mountain lion, bobcat, gray fox, black bear, grizzly bear, and golden eagle (Sawyer and Lindzey 2002, Parsons 2007, Smith et al. 2014, Cain et al. 2019, Gammons et al. 2021). In response, bighorn sheep have developed efficient anti-predator strategies, including gregarious behavior, keen eyesight, use of rugged escape terrain, and segregation of ewes and lambs from rams to reduce their vulnerability to predation (Geist 1971, Bleich et al. 1997, Jorgenson et al. 1997, Geist 1999, Wishart 2000). These behaviors appear to be particularly effective at reducing predation by coursing predators such as coyotes and wolves (Festa-Bianchet 1991*b*, Sawyer and Lindzey 2002), but are less effective against a stalking predator like mountain lion (Rominger 2018). Under specific circumstances, predators may limit bighorn sheep populations.

Mountain Lion Predation

Mountain lion predation on bighorn sheep can be variable, even within the same population (Ross et al. 1997, Sawyer and Lindzey 2002, McKinney et al. 2006*b*, Gammons et al. 2021), and mortality rates for ewes can be equal or greater than those of rams (Krausman et al. 1989, Hayes et al. 2000, Kamler et al. 2002, Festa-Bianchet et al. 2006). In some cases, high levels of predation are capable of depressing bighorn sheep populations (Kamler et al. 2002, McKinney et al. 2006b, Foster and Whittaker 2010, Brewer et al. 2013, Johnson et al. 2013, Gammons et al. 2021) and can cause the extirpation of small, isolated populations (Rominger 2018, Rominger and Weisenberger 2000). Larger populations (e.g., >100 individuals) have also documented declines with mountain lion predation as the primary cause of mortality (Wehausen 1996, Hayes et al. 2000, Foster and Whittaker 2010).

Mountain lion predation may be exacerbated by other factors that ultimately lead to low bighorn sheep densities and population declines (Anderson 2008), including prolonged drought (Logan and Sweanor 2001, Bender and Weisenberger 2005), changes in habitat (Holl et al. 2004), disease (Logan and Sweanor 2001), and changes in primary prey species abundance (Schaefer et al. 2000, Logan and Sweanor 2001, Kamler et al. 2002, Holl et al. 2004, Rominger et al. 2004, Festa-Bianchet et al. 2006, Brewer et al. 2013, Johnson et al. 2013, Rominger 2018). When bighorn sheep are already struggling with factors such as disease, inadequate habitat, or changes in availability of other prey species, mountain lion predation may have an undue impact on populations.

Other Predators

Wolf predation has not been documented to cause population-level impacts on bighorn sheep. In Yellowstone National Park wolves did not prevent the bighorn sheep population from increasing (7% annual increase from 1998–2005) during the decade after wolf reintroduction when wolf numbers increased from 21 to a maximum of 106 (White et al. 2008). In the Salmon River Mountains of central Idaho, Husseman et al. (2003) documented 120 wolf and 98 mountain lion-killed ungulates. Of these documented kills, bighorn sheep comprised 1% of mountain lion-killed ungulates and 0% of wolf-killed ungulates. In Jasper National Park, wolf predation on bighorn sheep was rare despite high wolf presence, and bighorn sheep were observed on or closer to escape terrain when wolves were present (Dekker 2009).

Smaller predators such as coyotes, bobcats, and golden eagles are likely more effective predators on young lambs. However, mountain lions have been documented as the primary predator of lambs in some studies (Parsons 2007, Smith et al. 2014, Karsch et al. 2016, Cain et al. 2019). Coyotes were the second-most important predator, after mountain lions, on lambs in two desert bighorn sheep studies (Karsch et al. 2016, Cain et al. 2019). Coyote predation was also a major source of lamb mortality in British Columbia (Harrison and Hebert 1988). Coyotes and mountain lions killed lambs less than 8 weeks old, but only mountain lions killed older lambs (Cain et al. 2019). Coyote predation sites on desert bighorn lambs were in areas with lower elevation, less rugged, and lower slopes than parturition sites, nursery sites, or mountain lion kill sites

(Karsch et al. 2016). During years of low precipitation and limited forage availability, desert bighorn sheep ewes may forage further from escape terrain potentially exposing lambs to higher predation risk from coyotes (Cain et al. 2019).

In multi-predator systems, the relationships can be complex. Wolves and bears may usurp mountain lion kills resulting in increased mountain lion kill rates. Mountain lion kill rates increased 48% in Colorado and California in the presence of black bears due to usurpation of kills, with bears detected at 48–77% of mountain lion kills (Elbroch et al. 2015). Wolves usurped 12% and scavenged 28% of mountain lion kills during a 4-year period in Banff National Park (Kortello et al. 2007). Wolves and bears may also negatively impact mountain lion survival (Boyd and Neale 1992, Kortello et al. 2007, Ruth et al. 2011). The potential effects of these interspecific interactions on bighorn sheep populations are unknown.

Idaho Cause-Specific Mortality Research

Research conducted in Big Jacks Creek between 1987 and 1991 documented only 1 mortality attributed to mountain lion predation of 38 radio-collared bighorn sheep (as cited in Berkley 2005). From March 2002 to February 2007, 52 adult bighorn sheep were collared and monitored to assess cause-specific mortality in the Big Jacks, Little Jacks, and Shoofly Creek drainages in Owyhee County, Idaho. Of the 27 confirmed mortalities during the study period, 7 were attributable to mountain lion predation, 4 were considered possible mountain lion predation, 1 succumbed to sinusitis, and 3 died from falls. The remaining 12 mortalities were due to unknown causes. Over the 5 years, annual ewe survival rate varied from 77% to 87% (Berkley 2005).

From 2011–2014 IDFG studied cause-specific mortality again in the Jacks Creek and Owyhee Front PMUs. From 2011–2012 IDFG captured and radio-collared 7 rams and 32 ewes. Four ewes and 1 ram were killed by mountain lions, 3 ewes and 2 rams died of unknown but non-predation causes, 1 ewe and 1 ram died of unknown causes, and 3 rams were harvested by hunters. Overall annual ewe survival varied from 90% to 96%.

IDFG initiated cause-specific mortality research from 2016–2020 in the Owyhee Front and Owyhee River PMUs following a pneumonia outbreak in neighboring populations in Oregon. Of the 31 radio-collared ewes, 7 died from mountain lion predation, 1 from malnutrition following a jaw injury, 1 unknown, and 1 unknown predation. Of the 18 rams captured, 4 were harvested by hunters over the 5-year study. No other causes of mortality were documented for rams during the life of the collars (<2 years).

Cassirer and Sinclair (2007) assessed mortality factors for bighorn sheep in Hells Canyon during 1997–2003. Pneumonia was the most common cause of adult mortality (43%) and the primary factor limiting population growth. Mountain lion predation was the second most frequent source of adult mortality (27%) but did not significantly reduce the rate of population growth. There has not been any documented wolf-caused mortality of bighorn sheep in Hells Canyon.

Predation Management

Management of predators to increase bighorn sheep populations is a contentious issue, in part because different segments of society value predators differently. Although the abundance of predators is commonly thought by the public to be the primary factor affecting predation rates, researchers have documented that predation on bighorn sheep can be a function of the behavior of individual mountain lions and not always the total number of mountain lions (Ross et al. 1997, Logan and Sweanor 2001, Dekker 2009). Due to this density-independent relationship, indiscriminate removal of mountain lions or overall reduction in mountain lion numbers may not always reduce the number of mountain lion-related bighorn sheep mortalities (Ernest et al. 2002, Cougar Management Guidelines Working Group 2005). Nonetheless, predation management is an important tool for IDFG to aid in management of prey populations when appropriate.

In 2000 the Idaho Fish and Game Commission implemented a “Policy for Avian and Mammalian Predation Management” to guide IDFG’s implementation of predator management activities (IDFG 2000). The policy directs IDFG to implement predator management if there is evidence predation is a significant factor preventing prey populations from meeting IDFG population management objectives. Furthermore, IDFG is directed to use best available scientific information to guide their actions concerning predator management.

Predator control is used by most western state and provincial wildlife agencies to protect big game populations (Rominger 2018) and has been used to aid restoration of bighorn sheep in New Mexico, California, Texas, Arizona, and Utah (Rominger 2007). Because mountain lions are the predator species most likely to cause population-level impacts on bighorn sheep, most research has focused on the effects of mountain lion control. However, coyote predation was also a major source of lamb mortality in British Columbia and coyote control resulted in a 2–2.5-fold increase in lamb:ewe ratios (Harrison and Hebert 1988).

Research indicates predator control is most effective at improving bighorn sheep population performance under very specific conditions, particularly when bighorn sheep survival rates and recruitment are low and mountain lion predation is a primary cause of mortality. In some instances, predation by relatively few individual mountain lions may be responsible for, or contributing to, bighorn sheep population declines or possibly extirpation in small, isolated populations (Festa-Bianchet et al. 2006, Logan and Sweanor 2001). Ross et al. (1997) and Mooring et al. (2004) suggested targeting specific mountain lions to address predation problems on bighorns. Small, isolated, and recently translocated populations of bighorn sheep are most vulnerable to declines caused by mountain lion predation (Wehausen 1996, Hayes et al. 2000, Logan and Sweanor 2001, Kamler et al. 2002, Real and Festa-Bianchet 2003, Rominger et al. 2004, Festa-Bianchet et al. 2006) and Anderson (2008) suggested short-term predator management may be appropriate to maintain such bighorn sheep populations where mountain lion predation is common. For populations with fewer than 15 bighorn females, mountain lion control was modeled to be the most effective option to mitigate predation (Ernest et al.

2002). Timing of mountain lion removals is likely more critical in reducing predation on young lambs compared to adults (Cain et al. 2019).

In Arizona, mountain lion control was implemented in areas overlapping a translocated desert bighorn sheep population after a protracted period of declining abundance, productivity, production, and recruitment of bighorn sheep. After lion populations were experimentally reduced, but not eliminated, mortalities and mortality rates of radio-collared sheep due to mountain lion predation were less than half of that in the pre-treatment period. The bighorn sheep population then increased despite multiple years of drought conditions, and productivity increased more than 33% (McKinney et al. 2006*b*).

In New Mexico, mean annual cause-specific mortality rates of mountain lion predation on desert bighorn sheep ewes went from 0.22 without mountain lion removal to 0.05 during periods with active mountain lion removal. Mortality rates from other causes were 0.03 during periods without removals, and 0.04 when removals were conducted, suggesting that mountain lion predation was likely additive (Goldstein and Rominger 2012). After the initiation of mountain lion control, desert bighorn sheep populations in New Mexico increased from <170 in 2001 to >1,100 in 2016 (Ruhl and Rominger 2015).

High levels of predation have been reported on translocated bighorn sheep (Krausman et al. 1999, Tominger et al. 2004, McKinney et al. 2006*a*). One translocation in Arizona lost 15 of 30 radio-collared sheep to mountain lions within 4 months at a site with no pre-release predator control (Krausman 2017). In areas where mountain lion predation may impact translocation success, researchers have recommended careful evaluation of translocation sites (Bender and Weisenberger 2005), release of a larger number of bighorns to increase group size and increase vigilance for predators (Mooring et al. 2004), and short-term mountain lion control prior to release of bighorns into new habitat (Rominger et al. 2004, McKinney et al. 2006*a*, Rominger 2018). In New Mexico, mountain lion control 3 to 4 months before bighorn sheep releases is standard practice after multiple translocation attempts failed due to mountain lion predation (Rominger 2018).

Predator control is often expensive, time consuming, and controversial. Therefore, it is essential that managers consider whether the investment in predator control is warranted by the anticipated benefits to prey populations. Bowyer et al. (2005) developed a model to aid in determining when predation might have a large impact on prey population size, and thus where the prey population would respond to predator removal. Ungulate populations that are likely to experience additive mortality because of predation exhibit certain demographic cues. For example, if a population of ungulates is comprised of animals in good physical condition that generally exhibit relatively high pregnancy rates, larger average litter sizes, and heavier birth weights, then predation mortality is likely to be additive. Conversely, ungulate populations comprised of animals that are in poorer physical condition and exhibit lower pregnancy rates, smaller average litter size, and lower birth weights are more likely to be mainly habitat limited. Predation mortality in these populations is more likely to be compensatory (Bowyer et al. 2005).

Within this context, it is important to consider predator management or research that gives insights into:

- habitat, prey, or predator population characteristics that indicate predator control may effectively improve bighorn sheep population demographics;
- efficiency of control efforts, given the benefit that may be derived from them;
- the most effective means of controlling predators to reduce the effects of predation on bighorn sheep; and
- secondary effects that might be expected to result from predator control efforts.

In summary, the effect of predation on bighorn sheep populations is complex and dependent on many factors including multi-prey species availability, population numbers and density of both bighorn sheep and predators, multi-predator systems, individual predator behavior, disease, and habitat. Research has shown that mountain lions can have population-level effects on bighorn sheep in some circumstances. Studies evaluating the effect of lion removal on bighorn populations in other states have shown positive results in populations with high ewe and lamb mortality from lions.

Predator Management Directions

Management Direction — Implement the Predator Management Policy when evidence indicates that predation is a major cause of bighorn sheep populations failing to meet state management objectives.

> Strategy: Focus predator reduction programs in specific areas for targeted time periods to ensure the long-term survival of bighorn sheep populations.

TRANSLOCATION

Translocations have been very important in restoring bighorn sheep to areas where they were extirpated in Idaho. Currently, most areas in Idaho that do not have bighorn sheep are either not suitable habitat or another factor (e.g., management to prevent disease) precludes reestablishment of the species. Consequently, most recent translocations were conducted to augment existing populations, either to increase numbers and speed population growth, or to encourage range expansion (Appendix C). However, translocations into unoccupied habitat may still occur in response to changing habitat conditions or risk factors.

Successful translocations lead to the establishment of self-sustaining populations, or to increasing the size, growth rate, genetic diversity, or occupied range of existing populations (Griffith et al. 1989, Roy and Irby 1994). While translocations have been an important tool in restoring bighorn sheep and other wildlife populations, they are expensive, pose risks to animals and humans, and are not always successful. The following guidelines are intended to build upon knowledge gained through many decades of translocations to increase the chances of success of bighorn sheep translocations in Idaho. As new information becomes available, it will be incorporated into these guidelines.

Factors correlated with enhanced success of native wildlife translocations generally include release of wild-caught rather than captive- reared animals; sourcing animals from an increasing source population; good or excellent habitat at release site, which is often associated with release into core rather than peripheral historical range; and removing causes of the original decline (Griffith et al. 1989, Wolf et al. 1996, Fischer and Lindenmayer 2000). Success of bighorn sheep translocations (Roy and Irby 1994, Singer et al. 2000*b*, McKinney et al. 2006*a*) has generally been correlated to:

- habitat suitability at the release site (including factors associated with disease and predation risks);
- health and ecological characteristics of the source and destination (if

augmentation) populations; and

- minimal or no additive mortality due to predation. This is typically facilitated by an abundance of alternate prey sources and/or a low density of predators, primarily mountain lions.

In addition to these factors, capture technique (Roy and Irby 1994) and number of animals released (Kormers and Curman 2000) have been suggested as possible factors affecting translocation success.

Habitat Guidelines for Translocation

Habitat Quality and Quantity

The quality and quantity of suitable habitat is one of the single most important factors affecting the success of wildlife translocations. Habitat includes not only vegetative and physical characteristics, but also factors especially important to the success of bighorn sheep translocations including predation risk (Kamler et al. 2002, Rominger et al. 2004, McKinney et al. 2006*a*) and risk of introduction of infectious disease (Zeigenfuss et al. 2000).

Prior to any translocation, a geographic information system (GIS)-based habitat evaluation should be conducted, followed by an on-site visit by a regional biologist, and several individuals with professional bighorn sheep habitat expertise. Extent, distribution, and quality of potential habitat, including seasonal habitats and migration routes, should be evaluated and used to estimate the bighorn sheep population size the habitat could support. The GIS evaluation of the desired physical attributes should include known distribution of domestic sheep and goats. Layers available for GIS evaluation (e.g., USFS and BLM allotment boundaries) may not include all domestic sheep and goats, especially those on private lands, so a regional biologist should map any additional locations. No bighorn sheep should be released in areas of known overlap to limit contact with domestic sheep and goats, or other bighorn sheep populations known to have acute or chronic pneumonia-caused mortality.

Proximity to Domestic Sheep and Goats

Singer et al. (2001) and Singer et al. (2000*a,b*), found a direct negative correlation to persistence and performance of translocated bighorn populations to their proximity to domestic sheep and goats. Translocated populations have shown high probabilities to dispersion across permeable barriers and areas of non-habitat to patch habitats that resulted in increased risk of contact. The Payette National Forest, during their forest plan amendment for domestic sheep and goat grazing in bighorn sheep habitat (USFS 2010), conducted a risk of contact assessment and found that individual forays (mostly males) may extend as far as 35 km from core population home ranges. This foray behavior demonstrates that although the 16–20 km (Singer et al. 2000*a,b*) and 23 km (Zeigenfuss et al. 2000) of separation of core habitat from domestic sheep and goats previously used may reduce the risk of contact, they are insufficient to prevent the risk in entirety. Instead, the 40 km of separation proposed by Monello et al. (2001) may be more appropriate. Therefore, no bighorn sheep should be translocated into locations where core habitat falls within 35 km of known domestic sheep or goats. In addition, 35 km should be used as a minimum distance and a site-specific analysis that looks at factors such as habitat composition, continuity, and barriers to movement should be conducted and may lead to a different recommendation.

Water Accessibility

It is recommended that all bighorn sheep be released into areas with water sources ≤3.2km from escape terrain (Whiting et al. 2010, 2012). If water is a limiting factor based on the GIS evaluation, a regional biologist may be able to provide additional information on water availability not captured by the GIS.

Predation

As outlined in the Predation section, recently translocated populations of bighorn sheep can be vulnerable to mountain lion predation. In areas with high rates of mountain lion predation, the abundance of alternative prey species as well as the amount and distribution of escape terrain relative to forage and water need to be considered prior to translocation. Regional wildlife staff should be consulted to evaluate potential impacts.

Population Guidelines for Translocation

Native Populations

The Salmon River drainage in central Idaho contains native (never extirpated) populations comprising the largest numbers of bighorn sheep in the state. These animals represent an irreplaceable genetic and ecological resource unique to Idaho. Native bighorn sheep populations in general have greater genetic variability than reintroduced populations (Luikart and Allendorf 1996, Fitzsimmons et al. 1997) and may be more valuable as source populations for reintroductions (Singer et al. 2000*a*). The risk of detrimental genetic and ecological resource impacts to native populations should be considered prior to any translocation (see Genetics section for additional information).

Health

Mixing populations of wildlife through translocations involves an inherent risk of inadvertently spreading diseases that can have either short- or long-term consequences. Parasites such as scabies mites or diseases such as contagious ecthyma (orf, sore mouth) can be relatively benign in bighorn sheep populations that have developed immunity to them, but may cause, at a minimum, significant short-term impacts if introduced into naïve populations. Exposure to respiratory or other serious disease agents (e.g., Movi, see Heath Assessment and Management section) can have long-term, serious consequences and any disease introduction can set back rather than further population restoration. While some diseases may be visually apparent, others may be transmitted through asymptomatic carriers. Treatments are currently unavailable to effectively prevent or mitigate disease agents in free-ranging bighorn sheep.

Assessment of the health histories of both source and resident populations that translocated bighorn sheep may encounter will be conducted prior to making decisions about translocation. If these data are not available, the translocation should not be conducted. Translocations for the purpose of range extension of an existing population may be an exception if they are unlikely to contact any other populations due to distance or likely barriers to movement. Mixing source populations is not recommended due to increased risk of disease exposure.

Supplementing bighorn sheep populations that have performed poorly because of pneumonia-caused mortality has not been shown to be successful. In these situations, translocated sheep are more likely to die from disease than resident sheep and lamb recruitment does not differ among resident and translocated animals (Enk et al. 2001, Cassirer and Sinclair 2007), thus no population growth occurs. This is likely due to immunologically naïve translocated animals being exposed to endemic pathogenic organisms in the resident population (Cunningham 1996). Likewise, if mountain lion predation is limiting a population, adding more bighorn sheep will not likely be beneficial.

Data on population dynamics and causes of mortality in a stagnant or declining recipient population are needed prior to consideration of supplementation. Similar information is needed for the source population. Populations with a recent (within 10 years) history of respiratory disease or autumn ratios of <25 lambs:100 ewes should not be considered as source or recipient populations. If these data are not available, then no translocations should be considered. If an initial supplement is unsuccessful, no further supplements will be undertaken until the problem is identified and remedied.

Numbers and Source Populations

Several studies have suggested that more animals increase the likelihood of translocation success (Griffith et al. 1989, Wolf et al.1996, Kormers and Curman 2000). This relationship generally has an upper limit depending on the species and increasing the number only enhances success to a certain point. Kormers and Curman (2000) suggested a minimum release size of 20 ungulates and a sex ratio of 1:1; however, many states typically include only 0.25–0.33:1 male to female in bighorn sheep translocations. Younger males are often preferred for translocations due to difficulties associated with transporting larger rams.

Finally, in general, animals do best when they are physiologically and genetically adapted to their environment. A minimum of 20 animals should be translocated to a new site, although fewer can be used for augmentation or range extensions. Habitat at source and release sites should be similar and as close as possible geographically.

Monitoring

All translocated animals should be marked with a tag in ≥1 ear. All animals moved should also be radio-marked. If all animals cannot be radio-marked, then at least 50% of females and all adult males should be marked. Radio collars should be individually identifiable with vinyl or plastic, colored, alphanumeric markers.

Where possible, animals should be monitored ≥1/week for the first month post-release, ≥1/month for the first year, and ≥2/year for the life of the animals or the radio collars. A population monitoring program should also be implemented to assess if translocation goals were achieved, and a progress report should be written within 3 years post-release to help improve and adapt the translocation program. These expenses should be included in the cost of the translocation project.

Prioritization for Translocation

A case-by-case evaluation will occur for all proposed translocations. This evaluation will address several factors including an assessment of the overarching population goals of the translocation, predicted suitable habitat, extent and juxtaposition of seasonal habitat types, risk of contact with domestic sheep and goats, predation risks, population characteristics, land ownership, and social acceptance. Translocations will be prioritized by IDFG based on proposals containing a justification for the translocation, expected outcome, and the case-specific evaluation.

Idaho Code for Translocation

All bighorn sheep translocations will be conducted in accordance with existing legislation and policy. Idaho Code 36-106 requires notification of county commissioners, federal and state land grazing permittees, and private owners or leaseholders of land in or contiguous to the proposed release site prior to a translocation. The president pro tempore of the Senate and the speaker of the House of Representatives shall also receive a translocation plan from the director of IDFG. Any affected individual or entity can request a hearing within 10 days of notification of the proposed translocation and a hearing shall be scheduled within 30 days of the request. IDFG will develop an agreement with other cooperating agencies and private entities to protect existing domestic sheep or livestock operations if there are any federal or state lands grazing permittees or owners or leaseholders of private lands that may be affected by a translocation. Title 36-408 states that no auction tag funding may be used for translocations south of the Snake River and west of US 93. A press release will be issued prior to any wildlife capture or translocation.

Translocation Management Directions

Management Direction — Maximize the likelihood of translocation success at establishing or augmenting bighorn sheep populations, consistent with Idaho Code.

> Strategy: Use the habitat and population guidelines established above to evaluate potential translocations.
>
> Strategy: Use source populations from within Idaho that are adapted to Idaho's climatic conditions whenever possible.
>
> Strategy: Match source and destination habitat and elevation.
>
> Strategy: Evaluate genetic information from source and destination populations.
>
> Strategy: To maintain the unique genetic identity of Idaho's native Rocky Mountain bighorn sheep, native genetic stock should be used for translocations in or adjacent to native populations (e.g., Lower Salmon, Middle Fork Salmon, Middle Main Salmon, Lower Panther–Main Salmon, East Fork PMUs).

Strategy: Evaluate individual population health histories of source, destination, and adjacent (if any) populations to reduce or eliminate potential transfer of pathogens from one location to another.

Strategy: Develop and implement a short- and long-term post-release monitoring protocol to determine the success of the translocation operation to include an assessment of population persistence and productivity.

Strategy: IDFG will not translocate bighorn sheep into areas where they are likely to contact domestic sheep or goats.

HARVEST MANAGEMENT AND MONITORING

Bighorn sheep are one of the most sought-after game species in North America, as evidenced by extremely high demand for limited hunting opportunities. Bighorn sheep hunting offers a unique experience, generally requiring significant effort in rugged, remote country. Because of the unique often once-in-a-lifetime opportunity, harvest is generally managed under a conservative framework to provide a high-quality experience.

Harvest Management

Over the last 85 years, ram tags and harvest have varied considerably with changes in populations (Figure 12). Disease-related die-offs that have impacted large portions of Idaho's bighorn sheep populations typically resulted in large reductions in tag levels, followed by slow increases in tags as populations recovered.

Beginning with the 1991–95 bighorn sheep management plan, hunting was not recommended unless a population was estimated at >100 animals. This criterion is likely appropriate for most healthy bighorn populations because most populations in Idaho function as components of larger metapopulations. However, a 100-animal minimum may preclude legitimate ram-only harvest opportunities in some smaller populations where habitat carrying capacity prevents achieving minimum population size or risk of catastrophic, all-age die-off is high.

In Idaho, harvest was restricted to ¾-curl or larger rams from 1970–1983 and ¾-curl or larger rams or rams >4 years old (≥3 annual growth rings on horns) from 1984–2006. The addition of the annual growth ring criterion was designed to allow harvest of older rams with broomed horns, California bighorn rams with widely flared horns, or older rams that did not attain ¾-curl horn length. In 2007, regulations were changed to allow harvest of any ram. This change simplified regulations, allowed hunters to define their own hunting experience, and reduced enforcement problems. Since 1994, this change had no effect on the average age of harvested rams in Idaho.

Since 1991, management direction is to set tag levels so that harvest is ≤20% of class III and IV rams (¾-curl or larger) observed during the most recent survey for each hunt area. This conservative harvest strategy ensures adequate mature rams for harvest and biological-behavioral requirements (social dominance hierarchy, genetics, mature male:female ratios, etc.). Average hunter success rates are typically incorporated in determination of appropriate tag levels. For example, given comparable numbers of harvestable rams, tag levels for hunts in which long-term success rates average 33% can be 3 times greater than for hunts where hunter success approaches 100%.

Current timing of bighorn sheep seasons avoids hunting during the breeding season. Most bighorn sheep seasons start 30 August and continue until 8 October for California bighorns and until 13 October for Rocky Mountain bighorns. Some late-season hunts exist; for example, some hunts for Rocky Mountain bighorns extend through 31 October. Depending on the hunt area, a split- or late-season structure is employed to provide a high-quality hunting experience (few hunters, greater opportunity for mature rams), address hunter density issues, or offer hunting opportunity for bighorns migrating into Idaho.

Reduction of ewe numbers may be necessary when sheep numbers have increased above population objectives, including when habitat degradation is possible due to overpopulation or bighorn sheep move into habitat with an increased risk of contact with domestic sheep and goats. Removal of ewes can be accomplished through capture and translocation (in-state or to other jurisdictions) or regulated harvest. Ewe removal is generally not recommended when populations are below habitat carrying capacity, newly reintroduced, or suppressed by a mortality factor (e.g., disease). In populations with a history of pneumonia, ewe removal is usually restricted because population growth following a die-off is often slow and density independent, and ewe removal would likely be additive to other mortality.

Under Idaho Code 36-408, 2 special bighorn sheep tags are set aside each year; 1 to be auctioned and 1 raffled by a qualified conservation organization via a bid system. Winners can hunt in any open bighorn sheep hunt in the state, except for GMU 11 (North Hells Canyon PMU), which alternates between auction (odd years) and raffle (even years) tag holders. Net proceeds generated from the tag auction are dedicated to "bighorn sheep research and management purposes" (except translocation of bighorn sheep in southwest Idaho), whereas raffle tag net proceeds must be used for "solving problems between bighorn sheep and domestic sheep, solving problems between wildlife and domestic animals, or improving relationships between sportsmen and private landowners by being utilized in the veterinarian program."

All bighorn sheep hunting in Idaho is allocated via a controlled hunt (random drawing) system. Prior to 1971, bighorn sheep were hunted and managed under a combination of controlled hunts and a general season framework. Currently, nonresidents are limited to ≤10% of all bighorn sheep tags and not more than 1 nonresident tag can be issued for controlled hunts with ≤10 tags (≤10% to nonresidents in hunts with >10 tags). Chances of obtaining a bighorn tag generally declined over time as interest and demand have increased, particularly for nonresidents (Figure 13). In addition to state-permitted hunting, Native Americans harvest bighorn sheep under provisions of various treaties. Tribal hunting regulations and harvest levels are generally not available to IDFG.

From 1975 to 1985 hunters were allowed to harvest only 1 bighorn sheep in their life (excluding sheep harvested before 1974). Beginning in 1986 the lifetime bag limit was expanded to allow harvest of 1 California bighorn and 1 Rocky Mountain bighorn. Ewes were excluded from lifetime limit restrictions beginning in 1991. Unsuccessful hunters may apply for another tag after a 2-year waiting period. Although current taxonomy suggests California bighorn sheep and Rocky Mountain bighorn sheep are a single subspecies, phenotypic differences are apparent and recent research suggests California and Rocky Mountain bighorn sheep are genetically different (see Genetics section).

Further, each type of bighorn sheep provides a unique hunting opportunity in distinctive habitat.

Currently, hunters are allowed to use any lawful weapon during controlled bighorn sheep hunts. Most bighorn sheep have been harvested with centerfire rifles and overall hunter success rates typically average 50–65%. However, success rates vary widely across hunt areas (20–100%) and type of bighorn sheep (2000–2019, Rocky Mountain approximately 58%, California approximately 77%). Because Idaho is a large state with diverse and contrasting habitats, many hunting opportunities exist for prospective bighorn sheep hunters. Many hunts have contrasting hunting and harvest expectations and provide distinct and often dissimilar sheep hunting opportunities. IDFG will continue to provide a diversity of hunting experiences in the state to meet the demands of hunters.

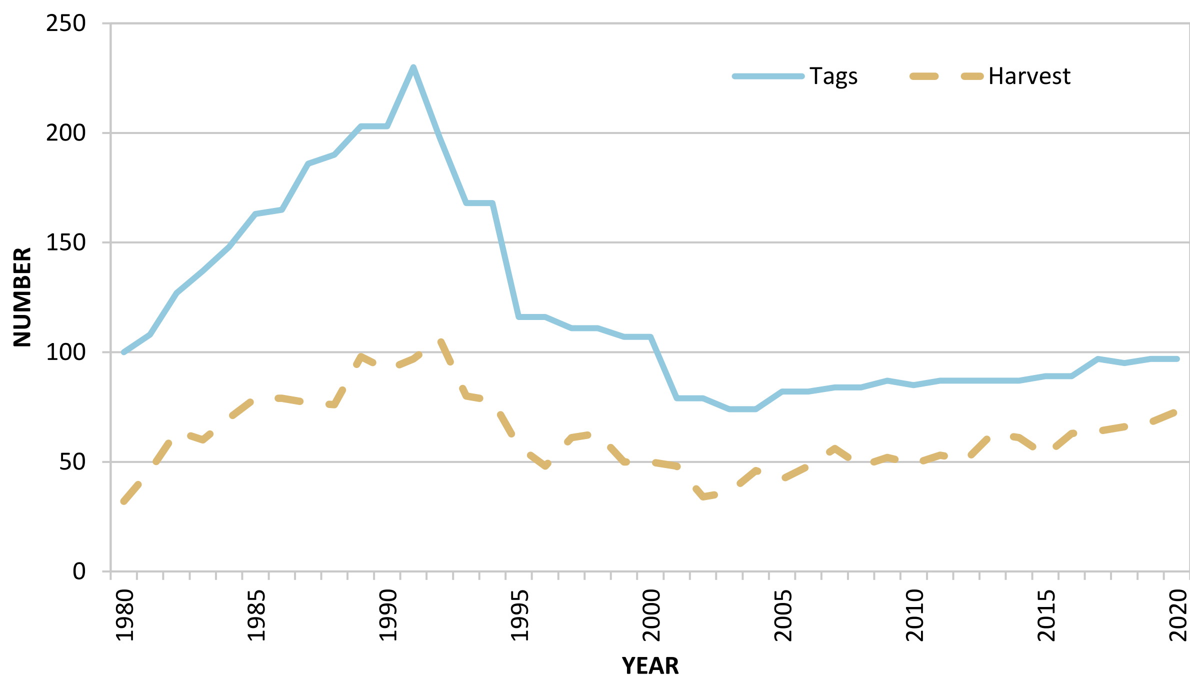


Figure 12. Bighorn sheep tags (actually issued) and harvest 1980–2020, Idaho.

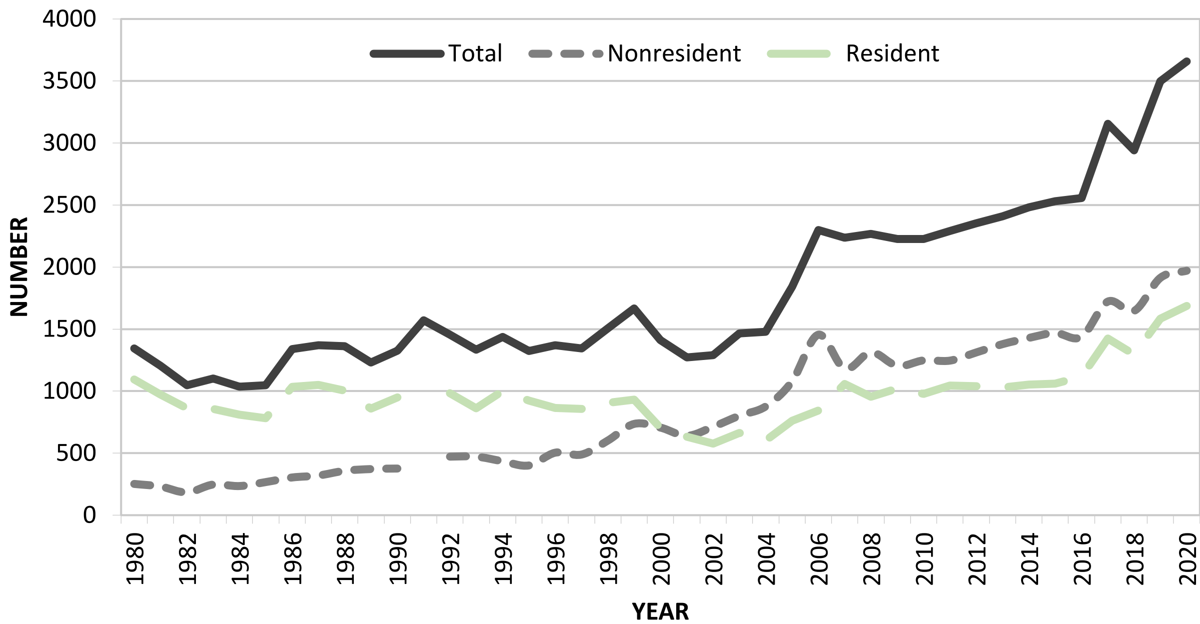


Figure 13. Resident, nonresident, and total number of applicants for bighorn sheep tags 1980–2020, Idaho.

Harvest Monitoring

Unsuccessful hunters are required to return unused tags to IDFG within 10 days of the close of their season. Successful hunters are required to present the horns of harvested rams at an IDFG regional office within 10 days of harvest. Information about the hunter (name, address, licensing), hunt (date, location, weapon, effort), and harvested animal (horn annuli and size) are recorded on a Big Game Mortality Report (BGMR). A uniquely numbered aluminum pin is placed in a hole drilled in a horn sheath and a sample of horn shavings resulting from the drilled hole are retained for DNA extraction. All information collected on BGMRs is entered in a statewide database. The same information and sample are collected from bighorn sheep found dead from other causes, except horns from ewes and small rams, and old, deteriorated horns are not pinned. Hunters who fail to turn in unused tags or check in harvested rams are contacted to ascertain results of their hunt.

Harvest Management Directions

Management Direction — Continue to manage Rocky Mountain and California bighorn sheep separately, with Rocky Mountain bighorn sheep north of Interstate 84 and California bighorn sheep south of Interstate 84.

Management Direction — Optimize hunting opportunity, hunter flexibility, and regulation simplicity.

> Strategy: Continue to allow Idaho hunters the opportunity to harvest 1 Rocky Mountain and 1 California bighorn sheep if successful in obtaining the appropriate tags.
>
> Strategy: Maximize harvest opportunity for rams in populations at high risk of all-age die-offs or in limited habitat. Consider allowing ram harvest in populations of <100 total sheep when:
>
> - range overlap with domestic sheep and goats has occurred regularly or is very likely to occur, or
> - analysis of habitat conditions and population performance indicate a population is unlikely to reach 100 individuals.
>
> Strategy: Maintain existing any-ram regulation.
>
> Strategy: Maintain current hunting season structure. Continue to offer early and late-season hunts, allowing applicants for tags to choose hunt periods from late summer until the period immediately preceding, but not including the "rut" or breeding season.
>
> Strategy: Maintain current any-weapon regulation which allows hunters to choose the type of weapon they wish to use.

Management Direction — Maintain the availability of mature rams by restricting harvest to no more than approximately 20% of the Class III and IV rams observed during the most recent survey or believed present based on the best judgment of the individual Regional Wildlife Manager (as some surveys may not be completed due to weather or other external influences).

Management Direction — Offer no more than 1 special bighorn sheep tag to be sold at auction annually and 1 special bighorn sheep tag to be offered by lottery annually, to raise funds to administer the bighorn sheep research, management, and health-monitoring programs.

Management Direction — Continue using hunter harvested samples to monitor health status. Encourage staff to collect tissue samples in addition to horn shavings to increase success of DNA extraction.

Management Direction — Provide training to anyone checking in bighorn sheep to correctly age and pin horns.

Management Direction — Use in-state translocation to manage ewe reduction when efficacious and translocation criteria are satisfied. Otherwise, establish ewe harvest seasons unless inter-jurisdictional obligations or need for out-of-state translocation are considered necessary for overall bighorn sheep conservation.

POPULATION MANAGEMENT UNITS

The following descriptions provide additional information on bighorn sheep distribution, populations, monitoring, harvest, current issues, accomplishments, and management actions in PMUs (see Figure 3). Boundaries of PMUs are based on current knowledge of bighorn sheep populations in these areas, including habitats, distribution, connectivity among populations, harvest, and other management issues. A PMU can be made up of single, multiple, or partial GMUs. Three of the PMUs (Lionhead, Palisades, and Pioneers) currently do not appear to have persistent bighorn sheep populations, only occasional sightings within their boundaries.

NORTH HELLS CANYON PMU

The North Hells Canyon PMU includes sheep in at least 2 distinct subpopulations in GMUs 11 and 14 and extends into GMU 8 (Figure 14, top). Extensive bighorn sheep habitat in this PMU consists of dry, bunchgrass vegetation and rocky cliffs along the Snake and Salmon River breaks and their tributaries. Land ownership in GMU 11 is primarily public along the Snake River and includes the IDFG Craig Mountain Wildlife Management Area (CMWMA). There are also several significant blocks of private land, including one of the primary lambing areas for the population which is protected by a conservation easement with IDFG. The Salmon River breaks in GMU 11 are mixed public and private ownership upriver of the CMWMA boundary. The BLM manages much of the river corridor along the Salmon River and most of the Snake River corridor is protected by conservation easements with the USFS. Road access into occupied sheep habitat is extremely limited in both GMUs. Bighorn sheep provide a valuable viewing resource for river recreationists in the Hells Canyon area.

In the 2010 Bighorn Sheep Management Plan, the “Hells Canyon” PMU was made up of what is now North Hells Canyon PMU and South Hells Canyon PMUs. Improved knowledge of bighorn sheep movements and genetics suggested that bighorn sheep in North Hells Canyon are distinct from those in South Hells Canyon. Furthermore, additional information from radio-marked animals and improved habitat modeling led to several boundary adjustments to better represent bighorn sheep habitat, distribution, and movements. The northeast portion of the North Hells Canyon PMU was expanded to include additional portions of GMU 14, and the southeast portion of South Hells Canyon PMU was reduced to exclude portions of GMU 22 with no bighorn sheep habitat or locations.

Historical Perspective

Bighorn sheep were native to Hells Canyon but were extirpated in the early part of the 20th century. The last-known native bighorn sheep in GMU 18 (South Hells Canyon PMU) was observed in 1932. Speculation at that time attributed the loss of bighorn sheep to over-hunting by miners for subsistence and disease outbreaks associated with domestic sheep contact.

In 1984, bighorn sheep were reintroduced into GMU 11 with a translocation of 17 bighorn sheep to Captain John Creek from Whiskey Basin, WY (Appendix C, Table C2). In 1995, North Hells Canyon experienced significant mortality from an all-age disease outbreak that started in Washington and spread through 5 populations (Cassirer et al. 1996). From 1996 – 2018 the population experienced intermittent adult mortality and poor lamb recruitment due to pneumonia-caused mortalities (Cassirer et al. 2013).

There were no surveys until 1992 when 57 animals were observed. The population was stable or slowly growing until the late 1990s when the population started increasing and reached 148 total sheep in 2002. Intermittent poor lamb survival from 1998 through 2008 and low adult survival in 2005 resulted in a decline to 109 bighorn sheep counted in 2010. The primary cause of mortality in recovered dead lambs and in adults that died in 2005 was pneumonia.

In 2013, IDFG research as part of the Hells Canyon Initiative (HCI) began working on test-and-remove (see Health section) in Asotin Creek, WA. The idea behind test-and-remove was the disease (Movi) was maintained in a population in a few individuals (super spreaders) that never cleared the disease but continually re-infected other population members, particularly lambs. Appearing to have been successful in Asotin Creek, the same technique was used in Hells Canyon in Idaho starting in 2017. By 2019 it was likely that sheep in the Idaho portion of Hells Canyon were Movi-free, but the captures to confirm it were not completed until 2020. Prior to clearing Movi in the Idaho portion of Hells Canyon, fall lamb-ewe ratios were routinely in the low teens and more than tripled post-Movi.

Since 2019 bighorn sheep populations in the North Hells Canyon PMU have been growing at a fast rate. Associated with this growth, bighorn sheep have pioneered new areas and dispersed out of the traditional use areas in GMU 11. Disease-free bighorn sheep populations may have different movement dynamics, and this may create new risks of reinfection or change how separation between domestic sheep and bighorn sheep populations is defined.

The HCI cooperators (Idaho, Washington, Oregon wildlife agencies and the 3 state chapters of the Wild Sheep Foundation) funded a position in the HCI study area to increase outreach, test animals, and promote best management practices for healthy, Movi-free domestic sheep flocks and goat herds. To date over 1,000 domestic sheep and goats have been tested in the HCI vicinity.

Hunting was initiated in GMU 11 in 1993. A controlled hunt with 2 tags was offered in 1993 and 1994. The likelihood of participation by the state auction and/or lottery tag holder in the GMU 11 hunt, as occurred from 1993–1996, led to a reduction in the number of tags offered in the hunt from 2 to 1 in 1995. In 1997, after the pneumonia outbreak, the hunt was closed through the 2000 hunting season. In 2001, when the hunting season was reinstated, the auction and lottery tags began the alternate rotation that continues today. Beginning in the early 2000s, GMU 11 hunt has consistently produced the largest rams taken statewide including many record book rams. The current Idaho state record bighorn ram was harvested from this GMU in 2020.

No bighorn sheep hunts have been offered in GMUs 8 or 14.

Issues

Disease has been the largest issue facing bighorn sheep in the North Hells Canyon PMU. The very low or nonexistent recruitment because of sporadic lamb die offs and pneumonia in adults is the reason populations in this PMU have not grown in the past. With the application of test-and-remove all populations in this PMU are currently disease free. In addition, they have experienced release from disease related reproduction issues and are currently experiencing robust population growth. High rates of reproduction and large body and horn size in bighorn sheep suggest forage is not limiting.

Management Direction

GMU 11 is the only area in the North Hells Canyon PMU that currently has a sheep population large enough to support a hunt (Table 5; Figure 14, bottom). The hunt in GMU 11 is the most sought-after sheep hunt in the state. The recipient of the auction and raffle tag (alternate years) have consistently hunted in GMU 11 and drawing odds are the most difficult in Idaho (0.22% in 2021). Despite relatively difficult access, hunter success is usually 100%. Hunting opportunity in GMU 11 will be managed to provide large mature rams and tag levels will depend on ram availability. Potential Movi-reinfection represents the largest threat to continued bighorn sheep hunting opportunity in this PMU.

Within current distribution, modeled habitat on public land comprises approximately 439 km^2, which could support approximately 834 bighorn sheep (assuming that all habitat is suitable year-round at bighorn sheep densities of 1.9 km^2). There is extensive lambing and year-round habitat in this PMU, but further refinement of habitat models could reduce estimates of available habitat and potential population size.

Invasive plants, especially yellow starthistle and cheatgrass, have become established in a significant portion of this PMU. Currently, IDFG is working with cooperative weed management groups and aggressively spraying weeds and using biological controls on IDFG managed ground to improve wildlife habitat. The invasion of cheatgrass and other annual grasses and forbs also appears to have increased the frequency of fire in the PMU and this may have long-term consequences.

Cooperation with wildlife agencies in Oregon and Washington, public land management agencies including USFS and BLM, and private individuals is necessary to manage habitat and bighorn sheep in the North Hells Canyon PMU.

The current objective in this PMU is to increase bighorn sheep populations.

Accomplishments, 2010–2021

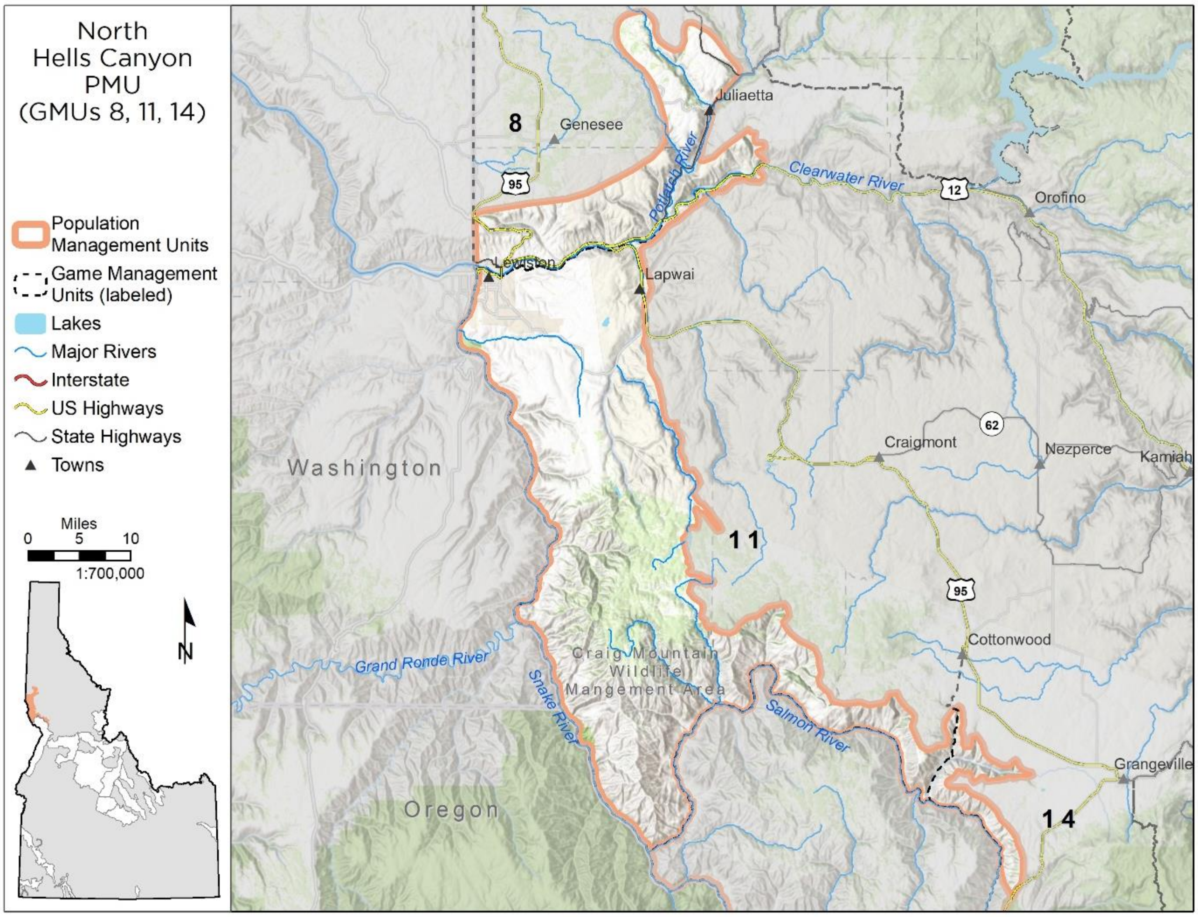
- Aerial and/or ground population surveys were conducted annually.
- A sightability model was completed for the Hiller 12E helicopter and incorporated into the Idaho Bighorn Sheep Survey Shiny App
- Health samples were collected by hunters.
- 130 bighorn sheep were captured, sampled, and marked in GMUs 11 (126) and 14 (4).
- Movi was cleared by 2018.
- A conservation easement restricting development, prohibiting grazing of domestic sheep and goats, and protecting habitat for bighorn sheep and other wildlife was purchased on the 2,919-acre Ten Mile ranch.

Management Actions

- Continue work with the Hells Canyon Initiative research.
- Improve bighorn sheep habitat by working to reduce invasive plants.
- Refine habitat modeling to characterize sustainable population levels more accurately.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 5. Minimum counts and estimated numbers of bighorn sheep from surveys in North Hells Canyon PMU since 2011.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Total Count	Model Est	Comments
2011	58	8	6	13	19	85	95	GMU 11; Helicopter survey
2012	63	8	9	11	20	91	100	GMU 11; Helicopter survey
2013	53	8	8	23	31	92	100	GMU 11; Helicopter survey
2014	50	10	7	14	21	81	90	GMU 11; Helicopter survey
2015	45	19	0	0	39	103	105	GMU 11; Helicopter survey
2016	76	10	5	17	22	108	110	GMU 11; Ground and Fixed wing
2017	64	4	10	15	25	93	95	GMU 11; Ground and Fixed wing
2018	42	25	14	20	34	101	138	GMU 11; Ground, mark-resight
2019	40	18	10	19	29	87	157	GMU 11; Ground, mark-resight
2019	3	0	2	0	2	5	-	GMU 14; Ground
Nov-Dec 2020	41	14	20	17	37	92	180	GMU 11; Ground, mark-resight
2020	3	3	3	0	3	9	-	GMU 14; Ground



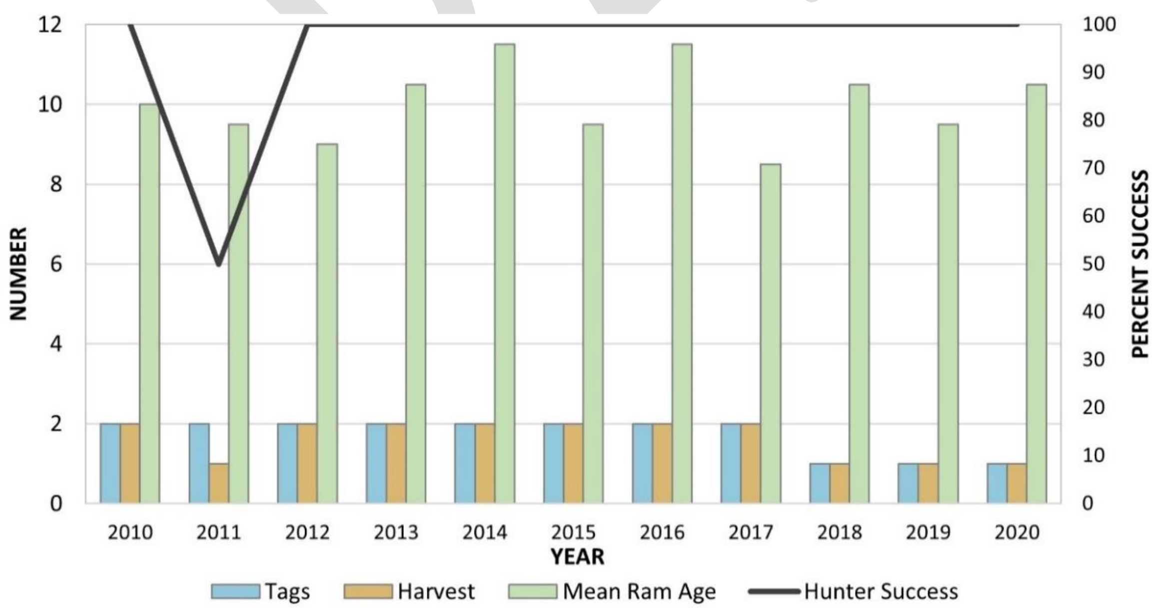


Figure 14. North Hells Canyon PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest reflects GMU 11 only except for 2017 and 2018 when GMUs 13 and 18 (South Hells Canyon) were included. Harvest may include rain checks, auction tags, or lottery tags.

SOUTH HELLS CANYON PMU

The South Hells Canyon PMU includes sheep in at least 3 populations in GMUs 13, 18, 22, and the western portion of 14 (Figure 15). Extensive bighorn sheep habitat in this PMU consists of dry, bunchgrass vegetation and rocky cliffs along the Snake and Salmon River breaks and their tributaries. The Salmon River breaks in GMU 13 and the western side of GMU 14 are predominantly in private ownership, although the BLM manages much of the river corridor along the Salmon River and most of the Snake River corridor is protected by conservation easements with the USFS. The USFS is the major land manager in the Snake River corridor portion of GMUs 18 and 22, which includes portions of the Hells Canyon National Recreation Area and Wilderness. Idaho Power manages the reservoirs and adjacent access sites in GMU 22 above Hells Canyon Dam. Road access into occupied sheep habitat is extremely limited in all 4 GMUs. Bighorn sheep provide a valuable viewing resource for river recreationists in the Hells Canyon area.

In the 2010 Bighorn Sheep Management Plan, this PMU included GMU 11 and was called "Hells Canyon". Improved knowledge of bighorn sheep movements and genetics suggested that bighorn sheep in GMU 11 are distinct from those in the GMUs in this PMU. For this plan, GMU 11 and a portion of GMU 14 are considered North Hells Canyon and the remaining GMUs are included in South Hells Canyon. Furthermore, additional information from radio-marked sheep and improved habitat modeling led to several boundary adjustments to better represent bighorn sheep habitat, distribution, and movements. The northeast portion of the PMU was expanded to include additional portions of GMU 14, and the southeast portion was reduced to exclude portions of GMU 22 with no bighorn sheep habitat or locations.

Historical Perspective

Bighorn sheep were native to Hells Canyon but were extirpated in the early part of the 20th century. The last-known native bighorn sheep in GMU 18 was observed in 1932. Speculation at that time attributed the loss of bighorn sheep to over-hunting by miners for subsistence and disease outbreaks associated with domestic sheep contact.

Bighorn sheep were reintroduced into Hells Canyon beginning with a translocation of bighorn sheep from the upper Salmon River into GMU 18 in 1975 and continued with releases in GMUs 13 and 18 through 2002 (Appendix C, Table C2). Since reintroduction, populations in GMUs 13, 18, and 22 have experienced significant mortality from all-age disease outbreaks. All populations have experienced intermittent adult mortality and poor lamb recruitment due to pneumonia-caused mortalities.

After translocations in 1997 and 1999, the GMU 13 population was estimated at a high of 45 animals in summer 2000. Disease outbreaks in adults between 2000 and 2003 due to scabies infection (2000) and pneumonia (2000–2003), and low recruitment of lambs (2000–2008) have resulted in a decline in this population. In 2021, only 23 bighorn sheep were observed in GMU 13 (Table 6).

Five translocations occurred in GMUs 18 and 22 from 1975–2002. Access is difficult and survey data are limited, however a high count of 87 sheep was tallied in 1982. Disease outbreaks were observed in 1983, 1991, and 2002. Since 1992 there have been 20–35 sheep observed in GMU 18. During the most recent survey, 19 bighorn sheep were observed in GMU 18 and none in GMU 22 below Hells Canyon Dam (Table 6).

Bighorn sheep translocated by the Oregon Department of Fish and Wildlife to the west side of the Snake River below Brownlee Reservoir (1990–1995), and above and below Hells Canyon Dam (1971–1999) periodically cross the river into GMU 22. The sheep released across from the extreme southern end of the GMU in 1990 and 1995 spend a significant portion of time in Dukes Creek. This population peaked at 76 sheep in 1998. In 1999 an all-age disease outbreak occurred, and the population failed to recover due to lack of lamb recruitment and sporadic chronic pneumonia mortality in adults. No rams or lamb recruitment were observed in this population following 2009. By 2015 only 3 ewes remained, and repeated testing indicated disease was persistent in all 3 animals. These remaining ewes were captured in February 2015 and sent to a captive facility at South Dakota State University. There is currently no resident bighorn sheep population south of Hells Canyon dam.

Hunts were offered in GMU 18 beginning in 1984. Tag levels were reduced in subsequent years concurrent with the population decline. The hunt was closed in 1993. In 2017 and 2018, GMUs 13 and 18 were included in the GMU 11 hunt area. However, following 2018 these GMUs were removed from the hunt area, and hunts have not been offered in these GMUs in subsequent years.

Issues

Disease has been the largest issue facing bighorn sheep in the Hells Canyon PMUs. The very low or nonexistent recruitment because of sporadic lamb die offs and pneumonia in adults is the reason populations in these PMUs have not grown. No populations in these PMUs are currently affected by disease, but they remain small. Increases in elk herds in this PMU could theoretically cause increased competition, but currently little spatial overlap is observed. High rates of reproduction and large body and horn size in bighorn sheep suggest forage is not limiting.

Management Direction

This PMU will be managed solely for population growth until such a time when hunting can be offered.

Within current distribution, modeled habitat on public land comprises approximately 709 km^2, which could support approximately 1,347 bighorn sheep (assuming that all habitat is suitable year-round at bighorn sheep densities of 1.9 km^2). There is extensive lambing and year-round habitat in this PMU, but further refinement of habitat models could reduce estimates of available habitat and potential population size.

Invasive plants, especially yellow starthistle, have become established in a significant portion of this PMU. Currently, IDFG is working with cooperative weed management groups and aggressively spraying weeds and using biological controls on IDFG managed ground to improve wildlife habitat.

Cooperation with wildlife agencies in Oregon and Washington, public land management agencies including USFS and BLM, and private individuals is necessary to manage habitat and bighorn sheep in the South Hells Canyon PMU. The current objective in this PMU is to maintain or increase bighorn sheep populations.

Accomplishments, 2010–2021

- IDFG has continued to participate in the Hells Canyon Initiative (HCI). Since 2010, HCI collaborators have published over 15 scientific articles focused on bighorn disease and management in peer reviewed journals.
- As noted above, as part of this planning process IDFG used additional location data on radio-collared bighorn sheep to improve habitat modeling statewide.

Management Actions

- Continue work with the Hells Canyon Initiative research.
- Work with BLM, USFS, and others to improve bighorn sheep habitat by working to reduce invasive plants and limit forest encroachment.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 6. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in South Hells Canyon PMU since 2014.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
2014	13	4	3	7	11	0	28	
2015	16	6	6	10	16	0	38	
2016	12	6	4	6	10	0	28	
2017	16	9	0	0	13	0	38	
2018	13	3	3	9	12	0	28	
2019	17	5	5	9	14	0	31	
2020	19	10	4	8	12	0	39	
Dec 2020, Feb 2021	16	6	8	12	20	0	42	GMU 13 and 18; aerial and ground

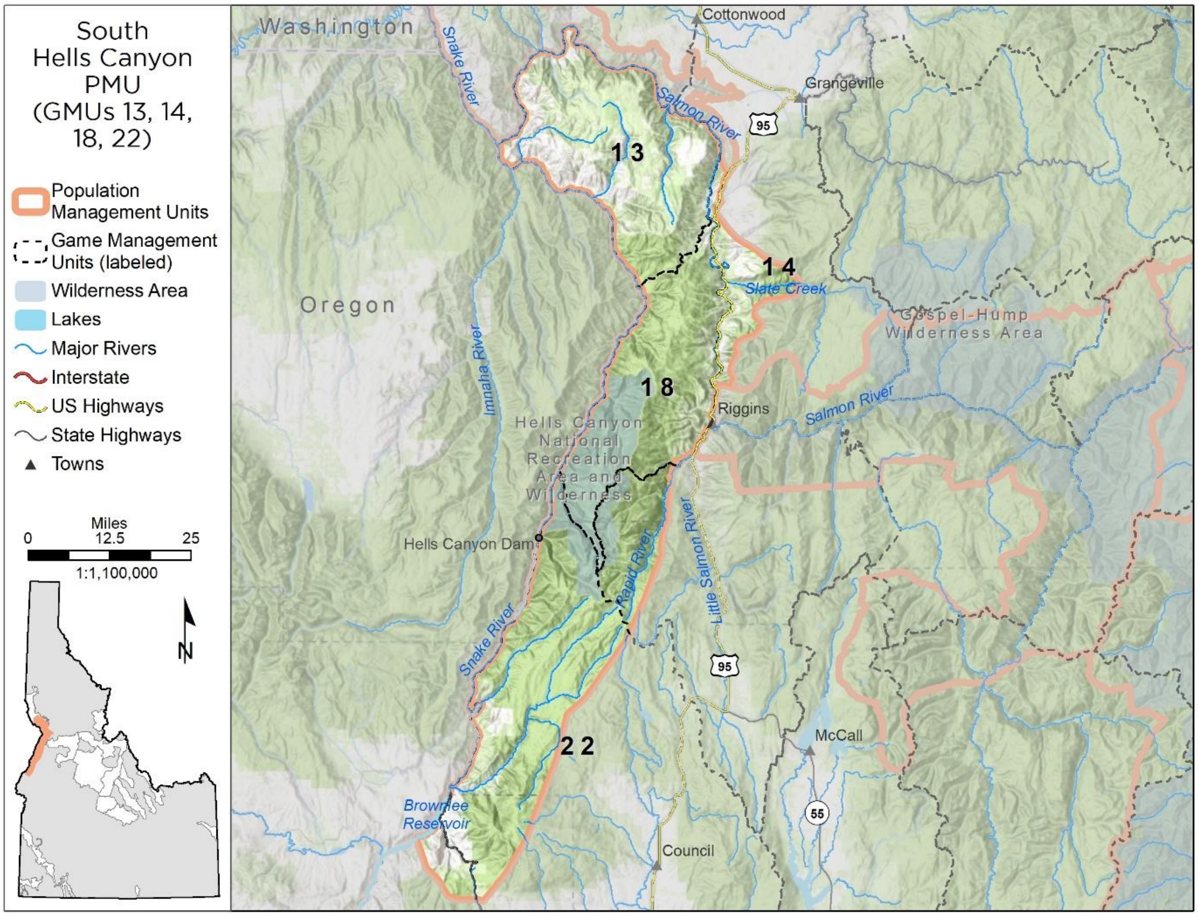


Figure 15. South Hells Canyon PMU area map.

LOWER SALMON RIVER PMU

The Salmon River PMU includes GMUs 14, 19, 19A, 20 (western portion), 20A (western portion), 23, 24, and 25 (Figure 16, top). Bighorn sheep habitat in these GMUs consists of dry, bunchgrass habitat types along the Salmon River breaks and some high elevation, alpine summer habitat. Habitat along this river corridor is primarily under USFS ownership with the eastern portions of this PMU occurring within the Gospel Hump and Frank Church-River of No Return Wilderness Areas. Habitat also occurs on some BLM land and small in-holdings of private land. Road access is extremely limited except for the Salmon River Road downstream of Vinegar Creek (primarily in GMU 14).

As part of this plan revision, the area of this PMU was reduced by a little over 105,000 acres based on improved knowledge of bighorn sheep habitat, distribution, and movements.

Historical Perspective

Bighorn sheep are native to these GMUs and were not extirpated in the early 1900s. No reintroductions or augmentations have occurred in the PMU.

Beginning in 1952 and lasting until 1970, bighorn sheep hunting in the Lower Salmon River PMU was offered on a general hunt basis. From 1971 to present, all sheep hunting in these GMUs has been by controlled hunts. Season structure and tag levels were modified starting in 1993 to reflect the decline in total numbers of sheep and lamb recruitment. Currently, there are two hunts offered in this area. Hunt Area 19 consists of portions of GMUs 14, 19 and 20 and has 4 tags. Hunt Area 19A consists of portions of GMUs 19A and 20A and has 3 tags.

Issues

Bighorn sheep have usually been surveyed by helicopter coincidentally with elk sightability surveys. Total numbers of bighorn sheep observed during surveys have declined in GMUs 19 and 20 since the early to mid-1980s. These surveys have yielded conservative bighorn sheep population estimates for this PMU.

In GMU 19, between 122 and 136 bighorn sheep were observed during 1983 and 1984 surveys. However, only 40–60 were observed on surveys between 1992 and 2007. Beginning in 2010, surveys have been flown specifically for bighorn sheep. These surveys have indicated between 115 and 133 bighorn sheep in GMU 19. The more recent data likely reflect improved survey methods, rather than an actual change in the population. Similar trends have been observed in GMUs 19A and 20A (Table 7). Overall, the bighorn sheep population in this PMU has been stable to increasing during the past decade.

Low recruitment rates and declines in sheep numbers in portions of this PMU may have been caused by disease and habitat conditions. Population numbers have dwindled in the western portion of this PMU (GMU 14) that is closest to active domestic sheep allotments. Respiratory disease has resulted in low lamb survival in adjacent populations along the Salmon River.

During 2010–2011, we monitored approximately 60 radio-marked bighorn sheep distributed throughout the PMU to collect movement, distribution, and habitat use data. In 2020, we radio-collared 15 bighorn sheep as part of a pilot study to assess test-and-remove as a potential disease mitigation strategy. Location data from radio-marked sheep were used to inform improved habitat modeling and refine PMU boundaries for this plan.

Dissatisfaction with the results of conducting bighorn sheep surveys in conjunction with elk surveys led to trying the Hells Canyon sightability model in the Lower Salmon River PMU. Although it did not perform well in the first attempt, refinement of the model for this PMU is in progress.

Management Direction

There are two hunts in the Lower Salmon River PMU, which encompass only a portion of the total PMU. Hunt Area 19 consists of portions of GMUs 14, 19, and 20. Hunt area 19A consists of portions of GMUs 19A and 20A. These hunts will continue to be managed primarily to maximize bighorn sheep hunting opportunity. Over the past 10 years, hunter success has averaged 86.5% across these two hunts (Figure 16, bottom). Bighorn sheep in this PMU will continue to be monitored for impacts from disease and conflicts with domestic sheep operations.

In this PMU the current management strategy for bighorn sheep is to manage for separation from domestic sheep and goats using BMPs as outlined in the health section of this document. The BMP agreements will be evaluated periodically and adjusted as necessary to try to achieve this goal.

Within current distribution, modeled habitat on public land comprises approximately 1,004 km^2, which could support approximately 1,907 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9 km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat. Thus, further refinement of habitat models and available habitat will likely reduce the estimate of potential population size. The current objective in this PMU is to maintain or increase bighorn sheep populations.

Accomplishments, 2010–2021

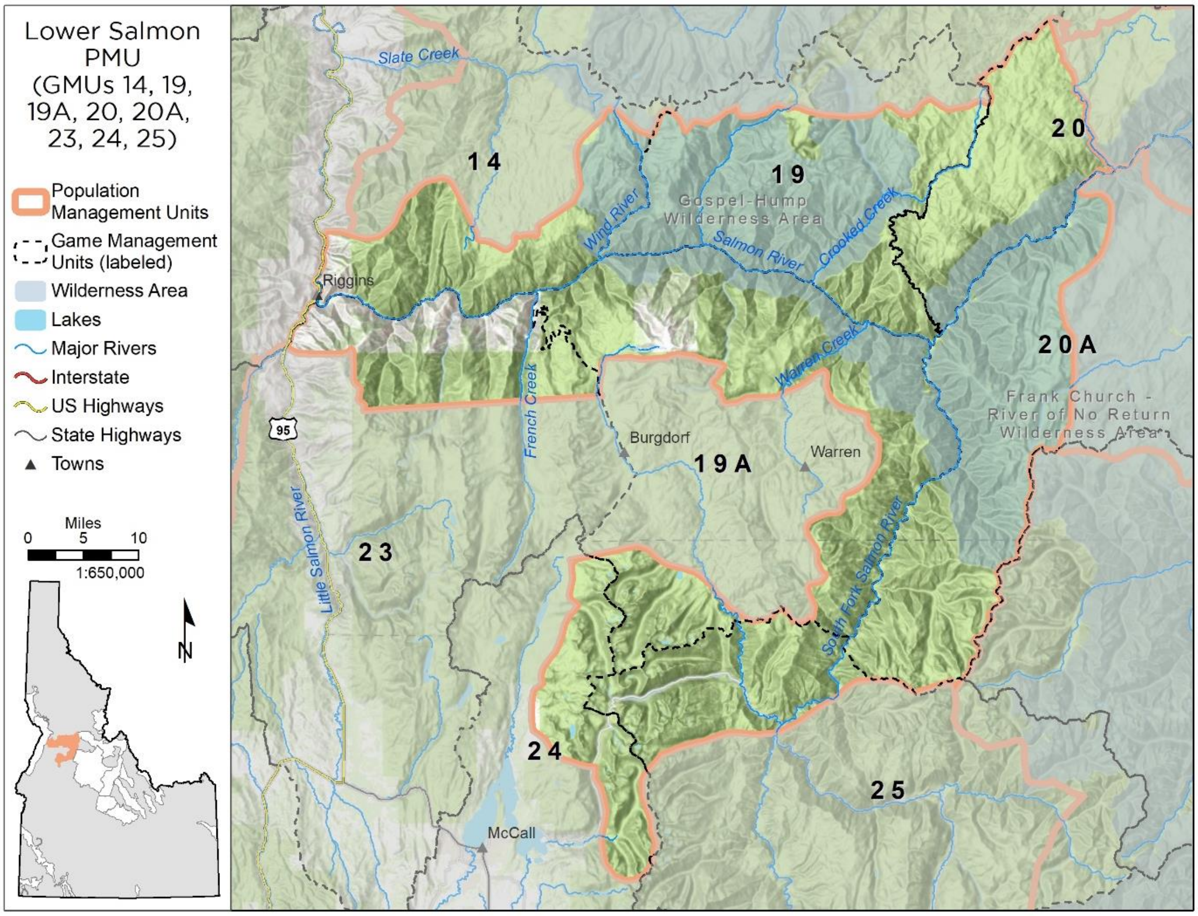
- During development of the previous plan, work was already underway to radio-collar and monitor bighorn sheep in this PMU. Between 2007–2012, 74 radio collars were deployed on bighorn sheep, with the primary intent of monitoring movements, determining connectivity among populations, and determining overall patterns of distribution and habitat use (see Borg et al. 2017).
- A sightability model for the Bell 47 helicopter was developed 2010 – 2013, is currently being refined, and will be incorporated into the Idaho Bighorn Sheep Survey Shiny App.
- Beginning in 2020, 15 bighorn sheep were captured, sampled, and radio-collared as part of a pilot study to determine the efficacy of test-and-remove as a disease mitigation tool.
- Habitat modeling was revised statewide as part of this planning process.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Initiate research efforts to gain more knowledge of how test-and-remove can be used to manage disease in populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Table 7. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Lower Salmon PMU since 2011.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Mar 2011	173	40	25	47	72	0	285	GMUs 14, 19, 20 (west), 19A/20A
Feb 2012	190	49	24	53	77	0	316	GMUs 14, 19, 20 (west), 19A/20A
Mar 2013	208	63	26	53	79	0	350	GMUs 14, 19, 20 (west), 19A/20A
Mar 2019	228	67	42	72	114	0	418	GMUs 14, 19, 20 (west), 19A/20A



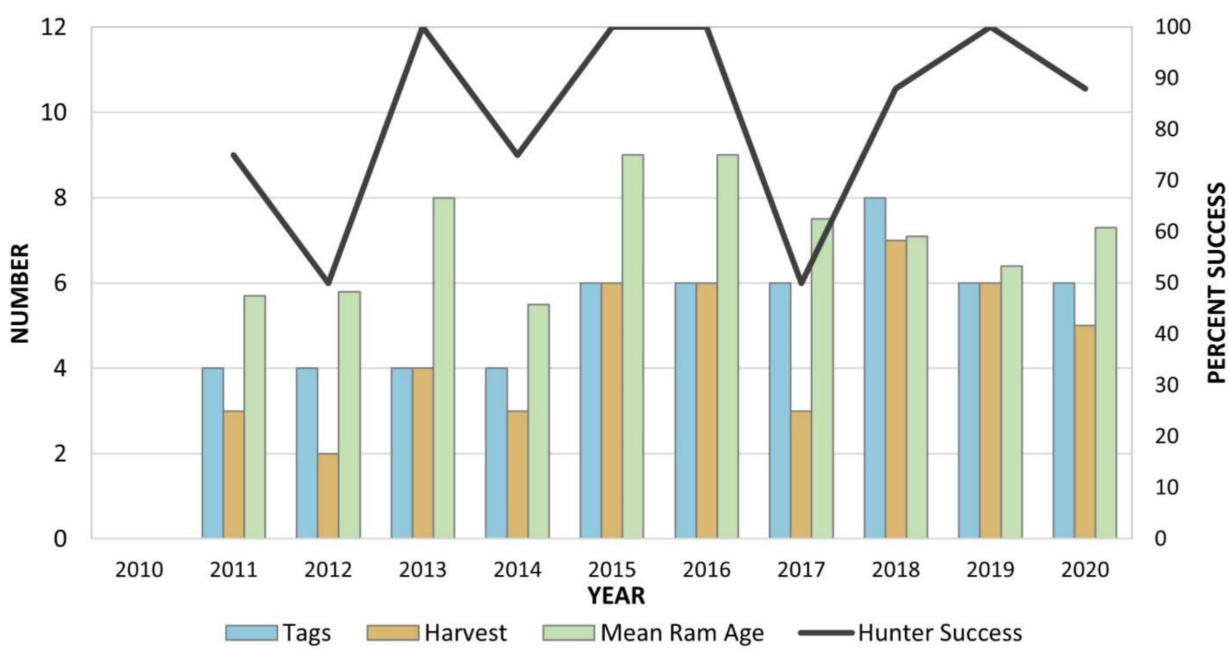


Figure 16. Lower Salmon River PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

SELWAY PMU

The Selway PMU includes the upper portion of the Selway River drainage in GMU 17 (Figure 17, top). Bighorn sheep occurred naturally in this area. Sheep in GMU 17 move between Idaho and Montana. Summer range lies along the border of the 2 states, with most animals moving down into Idaho to winter (between Indian Creek and White Cap Creek and on the east side of the Selway River). In some years, some of these sheep may winter in Montana. Sheep marked by Klaver (1978) were observed in both states over several years.

Sheep habitat in GMU 17 consists of dry, bunchgrass habitat types. Land ownership is almost entirely USFS, with just a few small in-holdings of private land. The area is encompassed by the Selway-Bitterroot and Frank Church - River of No Return Wilderness Areas. The only road access in this area is provided by USFS roads 468 and 6223, which run from Nez Perce Pass on the Idaho-Montana border down Deep Creek to the Selway River and downstream along the Selway to White Cap Creek.

Historical Perspective

In February 1989, a total of 29 bighorns from Morgan Creek in GMU 36B were translocated into 2 sites along the Selway River in GMU 17 (Appendix C). Both releases were made outside of currently occupied bighorn range within the GMU. Recent surveys and observations have suggested that neither translocation was successful.

Most bighorn sheep surveys have been conducted by helicopter coincidental to elk sightability surveys in January or February. Bighorns have been counted in GMU 17 since 1981. The highest counts were obtained in 1982, 1983 and 1984, and were 121, 99 and 109 total sheep, respectively. From 1985 to 2007, counts ranged between 26 and 52 total sheep. However, the survey methodology used may not have accurately reflected population status as they were conducted incidental to elk surveys. Surveys have not been conducted in the Selway PMU since 2007.

Bighorn sheep were hunted under a general season framework in the Clearwater Region between 1952 and 1970. This season framework allowed more accessible populations to be overexploited. The general season bighorn sheep hunt was discontinued in this PMU in 1971, and no hunting occurred in the Selway PMU until 2007 when a new hunt with 1 tag was initiated as Hunt Area 17L. The late timeframe of this hunt (14–31 October) was established to ensure enough time for bighorns to move from their summer range on the Idaho-Montana border back into Idaho where they would be available to Idaho hunters.

Issues

Low lamb survival and recruitment rates have been an issue in some years since the early 1980s. The timing and causes of this low survival are poorly understood.

The largest issue currently affecting management of sheep in this PMU is the lack of information, particularly regarding disease status. In recent years Montana Fish, Wildlife & Parks captured and tested a bighorn sheep near Blue Joint Creek, MT (<5 mi southeast of Selway PMU) and it tested positive for Movi. The level of interaction among ID and MT populations in this area is unknown.

Management Direction

Bighorn sheep have been hunted in a portion of GMU 17 (Hunt Area 17L) since 2007 (Figure 17, bottom). Hunt Area 17L will be managed primarily to provide limited bighorn sheep hunting opportunity.

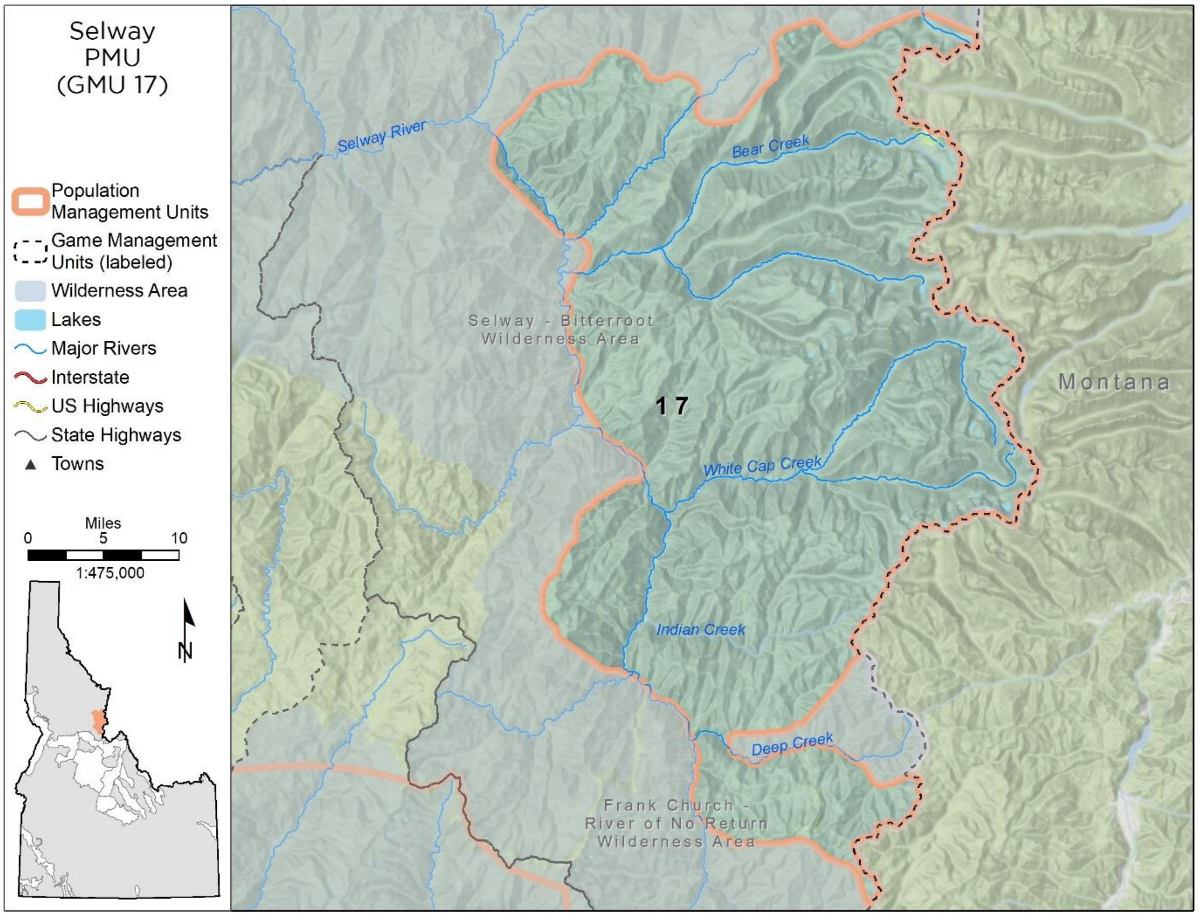
Given the short duration of this relatively new hunt and a general lack of reliable population data, future emphasis will be placed on improving knowledge of population status.

IDFG will continue to work with and encourage the USFS to improve bighorn sheep habitat in this PMU through prescribed burning, let-burn policies, and management of invasive plants.

Within current distribution, modeled habitat on public land occupies approximately 347 km^2, which could support approximately 659 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9 km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat. Thus, further refinement of habitat models and available habitat will likely reduce the estimate of potential population size. The current objective in this PMU is to increase bighorn sheep populations.

Management Actions

- Conduct an aerial survey specifically for bighorn sheep.
- Work with USFS to improve bighorn sheep habitat by working to reduce annual grass prevalence, improve bluebunch wheatgrass communities, and limit forest encroachment.
- Increase knowledge of movement patterns, habitat use, survival, etc. using radio-marked bighorn sheep.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.



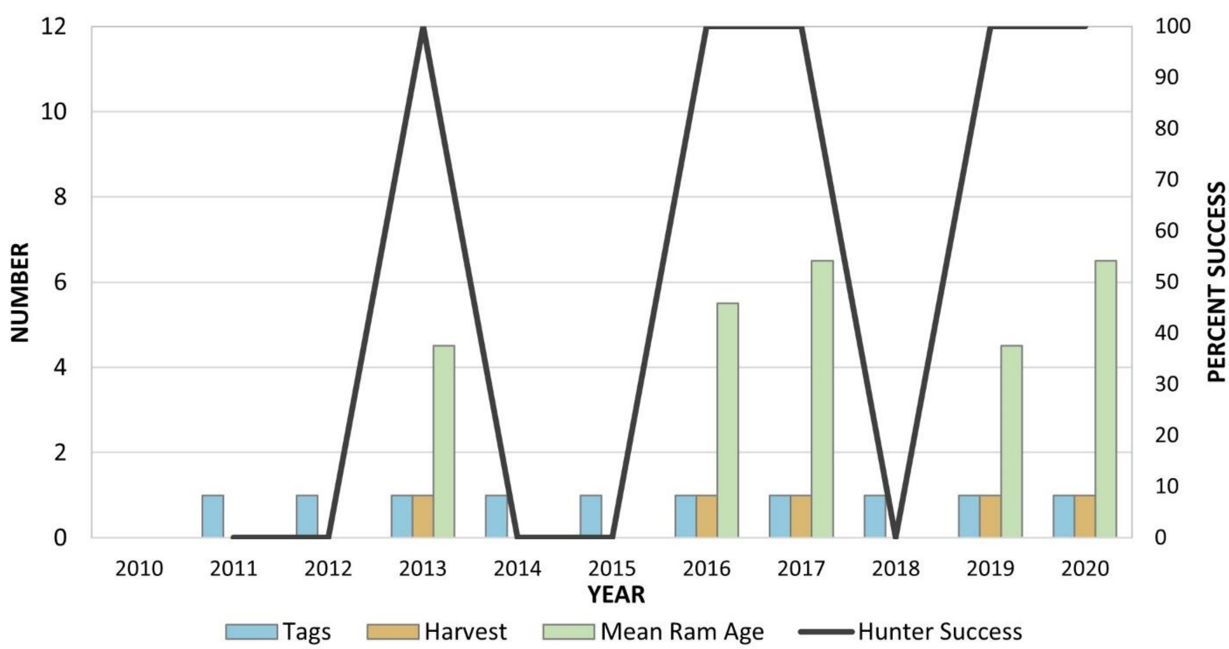


Figure 17. Selway PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

LOWER PANTHER–MAIN SALMON RIVER PMU

This population includes bighorn sheep in GMUs 20 (east), 20A (north central), 21, 21A (north), and 28 (north) (Figure 18, top). The area is managed primarily by the USFS and BLM. A significant portion of this landscape falls within the Frank Church-River of No Return Wilderness Area. The area is typified by rugged mountains and dry, coniferous forest-grassland habitats with very low to moderate road densities. Access into occupied bighorn sheep habitat within wilderness is limited, whereas sheep can be observed along roads in some portions of the PMU. Most bighorn sheep in the area winter along the Salmon River breaks corridor. Some animals migrate to sub-alpine habitats during summer, but many remain along the main Salmon River during summer, where they provide a valuable viewing resource for both river float parties and others traveling along Forest Road 030 ("River Road") downstream from North Fork and along Highway 93 between the towns of North Fork and Salmon.

The boundaries of this PMU were adjusted with the onset of this plan. The PMU was expanded to include what was previously known as the Tower-Kriley PMU in GMU 21A and much of the immediately surrounding area in GMUs 21 and 28. This adjustment was made due to better understanding of bighorn sheep populations and movements through aerial surveys and GPS collaring efforts. It was found that bighorn sheep within Tower-Kriley PMU, and adjacent areas, acted as a subpopulation to the larger Lower Panther-Main Salmon population.

Historical Perspective

Bighorn sheep populations in much of this area were somewhat protected from pressures of early settlement by the remote nature of the area and, thus, were better able to maintain viable population levels when most front-country populations were extirpated. However, subsistence hunting by mining camps and intensive livestock grazing in the late 1800s produced some negative impacts. Grass ranges important to bighorn sheep were converted to shrub habitats in the early part of the 20th century. Land and resource use changed after the mining boom, subsistence hunting and livestock use decreased, and many shrub-dominated ranges began reverting to grasslands. Smith (1954) estimated approximately 290 animals occupied the area in the early 1950s.

Bighorn sheep populations in GMUs 21 and 28 were considered high-quality, exhibiting high lamb production and population growth through the 1970s. An estimated high of 638 animals was counted in 1989. However, populations along Panther Creek experienced a decline in the early 1980s, probably due to weather-related mortality. The same population suffered a major decline (approximately 50%) during 1989–1990, likely caused by pneumonia. Low lamb recruitment followed the decline and persisted for several years. The population has remained suppressed with approximately 327 bighorn sheep counted in the most recent full survey in 2011. The subpopulation in GMU 21A was extirpated in the 1930s but was recolonized in the 1990s. This portion of the population remains relatively low, numbering between 20 and 30 on most years. These small numbers coupled with disease and loss to vehicle collisions along Hwy 93 likely limit its productivity.

The Panther Creek bighorn sheep population was the primary source of Rocky Mountain bighorn sheep for translocation to other sites; nearly 125 were captured and moved between 1975 and 1985 (Appendix C, Table C2). However, capture and translocation have been curtailed since populations and productivity declined. Only 1 translocation into the PMU has occurred (16 sheep from northeast Oregon were released near Shoup in 1984). Hunting occurred under various combinations of controlled and general season frameworks from the early 1950s through 1970 and under a controlled hunt system since 1971.

Issues

Human access to some portions of bighorn sheep range and ongoing or planned development projects dictates special management considerations in this area. GMUs 21 and 28 have high road densities, with potential for copper and cobalt mining, geothermal development, and timber harvest, which could lead to even more development and roads. Increased road densities can lead to high levels of unregulated harvest. GMU 21A has experienced a steady increase of residential development. With this increase in human habitations there is not only a direct loss of habitat, but an increase in risk of contact with domestic sheep and goats. Native American harvest occurs in portions of the PMU, but harvest levels are unknown.

Wildfire has been prevalent during the last decade. Over 300,000 acres within the area have burned since 2012. In some cases, fires have likely benefited wild sheep by reducing conifer encroachment and promoting grass and forb production. However, because of the semi-arid nature of parts of the landscape, habitat response to fire may be slow or negative. This has had negative impacts on winter range productivity and composition where noxious weeds and annual invasive grasses have become prevalent. Elk populations have declined somewhat since peaks during the mid-2000s, but competition with a large elk herd may impact winter habitat capacity for bighorns.

Currently, the population appears it may be disease-limited, as evidenced by generally low lamb:ewe ratios since the die-off in the early 1990s. Ratios declined from an average of 46:100 (range 22–76) between 1974 and 1989 to 27:100 (range 13–31) since 1990 (for years in which >50 sheep were classified). The population appears to remain suppressed at a current estimate of approximately 217 sheep (Table 8). However, there has not been a census survey conducted in this PMU and all minimum population counts to date have only encompassed a portion of the PMU. In addition these flight have not been focused bighorn surveys, but have been incidental observations during deer and elk surveys.

Management Direction

Because the PMU encompasses diverse access and land management objectives, hunting opportunity and experiences vary considerably. Hunter success rates can be quite low in predominantly wilderness hunt areas and range near 100% in areas with road access (Figure 18, bottom). Hunt area boundaries have been adjusted several times to better match sub-population groupings and access, as well as improve hunter and harvest distribution. Radio-collaring of bighorn sheep throughout the PMU to better understand subpopulation distribution and migratory behavior will help better align hunt structures in the future.

Modeled habitat on public land occupies approximately 1,545 km^2, which could support a maximum of approximately 2,936 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9 km^2). However, there are limitations to the PMUs carrying capacity based on specific habitat needs such as habitat quality and extent of lambing habitat that are not accounted for in this calculation. The variability in actual on the ground habitat is difficult to quantify in this landscape thus the realized estimate of potential population size is likely lower than the modeled number. Regardless, historical and recent data indicates the PMU can sustain significantly more bighorn sheep and management direction will be to increase population levels.

Accomplishments, 2010–2021

- Aerial surveys were conducted in 2011 that identified a minimum population of 267 and a ratio of 33 lambs:100 ewes, and again in 2016 that identified a minimum population of 217 with a ratio of 29 lambs:100 ewes (Table 8).
- 8 ewes and 4 rams were GPS collared in autumn of 2021 to inform management by looking at cause specific mortality, movement and migration, delineation of subpopulations, disease prevalence, and habitat use.

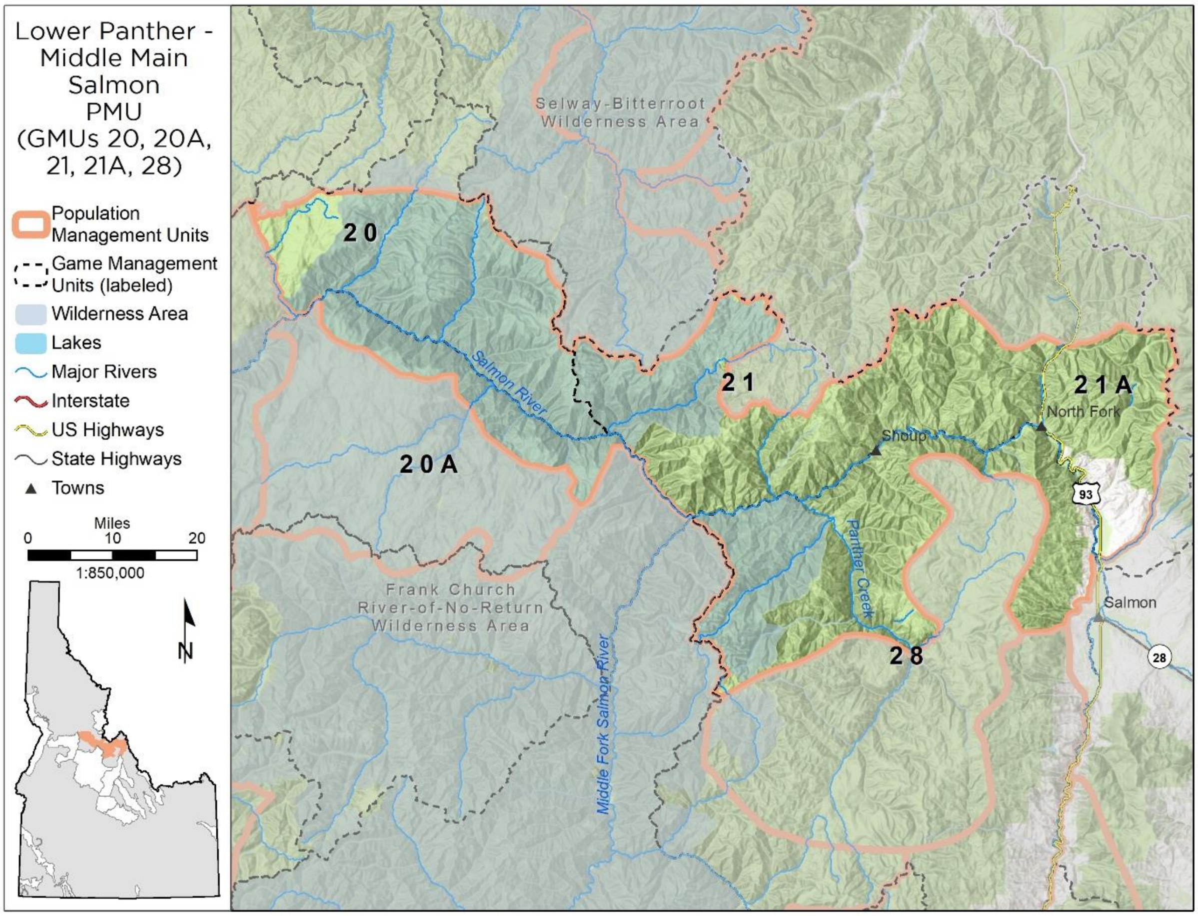
Management Actions

- Work with USFS to continue the Salmon River Breaks winter range improvement projects to reduce winter annual grass prevalence and improve bluebunch wheatgrass communities for bighorn sheep habitat.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Initiate research efforts to gain more knowledge of how test-and-remove can be used to manage disease in populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

- Increase knowledge of PMU minimum population estimates and movement patterns among subpopulations to better inform management decisions such as disease and harvest management. This should include radio-marked animals and aerial survey efforts.

Table 8. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Lower Panther–Main Salmon River PMU since 1996.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
1996	199	40	47	34	81	1	321	GMU 21A not surveyed.
Jan 2001	126	35	36	40	76	0	237	GMU 21A not surveyed.
Feb 2005	118	25	42	15	57	1	201	GMU 20 not surveyed.
Feb 2008	109	26	24	5	29	2	166	GMU 20 not surveyed.
Jan 2011	160	52	33	21	54	1	267	GMU 20 not surveyed.
Jan 2016	119	35	31	32	63	0	217	GMU 20 not surveyed.



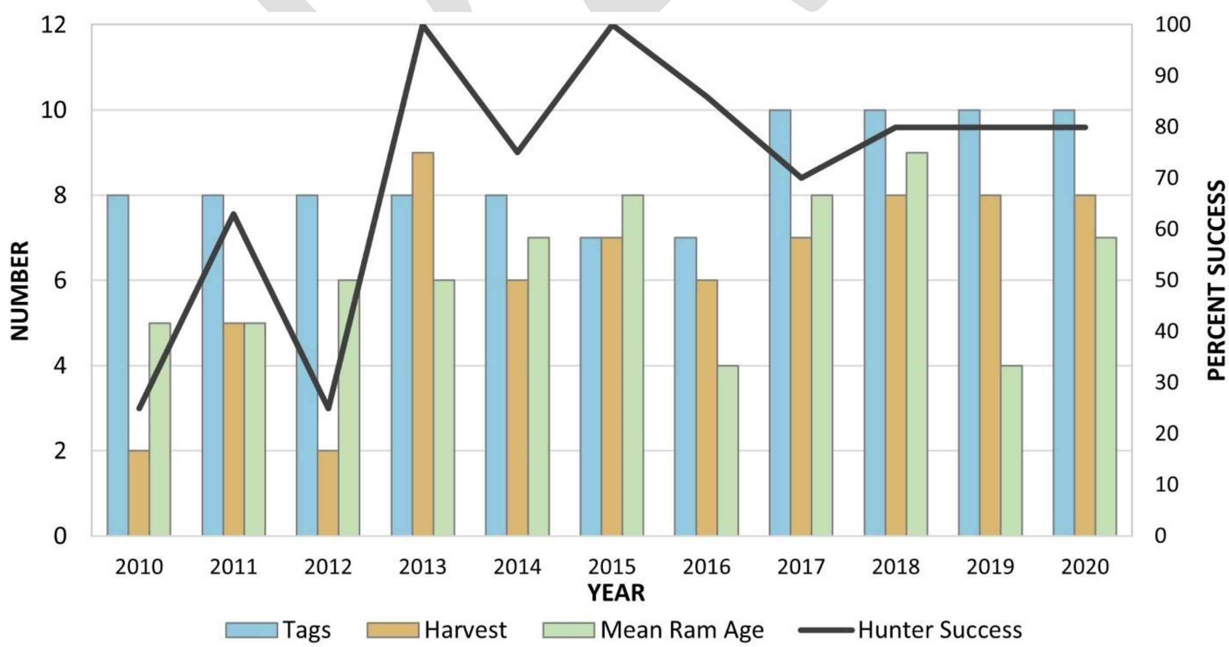


Figure 18. Lower Panther – Main Salmon River PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

MIDDLE FORK SALMON RIVER PMU

This population includes sheep in GMUs 20A (east), 26, and 27, as well as smaller portions of northeast 25, southwest 28, and northeast 36 (Figure 19, top). Most of the area is managed by the USFS and falls within the Frank Church-River of No Return Wilderness Area. The area is typified by rugged canyons and dry, coniferous forest-grassland habitats with very low road densities. Access into most occupied bighorn sheep habitats is limited. Most bighorn sheep in the area winter along the river breaks corridor and migrate to sub-alpine habitats during summer. However, some bighorn sheep remain along the Middle Fork Salmon River during summer, where they provide a valuable viewing resource for river float recreationists.

Historical Perspective

Bighorn sheep populations in this area were somewhat protected from pressures of early settlement by the remote nature of the area and thus were better able to maintain viable population levels when most front-country populations were extirpated. However, subsistence hunting for mining camps and intensive livestock grazing in the late 1800s produced some negative impacts. Grass ranges important to bighorn sheep were converted to shrub habitats in the early part of the 20th century and bighorn populations declined to a low of perhaps 200–500 animals in the late 1920s (Smith 1954).

No translocations have taken place in the Middle Fork PMU and most consider the area one of the few native bighorn sheep populations in North America that was not extirpated. Hunting occurred under various combinations of controlled and general season frameworks from the early 1950s through 1970 and under a controlled hunt system since 1971.

Land and resource use changed after the mining boom, subsistence hunting and livestock use decreased, and many shrub-dominated ranges began reverting to grasslands. The bighorn sheep population increased to approximately 1,000 animals by 1990 but declined by roughly 50% after a disease-driven, all-age die-off in the early 1990s and remains between 500–600 bighorn sheep.

Issues

Although modern land management activities in the wilderness are minimal, the landscape and productivity of habitats are continually changing. Wildfire has been prevalent during the last decade. Nearly 800,000 acres within the area have burned since 2000. In some cases, fires have likely benefited wild sheep by reducing conifer encroachment and promoting grass and forb production. However, because of the semi-arid nature of parts of the landscape, habitat response to fire may be slow or negative, particularly on winter ranges where invasive plants such as knapweed, rush skeletonweed, and leafy spurge could ultimately have significant impacts on winter range productivity. Although elk populations have declined somewhat since peaks during the late 1990s, elk densities in the Middle Fork Salmon PMU may be such that they are causing direct competition for habitat and are having a negative impact on habitat capacity for bighorn sheep.

Currently, the Middle Fork Salmon population appears to still be disease-limited, as evidenced by chronically low lamb:ewe ratios since the die-off in the early 1990s. Ratios declined from an average of almost 37:100 (range 11–74) between 1973 and 1989 to 20:100 (range 5–38) since 1990.

Management Direction

Because of the size of the area and population and access limitations, a variety of hunting experiences are available. During the standard season framework, hunter success is typically lower than in more accessible areas. Since 2010, average hunter success ranged from 16% to 67% depending on area and year (Figure 19, bottom). Most hunt areas are managed to maintain moderate success rates in a remote, wilderness setting. Because hunter success tends to be quite low and access is difficult, Hunt Area 27-1 will be managed primarily to maximize bighorn sheep hunting opportunity.

Within the Middle Fork PMU, modeled habitat on public land occupies approximately 2,981 km^2, which could support a maximum of approximately 5,664 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat. Thus, further refinement of habitat models and available habitat will likely reduce the estimate of potential population size. Regardless, historical and recent data indicates the PMU can sustain significantly more bighorn sheep and management direction will be to increase population levels.

Accomplishments, 2010–2021

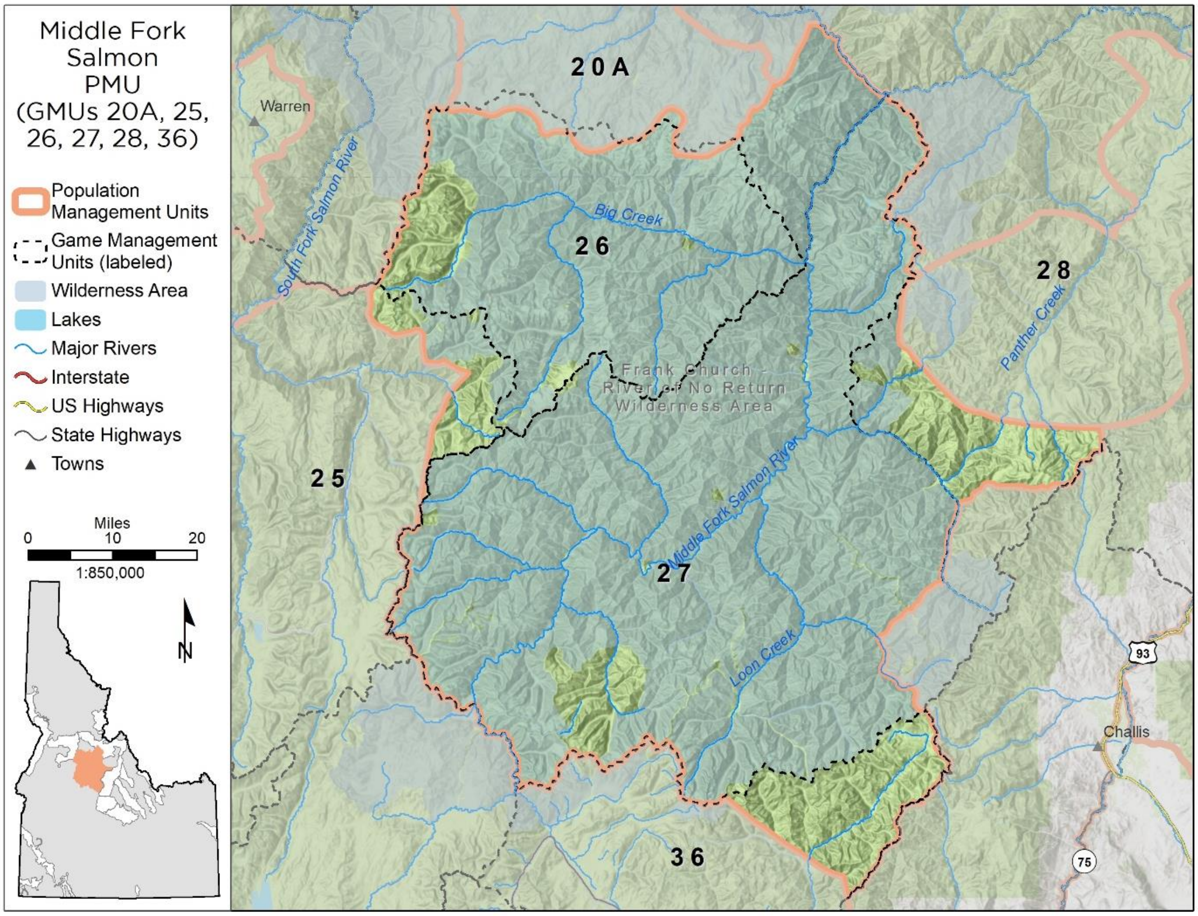
- A comprehensive aerial survey for bighorn sheep was conducted in 2017 with a total of 510 observed (Table 9).
- Bighorn sheep hunters have been asked to take biological samples immediately after harvesting since 2016. This provides valuable disease monitoring from this population of bighorn sheep that IDFG is largely unable to capture and collar.

Management Actions

- Work with USFS to allow management activities such as radio collaring and surveying to occur in the Frank Church-River of No Return Wilderness Area.
- Radio-collar bighorn sheep to increase knowledge of movement patterns among hunt areas and adjacent PMUs to better understand metapopulation characteristics (e.g., connectivity and genetic exchange).
- Conduct research and/or adaptive management to determine effectiveness and feasibility of using methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 9. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Middle Fork Salmon River PMU since 2004.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Apr 2004	324	85	56	63	119	4	532	
Feb 2006	282	78	50	79	129	7	496	
Apr 2009	347	75	81	64	145	1	568	
Feb 2011	151	28	45	52	97	9	285	GMUs 20A, 26 not surveyed.
Jan 2017	300	71	73	65	138	1	510	



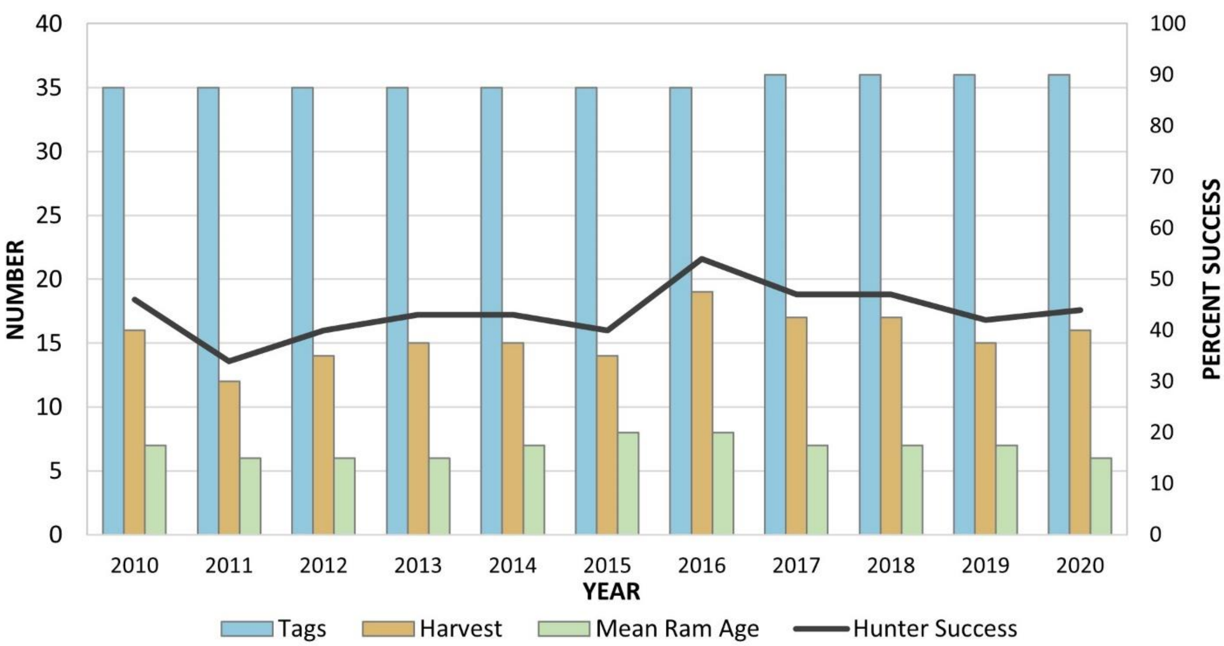


Figure 19. Middle Fork Salmon PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

MIDDLE MAIN SALMON PMU

The Middle Main Salmon population includes bighorn sheep in GMU 36B, small portions of GMUs 27 (upper Warm Springs and Camas creek drainages), and 28 (Hat Creek and upstream to the city of Salmon) (Figure 20, top). Ownership is split primarily between the BLM and USFS, including some area within the Frank Church – River of No Return Wilderness Area. Although it makes up a small portion of the bighorn sheep habitat, there are small parcels of private along the Salmon River that are frequently used as year-round habitat. Habitat grades from sagebrush-steppe at lower elevations though dry, coniferous forest-grassland to alpine at the highest elevations. This PMU contains some of the least rugged terrain occupied by bighorn sheep in eastern Idaho. There are moderate road densities that provide access to occupied bighorn sheep range throughout the PMU. Bighorn sheep in the area winter along the main Salmon River corridor. Some bighorns remain in these areas during summer, whereas others migrate to higher elevation sub-alpine and alpine habitats.

Historical Perspective

Even though they were near human population centers, bighorn sheep in this area persisted when most front-country populations were extirpated. Like most areas, subsistence hunting by mining camps and intensive livestock grazing in the late 1800s produced some negative impacts. Little information about historical population trends exists.

The native population of the Middle Main Salmon PMU provided a source of animals for translocation within and outside Idaho for >20 years (Appendix C, Table C2). A small number of bighorn sheep were moved from the adjacent Lower Panther-Main Salmon PMU to augment the Birch Creek subpopulation.

Land and resource use changed after the mining boom, subsistence hunting and livestock use decreased, and many shrub-dominated ranges began reverting to grasslands. The bighorn population increased to approximately 300 animals by 1988 but declined by roughly 50% after a disease-driven, all-age, die-off in the early 1990s and remains around 225 sheep (Table 10). A bighorn sheep focused aerial survey has not been conducted in the last decade and all minimum population estimates are the result of incidental sightings during deer and elk focused surveys.

Issues

This PMU has private inholdings and residential development scattered throughout its boundaries. With human settlement the presence of both commercial and hobby flocks of domestic sheep and goats are common. This population has an extremely high risk of contact and IDFG staff respond to commingling events annually. This is likely the most limiting factor to bighorn populations within this PMU.

Wildfire has impacted some portions of the PMU, particularly since 2007. In some cases, fires have likely benefited wild sheep by reducing conifer encroachment and promoting grass and forb production. However, because of the semi-arid nature of parts of the landscape, habitat response to fire may be slow or negative, particularly on winter ranges where noxious weeds and annual invasive grasses could ultimately have significant impacts on winter range productivity. Elk populations have declined somewhat since peaks during the mid-2000s, but competition with a large elk herd may impact habitat capacity for bighorns.

Because bighorns sheep in this PMU winter along Highway 93 and 75, mortality to vehicle strike may be somewhat higher than in other PMUs. Past attempts to reduce vehicle collisions by drawing sheep farther west of the highway with habitat improvements have met with limited success, as have highway signage. In April 2010, a sheep viewing station was opened to enhance public knowledge and appreciation of bighorn sheep and their habitat (a collaborative effort among Idaho Outfitters and Guides Association, Idaho Chapter Wild Sheep Foundation, IDFG, and several other entities).

Following the 1990s die-off, lamb recruitment has remained low at an averaged near 25:100 in recent years. This is likely a result of low level disease prevalence in the population.

Management Direction

Because of relatively easy access to much of the hunt area, hunter success tends to be high most years (Figure 20, bottom). Backcountry hunting experiences are available particularly in the western portion of the PMU within wilderness areas.

Within current distribution, modeled habitat on public land occupies approximately 1,309 km^2, which could support a maximum of approximately 2,487 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat that likely reduce the realized carrying capacity within this PMU. Regardless, historical and recent data indicates the PMU can sustain significantly more bighorn sheep and management direction will be to increase population levels.

Accomplishments, 2010–2021

- A Movi-free farm flock program was initiated in the Challis area in 2016. Several commercial and hobby domestic sheep flocks have been tested and managed annually to maintain Movi-free flocks that not only reduce risk to area bighorns but serve as clean source flocks for other domestic sheep owners across the state.
- 16 bighorn sheep have been GPS-collared since 2010 to assess cause-specific mortality, movement and migration, and risk of interactions with domestic sheep and goats.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Maintain a sample of GPS-marked bighorn sheep to better define subpopulations, migration routes, areas of high risk of interactions with domestic sheep and goats, and ground-based population assessments.

- Conduct research and/or adaptive management to determine effectiveness and feasibility of using methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Table 10. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Middle Main Salmon River PMU since 2005.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Feb 2005	125	28	40	22	62	0	215	
Jan 2008	134	34	24	33	57	0	225	Incidental to elk survey
Mar 2010	129	36	29	21	50	0	215	
Jan 2016	143	36	30	25	55	1	235	Incidental to elk survey

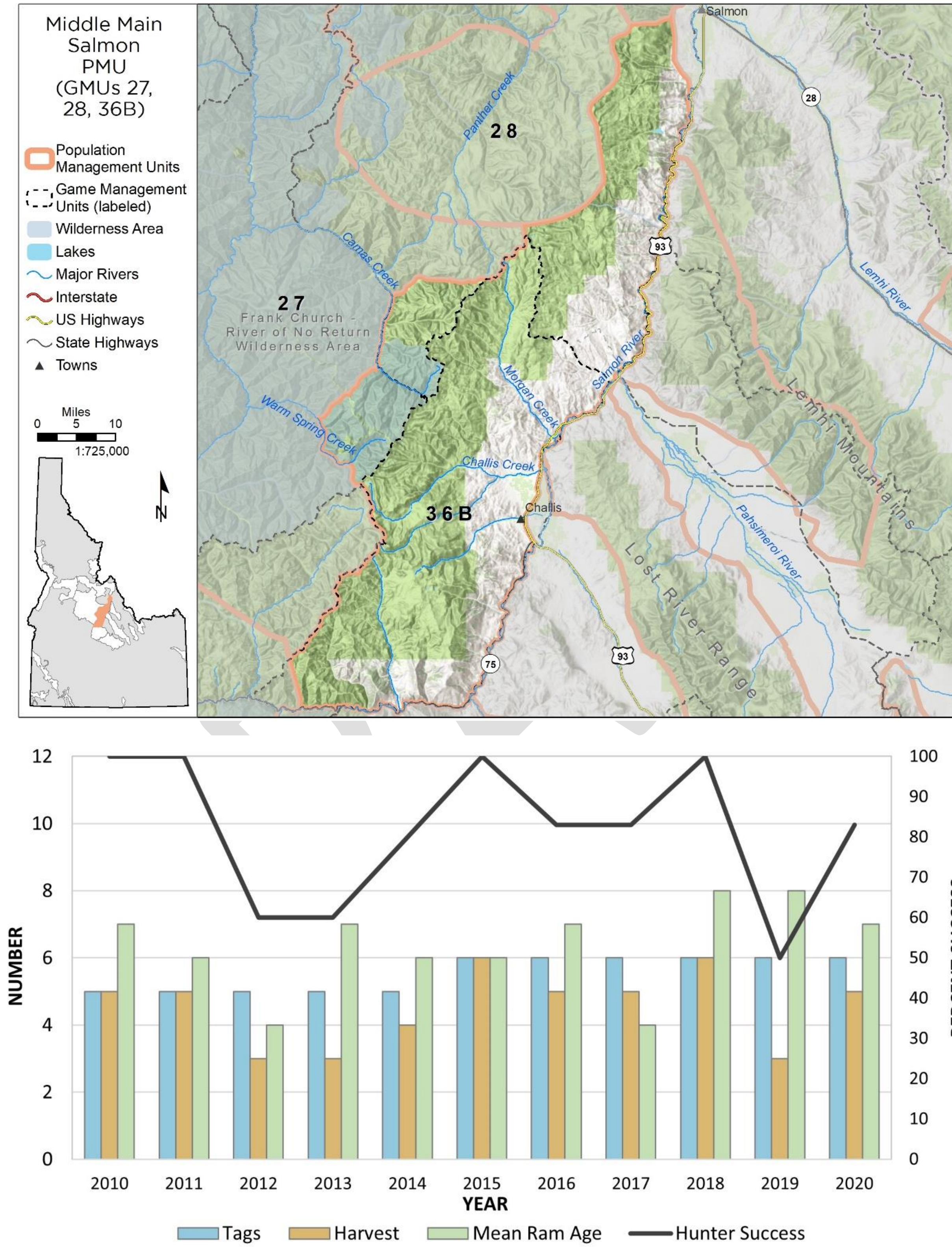


Figure 20. Middle Main Salmon PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

NORTH BEAVERHEAD PMU

This population includes bighorn sheep in GMUs 30 and 30A. Most of the area is managed by the USFS and BLM (Figure 21, top). The area is typified by dry, rocky sub-alpine habitats that descend into coniferous forest-grassland habitats and terminate in low elevation sagebrush-steppe and mountain mahogany communities in rugged canyons. The PMU has relatively low road densities but, given the small spatial scale of the bighorn sheep habitat, is relatively accessible. Bighorn sheep in the area winter in and around the mouths of small canyons on the north end of the PMU. The animals migrate to subalpine habitats to the south and east during summer, moving as far south as upper Eighteenmile Creek. Sheep regularly cross into Montana during summer and autumn.

Historical Perspective

As with most front-country populations, bighorn sheep in this area were extirpated in the late 1800s to early 1900s (Smith 1954). Restoration began with 2 translocation events in the mid-1980s (Appendix C, Table C2). Little population growth occurred after the translocations. Staff observed a high of 85 bighorns during an aerial survey in 2014. Fewer sheep were observed in recent years, but the population appears to have stabilized between 60 and 80 sheep (Table 11).

Issues

There are several factors that may be causing bighorn sheep populations to perform below capacity in this PMU. The existence of domestic sheep grazing allotments adjacent to and overlapping summer range in Montana may be leading to disease prevalence in the bighorn sheep population. Direct competition between a robust elk population and domestic cattle grazing on winter range is likely impeding growth of the bighorn population. In addition the robust elk population may support a moderate density of mountain lions that lead to increased predation on bighorn sheep.

For several wildlife species, including bighorn sheep, the Beaverhead Range forms a potential travel route between the Yellowstone ecosystem and ecosystems farther north and west. If populations increase, bighorn sheep may move along the length of the Beaverhead Range and form a more stable metapopulation.

Management Direction

Modern hunting seasons were established in 2001. Because the risk of an all-age die-off is relatively high, IDFG will continue to offer ram harvest even though the population does not exceed 100 individuals. Hunter success has averaged 75% since the Hunt Area was opened with the average ram harvested being 6.5 years of age (Figure 21, bottom).

The relatively small amount of occupied habitat and number of bighorn sheep somewhat limit management options. Within current distribution, modeled habitat on public land occupies approximately 385 km^2, which could support approximately 731 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat that likely reduce the realized carrying capacity within this PMU. Disease from contact with domestic sheep is a risk factor that also limits carrying capacity to a level below this estimate. Regardless, recent data indicate the PMU can sustain more bighorn sheep and management direction will be to increase population levels.

Accomplishments, 2010–2021

- Since 2010 a total of 13 bighorn sheep were GPS-collared to assess landscape use, risk of interactions with domestic sheep and goats, and cause-specific mortality.

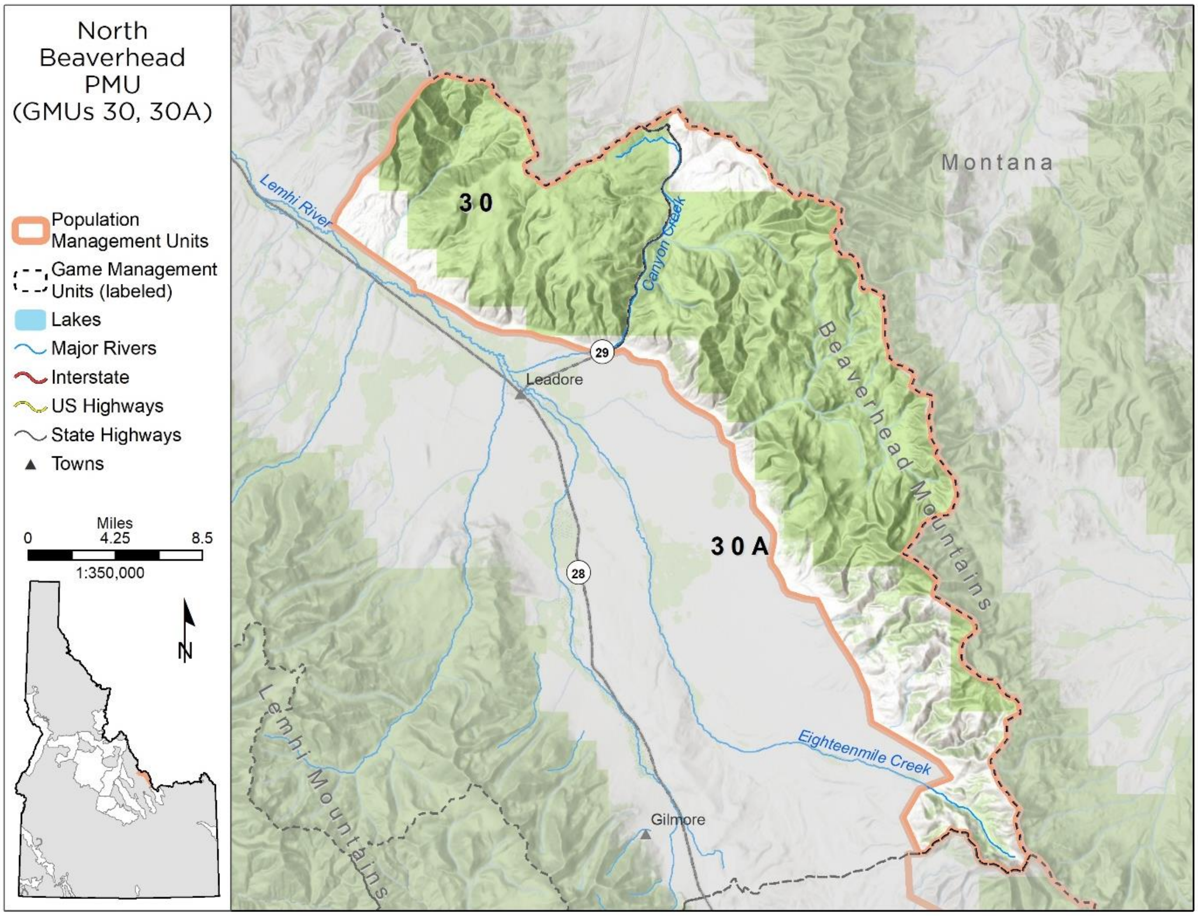
Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

- Use GPS-marked sheep to assess cause-specific mortality, risk of interactions with domestic sheep and goats, and migration routes to facilitate cooperative management of this population with Montana.
- Conduct an aerial survey to determine population size following the removal of an adjacent Movi infected bighorn sheep population in Montana.
- Conduct research and/or adaptive management to determine effectiveness and feasibility of using methods such as test-and-remove for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Table 11. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in North Beaverhead PMU since 2004.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Jan 2004	37	9	4	11	15	0	61	
Apr 2005	18	6	5	0	5	7	36	
Feb 2007	26	0	7	1	8	0	34	
Mar 2014	35	20	25	5	30	0	85	
Jan 2016	35	21	5	3	8	0	64	Incidental to elk survey



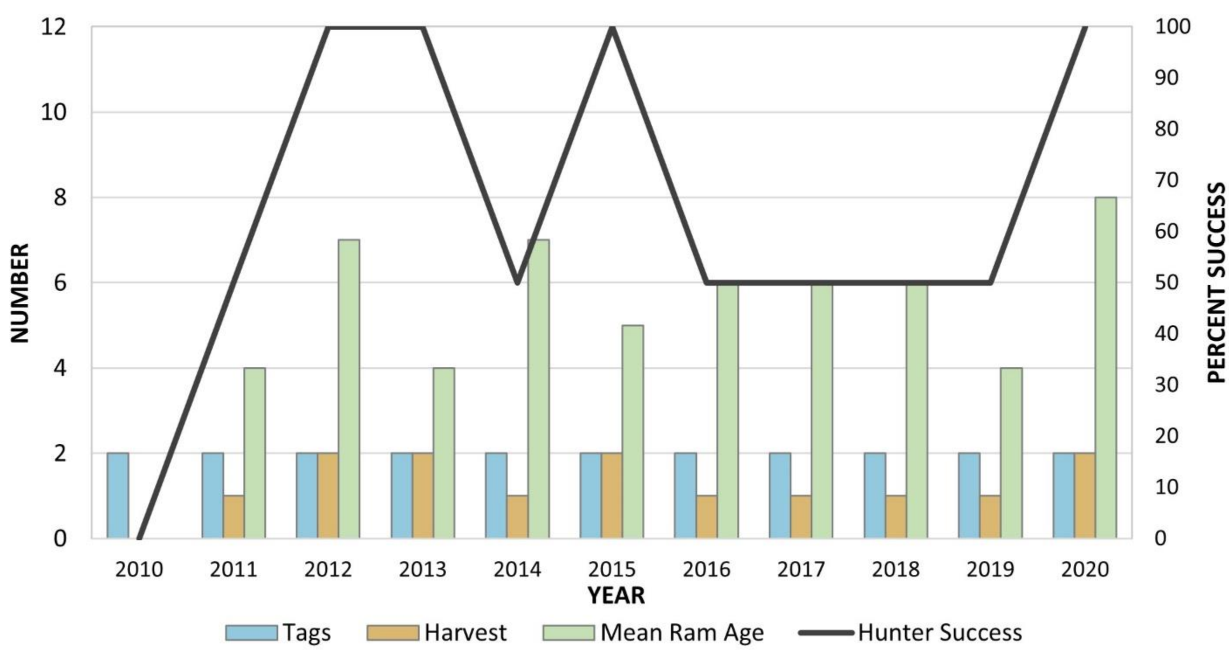


Figure 21. North Beaverhead PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

SOUTH BEAVERHEAD PMU

Bighorn sheep in the South Beaverhead PMU primarily occur in GMUs 58 (east) and 59A, and occasionally 59 (Figure 22). Habitats in the South Beaverhead PMU are diverse, generally mountainous types with bighorn sheep summering mostly at higher elevations on alpine and subalpine ranges. Winter ranges primarily consist of sagebrush and a variety of grass species or curl-leaf mountain mahogany types, and individuals tend to congregate in areas where snow depths are low and do not limit mobility. The USFS generally administers summer ranges, whereas both USFS and BLM manage winter ranges. Bighorn sheep are observed consistently in the southern Beaverhead Range.

The bighorn sheep population in the south Beaverhead Range commonly use private land from Goddard canyon north to Bruce canyon during breeding season and early winter. While the private ranch land that bighorn sheep inhabit in the South Beaverhead PMU no longer have domestic sheep operations, bighorns still come to the area and often feed with corralled cattle. Some bighorns from this population move south into Bloom, Deadman, and Peterson canyons as winter progresses, but the majority remain on the slopes from Goddard canyon north to Bruce canyon.

Historical Perspective

There is little historical data available for Rocky Mountain bighorn sheep in the South Beaverhead PMU. The journals of early trappers, settlers, miners, and other sources indicate that sheep were more plentiful and widely distributed than what is currently observed (Seton 1929, Smith 1954, Russell 1955). By the early 1900s, bighorn sheep were eliminated from most of the area and severely reduced in the remaining habitats. Vegetative changes due to livestock use on winter ranges, loss to disease, and indiscriminate harvest by settlers and miners are suspected as the main causes of bighorn sheep declines.

Subsistence and indiscriminate harvest of bighorn sheep by early settlers and pioneering travelers was greatly reduced after establishment of IDFG in 1937. Changes in federally controlled domestic sheep grazing allotments, habitat improvement projects, water developments, and bighorn sheep translocations have all been implemented in hopes of increasing wild sheep populations in the southern Beaverhead Range.

Forty-one bighorn sheep from GMU 28 were released into Long, Skull, and Bloom canyons of GMU 58 in 4 translocations between 1976 and 1982. Anecdotal information from locals in the area suggest that at some time in the mid-1980s there were somewhere between 60–80 bighorn sheep in this area. These numbers were likely a result of the translocations mentioned above. Since the early 2000s this population has remained around the 20–25 mark with a noticeable increase to about 41 individuals around 2010. These observations were quickly followed by a dramatic reduction down to 17 documented individuals (Table 12).

Counts in this PMU have generally been incidental to aerial surveys for other big game species and, therefore, do not represent thorough population surveys or composition trends. Bighorn sheep have been observed across the southern Beaverhead Range, however, the largest concentration of observations have been centered near the Skull canyon area, but there are observations from Crooked Creek, Horsethief Ridge, Snakey Canyon, the TNC ranch, Sullivan Ridge, Irving Creek, and numerous other locations throughout the area.

Issues

Risk of contact with domestic sheep may be present near allotments on USFS lands in GMUs 58 and 59A. Domestic sheep on private land near bighorn sheep habitat within the PMU are also a potential source of contact. The USFS has developed some water sources (guzzlers) to address potentially limited natural water distribution. With current available information and considering the potential of increased disease risk, IDFG currently discourages the development of water sources (see Habitat section).

Management Direction

There have been no bighorn sheep hunts in the South Beaverhead PMU and none are planned until the population increases enough to allow hunting.

Within current distribution, modeled habitat on public land occupies approximately 627 km^2, which could support approximately 1,191 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2).

More information is needed to manage this population; disease metrics and monitoring in particular because disease seems to be a consistent driver of this population, but also surveys (ground or aerial) to estimate population growth or reduction, survival rates, and production. Radio-marking may also be needed to determine recruitment and seasonal use patterns.

Accomplishments, 2010–2021

- Since 2010, 10 individuals were captured and radio-marked to extend knowledge on habitat use and seasonal movement patterns as well as provide insight on survival rates and biological samples to monitor population health.
- An aerial survey was conducted for this population in 2014 and a survey count was made incidentally to an elk survey in 2016. These helped establish a baseline population estimate.
- Changes made to allotment use and some allotments being retired from domestic sheep use has been a benefit.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Increase knowledge of movement patterns, habitat use, survival, health, and disease using radio-marked bighorn sheep.
- Conduct aerial surveys or ground counts specifically for bighorn sheep on a regular basis to monitor population health.
- Conduct research and/or adaptive management to determine effectiveness and feasibility of using methods such as test-and-remove

for clearing Movi from persistently infected bighorn sheep populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Table 12. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in South Beaverhead PMU since 2002.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Feb 2002	7	0	5	1	6	13	26	Incidental to aerial elk survey
Jan 2005	6	2	4	4	8	1	17	Incidental to aerial elk survey
Jan 2007	2	5	1	5	6	17	30	Incidental to aerial elk survey
Mar 2014	7	3	2	1	3	0	13	
Jan 2016	2	0	0	2	2	13	17	Incidental to aerial elk survey

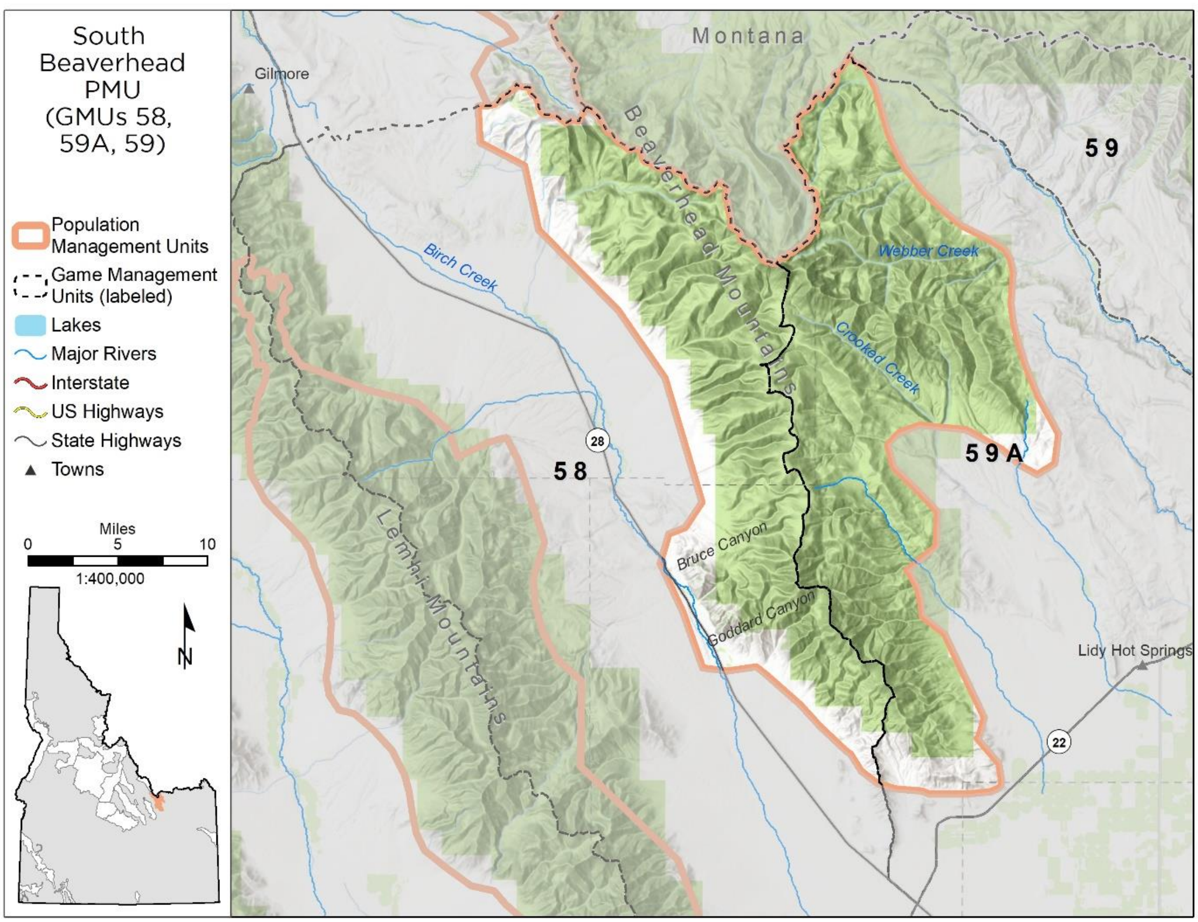


Figure 22. South Beaverhead PMU area map.

NORTH LEMHI PMU

Habitat used by this population occurs primarily in GMU 37A but includes some areas in GMU 29 (Figure 23, top). Although the USFS manages most of the bighorn sheep range, important portions of the winter and year-round range occur on BLM managed lands. The area is a combination of the rugged Salmon River canyon to the west and the equally rugged southwest flank of the Lemhi Range to the east. Habitat varies from sagebrush-steppe at lower elevations though dry coniferous forest-grassland to alpine at the highest elevations. US Highway 93 parallels the Salmon River along the western edge of the PMU, but few other roads provide access to occupied bighorn sheep range. Bighorn sheep in the area winter along the river breaks corridor and lower elevation south-southwest facing slopes in the Pahsimeroi River Valley. Some bighorn sheep remain in these areas during summer, whereas others apparently migrate to higher elevation subalpine and alpine habitats.

Historical Perspective

Bighorn sheep populations in this area were essentially extirpated during the early 20th century. Occasional sightings of small numbers of sheep from the 1960s to early 1980s likely resulted from temporary movements of animals from the adjacent Middle Main Salmon River or Lost River Range PMUs. The current population resulted from 3 translocation events between 1986 and 1989 (Appendix C, Table C2). Bighorn sheep numbers appeared rather stagnant for 10–15 years following translocation but increased to ≥128 animals in 2018 (Table 13). A hunting season was established in 2005.

Issues

Elk populations in this area expanded rapidly in the 1970s–80s and remain at relatively high numbers. Competition with this large elk herd may impact habitat capacity for bighorn sheep. Risk of contact with domestic sheep or goats is relatively high in this PMU, primarily related to “farm flocks” on adjacent private land. Although lamb ratios have increased to approximately 35:100 ewes in 2018 from lows of approximately 5:100 ewes in 1992, the population growth is likely still limited by disease prevalence.

Management Direction

Because of the relatively high risk of contact with domestic sheep and goats, a hunting season was established before the total population reached 100 individuals. Limited access and rugged terrain provide opportunity for backcountry hunting experience. Due to improving populations a late season tag was added in addition to the 2 early season tags in 2019. Since the area was opened for hunting 27 of 30 permits issued have been filled and hunters have had 100% success over the last 4 years (Figure 23, bottom).

Within current distribution, modeled habitat on public land occupies approximately 653 km^2, which could support a maximum of approximately 1,241 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However, there are limitations based on specific habitat needs such as lambing and wintering habitat that likely decrease actual carrying capacity to a level below this number. Given recent growth rates, the population is expected to continue growing in the near future and management direction will be to increase population levels.

Accomplishments, 2010–2021

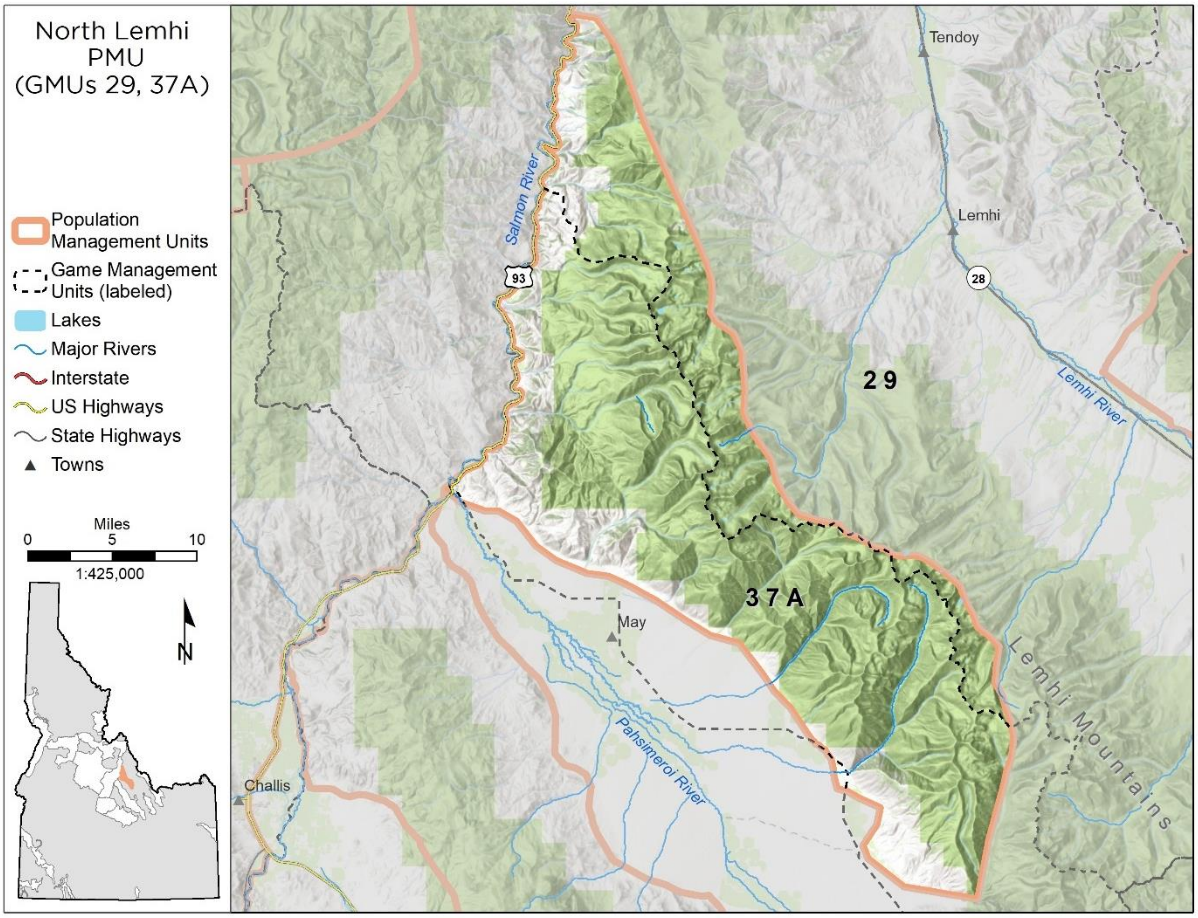
- Since 2010, a total of 23 bighorn sheep were radio-collared to assess landscape use, risk of interactions with domestic sheep and goats, and cause-specific mortality
- Aerial surveys were conducted in 2018 and found 128 total sheep. The highest minimum population counted in recent history.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Improve knowledge of landscape use, subpopulation behavior, and cause-specific mortality using GPS collaring and aerial surveys.

Table 13. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in North Lemhi PMU since 1992.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
1992	36	2	3	8	11	1	50	
Mar 2003	35	15	6	3	9	0	59	
Jan 2007	68	19	11	14	25	0	112	
Feb 2016	21	10	12	28	40	35	106	Incidental to deer survey
Jan 2018	57	20	29	22	51	0	128	



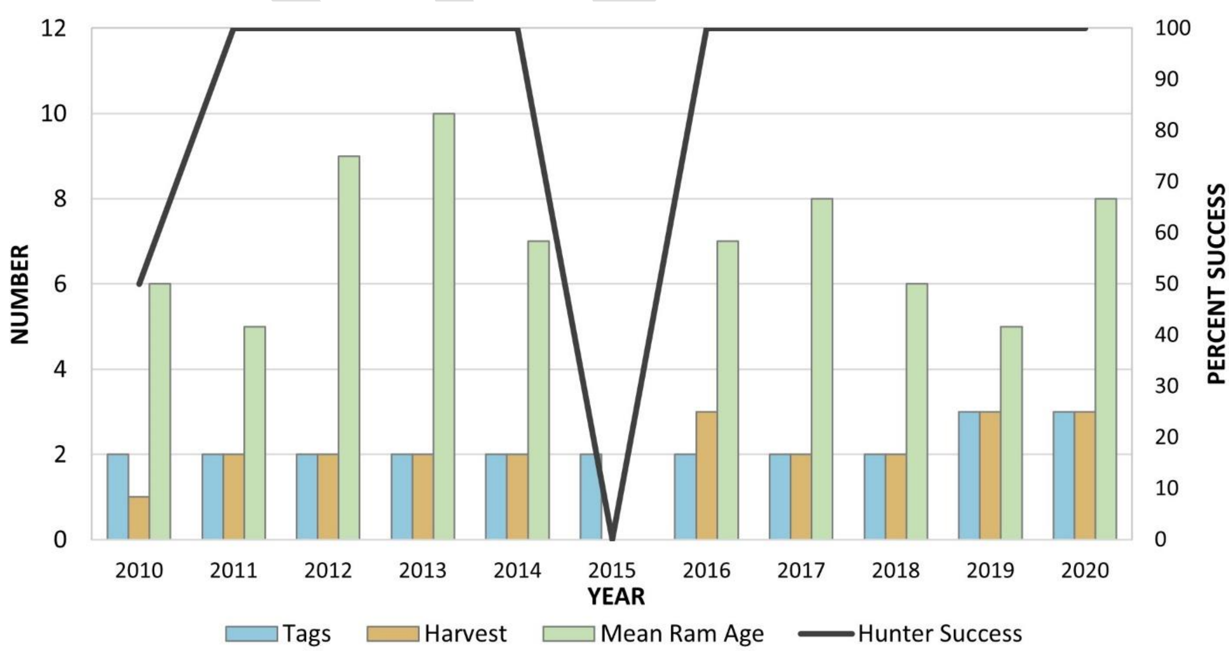


Figure 23. North Lemhi PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

SOUTH LEMHI PMU

Bighorn sheep in the South Lemhi PMU occur in GMUs 51 (east) and 58 (west) (Figure 24, top). Habitats are diverse, generally mountainous types with bighorn sheep summering mostly at higher elevations on alpine and subalpine ranges. Winter ranges mostly consist of sagebrush with various grass species or curl-leaf mountain mahogany types where snow accumulation is light. The USFS generally administers summer ranges, whereas both USFS and BLM manage winter ranges. Bighorn sheep have been observed throughout the southern Lemhi Range.

Historical Perspective

Like other areas in central Idaho, historical data for Rocky Mountain bighorn sheep in the southern Lemhi Range is lacking. The journals of early trappers, settlers, miners, and other sources indicate that sheep were more plentiful and widely spread than what is currently observed. By the early 1900s, bighorn sheep were eliminated from most of the area and severely reduced in the remaining habitats. Vegetative changes due to livestock use on winter ranges, loss to disease, and indiscriminate harvest by settlers and miners are likely the main causes of these bighorn sheep declines.

Subsistence and indiscriminate harvest of bighorn sheep by early settlers and pioneering travelers was greatly reduced after establishment of IDFG in 1937. Changes in federally controlled domestic sheep grazing allotments, habitat improvement projects, water developments, and bighorn sheep translocations have all been implemented in hopes of increasing populations in the Lemhi Range.

There have been 2 bighorn sheep translocations in the South Lemhi PMU (Appendix C, Table C2). All of the sheep (41 total) were captured from the Whiskey Basin population in Wyoming and were released in Badger Creek and Uncle Ike Creek on the west side of the Lemhi range in 1983 and 1984. Counts of these sheep have generally been made incidentally during aerial surveys for other big game species and, therefore, do not represent complete population surveys or composition trends. However, aerial surveys specific to this population of bighorn sheep have been conducted (Table 14).

Issues

There is risk of contact between domestic and wild sheep in parts of the Lemhi Range. There are both “farm flocks” on private land and active domestic sheep allotments that overlap bighorn sheep distribution in this area. Domestic sheep allotments that occur on Idaho National Laboratory land may also be a source of potential contact.

Management Direction

Management direction for this PMU is to maintain populations and increase them in areas of the PMU where separation with domestic sheep and goats can be maintained. A hunt consisting of 2 tags was initiated for this PMU in 2019 based on aerial survey counts. Harvest success rates have been 100% for the 2019 and 2020 hunting seasons (Figure 24, bottom). This hunt will be maintained in its current structure unless surveys indicate the ability to increase tags or the need for tag reduction.

Within current distribution, modeled habitat on public land occupies approximately 603 km^2, which could support approximately 1,146 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2).

Accomplishments, 2010–2021

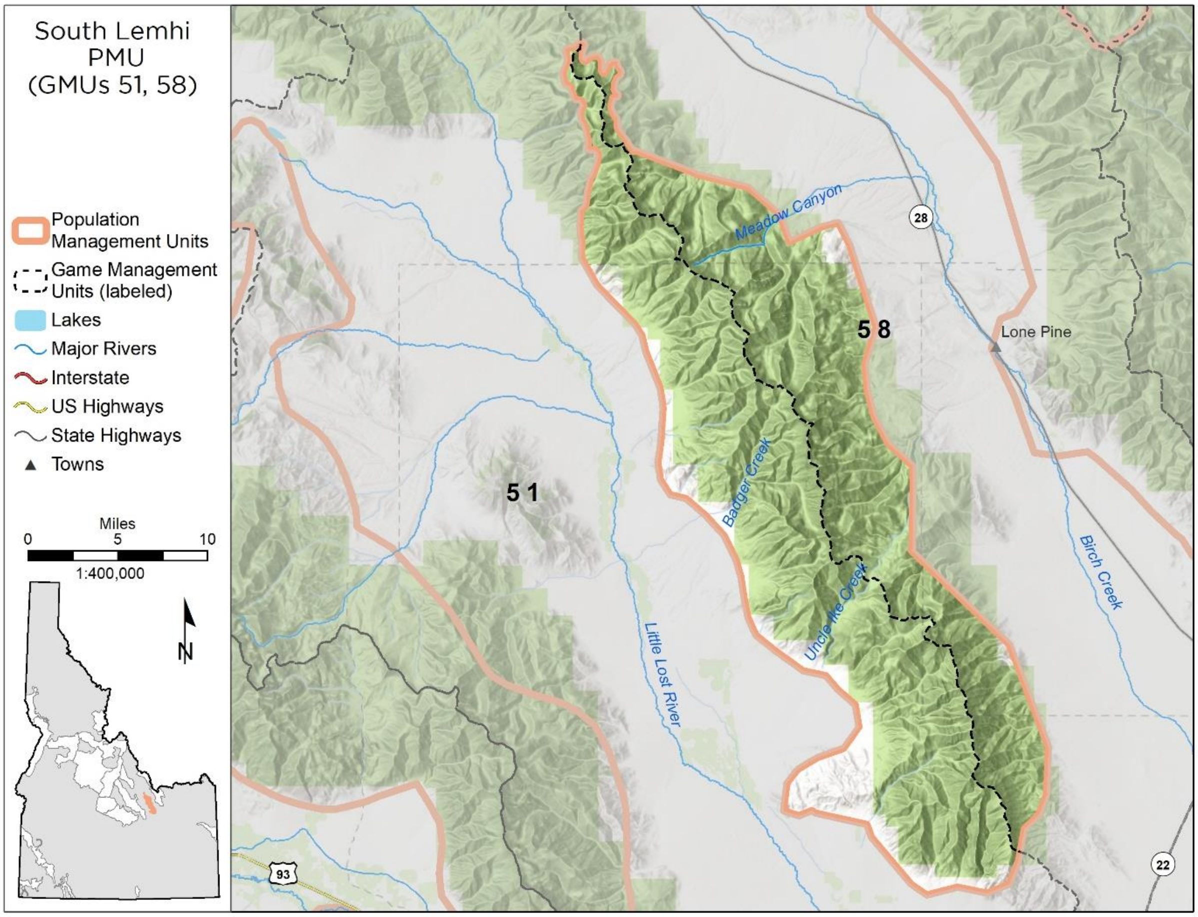
- Since 2010, 15 individuals were captured and radio-marked to extend knowledge on habitat use and seasonal movement patterns as well as provide insight on survival rates and samples to monitor population health.
- An aerial survey was conducted for this population in 2014 and survey counts were made incidentally to elk, mule deer, and mountain goat surveys in 2016, 2018, and 2021. These surveys increased the baseline population estimate (Table 14).

Management Actions

- Increase knowledge of movement patterns, habitat use, survival, etc. using radio-marked bighorn sheep, particularly outside of areas where radio-marking has been conducted.
- Conduct aerial surveys specifically for bighorn sheep on a 5 year or less time frame to monitor population totals and mature rams.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 14. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in South Lemhi PMU since 2003.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Jan 2003	10	5	3	1	4	0	19	Incidental to aerial deer survey
Jan 2005	6	3	2	3	5	0	14	Incidental to aerial deer survey
Jan 2007	1	1	0	0	0	7	9	Incidental to aerial deer survey
Mar 2014	20	5	5	15	20	0	45	
Jan 2016	20	8	6	7	13	0	40	Incidental to aerial deer survey
Jul 2018	41	15	10	14	24	0	80	Incidental to mountain goat survey
Aug 2021	48	26	17	19	36	0	110	Incidental to mountain goat survey



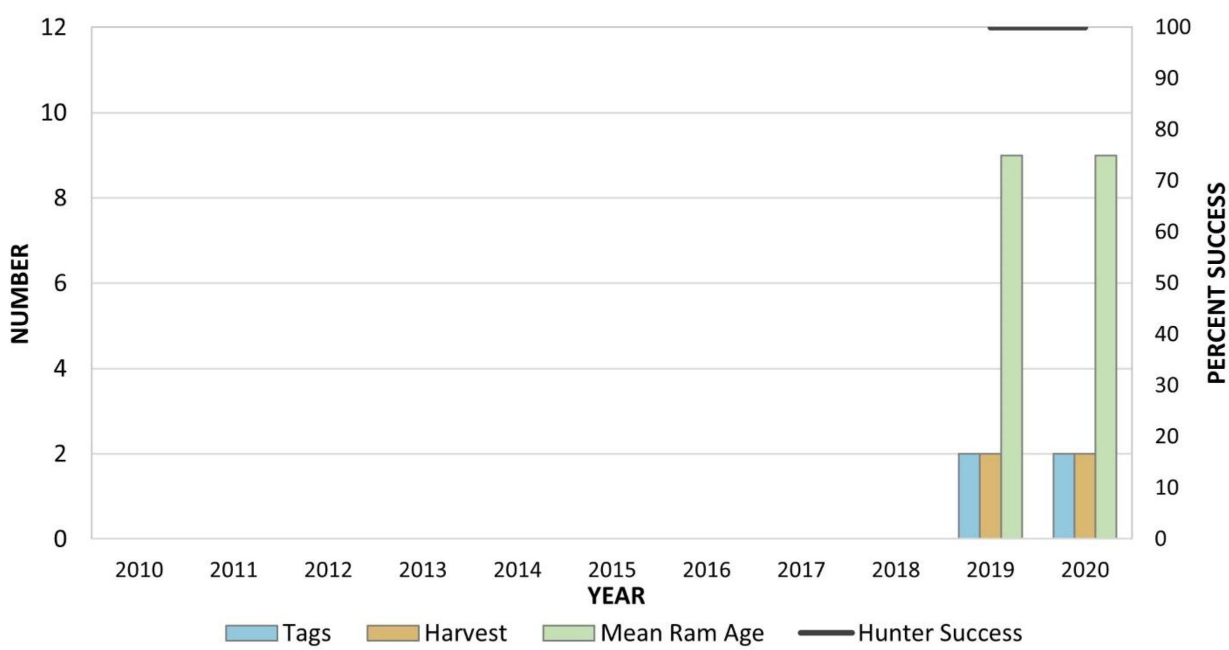


Figure 24. South Lemhi PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. No hunting season occurred in this PMU prior to 2019.

LOST RIVER RANGE PMU

This population occurs on the Lost River Range in GMUs 37, 50, and 51 (Figure 25, top). Although USFS manages most of the bighorn sheep range, there is some use of BLM managed lands. The area is typified by dry coniferous forest/grassland and alpine habitats with low to moderate motorized road or trail densities. Access into most occupied bighorn sheep habitat is limited. Bighorn sheep primarily summer at high elevations in alpine ranges. Winter ranges extend from the lower elevation foothills to mountain ridges >11,000 feet and include multiple habitat types. Bighorn sheep are observed consistently throughout this PMU.

Historical Perspective

There are no quantitative historical data for the number of bighorn sheep that occurred on the Lost River Range. However, by the 1950s bighorn throughout the central Idaho area had declined substantially. In the Lost River area where Seton (1929) reported thousands of bighorn sheep in the late 1800s, Smith (1954) reported there were only a few dozen bighorn left.

Initial releases of Rocky Mountain bighorn sheep into the Lost River Range began in 1969 and continued through 1980; a large augmentation occurred in 2005 (Appendix C, Table C2). All releases were considered successful. Prior to the 2005 augmentation, IDFG entered a Memorandum of Understanding (MOU) with the BLM and USFS to foster enhanced management of bighorn sheep in the Lost River Range. The MOU was spurred by removal of domestic sheep from grazing allotments within and adjacent to occupied bighorn sheep range.

Bighorn numbers on the Lost River Range appeared to increase steadily until the early 1980s, reaching a high of 182 observed during a 1980 survey. The population remained near that level through the late 1980s. However, by 1992 the population appeared to have suffered the same decline and persistent low recruitment as other bighorn sheep populations in the region. Recovery from a period of low recruitment and augmentation with 62 wild sheep from Montana apparently spurred significant population growth; a record high 444 (since reintroduction) bighorn sheep were observed during the most recent survey in 2020 (Table 15).

Issues

Although reduced by several changes in land management practices in recent years, risk of contact with domestic sheep remains an issue. At the time of the augmentation release, IDFG and USFS staff developed a response plan to address and reduce wild sheep-domestic contact in the event bighorns left the defined project area.

The Lost River Range is relatively dry and availability of surface water can be sporadic. The USFS has developed some water sources (guzzlers) to address potentially limited natural water distribution. With current available information and considering the potential of increased disease risk, IDFG currently discourages the development of water sources (see Habitat section).

Management Direction

This population has had an increase in hunting opportunity since 2010 with a total of 3 tags allocated in 2010, 8 tags allocated in 2018, and 10 tags in 2019. Harvest success rates have ranged from 40–100% over the last 10 years with 2–11 rams taken annually (Figure 25, bottom).

Within current distribution, modeled habitat on public land occupies approximately 1,583 km^2, which could support a maximum of approximately 3,008 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However, due to variation in specific habitat quality, distribution, and needs such as lambing and wintering habitat the actual carrying capacity is likely lower than this estimate. Regardless, the PMU can sustain more bighorn sheep and IDFG will continue to manage for an increase in population.

Accomplishments, 2010–2021

- Between 2016 and 2019, collaborated with University of Idaho on a research project on nutrition quality, disease prevalence, and lamb survival in the Owyhee River, Lost River Range, and East Fork Salmon populations (Bilodeau 2021).

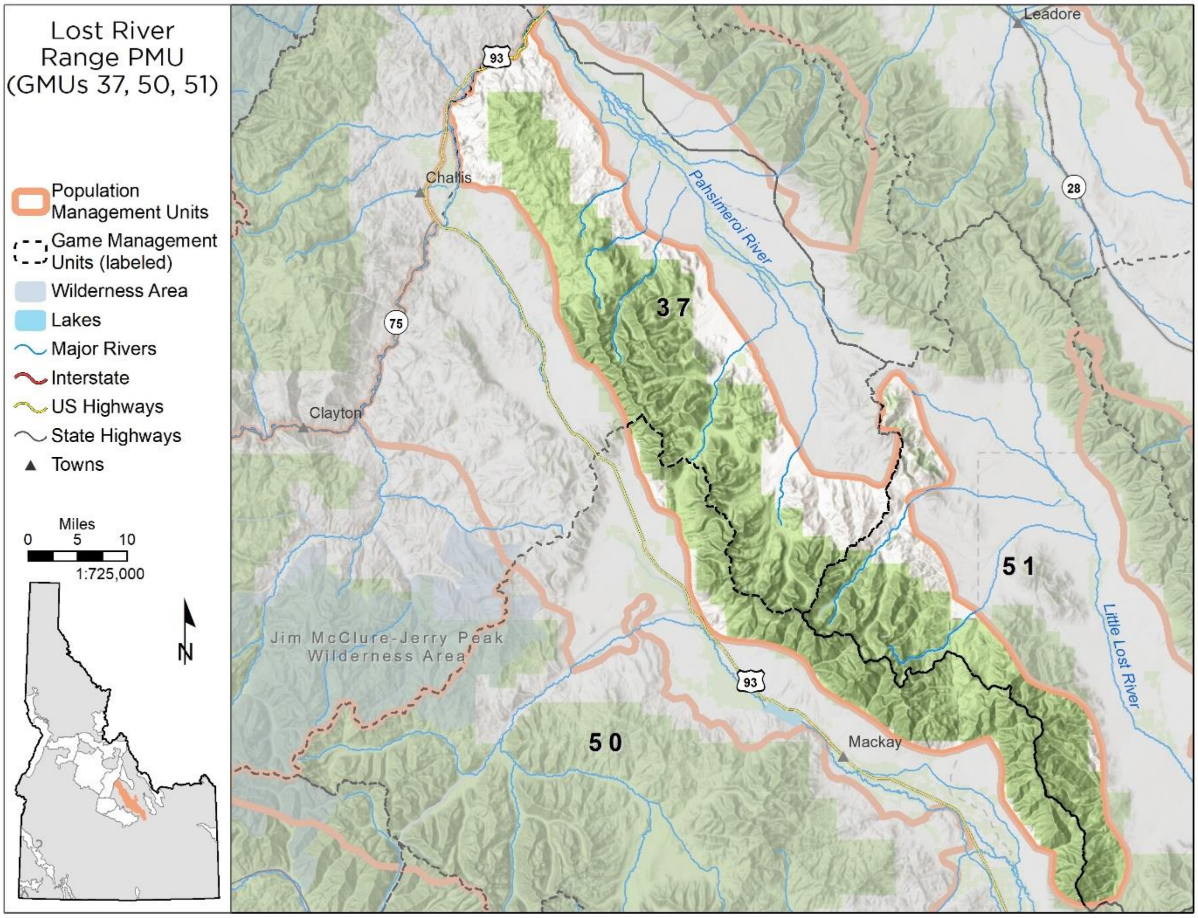
- A total of 75 individual sheep (59 ewes, 16 rams) were captured and radio-marked in various areas within this PMU to inform the above research project and aid in increasing knowledge of movement patterns among hunt areas and adjacent PMUs to better understand metapopulation characteristics (connectivity and genetic exchange), as well as survival rates.
- Tags permitted have increased with population growth from 3 offered in 2010 to 10 offered in 2020 within the PMU.
- Aerial surveys specifically for bighorn sheep to monitor population sizes were conducted in 2016 and 2020 (Table 15).

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 15. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Lost River Range PMU since 2000.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
2000	38	8	5	4	9	0	55	
Mar 2005	82	17	19	13	32	0	131	
Mar 2010	117	47	38	38	76	0	240	
Feb 2016	114	49	32	61	93	0	256	
Mar 2020	226	72	81	65	146	0	444	



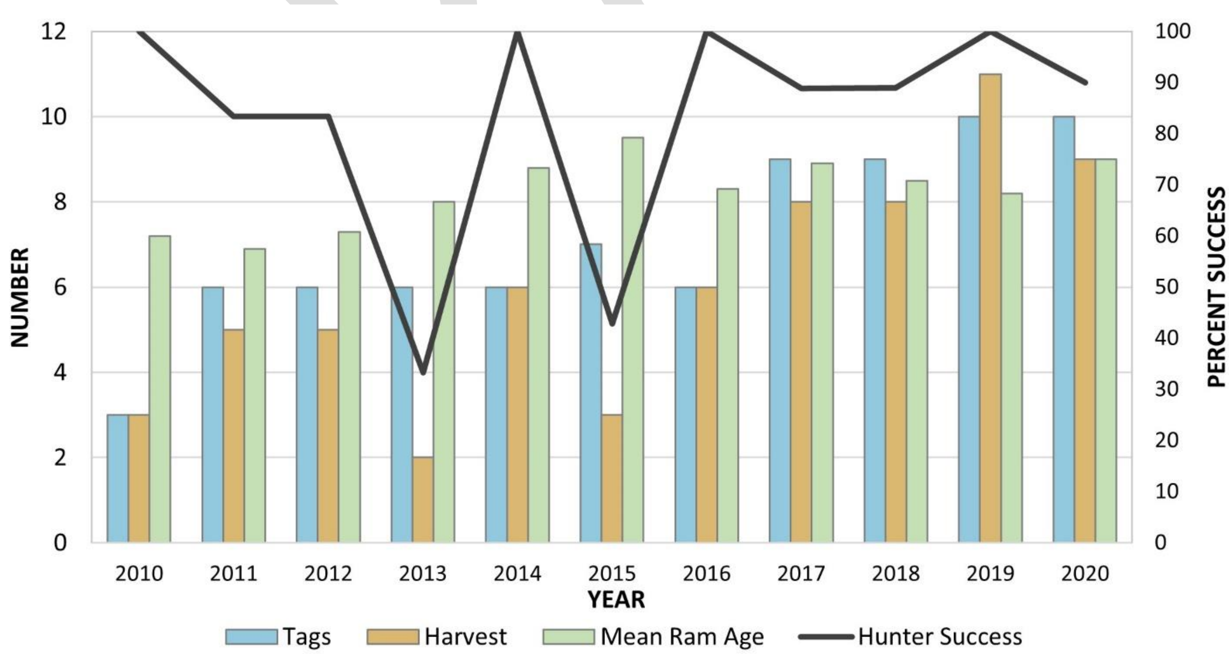


Figure 25. Lost River Range PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

EAST FORK SALMON PMU

This population includes bighorn sheep in GMUs 36A and 36 (southeastern portion) (Figure 26, top). Ownership of bighorn range is split between USFS (summer range) and BLM (winter range). The summer range is typified by high elevation subalpine to alpine and dry, coniferous forest-grassland habitats with low motorized road-trail densities. The winter range is typified by a mixture of sagebrush steppe and bluebunch wheatgrass dominated grasslands intermixed in rugged canyons. Access into most occupied bighorn sheep habitat is limited. Bighorn sheep in the area winter in a relatively small area of west of the East Fork Salmon River between Joe Jump Basin and Big Boulder Creek and migrate west into the White Cloud Mountains to summer.

Historical Perspective

Bighorn sheep populations in this area persisted despite pressures of early settlement. However, subsistence hunting by mining camps and intensive livestock grazing in the late 1800s reduced numbers to low levels. Estimated sheep numbers from various sources in the early 20th century ranged from 50 to 150. Sheep in this PMU became the subject of much social and political interest in the 1960s and 1970s, resulting in several research and habitat enhancement projects, as well as a cooperative management agreement between BLM and IDFG.

No animals have been translocated into this native population and only 1 translocation out of the PMU has occurred (Appendix C, Table C2). Population estimates for the PMU varied considerably over time (50–150 in the early-mid 20th century) depending on the source (USFS, private landowners, IDFG). Annual variations included some that do not appear biologically feasible. Regardless, the population apparently reached a modern peak in 1990 (191 observed), a level higher than estimates from earlier in the century. The population suffered an all-age die-off along with surrounding PMUs and declined by 50% by 1993. Hunting was permitted through 1996 but closed until 2007 because of low bighorn sheep numbers.

Issues

Quantity and quality of winter range may be important limiting factors for this PMU. Grazing management has changed over time and should have improved range for bighorns. However, the winter range is quite dry and vegetative production appears low. Recent expansion of annual invasive grasses in core winter range are likely decreasing the overall carrying capacity of this already spatially limited range. Elk numbers in the East Fork drainage increased dramatically beginning in the 1970s and competition with a large elk herd may impact habitat capacity for bighorns.

A large (167,848 acre) BLM Wild Horse Herd Management Area known as the Challis HMA exists in and adjacent to the eastern portion of the East Fork PMU. The extent of direct competition for resources between wild horses and bighorn sheep is unknown in Idaho. However bighorn sheep have been found to avoid water sources where wild horses are present (Ostermann-Kelm et al. 2008, Stoner et al. 2021). This may lead to lower habitat utilization in this portion of the PMU, particularly in fall and winter months when sheep are found at similar elevations to wild horses.

Contact with domestic sheep is a risk factor at the edges of occupied summer range near USFS allotments. Risk could increase in the event individuals of either species wander. Small flocks of domestic sheep and herds of goats exist on private lands immediately adjacent to winter range. Separation strategies have been developed to minimize risk of interactions.

Lastly, the East Fork population appears to still be disease-limited, as evidenced by very low lamb:ewe ratios since the die-off in the early 1990s. Ratios declined from an average of 57:100 (range 22–88) between 1977 and 1990 to an average of 17:100 (range 3–41) since 1991 (for years in which >50 sheep were classified). In the last ten years the lamb ratios have increased to an average of 36:100 ewes (Table 16). Although this increase is positive, it remains below desirable levels.

Management Direction

Hunting seasons were closed for 10 years and reopened in 2007 with 2 tags/year because adequate numbers of rams were available to support a limited harvest. Currently, 3 tags are offered in this PMU (Figure 26, bottom).

Within the East Fork PMU, modeled habitat on public land occupies approximately 945 km^2, which could support a maximum of 1,795 bighorn sheep (assuming all habitat is suitable year-round and relatively high densities of 1.9/km^2). However due to variation in habitat quality and distribution of habitat types, such as lambing habitat, this is a maximum population estimate. The restricted quantity of quality winter range in the East Fork likely reduces the total carrying capacity for bighorn sheep to a level much below this estimate. Regardless, historical and recent data indicates the PMU can sustain significantly more bighorn sheep and management direction will be to increase population levels.

Accomplishments, 2010–2021

- To date, 49 ewes and 13 rams have been collared in the East Fork PMU to inform research and management decisions.
- Between 2016 and 2019, collaborated with University of Idaho on a research project on nutrition quality, disease prevalence, and lamb survival in the Owyhee River, Lost River Range, and East Fork Salmon populations (Bilodeau 2021).
- In 2018 and 2019 ground based mark-resight surveys were conducted to assess sightability in a population that has experienced high levels of disturbance from air-based capture and survey efforts (Table 16). These surveys resulted in relatively dependable estimates in the geographic settings found in the East Fork.

Management Actions

- Use radio-collared bighorn sheep to better define movement and connectivity of subpopulations within the PMU and adjacent PMUs.

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Work with owners of small flocks of domestic sheep and herds of domestic goats to reduce risk of disease transmission to bighorn sheep (Movi-free program).
- Work directly with Challis BLM and private landowners to improve spatially limited winter range through aerial treatment and reseeding of annual invasive grasses along the East Fork Salmon River.
- Initiate research efforts in some populations (e.g., Lower Salmon PMU) to gain more knowledge of how test-and-remove can be used to manage disease in populations with different levels of management accessibility, population density, disease prevalence, and social interactions and behavior of both ewes and rams.

Table 16. Minimum counts and estimates of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in East Fork Salmon PMU since 2000.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Apr 2000	34	5	12	2	14	0	53	
Jan 2004	20	11	4	3	7	0	38	Incidental to elk survey
Feb 2007	20	0	16	3	19	0	39	
Jan 2008	33	5	16	14	30	0	68	
Jan 2017	39	14	5	20	25	0	78	Estimate from mark/resight
Jan 2019	34	19	20	12	32	0	85	Estimate from mark/resight

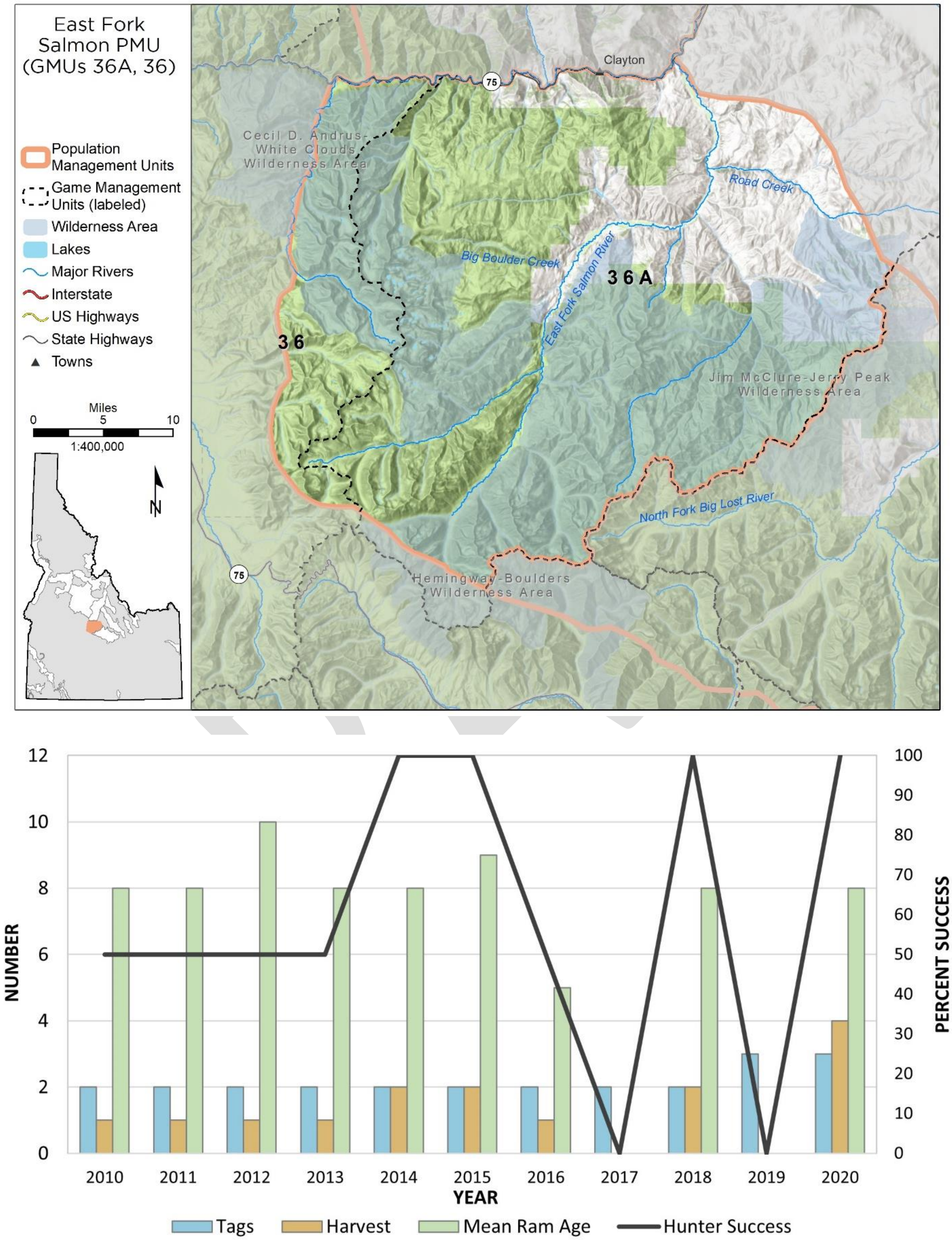


Figure 26. East Fork PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

PIONEERS PMU

This area includes portions of GMUs 48, 49, and 50 (Figure 27). On average, there are confirmed sightings of bighorn sheep in this area every 2–3 years. Often, these are young rams observed once or a few times, but then apparently leave the area. We are uncertain of the source populations for these individuals; they may migrate from either the East Fork Salmon River population or the Lost River Range population. There does not appear to be a persistent bighorn sheep population in the Pioneers PMU.

Management Direction

IDFG does not manage to maintain a population of bighorn sheep in the Pioneers PMU. Management will focus on minimizing potential contact between bighorn sheep and domestic sheep and goats and preventing bighorn sheep that contact domestic sheep in this area from returning to an established population of bighorn sheep. To this end, IDFG has agreed to BMPs with all the known domestic sheep producers who operate within this PMU. These BMPs focus on prompt communication of bighorn sheep sightings and minimizing the likelihood of contact between domestic and bighorn sheep. Furthermore, the BMPs outline tools IDFG may use when a bighorn sheep is sighted. These tools include monitoring, deploying a radio collar, or euthanizing the bighorn sheep.

Management Action

- Continue to collect observation data on bighorn sheep that move into the Pioneers PMU. If the opportunity arises, this may include collecting genetic samples and deploying radio collars on bighorn sheep to learn about movements, source populations, and other bighorn sheep that may use the Pioneers PMU.

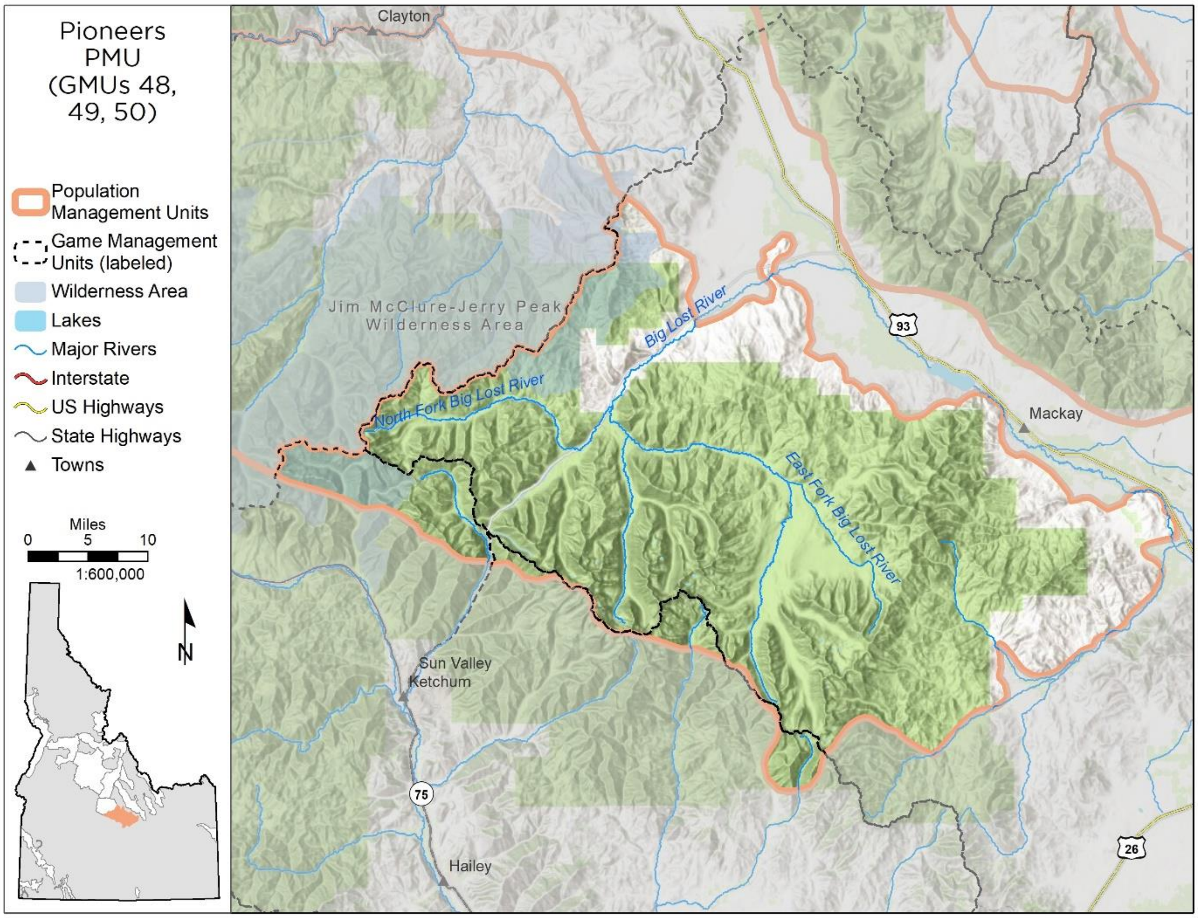


Figure 27. Pioneers PMU area map.

LIONHEAD PMU

This area includes portions of GMU 61 near Henrys Lake (Figure 28). There is a small population of bighorn sheep that occur on the Idaho-Montana border. These bighorn sheep spend varying amounts of time in Idaho. Montana has periodically issued hunting tags for this population. Idaho authorized a 5-tag controlled hunt on this population in 1962, 1964, 1965, and 1966. Currently this population of bighorn sheep is not hunted in Idaho but has a nonconsumptive value, particularly to those recreating in the Targhee Creek area.

Management Direction

Management direction is to document observations and provide for nonconsumptive use. IDFG does not currently manage this sheep population for hunting but there has been interest in the past to try to provide limited opportunity that is shared cooperatively between Montana and Idaho. Few observations are confirmed in this area, but sheep still persist or enter Idaho on a transient basis from known observations such as an observation of a young ram in June 2021.

Management Action

- Document bighorn sheep locations to better understand their use of this area.
- Provide information to those interested in bighorn sheep viewing opportunities.

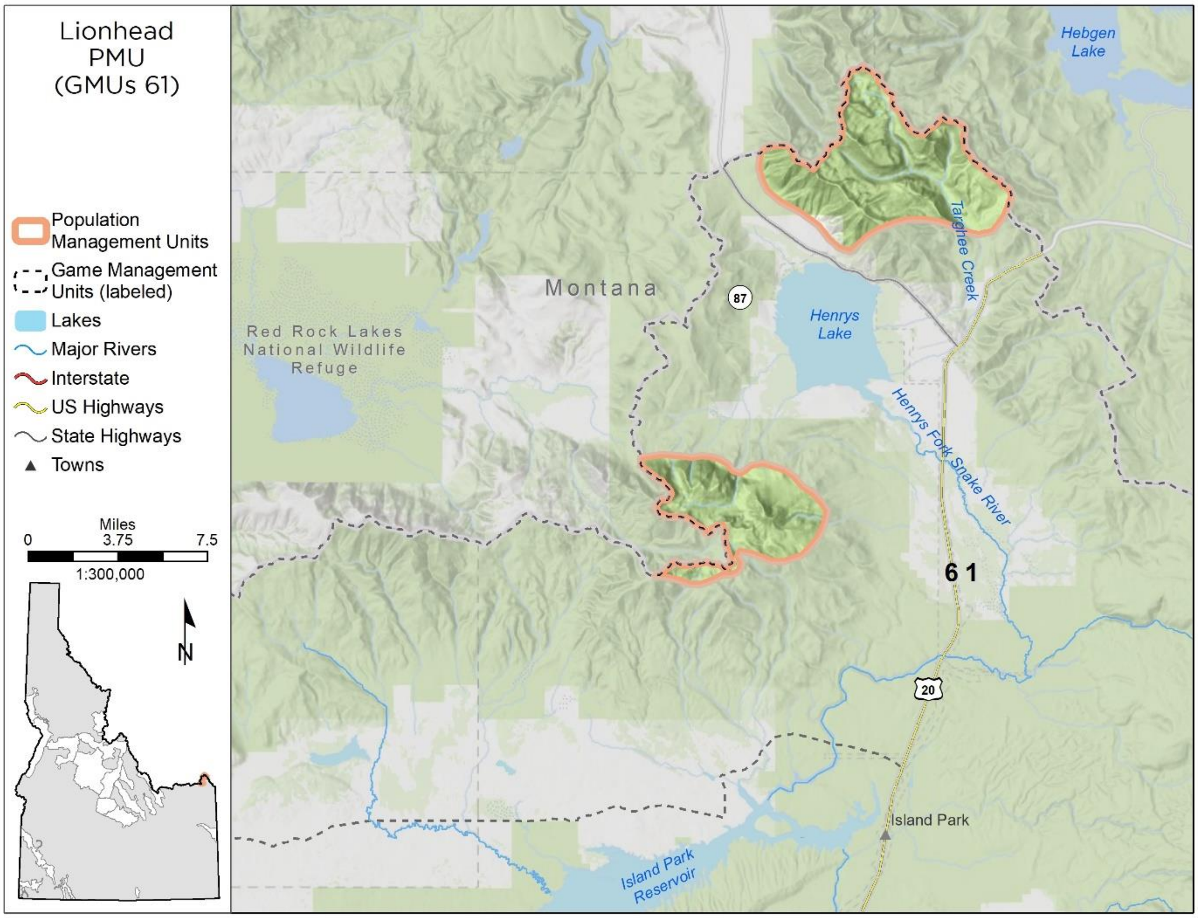


Figure 28. Lionhead PMU area map.

PALISADES PMU

This area includes portions of GMUs 64 and 67 (Figure 29). Periodically bighorn sheep are observed in this area. Individual sheep are usually seen a few times and then apparently leave the area. These individuals most likely come from Wyoming, but this has not been confirmed with telemetry data. There is not a resident or persistent bighorn sheep population in the Palisades PMU.

Management Direction

IDFG does not manage to maintain a population of bighorn sheep in the Palisades PMU. Management will focus on minimizing potential contact between bighorn sheep and domestic sheep and goats and preventing bighorn sheep that contact domestic sheep in this area from returning to an established population of bighorn sheep. If possible, the bighorn sheep that migrate into this area will be captured, radio-collared, and monitored to learn more about their travel routes and source population(s). Management may also include lethal removal of bighorn sheep that have contact with domestic sheep.

Management Action

- Continue to document observations of bighorn sheep in this PMU.
- When possible, radio-collar bighorn sheep and gather genetic samples to learn more about their movements and source population(s).
- Remove bighorn sheep that have contact with domestic sheep.

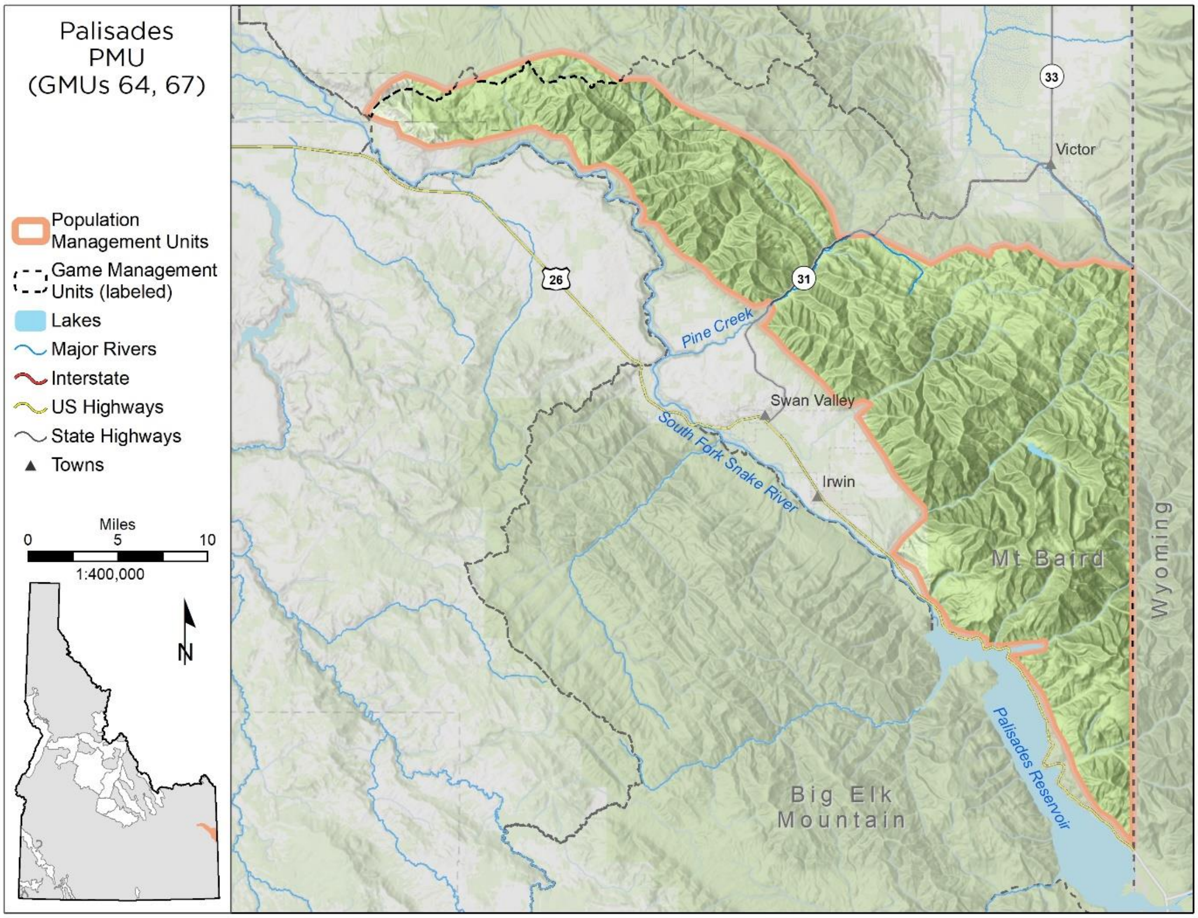


Figure 29. Palisades PMU area map.

OWYHEE FRONT PMU

The Owyhee Front in GMU 40 is characterized by sagebrush-steppe dominated foothills above the Snake River plain with scattered pockets of suitable escape terrain in which bighorn sheep persist (Figure 30, top). Reynolds Creek and Castle Creek are the main drainages bighorn sheep occupy. Ewes and lambs occupy the most rugged and broken country, whereas rams seek out areas that provide abundant forage and isolation from human disturbance such as Rough Mountain, often using low rock outcroppings or steep slopes in the absence of "typical" escape terrain. This PMU differs from other California bighorn sheep habitat in Idaho in that it lacks the deep canyon topography, which typifies much of the bighorn habitat in Owyhee County. While much of the Owyhee Front is managed by the BLM, approximately 1/3 is privately owned rangeland. In 2021, approximately 48 bighorn sheep occupied the Owyhee Front (Table 17).

In the 2010 Bighorn Sheep Management Plan, the Owyhee Front PMU included a small, isolated polygon in the Snake River Birds of Prey Natural Area. To better represent improved knowledge of bighorn sheep distribution, movements, and habitat, the boundaries were adjusted to form 1 contiguous polygon.

Historical Perspective

The first bighorn sheep to colonize the Owyhee Front after extirpation in the early 1900s were thought to have immigrated from Oregon's Leslie Gulch following a wildfire in the 1980s. The bighorn sheep occupying the Castle Creek drainage likely colonized from Shoofly Creek in GMU 41. Although included in the Little Jacks hunt area, only 1 ram had ever been taken in GMU 40. To better distribute hunting pressure, a hunt in this GMU alone was created in 2009.

Issues

The Owyhee Front is close to the largest human population center in Idaho, and the area is frequently used for recreation in the form of off-road vehicle use, hiking, hunting, trapping, horseback riding, wildlife viewing, sightseeing, and recreational shooting year-round.

Habitat degradation, due to increased and unregulated off-road motorized vehicle use, the spread of invasive annual grasses, wildfires, and risk of disease threaten this bighorn sheep population. The 2015 Soda Fire burned nearly 280,000 acres including Reynolds Creek and associated bighorn habitat. Potential transmission line development on the Owyhee Front may affect bighorn sheep and habitat. Livestock grazing is also prevalent, both on private and public lands, and feral horses occupy habitat near suitable bighorn sheep habitat. Competition with domestic livestock and feral horses is a concern, particularly due to the limited nature of bighorn sheep habitat.

Bighorn sheep, especially rams, are known to make long distance movements between the areas of suitable habitat. Generally, the bands of rams move 5–10 miles away from summer pastures to reach ewe groups during the rut. Bighorn sheep have been documented crossing GMU boundaries and the Oregon state line. These movements increase risk of contact with domestic sheep, risk of poaching, and likely risk of predation. A domestic sheep allotment and trailing route currently cross a portion of this PMU, and efforts have been made to reduce contact between bighorn sheep and domestic sheep. Additionally, due to the prevalence of roads, trails, and off-road vehicle use in the area, bighorn sheep migration habitat and routes are threatened by human recreation and the ability of sheep to move undisturbed between patches of habitat is reduced.

Radio collars were deployed on rams and ewes in the Owyhee Front PMU in 2011, 2012, and 2016. Data from collared animals documented long distance movements between available habitats, allowed IDFG to track movement patterns and travel routes, identify critical habitats, document population size and status, and determine cause-specific mortality.

Management Direction

This sheep population will continue to be managed to offer hunters a reasonable chance to harvest a mature ram (Figure 30, bottom).

Within the current distribution, modeled habitat on public land outside of domestic sheep allotment and trailing route areas comprises 813 km^2, which could support approximately 1,544 animals (assuming all habitat is suitable year-round and relatively high densities of 1.9 sheep/km^2). It is likely that the lack of lambing habitat, quality forage, and escape terrain would limit this bighorn sheep population and bighorn sheep numbers would remain lower than the currently predicted population estimate. Additionally, much of the area within bighorn sheep distribution in this PMU is used primarily for travel routes between isolated patches of critical habitat. The management objective is to maintain or increase this bighorn sheep population, provided the increase occurs in portions of the PMU where separation from domestic sheep can be maintained.

Accomplishments, 2010–2021

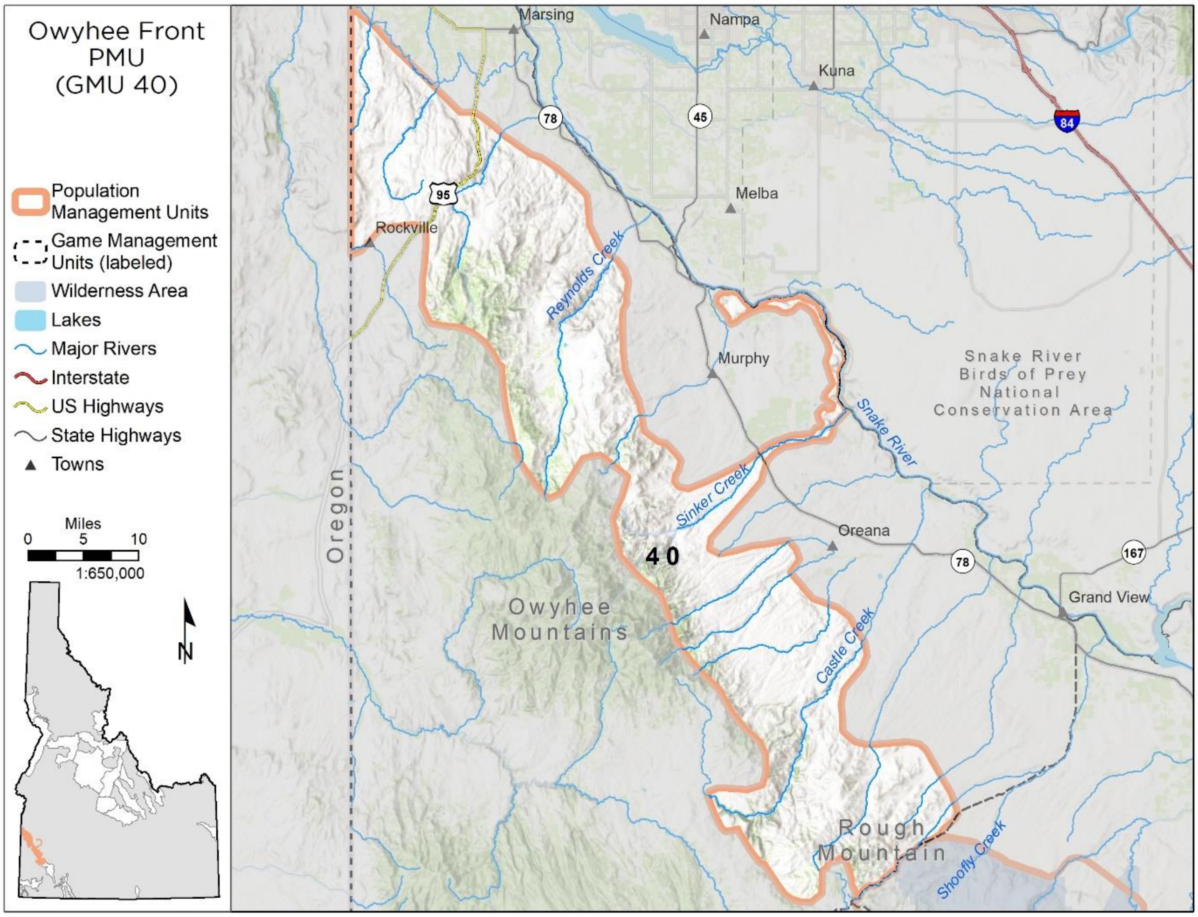
- In 2011 and 2012, IDFG collared 11 bighorn sheep (6 rams, 5 ewes) as part of a larger project with the Jacks Creek PMU.
- In 2016, 7 bighorn sheep were captured and tested for pneumonia, and 5 (3 rams, 2 ewes) fitted with GPS collars for a disease monitoring project following a pneumonia outbreak in Oregon.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Refine habitat modeling to characterize sustainable population levels more accurately.

Table 17. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Owyhee Front PMU since 2004.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
July 2004	10	3	1	0	1	0	14	
July 2008	0	0	7	17	24	0	24	
July 2010	10	5	4	17	21	0	36	
Feb 2016	12	4	4	11	15	0	31	Following pneumonia outbreak in Oregon
June 2021	16	12	6	14	20	0	48	



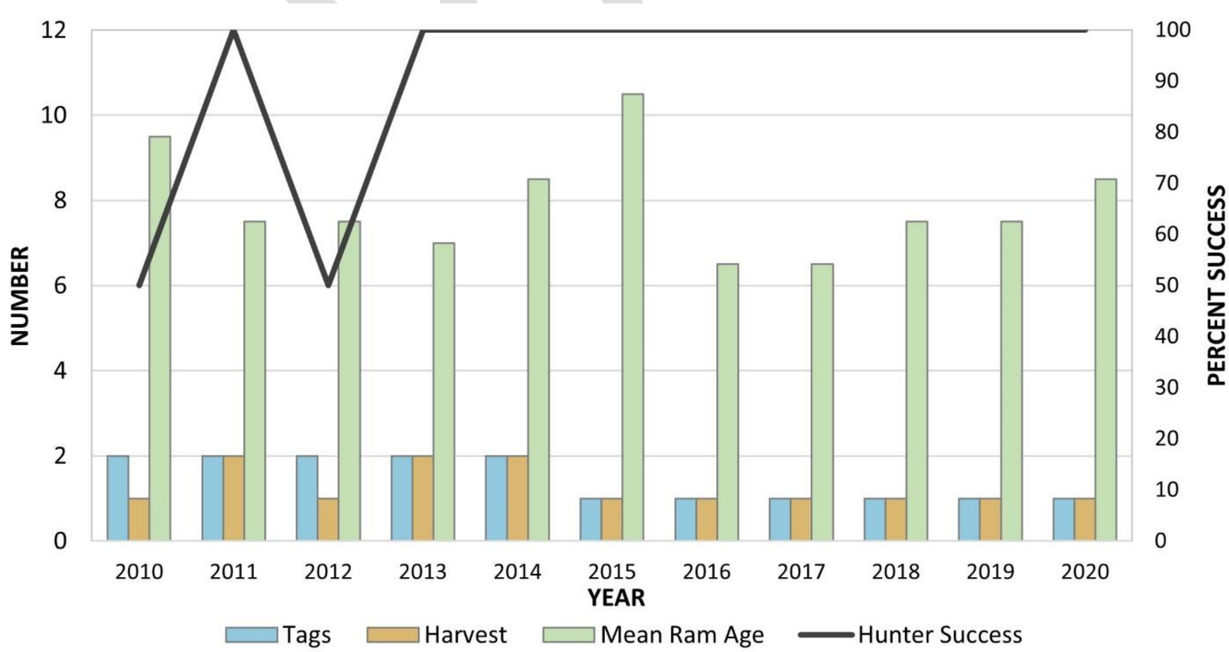


Figure 30. Owyhee Front PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

OWYHEE RIVER PMU

This PMU occurs in GMUs 41 and 42 in southwestern Idaho (Figure 31, top). Most of the habitat suitable for bighorn sheep is managed by the BLM, although a few private- and state-owned parcels exist in the area. Currently occupied sheep habitat primarily occurs within the Owyhee River Wilderness, which was created by the Omnibus Public Land Management Act and signed into law in March 2009. The PMU is characterized by large expanses of sagebrush-steppe habitat intersected by steep drainages that are 300-400 m deep. Grass-covered benches and terraces within the rugged canyons provide foraging areas preferred by California bighorn sheep, although it is common to see rams foraging 1 mile or more away from canyon rims. Sheep are typically found within the East Fork Owyhee River, Deep Creek, and Battle Creek canyons. This bighorn sheep population is non-migratory.

Historical Perspective

Native bighorn sheep were extirpated from this area in 1927 due to subsistence hunting by mining camps, heavy grazing, and diseases introduced by domestic livestock. Three releases of bighorn sheep translocated from British Columbia in the 1960s reestablished populations in the Owyhee River. By 1982, the sheep population was well enough established to be used as a source population for translocations to other parts of Idaho and 3 other states. Translocations from this PMU continued through 2003. The sheep population increased to a high of 753 animals in 1991 but declined after the severe winter of 1992–1993. In addition, over 200 bighorn sheep were translocated from this area in 1990–1993. The population remained relatively stable at approximately 250–300 animals from 2004 to 2012 before starting to decline again (Table 18). In the last 10 years the bighorn population has declined in Idaho along the Oregon border, although numbers remained more stable in the upper portions of the river.

Issues

The steep and rugged canyon terrain and isolation of some forage areas by rimrock reduces competition between bighorn sheep and domestic livestock. However, the potential for conflict may exist adjacent to the canyons, and in portions of canyons accessible to cattle. Competition for forage may increase as bighorn or cattle numbers increase, or as forage availability decreases due to drought, grazing pressure, wildfire, or invasion of unpalatable nonnative weeds or grasses. The number of elk wintering along the Owyhee River in Idaho (>700 animals) is increasing, and location data from radio-collared elk shows considerable habitat overlap. Elk could be competing with bighorn sheep for forage for nearly five months of the year. In addition, feral horses occupy habitat adjacent to canyons in sections of the PMU and compete directly with bighorn sheep for forage where their ranges overlap.

While this bighorn sheep population has largely been unaffected by disease (except for bighorn sheep from Red Canyon to the Oregon border) the potential exists due to the proximity of private inholdings in or adjacent to bighorn sheep habitat. However, as long as domestic sheep and bighorn sheep remain separated, potential for disease transmission is low. The nearest domestic sheep grazing allotment is 25 miles (40 km) away, but there is no way to regulate or monitor small farm flocks on private land. Harvested rams are tested for pneumonia each year, and hunters are asked to report sightings of any bighorn sheep showing symptoms.

Evidence of illegal off-road vehicle use in bighorn sheep habitat and along canyon rims has increased over the last 20–25 years. Enforcement is challenging due to the remoteness of the area, but the wilderness designation may have helped assuage some of the illegal use by off-road vehicles.

This area is used by the US Air Force for training missions. Impacts of military overflights to bighorn sheep are not fully understood. Agreements have been made to mitigate the potential impacts to bighorn sheep (e.g., flights will take place perpendicular to the canyons and not parallel to them) but monitoring and compliance is unknown. Expanded use of the area for military training could have negative impacts to bighorn sheep, especially during critical times of year (e.g., lambing, winter).

Predation by mountain lions is a concern for many bighorn sheep enthusiasts, and recent research showed pulses of high lion predation on collared bighorn sheep combined with poor lamb recruitment. In 2015, eastern Oregon experienced a pneumonia outbreak and, in response, IDFG conducted a population survey and capture events to determine if pneumonia had spread into neighboring GMU 42. From 2016 to 2018, IDFG captured 48 bighorn sheep in the Owyhee River PMU, tested them for pneumonia, fitted them with GPS tracking collars, and monitored them for cause-specific mortality. In 2017, IDFG and University of Idaho expanded this project to study lamb survival and nutritional quality in the Owyhee River, Lost River Range, and East Fork Salmon populations in Idaho. Pneumonia from the Oregon outbreak was not detected in Idaho populations over the course of the studies.

Management Direction

This bighorn sheep population will continue to be managed to offer hunters a reasonable chance at harvesting a mature ram (Figure 31, bottom).

Within the Owyhee River PMU, modeled habitat on public land comprises 747 km^2, which could support approximately 1,420 animals (assuming all habitat is suitable year-round and relatively high densities of 1.9 sheep/km^2). This estimated population size is nearly double the population high observed in early 1990s. However, seasonal habitats (i.e., winter range) and specific habitat needs (i.e., lambing areas) are not accounted for in the habitat model. Further refinement of the habitat model will likely result in a lower estimate of potential population size. The overall management goal is to increase the current population.

Accomplishments, 2010–2021

- From 2016 to 2018, IDFG captured 33 ewes and 15 rams in the Owyhee River PMU to monitor for pneumonia and determine cause-specific mortality.
- Between 2016 and 2019, IDFG collaborated with University of Idaho on a research project on nutrition quality, disease prevalence, and lamb

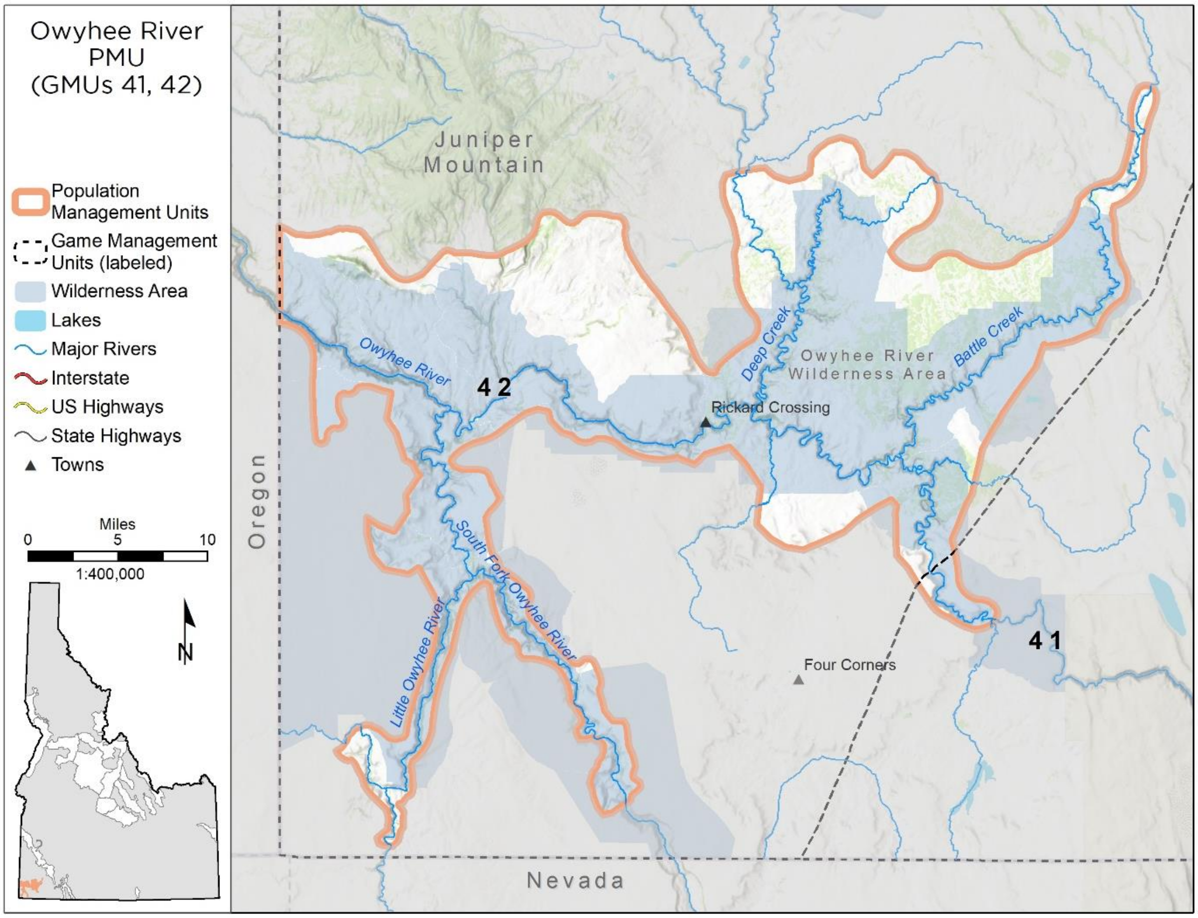
survival in the Owyhee River, Lost River Range, and East Fork Salmon populations (Bilodeau 2021).

Management Actions

- Refine habitat modeling to characterize sustainable population levels more accurately and identify critical habitat areas.
- Use cause-specific mortality information and recent survey data to evaluate the need for predator management.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 18. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Owyhee River PMU since 1983.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
1983	0	0	76	46	122	0	334	
1985	0	0	57	21	78	0	273	
Aug 1987	373	207	51	46	97	22	699	
1990	0	0	71	46	117	0	699	
Jun 1991	391	173	114	60	174	0	738	
Jul 1992	322	142	110	54	164	0	628	
Jun 1993	398	81	125	57	182	0	661	
Jul 1994	177	63	61	35	96	0	336	
Jun 1996	202	95	53	51	104	0	401	
Jun 1998	204	76	24	26	50	4	334	
Jun 2000	198	60	29	22	51	0	309	
Jun/Jul 2002	170	50	25	9	34	1	255	
Jul 2004	135	48	46	28	74	5	262	
Jul 2006	184	81	53	37	90	0	355	
Jul 2008	149	62	37	56	93	0	304	
Jul 2010	136	64	40	24	64	0	264	
Jun 2012	130	64	36	32	68	0	262	
Feb 2016	79	28	23	28	51	0	158	Following pneumonia outbreak in Oregon
Jun 2021	81	32	10	17	27	0	140	



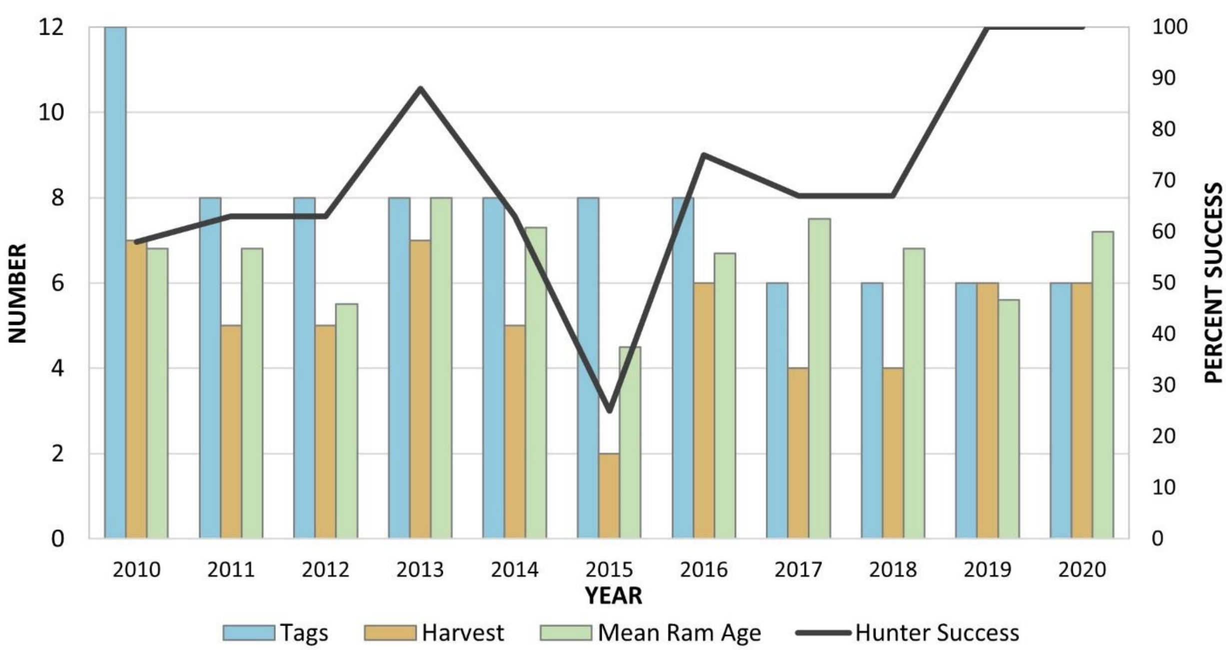


Figure 31. Owyhee River PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

JACKS CREEK PMU

This area ranges 1,100–1,900 m in elevation, and includes Big Jacks, Little Jacks, and Shoofly Creeks (Figure 32, top). These perennial streams cut through terraced canyons that average 300 m deep and are generally characterized by cliff bands interspersed with vegetated benches. The vegetative community is dominated by sagebrush, rabbitbrush, cheatgrass, and bluebunch wheatgrass.

Historical Perspective

Bighorn sheep were abundant in southwestern Idaho prior to European settlement, but numbers began to decline following the mining boom of the late 1800s. Several causes have been implicated in this decline, including competition from cattle, disease introduced by domestic sheep, and indiscriminate hunting to provide meat for mining camps. The last reported sighting of a native bighorn sheep in Owyhee County occurred in 1927.

The first release of California bighorn sheep into Jacks Creek occurred in 1967, when 12 sheep from British Columbia were released into Rattlesnake Creek, a tributary of Little Jacks Creek (see Appendix C, Table C1). Sheep were reintroduced into Big Jacks Creek in 1988. The Jacks Creek population of California bighorn sheep grew from those 12 animals to 392 animals observed on a 1999 helicopter survey. Following 1999, however, the number began to decline. Since 2004, the observed population has hovered around 170–230, although the most recent survey in 2021 found decreased numbers and low lamb:ewe ratios (Table 19).

Issues

The steep, rugged canyon terrain and isolation of some forage areas by rimrock reduces competition between bighorn sheep and domestic livestock. However, the potential for conflict may exist adjacent to the canyons and in portions of the canyons accessible by cattle. Competition for forage may increase as bighorn or cattle numbers increase, or as forage availability decreases due to drought, grazing pressure, wildfire, or invasion of unpalatable exotic weeds and grasses. The number of elk wintering between Big and Little Jacks (200–300 animals) is increasing, and location data from collared elk shows some habitat overlap with bighorn sheep. Elk are potentially competing with bighorn sheep for forage several months of the year.

The majority of occupied bighorn sheep habitat occurs within the Big Jacks Creek Wilderness and Little Jacks Creek Wilderness Areas. The wilderness designations were signed into law in March 2009. Enforcement of illegal off-road vehicle use in sheep habitat and along the canyon rims is challenging due to the remoteness of the area, but the wilderness designation may have helped assuage some of the illegal use by off-road vehicles.

A wildfire burned approximately 50,000 acres between Big Jacks and Little Jacks Creek in the summer of 2012. This fire burned a considerable amount of bighorn sheep habitat in both drainages and reestablished with both native and invasive grasses. It is uncertain how these habitat changes will affect bighorn sheep long-term. Additionally, rush skeletonweed was documented in Big Jacks Creek in 2014. This weed has the potential to establish across thousands of acres and could severely impact bighorn sheep habitat in the area.

While this bighorn sheep population has largely been unaffected by disease and die-offs experienced in other parts of the state and country, the potential exists due to the proximity of private inholdings in or adjacent to bighorn sheep habitat. However, as long as domestic sheep and bighorn sheep remain separated, potential for disease transmission is low. The nearest domestic sheep grazing allotment is 25 miles (40 km) away; however, there is no way to regulate or monitor small farm flocks on private land. The Bruneau River drainage had a significant pneumonia outbreak in 2017, but it does not currently appear to have spread to Jacks Creek. Harvested rams are tested for pneumonia each year, and hunters are asked to report sightings of any bighorn sheep showing symptoms. IDFG conducted a pneumonia observation survey in partnership with Idaho Wild Sheep Foundation volunteers in July 2019, and volunteers covered all occupied canyons in the PMU. No evidence of pneumonia was detected.

Predation by mountain lions is a concern by many sheep enthusiasts, but long-term predation monitoring is not available for the PMU. However, cause-specific mortality studies in Jacks Creek from 2002–2007 and 2011–2014 documented mountain lion predation on collared sheep, with variable annual ewe survival rates (77–87% in the 2002–2007 study and 90–96% in the 2011–2014 study). These studies also documented lamb survival and recruitment, sheep movements, and spatial use.

This area is used by the US Air Force for training and impacts to bighorn sheep are not fully understood. Agreements have been made to mitigate the potential impacts to bighorn sheep (e.g., flights will take place perpendicular to the canyons and not parallel to them). Compliance with overflight agreements is unknown and difficult to enforce. Expanded use of the area for military training could have negative impacts to bighorn sheep, especially during critical times of the year (e.g., lambing, winter).

Management Direction

This bighorn sheep population will continue to be managed to offer hunters a reasonable chance at harvesting a mature ram. Hunter success rates since 2010 have varied 67–100% (Figure 32, bottom).

Within the Jacks Creek PMU, modeled habitat on public land comprises 335 km^2, which could support approximately 636 animals (assuming all habitat is suitable year-round and relatively high densities of 1.9 sheep/km^2). This estimate is double the population high observed in early 1990s. However, seasonal habitats (winter range) and specific habitat needs (lambing areas), are not accounted for in the habitat model. Further refinement of the habitat model will likely decrease the estimated potential population size. The overall management goal is to increase the current population.

Accomplishments, 2010–2021

- In 2011 and 2012, IDFG collared 31 bighorn sheep (1 ram, 30 ewes) as part of a project combined with the Owyhee Front PMU.

- IDFG collaborated with Idaho Wild Sheep Foundation volunteers to conduct a pneumonia observation survey in July 2019.

Management Actions

- Refine habitat modeling to characterize sustainable population levels more accurately.
- Use cause-specific mortality information and recent survey data to evaluate the need for predator management.
- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.

Table 19. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Jacks Creek PMU since 1993.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Jun 1993	188	55	68	49	117	0	360	
Jun 1998	111	47	60	32	92	3	253	
Jun 2000	141	51	17	16	33	0	225	
Jun 2002	63	18	21	19	40	5	126	
Jul 2004	128	55	29	14	43	0	226	
Jul 2006	124	60	36	14	50	0	234	
Jul 2008	110	44	33	18	51	0	205	
Jul 2010	84	54	21	34	55	0	193	
Feb 2016	94	39	11	28	39	0	172	Following pneumonia outbreak in Oregon
Jun 2021	82	24	19	14	33	0	139	

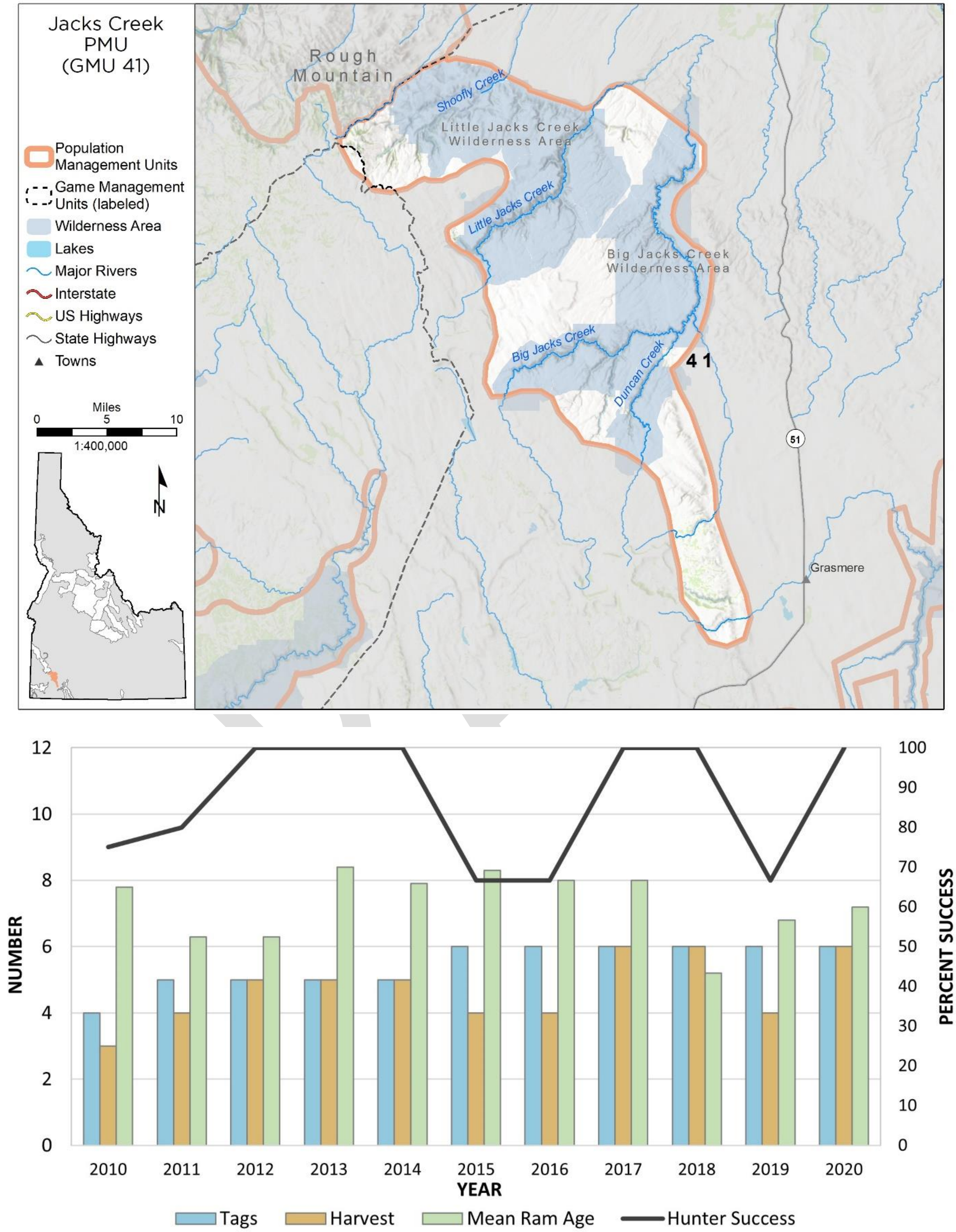


Figure 32. Jacks Creek PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

BRUNEAU-JARBIDGE PMU

This population includes bighorn sheep in GMUs 46, 47, and that portion of 41 east of Highway 51 (Figure 33, top). Bighorn sheep in this area primarily use lands managed by the BLM, but occasionally use private lands. Elevations in the area used by bighorn sheep range from 1,100 m in canyon bottoms to approximately 1,500 m on desert plateaus. The landscape is characterized by steep, rugged canyons that are 300–400 m deep. Vegetation is almost exclusively shrub-steppe, with some riparian shrub communities along river corridors. Road densities in the area are relatively low, and the distance and difficulty of travel serve as natural limitations on human use of the area. Bighorn sheep in this area do not exhibit seasonal migratory movements.

In the 2010 Bighorn Sheep Management Plan, the Bruneau-Jarbidge PMU included a small, isolated polygon along Marys Creek. To better represent improved knowledge of bighorn sheep distribution, movements, and habitat, the boundaries were adjusted to form 1 contiguous polygon.

Historical Perspective

Bighorn sheep were extirpated from southern Idaho in the early 1900s. In the 1960s, IDFG initiated a program to reestablish California bighorn sheep populations in the Owyhee River and Little Jacks Creek drainages in Owyhee County. These early releases were successful and bighorn sheep populations increased and expanded their range in southwest Idaho.

From 1982–1993, IDFG and Nevada Department of Wildlife (NDOW) released nearly 100 California bighorn sheep into portions of the Jarbidge and Bruneau drainages (Appendix C, Table C1). The bighorn sheep released by NDOW in 1982 and 1984 moved north into the Jarbidge River Canyon in Idaho. Bighorn sheep have also been released by IDFG near the confluence of the Jarbidge and West Fork Bruneau Rivers, at Dorsey Creek, and near Black Rock Pocket on the West Fork Bruneau Canyon. Currently, bighorn sheep are distributed throughout the Jarbidge and West Fork Bruneau canyons upstream from their confluence. Bighorns have been observed as far north in the Bruneau Canyon at Cave Draw and are occasionally observed in the Sheep Creek and Marys Creek drainages.

Issues

Population surveys in 1998 and 2000 indicated poor recruitment and a downturn in the Bruneau-Jarbidge bighorn population. The substantial and rapid decline of this sheep population suggested a disease die-off, although no conclusive evidence was available. Possible sources of disease for the Bruneau-Jarbidge population were identified in the Marys Creek and Contact, Nevada, areas. The decline in bighorn sheep numbers prompted the closure of the hunting season in 2001 and 2002. This hunt was reopened in 2005 with 3 tags and increased to 5 tags in 2011 when results from aerial surveys indicated the population was increasing.

In 2017 a hunter reported seeing two rams with thick nasal discharge. He harvested one of the rams and it subsequently tested positive for Movi. The Movi strain type was the same type thought to be responsible for a bighorn die-off on Currant Mountain in south-central Nevada. Method of transmission to Idaho bighorn sheep is unknown. Movi has been documented in harvested rams every year since 2017. Ram hunting permits were reduced from 5 to 2 in 2019 and reduced further to 1 permit in 2021 due to declining sheep numbers seen on aerial surveys, increasing age of harvested rams, and interviews with hunters. Only 26 sheep were observed on the most recent aerial survey in June 2021 (Table 20). It is anticipated that no tags will be offered in 2022.

In 2016, NDOW observed over 3,900 elk wintering in and near the Bruneau and Jarbidge River Canyons with an additional 1,000 elk in the Inside Desert. Whether elk are competing with bighorns is unknown, but elk are frequently observed wintering in bighorn sheep habitat. Efforts to reduce this elk herd by NDOW and to a lesser extent, IDFG, have been successful, and during two extremely mild winters (2019–20 and 2020–21), few elk were observed wintering in Idaho.

Several large wildfires have occurred in or near bighorn sheep habitat in the last 5 years. Much of the habitat impacted by wildfires in this area have reverted to annual grasses, which may not be beneficial for bighorn sheep. Furthermore, drought conditions in 2020 and 2021 were not conducive to successful vegetation rehabilitation following these fires, putting further stress on the remaining high-quality habitat in the area.

A domestic sheep was observed in the Jarbidge River canyon in May 2021, and lethally removed by IDFG personnel. The removed sheep had an USFS eartag, but efforts to track the origin of this sheep have been unsuccessful to date. This sheep tested negative for Movi. At least one other stray domestic sheep was reported in the canyon over the 2020–21 winter but was never confirmed.

Management Direction

Within current distribution, modeled habitat on public land comprises 630 km^2, which could support approximately 1,197 animals (assuming all habitat is suitable year-round and relatively high densities of 1.9 sheep/km^2). However, these models do not account for fine-scale variation in habitat quality or for specific habitat needs such as lambing and winter habitat. Thus, further refinement of habitat models and available habitat will likely reduce the estimate of potential population size.

Given previous survey data, the Bruneau-Jarbidge area seems capable of supporting ≥200 bighorn sheep. The overall management goal will be to maintain or increase the current population. No portion of the Bruneau-Jarbidge PMU overlaps any domestic sheep or goat grazing or trailing allotments. However, in those portions of bighorn sheep distribution that overlap private lands, management will focus on minimizing potential contact between bighorn sheep and small farm flocks of domestic sheep and herds of goats. Harvest has been consistent for several years (Figure 33, bottom); however, given that only 26 sheep were observed on the 2021 aerial survey, it is questionable whether this population will recover enough to offer any hunting opportunity during the life of this plan.

Accomplishments, 2010–2021

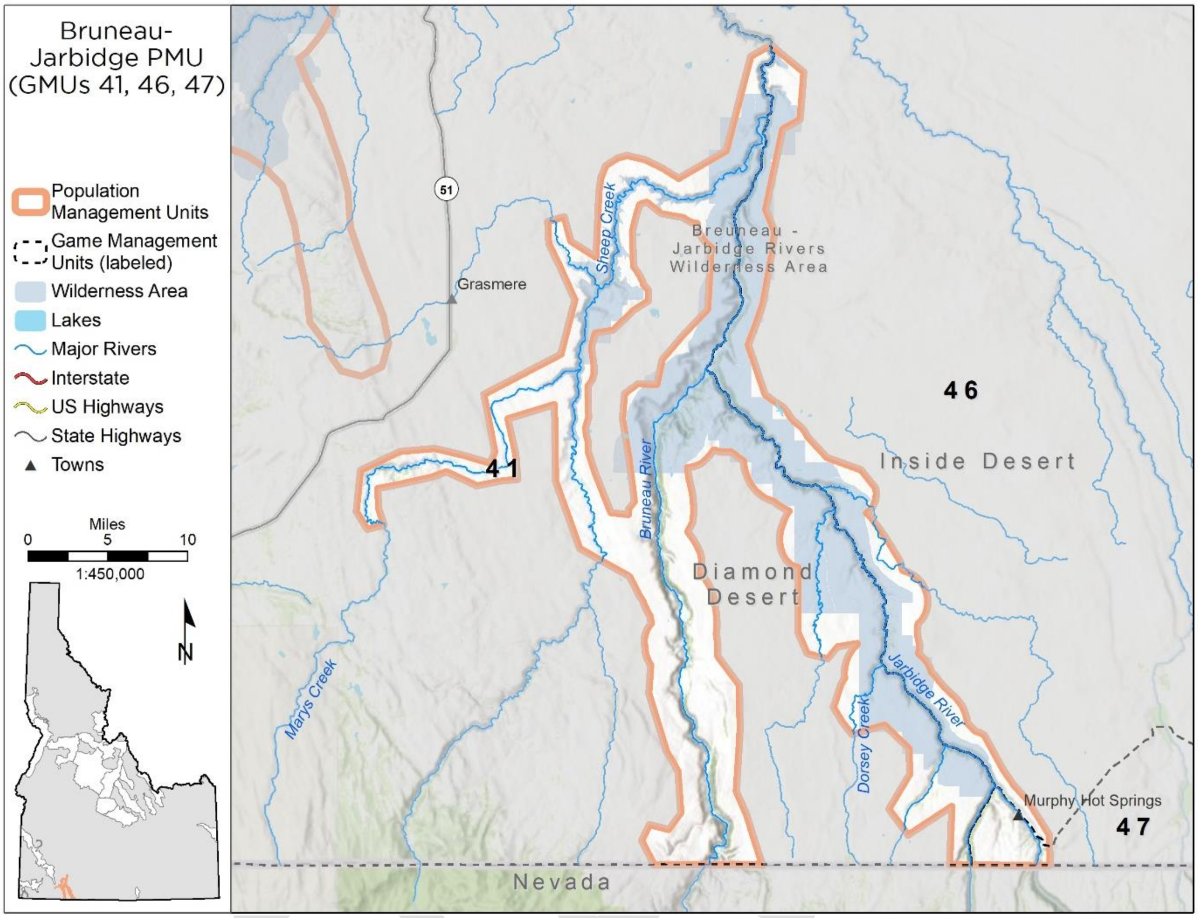
- Since 2010, ram permits were increased from 3 to a total of 5.
- Permits were reduced from 5 to 2 in 2019 in response to disease outbreak and reduced bighorn sheep numbers.
- Biological samples from hunter harvested rams enabled the detection of Movi and identification of strain type.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Investigate origins of most recent die-off and trace ownership of domestic sheep lethally removed in 2021.
- Conduct aerial survey within 5 years to monitor population response to disease.
- Opportunistically collect biological samples from bighorn sheep.

Table 20. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Bruneau-Jarbidge PMU since 2010.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Jun 2010	57	29	32	32	64	0	150	
Jun 2015	59	33	6	18	24	0	116	
Jul 2018	41	14	4	8	12	0	67	
Feb 2018	49	9	4	4	8	0	66	
Jun 2021	14	9	3	0	3	0	26	



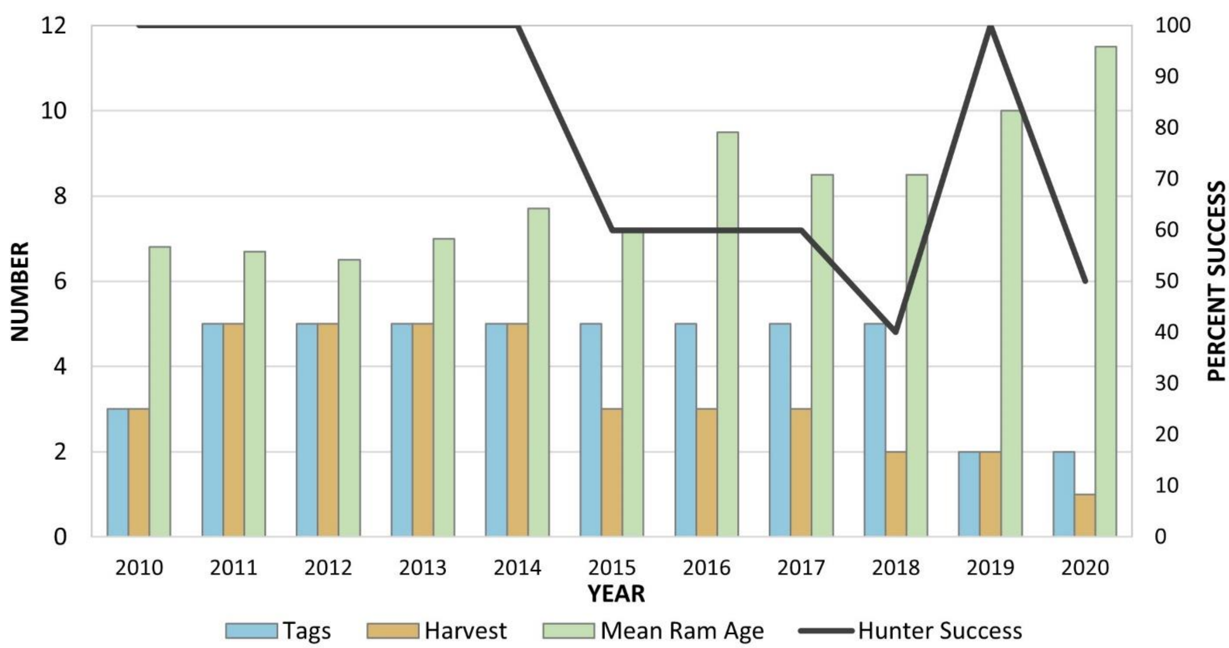


Figure 33. Bruneau-Jarbidge PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

JIM SAGE PMU

This population includes bighorn sheep in GMU 55 (Figure 34, top). Jim Sage Mountain is one of many small, isolated mountain ranges that occur throughout southern Idaho. Bighorn sheep primarily use lands managed by the BLM, but also occasionally use private land. Elevations in the area used by bighorn sheep range from 1,500 to 2,400 m. The landscape is characterized by moderately rugged canyons and low mountains. Lower elevations and south slopes feature predominately shrub-steppe vegetation. Many slopes on the southern and western portions of Jim Sage Mountain exhibit thick juniper cover. Road densities in the area used by bighorn sheep are moderate. Bighorn sheep in this area do not exhibit seasonal migratory movements.

In the 2010 Bighorn Sheep Management Plan, the Jim Sage PMU consisted of 2 small, isolated polygons. To better represent improved knowledge of bighorn sheep distribution, movements, and habitat, the boundaries were adjusted to form 1 contiguous polygon.

Historical Perspective

Bighorn sheep were extirpated from southern Idaho in the early 1900s. In the 1960s, IDFG initiated a program to reestablish California bighorn sheep populations in the Owyhee River and Little Jacks Creek drainages in Owyhee County.

By the 1980s the healthy bighorn sheep population in Owyhee County was providing sheep for translocation programs in several western states including Idaho. From 1988 through 2004, IDFG embarked on a program to reestablish California bighorns into historical range in several locations in Cassia County including the Jim Sage and Albion mountains.

During 1999, domestic sheep grazing on federal grazing allotments in GMU 55 was eliminated, clearing the way for bighorn sheep releases. From 2000 to 2004, 93 bighorns were released into historical habitat on the Jim Sage and Albion mountains (Appendix C, Table C1). The Jim Sage population has increased since 2012 to a current minimum count of 72 bighorn sheep (Table

21). The Albion Mountain releases were unsuccessful. Released sheep began dispersing immediately from the habitat selected for them and no bighorn sheep are known to currently exist in the area.

Issues

The bighorn sheep population on Jim Sage Mountain is likely near the carrying capacity of the existing habitat. Additionally, because Jim Sage is an island surrounded by private land, the potential for contact with domestic sheep, particularly small farm flocks, is high.

Key to maintaining a wild sheep population on Jim Sage Mountain will be minimizing the potential adverse effects of an increasing human population in the surrounding mountain valleys. Increasing human activities on and surrounding the mountain would be expected to lessen the suitability of existing habitat and could jeopardize the long-term viability of the population.

Thick juniper cover occurs on portions of Jim Sage Mountain, reducing the amount of suitable habitat. While bighorn sheep on Jim Sage Mountain tend to avoid thick juniper habitats, the junipers likely serve as a buffer to discourage bighorn movements to areas with increased human activities. A long-term juniper management program designed to improve bighorn sheep habitat, while considering the needs of mule deer and other wildlife, should be considered.

Rams annually leave Jim Sage Mountain every year to summer in different locales. One large ram routinely spent the summer in GMU 54. A group of rams is frequently seen in the Raft River Mountains in Utah and are thought to originate from Jim Sage. These movements are particularly troubling because these rams transverse many miles of private land to reach their summer destinations, and because both are in or near domestic sheep allotments on public land. Rams were observed in and among domestic sheep on Black Pine Mountain (GMU 57) in 2015 and 2016. The ram observed in 2016 was lethally removed but efforts were unsuccessful in 2015.

The last 4 remaining sheep in the adjacent South Hills PMU (GMU 54) were removed by IDFG personnel in 2019 because the population was not considered viable due to low population size and proximity to domestic sheep allotments. Subsequently, the South Hills PMU was eliminated with the creation of this plan. However, hunters with a GMU 55 bighorn sheep tag can also hunt in GMU 54 in the advent that rams try to summer in the now defunct PMU.

Management Direction

This bighorn sheep population will continue to be managed to offer hunters a reasonable chance at harvesting a mature ram (Figure 34, bottom).

Within current distribution, modeled habitat on public land comprises 69 km^2, which could support approximately 130 animals (assuming all habitat is suitable year-round and relatively high densities of 1.9 sheep/km^2). However, specific habitat needs such as lambing and seasonal habitats are not accounted for in these figures. Thus, further refinement of habitat models and available habitat could reduce the estimate of potential population size.

Given the isolated nature and limited amount of suitable habitat on Jim Sage Mountain, it is likely that this population is at carrying capacity. The habitat-based population modeling approach detailed in the Habitat section of this plan supports this theory. Because of these factors, management will likely focus on maintaining the bighorn sheep population on Jim Sage Mountain. In those portions of bighorn sheep distribution that overlap private lands, management will focus on minimizing potential contact between bighorn sheep and domestic sheep and goats.

Accomplishments, 2010–2021

- Increased ram permits on Jim Sage Mountain due to a favorable aerial survey in 2015.
- Lethally removed the last known 4 bighorn sheep from the non-viable South Hills population in 2019 to reduce the chance that a wandering bighorn sheep would bring pathogens back to Jim Sage. Similarly, IDFG lethally removed a ram observed with domestic sheep on Black Pine

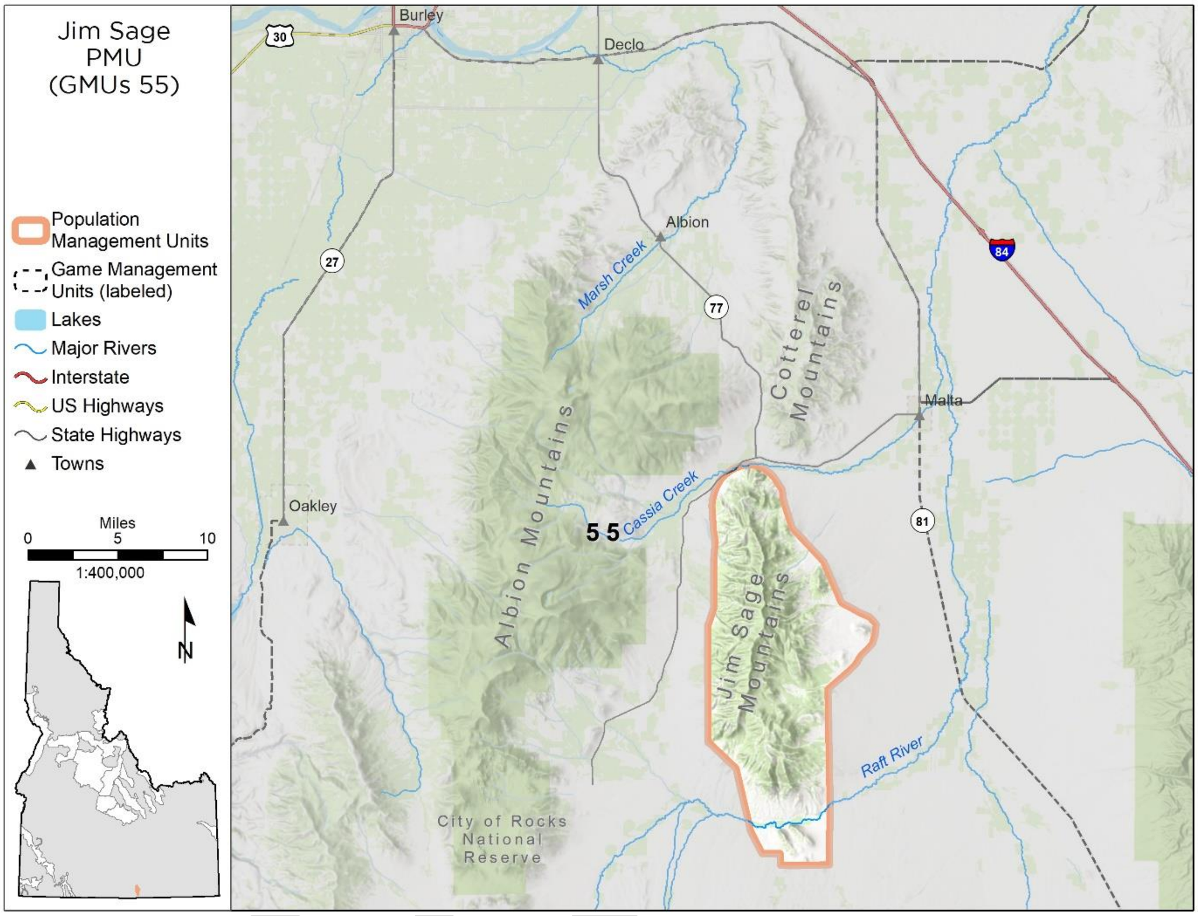
Mountain in 2016. Five domestic goats were lethally removed from Jim Sage Mountain in 2017 to prevent disease transmission to bighorn sheep, and a stray domestic sheep was lethally removed in 2020 on Jim Sage Mountain.

Management Actions

- Work with willing domestic sheep and goat owners, private landowners, permittees, USFS, BLM, tribes, and others to use BMPs to maintain separation between bighorn sheep and domestic sheep and goats.
- Work with BLM staff to discuss bighorn sheep habitat on Jim Sage Mountain, with particular emphasis on juniper encroachment within bighorn sheep habitat.
- Evaluate the use radio-marked bighorn sheep to define seasonal movements of rams, particularly interstate movements.
- Work with Utah Division of Wildlife, federal and state land management agencies, local landowners, and livestock permittees to document bighorn sheep-domestic sheep and goat contact. Develop response plan in the event contact is documented.

Table 21. Minimum counts of ewes, lambs, rams, unclassified (Unc) and total bighorn sheep from surveys in Jim Sage PMU since 2012.

Month Year	Ewes	Lambs	Rams (I, II)	Rams (III, IV)	Rams Total	Unc	Total	Comments
Jun 2012	37	14	1	0	1	0	52	
Jun 2015	51	25	8	13	21	0	97	
Jul 2018	35	18	6	8	14	0	67	
Jun 2021	40	23	7	3	10	0	73	



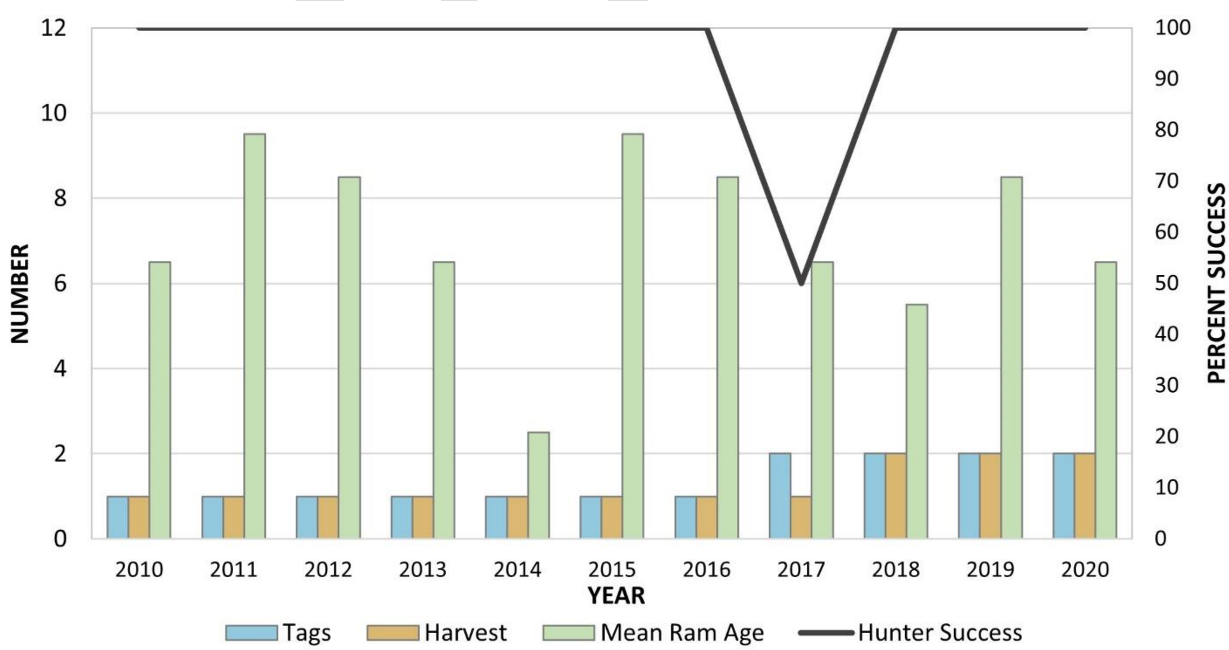


Figure 34. Jim Sage PMU area map (top) and bighorn sheep harvest information (bottom), 2010–2020. Harvest may include rain checks, auction tags, or lottery tags.

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APPENDIX A: Glossary of Terms

Allele: One of two or more versions of the same gene found at the same place on a chromosome. An individual inherits two alleles for each gene, one from each parent.

Big Game Mortality Report (BGMR): IDFG form that a hunter must complete at an IDFG office within 10 days of harvesting a bighorn sheep. A report is also mandatory (within 30 days) for any horns that are picked up from bighorn sheep found dead from natural causes.

Bighorn sheep: A member of the species *Ovis canadensis* (Family Bovidae, Tribe Caprinae) found in the mountains and canyons of western North America. Three subspecies are currently recognized: *O. c. canadensis, O. c. nelsoni*, and *O. c. sierrae*. Rocky Mountain and California bighorn sheep in Idaho are classified as *O. c. canadensis.*

Bighorn sheep distribution: Geographic range regularly or periodically occupied by bighorn sheep. Not all areas within this range have sufficient suitable habitat to support persistent populations and bighorn sheep can and do occasionally move outside this area. Distribution can change through time because of changes in population density, habitat, or other factors.

Contact: Direct contact or close proximity between body parts of 2 animals during which a disease might be transmitted from one to another. In this document, "contact" typically refers to nose-to-nose or face-to-face interaction that may lead to the transmission of respiratory disease via secretions or aerosols. Synonymous with "interaction."

Dispersal: Movement of individuals away from their area of birth or from centers of population density.

Escape terrain: Topographic areas with steep slopes. Degree of steepness used varies among multiple authors, but generally between 30° and 85°.

Fitness: Describes how good a genotype is at leaving offspring in the next generation relative to other genotypes. Fitness in this context is about how well a species or individual can survive and reproduce in its environment.

Founder effect: An example of genetic drift that occurs when a small group of individuals breaks off from a larger population to establish a new population.

Gene: A section of DNA that encodes for a certain trait, the complete set of which can be referred to as an individual's genotype (in a broad sense). In a narrow sense, the alleles at a single gene can also be referred to as genotype.

Genetic bottleneck: An extreme example of genetic drift that happens with the size of a population is severely reduced.

Genetic diversity: The range of different inherited traits (or alleles) within a population or species, low levels of which can affect fitness and the ability to adapt to changing environmental conditions.

Genetic drift: A change in allele frequencies in a population from generation to generation that occurs due to chance events.

Hunter survey: A quantitative technique designed to collect information and opinions from a random or stratified random sample of hunters that can then be extrapolated to represent the hunting population or different segments of the population (e.g., resident and nonresident).

Metapopulation: A set of spatially distinct populations of the same species that are linked by movements and dispersal.

Native: A species or population that is present because of natural processes with no human intervention.

Parasite: An organism that lives in or on another organism (its host) and gets food or protection from it.

Pathogen: A biological agent that causes disease.

Population: A group of individuals of a single species in a defined area. Bighorn sheep populations are generally defined by core use areas of males and females. In some cases it can be difficult to accurately identify distinct populations in continuous habitat (e.g., along the Salmon River). Therefore, we also use the term "population" relatively loosely to refer to management subgroups within population management units.

Population Management Unit (PMU): A population, or meta-population, in similar habitats with similar management priorities.

Reintroduced: Population of a native species that has been reestablished (usually through translocations) to a part of its historical range from which it was extirpated.

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

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

Quantitative Risk Assessment: Use of tangible data and measurements.

Strain, or Strain Type: A genetic variant, or subtype, of a microorganism (e.g., a virus, bacterium, or fungus). *Mycoplasma ovipneumoniae*, commonly referred to as “Movi”, is a genetically heterogeneous bacterium with numerous strain types that fall into distinct lineages.

Subpopulation: Cohesive, distinct groups within a population that interact infrequently (e.g., ewe groups).

Subspecies: Taxonomic groups within species that exhibit significantly different morphological or genetic structure (greater differences between groups than within groups).

Suitable bighorn sheep habitat: Areas that contain abiotic and biotic resources (e.g., forage, water, and steep, rugged, open escape terrain) selected by bighorn sheep. Not all suitable habitat is occupied by bighorn sheep or can support bighorn sheep populations. Changes in vegetation can alter suitability of habitat for bighorn sheep.

Test-and-Remove: A management strategy used to recover stagnant and declining bighorn sheep populations by eliminating bighorn sheep chronically infected with *Mycoplasma ovipneumoniae*, commonly referred to as “Movi”, and thus eliminating Movi from the population.

Translocation: Moving animals from one area to another with the intention of establishing or augmenting populations.

Viability: The probability of persistence of a population in a defined geographic area for a specified period of time.

Viable population: Numbers and distribution of reproductive animals that can be expected to persist through time.

APPENDIX B: Common and Scientific Names of Species in the Text

Taxa	Common name	Scientific name
Mammal	California bighorn sheep	*Ovis canadensis canadensis*
Mammal	Rocky Mountain bighorn sheep	*Ovis canadensis canadensis*
Mammal	Desert bighorn sheep	*Ovis canadensis nelsoni*
Mammal	Sierra Nevada bighorn sheep	*Ovis canadensis sierrae*
Mammal	Dall's sheep	*Ovis dalli*
Mammal	Elk	*Cervus canadensis*
Mammal	Mule deer	*Odocoileus hemionus*
Mammal	White-tailed deer	*Odocoileus virginianus*
Mammal	Moose	*Alces alces*
Mammal	Pronghorn	*Antilocapra americana*
Mammal	Mountain goat	*Oreamnos americanus*
Mammal	Gray wolf	*Canis lupus*
Mammal	Coyote	*Canis latrans*
Mammal	Gray fox	*Urocyon cinereoargenteus*
Mammal	Mountain lion	*Puma concolor*
Mammal	Bobcat	*Lynx rufus*
Mammal	Black bear	*Ursus americanus*
Mammal	Grizzly bear	*Ursus arctos*
Mammal	Bison	*Bison bison*
Mammal	Cattle	*Bos taurus*
Mammal	Feral horse	*Equus caballus*
Mammal	Feral burro	*Equus asinus*
Mammal	Domestic sheep	*Ovis aries*
Mammal	Domestic goats	*Capra hircus*
Bird	Golden Eagle	*Aquila chrysaetos*
Invertebrate	Scabies mites	*Psoroptes ovis*
Invertebrate	Mites	*Psoroptes* spp.
Invertebrate	Nasal botfly	*Oestrus ovis*
Invertebrate	Blacklegged deer tick	*Ixodes scapularis*
Virus	orbiviruses	*Orbivirus* spp.
Grass	Cheatgrass	*Bromus tectorum*
Grass	Bluebunch wheatgrass	*Pseudoroegneria spicata*
Forb	Yellow starthistle	*Centaurea solstitialis*
Forb	Leafy spurge	*Euphorbia esula*
Forb	Rush skeletonweed	*Chondrilla juncea*
Forb	Knapweed	*Centaurea* spp.
Shrub	Curl-leaf mountain mahogany	*Cercocarpus ledifolius*
Shrub	Sagebrush	*Artemisia* spp.
Shrub	Rabbitbrush	*Chrysothamnus* spp.
Shrub	Western juniper	*Juniperus occidentalis*

APPENDIX C: Translocations of Bighorn Sheep in Idaho.

Table C1. California bighorn sheep translocations, 1963–present.

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
31 Oct 1963		BC	Chilcotin R. (Junction)	OWY	42	E. Fork Owyhee R.	2	12	3	2	19	Hanna and Rath 1976, Hickey 1983*a*, Hatter and Blower 1996
18 Nov 1965		BC	Chilcotin R. (Junction)	OWY	42	E. Fork Owyhee R.	1	6	1	1	9	Hickey 1983*a*, Hatter and Blower 1996
2 Nov 1966		BC	Chilcotin R. (Junction)	OWY	42	E. Fork Owyhee R.	2	7	0	1	10	Hickey 1983*a*, Hatter and Blower 1996
27 Oct 1967		BC	Chilcotin R. (Junction)	JC	41	Little Jacks Cr.	3	7	1	1	12	IDFG 1968, Hickey 1983*a*, Hatter and Blower 1996
26–28 Mar 1980	JC	41	Little Jacks Cr.		NV	Washoe Co, S. Granite Range, Clear Cr.	1	3	0	0	4[c]	Hickey 1980
26 Feb – 1 Mar 1981	JC	41	Little Jacks Cr.	B-J	NV	Elko Co, E. Fork Jarbidge R., Slide Cr.	1	8	2	1	12[d]	IDFG 1981, IDFG 1990*a*, Cummings and Stevenson 1996
14–17 Dec 1982	OWY	42	E. Fork Owyhee R., Deep Cr.	B-J	41	W. Fork Bruneau R.	2	10	0	0	12[e]	Hickey 1982*a*
21 Mar 1984		BC	Chilcotin R. (Junction)	B-J	NV / 46	Elko Co., Jarbidge R. (Murphy Hot Springs)	2	8	1	1	12[f,g]	Oldenburg and Nellis 1984, IDFG 1992*a*
19–21 Dec 1984	OWY	42	E. Fork Owyhee R. Deep and Battle Crs.	B-J	41	Bruneau-Jarbidge confluence	1	8	1	1	11[g,h]	IDFG 1984*a*
30 Jan 1985	JC	41	Little Jacks Cr.	OWY	42	S. Fork Owyhee R., Coyote Hole	1	7	1	0	9[i]	IDFG 1985
30 Jan 1985	JC	41	Little Jacks Cr.	B-J	46	Bruneau-Jarbidge confluence	1	0	0	0	1	IDFG 1985

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
7 Dec 1985	OWY	42	E. Fork Owyhee R.		NV	Elko Co., S. Snowstorm Mts.	2	4	1	2	9[j]	Scott 1985, Oldenburg and Nellis 1989, Cummings and Stevenson 1996
16–17 Dec 1986	OWY	42	E. Fork Owyhee R.		NV	Humboldt Co., N. Jackson Mts.	0	2	0	0	2	Parker 1987, Oldenburg and Nellis 1989
16–17 Dec 1986	OWY	42	E. Fork Owyhee R.		NV	Elko Co., S. Snowstorm Mts.	1	3	2	0	6	Parker 1987, Oldenburg and Nellis 1989, Cummings and Stevenson 1996
16–20 Dec 1986	OWY	42	E. Fork Owyhee R., Battle and Deep Crs.	SH	54	Big Cottonwood Cr.	1	9	1	2	14[g,k]	Smith 1986, IDFG 1987, Parker 1987
15–17 Dec 1987	JC	41	Little Jacks Cr.	SH	54	Big Cottonwood Cr.	3	6	0	1	10[g,l]	Smith 1987, IDFG 1992*a*
3–5 Feb 1988		BC	Chilcotin R. (junction), Deer Park Ranch	JC	41	Big Jacks Cr.	0	10	3	1	14	Smith and Parker 1988*a,b*
4–5 Mar 1988	OWY	42	E. Fork Owyhee R., Battle and Yatahoney Crs.	JC	41	Big Jacks Cr.	2	0	0	0	2	Bodie 1988, Oldenburg and Nellis 1989
14–15 Nov 1988	JC	41	Shoofly Cr.-Poison Cr.	SH	54	Big Cottonwood Cr.	5	8	0	1	14[m]	IDFG 1988*a*, Oldenburg and Nellis 1989
15–16 Nov 1988	JC	41	Shoofly Cr.-Poison Cr.		NV	Elko Co., N. Snowstorm Mts., S. Fork Little Humboldt R.	2	7	0	3	12 [g,n]	IDFG 1988*b*, Oldenburg and Nellis 1989
29 Nov 1988	OWY	42	E. Fork Owyhee R., Yatahoney and Battle Crs.	JC	41	Duncan Cr.	6	13	3	2	24	Johnson 1988
6–7 Dec 1989	JC	41	Little Jacks Cr.	B-J	41	W. Fork Bruneau R.	2	8	1	1	12	IDFG 1989*a*

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
28–29 Nov 1990	OWY	42	E. Fork Owyhee R., Battle Cr.		ND	Killdeer Mts. WMA	5	16	1	1	23[g,o]	IDFG 1990*b*, NDGFD 1993, IDFG 1994, McKenzie 1996
29 Nov 1990	OWY	42	E. Fork Owyhee R.	B-J	41	W. Fork Bruneau R., Black Rock Crossing	1	9	4	2	16[g,p]	Gebhards 1990, IDFG 1990*c*
3–4 Dec 1991	OWY	42	E. Fork Owyhee R.		ND	Badlands	3	22	1	2	28[g]	IDFG 1991*a*, IDFG 1994
3–6 Dec 1991	OWY	42	E. Fork Owyhee R.		ND	Dutchman's Barn enclosure	2	6	1	1	10[g]	IDFG 1991*a*, McKenzie 1996
5–6 Dec 1991	OWY	42	E. Fork Owyhee R.	SH	54	E. Fork Dry Cr.	3	9	1	2	15[q]	IDFG 1991*a*, Smith et al. 1991
5–6 Dec 1991	OWY	42	E. Fork Owyhee R.		NV	Eureka Co., Sheep Cr. Range	3	16	2	0	21	IDFG 1991*a*
6 Dec 1991	OWY	42	E. Fork Owyhee R.		NV	Washoe Co., Virginia Mts.	1	12	1	0	14[r,s]	IDFG 1991*a,b*
18–20 Dec 1993	OWY	42	E. Fork Owyhee R.		NV	Lander Co., Sheep Cr. Range, Battle Mt.	3	20	1	1	25	Johnson 1990[3], IDFG 1994, Cummings and Stevenson 1996
19 Dec 1993	OWY	42	E. Fork Owyhee R.	SH	54	Big Cottonwood Cr.	3	8	0	0	11[g,t]	Johnson 1993*a*; IDFG 1993, 1994
19–21 Dec 1993	OWY	42	E. Fork Owyhee R.	SH	54	E. Fork Dry Cr.	1	7	1	1	10[g,t]	Johnson 1993*a*; IDFG 1993, 1994
20–21 Dec 1993	OWY	42	E. Fork Owyhee R.		OR	Deschutes R.	6	25	2	2	35[o,u]	Hunter 1993, IDFG 1994
21–22 Dec 1993	OWY	42	E. Fork Owyhee R.	B-J	41	Bruneau R., Black Rock Pocket	1	11	0	0	8[g,v]	Johnson 1993*b*; IDFG 1993, 1994
21–22 Dec 1993	OWY	42	E. Fork Owyhee R.	B-J	41	Jarbidge R., Dorsey Cr.	2	7	0	0	9[g,v]	Johnson 1993*b*; IDFG 1993, 1994
5–8 Feb 2000		OR	Aldrich Mt.	JS	55	Jim Sage Mt., Parks Cr.	1	9	0	0	10	ODFW 2000*a*, IDFG 2004*a*
6–8 Feb 2000		OR	John Day R., Thirtymile Cr.	JS	55	Jim Sage Mt., Parks Cr.	7	6	1	6	20[w]	ODFW 2000*b*, IDFG 2004*a*

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
30 Jan–1 Feb 2001		OR	Hart Mt. NWR	JS	55	Jim Sage Mt., Parks Cr.	0	14	0	1	15[x]	ODFW 2001, IDFG 2004*a*
8–9 Mar 2003	OWY	42	E. Fork Owyhee R.	JS	55	Albion Mts., Thunder Mt., Grape Cr.	1	5	0	0	6	IDFG 2003*a*, IDFG 2004*a*
8–9 Mar 2003	B-J	41	Bruneau R.	JS	55	Albion Mts., Thunder Mt., Grape Cr.	1	5	0	1	7[y]	IDFG 2003*b*, 2004*a*
30 Nov–1 Dec 2004		OR	Diablo Mt.	JS	55	Albion Mts., Little Cove Ranch	2	8	0	1	11	ODFW 2004*a*
2–3 Dec 2004		OR	Deschutes R.	JS	55	Albion Mts., Little Cove Ranch	1	3	0	0	4[z]	ODFW 2004*b*
14–16 Dec 2004		NV	Calico Mt., Leadville Canyon	JS	55	Albion Mts., Little Cove Ranch	3	16	1	0	20	IDFG 2004*b*

[a] Single dates represent capture or release dates. A range of dates represents capture through release, including multiple captures and releases.
[b] OWY = Owyhee River, JC = Jacks Creek, B-J = Bruneau-Jarbidge, SH = South Hills (this area is no longer considered a PMU), JS = Jim Sage
[c] Three additional sheep (2 adult female, 1 adult male) died during capture (helicopter darting) operation and 1 additional adult female escaped from the transport vehicle at the capture site (Hickey 1983*a*).
[d] Three additional adult females died during capture (helicopter darting) operation (IDFG 1981).
[e] Three additional sheep (2 adult female, 1 juvenile male) died during capture (helicopter darting) operation (Hickey 1982*a*).
[f] Nevada Department of Wildlife unable to reach intended release site further south in Jarbidge Mountains. Includes 1 adult female and 1 adult male that died shortly after release (Oldenburg and Nellis 1984).
[g] Discrepancies in sex-age composition or total numbers among sources, data shown represents best-supported values.
[h] One additional adult female died during capture (helicopter darting) operation (IDFG 1984*a*).
[i] Five additional sheep (3 adult male, 2 adult female) died during capture (helicopter darting) operation (IDFG 1985).
[j] Two additional sheep (unknown sex or age) died during capture operation (Scott 1985).
[k] Six additional sheep (5 adult female, 1 juvenile male) died and 1 adult male escaped (possible mortality due to net entanglement) during capture (drive net and helicopter net-gun) operation 16–19 Dec 1986 (Parker 1987). Big Cottonwood release included 1 sheep of unknown sex or age (Smith 1986).
[l] Two additional sheep (1 adult female, 1 juvenile female) died during capture and transport operation (Smith 1987).
[m] Two additional sheep (1 adult male, 1 adult female) died during capture (helicopter net-gun) operation (IDFG 1988*a*).
[n] One additional adult female died during capture operation (IDFG 1988*b*), NDOW records indicate only 12 sheep released (Cummings and Stevenson 1996), (2 adult male, 7 adult female, 3 juvenile female according to Oldenburg and Nellis 1989).
[o] Three additional sheep (1 adult male, 1 juvenile male, 1 unknown) died during capture (helicopter net-gun) operation (Gebhards 1990, IDFG 1990*b*).
[p] One additional adult female died during capture (helicopter net-gun) operation; 1 juvenile male originally intended for North Dakota was included in this release (IDFG 1990*c*).
[q] One additional adult female died during transport (Smith et al. 1991).

[r] Three additional adult female died during transport (IDFG 1991*b*).
[s] Seven additional sheep (unknown sex or age) died during the overall Dec 1991 capture (helicopter net-gun) operation (IDFG 1991*b*).
[t] One additional adult female died during capture (helicopter net-gun) operation (Johnson 1993*a*).
[u] One additional adult female intended for Oregon was not transported (Hunter 1993), disposition unknown.
[v] Four sheep (unknown sex or age) not accounted for and likely died during transport. Capture records (Johnson 1993*b*) show 21 total sheep (3 adult male, 16 adult female, 2 juvenile female) captured for Jarbidge and Bruneau release sites, but only 17 were released (IDFG 1993, 1994).
[w] One additional adult male died during capture (helicopter net-gun) operation. Unclear whether 1 of released males was age 0.5 or 1.5 (included as adult) (ODFW 2000*b*).
[x] One additional adult female died during capture (helicopter net-gun) operation. Sex of 2 released adults not recorded (included here as female) (ODFW 2001).
[y] One additional adult female died during capture (helicopter net-gun) operation (IDFG 2003*b*).
[z] One additional juvenile male died during capture (helicopter net-gun) operation (ODFW 2004*b*).

Table C2. Rocky Mountain bighorn sheep translocations, 1969–present.

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
27 Apr 1969	MMS	36B	Morgan Cr.	LR	37	Mahogany Cr.	2	4	0	1	7[c]	Morgan 1970
26 Aug 1970		AB	Banff NP, Panther Cr. Station	LR	37	Mahogany Cr.	5	19	0	0	24	Hickey 1983*a*
30–31 Jan 1975	P-S	28	Burnt Gulch	SHC	18	Little Granite Cr.	1	8	2	0	11[d]	Bodie 1975, Bodie and Hickey 1975, Hanna 1975, Hickey 1975
15 Jan 1976	P-S	28	Bacon Ranch	SB	58	Beaverhead Range, Long Canyon	1	3	1	1	6	Bodie 1976*a*
21–23 Jan 1976	P-S	28	Pretty Gulch	SHC	18	Little Granite Cr.	5	7	2	1	15[e]	Bodie 1976*b*
18 Jan 1978	P-S	28	Burnt Gulch	SB	58	Beaverhead Range, Long Canyon	2	7	0	2	11[f]	Hickey 1978*a,b*
26–27 Jan 1978		WY	Whiskey Basin	LR	50	Elbow Canyon	3	10	2	2	17[g]	Hockley and Hickey 1978
3–4 Jan 1979	P-S	28	Burnt Gulch		OR	Imnaha R., Cow Cr.	5	9	1	0	15	Stein 1979, Hickey 1983*a*
11–12 Jan 1979	P-S	28	Burnt Gulch	SHC	18	Bernard Cr.	0	7	0	0	7	Hickey 1979, Hickey 1983*a*
21–23 Jan 1980		WY	Whiskey Mt., BLM Ridge	LR	50	Jaggles Canyon	2	6	2	1	11	Hickey 1980, Hickey and Hockley 1980
29 Dec 1981	P-S	28	Burnt Gulch	SB	58	Beaverhead Range, Bloom Canyon	2	8	0	4	14[g]	Hickey and Parker 1982, Hickey 1982*b*
11 Jan 1982	P-S	28	Clear Cr.	SB	58	Beaverhead Range, Goddard Canyon	1	3	2	0	6	Hickey and Parker 1982, Hickey 1982*b*
11 Jan 1982	P-S	28	Pretty Gulch	SB	58	Beaverhead Range, Goddard Canyon	0	3	0	0	3	Hickey and Parker 1982, Hickey 1982*b*
14 Jan 1982	P-S	28	Clear Cr.	MMS	36B	Birch Cr., below Wood Cr.	2	3	0	3	8	Hickey 1982*b*
4–6 Jan 1983		WY	Whiskey Basin, Torrey Rim	SL	51	Lemhi Range, Badger Cr.	3	11	1	4	19[h]	Hickey 1983*a*

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
5–6 Jan 1984		WY	Whiskey Basin, Torrey Rim	SL	51	Lemhi Range, Uncle Ike Cr.	3	12	3	4	22	Hickey 1984, IDFG 1986
7 Jan 1984		WY	Whiskey Basin, Torrey Rim	NHC	11	Captain John Cr.	8	7	1	1	17	Hickey 1984, IDFG 1984*b*, Oldenburg and Nellis 1989
24 Jan 1984		OR	Lostine R.	P-S	21	Shoup bridge	3	7	3	3	16	Oldenburg and Nellis 1984, IDFG 1994
4–5 Feb 1984	P-S	28	Pretty Gulch		OR	Imnaha R., Hass Ridge/Horse Cr.	3	8	0	0	11	IDFG 1984*b*, Oldenburg and Nellis 1984, IDFG 1994, Coggins et al. 1996
11–13 Dec 1984	P-S	28	Burnt Gulch		OR	Grande Ronde R., Wenaha WMA	5	5	0	1	11[g]	IDFG 1986, Oldenburg and Nellis 1989, IDFG 1994, Coggins et al. 1996
27 Dec 1984	P-S	21	Cove Cr.		OR	Grande Ronde R., Wenaha WMA	1	10	3	2	16	IDFG 1994, Coggins et al. 1996
10–14 Jan 1985		OR	Lostine R.	NB	30A	Beaverhead Range, Rocky Canyon	3	14	3	2	22	Coggins and Van Dyke 1985, IDFG 1990*a*
16–17 Dec 1985	P-S	21	Ebenezer Bar		OR	Minam R.	2	9	1	0	12	Oldenburg and Nellis 1989, IDFG 1994
5–7 Jan 1986		OR	Lostine R.	NL	37A	Lemhi Range, Falls Cr.	4	11	1	2	18	Coggins and Parker 1986, IDFG 1986
18 Feb 1988	EFS	36A	E. Fork Salmon R.	NL	37A	Lemhi Range, Morse Cr.	3	9	1	0	13[j]	IDFG 1988*c*
19 Feb 1988	MMS	36B	Morgan Cr.	NB	30A	Beaverhead Range, Cedar Gulch	4	11	2	0	17	IDFG 1988*d*
19 Feb 1988	MMS	36B	Morgan Cr.	MMS	28	Williams Cr.	2	4	0	0	6	IDFG 1988*e*
15–17 Feb 1989	MMS	36B	Morgan Cr.	SEL	17	Tango Bar	5	8	1	1	15	Power 1989
15–16 Feb 1989	MMS	36B	Morgan Cr.	SEL	17	Elevator Mt.	2	12	0	0	14[k]	Power 1989

Date[a]	Capture site			Release site			Adults		Lambs		Total	Source
	PMU[b]	GMU / state	Location	PMU	GMU / state	Location	M	F	M	F		
16–17 Feb 1989	MMS	36B	Morgan Cr.	NL	37A	Lemhi Range, Falls Cr.	2	18	2	1	23	IDFG 1989*b*
3–4 Jan 1990		WY	Whiskey Basin, Torrey Rim	SHC	18	Three Cr.	6	18	4	2	30[l]	IDFG 1991*c*
6–7 Feb 1992	MMS	36B	Morgan Cr.		WY	Bighorn Mts., Shell Canyon	2	16	2	2	22[m]	IDFG 1992*a*,*b*
11–13 Dec 1997		BC	Spences Bridge	SHC	13	Big Canyon Cr.	3	12	1[n]	0	16[g]	IDFG 1997*a*,*b*; 1998
10–13 Feb 1999		AB	Hinton, Cadomin mine	SHC	13	Big Canyon Cr.	3	3	0	0	6[g]	IDFG 1999, 2000
12–13 Feb 2002		MT	Missouri R., Havre	SHC	18	Myers Cr.	4	16	0	0	20	IDFG 2002, 2003*c*
5–9 Jan 2005		MT	Sun R., Willow Cr.	LR	37	Rock Springs Cr.	3	27	0	4	34[g]	IDFG 2005
7–9 Jan 2005		MT	Sun R., Willow Cr.	LR	50	Cedar Cr.	1	23	1	3	28[g]	IDFG 2005

[a] Single dates represent capture or release dates. A range of dates represents capture through release, including multiple captures and releases.
[b] NHC = North Hells Canyon, SHC = South Hells Canyon, SEL = Selway, P-S = Lower Panther-Main Salmon., NB = North Beaverhead, SB = South Beaverhead, NL = North Lemhi, SL = South Lemhi, LR = Lost River Range, EFS = East Fork Salmon, MMS = Middle Main Salmon.
[c] Three additional bighorns died during capture (helicopter drive-net) operation (Morgan 1970).
[d] Three additional adult female died during capture (corral trap) and release operation (Bodie 1975); and 2 of the 8 adult female apparently died shortly after release (Bodie 1975, Hickey 1977).
[e] Six additional sheep (3 adult female, 1 juvenile female, 2 juvenile male) died during transport (Bodie 1976*b*).
[f] One additional adult female died shortly after release (Hickey 1978*b*).
[g] Discrepancies in sex-age composition or total numbers among sources, data shown represents best-supported values.
[h] Two additional adult female died during the capture operation (Hickey 1983*a*,*b*).
[i] Twelve sheep captured, but only 11 moved to OR (Parker 1985).
[j] One additional adult female died during capture (helicopter net-gunning) operation and 1 additional adult female was injured and taken to Boise Zoo (IDFG 1988*c*).
[k] One additional adult male died at the release site (Power 1989); 2 additional sheep (1 adult female, 1 juvenile female) died during capture (helicopter net-gunning) operation (Scott 1989).
[l] One additional adult female died during capture operation (IDFG 1991*c*).
[m] One additional adult female died during capture operation (IDFG 1992*a*).
[n] This juvenile male died shortly after release (IDFG 1998).

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APPENDIX D: Modeling Potential Habitat of Bighorn Sheep in Idaho

Several models have been developed to improve understanding of bighorn sheep habitats and distributions for both Rocky Mountain bighorn sheep (e.g., Poole et al. 2016, Devoe et al. 2020, Lula et al. 2020, Robinson et al. 2020, Donovan et al. 2021) and desert bighorn sheep (e.g., Bleich et al. 2010, Hoglander et al. 2015, Karsch et al. 2016, Gedir et al. 2020, Robinson et al. 2020). However, none of these provide potential habitat information for bighorn sheep in Idaho using the most current Idaho observation data.

To aid in development of this management plan, we developed a model of potential bighorn sheep habitat using maximum entropy analysis (Maxent 3.4.1; Phillips et al. 2006, Phillips and Dudík 2008, Phillips et al. 2017). Given a set of environmental variables and species presence locations, Maxent identifies correlations between each variable and presence data, compares those correlations with the range of environmental conditions available in the modeled region, and develops a continuous model of relative likelihood, or probability, of suitable habitat across the study area based on environmental similarity to known occupied sites. Our modeling process incorporated all available occurrence data and several environmental variables hypothesized to influence distributions of bighorn sheep in the previously mentioned modeling efforts. Conducting all spatial analyses in ArcGIS 10.8.1 (ESRI 2020), we ensured spatial data were in a common geographic coordinate system, spatial resolution (30 m x 30 m), and extent; then exported data as ASCII files for input into R 4.0.0 (R Core Team 2020) and Maxent.

Bighorn Observations

All known observations of bighorn sheep in Idaho as of June 2021 were compiled for this modeling effort (Habitat section, Table 2). The data set included observations from numerous radio-collared animal studies, helicopter and fixed-wing survey efforts, remote camera survey detections, records in the USFS Natural Resource Information System database and in IDFG regional data files and reports previously stored in the Idaho Fish and Wildlife

Information System (IFWIS) Species Diversity Database (including museum specimens, older survey efforts, and incidental observations).

We carefully evaluated all data for use in the distribution model to ensure observational, spatial, and temporal accuracy. Nearly all 611,342 compiled observations were categorized as verified (e.g., specimen, DNA, photograph, or radio-collared animal) or trusted (e.g., documented by a biologist, researcher, or taxonomic expert) and as having sufficient spatial accuracy (≤500 m) for our modeling purposes. However, compiled observation data such as these are prone to errors of sampling bias, both geographically and environmentally. Given most observations came from radio-collared animal studies in Regions 2, 3, and 7, data exhibited spatial clustering at fine scales in these portions of the state. Species distribution models can be sensitive to such bias and spatial filtering, or randomly subsampling presence data with a minimum distance separating sample points, can limit spatial autocorrelation and reduce environmental bias caused by such uneven sampling (Phillips et al. 2009, Veloz 2009, Kramer-Schadt et al. 2013, Boria et al. 2014, Radosavljevic and Anderson 2014). The minimum distance chosen is somewhat arbitrary and depends on the species of interest, environmental conditions of the study area as well as resolution of data used for modeling. We reduced locally dense sampling of bighorn sheep by randomly subsampling with a minimum distance of 800 m. These filtering procedures (verified or trusted, ≤500 m accuracy, within Idaho, and >800 m separation) resulted in a total of 6,020 observations available for use in our modeling effort (Figure D1).

Species are known to exhibit variability in habitat use across their range and this variability can significantly affect modeling results (e.g., Valladares et al. 2014, Moran et al. 2016, Lecocq et al. 2019). Recent bighorn sheep location data, together with local knowledge, indicated that populations in western (Hells Canyon), central (Idaho Batholith-Middle Rockies), and southern (Owyhee) areas of the state exhibit different habitat use characteristics. Because of this we distinguished among these three areas during model development for this plan (Figure D1). The three ecoregional models were combined into a single final statewide habitat layer, which still reflects habitat use differences across the three ecoregions. Because winter habitat is likely more limiting to Rocky Mountain bighorn sheep than summer habitat for some populations, particularly those in IDFG Region 7, we developed a winter model for the Idaho Batholith-Middle Rockies region. However, the resulting model did not differ substantially enough from the year-round model to be useful and, thus, was not considered further.

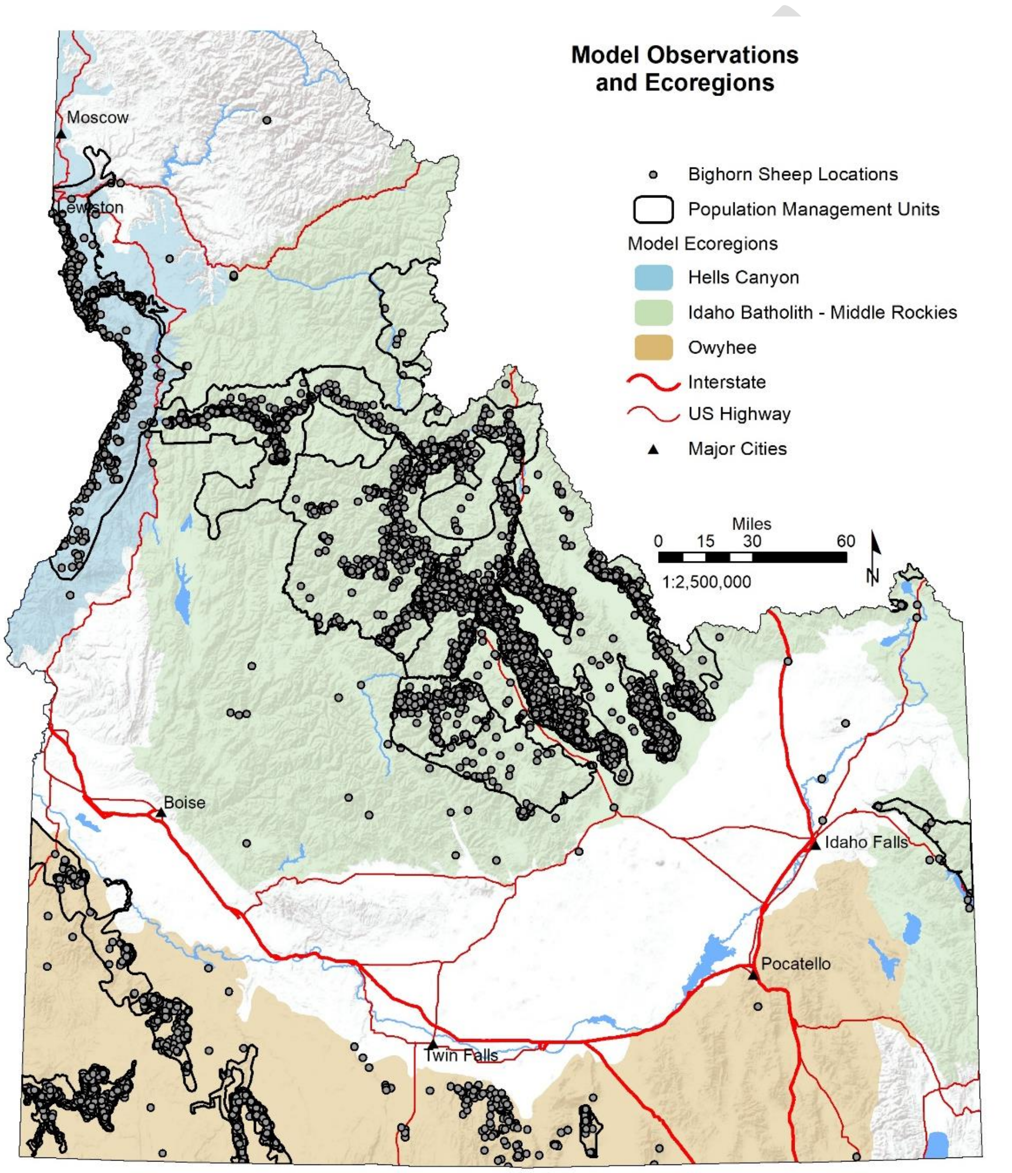

Figure D1. Bighorn sheep observations used in development of species distribution models for 3 ecoregions in Idaho. Point data are from various Idaho Department of Fish and Game databases as of June 2021 and are filtered to include only verified or trusted locations with ≤500 m accuracy and >800 m apart.

Environmental Variables

Previous modeling efforts have focused on a suite of topographic, vegetative and disturbance covariates at a variety of spatial scales. We selected similar variables, in addition to others potentially contributing to bighorn sheep habitat in Idaho, from a subset of fine-scale (30 m resolution) topographic, edaphic, climatic, and vegetative covariates (Table D1) already developed for use in other statewide modeling projects (L. K. Svancara, IDFG, unpublished data).

Topographic variables generally act as surrogates for factors influencing plant growth (e.g., temperature, light, and soils), but can also directly account for differences in local climate and be important in species distribution models (Luoto and Heikkinen 2008, Austin and Van Niel 2011). In addition, topographic variables are typically used to define ‘escape terrain’, i.e., steep, rugged terrain used by bighorn sheep to reduce predation risk (e.g., Sweanor et al. 1996, McKinney et al. 2003, DeCesare and Pletscher 2006, Sappington et al. 2007, Donovan et al. 2021). We incorporated several topographic variables including elevation, aspect, slope, relative slope position (within a 250m neighborhood), distance to steep terrain (defined as >30° slope), percent of steep terrain within 150m and 300m neighborhoods, roughness (within a 250m neighborhood), vector ruggedness measure (VRM) within 30m and 250m neighborhoods), compound topographic index (CTI), topographic solar-radiation index (TRASP), heat load index (HLI), and solar radiation index (SRI). Roughness, like terrain ruggedness index (Riley et al. 1999), calculates the amount of elevation difference between a grid cell and its neighbors; essentially measuring the variance of elevation within a specified neighborhood. The VRM, which measures terrain heterogeneity within a neighborhood, captures variability in both slope and aspect into a single measure (Sappington et al. 2007). The CTI is a steady-state wetness index that measures catenary topographic position represented by both slope and catchment size and aims to model soil water content (Moore et al. 1993). The TRASP, HLI, and SRI indices estimate the amount of incident radiation using different methods (McCune and Keon 2002, Roberts and Cooper 1989, Aycrigg et al. 2017). We calculated CTI, TRASP, HLI and roughness using Evans et al. (2014) and VRM using Sappington (2012), both freely available ArcGIS tools. All topographic variables, to varying degrees, were selected to reflect landscape characteristics that may contribute to bighorn sheep distributions either directly (e.g., escape terrain, temperature) or indirectly (e.g., light and moisture effects on forage). For example, CTI and roughness may serve as proxies for local temperature patterns (e.g., cold air drainage, Dobrowski et al. 2009), whereas VRM, slope, and aspect act as surrogates for light or solar radiation. All topographic variables were developed using the National Elevation Data (USGS 2016) at 10m resolution data and resampled to 30 m resolution for modeling.

We selected edaphic characteristics known to either affect the availability of soil nutrients or exert direct physiological limitations, or both, on plants. These included percent sand, percent silt, percent clay, pH, available water supply, calcium carbonate, cation-exchange capacity (the ability of soil to maintain nutrients), organic matter, and depth to a restrictive layer. To focus on the most critical soil for plant establishment, we used a weighted average of all soil mapunits in the top 0–25 cm. These data were developed at 10 m resolution following the national standard methodology used in development of similar products with the Soil Survey Geographic database (SSURGO, USDA NRCS 2016a), then resampled to 30 m resolution for modeling.

To the best of our knowledge, climate variables have not been used in any current bighorn sheep distribution model; however, they have been used extensively in modeling other species habitat and distributions (e.g., Elith et al. 2010, 2011; Anderson and Gonzalez 2011; Stanton et al. 2012; Booth et al. 2014). Climatic variables typically used in species modeling rely on temperature and precipitation at moderate (~1 km) spatial resolution (Hijmans et al. 2005, Daly et al. 2008, Wang et al. 2012, Wang et al. 2016). To better represent Idaho climate, we used temperature data developed at finer spatial resolution (250 m) for the Northern Rocky Mountains (Holden et al. 2015) in combination with precipitation data (originally 800 m, resampled to 250 m resolution using cubic convolution to match temperature data) from the Parameterized

Regression on Independent Slopes Model (PRISM, Version 14.1-20140502-1000) (PRISM Climate Group 2012, Daly et al. 2015). Both datasets represent monthly 30-year normals covering the period 1981–2010, from which we calculated 19 bioclimatic variables following Nix (1986) and Hijmans et al. (2005). These 19 bioclimatic variables characterize climatic conditions best related to species physiology (O'Donnell and Ignizio 2012, Booth et al. 2014).

Vegetation characteristics typically identified as important to bighorn sheep include tree or shrub canopy cover and presence of grasslands. We developed several variables from the most recent LANDFIRE 2016 land cover classification (USGS 2019) including height of all trees and shrubs, herbaceous canopy cover, shrub canopy cover, tree canopy cover, distance to dense (≥60%) tree canopy cover, percent natural land cover within 300 m, and percent natural land cover within 1,000 m. In addition, we included distance to intermittent streams and distance to perennial streams and waterbodies based on National Hydrography Data (USGS 2017) (FCodes 46006 and 46003, respectively).

Current Habitat Suitability

For each of the 3 modeling regions (Figure D1), we supplied Maxent with occurrence data as described above, as well as background points consisting of approximately 10,000 randomly generated pseudo-absences that were >800 m apart, >800 m from presence locations, and outside of waterbodies. Each regional model was developed using training and background locations from only that region and was then projected statewide for comparison with the other models.

Following recommended approaches, we addressed collinearity and calculated species-specific model parameters for the regularization multiplier and feature types. In an iterative approach, we optimized each model for regularization multiplier (values tested included 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 7, 8, 9, 10) and feature types (linear, quadratic, product, threshold, hinge, and interactions) using the *enmSdm* package (Smith 2017) in R 4.0.0 (R Core Team 2020) and selected the best performing combination based on AIC_c (Warren and Seifert 2011, Wright et al. 2015). Beginning with a full model inclusive of all covariates (n = 51), we implemented 10-fold cross-validation with jackknifing to measure importance of each variable to the resulting model. Variables were then ranked based on their permutation importance and removed if <2%. Correlated variables with *P* >0.75 were also removed, keeping the variable with higher permutation importance. This iterative process of model optimization, development, and variable ranking and removal was repeated until remaining variables displayed a minimum importance of ≥5%. Final models represent the average of 10 replicates using the optimized parameters and most important variables.

We imported mean model output into ArcGIS 10.8.1 (ESRI 2020) and, to identify suitable versus unsuitable habitat, we binned model values using the 10-percentile training presence threshold. This threshold identifies the model value that excludes 10% of training locations having the lowest predicted value and was used for models developed in all 3 regions. Final categorical models were then combined into 1 single statewide layer of suitable habitat.

Results and Discussion

Maxent accurately predicted bighorn sheep habitat in each of the 3 model ecoregions with Area Under Curve (AUC) = 0.860 in Hells Canyon, 0.804 in Idaho Batholith-Middle Rockies, and 0.906 in Owyhee.

For the Hells Canyon model ecoregion, the best-fit model based on AIC_c included linear and product features with a regularization multiplier of 0.5. Averaged over 10 replicate runs, the most important variables were precipitation of the wettest quarter (bio16), distance to escape terrain, percent of escape terrain within 300m, and minimum temperature of the coldest month (bio6) (in order of permutation importance) (Figure D2). Jackknife tests indicated percent of escape terrain within 300m had the most useful information by itself and minimum temperature of the coldest month had the most information that was not present in other variables. Predicted bighorn sheep habitat suitability in Hells Canyon was greatest in areas near to escape terrain and with a greater amount of escape terrain in the surrounding area. In

Hells Canyon, these areas have lower amounts of precipitation in the wettest quarter (generally spring) and higher minimum temperatures in the coldest month.

For the Idaho Batholith-Middle Rockies model ecoregion, the best-fit model based on AIC_c included linear, product, and quadratic features with a regularization multiplier of 0.5. Averaged over 10 replicate runs, the most important variables were elevation, precipitation of the coldest quarter (bio19), distance to escape terrain, tree/shrub height, percent of escape terrain within 300m, mean temperature of the wettest quarter (bio8), and precipitation seasonality (bio15) (in order of permutation importance) (Figure D3). Jackknife tests indicated tree/shrub height had the most useful information by itself and elevation had the most information that was not present in other variables. Predicted bighorn sheep habitat suitability in Idaho Batholith-Middle Rockies was greatest in areas at lower and higher elevations, near to escape terrain, with a greater amount of escape terrain in the surrounding area, and tree/shrub heights of <5 m. These areas were generally characterized by low precipitation in the coldest quarter (winter), higher mean temperature in the wettest quarter (generally spring), little seasonal variability in precipitation.

For the Owyhee model ecoregion, the best-fit model based on AIC_c included linear, product, and hinge features with a regularization multiplier of 1.0. Averaged over 10 replicate runs, the most important variables were distance to escape terrain, mean temperature of the coldest quarter (bio11), distance to dense tree canopy cover, and precipitation seasonality (bio15) (in order of permutation importance) (Figure D4). Jackknife tests indicated distance to escape terrain had the most useful information both by itself and that was not present in other variables. Predicted bighorn sheep habitat suitability in the Owyhee region was greatest in areas near to escape terrain and further from dense canopy cover. These areas were generally characterized by higher mean temperatures in the coldest quarter (generally winter) and moderate seasonal variability in precipitation.

Selection of specific model thresholds for determining suitability is somewhat arbitrary and biologically meaningful thresholds can be difficult to determine, thus careful consideration of resulting model accuracy is necessary (Liu et al. 2005, Merow et al. 2013). Using the selected 10 percentile threshold described above for each of the modeled ecoregions (Hells Canyon = 0.3124, Idaho Batholith-Middle Rockies = 0.3993, and Owyhee = 0.3056), predicted habitat for each area was independently categorized as suitable or not-suitable (Figure D5). All areas modeled as suitable habitat were then combined into a single statewide layer that included 15.5% (33,602 km^2) of Idaho (Habitat section, Figure 4). The majority of habitat classified as suitable is predicted to occur in 4 PMUs in IDFG Region 7 (Middle Fork Salmon, Lost River Range, Lower Panther-Main Salmon, and Middle Main Salmon) and 1 PMU in each of Region 2 (South Hells Canyon) and Region 3 (Lower Salmon). Although the 10-percentile threshold is easily interpretable and reduces likely commission error to some degree, it may still overestimate potential habitat in some areas (Radosavljevic and Anderson 2014).

Future Model Refinements

Given time constraints under which the bighorn sheep model was developed, we strongly recommend additional biologic and programmatic model refinements be considered. Biologically, developing smaller region-specific and/or season-specific models may address the sometimes dramatically different landscapes used by bighorn sheep across the state at different times of the year. Further, resource selection function models using radio-collared animals may address variable habitat use by sex, age, and/or season.

Programmatically, further refinement of background data, as well as inclusion of different covariates, may result in better fitting models. Because Maxent uses background locations where presence or absence of target species is unknown or unmeasured, choice of background data influences what is modeled and perceptions about results (Elith et al. 2011, Merow et al. 2013). By default, Maxent assumes the species is equally likely to be anywhere in the study extent (Phillips and Dudík 2008), thus, modifying the background sample is equivalent to modifying prior expectations for species distribution

(Merow et al. 2013). Using the 3 model ecoregions helped address this issue, but additional refinement may result in increased model performance (e.g., VanDerWal et al. 2009, Anderson and Raza 2010, Iturbide et al. 2015).

Similarly, including additional covariates such as landscape disturbance (fire), Normalized Difference Vegetation Index, snow depth, and multi-scale variations of these covariates may improve model performance as in other efforts (e.g., Donovan et al. 2021). Lastly, assessing potential future changes in modeled distribution of bighorn sheep under various climate change scenarios would be beneficial.

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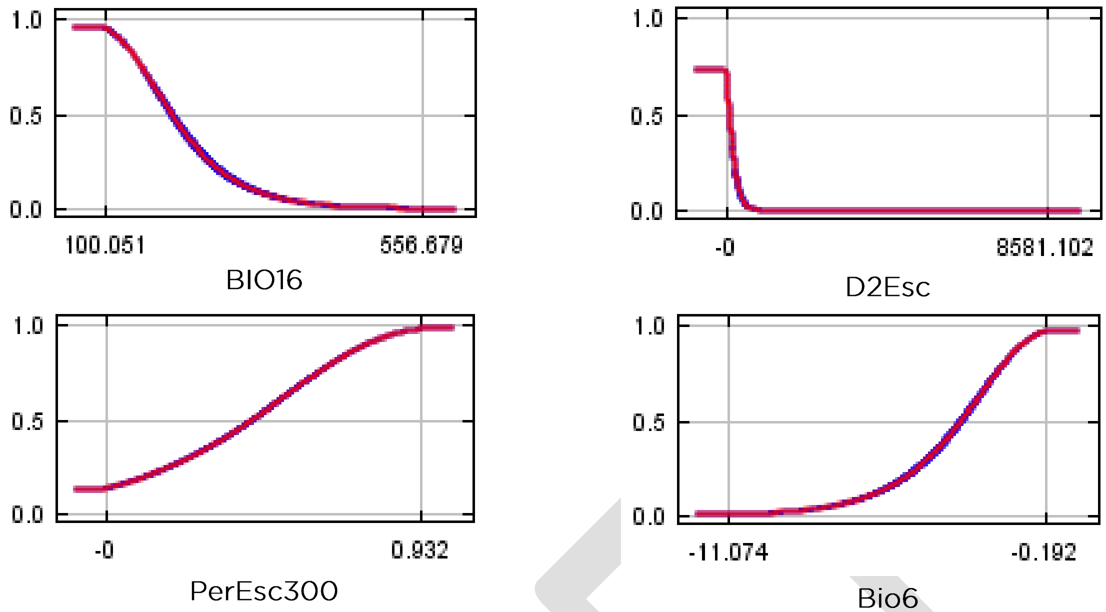
Table D1. Environmental variables used in modeling bighorn sheep habitat in Idaho.

Type	Variable	Code	Units	Source
Topography	Aspect	Asp	Degree	3D Elevation Program (USGS 2016), Evans et al. (2014) [CTI and Rough8], Sappington et al. (2007) [VRM]
	Slope	Slp	Degree	
	Elevation	Elev	m	
	Distance to escape terrain (>30°)	D2Esc	m	
	Percent of escape terrain within 150m	PerEsc150	Percent	
	Percent of escape terrain within 300m	PerEsc300	Percent	
	Compound Topographic Index	CTI	Index	
	Roughness (250m neighborhood)	Rough8	m	
	Topographic Solar-Radiation Index	TRASP10	Index	
	Heat Load Index	HLI	Index	
	Relative Slope Position (250m neighborhood)	SLPPOST10	Index	
	Vector Ruggedness Measure (30m neighborhood)	VRM30	Index	
	Vector Ruggedness Measure (250m neighborhood)	VRM250	Index	
	Solar Radiation Index	SRI	Index	Aycrigg et al. (2017)
Climate	Mean annual temperature	Bio1	°C	Holden et al. (2015), PRISM (2012), *dismo* package in R.
	Mean diurnal range	Bio2	°C	
	Isothermality (bio2 / bio7) (*100)	Bio3	%	
	Temperature seasonality (std deviation * 100)	Bio4	°C	
	Maximum temperature of warmest month	Bio5	°C	
	Minimum temperature of coldest month	Bio6	°C	
	Temperature annual range (bio5 – bio6)	Bio7	°C	
	Mean temperature of the wettest quarter[1]	Bio8	°C	
	Mean temperature of the driest quarter[1]	Bio9	°C	
	Mean temperature of warmest quarter[1]	Bio10	°C	
	Mean temperature of coldest quarter[1]	Bio11	°C	
	Total annual precipitation	Bio12	mm	
	Precipitation of wettest month	Bio13	mm	
	Precipitation of driest month	Bio14	mm	
	Precipitation seasonality (coefficient of variation)	Bio15	Percent	
	Precipitation of wettest quarter[1]	Bio16	mm	
	Precipitation of driest quarter[1]	Bio17	mm	
	Precipitation of warmest quarter[1]	Bio18	mm	
	Precipitation of coldest quarter[1]	Bio19	mm	
Edaphic	Percent Clay	Clay025	Percent	SSURGO, STATSGO2 (USDA NRCS 2016a,b).
	Percent Sand	Sand025	Percent	
	Percent Silt	Silt025	Percent	
	pH	pH025	pH	
	Available water supply	AWS025	cm	
	Calcium carbonate	CaCO3	Percent	
	Cation-exchange capacity	CEC7	Milliequivalents per 100gm	
	Organic matter	OM025	Percent	
	Depth to restrictive layer	Dep2Res	cm	
Land cover	Natural land cover (within 300 m)	PN300	Percent	LANDFIRE 2016 (USGS 2019)
	Natural land cover (within 1000 m)	PN1000	Percent	
	Herbaceous canopy cover	HbCC	Percent	
	Shrub canopy cover	ShCC	Percent	
	Tree canopy cover	TreeCC	Percent	
	Distance to >60% tree canopy cover	D2CC60	m	
	Tree and shrub height	TSHght	m	

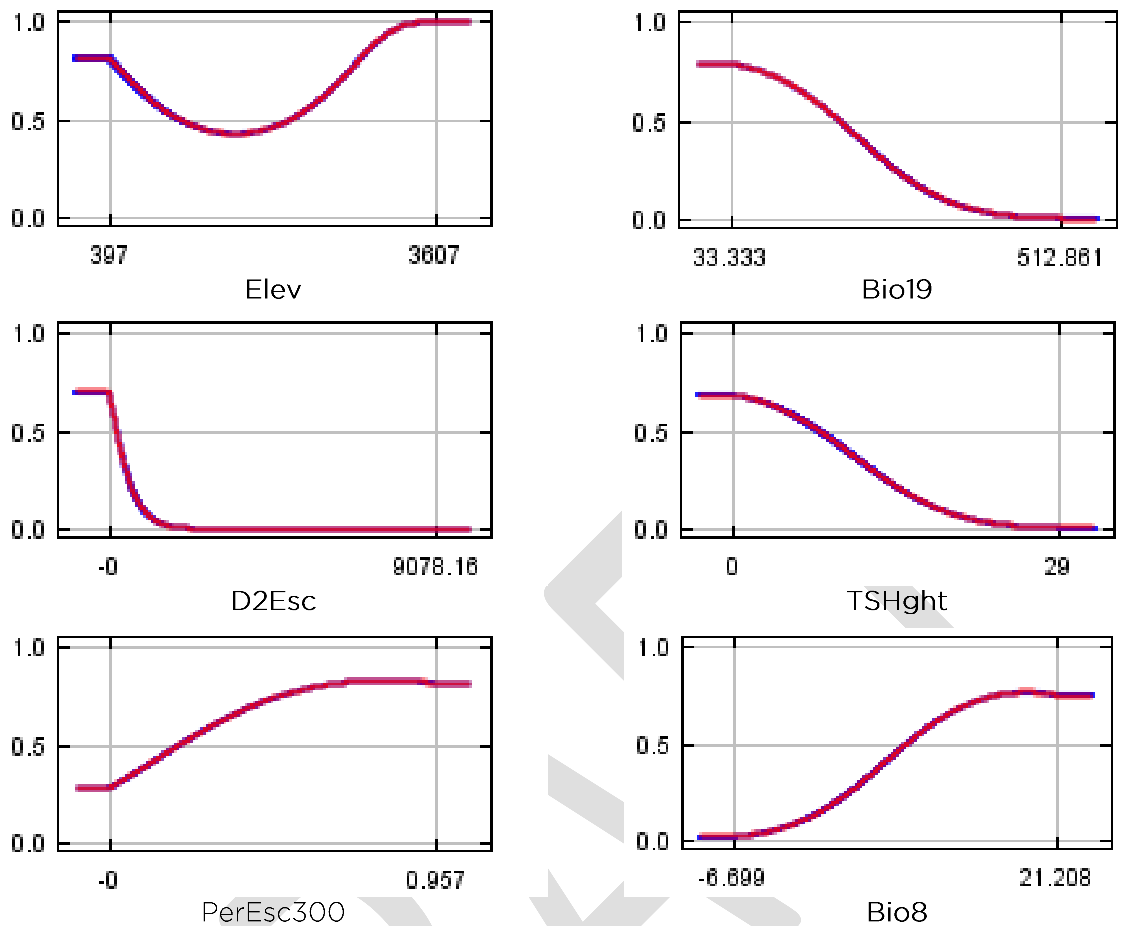
Type	Variable	Code	Units	Source
Water	Distance to all perennial streams and lakes	D2Peren	m	National Hydrography Dataset (USGS 2017)
	Distance to intermittent streams	D2Inter	m	

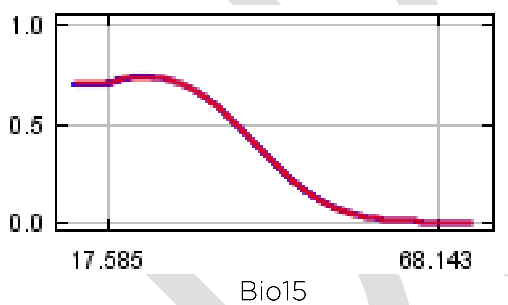
[1] Quarter is any 3-month time period.



Variable	Permutation Importance
Bio16	32.9
D2Esc	28
PerEsc300	21.4
Bio6	17.7

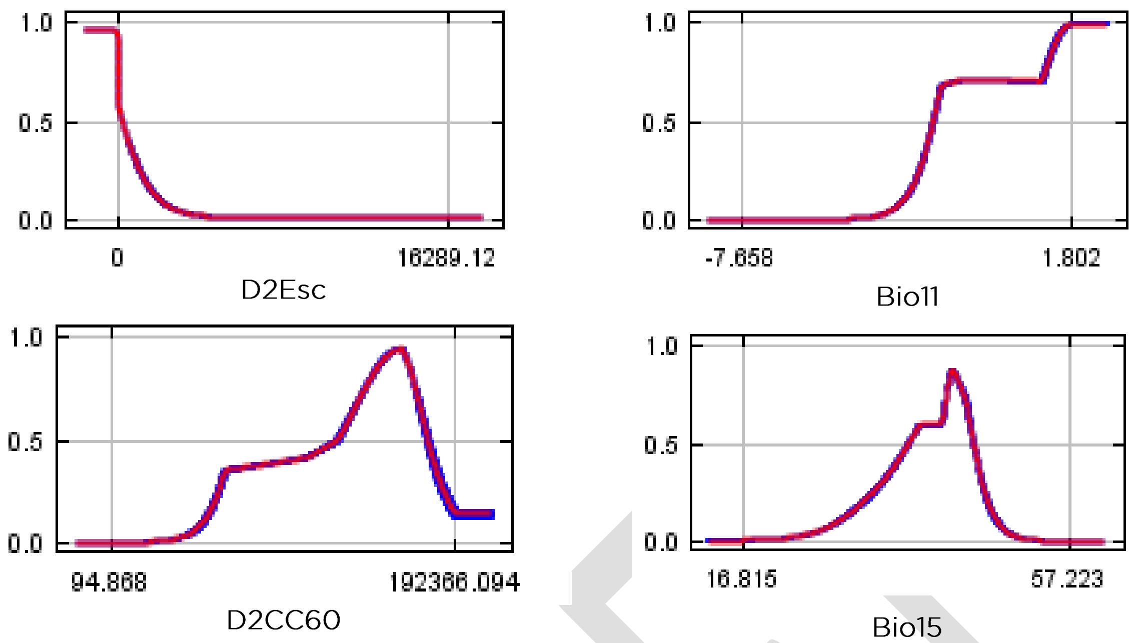
Figure D2. Response curves and permutation importance for the most important variables (see Table D1 for codes) in the Hells Canyon bighorn sheep habitat model. Each of the curves represents a model created using only that variable, thus these plots reflect dependence of predicted suitability both on the selected variable and on dependencies induced by correlations among selected variable and other variables. Mean response of 5 replicate runs is in red and mean +/- 1 standard deviation is in blue.





Variable	Permutation Importance
Elev	24.0
Bio19	16.8
D2Esc	15.8
TSHght	15.4
PerEsc300	11.8
Bio8	8.2
Bio15	7.9

Figure D3. Response curves and permutation importance for the most important variables (see Table D1 for codes) in the Idaho Batholith-Middle Rockies bighorn sheep habitat model. Each of the curves represents a model created using only that variable, thus these plots reflect dependence of predicted suitability both on the selected variable and on dependencies induced by correlations among selected variable and other variables. Mean response of 5 replicate runs is in red and mean +/- 1 standard deviation is in blue.



Variable	Permutation Importance
D2Esc	45.9
Bio11	22.6
D2CC60	19.9
Bio15	11.6

Figure D4. Response curves and permutation importance for the most important variables (see Table D1 for codes) in the Owyhee bighorn sheep habitat model. Each of the curves represents a model created using only that variable, thus these plots reflect dependence of predicted suitability both on the selected variable and on dependencies induced by correlations among selected variable and other variables. Mean response of 5 replicate runs is in red and mean +/- 1 standard deviation is in blue.

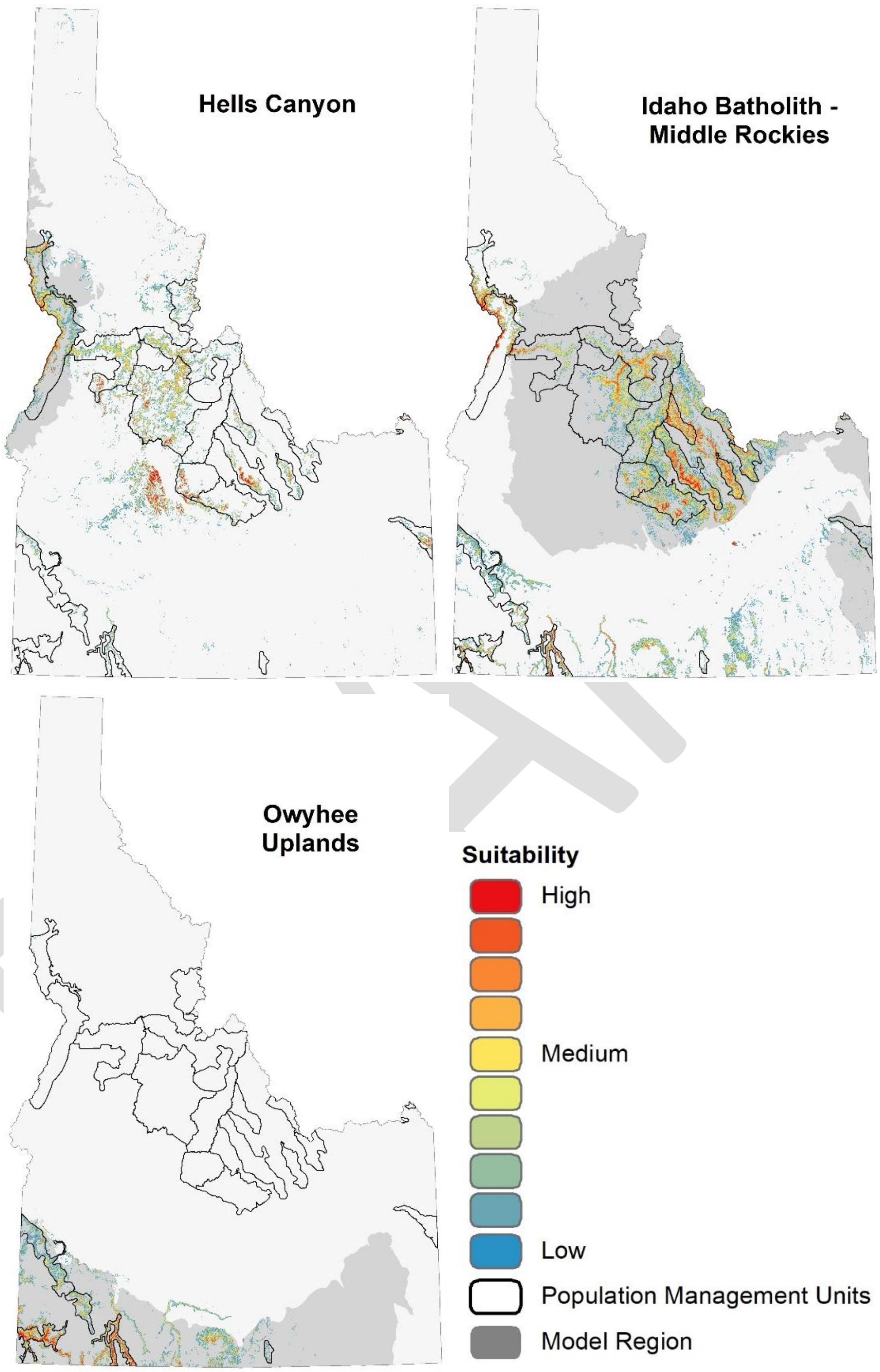


Figure D5. Continuous bighorn sheep habitat suitability models developed for Hells Canyon, Idaho Batholith-Middle Rockies, and Owyhee model ecoregions in Idaho. Each model was developed in the ecoregion and applied statewide. Model values below the 10 percentile threshold in each ecoregion are excluded as unsuitable.

APPENDIX E: Capture, Sampling, and Necropsy Protocols

Capture Guidelines

Planned capture events should be discussed with the IDFG wildlife veterinarian and statewide bighorn sheep biologist. Capture techniques and necessary resources will be decided prior to capture events. If an impromptu capture is necessary, consult with the veterinarian and/or statewide biologist. If consultation is not possible, follow basic capture guidelines (below) and sampling protocols for bighorn sheep capture.

Potential Impact on Animal Subjects

When performed correctly, the capture, processing, and release procedure has minimal ill effects on the animal. Serious injuries are rare and typically injuries and mortalities would be significantly below 5%. If injury or mortality rates exceed 5% the operation will be reassessed to identify and fix problems. If this is not possible, the capture may be stopped.

Description

Helicopter net-gunning, drop nets, drive nets, corral traps, and ground-based chemical immobilization are the common methods for capturing bighorn sheep (Foster 2005). Chemical immobilization protocols discussed during chemical immobilization training classes will be followed (IDFG Wildlife Restraint Manual 2018). BAM (butorphanol (27.3 mg/mL), azaperone (9.1 mg/mL) and medetomidine (10.9 mg/ml), Wildlife Pharmaceuticals/Zoo Pharm) is the current preferred drug combination for bighorn sheep capture.

Processing bighorn sheep may include taking biological measurements and samples, inserting ear tags, and fitting a radio collar.

Biologists will monitor the animal's heart rate, respiration, body temperature, and capillary refill approximately every 5 minutes. If the animal's vital rates are stable, monitoring can be done every 10 minutes. If the animal shows signs of distress, such as markedly reduced or increased heart rate or respiration, or a 3–4° increase in body temperature when compared to average values (IDFG Wildlife Restraint Manual 2018), then it should be released as quickly as possible. Normal body parameters for bighorn sheep are temperature 101.5 °F. heart rate 80 bpm, respiration 40 bpm. To mitigate increases in body temperature, animals can be cooled with one or a combination of snow/water, banamine (Flunixin), and/or ringer's solution.

Live Animal Sampling Protocol

Samples from bighorn sheep handled by IDFG personnel should be collected to allow for surveillance of general animal health and the presence of pathogens and parasites. Contact the IDFG wildlife veterinarian, the statewide bighorn sheep biologist and the bighorn sheep research biologist to coordinate sample collection before planned captures. Sampling needs and protocols change frequently and should be discussed prior to capture. However, at times it is necessary to carry out captures without a great deal of notice. Collect samples listed below if no other direction is provided. Personnel should be trained on proper sampling techniques and storage prior to capture. When in doubt, refrigerate samples.

Samples commonly collected during bighorn sheep capture include:

- Blood – Red top or red and gray top (serum) 2 10-ml tubes
- Nasal swabs (dry, no media, no natural materials – e.g., cotton or wood)
- Ear swab placed in whirl-pak bag – only for animals with visible signs of scabs in ears
- Feces placed in whirl-pak bag or glove
- DNA – tissue preferred (ear punch)

Necropsy Protocol

If necropsies are done as part of a specific project, then necropsy sampling protocols should be discussed with the IDFG veterinarian, statewide bighorn sheep biologist and bighorn sheep research biologist prior to the start of the project. If bighorn sheep are opportunistically necropsied and you cannot contact the veterinarian or statewide/research bighorn sheep biologist for consultation, follow general necropsy guidelines below.

Necropsy Process

Examine the carcass from head to toe or tail for evidence of wounds, trauma, discharges, or other abnormalities. Observe the immediate area for signs of struggling or interactions with other animals or humans. This information can help determine cause of death. Record observations and samples collected on a standard necropsy form.

Specimen Collection

The fresher and more complete the specimen, the more useful it is for diagnostic purposes. Freshly dead, chilled, whole carcasses are the most useful. Where this is not possible, collect the entire heart, lungs, and lower portion of the trachea (the "pluck") for diagnosis of respiratory disease at a diagnostic laboratory. The head including the upper trachea, sinuses, and middle ears can also provide important information and should be collected if possible. If unable to collect the pluck and/or head, collect a dry nasal swab. Collect samples of abnormal organs or other tissues. Highly decomposed, maggot infested, or skeletonized specimens are not suitable for diagnostic purposes. Label all samples with animal ID, date, species, and specimen type.

Literature Cited

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APPENDIX F: Public Input Summary

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