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Progress Report

HELLS CANYON BIGHORN SHEEP

Study I: Hells Canyon Bighorn Sheep Restoration Plan

July 1, 2003 to June 30, 2004

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PROGRESS REPORT
STATEWIDE WILDLIFE RESEARCH

STATE:	Idaho	**JOB TITLE:**	Hells Canyon Bighorn Sheep
PROJECT:	W-160-R-31		
SUBPROJECT:		**STUDY NAME:**	Hells Canyon Bighorn Sheep Restoration Plan
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ABSTRACT

The Hells Canyon Initiative (Initiative) is a state, federal, and private partnership to restore Rocky Mountain bighorn sheep *Ovis canadensis canadensis* in the Hells Canyon area of Oregon, Idaho, and Washington. The Initiative started in 1997, and this document is a revision of the original 1997 Hells Canyon Bighorn Sheep Restoration Plan (Hells Canyon Bighorn Sheep Restoration Committee 1997). This plan updates project goals and objectives, status of bighorn sheep and bighorn sheep management in Hells Canyon, and actions to be accomplished under the Initiative. This plan was written by and will be implemented by the Hells Canyon Bighorn Sheep Restoration Committee (HCBSRC), a committee operating under a Memorandum of Agreement (MOA) signed by the states of Oregon, Idaho, and Washington; the Wallowa-Whitman National Forest; the Bureau of Land Management (BLM); and the Foundation for North American Wild Sheep (FNAWS).

The Hells Canyon project area encompasses over 5.6 million acres in the Snake River drainage from the mouth of the Clearwater River, Idaho, south to Brownlee Reservoir. Elevations range from 800 ft in the Snake River Canyon to over 9,000 ft in the Seven Devils, Idaho, and Wallowa mountains, Oregon. Over 1.3 million acres (24%) of the project area is potential bighorn sheep habitat, 68% of which is publicly-owned, primarily managed by the U.S. Forest Service (USFS). Other public land managers are the states of Oregon, Idaho, and Washington and the BLM.

Bighorn sheep were historically abundant but were extirpated from Hells Canyon and the surrounding area by 1945 by a combination of competition for forage with domestic livestock, introduced diseases, and over-hunting. Bighorn sheep reintroductions and habitat management have been ongoing since 1971. Three hundred fifty-nine bighorn sheep from nine source populations were released into the project area 1971-1996. Another 115 bighorns from three source populations were released 1997-2003 under the Initiative. Currently, about 900 bighorn sheep occur in 16 herds or ewe groups. Four of these herds have been established since 1996 under the Initiative.

Historically, the population has increased in size at an average annual growth rate of 7%. Since 1997, under the Initiative, the population continued this rate of increase. Historically, disease transmitted by domestic sheep and perhaps other sources has been an important factor limiting population growth. At least seven disease epidemics between 1971 and 1997 reduced the annual

population growth rate by about 40%. Between 1997 and 2003, under the Initiative, extensive efforts were made to minimize contact between wild and domestic sheep and no large-scale disease outbreaks occurred. However, disease continued to limit population growth, primarily by a sporadic but chronic source of adult mortality and secondarily through lamb mortality.

Under this revised bighorn sheep restoration plan, state and federal agencies will maintain or increase efforts to restore bighorn numbers by reducing factors limiting population growth. The emphasis during this planning period will be on better understanding and managing disease in the Hells Canyon population. Information on bighorn sheep ecology will be combined with research into pathogens to provide more effective options for disease management. Experimental treatments and prevention methods will be tested as available. The project will strive to serve as a model for bighorn sheep restoration at a landscape level and provide information and techniques for use in bighorn sheep restoration and management in other areas.

INTRODUCTION

The Initiative is a long-term project to restore Rocky Mountain bighorn sheep *Ovis canadensis canadensis* to the Hells Canyon area in Oregon, Idaho, and Washington. This project represents a partnership among agencies and organizations with jurisdiction over and interest in the land and wildlife in Hells Canyon and the surrounding area. This plan is administered through an MOA, formalizing the cooperation between the state wildlife agencies, USFS, BLM, and FNAWS. The Nez Perce Tribe was invited to join as a signatory to the MOA in 2004.

This plan updates the original restoration plan completed by the HCBSRC in May 1997 (Restoration of Bighorn Sheep to Hells Canyon: The Hells Canyon Initiative). The current plan reviews data collected since 1997 and presents direction for future bighorn restoration work in Hells Canyon.

Goal

The goal of the Initiative is to restore self-sustaining bighorn sheep herds to suitable habitat in the Hells Canyon area. The project also offers the opportunity to test techniques and address hypotheses about factors that currently affect or limit bighorn herds and success of reintroductions.

Objectives

Specific objectives to be accomplished in this project are:

1. Implement habitat and population management measures to increase bighorn sheep population size and maintain or increase growth rates.
2. Identify and address factors limiting bighorn sheep population growth.
3. Identify causes of bighorn sheep die-offs.
4. Implement a population and habitat monitoring program to assess progress.
5. Develop strategies to address limiting factors identified through research and management.

Actions

Results of research and management conducted 1997-2003 in the initial phase of the Initiative was used to prioritize actions identified in this plan. Actions will be consistent with the Hells Canyon National Recreation Area Comprehensive Plan and the Oregon, Idaho, and Washington bighorn sheep management plans (Idaho Department of Fish and Game [IDFG] 1990, Oregon Department of Fish and Wildlife [ODFW] 2003, Washington Department of Fish and Wildlife [WDFW] 1995). Actions include:

1. Population monitoring and management.
2. Habitat monitoring and management.
3. Research into limiting factors.
4. Regulation of harvest.
5. Reintroductions and relocations.
6. Information dissemination, evaluation, and publication.

PROJECT AREA

The Hells Canyon Project area encompasses 2,273,194 ha (5,617,062 ac) in the Snake River drainage in Oregon, Idaho, and Washington from the mouth of Clearwater River, Idaho, south to Brownlee Reservoir. It is bounded on the east by the hydrologic divide between the Salmon and Snake rivers near Riggins, Idaho, south to Brownlee Creek on the Payette National Forest, Idaho, and extends just west of the Eagle Cap Wilderness, Wallowa-Whitman National Forest, Oregon. Major drainages include the Snake, Grande Ronde, Imnaha, and lower Salmon rivers. There are currently 16 bighorn sheep herds established in the project area (Figure 1).

Spatial distribution and extent of potential bighorn sheep habitat in the Hells Canyon project area was modeled (Table 1) using a geographic information system (GIS) at the start of the Initiative (HCBSRC 1997). At that time, satellite imagery was not available to this project for classification of the northwestern corner of the project area (including most of the Wenaha and Asotin herds), and these areas were omitted from the initial habitat analysis. In 2001, analysis of the northwestern corner of the project area was completed. Approximately 541,221 ha (1,337,356 ac) of suitable bighorn sheep habitat was predicted to occur within the initial analysis area. Extent of habitat does not appear to currently limit the number of bighorn sheep. Much of the suitable habitat is currently unoccupied (Figure 2). Approximately 68% of potential habitat is publicly-owned, primarily managed by the USFS. Approximately 60% of 427,189 ha (1,085,060 ac) of predicted winter range and 78% of 105,451 ha (260,570 ac) of predicted lambing habitat is in public ownership (Table 2). Privately-owned bighorn sheep habitat is concentrated in several areas: along the Snake River in Washington from the Oregon border north, along the Grande Ronde and Joseph Creek drainages in Oregon and Washington, in the Imnaha River drainage in Oregon, along the Snake River south of the Salmon River in Idaho, and along the lower Salmon River. Private in-holdings also occur within publicly-owned areas.

POPULATION MONITORING AND MANAGEMENT

Background

Bighorn sheep were extirpated from Hells Canyon and the adjacent Wallowa Mountains by 1945 (Smith 1954, Johnson 1980, ODFW 2003). Reintroductions started in 1971. By 2003, the Hells Canyon bighorn sheep population (or meta-population) was composed of 900 sheep in 16 herds or subpopulations (Table 3, Figure 3).

Seven population die-offs have been reported in the project area since reintroductions were initiated. Die-offs occurred in 1971-1972, 1983-1984, and 1991 in Upper Hells Canyon; 1986-1987 in Lostine; 1988 in Mountain View; and 1995-1996 in Lower Hells Canyon, Black Butte, Mountain View, and Wenaha (HCBSRC 1997). Five die-offs have been linked circumstantially to domestic sheep (Coggins and Matthews 1998, Coggins 2002, and unpublished reports), one circumstantially to a feral goat (Cassirer et al. 1996), and one to drought and scabies *Psoroptes ovis* (Foreyt et al. 1990).

Historically, annual growth rate for the Hells Canyon bighorn sheep populations, including die-off periods in five herds that have experienced them, has been 7%. This includes growth due to both production and immigration. Average annual growth rate in the absence of die-offs was 12%. The highest average growth rates were 22% in Lower Hells Canyon and 18% in the Black Butte herd prior to the 1995-1996 die-off and 22% at Sheep Mountain (Appendix A). Herd growth rates were higher during the 2nd through 4th years after bighorns were released into vacant habitat than subsequently (Table 4). Average herd growth rates were not significantly correlated to total number of bighorns released (mean = 28, range 16-58, $r = -0.13$, $p = 0.7$, $n = 9$).

Hells Canyon Initiative 1997-2003

Under the initial phase of the Initiative, 1997-2003, the Hells Canyon meta-population increased at an average annual growth rate of 6%, from 650 to 895 bighorn sheep in 16 Hells Canyon project area herds (Table 3). This included translocation of 115 bighorns into the population. Over this period, the rate of change of individual herds was highly variable and ranged from increases of over 125% in the absence of transplants to declines of over 50% (Table 3). Annual dynamics of individual herds or subpopulations ranged from declines of 46% to increases of 35% (Appendix A).

Between 1997 and 2003, 154 radio-collared animals (ewes: 112 individuals, 313 radio-years; rams: 42 individuals, 78 radio-years) were monitored in eight herds: Redbird, Black Butte, Wenaha, Asotin, Imnaha, Lostine, Big Canyon, and Muir Creek (Table 1). Annual survival (calculated on a biological year in Hells Canyon, June-May) of ewes averaged 0.90 (95% CI 0.85-0.95, n = 39 herd-years) and annual survival of rams averaged 0.83 (95% CI 0.75-0.92, n = 24 herd-years). Sixty-one radio-collared animals (39 ewes and 22 rams) died, and cause of mortality was determined for 49 animals. The most frequent known source of adult mortality (Figure 4) was disease (primarily pneumonia; 43%), followed by cougar predation (27%), falls or injuries (22%), and human-caused (harvest, poaching, or vehicle collisions; 8%). Human-caused mortality accounted for a higher percentage of ram mortality, and cougar predation

accounted for a higher percentage of ewe mortality, but these differences were not significant ($\chi^2 = 0.112$, 2 df, $P = 0.90$).

Causes of adult mortality varied seasonally, with most disease-related mortality occurring in the fall and early winter and most predation occurring in the spring. Little adult mortality occurred during summer (Figure 5).

Adult survival was significantly lower (ewes = 0.78, rams = 0.70) in herd-years where disease-related mortality occurred than in years where no disease-related mortality occurred (ewes = 0.94, rams = 0.89; ewes $t = 2.61$, 9.74 df, $P = 0.03$; rams $t = 2.71$, 31 df, $P = 0.01$). Subpopulations declined ($r = -0.08$) during herd-years when disease-related adult mortality was detected and not in its absence ($r = 0.11$, $t = 2.99$, 9.94 df, $P = 0.01$) (Figure 6). No disease-related adult mortality was detected in two subpopulations, Redbird and Asotin, and these subpopulations more than doubled in size during the study. The other six study subpopulations incurred pneumonia-related adult mortality and increased by less than 35% (Table 3).

Cougar predation occurred in all herds based on assessment of mortalities of unmarked adults during the study period and marked adults outside the study period. However, predation was only detected in radio-collared animals during 11 herd-years in six of the eight herds during the study. Cougar predation occurred in the absence of disease in seven herd-years. There was no interaction between the effects of predation and disease-related mortality on population growth ($F = 0.18$, 1df, $P = 0.67$). In contrast to observations in other bighorn populations, cougar predation on adults in the absence of disease did not have a significant effect on subpopulation growth rates, and subpopulations only declined in the presence of disease-related adult mortality.

Population growth was correlated with ewe survival and recruitment ($R^2 = 0.57$, $F = 25.37$, 41df, $P < 0.001$) but not to ram survival ($R^2 = 0.08$, $F = 3.38$, 38 df, $P = 0.07$). Rate of population growth was most sensitive to changes in adult ewe survival (elasticity = 0.566, *SE* 0.027) and secondly to recruitment (elasticity = 0.145, *SE* 0.009).

Summer lamb survival and recruitment were highly variable among herds and among years. In any given year, summer survival of lambs born to radio-collared ewes ranged from 0-100%. Forty-two dead lambs (Akenson 1998) were collected during summer (May-September). Cause of death could be determined in 29 cases, and 86% (25) of these were due to pneumonia. The other four were cougar predation, probable contagious ecthyma, injury, and starvation due to mortality of the ewe. Lamb pneumonia epizootics were interspersed with years of high lamb survival both following and in the absence of pneumonia epizootics in adults. Although lamb epizootics occurred in five of eight study subpopulations 1997-2003, summer lamb epizootics were confined to only a few subpopulations each year and these changed from year to year. Disease-related mortality in adults and lamb epizootics were not synchronized through space or time. Lamb recruitment was correlated with summer lamb survival, but when summer lamb survival was high (greater than 50%), highly variable fall and early winter lamb survival determined recruitment. Cause of fall and winter lamb mortality was unknown.

Future Direction

Population dynamics assessment will continue to focus on evaluating progress toward the goal of bighorn restoration and identifying causes of mortality.

Adult Survival

During the period covered in this plan, a sample of radio-collared ewes and rams will be maintained and monitored in at least the eight intensive study subpopulations (see above). A minimum sample will have six radio-collared ewes and three radio-collared rams in each herd (total of 72 radio-collared sheep). Where possible, existing radio-collars will be replaced as the battery life ends to maintain continuity in tracking individuals. A standardized sampling protocol (Table 5) will be followed for all bighorns captured in the project area to determine health status and possible exposure to disease. Additional sampling may be conducted for special projects or to be consistent with agency policy or regulations. Animals captured for health sampling will be marked with ear-tags and/or radio-collars. Radio-collared individuals will be located at least biweekly and more frequently during periods of high mortality to facilitate rapid detection of mortalities and subsequent necropsy and disease sampling. A necropsy protocol will be followed for all mortalities (HCBSRC files). Visual observations will be emphasized where feasible to enable collection of data on animal health and condition and group size and composition. GPS collars may be deployed to more thoroughly evaluate movements, particularly of interest in tracking disease transmission patterns.

Lamb Survival

Productivity and lamb survival will be tracked through weekly observations of radio-collared ewes during the lambing period (late April-early June) and a minimum of bimonthly observation of radio-collared ewes throughout the summer to monitor lamb status. Lamb health will be visually assessed whenever lambs are observed. In areas with low summer lamb survival, additional monitoring will be conducted to determine when and how lamb mortality is occurring. Necropsies will be conducted on dead lambs to determine causes of mortality. Lambs may be radio-collared in specific areas or time-periods (post-weaning) when finding unmarked dead lambs is unlikely.

Population Growth

Annual surveys to estimate population size and composition will be conducted consistently using similar timing, methods, and technology throughout the restoration area. Surveys will be designed to determine population status as accurately as possible in a cost-effective manner within budget and time constraints. Green-up in late February and early March is the preferred period for aerial surveys. Helicopter surveys will be corrected with the Hells Canyon-based sightability model developed in the initial phase of the project to derive confidence intervals for population estimates.

REINTRODUCTIONS AND RELOCATIONS

Background

The first reintroductions of bighorn sheep to Hells Canyon and the surrounding area occurred in 1971 when ODFW translocated 20 Rocky Mountain bighorn sheep from Jasper National Park, Alberta, to Hells Canyon Dam and 20 to the Lostine River in the Wallowa Mountains (ODFW 1992). Since 1971, 474 Rocky Mountain bighorn sheep have been reintroduced into the Hells Canyon area, and 126 bighorn sheep have been relocated within the project area (Appendix B). Bighorn sheep currently in Hells Canyon originated from nine sources: Waterton Lakes, Alberta; Jasper National Park, Alberta; Cardinal River, Alberta; Salmon River, Idaho; Wildhorse Island, Montana; Thompson Falls, Montana; Sun River, Montana; Tarryall, Colorado; and Whiskey Basin, Wyoming. Sheep from two or more source populations have been released into all herds except Lostine, Redbird, and Meyers Creek; however, bighorn sheep transplanted from other source populations have mixed with these herds.

Hells Canyon Initiative 1997-2003

A total of 145 bighorn sheep were released at eight sites 1997-2002. Of these, 115 bighorns were relocated from British Columbia, Alberta, and Montana (Table 6), and 30 were moved within the project area (Coggins et al. 2000). All relocated sheep transplanted were radio-collared except four lambs. Average annual survival of transplants monitored longer than one year ranged from 45% for sheep transplanted to McGraw from Lostine, OR in 1999 to 80% for sheep transplanted from Spences Bridge, BC, in 1997. First year survival of the most recent sheep transplanted (winter 2001-2002) was 85-90% (Table 8). Average annual survival rate of transplanted sheep was 70%. This was lower than survival rates of resident ewes (93%) and rams (84%) over the same period.

Two herds (Big Canyon and Muir Creek) were established in the Snake River canyon with transplanted sheep under the initial phase of the Initiative. Other releases supplemented these herds as well as the Asotin Creek, Washington, and Upper Hells Canyon, Oregon, herds. Releases from the Lostine, Oregon, herd to Quartz Creek, and the Missouri Breaks, Montana herd to Myers Creek in 2001 and 2002, respectively, supplemented existing herds but also started small subpopulations (Myers Creek and Saddle Creek) that may become self-sustaining herds, particularly if supplemented.

McGraw, Minam, and Sheep Divide releases in Oregon failed to establish new herds due to a combination of low survival rates and dispersal to existing herds (HCBSRC 2000, 2002, 2003).

Future Direction

Reintroduction and relocation of bighorn sheep will be conducted as necessary when animals are available to fill unoccupied habitats, augment existing herds, and expand distribution of herds within the project area. Reintroductions will expedite progress toward project goals by increasing the distribution of bighorn herds throughout the recovery area. However, because there is no evidence that reintroductions or relocations will increase the growth rate of

established herds, they are considered a short-term action that must be accompanied by adequate survival and recruitment of existing herds to establish self-sustaining populations.

Reintroductions will be conducted as long as suitable vacant habitat or under-stocked habitat that meets release site criteria (see below) is available. Bighorn sheep will not be released in areas with a high risk of contact with domestic sheep or goats or in areas with the potential to contact bighorn sheep that have survived a recent epidemic and may be carrying contagious diseases. In supplemental releases or releases adjacent to herds that have had a recent die-off, fall lamb:ewe ratios of the existing herd should be above 25:100 for at least two consecutive years.

Where possible, a minimum of 20 bighorns will be released per reintroduction with ratios of at least three ewes per ram. There should be at least 20 total bighorns (reintroductions plus resident sheep) with at least three ewes per ram for supplemental releases. If any bighorns are released on private land, a cooperative plan will be developed and adopted (signed) by the landowner(s) and wildlife agency in the respective state prior to release that ensures habitat quality is maintained or improved and reasonable public access is provided.

All bighorns reintroduced or relocated in the project area will be radio-collared and regularly relocated. Monitoring of radio-marked animals will include frequent (weekly) relocations for one month post-capture with less frequent but regular (1-2 per month) relocations for the life of the radio collar. Goals are to quantitatively document movements and to monitor extent and causes of mortality. Visual observations will be emphasized where feasible to facilitate quick detection of mortalities and subsequent necropsy and disease sampling. When dead bighorns are located, it will be a priority to examine the carcass to determine the probable cause of mortality.

Disease Testing

Any wildlife relocation carries a risk of disease transfer (Cunningham 1996). All bighorn sheep captured or released in the project area will be tested for presence of or exposure to pathogenic bacteria, viruses, and parasites. The purpose of disease testing is to prevent accidental introduction of additional infectious diseases into the project area, to establish baseline health information on relocated bighorn sheep, and to monitor the distribution and prevalence of known pathogens within the recovery area. Disease testing will follow a standard protocol (Table 5) and additional testing will be conducted where necessary to fulfill all state, provincial, and national requirements.

Release Sites

Bighorns will be released at the highest rated sites based on habitat characteristics and risk assessment, contingent on agreement by the states and land management agencies. Animals available for reintroduction will be distributed equitably among states when sites are rated evenly. Actual sites used during a given relocation effort may change should weather prohibit access or if risk associated with the release site changes. Potential release sites are rated using the following criteria:

1. Proximity to active domestic sheep allotments on public land.

2. Proximity to known farm flocks of domestic sheep or goats.
3. Proximity to bighorn sheep potentially carrying virulent pathogens (recent die-off or low lamb-ewe ratios).
4. Proximity to private land.
5. Presence of contiguous habitat between release site and criteria 1-4.
6. Presence of movement barriers between release site and criteria 1-4.
7. Amount of potential lambing habitat within a 10 km radius.
8. Amount of potential winter range within a 30 km radius.
9. Distance to adjacent occupied habitat.

Source Populations

Availability of bighorn sheep for relocation has historically limited reintroduction efforts. Generally, bighorns have been obtained when and where available, and relatively little attempt has been made to select specific source populations. Where possible, source populations will be matched to release sites based on habitat, health history, and other factors, and evaluation of differences in movements and habitat utilization among different source populations will continue.

Historically, bighorns from multiple sources have been released in an effort to manage genetic diversity. This may be a legitimate concern for bighorn populations that typically have been established with low numbers of founding individuals. However, demographic data collected in Hells Canyon does not suggest inbreeding. It is also likely that existing habitat continuity/ connectivity within Hells Canyon provides sufficient movement corridors to allow gene flow between subpopulations capable of maintaining existing genetic variability. Further, there may be detrimental consequences of mixing bighorns with differential vulnerability to disease (Sandoval et al. 1987), and disease history of potential source herds will be considered before proceeding with a relocation.

Bighorn sheep from Hells Canyon herds will be relocated as is feasible either within the project area or to other bighorn restoration areas. To be considered a potential source of animals for relocation, herds should have fall lamb:ewe ratios >25:100 and an increasing population trend. Release sites potentially receiving bighorns from within the recovery area must be far enough from source populations to preclude animals from returning to the source population.

HABITAT

Background

Habitat Availability

GIS-based habitat modeling conducted in the first phase of the Initiative indicated that in general, bighorn sheep habitat in Hells Canyon is abundant (over 1.3 million acres), and extent of habitat is limited primarily by the extent of steep, rugged terrain (Figure 2).

Source of perennial water is not generally a factor limiting bighorn sheep distribution in Hells Canyon. In addition to a wide distribution of naturally occurring water sources, at least 44 springs have been developed for wildlife use throughout the project area on state, federal, and private lands (Table 9).

Fires are a natural component of the Hells Canyon ecosystem and typically benefit bighorn sheep by retarding invasion of grasslands by shrubs and trees. Approximately 209,000 acres burned within the project area from 1986-1996 (Table 8). Canyon grasslands have a natural burn interval of 12-15 years. Prescribed burning to reduce conifer encroachment has rarely been necessary except in small, selected areas on winter ranges in the Minam and Lostine areas.

Range improvement projects have included irrigation, cultivation, and fertilization (Table 9). Yellow start-thistle *Centaurea soltistalis* is pervasive in lower Hells Canyon and the lower Salmon River drainage. Other widely distributed noxious weeds include white-top *Lepidium draba*, toadflax *Linaria vulgaris*, Scotch thistle *Onopordium acanthium*, and several species of knapweed *Centaurea stoebe, C. diffusa, Acroptilon repens*. Recently, extensive cooperative weed control efforts by public agencies and private landowners have been increasing under the Tri-State, Tri-County, and Salmon River Weed Management Projects.

Several natural mineral licks occur in the study area. Salt blocks containing selenium have been placed in Oregon and Washington (Table 9). Hells Canyon is considered selenium poor for livestock, and bighorn sheep have selenium levels that would be considered low for domestic sheep. Baseline data on blood and liver selenium levels in Hells Canyon has been collected since 1997. Monitoring has shown selenium levels in blood may be substantially increased in some herds when mineral blocks are provided; however, there has been no evidence that supplementation with selenium improves herd health.

Domestic Sheep Grazing Allotments

Historically, contact with domestic sheep is believed to have contributed to bighorn sheep die-offs and limited the Hells Canyon bighorn sheep population (Martin et al. 1996). The number and extent of domestic sheep grazing in the project area has declined considerably in the last 25 years (Figure 7). The Sheep Creek allotment on the Idaho side of the Snake River was placed in vacant status in 1995, when the permittee was provided a cattle allotment near Brownlee Reservoir in exchange. Grazing by domestic sheep on the Temperance-Snake allotment was terminated in October 1996, following a court ruling on lack of compatibility between bighorn sheep and domestic sheep and on provisions of the National Recreation Area Act of 1975 (Public Law 94-199).

In 1997, remaining public land domestic allotments included the Mud Duck, Curren Hill, Echols Butte, Deep Creek and adjacent allotments, and the Mud Creek allotment all in Idaho and Oregon. The Mud Creek allotment is administered by the Wallowa-Whitman National Forest and is southeast of the Upper Joseph Creek bighorn herd. This allotment is adjacent to private land and contains little suitable bighorn sheep habitat. The BLM administers two grazing allotments along the Little Salmon River in Idaho and three grazing allotments near the Powder

River and tributaries in Oregon. These allotments are intermingled with private land and are not in suitable bighorn sheep habitat (Figure 7).

Domestic sheep are also grazed on private land in suitable bighorn sheep habitat. These areas are concentrated in the north end of the project area in the Snake River drainage from Lewiston, Idaho, and Asotin, Washington, south; in the Grande Ronde River drainage; and in the Imnaha drainage (Figure 7). Private flocks are relatively small, ranging from a single sheep to several hundred. A dwindling herd of feral goats on privately-owned bighorn sheep habitat north of the Redbird herd since the 1960s was eliminated in 1995 when the remaining goats were captured and transferred to captivity. There are currently no restrictions on or monitoring of pack-goat use in the project area; although, use of pack goats in areas used by bighorn sheep is of concern.

Hells Canyon Initiative 1997-2003

Habitat Acquisitions

Since 1997, land acquisitions by Plan partners have secured 42,846 acres important to bighorn restoration efforts. In brief, these acquisitions have included purchases of about 15,300 acres of private land in Joseph Creek by Bonneville Power Administration for the Nez Perce Tribe, a 34-acre parcel of land adjacent to the Lostine Wildlife Area donated to ODFW by John Habberstad for bighorn sheep winter range, about 1,200 acres of land acquired by BLM through exchange, and purchase of 80 acres on the Bartlett Grade by BLM. About 7,500 acres of land was acquired by WDFW with the assistance of the Rocky Mountain Elk Foundation in the Asotin Creek drainage. In addition, BLM acquired 10,388 acres from the Nature Conservancy and an easement in the lower Salmon, Snake River Face, and Corral Creek/Cave Creek drainages. USFS purchased 160 acres adjacent to the Wenaha River in Oregon, as well as 6,556 acres in Cache Creek, 490 acres in Jim Creek, 1,112 acres at Ragtown Bar, 153 acres at Cave Gulch, and 873 acres at Cougar Bar.

Water Developments

Maintenance and development is continuing on an annual basis with volunteers and project personnel.

Forage Quality

Diet composition analysis conducted in 2001 indicates that grasses make up the greatest proportion of the bighorn sheep diet in Hells Canyon (Figure 8). This varies by herd and by season (Appendices C-F). Preliminary analysis of fecal nitrogen indicates annual variation in forage quality, with the highest quality in spring (March and April) and lowest quality in winter (December and January). Diet quality varies among herds and among years (Appendix G).

Weed Control

Ongoing agency weed control programs treat weeds with herbicides throughout the project area at annual costs of over $90,000. Several species of insects have also been released widely as potential biological controls of yellow star-thistle.

Use of domestic goats for weed control has recently become an issue for bighorn sheep due to concerns about disease transmission. In 2000, a domestic goat herd (over 1,000 goats) was contracted to control weeds on private land north of the Big Canyon bighorn herd. This goat herd has grazed this area during spring 2000, 2002, and 2003.

Wildfire

Approximately 337,000 acres of bighorn sheep habitat have burned within the project area since 1996 (Table 10, Figure 9). During this period, BLM conducted forage quality evaluations (pre- and post-burn) for bunchgrasses on the Craig Mountain Wildlife Management Area (WMA). Forage quality comparisons were conducted at various stages of grass phenology, from early winter "boot" to winter-cured. In addition, BLM has monitored big game use of vegetation in these areas. Initial monitoring data indicate the primary benefits derived from burning is stimulation of annual growth with nutritious green grasses receiving heavier use than normal by big game, in part, because it was more readily visible and available. Large amounts of dead-standing leached grasses restrict feeding on basal tillers of new growth. This could be very important during the winter when crude protein levels in new burned areas average 15%, while only 2-3% is available in unburned areas.

Domestic Sheep Allotments

In 2000, the Mud Duck allotments were put into vacant status after being waived by the USFS, based on financial incentives provided to the permittee by FNAWS and other conservation groups. All three allotments (and seven other vacant allotments) were permanently closed in 2003 by decisions made in the comprehensive plan for Hells Canyon (USFS 2003).

Future Direction

Habitat Evaluation

Landscape Level - Landscape level habitat modeling has been completed for the project area to provide coarse-scale, general habitat information. Information on bighorn sheep movements will be used with this broad-scale habitat data to track herd areas and movement and migration corridors. Coarse-scale habitat information will also be used to rank reintroduction sites and identify areas for habitat acquisition or protection. Habitat evaluation efforts at the landscape level should focus on:

- Identification of herd use-areas and seasonally important habitat components, such as lambing and wintering habitat and movement corridors.

- Identification of potential threats to bighorn sheep habitat, such as human development and use by domestic sheep and goats.
- Identification and prioritization of potential release sites for transplanted bighorn sheep.
- Identification of priorities for habitat protection or acquisition.

Fine Scale - Although extent of habitat does not appear to be limiting current bighorn sheep populations, in the future, habitat changes, such as spread and/or control of noxious weeds, could affect population growth. Habitat monitoring will be designed to assess effects of habitat quality (abundance and quality of forage) on productivity, population growth, dispersal, and vulnerability to disease. Vegetation condition and trend plots have been established by the USFS, BLM, and IDFG within the project area. These plots and transects will be evaluated for their applicability to this project. It should be noted that many of these rangeland and monitoring plots and transects were established in key livestock grazing areas and may not adequately address needs for bighorn sheep within the study area. New plots and transects may need to be established. Plots and transects will be monitored typically every one to four years, which is dependent on management concerns and needs. Monitoring will provide data on ecological condition, estimate forage availability, changes in species composition, and trend. Changes in vegetation condition and trend may be attributed to climatic conditions, grazing, fire, vegetation treatments, and other factors.

Increased use of GIS mapping for noxious weed infestation, herbicide treatments, wildfires, and prescribed fire is taking place. Use of GIS mapping will greatly facilitate monitoring land treatments such as weed control and fire.

At a fine scale, habitat evaluation efforts should focus on:

- Identification of existing monitoring plots and transects, and potential to establish new plots and transects.
- Identify specific needs for bighorn sheep diet studies.
- Identify specific needs for additional forage quality analyses.
- Map noxious weed infestations and treatments, natural and prescribed burns, and field seedings and food plots within the recovery area.

Public Land Domestic Sheep and Goat Allotments - The only remaining domestic sheep grazing allotments in the project area are three allotments administered by the Payette National Forest in the southeastern part of the project area. The Curren Hill, Echols Butte, Deep Creek, and other contiguous allotments in bighorn sheep habitat are currently active and are expected to remain so in the near future. All are grazed by a single permittee. The Upper Hells Canyon and Sheep Mountain bighorn sheep herds are within eight airline miles of these allotments. Monitoring has shown that radio-collared and unmarked bighorn sheep have moved into the area encompassed by these allotments in the past, and movements were followed by loss of bighorn sheep due to pneumonia associated with *Pasteurella (Manheimia)* bacteria. In particular, the McGraw bighorn herd was essentially decimated following contact with domestic sheep, and the Sheep Mountain herd has been affected and presently persists at low population

levels (Table 1). Radio-collared rams from the adjacent Upper Hells Canyon, Oregon, herd intermingle with bighorns from the Lostine bighorn sheep herd in Oregon's Wallowa Mountains. This may have allowed spread of pneumonia as far as 40 airline miles from the Snake River. Land management agencies will continue to work to reduce potential for disease transmission between domestic sheep and bighorn sheep using grazing management schemes to separate the two species in time and space.

Private Land Domestic Sheep and Goats - Although the majority of the project area is in public ownership, disease transfer from privately-owned domestic sheep and goats may also significantly affect restoration of bighorn sheep. It is expected that interaction between bighorn sheep and private landowners will become more frequent as populations of both increase within suitable habitat in the project area. Education of private landowners grazing domestic sheep and goats in bighorn habitat through dissemination of information and personal contact is a priority. Educational efforts will focus on explaining the conflict between wild sheep and domestic sheep and goats, suggesting ways to reduce opportunity for disease transfer, and encouraging landowners to contact agencies when bighorn sheep come into contact with their livestock.

Private farm flocks of domestic sheep are currently located at the mouth of Joseph Creek near the town of Imnaha in Oregon (two flocks), along the Wildhorse River in Idaho, near the town of Anatone in Washington, near Highway 129 along the Grande Ronde River in Washington, and along the Snake River in Washington (Figure 7). The Hells Canyon Committee will continue to work with owners of these flocks, provide educational materials concerning the risks of disease transmission to bighorns, and provide other information as appropriate.

Use of pack goats should be restricted in areas where there is a likelihood of contact with bighorn sheep. Use of goats for weed control is becoming more prevalent and is incompatible with bighorn restoration in Hells Canyon.

To reduce potential for the spread of disease, bighorn sheep that have come into contact with domestic sheep or goats will be captured and removed from the wild.

Future Habitat Improvements - Habitat protection and improvement actions are discussed below in order of priority. These projects are intended to address site-specific issues such as conflicts between bighorns and humans, local distribution and movements of bighorns, or specific factors that have been shown to limit numbers of bighorn sheep in the area.

Habitat acquisition and easements are a high priority and will be used to emphasize protection of critical habitat. Support for acquisition of habitat and/or protective easements within the project area will be prioritized based on contribution to bighorn sheep restoration, availability of land or cooperators, and cost-effectiveness of purchase or easement.

Noxious weed management will be coordinated with ongoing interagency actions by the states of Oregon, Idaho, and Washington, the USFS, BLM, Natural Resources Conservation Service, and private landowners. We anticipate future noxious weed control will continue at approximately

the same level of intensity as is currently occurring. Assistance may be provided in future noxious weed control efforts where weeds threaten bighorn sheep habitat.

Areas where prescribed fire could be used to improve bighorn sheep habitat and/or distribution will be evaluated on a site-specific basis and treated as appropriate in conjunction with land management agencies. The Lostine Range is planned for prescribed burns in 2004 (about 1,200 acres) to reduce conifer encroachment. Within the Craig Mountain WMA, it is anticipated that 1,000 to 2,500 acres may be burned annually. Such burning may include canyon grasslands and/or a combination of timber harvest and under-burns to favor more "open" ponderosa pine habitats. A priority for any natural or prescribed burn will be an evaluation of risks associated with potential colonization by noxious weeds. Consequently, pre- and post-burn weed treatment and monitoring will be associated with these projects. The areas with greatest risk appear to be those areas presently in fair or poor ecological condition.

Fertilization and/or cultivation of range plots may be conducted as appropriate to alter distribution or movements or otherwise benefit bighorn sheep. Reseeding of fields on the Wenaha Wildlife Area (about 200 acres) is planned to occur in 2004 or 2005. Within the Craig Mountain WMA, approximately 1,000 acres of old fields have high potential for reseeding and/or maintenance as food plots.

Salt blocks or mineral licks may be placed where needed to disperse bighorn sheep and avoid conflict between bighorns and humans or livestock. The benefits and drawbacks of salting will be assessed when establishing salt or mineral licks.

Existing water developments will be maintained, reconstructed as necessary, and monitored for evidence of bighorn sheep use. Additional sites may be developed based on site-specific information and wildlife needs. A priority for water development will be assigned to areas previously identified as being water-limited for bighorn sheep.

RESEARCH

Background

Research, monitoring, and evaluation are critical components for the long term success of bighorn restoration in Hells Canyon. Identification of those factors leading to successes or failures, and development or evaluation of new tools, techniques, or methods can be used to guide future direction through adaptive management. Carefully designed and controlled experiments and analyses are required to conclusively measure and evaluate the interactions of factors such as habitat, dispersal patterns, predation, and disease that may be limiting population growth, productivity, and ultimately the long term sustainability of bighorn sheep in Hells Canyon.

Hells Canyon Initiative 1997-2003

Under the initial phase of the Initiative, research focused on developing a framework to identify factors limiting population growth. Results of some of this research were previously presented

in this plan. Disease, especially pneumonia-related adult mortality, was identified as the primary factor limiting restoration. Pneumonia was also determined to be a critical factor determining summer lamb survival.

In 1997, we tested the efficacy of vaccinating pregnant ewes to increase lamb survival. Trials were conducted simultaneously in three wild herds in Hells Canyon affected or thought to be affected by a pneumonia epizootic in 1995-1996, and in seven wild caught ewes from Hells Canyon in captivity at the Idaho Wildlife Health Laboratory. Half the ewes were vaccinated with a combination of an experimental *Pasteurella trehalosi* and *Mannheimia haemolytica* (formerly *P. haemolytica*) vaccine and a commercially-available bovine *P. multocida* and *M. haemolytica* vaccine in March, about two months prior to lambing; the other half were injected with a saline solution as a control. The vaccine failed to increase lamb survival. Summer lamb survival differed among herds (range 22-100%), but survival of lambs born to vaccinated ewes was marginally lower ($P = 0.08$) than survival of lambs born to unvaccinated ewes. None of the lambs born to captive ewes survived. Bronchopneumonia (pasteurellosis) was the dominant cause of mortality among lambs examined (Cassirer et al. 2001).

In 2000, research was initiated into the phylogeny of *Pasteurella trehalosi* and *Mannheimia haemolytica* bacteria in wild and domestic sheep and domestic goats. The initial phase of the project investigated whether molecular analysis could identify host-specific strains of *Pasteurella* and *Mannheimia* and whether disease in bighorns was a result of host-switching by bacteria. A sample of 37 isolates from healthy bighorn, Dall's, domestic sheep, and domestic goats, and 13 isolates from pneumonic domestic (five) and bighorn (eight) sheep were compared using DNA-sequencing and phylogenetic analysis. Host-specific strains of *P. trehalosi* and *M. haemolytica* were identified and host-switching was found to occur. However, host-switching was not always linked to the occurrence of disease in bighorn sheep. In addition, sequencing analysis revealed horizontal transfer of the leucotoxin A (lktA) gene among isolates. The lktA gene is one of several genes associated with virulence in *P. trehalosi* and *Mannheimia*. The detection of horizontal gene transfer suggests that recombination may play a regular role in the development of virulent strains. If this is the case, rather than or perhaps in addition to, transfer of an entire organism between domestic and wild sheep, virulence may be the result of the insertion of gene(s) from a domestic bacterial strain to a wild strain (Kelley et al. in preparation).

Other research has included evaluation of the potential for aerosol transmission of *Pasteurella* bacteria (Dixon et al. 2002), investigation into the potential for genetically-based disease resistance (Rudolph et al. 2002), and genetic and phenotypic relationships of *Pasteurella* in healthy and pneumonic bighorns and domestic goats (Rudolph et al. 2003, Weiser et al. 2003).

During the initial phase of the Initiative, a logistic model was also developed to correct for bias in and provide confidence intervals for helicopter survey counts. The number of ewes in a group, cover type, and activity are the factors found to most significantly affect whether a group of sheep was seen or missed. Factors affecting visibility were significantly different than those in the Owyhee canyon-lands in southwestern Idaho (Bodie et al. 1995). The Hells Canyon model will be applied to future helicopter surveys in Hells Canyon.

Future Direction

Disease has had a significant impact on Hells Canyon bighorn sheep herds. This has been primarily linked to transfer from domestic livestock. However, disease can also be a symptom of other environmental factors, including sub-optimal habitat quality (for instance due to fire suppression, noxious weeds, overgrazing by livestock, or inter- or intra-specific competition), and loss of traditional movement patterns, which concentrates bighorns rather than distributing use over available habitat (Risenhoover et al. 1988). Mixing source populations of transplanted bighorns with potentially differential vulnerability to pathogens may also precipitate die-offs (Sandoval et al. 1987).

Research designed to address various aspects of vulnerability to disease, transmission, and disease ecology will focus on field application and disease management at the population level. To date, treatments in the absence of research (including medicated and mineralized feed, vaccination, and culling) have met with little success at reducing the effects of disease outbreaks on the population. The sporadic but chronic occurrence of disease suggests that novel pathogens may be periodically introduced into subpopulations. Research emphasis will be on understanding the ecology of disease in bighorn sheep in Hells Canyon and developing tools to resolve disease issues through preventive and acute management.

Some specific projects that will be considered under this plan include continuing research into identifying virulent pathogens and hosts. Research into potential treatments for domestic and bighorn sheep will also be supported and tested. This may involve collaboration with captive facilities. Completion of analysis of research into the ecology of disease conducted in the first phase of the initiative may also lead to additional avenues for study. Factors contributing to the highly variable observed survival of lambs to yearlings is also a topic that may be addressed in research conducted under this plan.

Disease currently limits bighorn sheep restoration in Hells Canyon and, therefore, will be the focus of research conducted under the Initiative. However, where possible, research on other topics pertaining to conservation of bighorn sheep will also be supported. Participating organizations are encouraged to provide internal research review to ensure that bighorn sheep research in Hells Canyon is consistent with management needs.

HARVEST

A total of 254 rams have been harvested by 270 draw permit holders and auction or lottery tag holders in the project area since the first season in 1978 (Table 9). Success rate has exceeded 90%. Hunting is by controlled permit and limited to rams only in all three states. In addition to draw tags, each state also has special auction and lottery tags which may be used in a number of units throughout the state. Oregon and Washington permit the taking of any ram, while Idaho requires a ¾ curl or greater or an age of at least four years. Washington herds must have at least eight mature rams, of which two are at least six years old or ¾ curl (WDFW 1995). In Idaho, permits can be issued for no more than 20% of mature rams (¾ curl or greater) (IDFG 1990). In Oregon, the number of tags authorized for a hunt is based on the number of mature rams available in the unit area and the size of the hunt area (ODFW 2003). Nez Perce tribal members

have treaty rights to hunt in all three states within the project area. Tribal harvest has been documented by the committee in Washington. The number of bighorns harvested by tribal hunting is unknown.

The Hells Canyon area is known for producing large rams (Figure 10). Oregon, Idaho, and Washington state record Rocky Mountain bighorn rams are all from Hells Canyon. The largest Oregon ram scored 203 ⅝ Boone and Crockett points and was taken in 2000 from the Lostine herd. The largest Washington ram scored 198 ¼ Boone and Crockett points and was taken in 1989 from the Black Butte herd. The Idaho state record was picked up from the Redbird herd in 1997 and scored 197 ⅞ Boone and Crockett points. A total of 47 rams over 180 Boone and Crockett points have been taken by tag holders in the Hells Canyon area.

Hells Canyon Restoration Committee members will cooperate in developing herd goals and management recommendations where herds overlap jurisdictional boundaries or where harvest in one herd could affect adjacent herds.

INFORMATION AND COMMUNICATION

Annual Report

The annual report will include a summary of activities during the previous year, pertinent summaries to date, and an outline of plans for the coming fiscal year. Data will include status of bighorn sheep herds and occupied herd area. It will also include a summary of known risks (disease, noxious weed infestation, human development), and summaries of control actions, habitat management, harvest, and research data. The annual report will be distributed by the Project Coordinator by June 30. Recipients will include:

- FNAWS: National (four copies, one each to the President/CEO, Development Director, Grant-in-Aid Coordinator, and Publications Manager), Idaho, Oregon and Washington chapters.
- Participating state agencies: one copy each to Directors of fish and wildlife management agencies in Idaho, Oregon, and Washington.
- USFS: one copy each to the National Bighorn Sheep Coordinator and to Forest Supervisors on the Wallowa-Whitman, Nez Perce, Payette, and Umatilla National Forests.
- BLM: one copy each to state Directors and Wildlife Program Leaders for Idaho, Oregon, and Washington.
- Nez Perce Tribe: one copy to the Tribal Council Chair.
- Hells Canyon Restoration Committee: electronic copy to each Administrative and Technical member.
- One copy to the head of each agency or organization that is a major financial contributor.

Each Technical member will be encouraged to distribute electronic copies of the annual report to others who may be interested. National FNAWS will provide space in *Wild Sheep Magazine* as an abbreviated report to FNAWS membership.

Other Communications

A biweekly herd report will be prepared by the Project Coordinator and sent electronically to all Technical team members. Committee members will be encouraged to provide seminars on bighorn sheep research and management activities at the annual FNAWS convention. In addition, Committee members will be encouraged to provide information concerning the Hells Canyon Bighorn Sheep restoration effort at a convention booth and to utilize the booth to communicate with others at fairs, civic group meetings, sportsman shows, meetings, etc. throughout the year.

Meetings

Restoration Committee Meetings will be scheduled at least twice annually, usually in May or June, and in December. The focus of the spring meeting will be a summary of the annual report, and the focus of the fall meeting will be budget preparation and work plan. Following the fall meeting, a report will be developed and provided to the national FNAWS board at their pre-convention meeting in January to highlight accomplishments and identify areas of concern prior to the annual FNAWS convention.

Publications and Reports

Public outreach is an important aspect of this project. Public outreach may take many forms, from preparation and publication of scientific findings to sportsman's newsletters, magazine or newspaper articles, to radio and television "spots". Other outreach may include classroom presentations, "adopt-a-sheep" programs, slide and video presentations, work with volunteers, establishment of interpretive sites or displays, and logo development to highlight bighorn sheep restoration efforts. All such activities are encouraged. Technical Committee members are requested to provide details of such activities to the project coordinator so that a record may be maintained.

BUDGET

The Initiative operates on a fiscal year basis, July 1 to June 30. Internal and external project proposals will be submitted to the HCBSRC by November 15 for discussion at an annual December meeting. Proposals will be rated using a consistent set of criteria established by the committee. Recommendations will go to FNAWS by December 15 to be discussed at their April board meeting.

Budget Variances

Budgets will be adjusted as needed based on project needs and funding availability. Table 12 shows a conservative estimate of funding requirements necessary for continuance of this project at historic levels of bighorn sheep management and data collection.

RESTORATION COMMITTEE

The Hells Canyon Bighorn Sheep Restoration Plan was prepared by the HCBSRC. The committee is comprised of state, federal, tribal, and private organizations, of which each provide an administrative (A) and technical (T) committee member. Organizations and committee members in 2004 are:

Idaho Fish and Game

- Dale E. Toweill, Wildlife Program Coordinator (A)
- Frances Cassirer, Tri-State Coordinator/Wildlife Research Biologist (T)

Oregon Department of Fish and Wildlife

- Don Whitaker, Program Coordinator (A)
- Vic Coggins, District Wildlife Biologist (T)

Washington Department of Fish and Wildlife

- Donny Martorello, Big Game Program Manager (A)
- Paul Wik, Wildlife Biologist (T)

USDA Forest Service

- Bob Rock, Natural Resources Staff, Wallowa-Whitman National Forest (A)
- Tim Schommer, Forest Biologist, Wallowa-Whitman National Forest (T)

USDI Bureau of Land Management

- John Augsburger, Wildlife Biologist, Idaho State Office(A)
- Craig Johnson, Wildlife Biologist, Salmon-Clearwater Resource Area (T)

Foundation for North American Wild Sheep

- Raymond Lee, President/CEO (A)
- Lloyd Oldenburg, Member (T)

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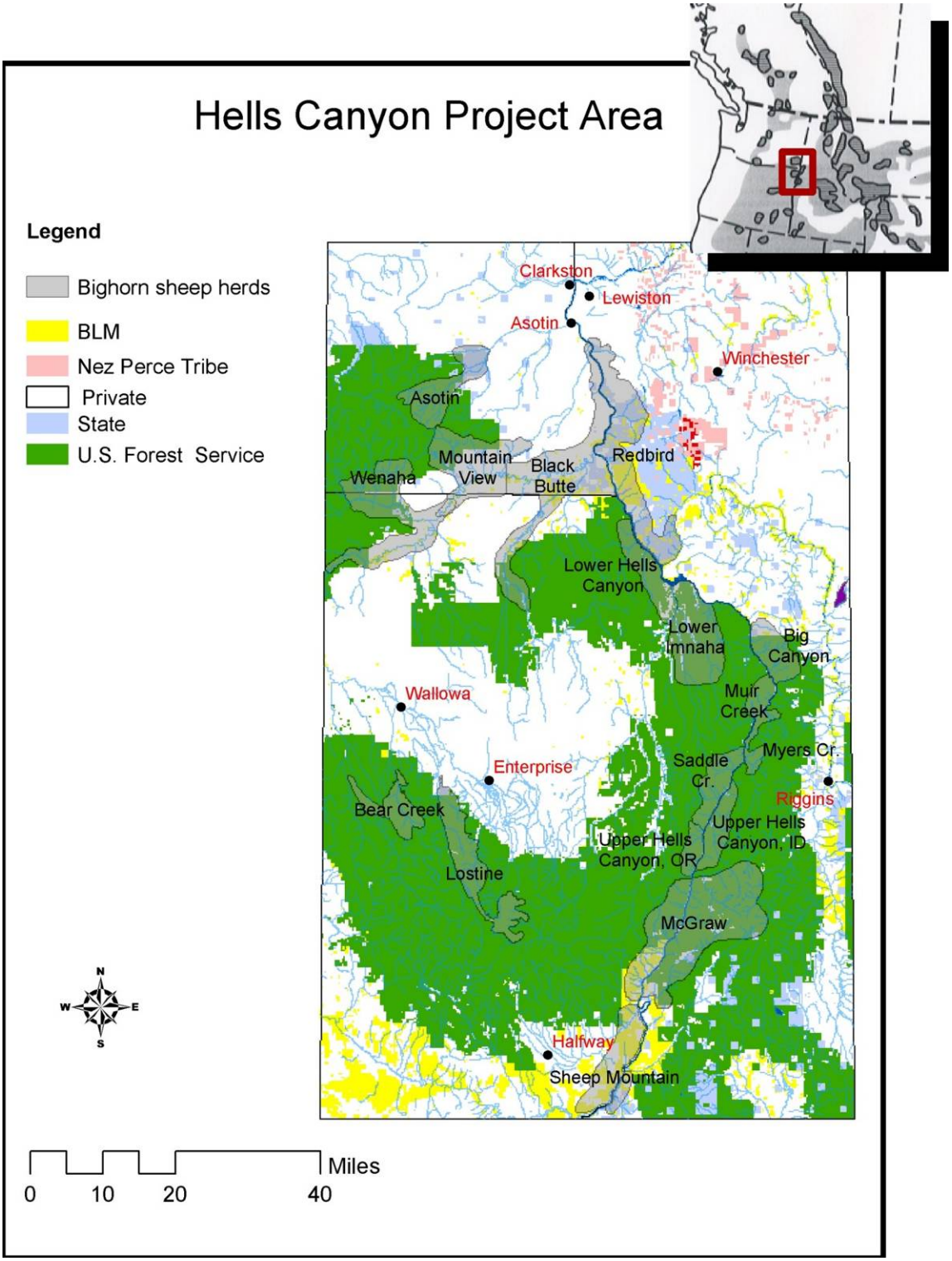


Figure 1. Hells Canyon Initiative Project Area.

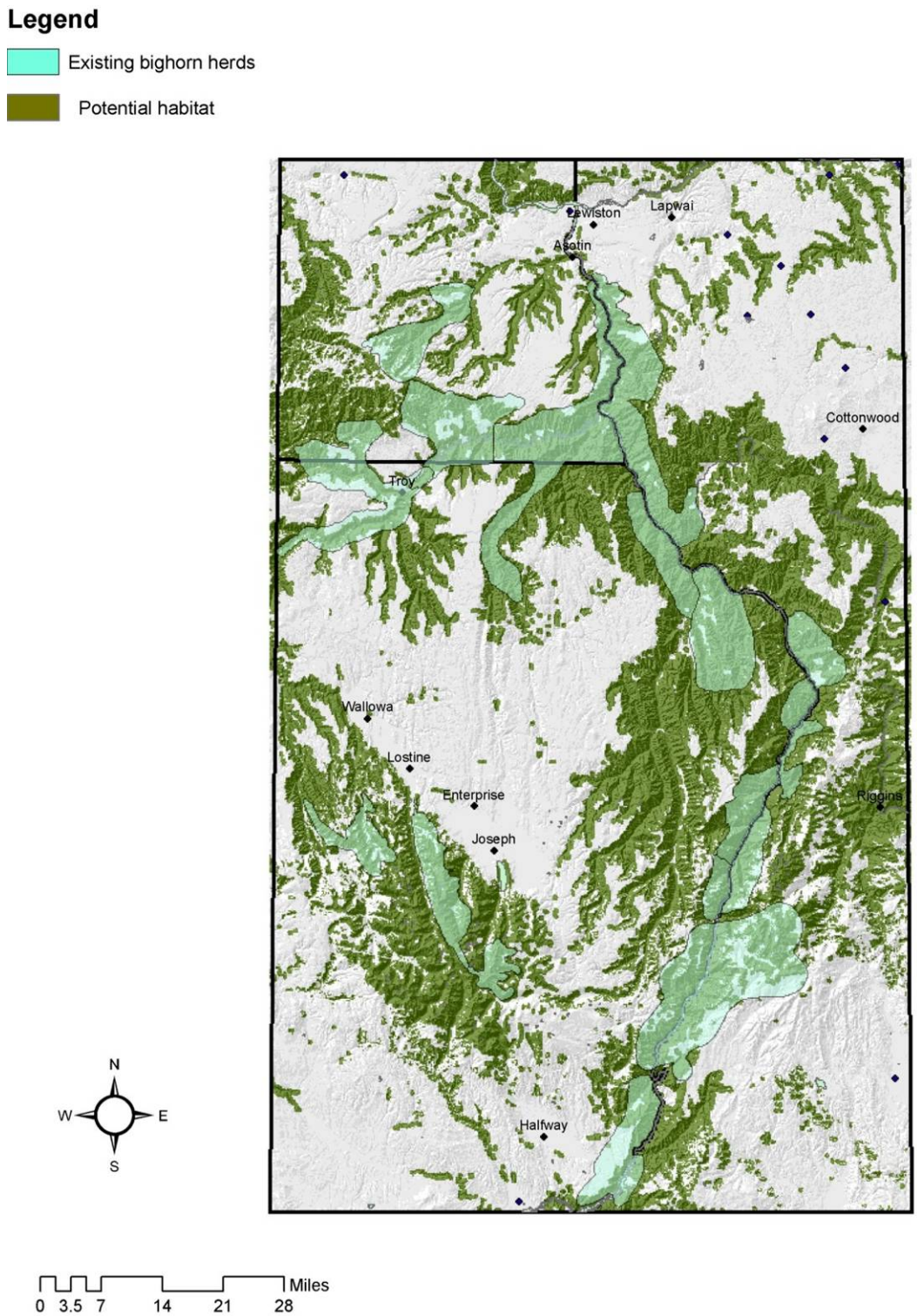


Figure 2. Distribution of potential bighorn habitat and existing bighorn herds in Hells Canyon, 2003.

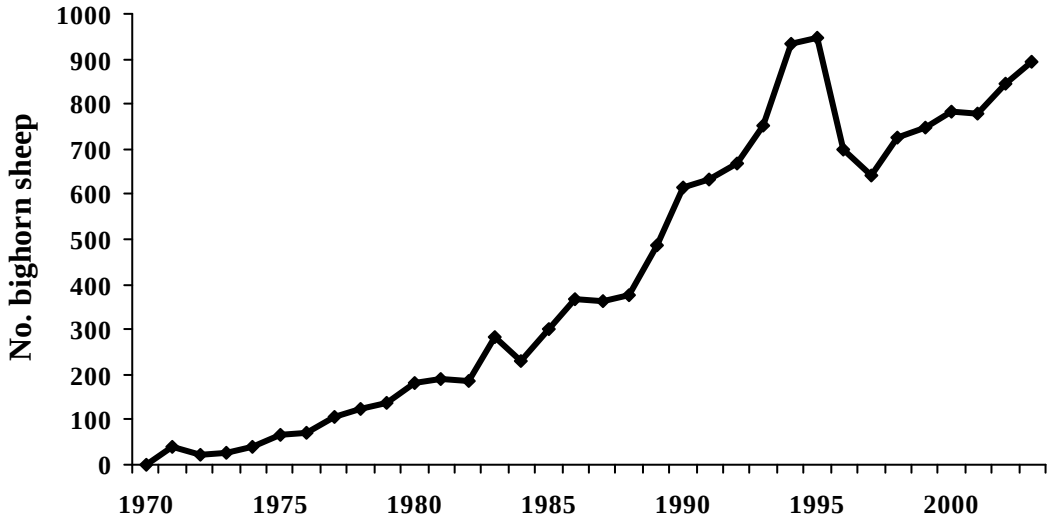


Figure 3. Hells Canyon bighorn sheep population, 1971-2003.

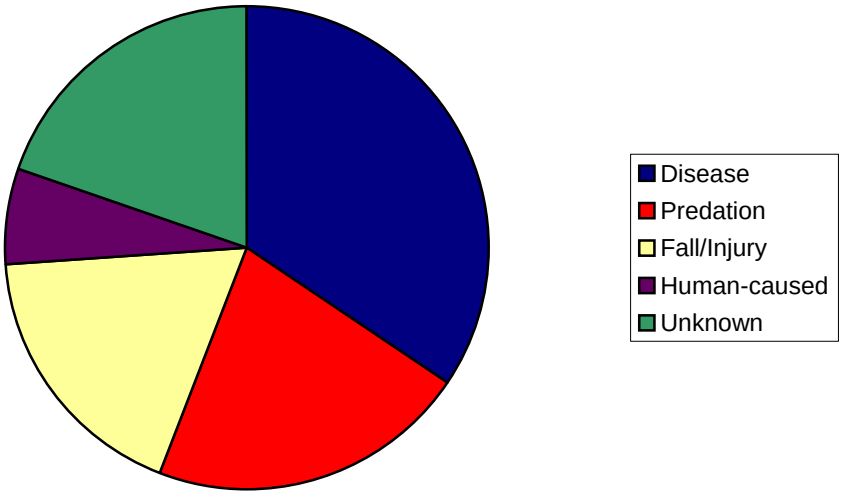


Figure 4. Sources of adult bighorn mortality in eight Hells Canyon herds, 1997-2003.

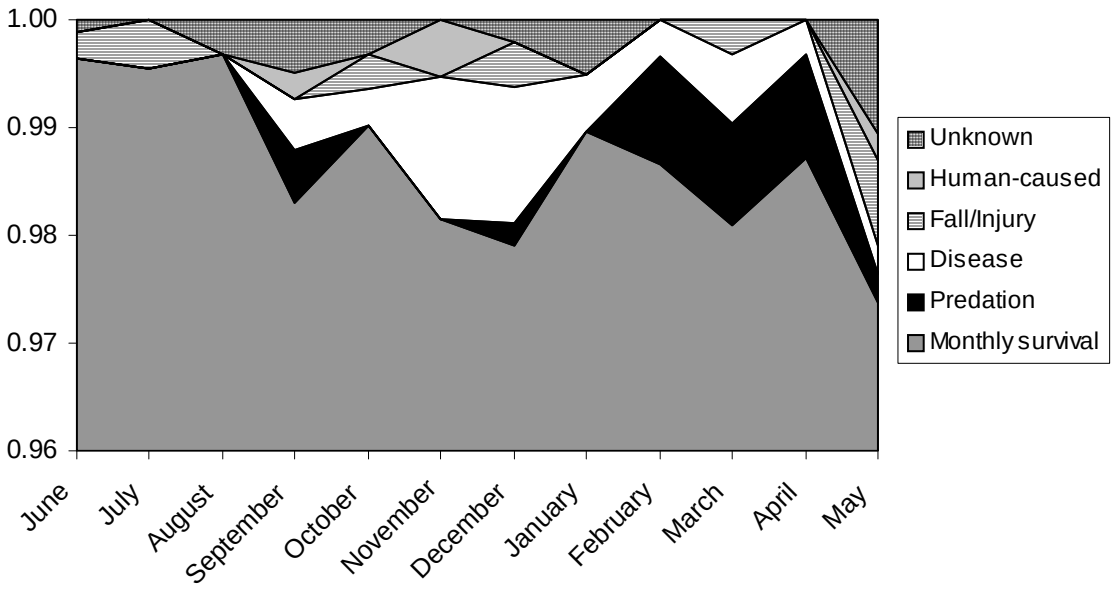


Figure 5. Monthly survival and causes of mortality of adult bighorn sheep in Hells Canyon, 1997-2003.

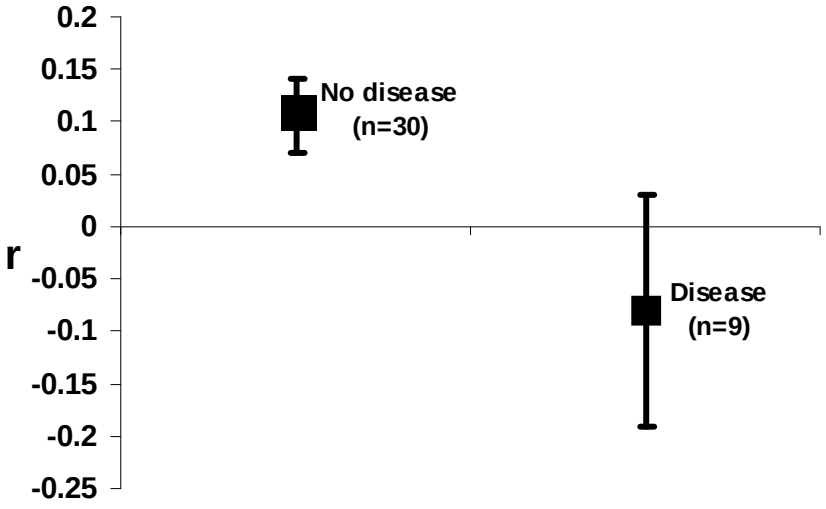
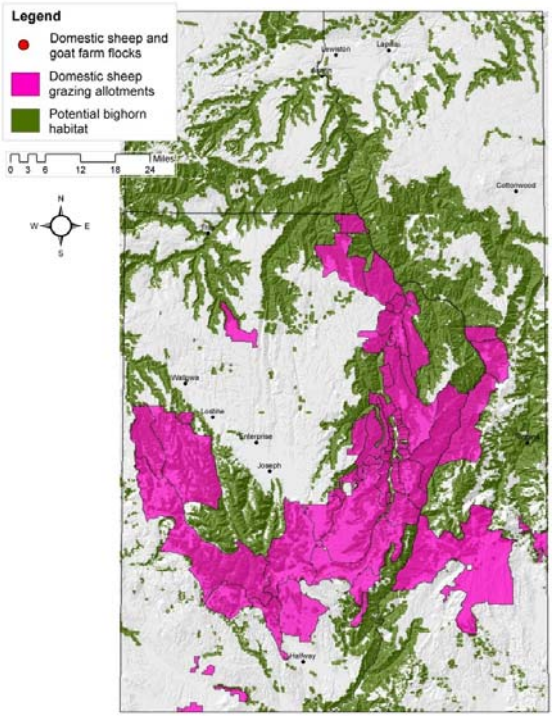
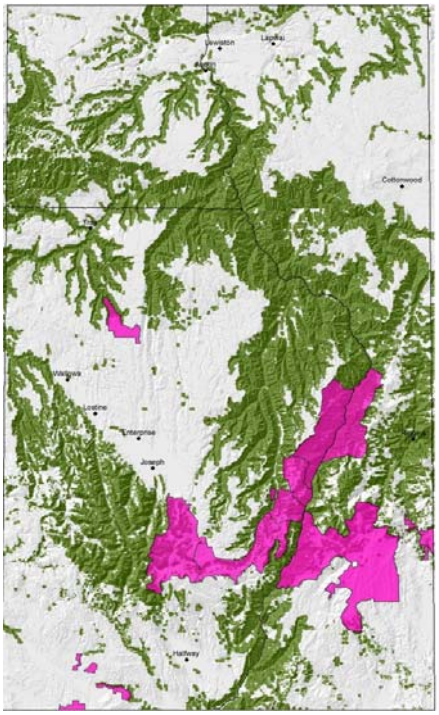


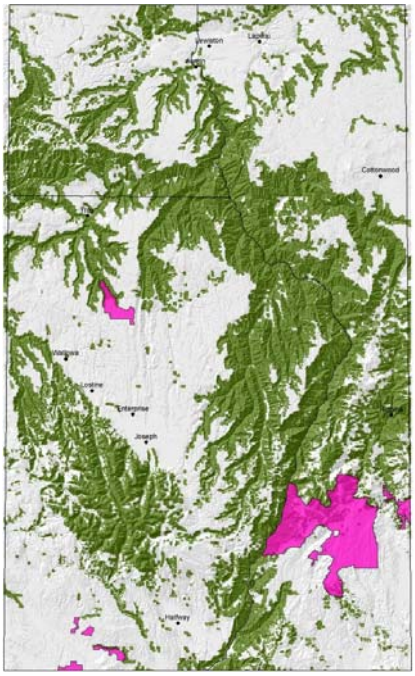
Figure 6. Subpopulation growth in Hells Canyon in the presence and absence of disease-related mortality, 1997-2003.



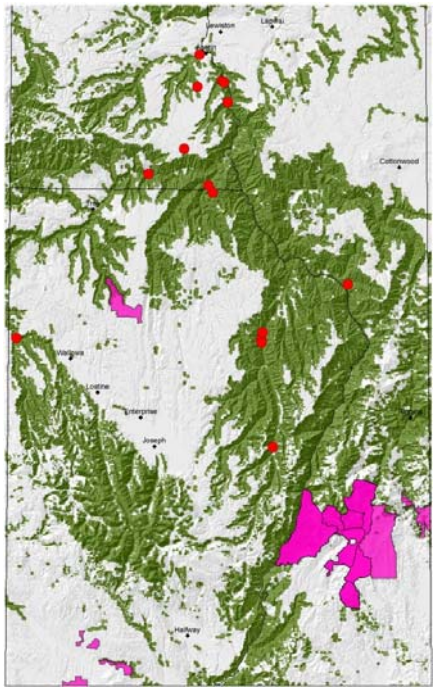
1970 – Grazing allotments



1990 – Grazing allotments



2004 – Grazing allotments



2004 - Grazing allotments and farm flocks

Figure 7. Domestic sheep and goat grazing in potential bighorn sheep habitat in the Hells Canyon bighorn sheep restoration area, 1970-2004.

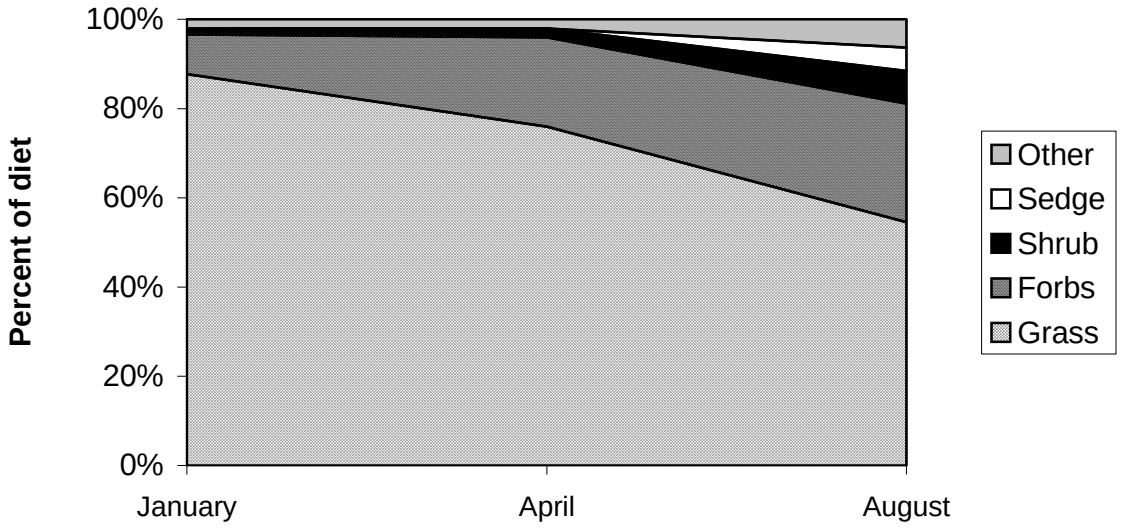


Figure 8. Bighorn diet composition based on fecal analysis in eight Hells Canyon bighorn herds, 2001.

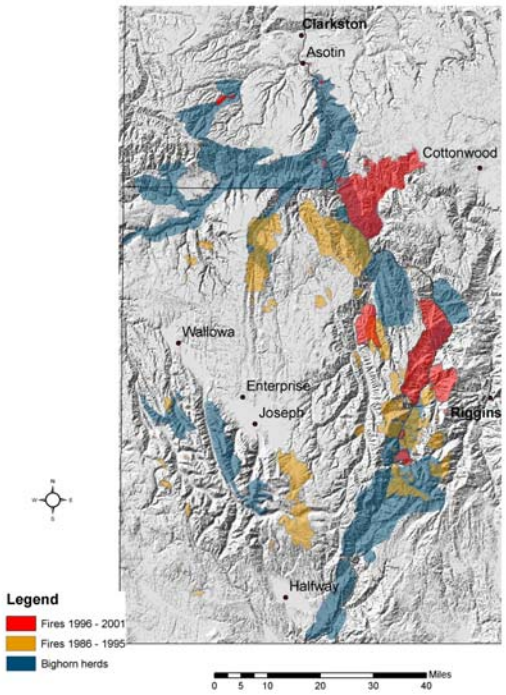


Figure 9. Selected wildfires in the Hells Canyon bighorn sheep restoration area, 1986-2001.

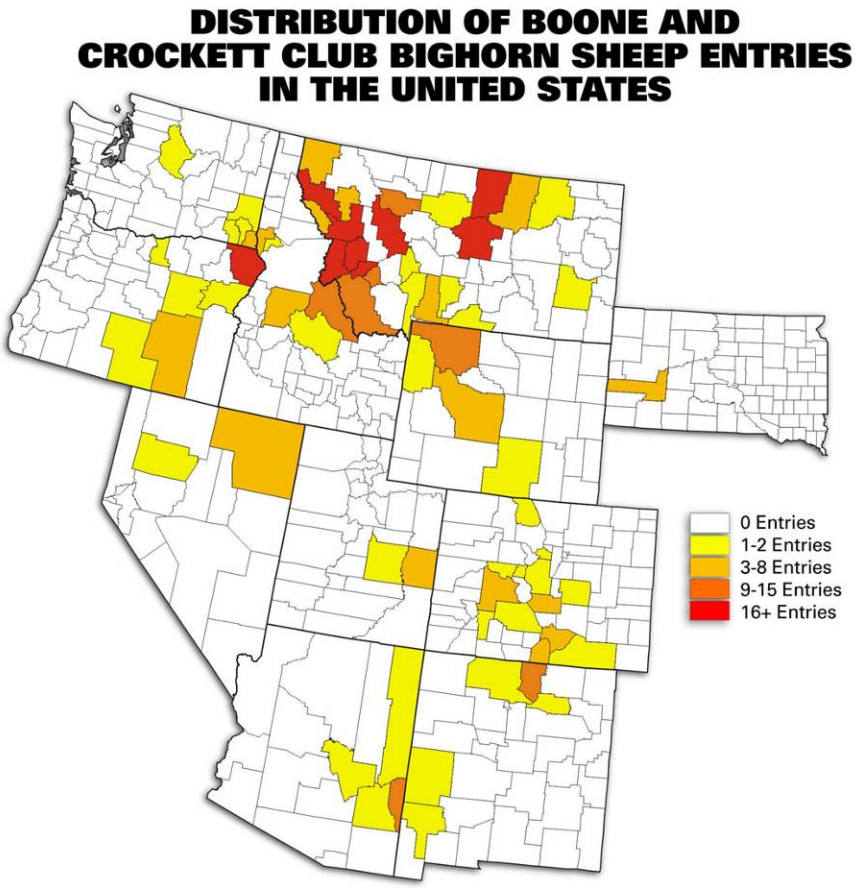


Figure 10. Distribution of Boone and Crockett Club bighorn sheep entries in the United States.

Table 1. Hells Canyon bighorn sheep habitat model.

Habitat component	Criteria	Source
Escape terrain		
Slope	31º ≤ slope ≤85º	Gudorf et al. 1996 Smith et al. 1991
Buffer	300 m or land areas ≤1000 m wide bounded on ≤2 sides by escape terrain (500 m)	Gudorf et al. 1996 Smith et al. 1991
Minimum area	1.6 ha	Gudorf et al. 1996
Horizontal visibility	grassland, rock, open shrub, or forest cover <40%, from satellite imagery	Schirokauer 1996
Water sources	≤3.2 km	Gudorf et al. 1996 Smith et al. 1991
Summer range	suitable habitat within 300 m of escape terrain	Gudorf et al. 1996 Schirokauer 1996 Smith et al. 1991
Winter range	suitable habitat all aspects below 4,800 ft, aspect 135º - 225º above 4,800 ft	Gudorf et al. 1996 Smith et al. 1991 Coggins pers. comm.
Lambing range	escape terrain 45º - 315º ≤1 km from water ≥2 contiguous ha	Gudorf et al. 1996

Table 2. Extent and ownership of potential bighorn sheep habitat in 1997 Hells Canyon habitat analysis area.

		Ownership % (ha)				
Bighorn habitat type	Area ha (ac)	USFS	BLM	State	Private	Other[a]
Lambing	105,451 (260,570)	64% (67,144)	9% (9,643)	4% (4,351)	22% (23,262)	1% (762)
Winter	427,189 (1,055,588)	41% (176,416)	10% (44,372)	7% (28,690)	40% (172,799)	2% (4,912)
Total	541,221 (1,337,356)	53% (285,737)	8% (44,921)	6% (29,751)	32% (175,845)	1% (4,967)

[a] Other federal, county, tribal, and Nature Conservancy.

Table 3. Hells Canyon Project Area bighorn sheep herd sizes, March 1997 and 2003.

Herd name	1998 Total	2003 Total	2003 Lambs: 100 ewes	2003 Rams: 100 ewes
Black Butte, WA, / Upper Joseph Cr., OR	95	100	54	67
Asotin, WA	10	45	48	35
Wenaha, OR/WA	55	65	41	62
Mountain View, OR/WA	25	20	0	64
Lower Hells Canyon, OR	25	35	47	27
Lower Imnaha, OR	150	165	60	38
Upper Hells Canyon, OR	20	45	13	80
Lostine, OR	85	80	36	51
Bear Creek, OR	25	35	40	120
Sheep Mountain, OR	70	35	0	71
Redbird, ID	85	150	59	64
Upper Hells Canyon, ID	5	25	50	150
Big Canyon, ID	NA	32	0	60
Muir Creek, OR	NA	37	13	38
Saddle Creek, OR	NA	8	0	14
Myers Creek, ID	NA	16	67	11
Average	54	56	36	55
Total	650	893		

Table 4. Comparison of Hells Canyon bighorn sheep herd annual growth rates after initial release and in subsequent years.

Herd	Initial growth rate[a] λ *(sd)*	Subsequent growth rate λ *(sd)*	P value
Lostine	1.37 (0.23)	1.10 (0.12)	0.01
Black Butte	1.29 (0.43)	1.19 (0.23)	0.57
Imnaha	1.17 (0.03)	1.10 (0.14)	0.45
Sheep Mountain	1.46 (0.77)	0.96 (0.16)	0.46
Average	1.32 (0.12)	1.08 (0.09)	0.10

[a] Initial growth rate = 2-4 years after release.

Table 5. Hells Canyon bighorn sheep sampling protocol.

Type of sample	Amount	Purpose	Disposition
Bacterial	1 pharyngeal swab	*Pasteurella* classification	Caine Veterinary Teaching Center
Blood serum	2 red tops (20 cc)	serology, pregnancy, serum banking	Guelph University Idaho Dept. of Ag. Lab, Univ. of Idaho Wildlife Health Lab
	1 blue top (7 cc) 1 purple top (5cc)	Trace elements Selenium	University of Idaho Toxicology Lab
Whole blood	1 green top (10 cc)	DNA analysis	Wildlife Health Lab
Fecal	10+ pellets	parasitology	Washington State Univ.
Ear swabs	1	parasitology (scabies)	Washington State Univ.

Table 6. Bighorn sheep transplants in Hells Canyon, 1997-2003.

Source	% alive[a] (n)	Year since release	Average annual adult survival
Spences Bridge, BC, 1997	33% (12)	5	0.80
Cadomin, AB, 1999	25% (5)	4	0.70
Lostine, OR, 1999	20% (3)	3	0.45
Cadomin, AB, 2000	30% (11)	3	0.67
Lostine, OR, 2001	90% (14)	1	0.90
Missouri Breaks, MT, 2002	85% (17)	1	0.85
All sources	41% (59)		0.73

[a] As of March 2003.

Table 7. Potential supplemental bighorn release sites, 2004-2007.

Herd	Risk	Comments
Sheep Creek, ID	Potential risk from domestic sheep and goats through resident bighorns in the Muir and Big Canyon herds	Supplement to 2002 Myers Creek release
Saddle Creek, OR	Potential risk from domestic sheep and goats through resident bighorns in Muir, Big Canyon, and Upper Hells Canyon herds	Supplement to 2001 Quartz Creek release
Big Canyon, ID	Only suitable if risk of disease transfer from domestic goat herds on private land is eliminated	Supplement to 1997 and 1999 Big Canyon releases

Table 8. Wildfires in the Hells Canyon Project Area, 1986-1995.

Year	Area		Acres burned
1986	Little Granite		9,230
	Pumpkin Creek		15,080
	Joseph		46,550
	Sheep Divide		2,850
	Grouse Creek		3,280
	Heavens Tooth		650
		Total	*77,640*
1987	Bean Creek		260
	Green Lake		680
	Dixon Corrals		65
	Squaw Butte		2,250
	Ditch Creek		1,845
		Total	*5,100*
1988	Teepee Butte		64,400
	Eagle Bar		27,080
		Total	*91,480*
1994	Starvation		920
	Fox Point		1,790
	Twin Lakes		29,900
		Total	*32,610*
1995	Sheep Creek		680
	Summit		1,245
		Total	*1,925*
Total			208,755

Table 9. Habitat improvements, Hells Canyon Project Area through 2003.

Improvement	Location	Number of sites or area
Water developments	Lower Hells Canyon	18
	Lower Imnaha	9
	Lostine	1
	Wenaha	7
	Upper Joseph Creek	4
	Redbird	8
	All areas	*47*
Mineral/salt licks	Lower Imnaha	2
	Lower Hells Canyon	7
	Wenaha	2
	Upper Joseph Creek	2
	Upper Hells Canyon	1
	Lostine	5
	All areas	*19*
Planting/irrigation	Lower Imnaha	5 acres
	Wenaha	155 acres
	All areas	*160 acres*
Prescribed burns	Lostine, 1992	200 acres
	Lower Imnaha, 1992	300 acres
	Lower Imnaha, 1993	100 acres
	Redbird, 1995	30 acres
	Minam, 1997-1998	830 acres
	Craig Mountain, 1990-2003	7,000 acres
	All areas	*8,460 acres*

Table 10. Wildfires in the Hells Canyon Project Area, 1996-2003.

Year	Area		Acres burned
1996	Salt Creek		72,010
	Sheep Creek		23,100
	Heavens Gate		570
	Hells Canyon Dam		5,440
		Total	*101,120*
1997	Bull Creek		750
	Wapshilla Ridge		20,950
	Bracken Point		750
		Total	*22,450*
1998	Tenmile		50
2000	Deep Creek		41,400
	Jim Creek		40,850
	Cache Creek		18,700
	State line		3,300
	Corral Creek		6,600
	Carrol Creek		1,990
	Big Sheep		1,450
	Maloney Creek		74,500
		Total	*188,790*
2001	Horse Creek		6,840
	Lime Point		300
		Total	*7,140*
2002	Mouth of Grande Ronde		100
	Corral Creek		1,314
		Total	*1,414*
2003	Geneva Bar		75
	Grouse Creek		207
	Haas Ridge/ Butcher Knife		4,995
	Hazel Mountain		500
	Two Corral		10,504
		Total	*16,281*
Total			337,245

Table 11. Permits and harvest of bighorn sheep in Hells Canyon through 2003.

State	Herd	Total permits	Total number harvested[a]	2003 Permits	2003 Season
Washington[b]	Black Butte/ Joseph Cr.	17	20	0	No season
	Mountain View	8	6	0	No season
	Wenaha	16	14	0	No season
Idaho	Redbird	9	16	1	8/30-10/13
	Upper Hells Canyon	20	11	0	No season
Oregon	Lower Imnaha	88	85	6	9/6-17, 10/18-28
	Lostine	75	69	2	9/6-17
	Black Butte/ Joseph Cr.	9	7	0	No season
	Bear Creek	5	4	1	9/6-17
	Lower Hells Canyon	3	3	0	No season
	Wenaha	12	12	0	No season
	Sheep Mountain	8	7	1	9/6-17
Total		270	254	11	

[a] Number of bighorns harvested includes auction and lottery tags.
[b] No season has been authorized since 1996.

Table 12. Projected annual costs for restoration of bighorn sheep in Hells Canyon, FY 2005 ─ FY 2007.

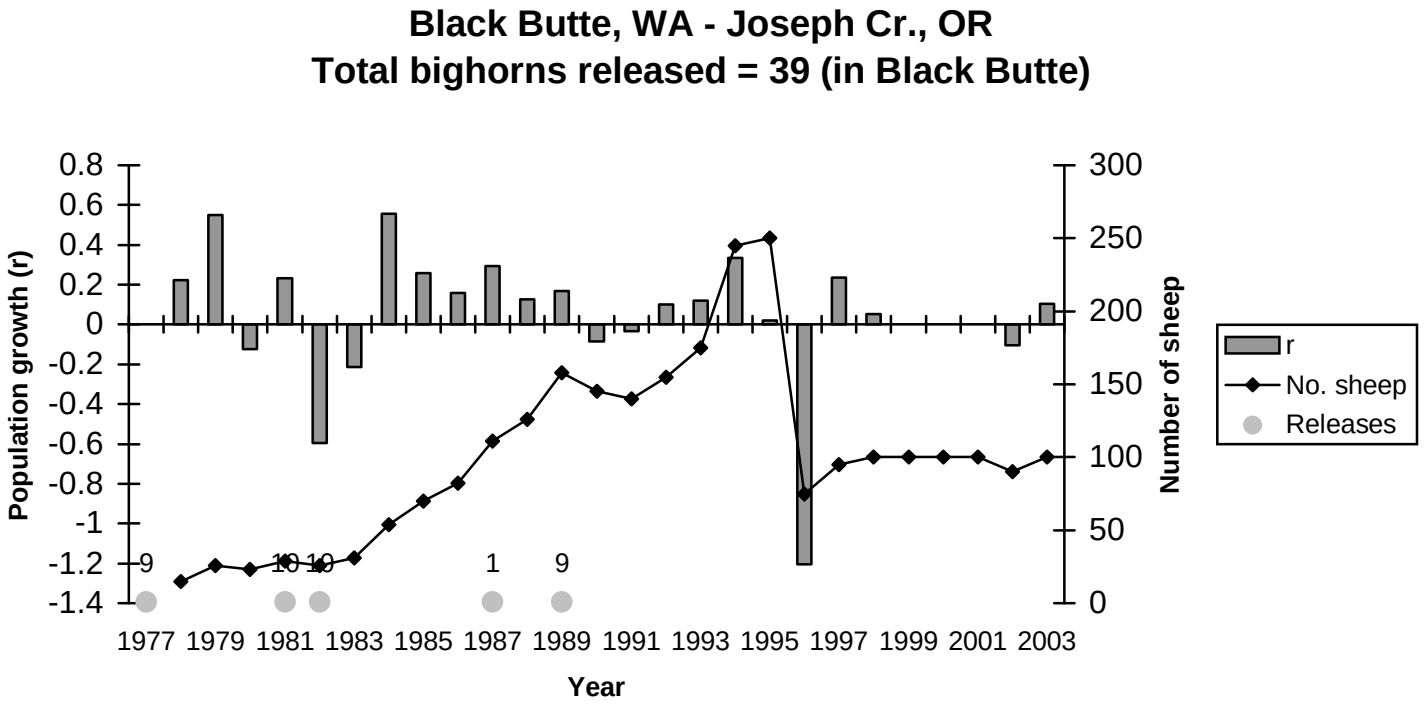
Item		Annual Cost 2005-2007
Reintroduction (50 bighorns/year)		
Salaries		$5,000
Travel		$5,000
Trapping supplies		$2,000
Radio collars		$12,000
Helicopter (as needed depending on capture and release locations)		$0─25,000
	Subtotal	*$24,000─49,000*
Research		
Disease Research		$5,000
Genetics Research		0
Population ecology		$10,000
	Subtotal	*$15,000*
Habitat improvements (habitat acquisition not included)		
Weed control		$5,000
Water developments		$3,000
Other (Prescribed fire, food plots)		$1,000
	Subtotal	*$9,000*
Monitoring and Management		
Equipment - Computer, Receivers, Camera, Scope, etc.		$1,000
Salaries		$115,000
Operations - Aircraft time, travel, per diem		$90,000
	Subtotal	*$216,000*
Annual Project Cost 2005-2007		$240,000─265,000

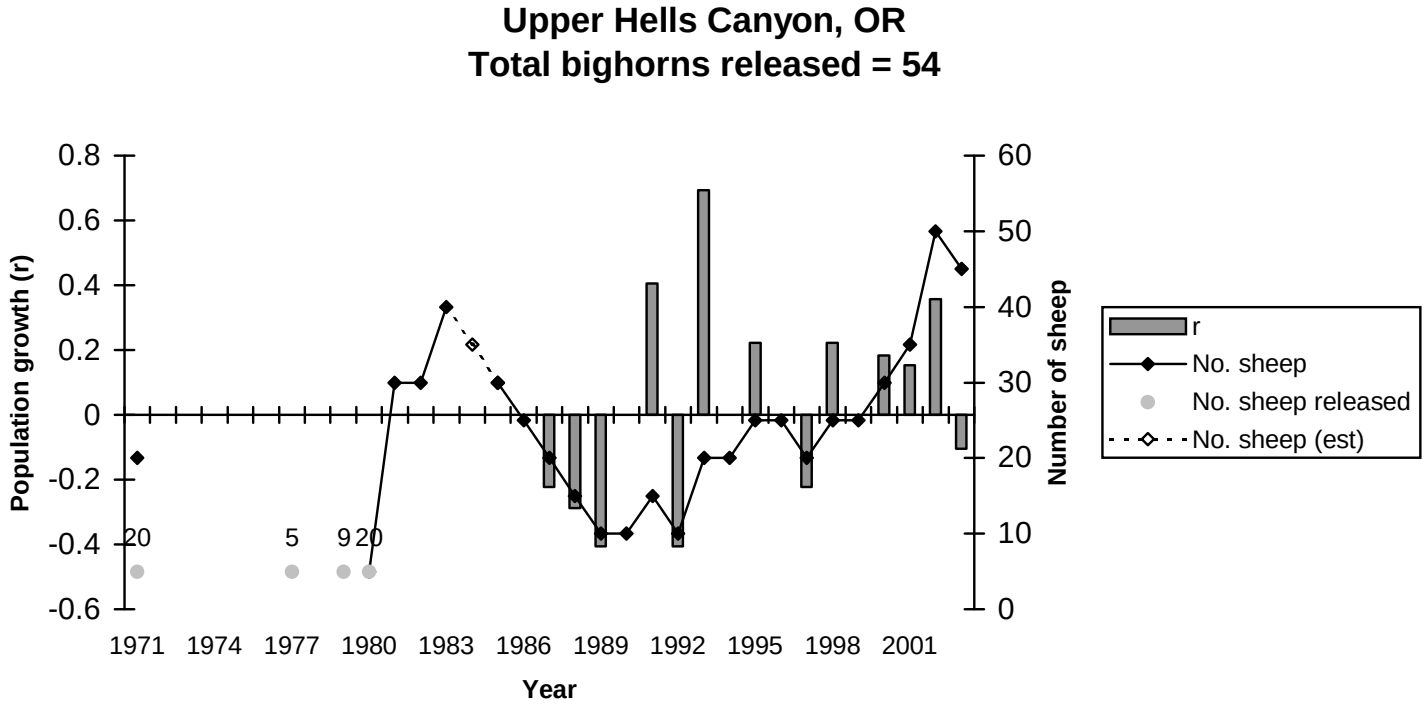
APPENDICES

APPENDIX A

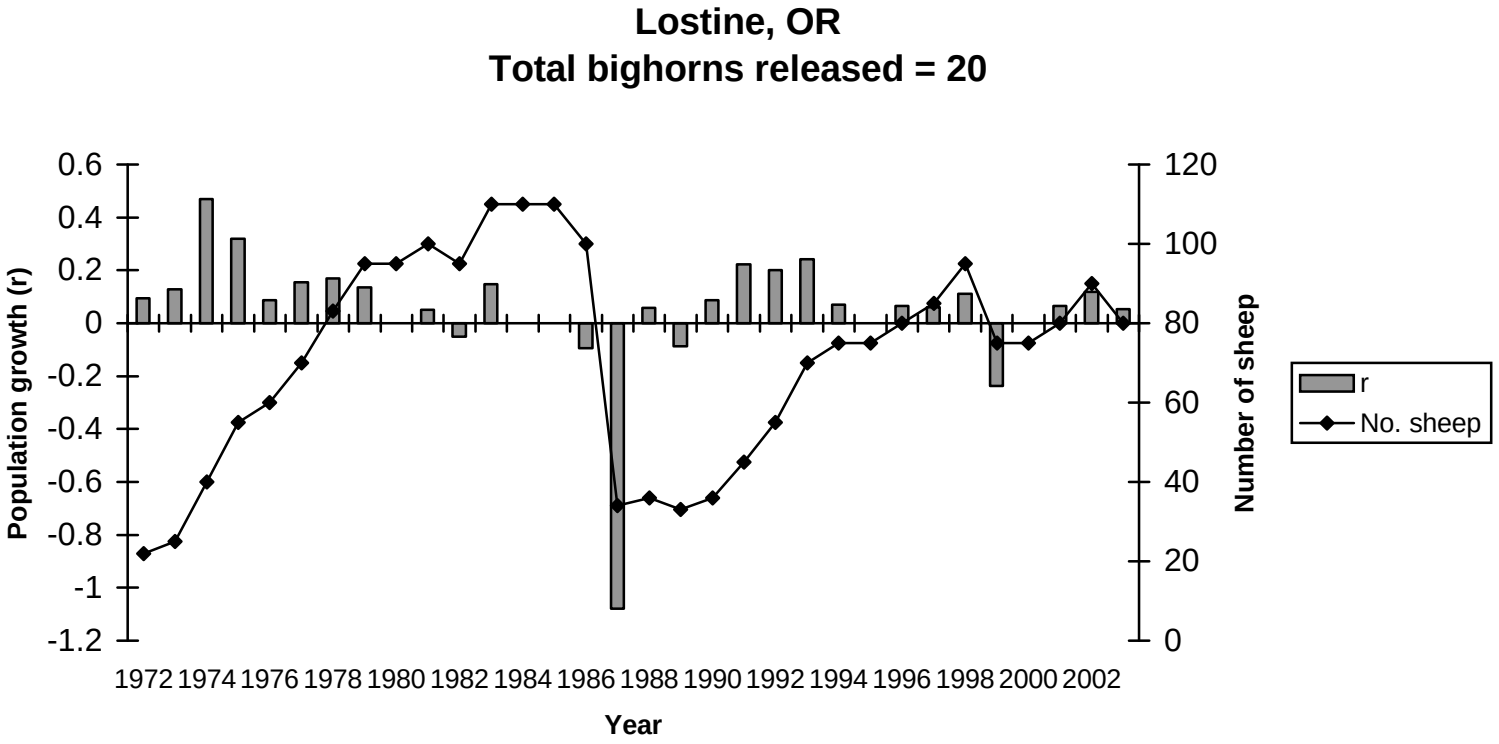
Population dynamics of Hells Canyon bighorn sheep subpopulations

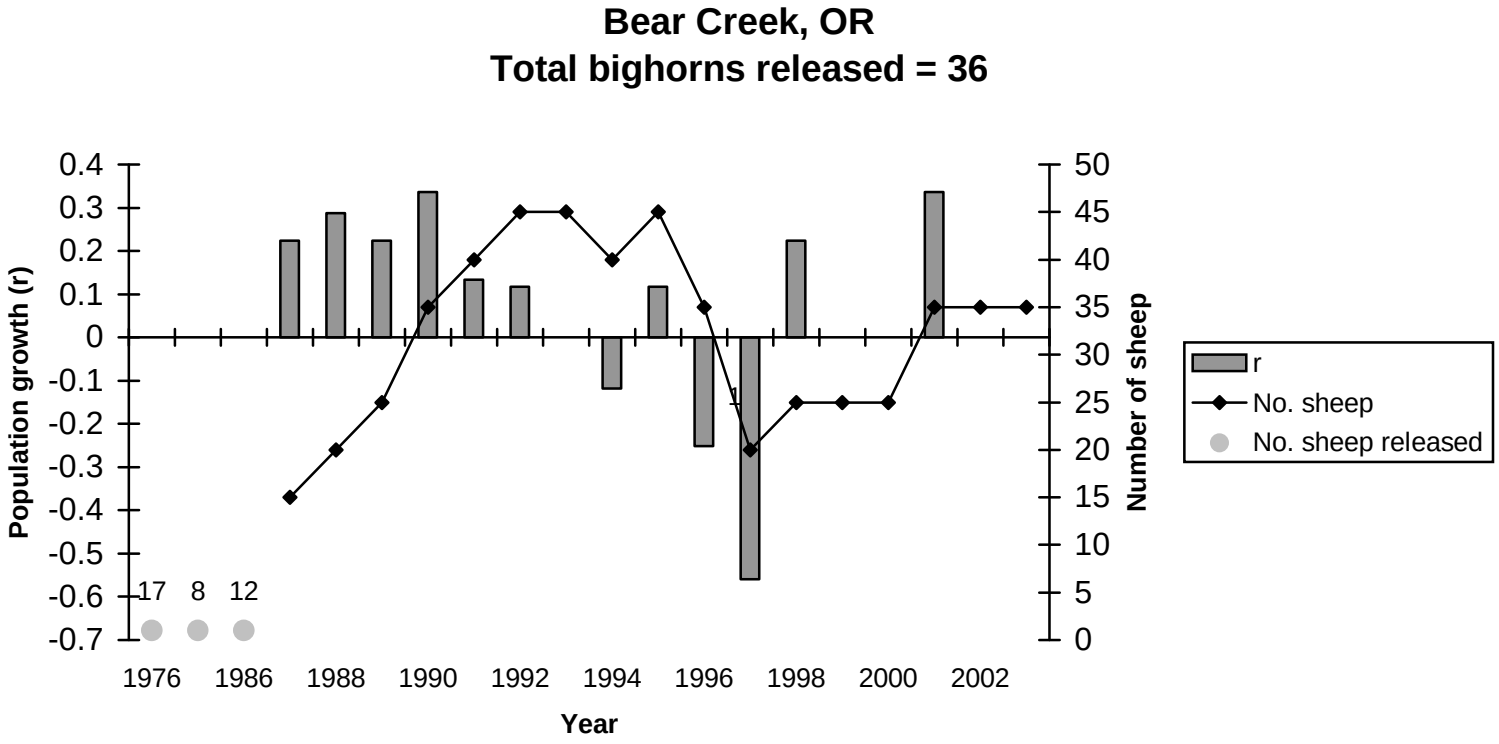
Appendix A.


Black Butte, WA - Joseph Cr., OR
Total bighorns released = 39 (in Black Butte)
Population growth (r)
Number of sheep
Year
r
No. sheep
Releases
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
300
250
200
150
100
50
0
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003
9
10 10
1
9


Upper Hells Canyon, OR
Total bighorns released = 54
Population growth (r)
Number of sheep
Year
r
No. sheep
No. sheep released
No. sheep (est)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
60
50
40
30
20
10
0
1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001
20
5
9 20

Appendix A. Continued.





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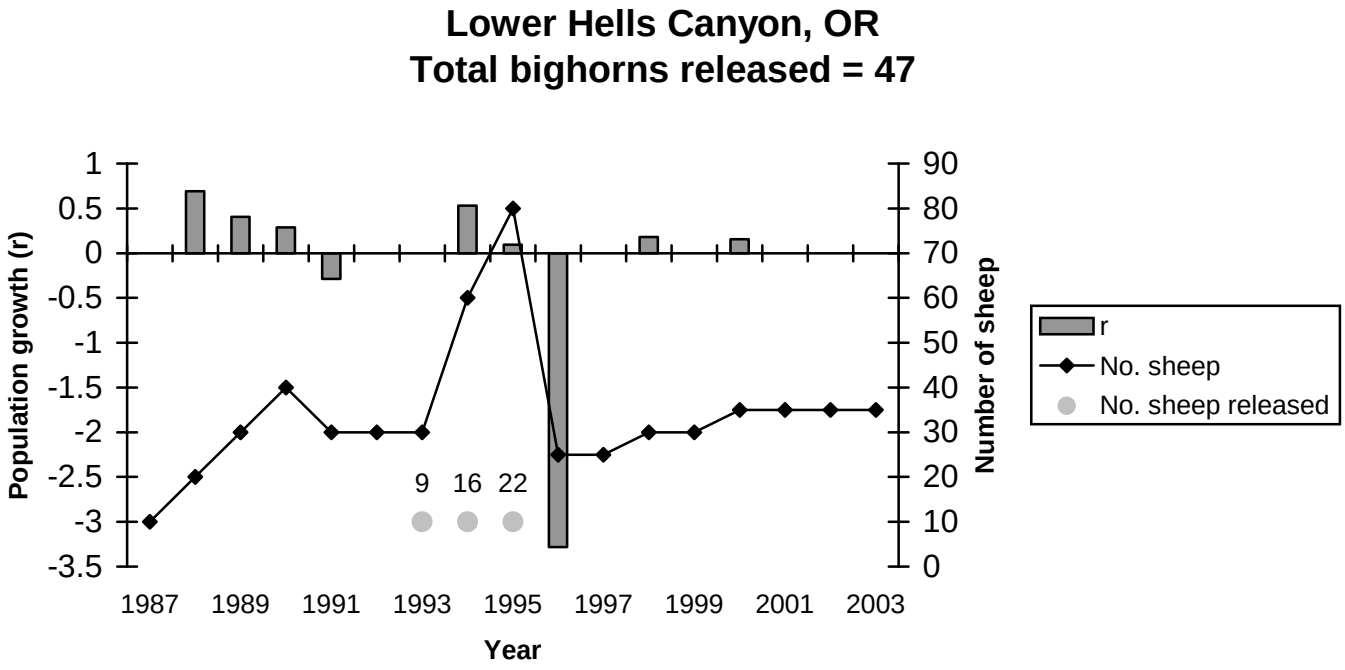

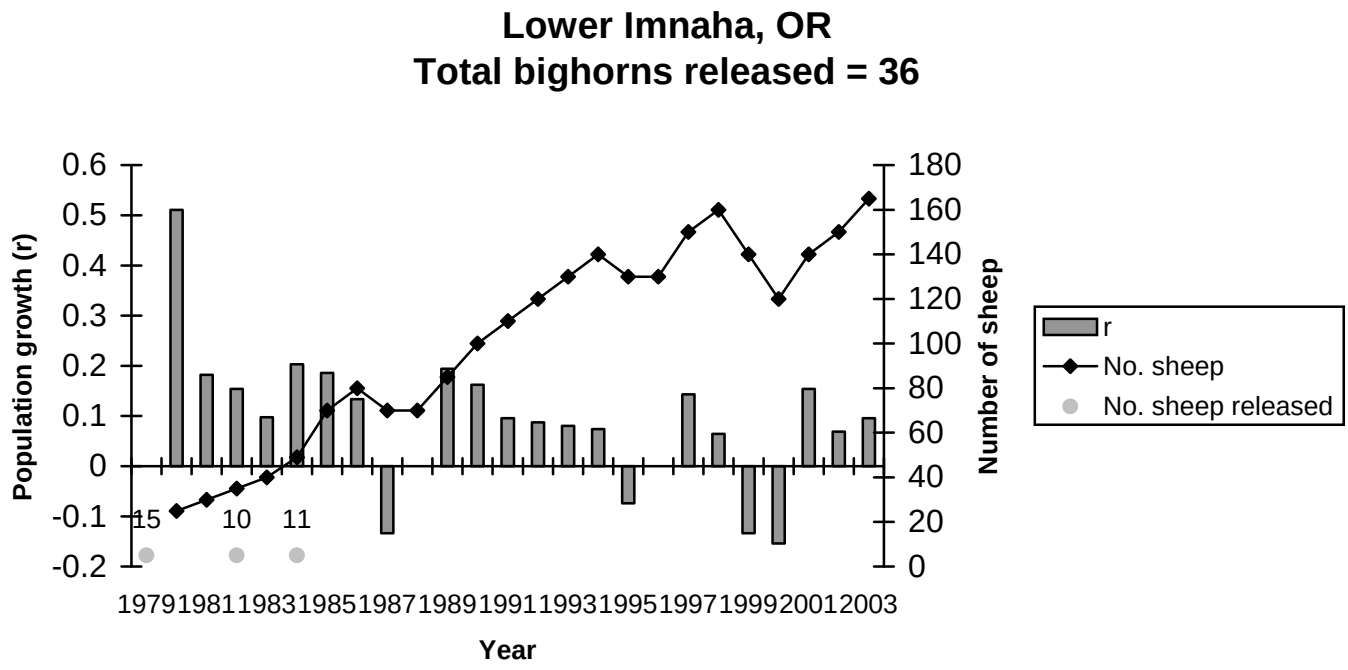

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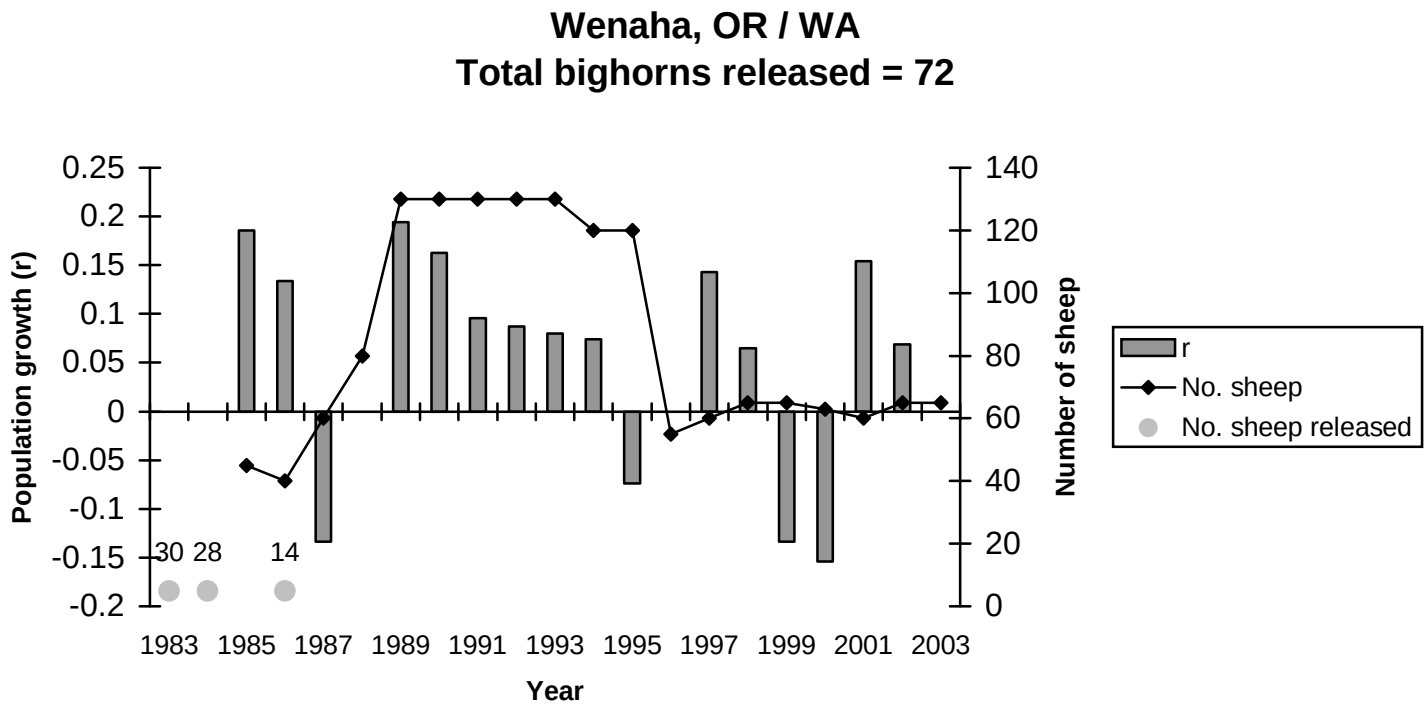

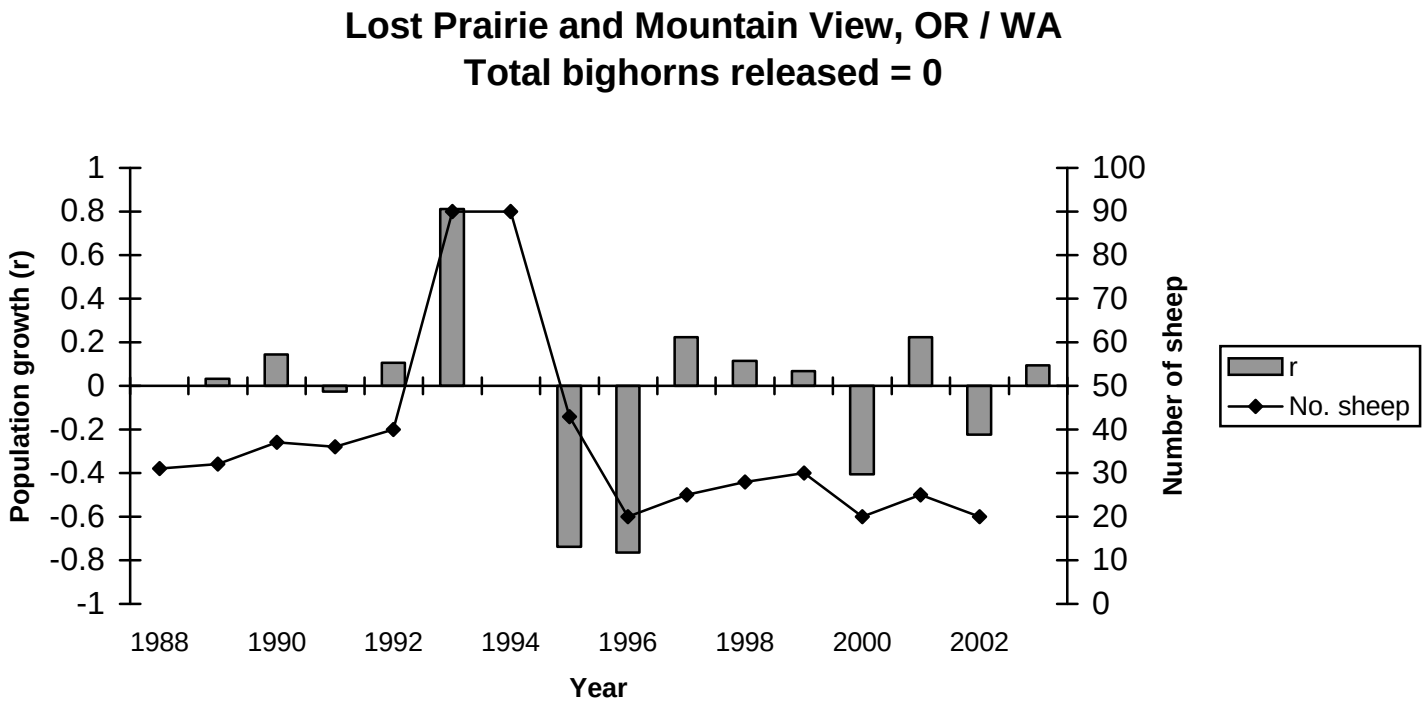

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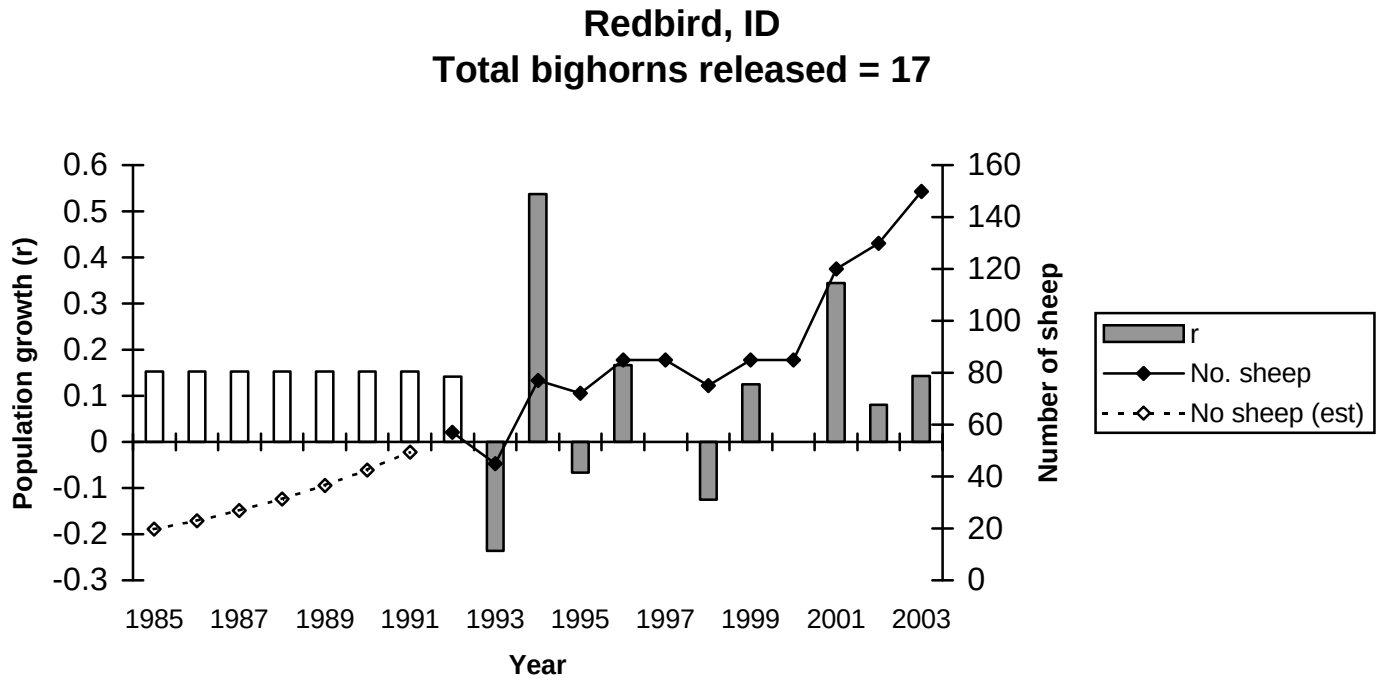

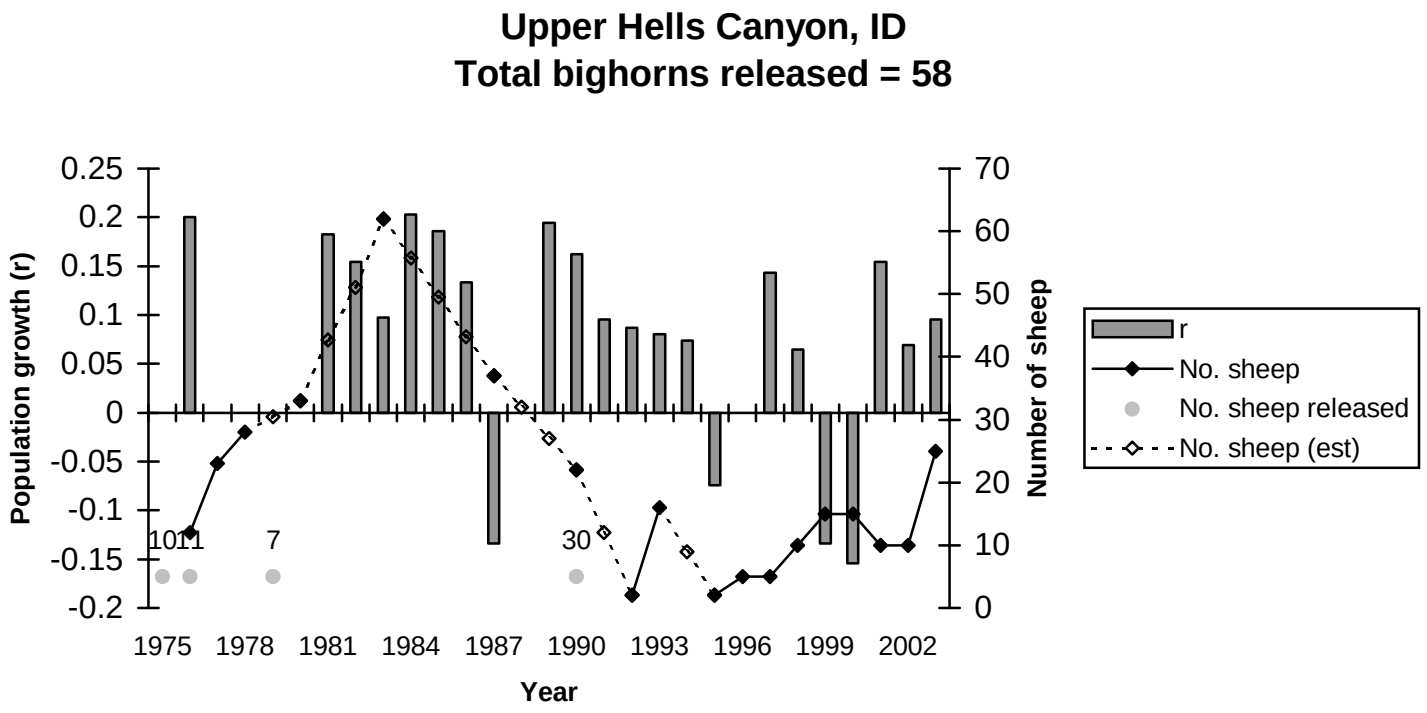

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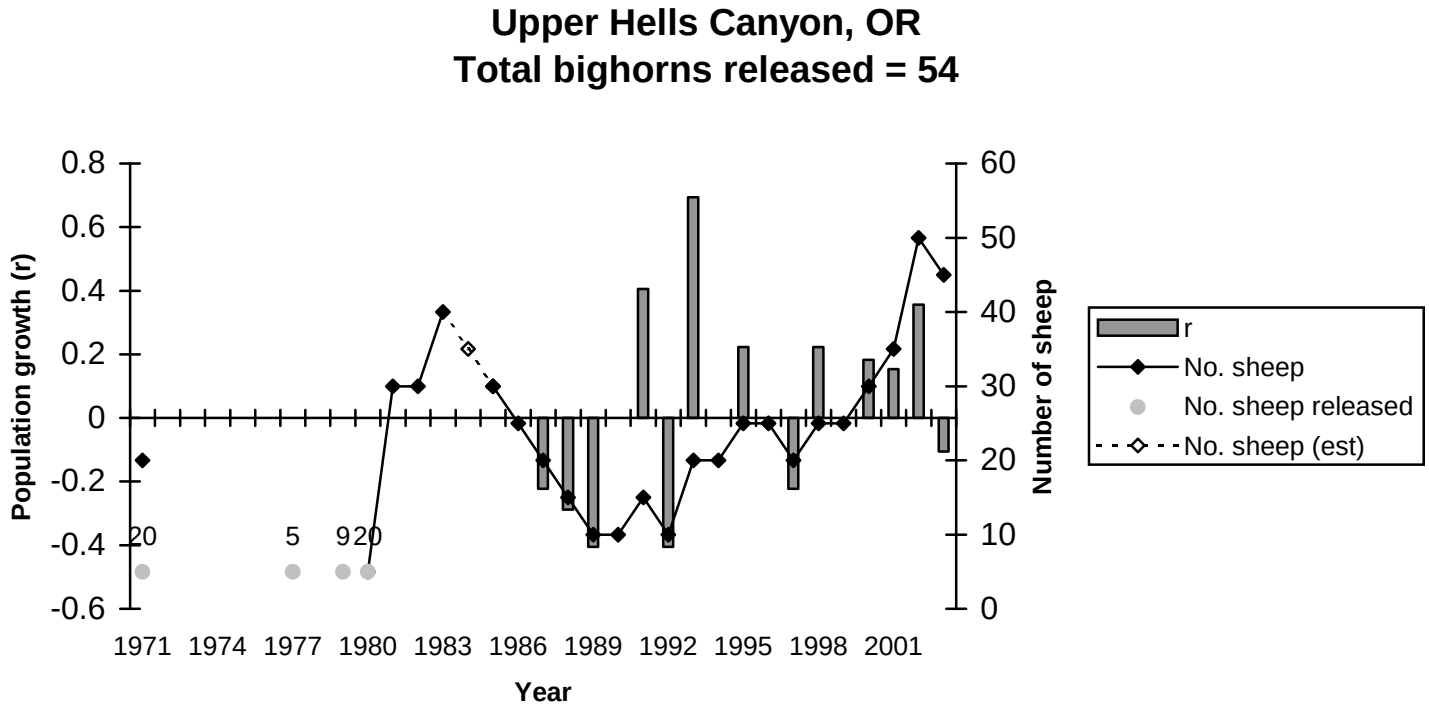

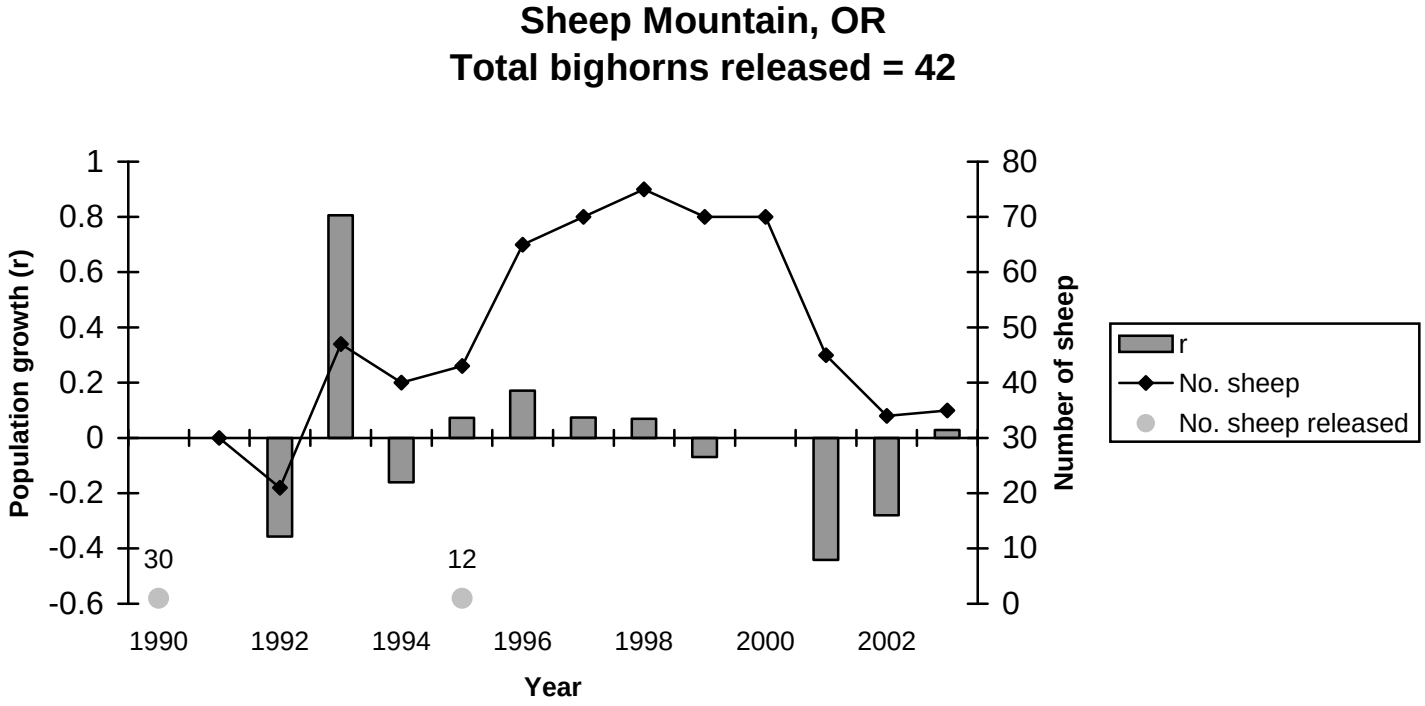

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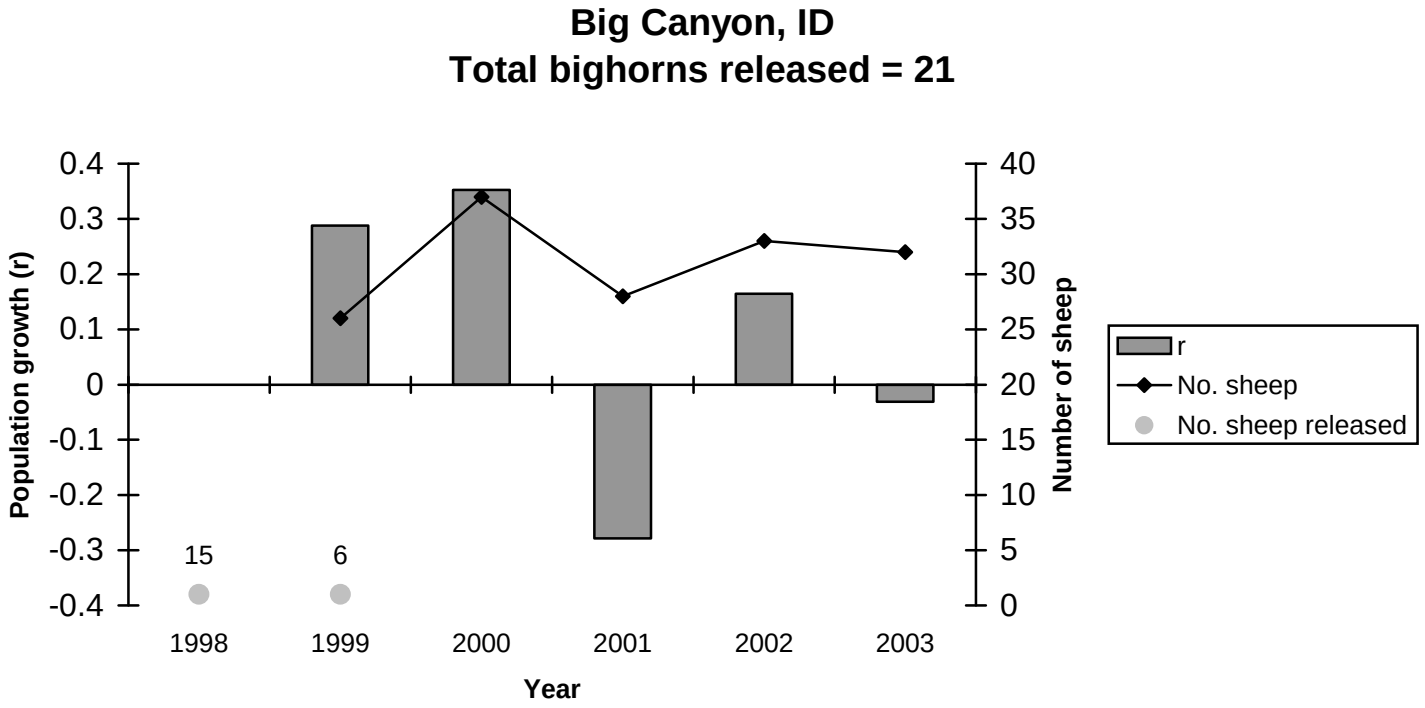

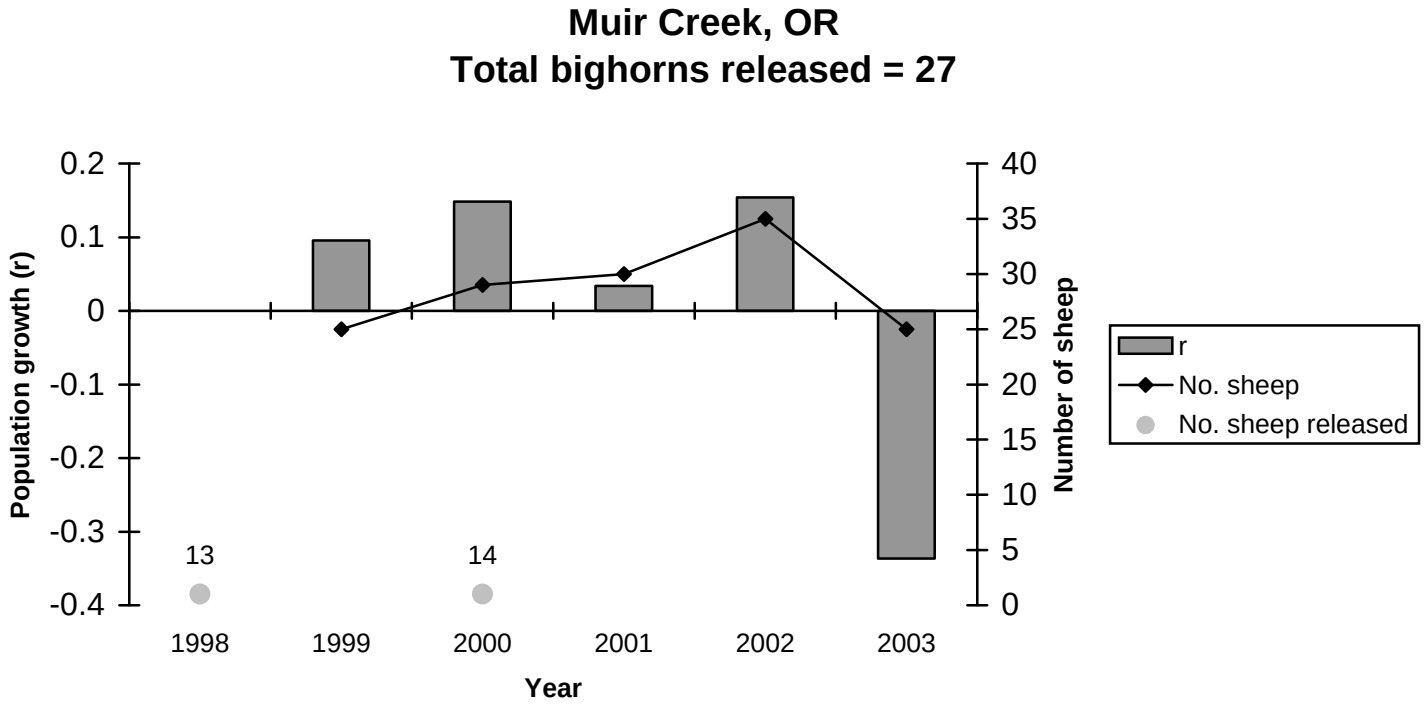

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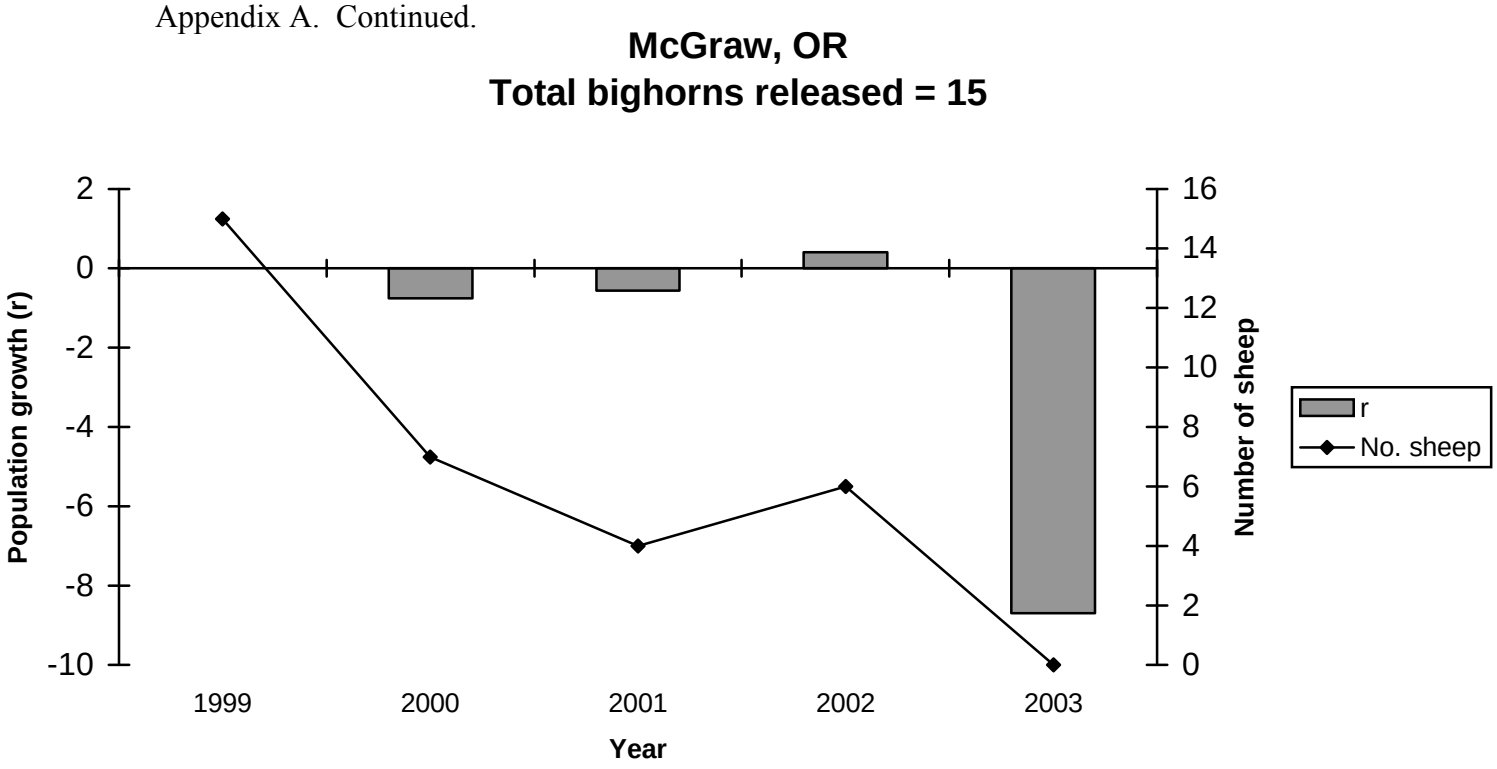


APPENDIX B

Bighorn sheep transplants in the Hells Canyon Bighorn Sheep Restoration Area through 2003

Appendix B.

Date	State	Release Location	Total	Ewes	Rams	Female Lambs	Male Lambs	Source[a]
April 1971	Oregon	Short Creek, Black Mountain	20	12	8	0	0	Jasper National Park, Alberta
April 1971	Oregon	Lostine River	20	11	4	4	1	Jasper National Park, Alberta
31 Jan 1975	Idaho	Granite Creek	10	7	1	0	2	Panther Creek, Salmon R., Idaho
January 1976	Oregon	Bear Creek	17	7	3	3	4	Lostine, Oregon (Jasper NP)
22 Jan 1976	Idaho	Granite Creek	11	3	5	1	2	Panther Creek, Salmon R., Idaho
18 Dec 1977	Oregon	Black Mountain, Battle Creek	5	2	2	0	1	Lostine, Oregon (Jasper NP)
January 1977	Oregon	Bear Creek	8	2	0	2	4	Lostine, Oregon (Jasper NP)
January 1977	Wash.	Joseph Creek WRA	9	6	1	1	1	Hall Mtn., Wash. (Banff NP)
Jan - Feb 1979	Oregon	Battle Creek	9	1	3	2	3	Lostine, Oregon (Jasper NP)
04 Jan 1979	Oregon	Cow Creek, Imnaha River	15	9	5	0	1	Panther Creek, Salmon R., Idaho
12 Jan 1979	Idaho	Bernard Creek	7	7	0	0	0	Panther Creek, Salmon R., Idaho
9-29 Dec 1979	Oregon	Battle Creek	12	1	1	6	4	Lostine, Oregon (Jasper NP)
8 Feb. 1980	Oregon	Hells Canyon Creek	8	5	2	0	1	Lostine, Oregon (Jasper NP)
31 Jan 1981	Wash.	Joseph Creek WRA	10	6	4	0	0	Lostine, Oregon (Jasper NP)
20 Jan 1982	Wash.	Joseph Creek WRA	10	5	4	0	1	Thompson Falls, Montana

Appendix B. Continued.

Date	State	Release Location	Total	Ewes	Rams	Female Lambs	Male Lambs	Source[a]
January 1982	Oregon	Imnaha River, Hass Ridge	10	4	1	3	2	Lostine, Oregon (Jasper NP)
January 1983	Wash.	Wenaha Canyon	15	8	3	2	2	Hall Mtn., Wash (Banff NP/MT)
January 1983	Oregon	Wenaha Canyon	15	7	3	1	4	Lostine, Oregon (Jasper NP)
07 Jan 1984	Idaho	Captain John Creek, Craig Mt.	17	7	8	1	1	Whiskey Mountain, Wyoming
05 Feb 1984	Oregon	Imnaha River, Hass Ridge	11	8	3	0	0	Panther Creek, Salmon R., Idaho
December 1984	Oregon	Wenaha Wildlife Area	28	15	7	3	3	Cove Creek, Salmon R., Idaho
18 Dec. 1985	Oregon	Bear Creek	12	9	2	0	1	Ebenezer Cr., Salmon R., Idaho
18 Apr 1987	Wash.	Joseph Creek WRA	1	0	1	0	0	WSU (Hall Mtn.)
January 1986	Wash.	Wenaha	14	6	3	4	1	Hall Mtn. (Banff NP/MT)
January 1989	Wash.	Joseph Creek WRA	9	6	1	1	1	Thompson Falls, Montana
23 January 1990	Oregon	Sheep Mountain	21	8	5	3	5	Tarryall, Colorado
04 Jan 1990	Idaho	Granite Creek	30	18	6	2	4	Whiskey Basin, Wyoming
03 Feb 1990	Oregon	Sheep Mountain	9	6	0	3	0	Cottonwood Creek, Colorado
Dec 1991	Wash.	Asotin Creek	6	3	1	1	1	Hall Mtn. (Banff NP/MT)
23 Dec 1993	Oregon	Cherry Creek	9	6	2	1	0	Wildhorse Isl., MT (Sun River,

Appendix B. Continued.

Date	State	Release Location	Total	Ewes	Rams	Female Lambs	Male Lambs	Source[a]
								MT)
1994	Wash.	Asotin Creek	9	4	2	1	2	Hall Mtn. (Banff NP/MT)
11 Feb 1994	Oregon	Cook Creek/Downey Creek	14	10	3	1	0	Wildhorse Isl., MT (Sun River, MT)
10 Feb 1995	Oregon	Cottonwood Creek	16	5	2	4	5	Cardinal River, Alberta
10 Feb 1995	Oregon	Jim Creek	22	15	0	5	2	Cardinal River, Alberta
7 Feb 1995	Oregon	Sheep Mountain	12	6	1	1	2	Cardinal River, Alberta
Feb 1995	Oregon	Sheep Mountain	2	0	0	0	2	Lostine, OR (Jasper NP/ Salmon R.)
13 Dec 1997	Idaho	Big Canyon	16	12	3	0	1	Spences Bridge, BC (Jasper NP)
13 Dec 1997	Oregon	Muir Creek	13	7	4	2	0	Spences Bridge, BC (Jasper NP)
13 Dec 1997	Wash.	Asotin Creek	10	7	2	1	0	Spences Bridge, BC (Jasper NP)
10 Feb 1999	Idaho	Big Canyon	6	3	3	0	0	Cardinal River, Alberta
10 Feb 1999	Oregon	Muir Creek	14	11	0	0	3	Cardinal River, Alberta
13 Jan 1999	Oregon	McGraw	15	8	6	1	0	Lostine, OR
8 Feb 2000	Oregon	Sheep Divide	20	12	3	3	2	Cardinal River, Alberta
8 Feb 2000	Oregon	Minam	18	12	3	1	2	Cardinal River, Alberta

Appendix B. Continued.

Date	State	Release Location	Total	Ewes	Rams	Female Lambs	Male Lambs	Source[a]
Dec 2001	Oregon	Quartz Cr.	15	11	3	0	1	Lostine, OR
13 Feb 2002	Idaho	Upriver Kirkwood	20	16	4	0	0	Missouri Breaks, MT (Sun River, MT)
Total	45 transplants	Oregon - 28, Idaho -8 Washington -9	600	334	128	64	72	
				56%	21%	11%	12%	

APPENDIX C

Diet composition in eight Hells Canyon bighorn sheep herds January 2001

Appendix C.

Plants	Jan-01 Wenaha	Jan-01 McGraw/ UHC	Jan-01 Redbird Jim Cr.	Jan-01 Redbird Tenmile	Jan-01 Asotin Creek	Jan-01 Black Butte	Jan-01 Muir Creek	Jan-01 Imnaha	Jan-01 Lostine
Agropyron intermedium	3.4	3.4	1.3	0.5	2.7	4.8	1.7	6.2	8.9
Agropyron smithii	2.1	2.1	1.8		4.1	1.0			0.8
Agropyron spicatum	11.3	10.3	10.4	13.4	22.5	11.4	13.0	18.9	11.4
Agropyron spp.	1.7	6.4	3.6	3.5	5.0	1.9	4.3	3.3	3.0
Agrostis sp.	7.6	12.9	6.8	8.9		3.8	4.8	12.7	*
Aristida longiseta		*		*	5.0				
Bromus carinatus	6.7	14.6	9.9	1.0	4.5	4.3	2.6	4.5	0.8
Bromus inermis				9.4	1.3				
Bromus tectorum			3.2		1.3				1.7
Bromus spp.	0.8	0.4	0.9	5.0	4.5	1.9	1.7	3.3	0.9
Festuca sp.	15.5	7.3	3.2	4.0	4.1	15.2	13.8	6.2	8.9
Hordeum spp.	3.8	*		4.5	*	*		*	
Koeleria cristata	8.0	5.2	11.7	3.0	6.8	4.8	7.8		8.9
Phleum spp.									
Poa spp.	12.6	19.7	18.1	3.5	9.0	15.7	20.8	16.4	18.1
Sitanion hystrix						*			
Sporobolus cryptandrus									
Stipa spp.	9.6	5.6	8.1	6.4	13.1	14.3	13.9	14.4	17.3
Other Grasses	5.0	3.9	4.1	4.9	9.0	4.5	6.1	4.1	6.3
Grasses (see * above)		3.4		1.5	2.7	3.8		0.8	2.5
Total Grasses:	88.1%	95.2%	83.1%	69.5%	95.6%	87.4%	90.5%	90.8%	89.5
Carex spp.									
Eleocharis spp.									
Juncus spp.									
Scirpus pallidus									
Other Sedge/Rush (see *above)									
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0

Appendix C. Continued.

Plants	Jan-01 Wenaha	Jan-01 McGraw/ UHC	Jan-01 Redbird Jim Cr.	Jan-01 Redbird Tenmile	Jan-01 Asotin Creek	Jan-01 Black Butte	Jan-01 Muir Creek	Jan-01 Imnaha	Jan-01 Lostine
Achillea millefolium			*	*	*	*	*	*	
Allium spp.									*
Amsinckia spp.			*	*					
Anaphalis margaritacea				*					
Astragalus spp.				*				*	
Balsamorhiza spp.	*		*			4.3		*	
Cirsium spp.	*			*					*
Collinsia parviflora			*	*					
Delphinium spp.				*					
Eriogonum spp.									*
Erodium cicutarium				*				*	*
Erysimum asperum								*	
Geranium spp.			*	*					
Helianthus annuus				*					
Heuchera spp.		*							
Lactuca spp.			*						
Lathyrus nevadensis				*					
Lily* family				4.5					
Lomatium spp.							*		
Lupinus spp.	*			*	*			*	
Mertensia spp.									*
Monardella odoratissima							*		
Penstemon spp.							*		
Phacelia spp.			*					*	
Phlox spp.			*					*	3.8
Ranunculus spp.				3.5					
Stellaria spp.									*
Verbascum spp.							*		*
Other Forb	2.5	0.9	1.6	4.0	0.9	2.6		1.2	2.1
Forbs (see * above)	1.9	0.9	10.8	15.5	1.3	1.4	6.1	5.6	4.6
Total Forbs:	4.4%	1.8%	12.4%	27.5%	2.2%	8.3%	6.1%	6.8%	10.5

Appendix C. Continued.

Plants	Jan-01 Wenaha	Jan-01 McGraw/ UHC	Jan-01 Redbird Jim Cr.	Jan-01 Redbird Tenmile	Jan-01 Asotin Creek	Jan-01 Black Butte	Jan-01 Muir Creek	Jan-01 Imnaha	Jan-01 Lostine
Artemisia tridentata						*			
Berberis/Mahonia repens	*				*	*			
Potentilla spp. stem		*							
Rosa spp. stem						*	*		
Salix spp. stem				*					
Shrub leaf	0.4					0.9		0.4	
Shrub stem		0.4	2.3				0.9		
Shrubs (see * above)	0.8	0.9		1.0	0.9	1.5	0.4		
Total Shrubs:	1.2%	1.3%	2.3%	1.0%	0.9%	2.4%	1.3%	0.4%	0.0
Juniperus scopulorum	3.8		*				*		
Pinus spp.	*								
Conifers (see * above)	0.8		0.4				1.7		
Total Conifers:	4.6%	0.0%	0.4%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0
Composite	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Moss:	1.7%	0.4%	1.8%	2.0%	1.3%	0.0%	0.4%	0.4%	0.0
Lichen:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Fern:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Seed/Nut:	0.0%	1.3%	0.0%	0.0%	0.0%	1.9%	0.0%	1.6%	0.0
Insect:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Thorn	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Total:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0

APPENDIX D

Bighorn sheep diet composition in eight Hells Canyon subpopulations April 2001

Appendix D.

Plants	Apr-01 Black Butte Dixon's	Apr-01 Black Butte Lime Point	Apr-01 Imnaha	Apr-01 Asotin Creek	Apr-01 Big Canyon	Apr-01 Muir Creek	Apr-01 Lostine	Apr-01 Wenaha	Apr-01 Redbird Salmon&Jim Cr.	Apr-01 Redbird	Apr-01 Upper Hells Canyon	Apr-01 McGraw
Agropyron intermedium		5.3	4.1	3.2	0.7	0.7	2.9				3.4	
Agropyron smithii							3.3		1.3	0.9	0.9	1.3
Agropyron spicatum	20.2	17.7	26.2	21.4	15.8	25.9	15.2	13.0	26.6	8.0	17.7	10.2
Agropyron spp.	4.7		6.4	9.9	2.5	8.0	2.6	14.5	8.0		2.6	7.6
Agrostis sp.			4.9	*	*	9.3	3.0	6.1		*	*	6.2
Aristida longiseta	*		*				*	*				
Bromus carinatus	1.0	1.7	6.7		3.2	1.3		*		1.4		20.0
Bromus inermis												
Bromus tectorum	1.0	13.8	3.4	3.2	1.1	2.7			1.3	0.9	*	
Bromus spp.	3.1	1.2		5.3	1.1	7.0	*	*	2.2	2.8		4.4
Dactylis glomerata				*								
Danthonia spp.	*											
Festuca sp.	7.8	4.1	7.1	5.3	*	4.3	11.8	6.5	6.2	7.6	9.5	8.9
Hordeum spp.		*				*		*	*			*
Koeleria cristata	*		*	*	*	*	4.4		*	*	6.9	*
Phleum spp.							*	*				
Poa spp.	11.4	10.0	11.2	8.2	4.3	11.3	29.6	14.1	7.1	3.3	13.8	15.1
Sitanion hystrix				*	5.8			*	*		*	
Sporobolus cryptandrus				*			*					
Stipa spp.	7.8	6.5	13.1	9.6	10.8	13.0	12.9	14.1	3.5	11.8	9.9	5.8
Other Grasses	4.1	4.7	1.9	5.0	2.5	4.0	5.9	5.7	3.1	4.7	4.7	5.8
Grasses (see * above)	4.6	2.9	2.2	7.8	4.3	3.3	4.1	8.5	3.6	3.3	4.8	3.6
Total Grasses:	65.7%	67.9%	87.2%	78.9%	52.1%	90.8%	95.7%	82.5%	62.9%	44.7%	74.2%	88.9
Carex spp.												
Eleocharis spp.												
Juncus spp.												
Scirpus pallidus												
Other Sedge/Rush (see *above)												
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0
Achillea millefolium		*	3.9	5.3	11.7				6.6	4.5	*	*

Appendix D. Continued.

Plants	Apr-01 Black Butte Dixon's	Apr-01 Black Butte Lime Point	Apr-01 Imnaha	Apr-01 Asotin Creek	Apr-01 Big Canyon	Apr-01 Muir Creek	Apr-01 Lostine	Apr-01 Wenaha	Apr-01 Redbird Salmon&Jim Cr.	Apr-01 Redbird	Apr-01 Upper Hells Canyon	Apr-01 McGraw
Allium spp.					*			*		*		
Amsinckia spp.		*										
Amaranthus retroflexus										*		
Anaphalis margaritacea										*		
Arabis spp.							*			*	*	
Astragalus spp.	*			*					*	*		
Balsamorhiza spp.	*	7.1						*		*		
Campanula rotundifolia	*	*	*	*			*	*	3.5	5.7		
Chenopodium spp.												
Cirsium spp.	*	*		*					*			
Clarkia pulchella				*						*		
Collinsia parviflora	*											
Cryptantha spp.												
Delphinium spp.		*				*			*		*	
Epilobium/Oenothera					*							
Erigeron spp.			*		*							
Eriogonum spp.	*						*	*			*	*
Erodium cicutarium	*	*							*			
Erythronium/Fritillaria					4.7	*				*		
Fragaria spp.												
Galium spp.					*							
Geranium spp.	4.1	*	*					3.4	6.9	*		*
Geum spp.	3.1											
Lesquerella douglasii	*		*				*					
Lily* family										*		
Lomatium spp.					10.4	*				11.4		
Lotus spp.				*								
Lupinus spp.					*		*			10.2		
Mertensia spp.		*					*	*	*			
Monardella odoratissima									*			
Montia spp.			*						*			

Appendix D. Continued.

Plants	Apr-01 Black Butte Dixon's	Apr-01 Black Butte Lime Point	Apr-01 Imnaha	Apr-01 Asotin Creek	Apr-01 Big Canyon	Apr-01 Muir Creek	Apr-01 Lostine	Apr-01 Wenaha	Apr-01 Redbird Salmon&Jim Cr.	Apr-01 Redbird	Apr-01 Upper Hells Canyon	Apr-01 McGraw
Penstemon spp.		*			*							
Phacelia spp.	*	*			*	*		*	*			
Phlox spp.			*	*	7.5	*				*	*	
Plantago spp.					*							
Polygonum spp.		*	*							*		*
Ranunculus spp.										*		
Rumex spp.										*		
Senecio spp.									*	*		
Stellaria spp.											*	
Vicia spp.				*					*			
Composite					*							
Flower						*		*	*			
Legume pod		*		*					*			
Monocot Forb	*											
Other Forb	10.1	6.2	3.0	7.5	4.7	1.3		5.0	5.5	2.4	8.6	0.9
Forbs (see * above)	9.8	14.6	4.4	4.2	7.5	4.5	2.4	5.3	13.7	20.2	10.2	5.3
Total Forbs:	27.1%	27.9%	11.3%	17.0%	46.5%	5.8%	2.4%	13.7%	36.2%	54.4%	18.8%	6.2
Amelanchier alnifolia leaf												
Amelanchier alnifolia stem						*						
Artemisia tridentata	*											
Chrysothamnus spp. leaf								*			*	
Potentilla spp. leaf				*		*						
Ribes spp. stem	5.2											
Rosa spp. stem		*		*								
Salix spp. stem											*	
Symphoricarpos spp. stem								*				
Shrub leaf		1.2									*	0.4
Shrub stem		1.2	0.7	0.6	1.4		0.4	0.4				
Shrubs (see * above)	0.5	1.2		2.6		2.7		3.0			3.2	
Total Shrubs:	5.7%	3.6%	0.7%	3.2%	1.4%	2.7%	0.4%	3.4%	0.0%	0.0%	3.2%	0.4

Appendix D. Continued.

Plants	Apr-01 Black Butte Dixon's	Apr-01 Black Butte Lime Point	Apr-01 Imnaha	Apr-01 Asotin Creek	Apr-01 Big Canyon	Apr-01 Muir Creek	Apr-01 Lostine	Apr-01 Wenaha	Apr-01 Redbird Salmon&Jim Cr.	Apr-01 Redbird	Apr-01 Upper Hells Canyon	Apr-01 McGraw
Juniperus scopulorum						*		*			3.4	*
Pinus spp.												
Conifers (see * above)						0.7		0.4				2.7
Total Conifers:	0.0%	0.0%	0.0	0.0%	0.0%	0.7%	0.0%	0.4%	0.0%	0.0%	3.4%	2.7
Composite	0.0%	0.0%	0.0	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0.0%	0.0	
Moss:	0.0%	0.6%	0.4	0.9%	0.0%	0.0%	1.5%	0.0	0.0	0.4%	0.9	
Lichen:	1.5%	0.0%	0.4	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0.0%	0.0	
Fern:	0.0%	0.0%	0.0	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0.0%	0.0	
Seed/Nut:	0.0%	0.0%	0.0	0.0%	0.0%	0.0%	0.0%	0.9	0.0	0.0%	0.0	
Insect:	0.0%	0.0%	0.0	0.0%	0.0%	0.0%	0.0%	0.0	0.9	0.0%	0.9	
Thorn	0.0%	0.0%	0.0	0.0%	0.0%	0.0%	0.0%	0.0	0.0	0.0%	0.0	
Total:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0

APPENDIX E

Bighorn sheep diet composition in three Hells Canyon herds June and July, 2001

Appendix E.

Plants	Jun-01 Redbird Ackerman Bar	Jun-01 Redbird Cottonwood Cr	Jun-01 Black Butte	Jun-01 Asotin Creek Bracken Point	Jul-01 Asotin Creek	Jul-01 Black Butte	Jul-01 Redbird
Agropyron intermedium		1.9			1.7	1.0	
Agropyron spicatum	11.2	14.9	18.5	8.5	9.3	23.3	20.1
Agropyron spp.	14.6	0.5	4.5	1.3	6.7	4.5	3.4
Agrostis sp.	*		5.8	*	*	*	
Aristida longiseta		*				*	
Bromus carinatus			0.8			*	
Bromus tectorum	9.7	*	7.4	8.9	2.1		
Bromus spp.		*	2.9	2.7	3.4	*	*
Danthonia spp.			*	*			*
Festuca sp.	3.4	10.2	4.1	6.2	4.6	6.9	*
Hordeum spp.				*	*	*	
Koeleria cristata	*		*		*	*	*
Poa spp.	8.3	7.4	9.5	8.0	5.1	17.4	3.7
Sitanion hystrix				*			
Sporobolus cryptandrus	4.4	23.8			*	*	14.0
Stipa spp.	11.7	13.0	8.7	*	9.3	16.7	8.2
Other Grasses	3.9	3.3	6.2	4.5	3.0	2.8	6.1
Grasses (see * above)	4.3	3.2	5.4	9.8	6.2	7.6	7.2
Total Grasses:	71.5 %	78.2 %	73.8 %	49.9 %	51.4 %	80.2 %	62.7 %
Carex spp.							
Other Sedge/Rush (see *above)							
	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Achillea millefolium	3.9	*	*	*	*		
Amsinckia spp.							*
Arabis spp.		*		*	*		
Astragalus spp.	*		*				
Balsamorhiza spp.	*	*	*			*	
Campanula rotundifolia				*			
Castilleja spp.					*		
Centaurea spp.	*	*		*	4.6	*	*
Cirsium spp.	3.9	*	*	3.6	8.4	*	*
Clarkia pulchella				*			
Cryptantha spp.						*	*
Equisetum spp.			*				
Erigeron spp.			*				
Eriogonum spp.					*		
Erythronium/Fritillaria			*				
Galium spp.		*	*			*	*
Geranium spp.		*					*
Geum spp.	*	4.2	*				
Lithospermum ruderale			*				
Lupinus spp.	*		5.0	*			
Mertensia spp.	*	*	*		*	*	3.1
Montia spp.		*					

Appendix E. Continued.

Plants	Jun-01 Redbird Ackerman Bar	Jun-01 Redbird Cottonwood Cr	Jun-01 Black Butte	Jun-01 Asotin Creek Bracken Point	Jul-01 Asotin Creek	Jul-01 Black Butte	Jul-01 Redbird
Opuntia polycantha				*			
Penstemon spp.	*	*					
Phacelia spp.	*	*					
Rumex spp.			*				
Senecio spp.					*		
Solidago spp.						*	
Sphaeralcea munroana							3.8
Tragopogon dubius							
Trifolium/Medicago	*			18.9	*	*	*
Verbascum spp.							
Vicia spp.			*	6.9	*	*	*
Flower	4.4						*
Other Forb	5.1	4.2	2.5	5.1	8.8	3.1	2.0
Forbs (see * above)	10.0	9.3	13.8	8.5	10.8	12.2	9.2
Total Forbs:	27.3 %	17.7 %	21.3 %	43.0 %	32.6 %	15.3 %	18.1 %
Artemisia tridentata				*			
Chrysothamnus spp. leaf	*			*	7.2		*
Potentilla spp. leaf		*		*			
Prunus spp. stem					*		
Rosa spp. stem			*		*	*	
Salix spp. leaf/catkin		*					2.0
Salix spp. stem					*		1.7
Symphoricarpos spp. leaf			*				
Shrub leaf	1.0			1.3			
Shrub stem		1.4	0.8				1.4
Shrubs (see * above)	0.2	1.8	2.0	4.0	5.0	2.1	0.5
Total Shrubs:	1.2 %	3.2 %	2.8 %	5.3 %	12.2 %	2.1 %	5.6 %
Juniperus scopulorum		*	*		*		*
Pinus spp.							
Conifers (see * above)		0.9	1.7		2.5		0.7
Total Conifers:	0.0 %	0.9 %	1.7 %	0.0 %	2.5 %	0.0 %	0.7 %
Total:	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

APPENDIX F

Bighorn sheep diet analysis in eight Hells Canyon herds August 2001

Appendix F.

Plants	Aug-01 Wenaha	Aug-01 Black Butte	Aug-01 Black Butte Shovel Cr.	Aug-01 Imnaha	Aug-01 Upper Hells Canyon/Mc Graw	Aug-01 Redbird Salmon River	Aug-01 Redbird Tenmile	Aug-01 Big Canyon	Aug-01 Asotin Creek	Aug-01 Lostine	Aug-01 Muir Creek
Agropyron intermedium					2.6						6.1
Agropyron smithii								1.5			
Agropyron spicatum	9.3	10.1	8.1	4.4	17.2	14.4	7.0	13.1	11.8		18.9
Agropyron spp.	2.8		7.3	11.0	3.1	9.1	3.9	4.0	9.7	4.7	5.6
Agrostis sp.	*	*	7.7	*	*					4.0	
Aristida longiseta			*			*					
Bromus carinatus	1.7		2.6		3.6						
Bromus tectorum								*	1.6		
Bromus spp.	4.5		6.4	*	1.6	*	8.3	*	4.3	10.5	*
Dactylis glomerata	*										
Danthonia spp.				7.0			*				
Deschampsia spp.										*	
Festuca sp.	3.9	5.8	3.4	*	15.6	10.3	*	4.0	*	3.6	3.3
Hordeum spp.									4.3		
Koeleria cristata	*	*	3.4	*	3.6		*	*			*
Phleum spp.	*										
Poa spp.	4.5	12.3	7.7	5.3	16.7	12.8	*	5.0	*	*	4.7
Sitanion hystrix		*	*					*			*
Sporobolus cryptandrus				26.3		3.7	22.2	11.1			
Stipa spp.	*	4.3	*	13.6	4.7	12.8	5.2	5.0	4.3		5.1
Other Grasses	5.0	4.3	4.3	7.9	3.6		6.5	3.5	8.1	4.3	2.8
Grasses (see * above)	8.9	3.5	4.7	5.3	1.6	1.7	6.5	5.5	3.8	3.6	4.3
Total Grasses:	40.6%	40.3%	55.6%	80.8%	73.9%	64.8%	59.6%	52.7%	47.9%	30.7%	50.8%
Carex spp.										28.2	
Eleocharis spp.							*				
Juncus spp.							*			19.1	
Scirpus pallidus							*				
Other Sedge/Rush (see *above)							5.7				
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.7%	0.0%	0.0%	47.3%	0.0%

Appendix F. Continued.

Plants	Aug-01 Wenaha	Aug-01 Black Butte	Aug-01 Black Butte Shovel Cr.	Aug-01 Imnaha	Aug-01 Upper Hells Canyon/Mc Graw	Aug-01 Redbird Salmon River	Aug-01 Redbird Tenmile	Aug-01 Big Canyon	Aug-01 Asotin Creek	Aug-01 Lostine	Aug-01 Muir Creek
Achillea millefolium		*	*		*	*	*	*		*	3.3
Amaranthus retroflexus									*		
Aster spp.									*		
Astragalus spp.	*		*	*			*				
Balsamorhiza spp.	21.0	13.4	3.6		*	*					
Castilleja spp.									*		
Centaurea spp.	*	*	5.1		*		*	4.5	*		7.9
Chenopodium spp.											*
Cirsium spp.	*	*	*		7.3		*	*	5.4		
Epilobium/Oenothera						*					
Equisetum spp.	9.5		*	*			7.4	10.1		*	7.0
Erigeron spp.	*	*	*			*			*	*	*
Eriogonum spp.		*			*						
Erodium cicutarium					*						
Fragaria spp.										*	
Galium spp.		3.6			*						3.3
Geum spp.											
Haplopappus spp.				*			*				
Heracleum lanatum?	*					*					
Lily* family										*	
Lupinus spp.	*	*	4.5	7.9	*	*	3.7		4.3	*	
Mertensia spp.					*	5.0	3.5	5.6			
Monardella odoratissima							*	*	3.2		
Montia spp.						*					
Opuntia polycantha	*										
Penstemon spp.										*	
Phacelia spp.					*						*
Phlox spp.					*	*					
Plantago spp.	*								*		

Appendix F. Continued.

Plants	Aug-01 Wenaha	Aug-01 Black Butte	Aug-01 Black Butte Shovel Cr.	Aug-01 Imnaha	Aug-01 Upper Hells Canyon/Mc Graw	Aug-01 Redbird Salmon River	Aug-01 Redbird Tenmile	Aug-01 Big Canyon	Aug-01 Asotin Creek	Aug-01 Lostine	Aug-01 Muir Creek
Polygonum spp.	*		*		*						
Rumex spp.											*
Senecio spp.		*		*		*					
Solidago spp.							*				
Tragopogon dubius		*									
Trifolium/Medicago			*		*	*	*		3.8	*	
Verbascum spp.	*					*					*
Vicia spp.		*					*		*		
Composite				*				*		*	
Flower	*								*	*	
Legume pod							*	*		*	
Other Forb	7.0	5.1	3.9	1.7	3.4	3.7	3.5	5.6	9.7	3.6	3.3
Forbs (see * above)	14.0	10.6	5.3	4.3	12.3	6.1	9.6	5.0	8.0	9.8	7.1
Total Forbs:	51.5%	32.7%	22.4%	13.9%	23.0%	14.8%	27.7%	30.8%	34.4%	13.4%	31.9%
Amelanchier alnifolia leaf								*			
Amelanchier alnifolia stem		*									*
Cercocarpus ledifolius stem							*				
Chrysothamnus spp. leaf		*	*								
Potentilla spp. leaf	*								*		
Prunus spp. stem		3.6									
Ribes spp. stem								*			
Rosa spp. stem		6.5	*			*		3.0			
Rubus discolor leaf		12.6	*			10.1					
Salix spp. leaf/catkin		*				*		2.0		5.9	
Salix spp. stem								3.0			*
Shrub leaf			1.7			2.5		1.5	2.7	1.6	2.8
Shrub stem	1.7		3.4		2.6		1.8	3.0			
Shrubs (see * above)	0.6	2.1	3.2			2.5	1.3	1.5	1.6		1.9
Total Shrubs:	2.3%	24.8%	8.3%	0.0%	2.6%	15.1%	3.1%	14.0%	4.3%	7.5%	4.7%

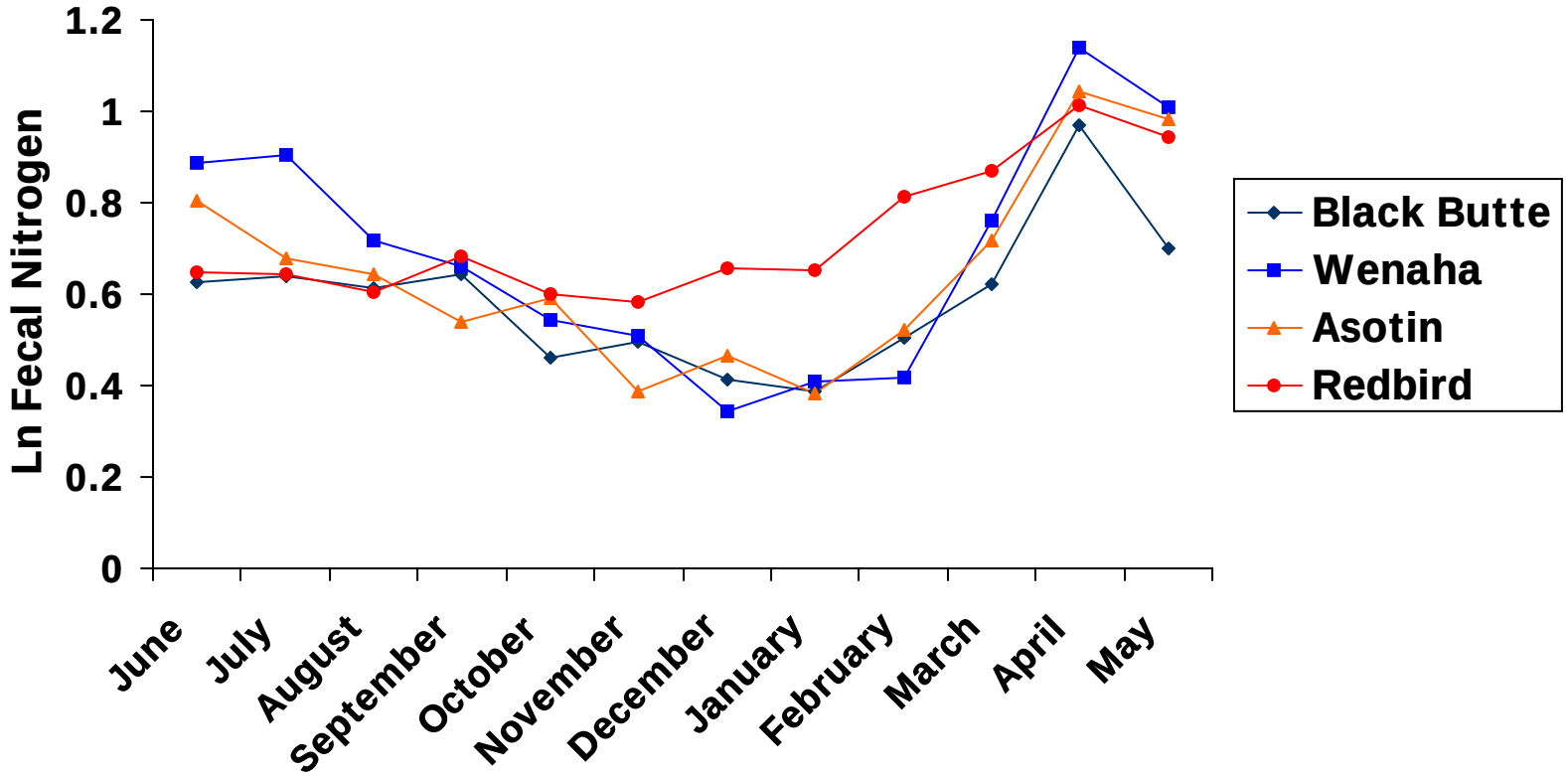
Appendix F. Continued.

Plants	Aug-01 Wenaha	Aug-01 Black Butte	Aug-01 Black Butte Shovel Cr.	Aug-01 Imnaha	Aug-01 Upper Hells Canyon/Mc Graw	Aug-01 Redbird Salmon River	Aug-01 Redbird Tenmile	Aug-01 Big Canyon	Aug-01 Asotin Creek	Aug-01 Lostine	Aug-01 Muir Creek
Conifers (see * above)											
Total Conifers:	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Composite	0.0	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Moss:	2.8	0.0%	3.8%	3.5%	0.0%	0.8%	0.0%	1.0%	10.7%	1.1%	
Lichen:	0.0	0.0%	0.9%	0.0%	0.5%	2.5%	0.0%	0.0%	0.0%	0.0%	
Fern:	0.0	0.0%	0.4%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	
Seed/Nut:	0.0	2.2%	7.7%	0.9%	0.0%	0.4%	3.9%	1.5%	2.7%	0.0%	
Insect:	0.0	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	
Thorn	2.8	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Total:	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

APPENDIX G

Average bighorn sheep fecal nitrogen values in four Hells Canyon herds 1999-2003

Appendix G.


Ln Fecal Nitrogen
1.2
1
0.8
0.6
0.4
0.2
0
June
July
August
September
October
November
December
January
February
March
April
May
Black Butte
Wenaha
Asotin
Redbird

Submitted by:

Francis Cassirer
Wildlife Research Biologist

Approved by:

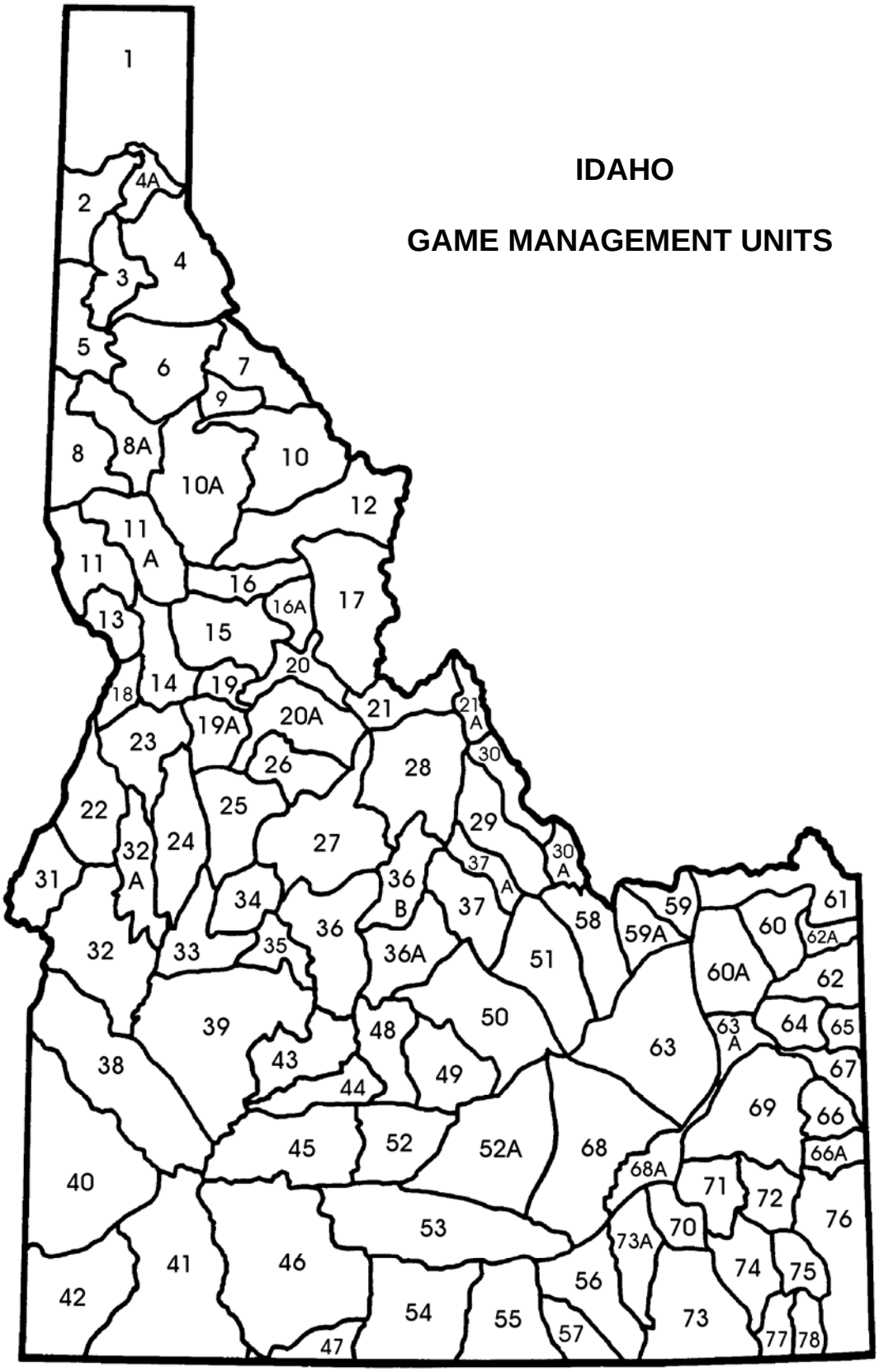
IDAHO DEPARTMENT OF FISH AND GAME

Dale E. Toweill
Wildlife Program Coordinator
Federal Aid Coordinator

James W. Unsworth, Chief
Bureau of Wildlife

IDAHO

GAME MANAGEMENT UNITS



FEDERAL AID IN WILDLIFE RESTORATION

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sale of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. The Idaho Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be responsible, ethical hunters. Seventy-five percent of the funds for this project are from Federal Aid. The other 25% comes from license-generated funds.