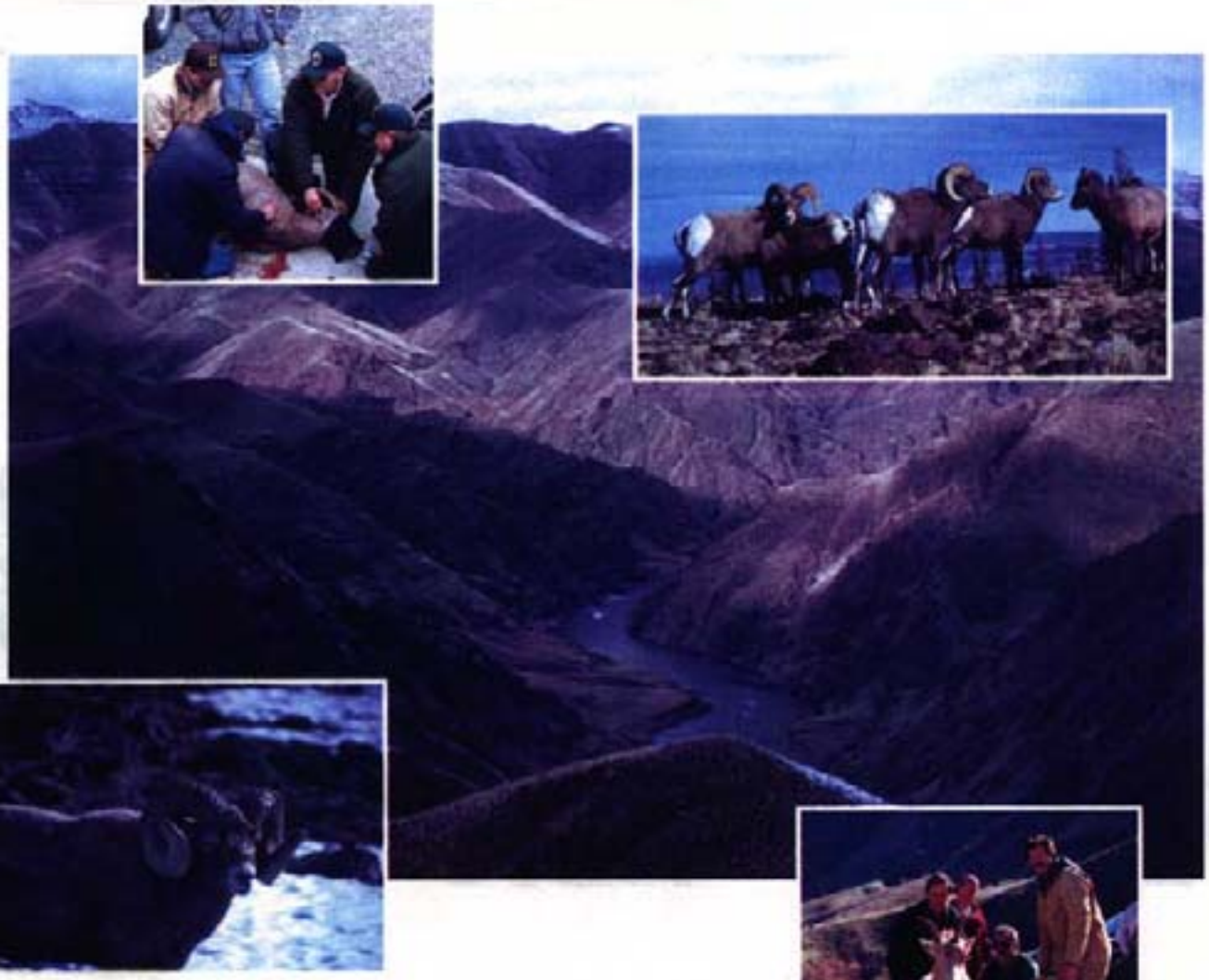
Restoration of Bighorn Sheep to Hells Canyon:
The Hells Canyon Initiative



By the Hells Canyon Restoration Committee

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RESTORATION OF BIGHORN SHEEP TO HELLS CANYON

THE HELLS CANYON INITIATIVE

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Idaho Department of Fish and Game

Oregon Department of Fish and Wildlife

Washington Department of Fish and Wildlife

U.S. Forest Service

Bureau of Land Management

Foundation for North American Wild Sheep

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Cover photographs by Tim Schommer, Bill Loftus, and Vic Coggins

LIST OF AUTHORS

The Hells Canyon Bighorn Sheep Restoration Plan was prepared by the Hells Canyon Bighorn Sheep Restoration Committee. Committee members are:

Frances Cassirer, Idaho Department of Fish and Game, Wildlife Research Biologist, Hells Canyon Bighorn Sheep Restoration Project Coordinator

John Beecham, Idaho Department of Fish and Game, Wildlife Game Manager

Vic Coggins, Oregon Department of Fish and Wildlife, District Wildlife Biologist

Don Whittaker, Oregon Department of Fish and Wildlife, Program Coordinator

Pat Fowler, Washington Department of Fish and Wildlife, District Wildlife Biologist

Rolf Johnson, Washington Department of Fish and Wildlife, Big Game Program Manager

Kevin Martin, U.S. Forest Service, Zone Biologist, Hells Canyon National Recreation Area/Wallowa Valley Ranger District

Tim Schommer, U.S. Forest Service, Forest Biologist, Wallowa-Whitman National Forest

ElRoy Taylor, Bureau of Land Management, Wildlife Biologist

Allan Thomas, Bureau of Land Management, Idaho State Biologist

Duncan Gilchrist, Foundation for North American Wild Sheep, Secretary

Lloyd Oldenburg, Foundation for North American Wild Sheep

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SUMMARY

The Hells Canyon 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. This plan describes project goals and objectives, the background and current condition of bighorn sheep and bighorn sheep management in Hells Canyon, and actions to be accomplished under the Hells Canyon Initiative. The plan was written by and will be implemented by the Hells Canyon Bighorn Sheep Restoration Committee, a committee operating under a Memorandum of Agreement signed by the states of Oregon, Idaho, and Washington, the Wallowa-Whitman National Forest, the Bureau of Land Management, and the Foundation for North American Wild Sheep.

The Hells Canyon project area encompasses over 5.5 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. Other public land managers are the states of Idaho, Oregon, and Washington and the Bureau of Land Management.

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-seven bighorn sheep from 9 source populations have been released into the project area. Currently, about 700 bighorn sheep occur in 14 herds. The population has increased in size at an average annual growth rate of 7%. Disease transmitted by livestock and unknown sources has been an important factor limiting population growth. At least 7 disease epidemics have reduced the annual population growth rate by about 40%.

Considerable bighorn sheep habitat, particularly summer range, exists in the Wallowa, Seven Devils, and Blue Mountains portion of the project area. Extensive year round habitat occurs in the low elevation Snake River canyon grasslands. Habitat improvement projects completed to date include development of 44 water sources, pasture cultivation for bighorn sheep, treatment of over 70,000 acres with prescribed and wildfire since 1992, and placement of salt and medication blocks in bighorn sheep herd areas. Interagency noxious weed projects are active and ongoing. Several U.S. Forest Service domestic sheep allotments have been vacated since 1990. Public land domestic sheep allotments currently occur at 5 locations within the project area.

Under the Hells Canyon Initiative, state and federal agencies will increase efforts to reintroduce bighorn sheep and manage habitat and populations to establish new herds and increase the size of existing herds. Information on bighorn sheep ecology and factors limiting population size will be collected, evaluated, and incorporated into management. The area will 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.

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I. PROJECT GOALS

Introduction

The Hells Canyon 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 will be administered through a Memorandum of Agreement, formalizing the cooperation between the state wildlife agencies, the U.S. Forest Service, the Bureau of Land Management, and the Foundation for North American Wild Sheep. The Memorandum of Agreement covers the portion of the project area within the Pacific Northwest Region (Region 6) of the U.S. Forest Service.

Goal

The goal of the Hells Canyon Initiative is to: **restore self-sustaining bighorn sheep herds to suitable habitat in the Hells Canyon area**. This project will be a model for bighorn sheep restoration and offer 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 factors limiting bighorn sheep population growth.
3. Identify causes of bighorn sheep die-offs.
4. Implement a population monitoring program to assess progress towards the project goal.
5. Adapt management to reflect monitoring and research data.

Project area

The Hells Canyon Project area encompasses 2,273,194 ha (5,617,062 ac) in the Snake River drainage in Idaho, Oregon, and Washington from the mouth of Clearwater River, Idaho south to Brownlee Reservoir. It is bounded on the east by the Salmon River drainage, near Riggins, Idaho and extends just west of the Eagle Cap Wilderness, Wallowa-Whitman National Forest, Oregon (Fig. 1). Major drainages include the Snake, Grande Ronde, Imnaha, and lower Salmon rivers. There are currently 14 bighorn sheep herds established in the project area (Table 1).

II. BACKGROUND

Reintroductions

Bighorn sheep were extirpated from Hells Canyon and the adjacent Wallowa Mountains by 1945 (Smith 1954, Johnson 1980, ODFW 1992). As elsewhere in the western United States this was probably due to a combination of competition with livestock for forage, diseases introduced by domestic sheep, and over hunting. The first reintroductions of bighorn sheep to Hells Canyon and the surrounding area occurred in 1971 when the Oregon Department of Fish and Wildlife (ODFW) translocated 20 Rocky Mountain bighorn sheep from Jasper National Park, Alberta to the Black Mountain area near Hells Canyon Dam and 20 to the Lostine River in the Wallowa Mountains (ODFW 1992). Since 1971, 357 Rocky Mountain bighorn sheep have been translocated into the Hells Canyon area and 94 bighorn sheep have been relocated within the project area (Table 2). Bighorn sheep currently in Hells Canyon originated from 9 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 2 or more source populations have been released into all herds except Redbird (Table 3).

Herd history and die-offs

The Hells Canyon bighorn sheep population (or metapopulation) is composed of 14 ewe herds (Figs. 1 and 2). Reintroductions have established 10 herds; 4 herds were established by dispersal, presumably from adjacent herd areas.

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 suboptimal habitat quality (for instance due to fire suppression, noxious weeds, overgrazing by livestock, or inter- or intraspecific 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).

Seven population die-offs have been reported in the project area since reintroductions were initiated. Die-offs occurred in 1971-72, 1983-84, and 1991 in Upper Hells Canyon; 1986-87 in Lostine; 1988 in Mountain View; and 1995-96 in Lower Hells Canyon and Black Butte. Five die-offs have been linked circumstantially to domestic sheep (Coggins 1988, and unpubl. reports), 1 circumstantially to a feral goat (Cassirer et al. 1996), and 1 to drought and scabies (*Psoroptes ovis*) (Foreyt et al. 1990).

Little information was collected during most early die-offs and most of it after the fact, when numerous dead bighorn sheep were observed by agency personnel, or reported by the public. Pneumonia was the eventual cause of death in all cases where a cause of death could be identified (1984, 1986-87, 1988, and 1995-96 die-offs) however the factors that

started or predisposed the sheep to the die-offs could not be confirmed. Bighorn sheep released at Black Mountain, Oregon in 1971 had disappeared by 1973. Contact with domestic sheep was observed during this period and was suspected to be the cause for the die-off (ODFW 1992). In 1983, most of a population of about 15 bighorn sheep in the Sand Creek area disappeared and presumably died. The cause of the population decline was not determined. Sixty percent of the bighorn sheep across the Snake River in the Granite-Three Creeks area, Idaho also died in 1983 and 1984. Some bighorns were sampled, and *Pasteurella*-associated pneumonia was identified as the cause of this die-off. Parainfluenza-3, epizootic hemorrhagic disease, and chlamydia were also detected. Domestic sheep were thought to be the source of the pathogens (McNeill et al. 1987). Bighorn sheep populations have not recovered in either the Black Mountain or Granite Creek areas, despite total releases of 103 sheep including the most recent release of 30 bighorn sheep to Granite Creek by Idaho in 1990. Most bighorn sheep from this release died in 1991, apparently due to contact with domestic sheep.

From November 1986 through March 1987, an estimated two-thirds of the 110 bighorn sheep in the Lostine herd in Oregon died from bacterial pneumonia attributed to contact with domestic sheep (Coggins 1988, ODFW 1992). This population has since recovered and is now estimated at 80 bighorns. In 1988, about two-thirds of the California bighorn sheep (*O. c. californiana*) died at Cottonwood Creek on the Grande Ronde River, Washington. The sheep apparently died from a combination of poor range conditions due to drought and infection by scabies parasites introduced during a transplant of Rocky Mountain bighorn sheep from Idaho. Although both Rocky Mountain and California bighorn sheep were exposed to the scabies, it appeared to be lethal only to the California bighorn sheep (Foreyt et al. 1990).

The most recent Hells Canyon disease episode occurred in the winter of 1995-96. A population die-off believed to have started near 10-mile Creek, Washington extended 40 miles to the Imnaha River, Oregon. About 235 bighorns died from bacterial pneumonia, most in the Black Butte and Lower Hells Canyon, Oregon herds. Sheep in the Wenaha, Joseph Creek, Mountain View/Lost Prairie, Redbird, and Lower Hells Canyon, Idaho herds were also affected to varying degrees (Cassirer et al. 1996).

Current population status and dynamics

As of 1996, there were approximately 700 bighorn sheep in the 14 Hells Canyon project area herds (Fig. 1, Table 1). Movements have been documented among many of the herds, often during the rut.

Average annual growth rate for all herds, including die-off periods in 5 herds that have experienced them, is 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 1995-96 die-off and 22% at Sheep Mountain (Table 5). Herd growth rates were higher during the 2nd - 4th years after bighorns were released into vacant habitat than subsequently (Table 5). 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). Growth rates were negatively correlated with population size in herds with more than 4 years of data where effects of die-offs could be eliminated (Figure 4).

Average lamb:ewe ratios in Hells Canyon herds are 41 lambs:100 ewes, and range from an average of 14 lambs:100 ewes in the Upper Hells Canyon, Idaho herd to 76 lambs:100 ewes at Sheep Mountain. Other herds with relatively high average lamb:ewe ratios are Bear Creek, the Imnaha, and Black Butte. Herd lamb:ewe ratios are not correlated to average annual growth rate (r=-0.08, p=0.8, n=10). This may be because lamb:ewe ratios were estimated at different times of years for different herds and may not be comparable among herds. Ram:ewe ratios average 52:100 and are highest in the Joseph Creek and Bear Creek herds (Table 5).

Five herds are at or below the number of bighorn sheep released into them. These are the Asotin; Lower Hells Canyon, Oregon; Upper Hells Canyon, Oregon; Upper Hells Canyon, Idaho; and Bear Creek, Oregon herds. The declines in these herds are primarily due to disease-related die-offs, movements of sheep away from release sites into other herds (Coggins and Matthews 1996), or to low numbers of bighorns released (Asotin).

If the current population trend continues, the Hells Canyon bighorn sheep metapopulation will continue to increase at approximately 7% annually. Overall numbers would double in about 10 years ($0.6931/\log_e 1.07$, Caughley 1977:52) with some herds likely experiencing die-offs or disappearing, and other herds increasing in size.

Harvest

Nearly 200 bighorns have been harvested in the project area since the first hunt in 1976 (Table 4). Harvest in all states is by controlled permit and limited to rams. Success rates are 80 - 90%. Idaho requires rams have a 3/4 curl or greater or be at least 4 years old; Oregon and Washington permit the taking of any ram. Minimum herd size for a hunt is 60 bighorns in Oregon, 100 bighorns in Idaho, and 30 adult bighorns with population stable or increasing in Washington. Washington herds must have at least 8 mature rams of which 2 are at least 6 years old or 3/4 curl. In Idaho, permits can be issued for no more than 20% of mature rams (3/4 curl or greater). In Washington permits are limited to 20% of mature rams when ram:ewe ratio > 50:100, 15% of mature rams when ram:ewe ratio = 25-50:100, and 10% of mature rams when ram:ewe ratios < 25:100. There are also additional herd-specific criteria in Washington. Each state has an auction tag and a lottery tag. These tags can be used in any open unit (IDFG 1991, ODFW 1992, WDFW 1995).

Habitat availability

Extent of bighorn sheep habitat in the Hells Canyon project area was evaluated using a Geographic Information System and a predictive model based on habitat models used in Utah, Montana, New Mexico, and Washington and throughout the western U.S. (Smith et al. 1991, Dunn 1993, Johnson and Ringo 1995, Gudorf and Sweanor 1996, Schirokauer 1996)

(Tables 7 and 8). Vegetation information was obtained from a supervised classification of TM satellite imagery. Satellite imagery was not available in this form for classification of the northwestern corner of the project area (including most of the Wenaha and Asotin herds) and these areas were omitted from habitat analysis. Slope and elevation information was obtained from USGS 1:24,000 digital elevation models for all areas where available. Digital elevation models at a scale of 1:100,000 were patched in for the Rattlesnake Ridge, Idaho and Silcott Island, Washington topographic quads. Water availability was obtained from USGS 1:100,000 hydrography. Information on land ownership and domestic sheep allotments on public land were obtained from the U.S. Forest Service and BLM Upper Columbia Basin Project and local agency sources.

Suitable bighorn sheep habitat is steep, with high visibility, in proximity to free water, and winter range must be relatively snow-free. All areas at least 1.6 ha in size with slopes of 31° - 85° ("escape terrain") and areas within 300m of escape terrain or bordered on 2 sides within 500m of escape terrain were initially selected by the model. Areas with dense forest or shrub vegetation and areas greater than 3.2 km from water were then eliminated.

Approximately 541,221 ha (1,337,356 ac) of suitable bighorn sheep habitat was predicted to occur within the analysis area. Approximately 68% of potential habitat is publicly-owned, primarily managed by the U.S. Forest Service. 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 9). 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 inholdings also occur within publicly-owned areas.

Habitat limitations

Slope was the primary factor determining the extent of potential bighorn sheep habitat within the project area. Extensive grasslands are available, and overall, forest succession did not seem to be a major determinant of the amount of habitat available, although it may affect individual herds. Winter range is limited at the higher elevations of the Wallowa and Seven Devils Mountains but is extensive within the Snake River portion of the project area. Less than 1% of potential habitat was eliminated because of lack of water even though natural and developed springs were not included. Three of the areas eliminated due to distance from water were on public land: Wapshilla Ridge at Craig Mountain, Joseph Creek Wildlife Management Area south of Joseph Creek, and the lower Imnaha drainage (Fig. 2). Spring development projects have been conducted or are planned in the vicinity of these areas (Table 10).

Extent of habitat does not appear to currently limit the number of bighorn sheep. Much suitable habitat is currently unoccupied by bighorn sheep. However, habitat quality, including factors such as forage species composition and nutritional value were not measured in this analysis and may affect herd size, productivity, and distribution. For example,

noxious weeds in general and Yellow Starthistle (*Centaurea soltistalis*) in particular are invading the Hells Canyon grasslands and may affect bighorn sheep habitat quality.

Livestock

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. There are currently 3 active domestic sheep grazing allotment areas on U.S. Forest Service land within the project area. The Mud Duck allotment is located in bighorn sheep habitat in the Wallowa Mountains between the Lostine and Upper Hells Canyon herds and administered by the Wallowa-Whitman National Forest. The Mud Duck outside the Hells Canyon National Recreation Area (HCNRA) was previously combined with the Mud Duck and Temperance-Snake allotments within the HCNRA. These allotments were terminated in October 1996 (USFS 1995). The Mud Duck allotment outside HCNRA provides summer grazing only.

The Curren Hill, Echols Butte, Deep Creek and other contiguous allotments in bighorn sheep habitat are administered primarily by the Payette National Forest in the southeastern part of the project area nearest the upper Hells Canyon, Idaho bighorn herd. Most of these allotments are not covered under the Hells Canyon Initiative Memorandum of Understanding. They are currently active and are expected to remain so in the near future.

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 Bureau of Land Management administers 2 grazing allotments along the Little Salmon River in Idaho and 3 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.

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 and Salmon River drainages. 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. A single feral goat has been reported in Kurry Creek above Pittsburgh landing. There are currently no restrictions or monitoring of pack goat use in the project area.

Existing habitat improvements

Water developments

At least 44 springs have been, or are planned to be, developed for wildlife use throughout the project area on state, federal, and private lands (Table 10).

Mineral licks

Several natural mineral licks occur in the study area. Salt blocks containing selenium and/or medication (anthelmintic) blocks have been placed in Oregon and Washington (Table 10). Hells Canyon is considered selenium poor for livestock, and bighorn sheep have selenium levels that would be considered low for domestic sheep. However, there is currently little baseline data on normal selenium levels for bighorn sheep.

Range improvement

Four irrigation, cultivation, and fertilization projects have been conducted in Idaho, Oregon, and Washington (Table 10). Nearly 70,000 acres in Oregon and Idaho have been treated with prescribed and natural burns since 1992. Extensive cooperative weed control efforts by all public agencies are ongoing and increasing under the Tri-State, Tri-County, and Salmon River Weed Management Projects.

III. PROPOSED ACTIONS

Actions taken under the Hells Canyon Initiative will address factors limiting bighorn sheep populations in Hells Canyon. Emphasis is on achieving self-sustaining bighorn sheep populations that, by definition, do not need continuous intensive management. These herds may also be used for relocations elsewhere in the future. Information gathered in the Hells Canyon project will also be available for application to bighorn sheep restoration in other areas. Actions in this project will be consistent with the Hells Canyon National Recreation Area Comprehensive Plan and with actions identified in the Oregon, Idaho, and Washington bighorn sheep management plans (IDFG 1991, ODFW 1992, WDFW 1995). Actions include:

1. reintroductions
2. population monitoring and research
3. habitat monitoring and management
4. harvest regulations
5. information and evaluation

Reintroductions

Relocation of bighorn sheep will be conducted as necessary (when animals are available) to fill unoccupied habitat and augment existing herds. Reintroductions will significantly expedite progress toward project goals because of the relatively slow growth rate of bighorn sheep populations and the slow rate of dispersal into unoccupied habitat. However, reintroductions are a short-term action that must be accompanied by survival and recruitment of existing herds to establish a self-sustaining population. If successful releases of 50 bighorns are made each year for 10 years, several new herds will be established, existing herds will be augmented, and the total number of bighorns in the project area could nearly triple. If, in addition to releasing bighorns, measures can be developed and implemented to counteract disease or other potentially limiting factors and increase the population growth rate to 10%, numbers could increase 370% in 10 years (Fig. 5). Reintroductions will be conducted as long as suitable vacant habitat or understocked habitat that meets release site criteria (see below) is available. Reintroductions are intended to increase the number and size of the bighorn sheep herds in the project area. There is no evidence that reintroductions will increase the growth rate of established herds.

Bighorn sheep will not be released in areas where there is high risk of contact with domestic sheep or goats, or with bighorn sheep that have survived a recent epidemic and are possibly carrying contagious diseases. In supplemental releases or releases adjacent to herds that have had a die-off, fall lamb:ewe ratios of existing herd should be above 25:100 for at least 2 years. Where possible, a minimum of bighorns will be released per introduction with ratios of at least 3 ewes/ram. There should be at least 20 total bighorns (reintroductions plus resident sheep) in supplemental releases. If any bighorns are released on private land, a cooperative plan will be developed to ensure habitat quality is maintained

or improved and reasonable public access is provided.

Release sites

The states of Oregon, Washington, and Idaho have identified a number of potential release sites within the Hells Canyon project area (Schommer et al. 1991, ODFW 1992, Morgan 1995). These sites were chosen based on visual assessment of habitat and accessibility. In order to assess current suitability, these and other sites (Table 11, Fig. 6) have been rated and bighorns will be released at the highest rated sites, contingent on agreement by the states and land management agencies. When sites are rated evenly, reintroductions will be distributed equitably among states. Release sites were rated using the following criteria:

Risk

1. Proximity to active domestic sheep allotments on public land.
2. Proximity to bighorn sheep potentially carrying a lethal *Pasteurella* bacteria (recent die-off or low lamb-ewe ratios).
3. Proximity to private land.
4. Presence of contiguous habitat between release site and 1, 2, or 3.
5. Presence of movement barriers between release site and 1, 2, or 3.

Habitat suitability

1. Amount of potential lambing habitat within a 10 km radius.
2. Amount of potential winter range within a 30 km radius.
3. Distance to adjacent occupied habitat.

Current site rating is presented in Tables 12 - 17. Sites scoring in the top 10 of the first 2 criteria in both categories (low risk and high habitat suitability) were selected as the overall top release sites (Table 18). Several of the sites with the most extensive habitat rank relatively high for risk of contact with domestic sheep, or risk of contact with bighorn sheep in herds affected by the 1995-96 die-off (Table 18). If these risks can be reduced it will improve ranking of these sites for future reintroductions. Habitat modeling information was unavailable for 2 sites that scored in the top 10 for low risk of contact with domestic sheep or bighorn sheep affected by the 1995-96 die-off. These two sites, Deer Creek, Idaho and Asotin Creek, Washington were include in the top-rated sites based on biologists' visual assessment of habitat quality (Table 18).

Disease testing

Any wildlife relocation carries a risk of disease transfer (Cunningham 1996). All

bighorn sheep released in the project area will be tested for presence of or exposure to pathogenic bacteria, viruses, and parasites at capture. The purpose of disease testing is to prevent accidental introduction of additional infectious diseases into the project area and to establish baseline information on relocated bighorn sheep. Disease testing will follow a standard protocol and will fulfill all necessary state, provincial, and national requirements.

Source populations

Obtaining bighorn sheep for release has historically been a factor limiting reintroductions. For the most part, bighorns have been obtained where available and relatively little attempt has been made to select specific source populations. Coggins and Matthews (1996) evaluated success of previous bighorn sheep releases in Oregon and concluded that releases of "nonmigratory" bighorns, defined as bighorns that do not use elevationally distinct winter and summer ranges, were more successful at establishing a self-sustaining population within 10 air miles of the release site than releases of migratory bighorns. However, other authors (Risenhoover et al. 1988) have noted that translocated bighorns often lack the historic migratory patterns that allowed for full utilization of habitat. Migratory bighorns would presumably be able to better utilize high elevation sites, for instance in the Wallowa Mountains and the Wenaha Wilderness. Nonmigratory bighorns may be better adapted to areas along the Snake River canyon, where winter and summer range habitats are at the same elevation and extensive movements increase the potential for contact with domestic livestock or humans. Where possible, the source population will be matched to the release site, and differences in movements and habitat utilization among different source populations will continue to be evaluated through monitoring.

In the past, Oregon and Washington have established 2 herds (Lostine and Hall Mountain) subsequently used for release into new areas. This is desirable from a logistics standpoint because it avoids the difficulty associated with moving animals across state or national borders, and having to compete with other states for allocation of bighorns. The main drawback to this strategy is that the source population has to be a long distance from the release site, or the sheep will attempt to return to their original area (Coggins and Matthews 1996). In addition, logistical constraints of capturing bighorns must be considered, for example, it may not be possible to use helicopters to capture bighorn sheep in designated wilderness areas within the project area. Surplus bighorn sheep from herds within Hells Canyon will be relocated as is feasible. Past and possible future source herds within the project area are Lostine (migratory), Imnaha (nonmigratory), Black Butte (nonmigratory), Asotin (unknown), Redbird (nonmigratory), and lower Hells Canyon, Idaho and Oregon (nonmigratory). Source herds should have fall lamb:ewe ratios greater than 25:100 and an increasing population trend in order to be used for transplants, and release areas must be isolated from the source population.

Until source populations are available within the project area, bighorn sheep will be relocated from outside Hells Canyon. In the past bighorns from several sources have been released into new herds to increase genetic diversity. This may be a legitimate concern, but data collected in Hells Canyon have not provided any demographic or physical evidence of

inbreeding. The herd (Redbird) established from a single source has similar growth rates to other herds and has produced large rams (scoring greater than 190 Boone and Crockett points) including the 3 largest rams taken in Idaho. It is possible there is adequate genetic diversity and mixing among herds within Hells Canyon. There may actually be detrimental consequences of mixing bighorns with differential vulnerability to disease (Sandoval et al. 1987). Information on the disease history of source herds being considered for transplants will be obtained and compared with that of existing herd before proceeding with a relocation.

Monitoring and research

Monitoring and research are designed to evaluate the success of the project, determine causes for success or failure, and guide future direction through adaptive management. Carefully designed methodology is needed to measure and evaluate the multiple interacting factors including habitat, dispersal, predation, and disease, that affect bighorn sheep population growth and productivity. Differences of a few percentage points in population growth rates could have a substantial effect on project success. An increase in population growth rate from 7% to 10% has a similar impact as releasing 30 bighorns per year. Monitoring and research are critical to testing new ideas, understanding what is working and why, and developing methods that could be applied in other areas. Monitoring will be reevaluated annually and adjusted as necessary based on the data collected.

Survival and movements

Bighorns released in the project area will be radio-collared and regularly relocated. Goals are to quantitatively document post-release movements and to monitor extent and causes of mortality. A monitoring plan will be developed by the HCBSRC for each release. This will include frequent (weekly) relocations of radioed sheep for a month post-release and less frequent, regular relocations for the life of the radio collar. Emphasis will be placed on visual observations of bighorns where feasible, in order to detect mortalities as soon as possible. When dead sheep are located, it will be a priority to examine the carcass to collect information on the probable cause of mortality. In areas of low lamb survival, additional monitoring will be conducted to determine when and how mortality is occurring. This information will be used to determine whether predators or disease could be having an impact on project success and whether additional information and/or management actions are needed.

Blood or tissue samples will also be collected from all bighorns released or handled in the project area. This information will be used in conjuction with movement data to determine the relative contribution of bighorns from different source populations and to assess the potential for genetically-based disease resistance in bighorn sheep.

Population size and trend

Annual project-wide surveys will be conducted in a consistent manner. Additional surveys will be conducted where needed. Some herds will be surveyed more intensively to monitor lamb survival (see above). Project surveys will determine population status in an accurate cost-efficient manner, within budget and time constraints. In order to provide accurate and comparable population estimates within the project area, radio-collared bighorns will be used to test and modify as necessary an existing bighorn sheep sightability model (Bodie et al. 1995) to be used during a consistent sampling period. Models can be developed for different survey techniques (fixed-wing, helicopter, and ground surveys).

Disease treatment, monitoring, and research

Disease has apparently historically reduced population growth rates by at least 40% in the project area (Table 5). Disease monitoring, treatment, and research are important components of successful restoration of bighorn sheep in Hells Canyon and elsewhere. All bighorn sheep handled in the project area will be tested for disease according to a standard protocol. Blood samples will be collected for bacterial, viral, chemistry, trace mineral, and genetic testing. Viral and bacterial pharyngeal swabs, ear swabs, external parasites, and fecal samples will also be collected from all bighorns. All bighorns that die in the canyon will be retrieved where possible and will be necropsied using a standard protocol developed in this project.

An emergency disease response plan will be developed prior to, and implemented during and after, disease outbreaks. Summer lamb production and survival will be monitored annually following die-offs to evaluate recovery of the herd. Results of disease testing, information on radio-collared bighorn sheep movements, survival, and productivity; and fall and spring survey information will also provide a basis for decisions regarding future bighorn transplants in and near the die-off area.

Treatment of bighorn sheep including administering anthelmintics, antibiotics, and vaccines will be conducted in an experimental manner in order to assess effectiveness. Preventive and acute disease treatment protocols will be established and included in an emergency response team plan. Treatments will be evaluated and modified as indicated by the data collected. Research may address various aspects of vulnerability to disease, transmission, and disease ecology and will focus on field application. An annual research priority list will be developed by the Hells Canyon Bighorn Sheep Restoration Committee and internal and external research proposals will be ranked and funded accordingly. Agencies may provide internal research review to ensure that bighorn sheep research is consistent with agency management needs.

Habitat evaluation

Landscape level

Habitat modeling will be completed for the remainder of 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.

Fine scale

Although extent of habitat does not appear to be limiting current bighorn sheep populations, the negative relationship between population growth rate and herd size suggests that habitat quality could be affecting population growth. In the future, habitat changes, such as spread and/or control of noxious weeds could also 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 plots have been established by the USFS, BLM, and IDFG within the project area. These plots will be evaluated for their applicability to this project. New plots may also be established. Plots will be monitored annually to estimate forage availability and changes in species composition in association with weather, grazing, and other factors.

Habitat management

Public land domestic sheep and goat allotments

Domestic sheep and goats grazing on public lands could significantly affect the success of this project if diseases are transferred to bighorn sheep. Land management agencies will be encouraged to manage grazing within the project area in a manner compatible with project goals. Use of pack goats should be restricted in areas where there is a likelihood of contact with bighorn sheep. State agencies will capture bighorn sheep that have come into contact with domestic sheep or goats and remove them from the wild.

Private 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.

Future habitat improvements

Habitat protection and improvement actions are listed in order of priority. Habitat acquisition and easements are high priority and will emphasize protection of critical habitat. Habitat improvements 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

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.

Range improvement

Noxious weed management will be coordinated with ongoing interagency actions by the states of Oregon, Idaho, and Washington, the USFS, BLM, and Natural Resources Conservation Service. Assistance may be provided in future noxious weed control efforts where weeds threaten bighorn sheep habitat.

Prescribed (and natural) fire may be beneficial for bighorn sheep in certain areas. Areas where prescribed fire could be used to improve bighorn sheep habitat will be evaluated on a site-specific basis and treated as appropriate in conjunction with land management agencies.

Fertilization and/or cultivation of range plots may be conducted as appropriate to alter distribution or movements of bighorn sheep.

Salting and mineral licks

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.

Water developments

Existing water developments will be maintained and monitored for evidence of bighorn sheep use. Additional sites may be developed based on site-specific information.

Harvest

Bighorn sheep harvest will continue to be managed and regulated by individual states. States will cooperate in developing herd goals and setting seasons where herds overlap state boundaries or where harvest in one herd could affect adjacent herds.

Information and evaluation

Plan evaluation

This restoration plan will be revised at 5-year intervals, or as needed, to reflect the most current information and management direction in the project area.

Publications and reports

All project partners will contribute data and reports to the project coordinator to be summarized in an annual report due 31 July. The annual report will include accounting and evaluation of all activities conducted during the previous year and proposals and project goals for the coming year. This will include reports on the status of all releases and herds, including estimated population size and growth rate, lamb:ewe ratio, and herd area. A summary and analysis of any disease information collected, including that collected at capture of bighorns to be released in the project area, will also be included. Reports on any control actions, habitat management activities, research, and harvest information will be included. Peer-reviewed publication of data is encouraged and all partners in projects will be acknowledged as appropriate.

The project coordinator will also provide monthly project updates to all project partners.

Peer review

External biologists will be invited to an annual meeting and/or as needed by the Hells Canyon Bighorn Sheep Restoration Committee to evaluate project progress. External biologists may be asked to review written reports and meet with the committee to provide recommendations for future direction.

Public information

Public outreach is an important component of the project and may include developing a newsletter, an adopt-a-sheep program, putting together slide shows or videos and giving presentations, working with volunteers, giving tours, establishing interpretive sites and developing a logo for t-shirts, hats, and a letterhead. States will coordinate press releases to inform the public about activities and project progress. Interested individuals and organizations outside the Hells Canyon Bighorn Sheep Restoration Committee will receive an annual summary of project activities.

Budget

Funding requests

Internal and external project proposals will be submitted to the Hells Canyon Bighorn Sheep Restoration Committee by July 31 for discussion at an annual August meeting. Project proponents will be invited to present their proposals at this meeting. Proposals will be rated using a consistent set of criteria established by the committee. Recommendations will go to FNAWS to be discussed at their fall quarterly board meeting and funding allocation will be announced by November 1.

Budget variances

It is recognized, that as this project develops, annual budget needs may vary significantly. Currently, the 5-year budget projection is a conservative estimate of funding levels necessary to initiate the project. With sufficient additional funding, the project could be expanded dramatically, particularly in the areas of research, habitat improvement, and securing critical habitat. Annual budgets will be adjusted as needed based on project needs and funding availability.

Projected costs for the Hells Canyon Initiative

	Annual Cost 1997 - 2002 (5-year projection)
Reintroduction (50 bighorns/year)	
Salaries	$5,000.00
Travel	$5,000.00
Trapping supplies	$2,000.00
Radiocollars	$12,000.00
Helicopter (as needed depending on capture and release locations)	$0 - 25,000
Subtotal of annual costs for reintroductions	**$24,000 - 49,000**
Research *(costs are estimates and would be project dependent)*	
Disease Research	$35,000.00
Genetics Research	$20,000.00
Population ecology	$20,000.00
Subtotal of annual costs for research	**$75,000.00**
Habitat improvements *(costs are estimates and would be project dependent, does not include habitat acquisition)*	
Weed control	$30,000.00
Water developments	$3,000.00
Other (Prescribed fire, food plots)	$1,000.00
Subtotal of annual costs for habitat improvements	**$36,000.00**
Monitoring and Management	
Equipment - Computer, Receivers, Camera, Scope, etc.	$5,000.00
Salaries	$66,000.00
Operations - Aircraft time, travel, per diem	$35,000.00
Subtotal of annual costs for monitoring and management	**$106,000.00**
Annual Project Cost 1997 - 2002	**$241,000 - 266,000**

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Table 1. Hells Canyon project area bighorn sheep herd sizes, 1995-96.

Herd name	Total	Lambs:100 ewes	Rams:100 ewes
Black Butte, WA	55	6	11
Asotin, WA	9	-	-
Wenaha, OR/WA	120	40	29
Lost Prairie/Mt. View, OR/WA	43	25	42
Lower Hells Canyon, OR	25	11	25
Upper Joseph Creek, OR	20	30	40
Lower Imnaha, OR	130	63	90
Upper Hells Canyon, OR	25	60	160
Lostine, OR	80	43	49
Bear Creek, OR	35	75	150
Sheep Mountain, OR	65	44	72
Redbird, ID	60	48	57
Lower Hells Canyon, ID	25	8	50
Upper Hells Canyon, ID	5	0	0
AVERAGE	50	35	60
TOTAL	697		

Table 2. Bighorn sheep transplants in Hells Canyon and the Wallowa Mountains through 1996.

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
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

[a] Original source location in parentheses where source herd was established from a transplant (see Table 3)

Table 2, cont'd. Bighorn sheep transplants in Hells Canyon and the Wallowa Mountains through 1996.

Date	State	Release Location	Total	Ewes	Rams	Female Lambs	Male Lambs	Source[a]
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, 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.)
Total	35 transplants	Oregon - 22, Idaho -5 Washington -8	451	229	96	55	59	
				52%	22%	13%	13%	

[a] Original source location in parentheses where source herd was established from a transplant (see Table 3)

Table 3. Source populations for Hells Canyon project area bighorn sheep herds.

Herd	Source population	No. released	Date
Black Butte	Waterton Lakes (via Hall Mountain)	9	1977
	Jasper National Park (via Lostine)	10	1981
	Thompson Falls, Montana	10	1982
	Waterton Lakes/Thompson Falls (via Hall Mountain)	1	1987
	Sun River, Montana	10	1989
Redbird	Whiskey Basin, Wyoming	17	1984
Upper Hells Canyon, OR	Jasper National Park	20	1971
	Jasper National Park (via Lostine)	5	1977
	Jasper National Park (via Lostine)	9	1979
	Jasper National Park (via Lostine)	20	1979-80
Upper Hells Canyon, ID	Salmon River, Idaho	10	1975
	Salmon River, Idaho	11	1976
	Salmon River, Idaho	7	1979
	Whiskey Basin, Wyoming	30	1990
Lower Imnaha, OR	Salmon River, Idaho	15	1979
	Jasper National Park (via Lostine)	10	1982
	Salmon River, Idaho	11	1984
Lower Hells Canyon, OR	Wildhorse Island, Montana	23	1993-94
	Cardinal River, Alberta	22	1995
Wenaha, OR/WA	Waterton Lakes/Thompson Falls (via Hall Mountain)	15	1983
	Jasper National Park (via Lostine)	15	1983
	Cove Creek, Salmon River	28	1984

Table 3, cont'd. Source populations for Hells Canyon project area bighorn sheep herds.

Herd	Source population	No. released	Date
Wenaha	Waterton Lakes/Thompson Falls (via Hall Mountain)	14	1986
Sheep Mountain	Tarryall, Colorado	30	1990
	Cardinal River, Alberta	10	1995
	Jasper National Park /Salmon River, Idaho (via Lostine)	2	1995
Bear Creek	Jasper National Park (via Lostine)	17	1976
	Jasper National Park (via Lostine)	8	1977
	Waterton Lakes/Thompson Falls (via Hall Mountain)	11	1984
	Salmon River, Idaho	12	1985
Lostine	Jasper National Park, Alberta	20	1971
	Salmon River, Idaho (originally released at Minam)	12	1985
Asotin Creek	Waterton Lakes/Thompson Falls (via Hall Mountain)	6	1991
	Waterton Lakes/Thompson Falls (via Hall Mountain)	9	1994

Table 4. Permits and harvest of bighorn sheep in Hells Canyon through 1996.

State	Herd	Total No. Permits	Total No. Harvested[a]	No. Permits 1996	1996 Season
Washington	Black Butte	17	19	0	9/15 - 10/11
	Mountain View	8	6	1	9/15 - 10/11
	Wenaha	16	14	1	9/15 - 10/11
Idaho	Redbird	6	9	1	8/30 - 10/13
	Upper Hells Canyon	20	11	0	-
Oregon	Imnaha	48	45	6	9/6 - 9/17 10/16 - 10/27
	Lostine	63	55	1	9/6 - 9/17
	Joseph Creek	9	7	0	-
	Bear Creek	4	3	1	9/6 - 9/17
	Lower Hells Canyon	3	3	0	-
	Wenaha	12	12	2	10/12 - 10/31
	Sheep Mountain	1	1	1	9/6 - 9/17
Total		207	185	14	

[a] Number of bighorns harvested includes auction and lottery tags.

Table 5. Demography of Hells Canyon bighorn sheep herds 1971 - 1996.

Herd	Year first established	Total bighorns released	Years survey data	Lambs:100 ewes *x (sd)*	Rams:100 ewes *x (sd)*	Average annual population growth rate [a]	Average annual population growth rate exclusive of die-offs
Upper Hells Canyon, Ore.	1971	54	18	38 (30.8)	47 (50.9)	1.04	
Lostine [b]	1971	20	18	41 (19.9)	51 (15.9)	1.05	1.15
Upper Hells Canyon, Idaho	1975	58		14 (23.3)	50 (37.1)	0.93	1.22
Black Butte	1977	39	21	49 (14.1)	54 (18.7)	1.09	1.18
Imnaha	1979	36	17	58 (14.2)	70 (22.3)	1.09	1.09
Wenaha	1983	57	11	43 (12.4)	46 (8.7)	1.07	1.10
Redbird/Lower Hells Canyon, Idaho	1984	17	5	29 (9.0)	57 (13.8)	1.13	1.13
Bear Creek [c]	1985	36	10	54 (17.2)	70 (45.3)	1.10	1.12
Lower Hells Canyon, Ore.	1985	22	11	46 (29.4)	35 (34.6)	1.06	1.10
Lost Prairie/Mountain View		0	3	39 (20.1)	32 (15.0)	0.91	0.91
Joseph Creek	1987	16	9	76 (19.6)	76 (89.3)	1.13	1.15
Sheep Mountain	1990	42	7	30 (15.5)	69 (4.2)	1.22	1.22
Asotin	1991	15	5	-	-	-	-
Average		28	9.9	41 (15.8)	52 (14.2)	1.07 (0.08)	1.12 (0.08)

[a] Average annual herd growth rates (lambda) were calculated as $\Sigma\ (N_{(t)}/N_{(t-1)})/(t-1)$. Relocated sheep were excluded from the population total (N) in the year of the release but were included in subsequent years. No corrections were made for 0 - 6 rams harvested per herd/per year (~200 rams total) since 1975 (Table 3).

[b] From 1976 to 1986, 152 bighorns were transplanted out of the Lostine herd.

[c] Bighorns were first released in Bear Creek in 1976, but the herd was not established until after a 1985 release.

Table 6. Comparison of Hells Canyon bighorn sheep herd annual growth rates after initial release and in subsequent years.

Herd	Initial growth rate[a] *x (sd)*	Subsequent growth rate *x (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 7. Comparison of 5 Rocky Mountain bighorn sheep habitat models.

HABITAT COMPONENT	Gudorf and Sweanor 1996	Shirokauer 1996	Smith et al. 1991	Dunn 1993	Johnson and Ringo 1995
ESCAPE TERRAIN					
Slope	27° < slope < 85°	27° ≤ slope ≤ 60°	slope ≥ 60%	slope ≥ 60%	slope > 60%
Buffer	300m or land areas ≤ 1000m wide bounded on ≥ 2 sides by escape terrain (500m)	300m	300m or land areas ≤ 1000m wide bounded on ≥ 2 sides by escape terrain (500m)	5 km	0.5 mi (800m)
Minimum area	1.6 ha	1.6 ha	na[1]	5 km^2	min 8 mi^2 escape and forage
HORIZONTAL VISIBILITY	≥ 62% (55%) visibility	high visibility = barren (< 15% vegetative cover), rocky reef (> 50% rock), grassland (including shrub patches, < 15% forest cover), conifer 15-39% canopy cover. low visibility = conifer w/ > 40% canopy cover, aspen	≥ 80% visibility low visibility = shrub communities with mean height > 0.5m, riparian areas with dense understory, heavily forested areas, open forest with understory > 0.5m	≤ 25% canopy cover	> 35% forage cover
WATER SOURCES	≤ 3.2 km from water	lambing only	≤ 3.2 km from water	≤ 3.2 km from water	≤ 1.6 km from water
HUMAN USE AREAS	150m buffer on a case by case basis	na	100m buffer around trails, roads, dwellings, campgrounds, 150m buffer around airports, mines, tramways, campgrounds, ski resorts	200m buffer around primitive roads/trails, 500m buffer around improved roads, recreation sites, housing developments	na

Table 7, cont'd. Comparison of 5 Rocky Mountain bighorn sheep habitat models.

HABITAT COMPONENT	Gudorf and Sweanor 1996	Shirokauer 1996	Smith et al. 1991	Dunn 1993	Johnson and Ringo 1995
DOMESTIC LIVESTOCK	≥16 km from domestic or exotic sheep	na	no possibility of contact with domestic sheep	≥15 km from domestic sheep	na
SUMMER RANGE	suitable habitat slopes <27°	suitable habitat within 300m of escape terrain	areas w/in 300 m of but not including escape terrain, HV > 80%, min. 8.4-9.7 km^2	low elevation suitable habitat ≤ 200m from escape terrain	na
WINTER RANGE	suitable habitat, aspect 136° - 224°, snowpack ≤ 25 cm	suitable habitat, aspect 135°-270°, elevation < 6,000'. Winter ranges w/in 120m combined (see comments).	Suitable habitat, ≤25cm snowpack, 135°-225°, min of 6.5 km^2	high elevation suitable habitat, snowfree	not delineated, all habitat defined as <4,000', min of 8 mi^2 forage + escape or 4 mi^2 within 0.5 mi of 8 mi^2 block
LAMBING RANGE	escape terrain, aspect 46°-314°, ≤1 km from water, ≥2 contiguous ha	escape terrain, ≤1 km from water, ≥2 contiguous ha	escape terrain 90° - 270°, ≤1 km from water, ≥2 contiguous ha, min total ≥ 360 ha	na	na
MOVEMENT ZONES	patches connected by areas w/HV=30 - 50% < 4.5km apart or HV <30% < 100m apart	na	na	na	na
BARRIERS	case by case basis, horizontal visibility (HV) < 30% > 100m wide	canals, reservoirs, areas of low visibility > 120m wide	wide rivers, lakes, reservoirs, dense vegetation > 100m wide, sheer cliffs, valleys, fencing, major highways, centers of human activity.	na	na

Table 7, cont'd. Comparison of 5 Rocky Mountain bighorn sheep habitat models.

HABITAT COMPONENT	Gudorf and Sweanor 1996	Shirokauer 1996	Smith et al. 1991	Dunn 1993	Johnson and Ringo 1995
COMMENTS	min. of 9km^2 of suitable habitat	winter ranges w/in 120m combines, then winter ranges <1.5km^2 eliminated. Used FRAGSTATS to report mean patch size, nearest neighbor index, contagion.	minimum of 32 km^2 habitat or 17 km^2 core habitat. Probability model (PATREC) is more detailed.	herds ≤ 15 km apart form metapopulation. Escape terrain patches ≤ 200m apart combined. Contiguity index calculated by comparing size and distance of each escape terrain patch 2 km from patch center.	

Table 8. Hells Canyon bighorn sheep habitat model

HABITAT COMPONENT	Criteria	Source
ESCAPE TERRAIN		
Slope	31° ≤ slope ≤ 85°	Gudorf and Sweanor 1996, Smith et al.
Buffer	300m or land areas ≤1000m wide bounded on ≥2 sides by escape terrain (500m)	Smith et al. 1991, Gudorf and Sweanor 1996
Minimum area	1.6 ha	Gudorf and Sweanor 1996
HORIZONTAL VISIBILITY	grassland, rock, open shrub or forest cover <40%, from satellite imagery	Schirokauer 1996
WATER SOURCES	≤ 3.2 km	Smith et al. 1991, Gudorf and Sweanor 1996
SUMMER RANGE	suitable habitat within 300m of escape terrain	Smith et al. 1991, Gudorf and Sweanor 1996, Schirokauer 1996
WINTER RANGE	suitable habitat all aspects below 4,800', aspect 135° - 225° above 4,800'	Smith et al. 1991, Gudorf and Sweanor 1996, Coggins pers. comm.
LAMBING RANGE	escape terrain 45° - 315° ≤ 1 km from water ≥ 2 contiguous ha	Gudorf and Sweanor 1996

Table 9. Extent and ownership of potential bighorn sheep habitat in the Hells Canyon project area.

Bighorn habitat type	Area ha (ac)	Ownership % (ha)				
		USFS	BLM	State	Private	Other[1]
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)

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

Table 10. Habitat improvements, Hells Canyon project area through 1997.

	Location	No. of sites or area
Water developments	Chalk - Mountain Sheep Creek	2
	Lower Imnaha	9
	Jim Creek/Downey Gulch	10
	Cherry Creek	6
	Lostine	1
	Wenaha	3
	Joseph Creek	4 (planned)
	Redbird-Captain John Creek	8
	Cottonwood Creek	1
Total water developments		44
Mineral/salt licks	Hass Ridge	2 salt
	Imnaha Gorge	3 salt/ivermectin
	Chalk Creek - Knight Creek	2 salt/ivermectin
	Chalk Creek	1 natural lick
	Downey Creek	2 salt/ivermectin
	Wenaha	2 salt/ivermectin
	Table Mountain	2 salt/ivermectin
	Hells Canyon Creek	1 salt
	Stud Creek	1 natural lick
	Lostine	1 salt/ivermectin
	Bear - Hurricane Creek	2 salt
Total mineral/salt licks		19
Planting/irrigation	Eden Bench alfalfa field	30 acres
	Wenaha Sheep Trap alfalfa field	30 acres

Table 10, cont'd. Habitat improvements, Hells Canyon project area through 1997.

	Location	No. of sites or area
	Wenaha Sargent alfalfa field	15 acres
	Captain Lewis irrigation/pasture	20 acres (planned)
Total planting area		95
Prescribed burns	Lostine - 1992	200 acres
	Cactus Mountain - 1992	300 acres
	Haas Ridge - 1993	100 acres
	Dough Creek - 1995	30 acres
Total prescribed fire area		630 acres
Wildfires	Heavens Gate - 1996	425 acres
	Dam - 1996	4,800 acres
	Sheep Creek - 1996	11,000 acres
	Salt Creek - 1996	52,600 acres
	Captain John - 1996	400 acres
Total wildfire area		69,225 acres

Table 11. Potential bighorn sheep release sites in the Hells Canyon project area.

Location	State	Status
Bear Ridge	Oregon	Reintroduction
Cache Creek	Oregon	Reintroduction
Deep Creek	Oregon	Reintroduction
Tryon Creek	Oregon	Reintroduction
Pumpkin Creek	Oregon	Reintroduction
Sheep Divide	Oregon	Reintroduction
Devils Gulch	Oregon	Reintroduction
Cornucopia	Oregon	Reintroduction
Sand Creek	Oregon	Reintroduction
Spring Creek	Oregon	Reintroduction
Mud Creek	Oregon	Reintroduction
Grande Ronde	Oregon	Reintroduction
Table Mountain	Oregon	Supplement
Deadhorse Ridge	Oregon	Supplement
Minam	Oregon	Supplement
Battle Creek	Oregon	Supplement
Hells Canyon Dam	Oregon	Supplement
Deer Creek	Idaho	Reintroduction
Wolf Creek	Idaho	Reintroduction
Big Canyon Creek	Idaho	Reintroduction
Sheep Creek	Idaho	Reintroduction
Granite Creek	Idaho	Supplement
Bernard Creek	Idaho	Supplement
Frenchy Creek	Idaho	Supplement

Table 11, cont'd. Potential bighorn sheep release sites in the Hells Canyon project area.

Location	State	Status
Captain John Creek	Idaho	Supplement
Birch Creek	Idaho	Supplement
Asotin Creek	Washington	Supplement
Wenaha	Washington	Supplement
Joseph Creek	Washington	Supplement

[1] Reintroduction indicates site is currently unoccupied. Supplement indicates bighorn sheep are present.

Table 12. Release site ranking: distance and barriers to domestic sheep allotments.

Location	State	Distance to closest domestic sheep allotment (km)	20 points for each barrier to domestic sheep[a]	Score
Captain John Creek	Idaho	101.2	20	121.2
Cache Creek	Oregon	84.3	20	104.3
Deer Creek	Idaho	83.3	20	103.3
Bear Ridge	Oregon	78.5	20	98.5
Birch Creek	Idaho	75.2	20	95.2
Deadhorse Ridge	Oregon	71.8	20	91.8
Cave Gulch	Idaho	83.4	0	83.4
Frenchy Creek	Idaho	71.1	0	71.1
Deep Creek	Oregon	57.5	20	77.5
Tryon Creek	Oregon	46.1	20	66.1
Minam	Oregon	45.1	20	65.1
Devils Gulch	Oregon	24.6	40	64.6
Sheep Divide	Oregon	23.7	40	63.7
Pumpkin Creek	Oregon	38.6	20	58.6
Table Mountain	Oregon	16.5	40	56.5
Wolf Creek	Idaho	56.1	0	56.1
Asotin Creek	Washington	55.2	0	55.2
Wenaha	Washington	29.9	20	49.9
Joseph Creek	Washington	46.2	0	46.2
Big Canyon Creek	Idaho	45.6	0	45.6
Grande Ronde	Oregon	23.5	20	43.5

[a] Barriers are major rivers (Snake, Salmon,and Imnaha) and extensive areas of unsuitable habitat.

Table 12, cont'd. Release site ranking: distance and barriers to domestic sheep allotments.

Location	State	Distance to closest domestic sheep allotment (km)	20 points for each barrier to domestic sheep[a]	Score
Sheep Mountain	Oregon	23.3	20	43.3
Sand Creek	Oregon	22.5	20	42.5
Kirkwood Creek	Idaho	32.5	0	32.5
Battle Creek	Oregon	8.0	20	28
Sheep Creek	Idaho	22.6	0	22.6
Hells Canyon Dam	Oregon	0.6	20	20.6
Spring Creek	Oregon	0.6	20	20.6
Bernard Creek	Idaho	16.7	0	16.7
Mud Creek	Oregon	13.0	0	13
Granite Creek	Idaho	12.0	0	12
Granite Cliffs	Oregon	7.7	0	7.7
Cornucopia	Oregon	2.4	0	2.4

[a] Barriers are major rivers (Snake, Salmon, and Imnaha) and extensive areas of unsuitable habitat.

Table 13. Release site ranking: distance and barriers to private land.

Location	State	Distance to private land (km)	20 points for each barrier[a] to private land	Score
Bernard Creek	Idaho	35.4	0	35.4
Sand Creek	Oregon	11.9	20	31.9
Granite Creek	Idaho	31.5	0	31.5
Battle Creek	Oregon	7.8	20	27.8
Sheep Creek	Idaho	27.3	0	27.3
Hells Canyon Dam	Oregon	18.6	0	18.6
Kirkwood Creek	Idaho	17.4	0	17.4
Tryon Creek	Oregon	14.4	0	14.4
Granite Cliffs	Oregon	12.6	0	12.6
Birch Creek	Idaho	5.4	0	5.4
Spring Creek	Oregon	4.6	0	4.6
Big Canyon Creek	Idaho	4.1	0	4.1
Deep Creek	Oregon	2.0	0	2.0
Pumpkin Creek	Oregon	1.9	0	1.9
Cache Creek	Oregon	1.4	0	1.4
Frenchy Creek	Idaho	1.4	0	1.4
Wenaha	Washington	1.0	0	1.0
Sheep Divide	Oregon	1.0	0	1.0
Minam	Oregon	0.8	0	0.8
Deadhorse Ridge	Oregon	0.7	0	0.7
Bear Ridge	Oregon	0.6	0	0.6

[a] Barriers are major rivers (Snake, Salmon, and Imnaha) and extensive areas of unsuitable habitat.

Table 13, cont'd. Release site ranking: distance and barriers to private land.

Location	State	Distance to private land (km)	20 points for each barrier[a] to private land	Score
Asotin Creek	Washington	0.6	0	0.6
Mud Creek	Oregon	0.3	0	0.3
Grande Ronde	Oregon	0.3	0	0.3
Captain John Creek	Idaho	0.2	0	0.2
Deer Creek	Idaho	0.1	0	0.1
Devils Gulch	Oregon	0.1	0	0.1
Cave Gulch	Idaho	0.0	0	0.0
Sheep Mountain	Oregon	0.0	0	0.0
Cornucopia	Oregon	0.0	0	0.0
Table Mountain	Oregon	0.0	0	0.0
Wolf Creek	Idaho	0	0	0.0
Joseph Creek	Washington	0	0	0.0

[a] Barriers are major rivers (Snake, Salmon, and Imnaha) and extensive areas of unsuitable habitat.

Table 14. Release site ranking: distance and barriers to 1995-96 die-off.

Location	State	Distance to 1995-96 die-off (km)	20 points for barriers[a] to die-off	Score
Sheep Mountain	Oregon	98.4	20	118.4
Granite Cliffs	Oregon	87.6	20	107.6
Spring Creek	Oregon	69	20	89
Cornucopia	Oregon	87.6	0	87.6
Hells Canyon Dam	Oregon	55.5	20	75.5
Battle Creek	Oregon	47.6	20	67.6
Granite Creek	Idaho	44.2	20	64.2
Minam	Oregon	39.3	20	59.3
Bernard Creek	Idaho	39.1	20	59.1
Sheep Creek	Idaho	34.2	20	54.2
Sand Creek	Oregon	34.1	20	54.1
Kirkwood Creek	Idaho	28.4	20	48.4
Big Canyon Creek	Idaho	20.5	20	40.5
Devils Gulch	Oregon	34.4	0	34.4
Wolf Creek	Idaho	13.5	20	33.5
Sheep Divide	Oregon	33.0	0	33
Tryon Creek	Oregon	18.6	0	18.6
Asotin Creek	Washington	16.9	0	16.9
Deer Creek	Idaho	15.3	0	15.3
Pumpkin Creek	Oregon	13.8	0	13.8
Table Mountain	Oregon	13.5	0	13.5

[a] Barriers are major rivers (Snake, Salmon, and Imnaha) and extensive areas of unsuitable habitat.

Table 14, cont'd. Release site ranking: distance and barriers to 1995-96 die-off.

Location	State	Distance to 1995-96 die-off (km)	20 points for barriers[a] to die-off	Score
Deep Creek	Oregon	7.4	0	7.4
Birch Creek	Idaho	6.6	0	6.6
Bear Ridge	Oregon	6.1	0	6.1
Mud Creek	Oregon	3.9	0	3.9
Cave Gulch	Idaho	2.7	0	2.7
Cache Creek	Oregon	1.6	0	1.6
Grande Ronde	Oregon	0	0	0
Deadhorse Ridge	Oregon	0	0	0
Frenchy Creek	Idaho	0	0	0
Captain John Creek	Idaho	0	0	0
Wenaha	Washington	0	0	0
Joseph Creek	Washington	0	0	0

[a] Barriers are major rivers (Snake, Salmon, and Imnaha) and extensive areas of unsuitable habitat.

Table 15. Release site ranking: extent of lambing habitat.

Location	State	Potential lambing habitat (m^2) within 10 km radius	Percent[a]
Bernard Creek	Idaho	137,488,583	43.99%
Granite Creek	Idaho	81,809,249	26.17%
Battle Creek	Oregon	79,435,576	25.41%
Sheep Creek	Idaho	76,116,971	24.35%
Hells Canyon Dam	Oregon	64,626,641	20.68%
Kirkwood Creek	Idaho	54,259,032	17.36%
Sand Creek	Oregon	52,192,426	16.70%
Frenchy Creek	Idaho	52,000,724	16.64%
Granite Cliffs	Oregon	51,649,741	16.52%
Deadhorse Ridge	Oregon	49,925,869	15.97%
Pumpkin Creek	Oregon	45,977,423	14.71%
Bear Ridge	Oregon	45,863,198	14.67%
Cache Creek	Oregon	39,747,084	12.72%
Cave Gulch	Idaho	39,545,390	12.65%
Sheep Divide	Oregon	39,500,770	12.64%
Birch Creek	Idaho	38,003,652	12.16%
Big Canyon Creek	Idaho	36,602,245	11.71%
Joseph Creek	Washington	34,711,695	11.11%
Tryon Creek	Oregon	34,359,585	10.99%
Spring Creek	Oregon	32,654,204	10.45%
Deep Creek	Oregon	32,371,101	10.36%
Wolf Creek	Idaho	29,904,458	9.57%

[a] Calculated as the percent of the area within 10 km of release site with habitat information available that was classified as lambing habitat.

Table 15, cont'd. Release site ranking: extent of lambing habitat.

Location	State	Potential lambing habitat (m^2) within 10 km radius	Percent[a]
Devils Gulch	Oregon	26,266,435	8.40%
Table Mountain	Oregon	23,199,723	7.42%
Sheep Mountain	Oregon	22,000,761	7.04%
Minam	Oregon	-[b]	5.56%
Captain John Creek	Idaho	16,155,907	5.17%
Cornucopia	Oregon	15,743,986	5.04%
Mud Creek	Oregon	-[b]	4.83%
Grande Ronde	Oregon	-	2.30%
Wenaha	Washington	-	1.71%
Asotin Creek	Washington	-	0.28%
Deer Creek	Idaho	-	-

[a] Calculated as the percent of the area within 10 km of release site with habitat information available that was classified as lambing habitat.

[b] Habitat information not available for entire 10 km radius around release site.

Table 16. Release site ranking: extent of wintering habitat.

Location	State	Potential wintering habitat (m^2) within 30 km radius	Percent[a]
Deadhorse Ridge	Oregon	1,413,485,327	50.25%
Deep Creek	Oregon	1,383,472,979	49.18%
Frenchy Creek	Idaho	1,376,137,068	48.92%
Wolf Creek	Idaho	-[a]	48.55%
Tryon Creek	Oregon	-	46.79%
Kirkwood Creek	Idaho	-	46.64%
Big Canyon Creek	Idaho	-	46.59%
Birch Creek	Idaho	1,307,109,169	46.47%
Bear Ridge	Oregon	1,256,813,658	44.68%
Cache Creek	Oregon	1,248,402,120	44.38%
Cave Gulch	Idaho	1,245,976,545	44.29%
Pumpkin Creek	Oregon	1,218,899,281	43.33%
Joseph Creek	Washington	1,176,851,035	41.84%
Sand Creek	Oregon	-	41.78%
Sheep Creek	Idaho	-	41.52%
Bernard Creek	Idaho	137,488,583	36.55%
Captain John Creek	Idaho	993,926,175	35.33%
Granite Creek	Idaho	921,494,562	32.76%
Sheep Divide	Oregon	899,358,854	31.97%
Grande Ronde	Oregon	-	30.47%
Battle Creek	Oregon	842,380,804	29.95%
Table Mountain	Oregon	-	29.89%

[a] Habitat information not available for entire 30 km radius.

[b] Calculated as the percent of the area within 30 km of release site with habitat information available that was classified as wintering habitat.

Table 16, cont'd. Release site ranking: extent of wintering habitat.

Location	State	Potential wintering habitat (m^2) within 30 km radius	Percent[a]
Mud Creek	Oregon	-	26.39%
Wenaha	Washington	-	25.76%
Devils Gulch	Oregon	712,931,270	25.34%
Hells Canyon Dam	Oregon	664,947,444	23.64%
Spring Creek	Oregon	577,378,145	20.53%
Asotin Creek	Washington	-	20.42%
Sheep Mountain	Oregon	-	19.64%
Cornucopia	Oregon	-	12.10%
Granite Cliffs	Oregon	231,147,885	8.22%
Minam	Oregon	-	7.52%
Deer Creek	Idaho	-	-

[a] Habitat information not available for entire 30 km radius.

[b] Calculated as the percent of the area within 30 km of release site with habitat information available that was classified as wintering habitat.

Table 17. Release site ranking: distance to occupied habitat.

Location	State	Distance to nearest herd (km)
Devils Gulch	Oregon	21.3
Kirkwood Creek	Idaho	16.2
Spring Creek	Oregon	13.7
Cornucopia	Oregon	13.2
Minam	Oregon	12.5
Deer Creek	Idaho	12.5
Sheep Divide	Oregon	12.5
Granite Cliffs	Oregon	9.6
Big Canyon Creek	Idaho	7.6
Bear Ridge	Oregon	6.1
Tryon Creek	Oregon	5.8
Sheep Creek	Idaho	5.8
Wolf Creek	Idaho	5.3
Sand Creek	Oregon	4.9
Mud Creek	Oregon	3.9
Pumpkin Creek	Oregon	3
Cave Gulch	Idaho	2.3
Cache Creek	Oregon	1.6
Birch Creek	Idaho	1
Deadhorse Ridge	Oregon	0
Deep Creek	Oregon	0
Frenchy Creek	Idaho	0
Joseph Creek	Washington	0
Bernard Creek	Idaho	0

Table 17, cont'd. Release site ranking: distance to occupied habitat.

Location	State	Distance to nearest herd (km)
Captain John Creek	Idaho	0
Granite Creek	Idaho	0
Grande Ronde	Oregon	0
Battle Creek	Oregon	0
Table Mountain	Oregon	0
Wenaha	Washington	0
Hells Canyon Dam	Oregon	0
Asotin Creek	Washington	0
Sheep Mountain	Oregon	0

Table 18. Overall ranking of highest ranked release sites [a], 1997.

Sites near the most lambing and winter range	Sites with least risk	**Overall site ranking**	Comments
Deadhorse Ridge, OR	Minam, OR	**Tryon, OR**	
Frenchy Creek, ID	Deer Creek, ID	**Birch Creek, ID**	Supplement
Kirkwood Creek, ID	Devil's Gulch, OR	**Deep Creek, OR**	
Bernard Creek, ID	Tryon, OR	**Pumpkin Creek, OR**	Near private land (1.9 km)
Sheep Creek, ID	Birch Creek, ID	**Big Canyon Creek, ID**	Near private land (4.1 km)
Granite Creek, ID	Sheep Divide, OR	**Deer Creek, ID**	Habitat information not available, on private land
Sand Creek, OR	Deep Creek, OR	**Asotin Creek, WA**	Habitat information incomplete, near private land (0.6 km), supplement
Pumpkin Creek, OR	Big Canyon Creek, ID		
Cache Creek, OR	Pumpkin Creek, OR		
Deep Creek, OR	Asotin Creek, WA		
Tryon Creek, OR			
Big Canyon Creek, ID			
Birch Creek, ID			

[a] Release sites scoring in the top 10 (including ties) for habitat quantity, where available, and bottom 10 for risk.

Figure 1. Hells Canyon initiative project area and bighorn sheep herds.

Bighorn Sheep Herd Areas

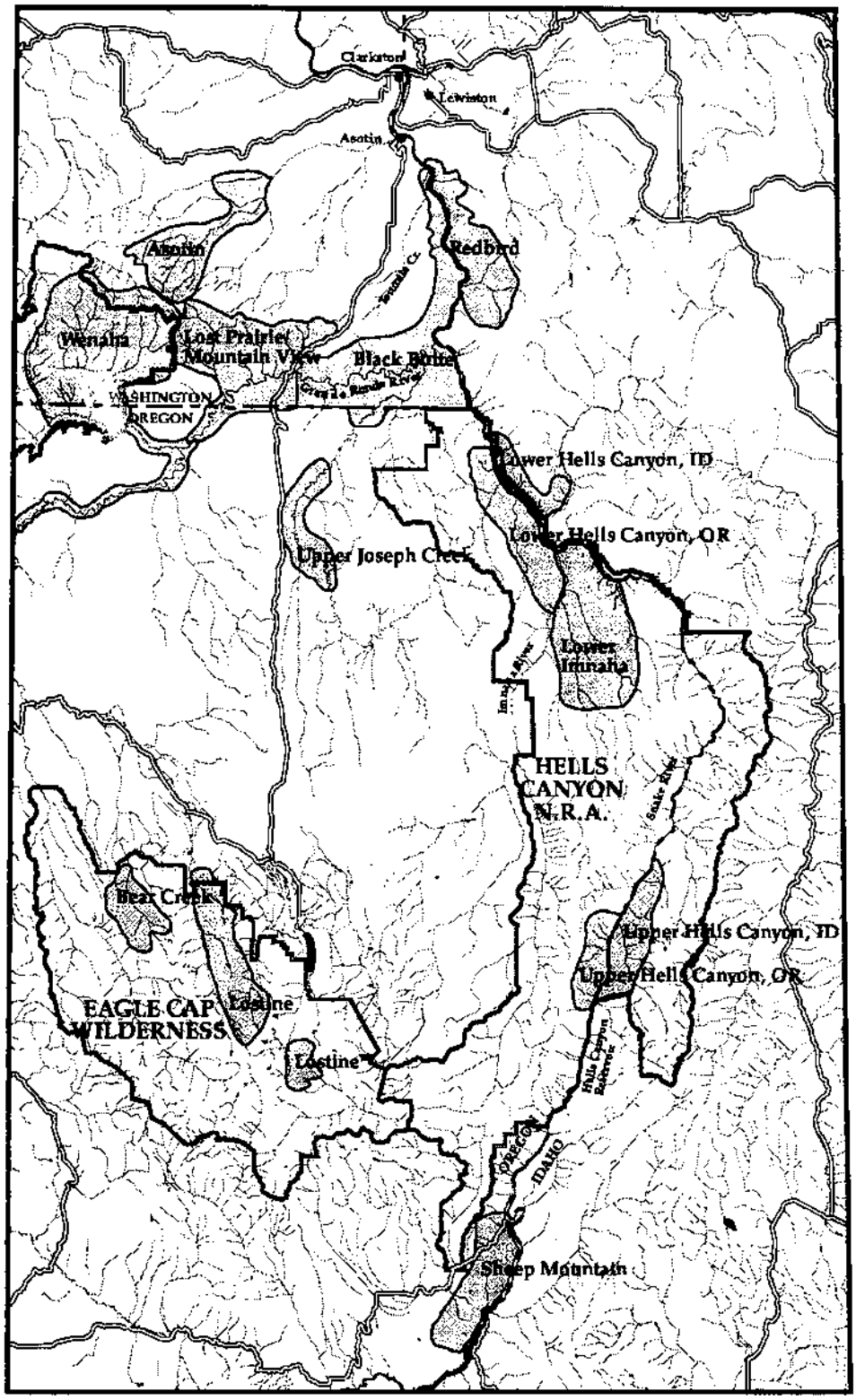
State Boundaries

Primary and Secondary Roads

Perennial Streams and Lakes

KILOMETERS

0 5 10 15



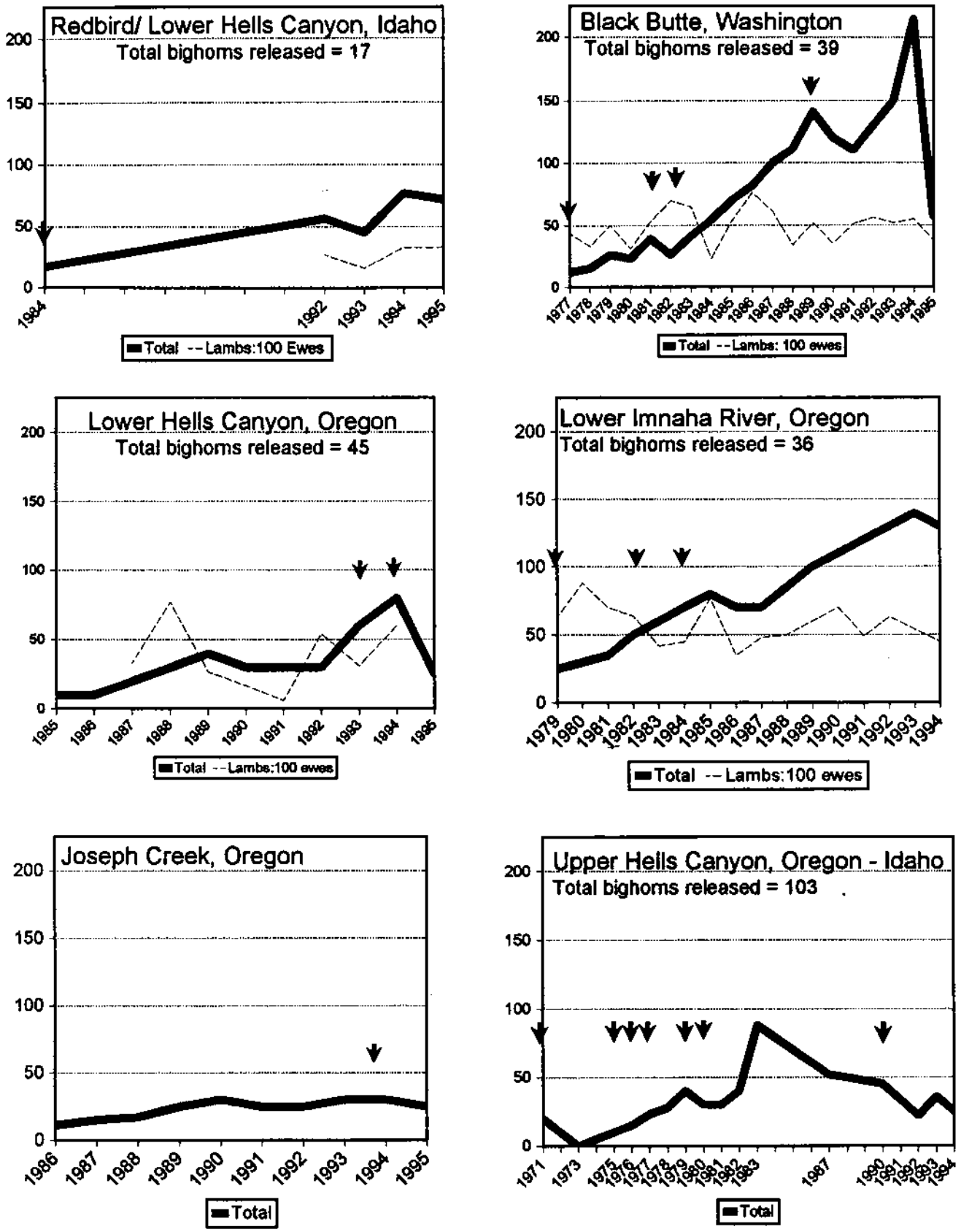


Figure 2. Size and lamb:ewe ratios of bighorn sheep herds in Hells Canyon 1971 - 1995. ↓ =date of release(s).

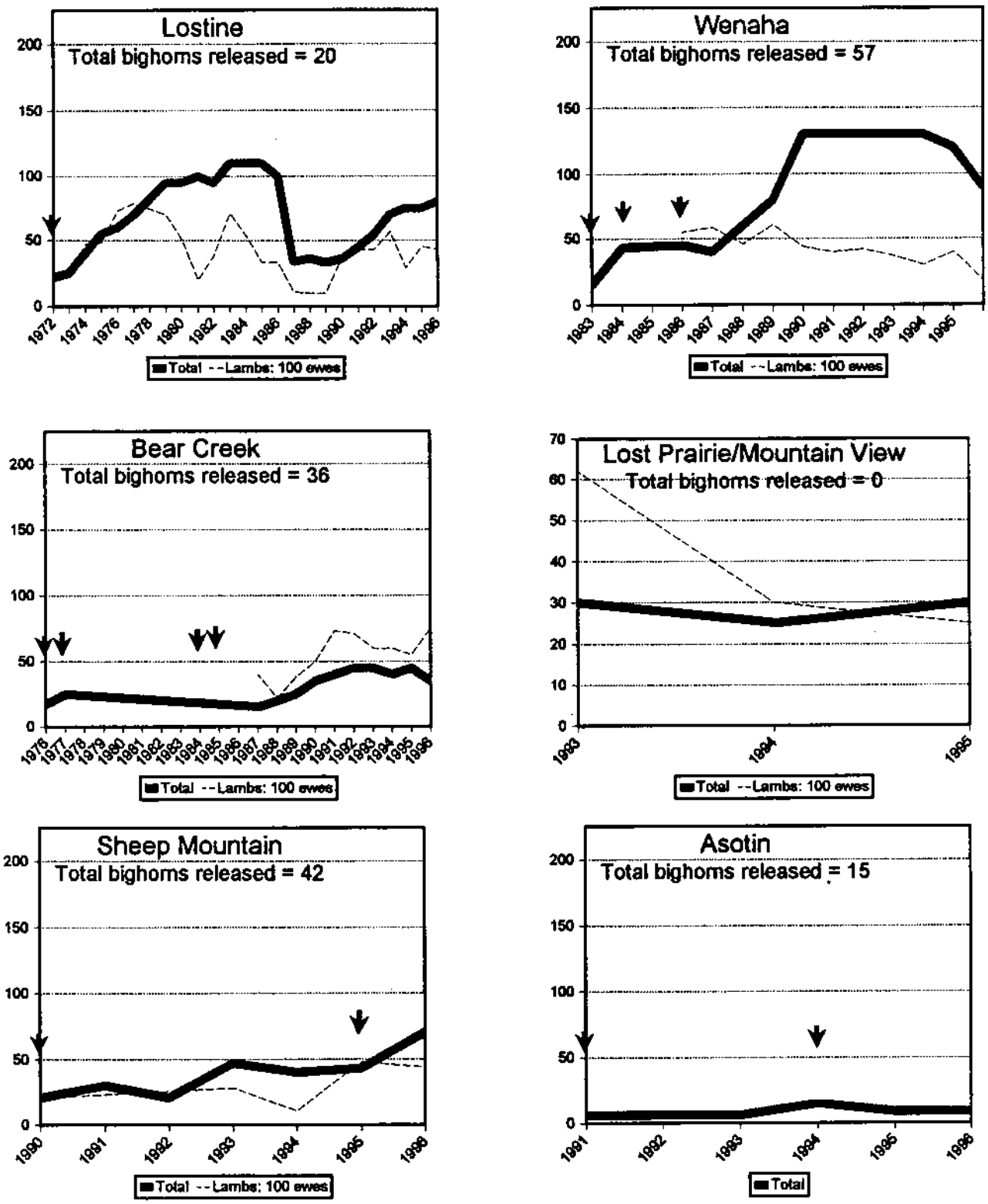


Figure 2, cont'd. Size and lamb:ewe ratios of bighorn sheep herds in Hells Canyon 1971 - 1995.
↓ =date of release(s).

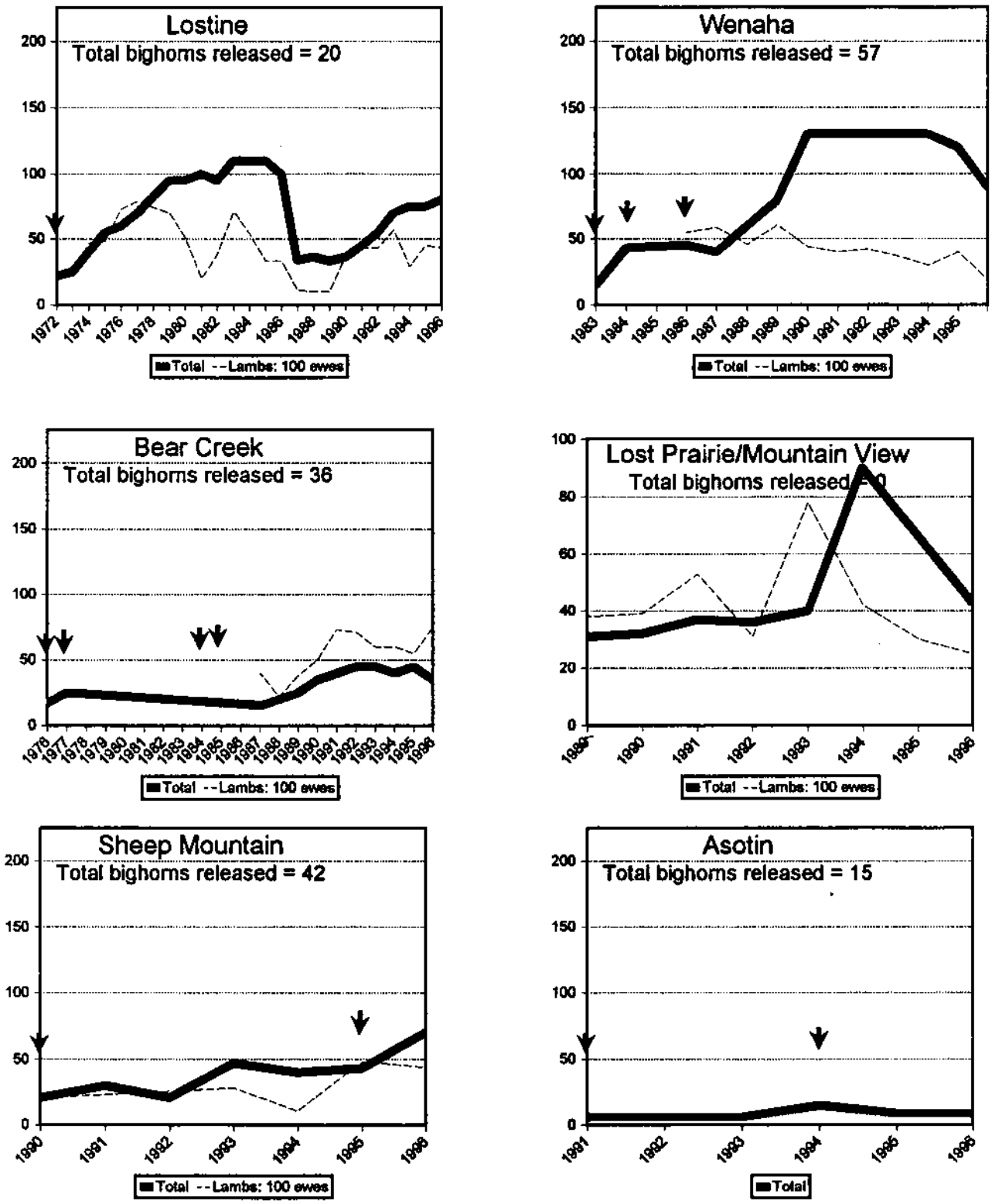


Figure 2, cont'd. Size and lamb:ewe ratios of bighorn sheep herds in Hells Canyon 1971 - 1995.
↓ =date of release(s).

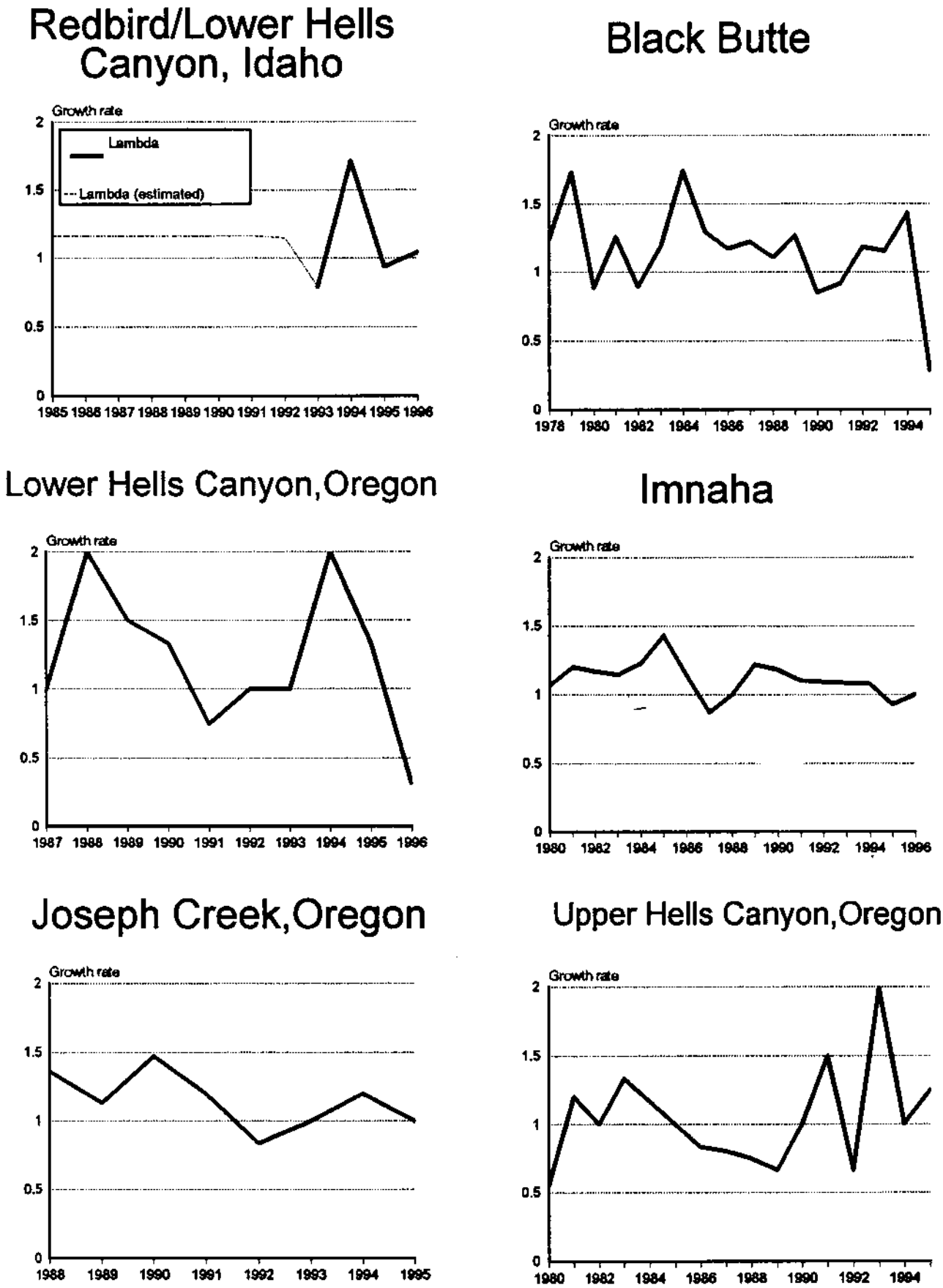


Figure 3. Growth rates of bighorn sheep herds in Hells Canyon.

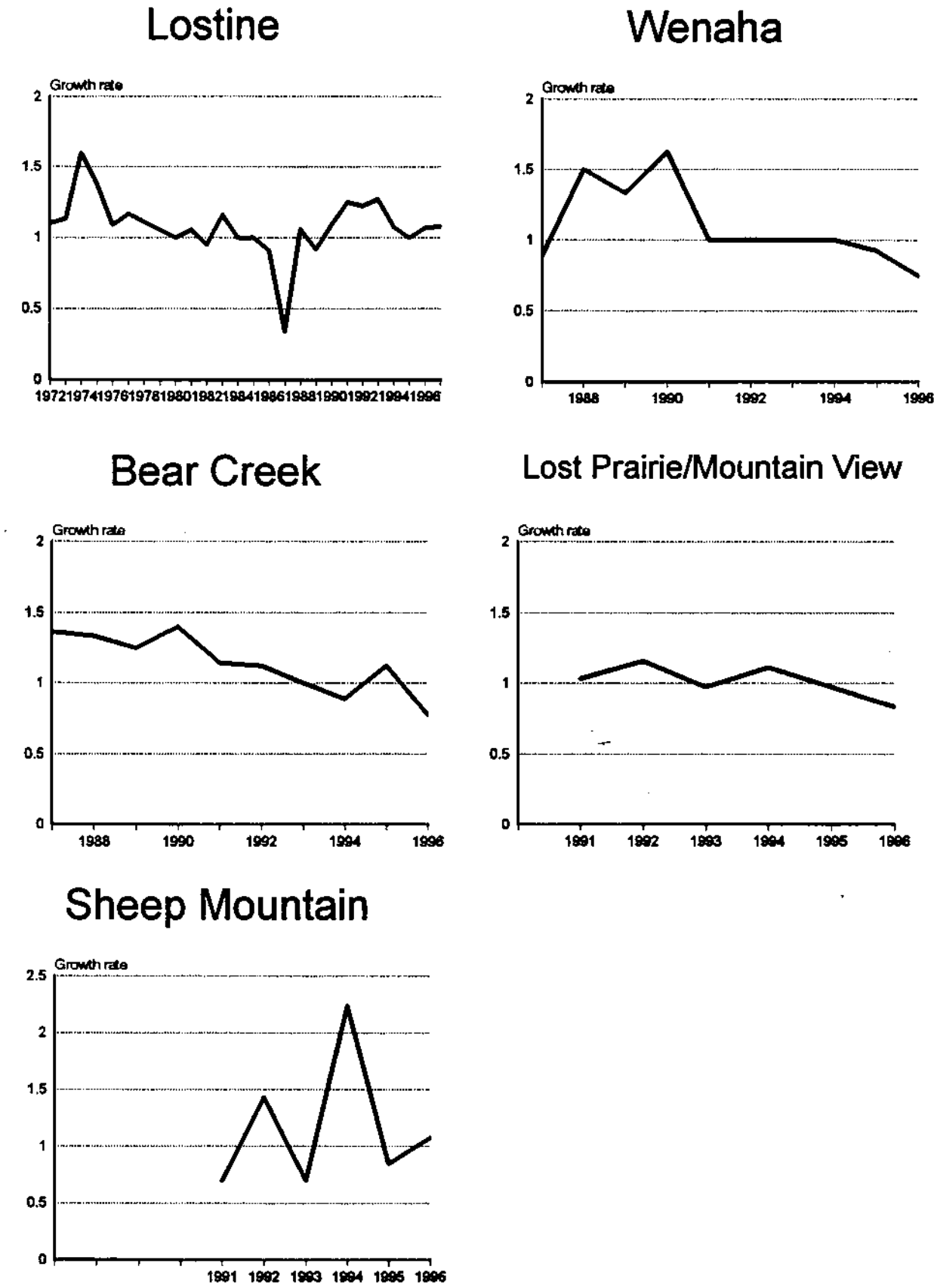
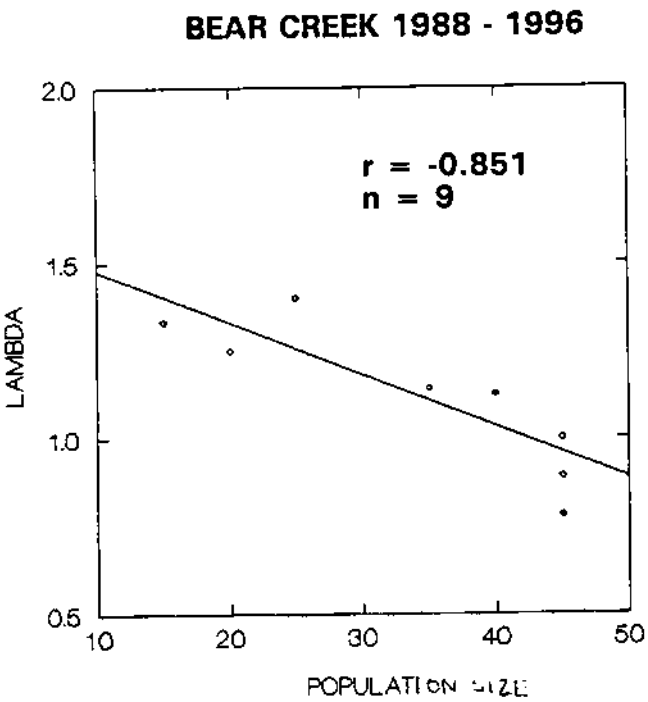
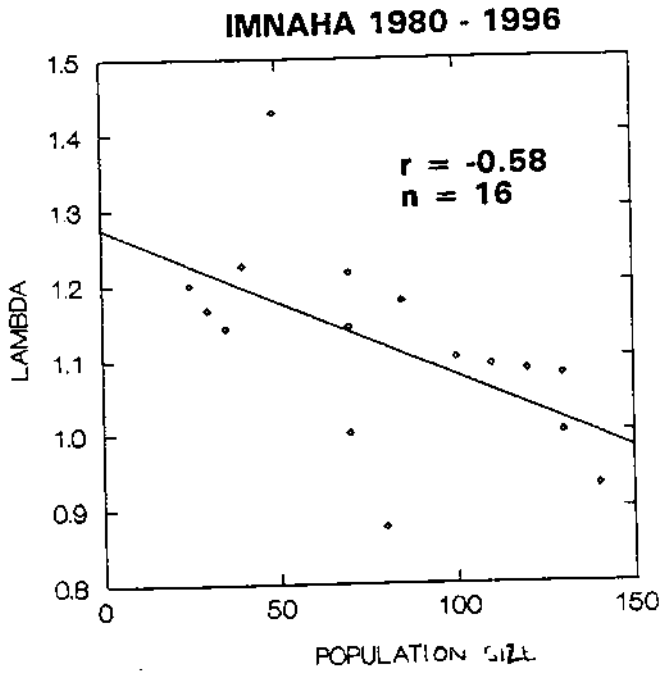


Figure 3, cont'd. Growth rates of bighorn sheep herds in Hells Canyon.

Figure 4. Relationship between growth rates and population size in Hells Canyon bighorn sheep.


BEAR CREEK 1988 - 1996
r = -0.851
n = 9
LAMBDA
POPULATION SIZE
2.0
1.5
1.0
0.5
10
20
30
40
50


IMNAHA 1980 - 1996
r = -0.58
n = 16
LAMBDA
POPULATION SIZE
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0
50
100
150

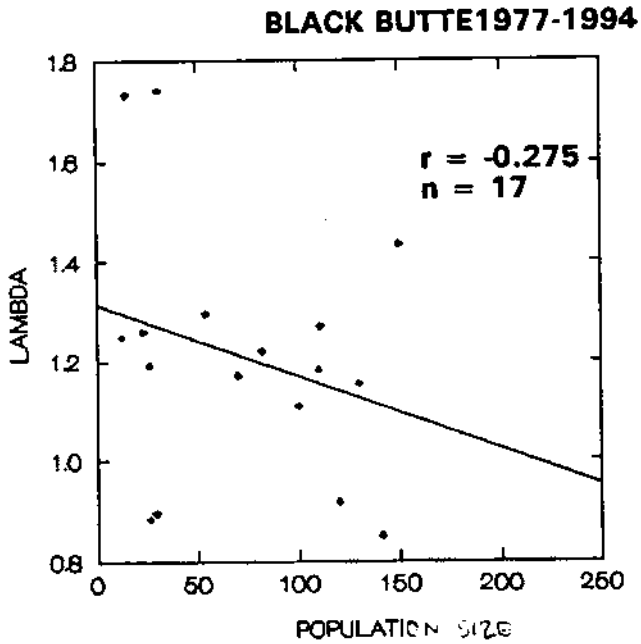

BLACK BUTTE1977-1994
r = -0.275
n = 17
LAMBDA
POPULATION SIZE
1.8
1.6
1.4
1.2
1.0
0.8
0
50
100
150
200
250

Figure 5. Projected bighorn sheep population trend in the Hells Canyon project area at various population growth rates and including annual releases of 50 bighorn sheep.

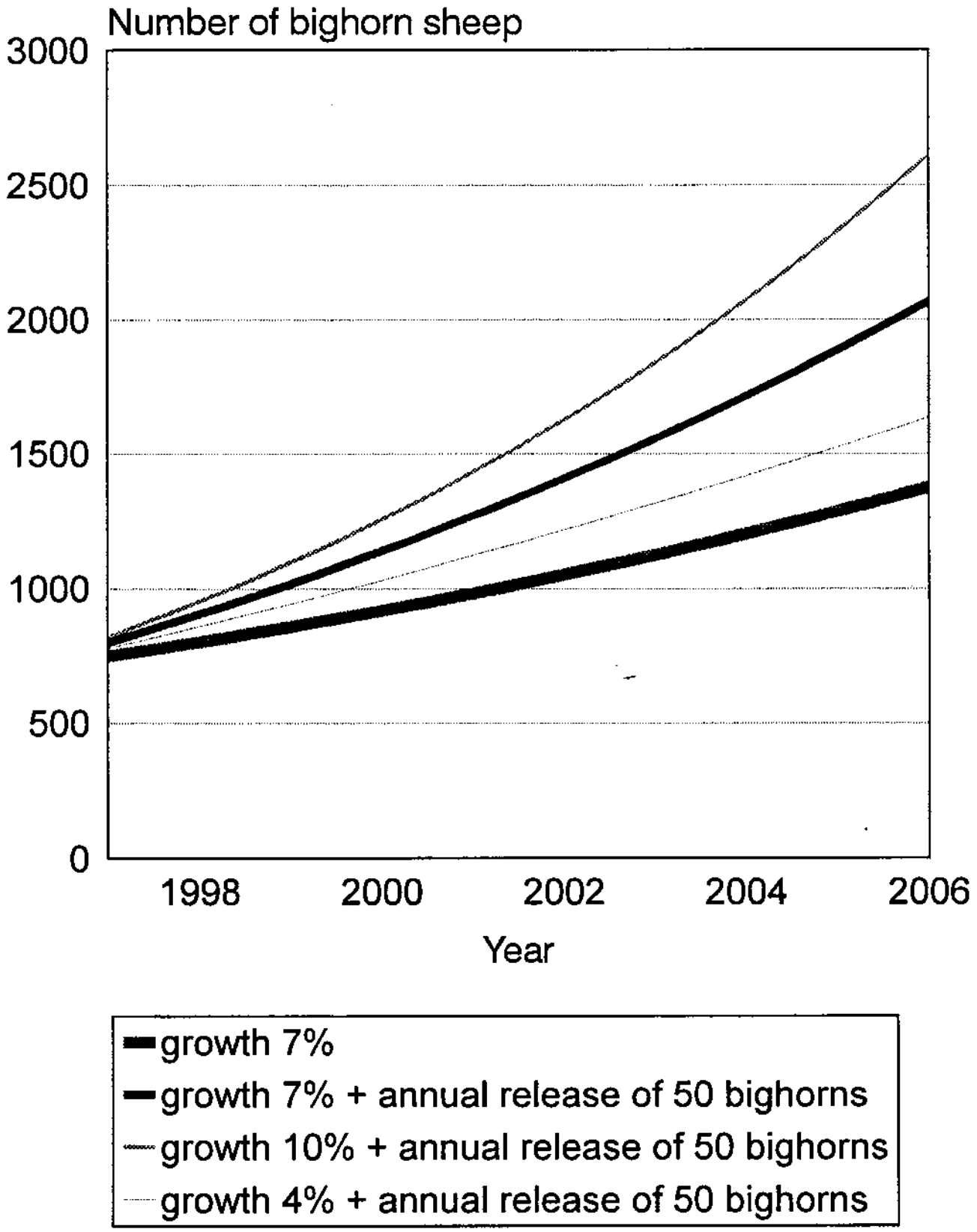
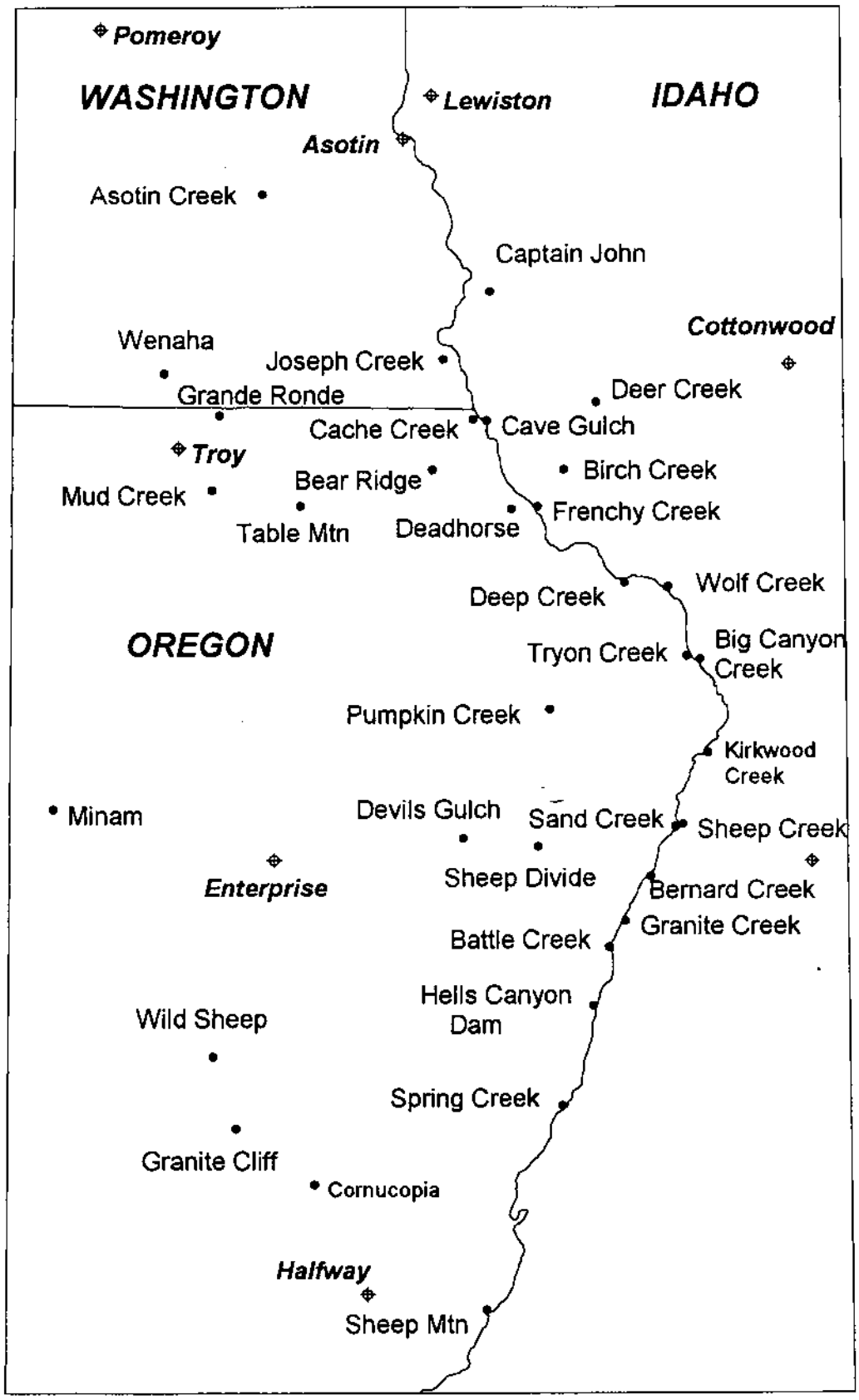

Number of bighorn sheep
3000
2500
2000
1500
1000
500
0
1998
2000
2002
2004
2006
Year
growth 7%
growth 7% + annual release of 50 bighorns
growth 10% + annual release of 50 bighorns
growth 4% + annual release of 50 bighorns

Figure 6. Potential bighorn sheep release sites, Hells Canyon project area.


Pomeroy
WASHINGTON
Lewiston
IDAHO
Asotin
Asotin Creek
Captain John
Cottonwood
Wenaha
Joseph Creek
Grande Ronde
Deer Creek
Cache Creek
Cave Gulch
Troy
Birch Creek
Bear Ridge
Mud Creek
Frenchy Creek
Table Mtn
Deadhorse
Wolf Creek
Deep Creek
OREGON
Big Canyon Creek
Tryon Creek
Pumpkin Creek
Kirkwood Creek
Minam
Devils Gulch
Sand Creek
Sheep Creek
Enterprise
Sheep Divide
Bernard Creek
Granite Creek
Battle Creek
Hells Canyon Dam
Wild Sheep
Spring Creek
Granite Cliff
Cornucopia
Halfway
Sheep Mtn
N

Bureau of Land Management
Idaho State Office
1387 S. Vinnell Way
Boise, Idaho 83709

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