EXHIBIT INDEX

BATES #	DOCUMENT
Ex001 - 056	Robin J. Innes, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, *Oreamnos americanus*, Fire Effects Information System (2011), Available: http://www.fs.fed.us/database/feis/ (last visited August 8, 2017)
Ex057 - 066	Elizabeth Flesh et al., *Range Expansion and Population Growth of Nonnative Mountain Goats in the Greater Yellowstone Area: Challenges for Management*, Wildlife Society Bulletin, July 10, 2016
Ex067 - 081	Rolf Johnson, Washington Dept. of Game, *Mountain Goats and Mountain Sheep of Washington*, January 1983 (excerpt)
Ex082 - 100	Clifford Rice & Don Gay, *Effects of Mountain Goat Harvest on Historic and Contemporary Populations*, 91 Northwestern Naturalist 40 (2010)
Ex101 - 112	Bureau of Land Management, *Status of the Science on Questions that Relate to BLM Plan Amendment Decisions and Peninsular Ranges Bighorn Sheep* (2001)
Ex113 - 124	Craig A. Stockwell & Gary C. Bateman, *Conflicts in National Parks: A Case Study of Helicopters and Bighorn Sheep Time Budgets at the Grand Canyon*, 56 Biological Conservation 317 (1991)
Ex125 - 130	Steeve D. Cote, *Mountain Goat Responses to Helicopter Disturbance*, 24(4) Wildlife Society Bulletin 681 (1996)
Ex131 - 135	Alexandre L. Rasiulis et al., *The Effect of Radio-Collar Weight on Survival of Migratory Caribou*, 78(5) The Journal of Wildlife Management 953 (2014)
Ex136 - 138	Steven J. Cooke et al., *Troubling issues at the frontier of animal tracking for conservation and management*, 00 Conservation Biology 0, 1 (2017)
Ex139 - 166	National Park Service, Olympic Nat'l Park, *Draft Mountain Goat Management Plan / Environmental Impact Statement* (2017) (excerpt)
Ex167 - 192	National Park Service, Olympic Nat'l Park, *Olympic National Park Minimum Requirements Analysis*, 2017

Ex193 - 216	U.S. Forest Service, Olympic, Mt. Baker-Snoqualmie, and Okanogan-Wenatchee National Forests, *Minimum Requirements Analysis Mountain Goat Removal from Olympic National Forest Wilderness Areas*, 2016
Ex217 - 218	E-mail from Pamela Manders, Fish and Wildlife Manager, Uinta-Wasatch-Cache National Forest, to Rusty Robinson, Bighorn Sheep / Mountain Goat Biologist, UDWR (March 29, 2017)
Ex219 - 221	E-mail from Rusty Robinson, Bighorn Sheep / Mountain Goat Biologist, UDWR, to Pamela Manders, Fish and Wildlife Manager, Uinta-Wasatch-Cache National Forest (June 1, 2017)
Ex222 - 225	E-mails between Pamela Manders, Fish and Wildlife Manager, Uinta-Wasatch-Cache National Forest, and Rusty Robinson, Bighorn Sheep / Mountain Goat Biologist, UDWR (August 7 – 9, 2017)
Ex226 - 249	UDWR, *Utah Mountain Goat Statewide Management Plan* (2013)
Ex250 - 278	UDWR, *Utah Bighorn Sheep Statewide Management Plan* (2013)
Ex279 - 285	Western Association of Fish and Wildlife Agencies, Wild Sheep Working Group, *Adaptive Wild Sheep Disease Management Venture (DMV) Strategy* (January 2017)
Ex286 - 327	IDFG, *Middle Fork Zone Elk Monitoring MRA* (August 7, 2015)
Ex328 - 341	E. Frances Cassirer, *Pneumonia in Bighorn Sheep: Risk and Resilience*, The Journal of Wildlife Management 82(1):32-45 (2018)
Ex342 - 346	Katie England, *Flying sheep: DWR transports wildlife via helicopter to test for disease*, Daily Herald (January 11, 2017)
Ex347 - 350	Brian Maffly, *Judge rejects suit over La Sal goat introduction*, The Salt Lake Tribune (March 4, 2017)

Ex001

Oreamnos americanus

Table of Contents

- INTRODUCTORY
- DISTRIBUTION AND OCCURRENCE
- BIOLOGICAL DATA AND HABITAT REQUIREMENTS
- FIRE EFFECTS AND MANAGEMENT
- APPENDIX: FIRE REGIME TABLE
- REFERENCES

INTRODUCTORY

- AUTHORSHIP AND CITATION
- FEIS ABBREVIATION
- COMMON NAMES
- TAXONOMY
- SYNONYMS
- ORDER
- CLASS

Nanny and kid in Glacier National Park, Montana. Photo courtesy of G. Keith Douce, University of Georgia, Bugwood.org.

AUTHORSHIP AND CITATION:
Innes, Robin J. 2011. Oreamnos americanus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2017, August 8].

FEIS ABBREVIATION:
ORAM

COMMON NAMES:

Ex002

mountain goat
Rocky Mountain goat
white goat

TAXONOMY:
The scientific name of mountain goat is *Oreamnos americanus* (Blainville) (Bovidae) [143].

SYNONYMS:
None

ORDER:
Artiodactyla

CLASS:
Mammal

DISTRIBUTION AND OCCURRENCE

SPECIES: Oreamnos americanus

- GENERAL DISTRIBUTION
- PLANT COMMUNITIES

GENERAL DISTRIBUTION:
The mountain goat is native to mountainous regions of northwestern North America from about 44 °N latitude to 63 °N latitude [26]. Its native range occurs from southeastern Alaska south to the Columbia River in Washington; east into Idaho and western Montana; and north to southern Yukon [34,110]. Throughout the 1900s, mountain goats were introduced in some areas outside of their known historical range in Alaska, Washington, Oregon, Idaho, Montana, Wyoming, South Dakota, Colorado, Utah, and Nevada [24,34,89,110]. They were reintroduced in parts of their native range where they had been extirpated in Alaska, Alberta, Idaho, Montana, and Washington [24,34]. For more information, see Population status and threats. NatureServe provides a distributional map of the mountain goat.

PLANT COMMUNITIES:
Mountain goats occur in alpine and subalpine areas with rocky, steep terrain in the Coast, Cascade, and Rocky Mountain ranges [24,110]. Mountain goats occur in forests, krummholz, and alpine meadows varying from temperate rainforests near sea level in coastal British Columbia and Alaska to xeric alpine communities at >13,000 feet (4,000 m) in Colorado [34]. In the northern Rocky Mountains, mountain goats range from approximately 4,900 to 8,900 feet (1,500-2,700 m) [24]. In southern and western parts of their range, mountain goats use primarily areas with steep cliffs, but in their northern distribution they are often found in rolling terrain above treeline [34]. For more information, see Preferred Habitat.

Alaska: On the Cleveland Peninsula in southeastern Alaska, mountain goats occurred in steep, broken terrain at elevations ranging from sea level to >4,900 feet (1,500 m). Below 2,300 feet (700 m), they occurred primarily in old-growth forests of western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea*

Ex003

sitchensis), and western redcedar (*Thuja plicata*); Alaska-cedar/sedge (*Cupressus nootkatensis*/*Carex* spp.) muskegs in poorly drained areas; and alder (*Alnus* spp.) on steep slide zones. Above 2,300 feet, mountain goats occurred in alpine heath (Ericaceae) interspersed with rock, scree, and snowfields [41,120].

British Columbia: In British Columbia, mountain goats occur from sea level in the western hemlock forest zone in the Coast Ranges to >7,500 feet (2,300 m) in alpine communities in the southern Rocky Mountains. In the Coast Ranges, mountain goats occur in the western hemlock forest zone on cliffs, talus, and sparsely vegetated rocks, often in old growth [103] and in the subalpine mountain hemlock (*Tsuga mertensiana*) forest zone on rock outcrops and talus, in avalanche tracks, and at seepage sites [104]. Mountain goats occur on cliffs and talus in the interior Douglas-fir (*Pseudotsuga menziesii*) forest zone [65] and in the interior western redcedar-western hemlock forest zone [82]. They occur in avalanche tracks and on cliffs and talus in the montane interior spruce (*Picea glauca* × *P. engelmannii*) forest zone [66]. In the subboreal lodgepole pine-white spruce (*Pinus contorta-Abies concolor*) forest zone, mountain goats occur in subalpine parklands and grasslands on steep, rugged slopes, in avalanche tracks, and on sparsely vegetated cliffs, talus, and other rock habitats [125]. They occur in grasslands and scrub on rugged slopes in the subalpine Engelmann spruce-subalpine fir (*Picea engelmannii-Abies lasiocarpa*) forest zone [25]. In the boreal white and black spruce (*P. mariana*) zone, they occur in grass-shrub communities along major valleys and foothills [31]. Mountain goats occur in rugged terrain in the white spruce-willow-bog birch (*Salix* spp.-*Betula glandulosa*) forest zone [106]. At the highest elevations in the alpine zone, mountain goats occur in alpine heath, grasslands, and shrublands on windswept and south-facing aspects, in krummholz, and on cliffs, talus, and sparsely vegetated rock habitats [105]. In southeastern British Columbia, mountain goats used mineral licks in lodgepole pine, Douglas-fir, and spruce-subalpine fir stands that were 96 to 213 years old [107].

Alberta: In Banff and Jasper National Parks, Alberta, mountain goats occurred in rugged, rocky terrain in alpine areas above 7,000 feet (2,100 m) in summer and winter but also occurred in subalpine areas. In subalpine zones, mountain goats used grassy avalanche and rock-slide slopes; rocky slopes and ledges with sparse grass (Poaceae) and sedge cover; and grass-sedge communities on south-facing slopes of burned areas [38]. On Caw Ridge in west-central Alberta, mountain goats occurred in open alpine communities, krummholz, and subalpine fir-Engelmann spruce forest from 5,740 to 7,120 feet (1,750-2,170 m), where treeline occurred at approximately 6,200 feet (1,900 m). They occurred on gently rolling hills, rockslides, steep grassy slopes, and short cliffs [35]. In west-central Alberta, mountain goats occurred on talus and cliffs in a canyon along Pinto Creek. They occurred in lodgepole pine and white spruce forests with an understory of Labrador tea (*Ledum groenlandicum*) and Schreber's moss (*Pleurozium schreberi*) and traveled through riparian habitats dominated by willows, young quaking aspen (*Populus tremuloides*), and scattered white spruce trees [57].

Washington: In Washington, mountain goats occurred in mountain hemlock, Pacific silver fir (*Abies amabilis*), subalpine fir, and alpine larch (*Larix lyallii*) forests and in heath habitats dominated by mockorange (*Philadelphus* spp.), mountain heather (*Cassiope* spp.), and partridgefoot (*Luetkea pectinata*) [84]. In Olympic National Park below 4,900 feet (1,500 m), introduced mountain goats occurred in Douglas-fir-western hemlock forests with rock outcrops and bluffs. Above 4,900 feet, they occurred in subalpine fir forests, subalpine meadows, and herb-dominated communities on talus, scree slopes, and rock [71]. In the north-central Cascade Range, mountain goats occurred from 700 to 5,000 feet (200-1,500 m). At low elevations, mountain goats occurred in western hemlock and Douglas-fir forests. At mid- to upper elevations, they occurred where cliffs and steep, rocky terrain occurred in mountain

Ex004

hemlock and fir (*Abies* spp.) forests [45].

Idaho: In the Pahsimeroi River drainage in winter, mountain goats occurred in curlleaf mountain-mahogany (*Cercocarpus ledifolius*) habitat on steep, south-facing cliffs [85]. On winter range at 4,000 to 5,000 feet (1,200-1,500 m) elevation in the Selkirk Range of northern Idaho, 20-year-old postfire shrub communities dominated by Rocky Mountain maple (*Acer glabrum*), rose (*Rosa* spp.), serviceberry (*Amelanchier* spp.), black chokecherry (*Prunus virginiana* var. *melanocarpa*), Lewis' mockorange (*Philadelphus lewisii*), and redstem ceanothus (*Ceanothus sanguineus*) were considered the most important foraging sites for mountain goats [17].

Montana: In northwestern Montana in the Swan Range, mountain goats occurred in meadows at 6,800 feet (2,100 m) and on talus slopes near mountain summits at 7,600 feet (2,300 m) [32]. They used cliffs, ledges, and rock outcrops dominated by moss, spikemoss (*Selaginella* spp.), and grasses, primarily bluebunch wheatgrass (*Pseudoroegneria spicata*) and bluegrass (*Poa* spp.); sparsely vegetated dry meadows dominated by bluebunch wheatgrass and sedges; windswept, sparsely vegetated ridgetops dominated by grasses such as bluebunch wheatgrass and purple pinegrass (*Calamagrostis purpurascens*) and forbs such as sticky cinquefoil (*Potentilla glandulosa*); shrub- and herb-dominated ravines where avalanches occurred regularly; wet meadows, often near cliff bases; and subalpine fir/menziesia (*Menziesia ferruginea*), subalpine fir-Engelmann spruce-grand fir (*Abies grandis*), and whitebark pine (*Pinus albicaulis*) forests [20]. In south-central Montana, introduced mountain goats in the Absaroka Mountains occurred in tufted hairgrass (*Deschampsia cespitosa*)-sedge meadows above treeline (>9,500 feet (2,900 m)) and in whitebark pine and subalpine fir stands at treeline [128]. In summer on Running Rabbit Mountain in Glacier National Park, mountain goats preferred subalpine fir/beargrass (*Xerophyllum tenax*) krummholz, mesic alpine forb meadows, a mineral lick, and rock outcrops (bedrock, talus-scree, forb outcrop, shrub outcrop, and forested outcrop) more than expected based upon availability ($P<0.05$ for all variables) [118].

South Dakota: In the Black Elk Wilderness, introduced mountain goats occurred in ponderosa pine (*Pinus ponderosa*) forest interspersed with granite outcrops, open ridges, and meadows [12].

Colorado: An introduced mountain goat population in the Sawatch Range occurred at 9,120 to 13,230 feet (2,780-4030 m). Above treeline at 11,480 feet (3,500 m), mountain goats occurred in open alpine habitats with herbs and patches of Engelmann spruce, bristlecone pine (*Pinus aristata*), and willows. Below treeline, mountain goats occurred in Engelmann spruce, Douglas-fir, bristlecone pine, and lodgepole pine forests interspersed with cliffs and old burns dominated by quaking aspen or shrubs [3,10]. In the Gore Range, an introduced mountain goat population occurred on an alpine ridge dominated by tufted hairgrass, sheep fescue (*Festuca ovina*), sedge, and clover (*Trifolium* spp.), with some willow stands [67].

BIOLOGICAL DATA AND HABITAT REQUIREMENTS

SPECIES: Oreamnos americanus

Numerous reviews describing the biology of mountain goats are available and cited frequently in this review. These include the following sources: [16,24,34,62,75,78,99,135]. This review includes

Ex005

information for many of the life history aspects of the species but focuses on those life history aspects most relevant to fire.

- LIFE HISTORY
- DISEASES AND SOURCES OF MORTALITY
- PREFERRED HABITAT
- FOOD HABITS
- FEDERAL LEGAL STATUS
- OTHER STATUS
- MANAGEMENT CONSIDERATIONS

LIFE HISTORY:

- **Physical description**
- **Courtship and mating**
- **Reproduction and development**
- **Social behavior**
- **Home range and movements**
- **Population density**
- **Survival**
- **Life span**

Physical description: Mountain goats have distinctive white wool pelage [110] that is shed once each year [19,24,62]. Adult male mountain goats (billies) shed their coats first. They begin shedding in June, and molt is usually complete mid-July. Adult females (nannies) with young-of-the-year (kids) shed their coats later than nannies without kids, and yearlings are the last to molt, usually by mid-August [19,110]. Winter coat growth is complete in November or early December [24].

Mountain goats have black, recurved horns that are 8 to 10 inches (20-25 cm) long [110]. The horns of males are thicker and more curved than those of females. Horns grow longer and thicker as the animal ages. They are first visible on mountain goat kids in July [34].

Adult males are larger than adult females [34,35]. According to a review, adult body mass in midsummer ranges from 209 to 342 pounds (95-155 kg) for males and 132 to 165 pounds (60-75 kg) for females [24]. Mountain goats in northern parts of their range show greater differences in size between genders than those in southern regions [27]. Because of their larger body size, males may occupy areas with deeper snow than females [24,135]. See Growth for more information.

Courtship and mating: Mountain goats are polygamous [78,99,100]. The rut—the peak breeding period—occurs from late October to December, but primarily in November [24,110]. Based on the short birthing period in spring, it is likely that most females in a population attain estrus within a 2-week period [24].

Sexually active males fight and use aggressive displays to gain dominance and access to females for mating [78]. Large males are usually dominant and mate most often [24]. Dominant males defend one estrous female at a time ("tending tactic") [100] for up to 2 to 3 days [135]. Subordinate males attempt to

Ex006

mate by pursuing females ("coursing tactic") [100]. Males attempt to breed as many nannies as possible [78] by moving among nanny groups during the rut [135]. A 2003 review stated that it was not known whether females mate with more than one male [24]. See Age at first reproduction for more information.

Reproduction and development: The gestation period ranges from 147 to 186 days [24,99,110]. Most kids are born from mid-May to early June [24,110,139]. Mountain goats were born as early as late February [19] and as late as late August [21] in Montana, possibly indicating recurrent estrus [21,34]. According to a 2003 review, about 80% of kids are born within a 2-week period [24]. On Caw Ridge, 80% of kids were born within a 17-day period [34].

As parturition approaches, pregnant females isolate themselves from other mountain goats to give birth [24], although occasionally a previous year's offspring may accompany a parturient female to the birthing site [34]. A female remains with her kid at the birthing site until the kid can follow her. Kids are precocial [110] and can stand and nurse within about 45 minutes [34]. Within 2 to 3 days, a kid can follow its mother [24]. After approximately 2 weeks of seclusion, nannies and kids form groups (see Social behavior) [135].

Kids can eat vegetation at 1 week old [20,24] and are weaned at about 4 months old. Young remain with their mothers until the following spring when the mother gives birth again [24,110]. For more information on mother-offspring associations, see Social behavior.

Growth: Mountain goats weigh approximately 5.5 to 7.7 pounds (2.5-3.5 kg) at birth [24,99,110]. Male and female kids weigh the same. Weight gain during the first summer is similar between males and females, averaging 0.43 pound (0.20 kg)/day. Sexual dimorphism in body mass develops after weaning, increasing gradually up to at least 6 years old. As yearlings, males are about 10% heavier than females. At ≥5 years old, males are about 40% to 60% heavier than females. A review stated that females may reach maximum body size at 6 years old, whereas males may continue to increase in mass with age [24].

Age at first reproduction: Females and males are sexually mature at 18 months, but it is rare for mountain goats to reproduce this young in the wild [20,24,70]. In the wild, females may first reproduce at 30 months old [10,24,44,110], although most females first reproduce at 42 or 54 months old [10,24]. Age at first reproduction in female mountain goats <54 months old is most common in expanding, introduced populations such as those in Washington [71] and Colorado [10]. Some females introduced into the Olympic Mountains apparently conceived at 18 months old, although most bred at 30 or 42 months old [72]. In a native population on Caw Ridge, females <54 months old did not reproduce; 29% of females produced their first kid at 54 months old; and most females reproduced at 66 months old [35]. Festa-Bianchet and Cote [34] stated that in ungulates in general, primiparity (giving birth for the first time) does not occur at a set age but occurs at the age when females reach approximately 80% of their peak body mass. However, the association between nanny body mass and age of primiparity was weak in the Caw Ridge population [34]. Houston and others [70] reported that on Klahhane Ridge in Olympic National Park, all females that were ≥3 years old and weighed >110 pounds (50 kg) were lactating, whereas those <110 pounds were not. Reproductive senescence in females apparently occurs after they are 13 years old [34]. See Frequency of reproduction for more information.

Males may first reproduce at 18 or 30 months old [20,24,44,110], but most males <42 months old do not reproduce [20,92]. On Caw Ridge, only males ≥54 months old mated [92]. In the Swan Range, Montana, 30-month-old males mated in a population where adult sex ratios were highly skewed towards females,

Ex007

and some nanny groups had no males present during the rut. However, males >30 months old mated most often [20].

Pregnancy and twinning rates: Usually nannies give birth to single kids; up to 33% of births are twins, and triplets are rare [24,110]. Researchers suggested that twinning is more common in introduced and rapidly growing populations than in established and stable populations [24]. An increasing native population in the Stikine River drainage, British Columbia, averaged 18% twins during 1 year [40]. An increasing population of mountain goats introduced along the Snake River, Idaho, about 12 years prior to the study, had twinning rates ranging from 25% to 33% over 2 years [58]. In a native population on Caw Ridge, where nutrient availability apparently limited mountain goat reproduction, 2% of mountain goat births were twins during 5 years [35]. An introduced population on Klahhane Ridge had a mean twinning rate that was lower at high density (2.1%) than at low density (12.4%) over 10 years ($P<0.05$) [72]. Mountain goats apparently take advantage of favorable environmental conditions by increasing reproductive output. This suggests that the number of offspring may be related to resource availability [24].

Frequency of reproduction: Mountain goats do not reproduce every year. According to a 2000 review of mountain goats in British Columbia, up to 40% of mature females in a given year may not produce any offspring [14]. In the Coast Ranges of southwestern British Columbia over 33 years, the percent of females breeding annually was 4% to 10% when the herd was static or declining and 68% when the herd was increasing [30]. On Klahhane Ridge, production of kids over 5 years ranged from 0.2 kid/year (1 kid in 5 years) to 1.2 kids/year [72]. On Caw Ridge during 18 years, adult females reproduced in about 25% of years [52]. In years when a female did not reproduce she was more likely to care for her yearling, but extended maternal care did not appear to improve yearling growth or survival [34].

The frequency of reproduction and the number of kids produced by a nanny increase with her age, social rank, and previous reproductive effort. According to a 2003 review, kid production increases with maternal age during the first few years following primiparity, remains stable until about 10 years old, and declines thereafter [24]. On Caw Ridge, the percent of females giving birth increased for 3- to 6-year-old nannies, peaked at 81% for 8- to 12-year-old nannies, then declined to 67% for older nannies [34]. On Sheep Mountain-Gladstone Ridge, Colorado, maximum female reproductive output for an introduced population occurred from 4 to 9 years old (66%) and declined for females ≥10 years old (53%) [10]. Kid production also increases with nanny social rank. On Caw Ridge, females that were dominant for their age had higher probability of producing a kid than subordinate females of the same age [34].

Female mountain goats may have a lower probability of reproducing in a given year if they reproduced the previous year, particularly if they are young and in poor condition or population density is high. Hamel and others [52] reported that low-quality females (light weight, socially subordinate) on Caw Ridge had a lower probability of reproduction if they had reproduced the previous year than if they did not ($P<0.001$), whereas high-quality females showed no cost of successive reproduction. Young females had a lower probability of reproduction if they had bred the previous year than if they did not, whereas older females showed no effect of previous parturition. Young females bear the cost of growth and reproduction simultaneously, which may explain why young females had lower probability of reproduction. At low population density, previously breeding and nonbreeding females had similar probability of reproducing; however, at high density, the probability of reproduction was 25% lower for previously breeding than for previously nonbreeding females. Apparently, at low population density, reduced competition allowed females to compensate for the high energetic costs of reproduction [51].

Ex008

Sex ratios: Kid sex ratios in mountain goats may be skewed due to differential production or mortality. On Klahhane Ridge, the kid sex ratio in midsummer was 38% male. The authors hypothesized that the scarcity of male kids may have indicated either greater production of female kids by nannies or higher mortality of male kids [73]. Conversely, in the Sapphire Mountains, Montana, Rideout [111] observed more male than female kids. Kid sex ratio on Caw Ridge was apparently affected by maternal age. During a 14-year study, the percent of daughters decreased from 59% for mothers ≤6 years to 38% for mothers ≥10 years. The authors hypothesized that males may be more costly to wean than females due to their larger body size, and that young mothers may be less able to support male kids due to their need to bear the cost of their own growth as well as reproduction. However, the authors found no evidence that sons were costlier to wean than daughters, and there was little sexual dimorphism in kid mass prior to weaning [34].

Adult sex ratios in mountain goats range from close to parity to skewed towards females because of higher male mortality [24,110]. A 1975 review reported adult sex ratios ranging from 23% to 87% male [110]. Populations near East Kootenay in southern interior British Columbia (60% males) [60] and Glacier National Park in western Montana (53% males) [111] reported adult sex ratios skewed towards males in populations with no or light hunting pressure. In the Swan Mountains, Montana, adult male:adult female ratios were low after 2 severe winters (27-33% males) and increased after a mild winter (55% males), suggesting that severe winters affected the survival of males more strongly than females [20].

Social behavior: Groups of mountain goats within a herd are commonly referred to as "bands". Bands may consist of >100 individuals (Cote 1999 cited in [24]). Bands appear to consist of "loosely associated, interchanging individuals" [21]. Band composition and size vary between activity, season, habitat, population density, and individual age, gender, and social status [24,99]. Typically, adult males and adult females are segregated into separate bands except during the summer at mineral licks and during and after the rut, when males and females are concentrated on winter ranges [24,111]. A "unique" population in Glacier National Park was not segregated by gender [118].

Adult females form nanny groups or nursery bands with kids and 1- and 2-year-olds of both genders [24]. Nursery bands usually average about 4 to 5 individuals, but many increase to 15 to 20 or more after kidding [14]. Nursery bands are smallest in spring during the kidding period, when gravid females isolate themselves from most other mountain goats to give birth [17,67,135]. Females start to form nursery bands after 1 week of parturition in early June. By July, nursery bands attain peak size [67]. Adult males are solitary or form bachelor groups, typically consisting of 2 to 6 individuals [14,24]. In spring, bachelor groups are often larger (≤15 individuals) than other times because young males (≥2 years) often split from nursery bands and join bachelor groups [20,24,34,135]. Band size is often largest when males and females are concentrated on winter ranges. In 2 native populations in western Montana, mountain goat bands tended to join together in winter, possibly to take advantage of mountain goat trails that provided access to forage in deep snow [19]. In an introduced population in the Crazy Mountains, Montana, mountain goat groups tended to be small (<10 individuals) overall, but groups tended to be largest (up to 40 individuals) in winter when range was limited [90]. For more information on this topic, see Home range.

Mother-offspring groups are the most common aggregation and persist after weaning and the birth of a new kid. On Caw Ridge, yearlings commonly associated with their mothers, and occasionally older offspring (2- and 3-year-olds) remained closely associated with their mothers. Females without a kid present were most likely to associate with their older offspring [34]. Nannies generally do not tolerate

Ex009

close proximity of unrelated young [19,34]. On Caw Ridge, although adult females preferentially associated with related young, they did not appear to preferentially associate with related adults. Thus, mountain goat bands consisted of both related and unrelated individuals [34]. Adult females associated more often with adult females of similar social rank than with individuals that were distant in the dominance hierarchy [23].

Nursery band in Jasper National Park, Canada. Photo courtesy of Joy Viola, Northeastern University, Bugwood.org.

In general, group size tends to increase with population density. On Klahhane Ridge, mean group size in June was positively associated with June population size (r^2=0.88, P<0.05) during 5 years [74]. Group composition may also be influenced by population density. On Running Rabbit Mountain in Glacier National Park, mountain goats were not sexually segregated. Rather, both genders utilized the same feeding areas and ledges, and were frequently observed in mixed-gender groups. The authors proposed that the high population density (mean annual group size: 24 mountain goats), small home range, and/or potentially abundant food resources may have forced a closer non-rut association of genders than observed in other populations [118].

Mountain goat groups may be more efficient at detecting potential predators than single individuals. In mountain goats, individual vigilance decreased as group size increased to at least 10 to 15 individuals [64,112]. Bachelor groups are small and occur more often in closed habitats such as forests than nursery groups, which are large and most often occur in open habitats (see Preferred Habitat). Males may accept a higher risk of predation to obtain more or better food than females because of their larger body size [34]. Females may be more vulnerable to attacks by large mammalian predators than males because of their smaller body size and association with young [141].

Mountain goat bands have well-developed dominance hierarchies based on individual size, strength, and age [14]. Dominance is achieved via antagonistic vocalizations and threat displays [74,110]. Dominant individuals are frequently older and larger than subordinates [23,74]. Dominance between genders may vary among populations [74]. In some locations, such as the Olympic Mountains [111], large adult males seemed to be dominant over females; however, in other populations, such as northern British Columbia [44], females appeared to be dominant over males [74]. Rideout [111] proposed that differences in

Ex010

dominance among studies appeared related to differences in food resources, with females increasing aggression and attaining dominance in areas of limited summer food. Socially subordinate individuals may be forced to use less preferred habitats. See Forage site selection for more information on this topic.

Home range and movements: Mountain goats, particularly females, show strong fidelity to established seasonal ranges [21,99]. Within home ranges, use patterns are "highly predictable", with individuals using the same travel routes, feeding sites, and bedding sites daily. Males are more likely than females to show variable movement patterns and to travel through atypical terrain [21].

- Daily activity
- Seasonal movements and migration
- Dispersal
- Home range

Daily activity: Mountain goats feed throughout the day but are most active from dawn to midmorning and again from late afternoon to evening. They are often inactive at midday [17,19,24,110,118,119,126]. Because bedding and foraging sites may be remote from each other, mountain goat movements often peak during travel to and from these areas. Thus, mountain goat movements typically peak at dusk, midday, and dawn [126]. Mountain goats are frequently active at night [17,20,24,110,111,126]. Weather, particularly temperature, affects mountain goat daily activity. During hot midsummer days, afternoon activity is often reduced [20,24]. Conversely, cloud cover may increase midday feeding activity in summer [17,126]. During inclement weather mountain goats remain relatively inactive [17,19,20,62,78].

Seasonal movements and migration: Some mountain goat populations have distinct summer and winter ranges, whereas others remain in the same area throughout the year [24]. Winter ranges are frequently at lower elevations than summer ranges (e.g., [17,43,119]). If mountain goats are at high elevations in winter, they preferred windswept slopes with minimal snow accumulation (e.g., [43,47,111]). On the coast of Alaska, mountain goats summered at high elevation (5,600 feet (1,700 m)) in alpine habitats and wintered from alpine habitats down to sea level in rock outcrops surrounded by forest [43]. In the Olympic Mountains, introduced mountain goats summered above 5,000 feet (1,500 m), although they occurred as low as 2,000 feet (600 m). They wintered on steep south- and southeast-facing outcrops and cliffs below 5,000 feet but were found as low as 1,000 feet (300 m) [117]. On mountain ranges along the breaks of the Salmon River in Idaho, mountain goats moved to low elevations in winter, moving to their lowest elevations in April and early May to access new growth on south-facing slopes [17]. In coastal and interior British Columbia, mountain goats usually remained at low elevations in spring in order to obtain the earliest flush of green vegetation. As spring progressed into summer, they followed the development of new growth upwards. In summer and early fall, most mountain goats grazed at and above treeline, where they used lush alpine swales and boulder meadows adjacent to steep cliffs. In coastal British Columbia, winter ranges were at low elevations because at high elevations the deep, heavy snow was not readily blown away to expose forage, while sites near sea level had little or no snow. Mountain goats occasionally wintered on cliffs that rose directly from the beach. In interior British Columbia, where snow was usually shallower and drier and high winds were frequent, mountain goats wintered on cliffs at varying elevations, including high windswept ridges. Most winter ranges throughout coastal and interior British Columbia were steep sites that shed snow and had south to west exposures [14].

Ex011

Migration distances range from <1 mile to >10 miles (2-16 km) [78]. In the Sapphire Mountains, Montana, migration distances between summer and winter activity centers ranged from 1.1 to 6.9 miles (1.7-11.1 km); mountain goats migrated greater distances on average during a severe winter (5.7 miles (9.2 km)) than during a mild winter (1.8 miles (2.9 km)). During the severe winter, mountain goats traveled to lower elevations than during the mild winter, whereas during the mild winter, mountain goats rarely left their summer-fall ranges [111]. In the Kenai Mountains, southeastern Alaska, some mountain goats used small home ranges year-round, whereas others migrated >15 miles (24 km) between winter and summer ranges [98]. In the Bitterrroot Mountains, Montana, mountain goats migrated 5 to 10 miles (8-16 km) between ranges [119].

Mountain goats, particularly females, show strong fidelity to established seasonal ranges [20,21,74,78,99,130]. In Olympic National Park, 84% of mountain goats returned to the same summer ranges each year, some for 5 to 10 years [74]. In southeastern Alaska, mountain goats moved from high-elevation summer range to winter range below treeline, usually on the same mountain, although erratic movements to new ranges sometimes occurred [96]. In the Kenai Mountains, adult males ≥5 years old showed the highest fidelity to their summer ranges, and adult females ≥5 years old showed the second highest fidelity. During winter, adult females showed the highest fidelity to winter ranges, and adult males showed the most mobility and least fidelity. Young females showed fidelity similar to that of older females, whereas young males were the least faithful to a given range and most prone to change ranges [98]. In general, males are more likely than females to show variable movement patterns and to travel through atypical terrain. In northwestern Montana, all breeding took place on nursery-band wintering areas; so, in the fall, females returned to the same wintering ranges, while rutting males crossed between ranges to access estrous females [21]. Before returning to separate or peripheral ranges around midwinter (depending upon snow depth), adult males then spent at least early winter on whichever nursery band's range they occupied at the end of the rut [21,85]. Several researchers reported that males made extensive movements during the rut in populations where the distance between neighboring groups of females was large [24,78].

Mountain goat habitats are characterized by low mean temperatures, high winds, prolonged snow cover, short growing seasons, and intense ultraviolet radiation [94]. Because summer is short, mountain goats may spend more time on winter range than summer range. In the Cascade Range, the median time mountain goats spent on summer range was 4.6 months, with the remaining time spent on winter range [109]. Because snow melts slowly above 4,000 feet (1,200 m), use of alpine areas in southeastern Alaska was "brief" [96].

Dispersal: Dispersal is commonly reported in mountain goat studies (e.g., [30,78,142]). A review of studies of mountain goats on Caw Ridge concluded that young mountain goats of both genders have "strong dispersal tendency" [34]. Typically, males are more likely to disperse than females, and juveniles (1-3 years old) are more likely to disperse than adults [34,35,53,73,127]. On Klahhane Ridge, 10% of mountain goats in a high-density population dispersed over 4 years. Males (20%) dispersed more frequently than females (6%), and 1- to 3-year-olds (18%) dispersed more frequently than older mountain goats (5%) [73]. Dispersal distances up to 19 miles (30 km) were reported in native populations [35]. Exploratory movements up to 38 miles (61 km) were reported for introduced mountain goats [134]. High population density and resource limitation may prompt dispersal [73,78,127].

Home range: According to a 2000 review, annual mountain goat home range sizes range from 2.4 to 17.3 miles^2 (6.3-44.9 km^2) [99]. Males often have smaller home ranges than females (e.g., [24,34,118]),

Ex012

although in southeastern British Columbia [108], southeastern Alaska [120,141], and Montana [79] males had larger home ranges than females. Researchers hypothesized that females with kids may travel more than males because longer movements could make their location less predictable to predators [24,34]. Conversely, males may travel more than females because males often move long distances between groups of females during the rut [17,20,40,44].

Summer ranges are often larger than winter ranges [47,78,119]. During winter, when deep snow hinders movements, mountain goats may be confined to small areas for long periods [17,20,24,44,62,63]. Near the Salmon River, Idaho, a band of 10 mountain goats lived for 3 months on a winter range <200 acres (81 ha) [17]. In the Swan Range, Montana, wintering mountain goats used 8.6 acres (3.5 ha) [20]. In the East Kootenay region of southeastern British Columbia, winter home range was <15% of their annual home range, indicating restricted movement during winter. During a winter when snow depth was 25% to 40% below average, winter ranges were 3.4 times larger for males and 2.2 times larger for females than during a winter when snow depth was within 10% to 15% of average [108]. In Colorado, home range sizes of an introduced mountain goat population did not differ between 2 summers, but summer home ranges were 8 times greater than winter home ranges. Winter range sizes were apparently not limited by deep snow [4].

Mountain goat home range sizes and movements may be modified by the presence of licks. In Colorado, mountain goat movements in summer seemed limited by licks occurring at one end of the study area. When a new lick was established at the other end of the area, movements expanded (Bailey unpublished data cited in [16]).

Population density: According to a review, there were an estimated 75,000 to 110,000 mountain goats in North America in 2003 [24]; about 33% occur in the United States [135].

According to a 1991 review, mountain goat densities range from 0.2 mountain goat/km^2 to 15.4 mountain goats/km^2 [89]. The highest mountain goat population density was reported on Running Rabbit Mountain in Glacier National Park, an area that was relatively wet and had numerous rocky outcrops and ledges at low elevation. The authors concluded that the highest mountain goat densities reported in published literature prior to 1985 were generally from expanding, introduced coastal populations; populations inhabiting environments with high precipitation; and populations inhabiting shallow snow areas with "suitable" size, slope, and distribution of rock outcrops and ledges [118]. In southeastern Alaska, southwestern Yukon, and northwestern British Columbia, the highest mountain goat densities occurred where precipitation was greatest [29].

Survival: Survival of mountain goats follows the general mammalian pattern of higher mortality for juvenile and senescent individuals and relatively low mortality for prime-aged individuals [121]. Male survival is generally lower than female survival [24].

Mortality is highest among neonates and kids. After 2 years of study, Smith [119] estimated that 67% to 71% of kids survived to 1 year old in the Bitterroot Mountains, Montana. In an introduced population near Buena Vista, Colorado, the mean number of kids that survived for at least 3 to 6 months ranged from 52% to 69% [10]. On Caw Ridge, survival of kids during 13 years was 87% to weaning and 64% to 1 year old. Variability in kid survival among years was high (38-92%). Survival was greater for males (92%) than females (85%) to weaning, but there was no gender difference in kid survival to 1 year. Kids that survived to 1 year tended to be heavier (30.6 pounds (13.9 kg)) in mid-July than those that did not

Ex013

survive (28.0 pounds (12.7 kg)) to 1 year [34].

Survival of mountain goat yearlings is intermediate between that of kids and adults [24]. In the Bitterroot Mountains, survival of yearlings during 2 years averaged 84%; survival of males ≥2 years old was 82%, and survival of females ≥2 years old was 87% [119]. On Caw Ridge, survival of yearlings during a 13-year period was high (males: 74%, females: 85%). Survival of females 2 to 7 years old averaged 92%, and survival of females 10 to 16 years old averaged 76% [34]. In coastal Alaska near Ketchikan, annual survival was 71% for yearlings; 95% for 2- to 8-year-olds (included hunting mortality, 99% if hunting mortality was excluded); and 68% for ≥9-year-olds (none of which was due to hunting) [121].

Weather: Severe weather causes mountain goat mortality. In Glacier National Park, kid mortality was 41% and yearling mortality was 44% after a severe winter, but kid mortality was 27% and yearling mortality was 15% after a mild winter [21]. In the Sapphire Mountains, Montana, mortality during a severe winter was 73% for kids and 59% for yearlings, while during a mild winter, mortality was 27% for kids and 2% for yearlings [111]. Total population declines of 82% to 92% occurred following severe winters in coastal British Columbia (Hebert and Langin 1982 cited in [135]). Wadkins (1967 cited in [78]) correlated mortality rates with snowpack on Nason Ridge in Washington and found that above-average snowpack was correlated with a 40% loss of kids and a complete loss of yearlings.

Kid production appears to be negatively associated with winter severity and spring snow conditions, particularly in increasing populations [2,67,78,128,129]. Several researchers in Idaho, Montana, and Alaska found lower age ratios (kids:older animals)—a measure of reproductive success—after severe winters. Their studies suggest high in-utero or neonatal losses due to severe winter weather [17,21,63,111,119]. In an increasing introduced population in the Sawatch Range of Colorado, Adams and Bailey [2] found a negative correlation between summer age ratios (kids:older animals) and previous spring (1 May) snow depths at high elevation during 13 years ($P<0.10$). However, a subsequent study of the same population covering 24 years reported that the correlation did not persist after the population stabilized. Although previous spring snow depths were not related to mountain goat summer age ratios over the 24-year period, snow depth 2 springs prior to birth was positively related to mountain goat summer age ratios ($R^2=0.69$, $P=0.01$) [10]. During a 5-year study of an introduced population on Klahhane Ridge, a positive relationship was found between reproductive rate and total winter precipitation 2 winters prior to birth ($r=0.93$, $P<0.05$) [127]. The amount of snow 2 winters or springs prior to birth may possibly affect the quality and/or availability of forage prior to ovulation [10,127]. During 6 years of below-average snow depth in the Sawtooth Range of northwestern Montana, there was no correlation between snow depth and kid:older animal ratios; thus, low snow depths apparently had little effect on kid survival [79]. While there are hazards in interpreting reproductive success from kid:adult ratios [34], this information may allow detection of large differences in reproduction [78].

Spring snow depth influences the timing of snowmelt and the initiation of vegetation growth. Late snowmelt likely increases mountain goat mortality, particularly of juveniles and senescent individuals, because it prolongs the period during which individuals must rely on stored fat. Year-to-year differences in the initiation of vegetation growth in spring likely affect the growth and survival of neonates because mothers are unable to produce sufficient milk when feeding on low-quality winter forage [34]. Low natality rates inferred from low kid:adult female ratios (about 40 kids:100 females) in the Bitterroot Mountains, Montana, were attributed to severe winter weather and delayed spring green-up [119]. On Caw Ridge during an 18-year study, cohorts born in years of high vegetation productivity, representing early springs, were of higher quality (body mass, social rank, and longevity) than cohorts born in years of

Ex014

low vegetation productivity, representing late springs. This suggests that kids born in years with early springs may benefit from early access to high-quality forage [54]. Conversely, a subsequent study on Caw Ridge found that the probability that kids would survive to weaning was lower when spring was early than when it was late [51].

Early springs may allow predators better access to mountain goat habitat during the first weeks after birth, when offspring are most vulnerable to predation, thus increasing offspring mortality [51]. Klein [83] reported that mountain goats in southeastern Alaska were most susceptible to predation in spring following kidding and in winter when snow was deep.

Mountain goat density and forage availability may affect mountain goat kid production and survival. On Caw Ridge, offspring survival during summer decreased with increased mountain goat population density: when density was about 1.8 times higher, survival was about 10% lower [51]. In an increasing population on Caw Ridge, a 13-year study found that kid survival (r=0.72, P=0.005) and population growth rate (r=0.61, P=0.26) were both positively correlated with the mass of yearling males, suggesting that yearlings were small and kids were less likely to survive in years when forage resources were fewer or of poor quality. No such relationships occurred with yearling female body mass, possibly because summer body mass gain was 25% faster for males than females. The authors surmised that forage availability and quality affected population growth, which was mostly independent of mountain goat density [34]. On Caw Ridge, kid mortality was low from February to May (close to 0%), suggesting that low food abundance in winter did not substantially contribute to kid mortality [35].

Solitary mountain goat in early September, Boulder Pass, Glacier National Park, Montana. Photo courtesy of Robin J. Innes, US Forest Service.

Life span: According to a 2003 review, the oldest mountain goats reported were an 18-year-old female and a 15.5-year-old male. However, few mountain goats survive >12 years [21,24]. During a 14-year study on Caw Ridge only 34% of yearling females and 5% of yearling males survived to age 13 [34]. In Olympic National Park, Taber and Stevens (1980 cited in [78]) calculated that the average age of death was 6.1 years among females and 3.5 years among males. Because mountain goat females produce typically 1 kid/year, longevity likely has an important effect on their lifetime reproductive success [24]. Festa-Bianchet and Cote [34] concluded that most female mountain goats on Caw Ridge have only 6 to 8

Ex015

reproductive opportunities over their lifetime.

DISEASES AND SOURCES OF MORTALITY:

Diseases and parasites: Ticks (e.g., Rocky Mountain wood tick (*Dermacentor andersoni*), winter tick (*D. albipictus*) and spinose ear tick (*Otobius megnini*)), biting lice (*Damalinia parallelus*), lungworms (*Protostrongylus stilesi* and *P. rushi*), nematodes (e.g., *Nematodirus maculosus* and *N. fillicollis*), and tapeworms (e.g., *Thysanosoma actinoides* and *Cysticercus tenuicollis*) infest mountain goats [62,99,110]. A 1983 review reported high mortality of kids in a mountain goat population heavily infested with nematodes in the northwestern Cascade Range [78]. Protozoan parasites in the genus *Sarcoscystis* occur in mountain goat muscle tissue. According to a review, in Washington 43% of mountain goats were infested, and in Alberta 73% were infested. As of 2000, it was unclear whether sarcocyst infections kill mountain goats [99]. White muscle disease resulting from selenium deficiency may kill mountain goats (Hebert and Cowan 1971 cited in [99]). Although mountain goats are infested with many parasites, Kerr and Holmes (1966 cited in [24]) found no evidence that parasitism has a strong effect on individual body condition, survival, or reproduction. As of this writing (2010), however, no studies had examined the ecological effects of parasites on mountain goats. Brandborg [17] did not consider parasites and diseases an important source of mortality in mountain goats, but he suggested that they may contribute to mortality during severe winters when animals suffer from malnutrition. See Johnson [78] and Toweill and others [135] for reviews of diseases and parasites affecting mountain goats.

Sources of mortality: Sources of mountain goat mortality include predators, hunting, and accidents. Snow depth and morphology may increase mountain goat susceptibility to predation, malnutrition, accidents, diseases, and parasites [138]. See Weather for more information on this topic.

Predators: A 2003 review concluded that predation is likely the most important cause of mortality in mountain goats [24]. Mountain goat predators include mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), gray wolves (*Canis lupus*), coyotes (*Canis latrans*), wolverines (*Gulo gulo*), American black bears (*Ursus americanus*), brown bears (*Ursus arctos*), and golden eagles (*Aquila chrysaetos*) [21,24,35,62,78,99,110]. The most important predators are mountain lions, gray wolves, and brown bears [24,42,78,110]. Coyotes and wolverines primarily consume mountain goat carrion [68,78,110], but anecdotal evidence suggests that they may attempt to kill mountain goats [20,24,48,111]. Golden eagles may be particularly important predators of <2-week-old kids [62,78].

Predation can be high in some populations. In west-central Alberta, 88% of annual juvenile mortality was due to predation by gray wolves, grizzly bears (*Ursus arctos horribilis*), and mountain lions [135]. Festa-Bianchet and others [35] suggested that because mountain goat densities on Caw Ridge were low, predation was likely incidental or opportunistic, and thus, unlikely to regulate the mountain goat population. Festa-Bianchet and Cote [34] stated that very few mountain goat populations are large enough to sustain or be a major food source for a population of predators, although an individual predator such as a mountain lion may specialize on mountain goats and affect a population's dynamics. In southeastern Alaska, gray wolves killed mountain goats, and mountain goat occurred in 53% of gray wolf scats. The authors attributed a decline in the mountain goat population during 5 years in part to gray wolf predation [42].

Hunting: Mountain goat population declines have been related primarily to overharvest [99]. For more information on this topic, see Population management.

Ex016

Accidents and other sources of mortality: Although a 2003 review concluded that accidents are not a frequent mortality factor in mountain goats [24], a study in southeastern Alaska reported that snowslides were the most common cause of nonhunting mortality [83], and a study in the Salmon River drainage, Idaho, found that snowslides were responsible for more accidental deaths than any other natural cause [17]. Climbing accidents, starvation, separation of kids from their mothers, motor vehicle accidents, and aggressive interspecific fighting, particularly during the rut, have also caused injury and mortality in mountain goats [17,21,24,78,110].

PREFERRED HABITAT:

- **Elevation**
- **Slope**
- **Aspect**
- **Escape terrain**
- **Forage site selection**
- **Movement corridors**
- **Cover requirements**

Mountain goats often forage in open, grassy alpine and subalpine habitats where they are most vulnerable to predation, whereas security from predation is highest in cliffs and ledges where food is relatively sparse. Thus, to avoid predators, mountain goats tend to select foraging sites within 1,300 feet (400 m) of steep, broken, rocky terrain—often called escape terrain—that includes rock ledges, outcrops, and cliffs. Shear, unbroken cliffs and slopes are unsuitable for mountain goats. Mountain goats use escape terrain for bedding throughout the year. They also use escape terrain as birthing sites. In summer, foraging mountain goats typically use alpine and subalpine meadows and rock outcrops. In winter, mountain goat habitat use is largely determined by snow depth and hardness, but typically foraging mountain goats select treeline rock outcrops, windblown alpine ridges, and shrubby and forested sites that lack persistent, deep or crusted snow. Suitable foraging sites in winter may be at lower elevations where snow is less abundant and less persistent, or they may be on windswept slopes or steep south-facing slopes where snow sloughs and/or melts rapidly. Thus, mountain goats select habitats for elevation, slope, aspect, and forage availability. Throughout the year, storms may drive mountain goats to sheltered microsites in caves and under overhanging ledges, and individual thermoregulatory needs may influence aspect use. Mountain goats use forested habitats to travel between cliffs, to access mineral licks, for foraging, and as movement corridors between summer and winter ranges. Mountain goat habitat use may be modified by the presence of predators; group size; and individual age, gender, and social status [16,24,43,146].

Elevation: Mountain goats occur mainly from treeline to high-elevation alpine meadows. They also occur near sea level on coastal British Columbia and Alaska and on open cliffs along river canyons throughout their range [11,24,40,57]. Mountain goats typically summer at high elevations. In winter, mountain goats may move to elevations lower than their summer range to escape deep snow, but many populations winter at elevations the same as or higher than those of their summer range. In winter range, mountain goats often seek small, protected areas with steep, snow-shedding slopes, windblown slopes with shallow snow, or warm south-facing slopes where snow melts first [135]. In summer on White Chuck Mountain in the Cascade Range, Washington, mountain goats preferred areas >4,900 feet (1,500 m) elevation. In winter, they preferred lower elevations (3,000-3,900 feet (900-1,200 m)) [140]. Because Idaho has little alpine habitat, most mountain goat herds occur in subalpine habitats near treeline at

Ex017

elevations ranging from 7,000 to 10,000 feet (2,000-3000 m) [132]. In the Sawatch Range, Colorado, mountain goats wintered in alpine (12,140-13,220 feet (3,700-4,030 m)) and subalpine (9,190-11,940 feet (2,800-3,640 m)) areas, but habitat use within each area differed according to snow depth. During a year of low snow accumulation, mountain goats used all elevations similarly, whereas during a winter with deep snow, they avoided elevations >11,004 (3,354 m) [1]. A review stated that mountain goats in coastal British Columbia wintered from sea level to about 4,500 feet (1,400 m), although the majority wintered from about 1,200 to 4,500 feet (400-1,400 m). Within about 20 to 30 miles (30-50 km) of the ocean, mountain goats in British Columbia wintered at low elevations because snow was deep at high elevations. Beyond 20 to 30 miles from the ocean, they wintered at high elevations (>6,000 feet (1,800 m)) because snow was generally shallow due to wind [60]. In the East Kootenay region of southern interior British Columbia, mountain goats often wintered on snow-free ridgetops at >7,000 feet (2,100 m) and in Engelmann spruce-subalpine fir, Douglas-fir, and ponderosa pine forests at midelevations [60]. In contrast, in the Grand Canyon of the Stikine River in northwestern British Columbia, mountain goats occurred from 768 to 4,823 feet (234-1,470 m). In summer when temperatures were highest, they occurred at low elevations along canyon walls; in winter, they occurred along the canyon rim at high elevations due to icy conditions in the canyon and the presence of thermal cover in adjacent forests [40]. For more information on this topic, see Seasonal movements and migration.

Slope: Mountain goats typically select habitats on steep terrain [16]. They typically prefer slopes that are >30° (e.g., [43,59,78,120]). In southeastern Alaska, most mountain goats (70%) preferred slopes 31° to 50° in winter and avoided slopes <30° [120]. On White Chuck Mountain, Washington, mountain goats preferred habitat on slopes >50° year-round [140]. On the Beartooth Plateau in northwestern Wyoming, mountain goats preferred slopes ≥37° year-round more than expected based upon availability [59]. In coastal British Columbia in winter, male mountain goats preferred slopes between 41° and 60°, and females preferred slopes from 41° to 70° [130].

Aspect: Mountain goats use all aspects (e.g., [19,60]). Aspect use is constrained by local topography and direction of the prevailing wind [19,19,60]. The aspects that mountain goats use are also constrained by the time of snowmelt and resultant forage availability and the mountain goat's thermoregulatory needs. In winter, mountain goats use snow-free south- and west-facing slopes most frequently. In summer, they select north- and east-facing slopes most frequently [78,102,110,111,119,120]. In general, mountain goats thermoregulate by selecting south-facing slopes when temperatures are low and north-facing slopes, snowfields, and windy sites to cool off [43,126,140]. On Klahhane Ridge, mountain goats foraged on south-facing aspects in May and June. At this time, deep snow limited their use of north-facing slopes. Mountain goats fed mostly on cool, mesic north-facing aspects when these slopes were snow-free from July to mid-August. Although all aspects were available in midsummer, mountain goats apparently preferred to forage on north-facing slopes because forage grew most rapidly there due to snowmelt. Mid-August to November, when temperatures during the day decreased and precipitation increased, mountain goats fed on all aspects but tended to use south-facing slopes during cool weather and north-facing slopes during warm weather [102]. An earlier study on the Klahhane Ridge also reported that during cool summer days, mountain goats tended to use south slopes, and during hot summer days they tended to use cooler, north slopes [126]. Most mountain goats in Montana wintered on the same ranges in summer and winter, but in winter they used south- and west-facing slopes where the wind exposed vegetation. However, where windblown windward slopes were unavailable in winter, mountain goats moved to low-elevation south-facing cliffs and ledges [19]. In the Sapphire Mountains, mountain goats apparently used habitats with respect to forage availability, using north- and east-facing slopes most frequently from July to October and south- and west-facing slopes most frequently in November. North- and east-facing slopes

Ex018

had the greatest supply of snow, water, and succulent forage during summer and early fall, and food availability was greatest on south- and west-facing slopes in late fall and winter [111]. In winter when deep snow restricted movements in the Kenai Mountains, Alaska, most mountain goats were found on south-facing slopes at or below treeline [98]. In summer in the Sawatch Range of Colorado, introduced mountain goats increasingly selected habitats on northern aspects and at higher elevations as the summer progressed, possibly attracted by the green forage; sites on other aspects and at lower elevations were devoid of snowfields and very dry by late summer (Adams 1981 cited in [10]). For more information on this topic, see Elevation.

Escape terrain: When approached by a large mammalian predator, a mountain goat will remain in or move to steep and broken terrain [43]. Predation risk appears highest in forests or in krummholz, which provide cover for ambush predators [24,34]. On Caw Ridge, predation appeared to be the main cause of neonate and kid mortality, and most predation occurred in forests or in krummholz where some tree cover was present [35]. In Jasper National Park, mountain goats left crags and high grasslands and traveled "long distances" through forests to access dry mineral licks. Mountain goat kills were often found adjacent to the licks [26].

Most studies indicate that mountain goats select foraging sites close to escape terrain (e.g., [16,21,43,139]). On the Beartooth Plateau in northwestern Wyoming, mountain goats preferred areas <1,300 feet (400 m) from cliffs and avoided areas farther away [59]. On White Chuck Mountain, Washington, mountain goats preferred meadows, rocky benches, and chutes within 1,300 feet (400 m) of cliffs year-round [140]. In southeastern Alaska, 80% of annual mountain goat observations were within 1,300 feet (400 m) of cliffs [120]. Mountain goats in an introduced population in South Dakota spent most of their time (spring: 69%; summer: 65%; fall: 49%) on open slopes, meadows, and clearcuts that were within 160 feet (50 m) of granite outcrops [12]. In a canyon along Pinto Creek, Alberta, the size and number of cliffs within an area determined cliff use by mountain goats, with mountain goats preferring large cliffs grouped with other cliffs [57].

Mountain goats appear to make trade-offs between their competing needs for food and protection from predators [43,139]. Mountain goat forage availability tends to be highest in open, grassy areas where predation risk is high; food is relatively sparse on cliffs and rocky terrain, where security is highest [43,139]. Von Elsner-Schack [139] contended that food and safety for mountain goats occur on a continuum in which food increases with increasing grass cover and security increases with increasing rock cover. On Caw Ridge during summer, females spent 60% of their time foraging within 260 feet (80 m) of escape terrain. During most months of the summer (July-September), forage abundance at distances <260 feet from escape terrain was lower than forage abundance at distances >260 feet [50]. In southeastern Alaska, 75% of mountain goat observations in alpine habitat were in unproductive, steep and broken terrain, which was more than expected based upon availability ($P<0.001$). When proximity to escape terrain was taken into account by including only foraging sites within 160 feet (50 m) of escape terrain, Fox [43] found a positive correlation between available forage biomass above the snow and mountain goat habitat use ($P<0.001$). Mountain goats used the "best predator avoidance habitat" 77% of the time, the best food acquisition habitats near escape terrain 18% of the time, and the best habitats for thermoregulation the remaining time (6%). This indicated that predator avoidance was the most important determinant of mountain goat habitat selection, followed by food acquisition; thermoregulation was of minor importance [43].

Mountain goat use of habitats close to escape terrain varies according to predator abundance, individual

gender, and group size (e.g., [43,47,108,139]). An introduced population in the Gore Range, Colorado, used habitats without escape cover. They had little access to escape terrain, with the nearest escape terrain 5 miles (8 km) away; large mammalian predators were absent from the area [67]. On Mt Evans, Colorado, where predator density was low, some mountain goats were observed >0.6 mile (1 km) from escape terrain, although most mountain goats were closer [47].

Males apparently are more tolerant of predation risk than females and therefore may have access to higher quality and/or quantity forage than females during spring and summer. Nursery bands rarely wander far from escape terrain or below treeline, whereas adult males often forage in conifer forests remote from escape terrain [6,24,34,130,135]. Females with young appear more reluctant to use habitat far from escape terrain than females without young [50,126]. On Caw Ridge in summer, male groups were seen in forested habitat 45% of the time, apparently taking advantage of abundant food resources in forests in summer, whereas nursery groups were seen in forested habitat only 9% of the time [34]. In June, when offspring were about 1 month old and particularly vulnerable to predation, females with young foraged an average of 70 feet (20 m) closer to escape terrain than females without young, but there was no difference in July, August, or September [50]. In the Sapphire Mountains, Montana, males were more mobile than females and often used habitat that was forested and lacked escape terrain, whereas females used open areas with escape terrain most often [111]. Near Haines, Alaska, male and female mountain goats occurred at similar elevations, but females used steeper slopes that were more rugged and closer to cliffs than males [141].

Small groups may use escape terrain more frequently than large groups. On Mt Hamell in Alberta, small groups (≤4 individuals) used escape terrain (gravel and rock habitats) more than large groups (>4 individuals). Large groups used grassy slopes, ridges, and alpine meadows most often when active but used rock habitats most often for resting. Small groups used grasslands and gravel areas equally when active and rock and gravel areas when resting. Small groups apparently used gravel habitats most because gravel habitats were located between grass and rock habitats, thus providing access to both food and escape terrain but not the best of either. This suggested that larger groups had increased security [139]. In the Sawatch Range, Colorado, group sizes were larger, and fewer mountain goats were solitary above treeline (mean group size: 10.4; solitary goats: 1%) than below treeline (mean group size: 3.1; solitary goats: 12%) [1]. On Klahhane Ridge, the largest groups (≥20 mountain goats) often occurred in open meadows distant from escape terrain [74]. Band size increases with population density (see Social behavior) [74]. This suggests that population density indirectly influences use of escape terrain.

Forage site selection: Mountain goat foraging sites vary by season. Mountain goats shift habitat use in response to changes in food availability because of snow accumulation, moisture, wind, and solar exposure [146]. Typical foraging sites are open meadows near cliffs. In summer, nursery bands use all foraging sites that are close to escape terrain from treeline to the limit of vegetation. In winter, mountain goats of both genders are restricted to foraging sites near escape terrain at and just below treeline that are either windswept or on west- or south-facing slopes. Bachelor groups and solitary males may use forested areas near treeline throughout the year [24]. In the Crazy Mountains, Montana, the order of importance of habitat as year-round feeding areas to an introduced mountain goat population was grassy slide-rock slopes, ridgetops, alpine meadows, mixed-conifer forests, and cliffs [115]. On Klahhane Ridge in summer, mountain goats foraged mostly in open meadows (55%) and on scree or talus slopes (32%). Open meadows were most heavily used because they had the highest herbaceous cover of any available habitat [126]. In another study on the Klahhane Ridge during the snow-free period (May-November), mountain goats grazed most frequently in varileaf phacelia-edible thistle (*Phacelia heterophylla-Cirsium*

edule) meadows on steep, erodible slopes (30-36°) with moderate (46%) plant cover; in varileaf phacelia-western yarrow (*Achillea millefolium*) meadows on very steep, active scree slopes (35-40°) with low (17%) plant cover; in black alpine sedge-showy sedge (*Carex nigricans-C. spectabilis*) turfs on stable soil in late-melting (late-June to late July) snow basins with high (73%) plant cover; in well-drained broadleaf lupine (*Lupinus latifolius*)-showy sedge associations on stable soil in late-melting snow basins with high (74%) plant cover; and in showy sedge-arnica (*Arnica* spp.) associations on a moist site at low elevation in a north-facing cirque with moderate (55%) plant cover [102].

Mountain goats exploit phenological differences among plants to obtain the most nutritious forage. They often move to low elevations in spring and seek green forage at high elevations in summer (see Elevation). They use different aspects, depending on timing of snowmelt and plant phenology. In spring, mountain goats feed in snow-free habitats on south aspects. As the summer progresses, mountain goats follow receding snow lines and the emergence of young, succulent vegetation to habitats on west aspects. By late summer to early fall, they use north and east aspects on steep, shaded ledges with melting snow (see Aspect) [16,137]. In spring in the Swan Range, Montana, mountain goats foraged mostly on south- and west-facing cliffs where vegetation, primarily grasses and sedges, was first exposed from snow. In summer, mountain goats moved among cliffs, meadows, and ravine-wet meadows, following vegetation green-up, particularly that of succulent forbs and shrubs. In fall, mountain goats concentrated foraging on bunchgrasses in dry meadows. In late fall and early winter, deep snow restricted mountain goats to cliffs where snow was shallow. In mid- to late winter, mountain goats increased use of snow-free ridgetops, although they continued to use cliffs where wind and steep terrain prevented deep snow accumulations [20].

In winter, mountain goats often select foraging sites to avoid deep snow. The influence of snow accumulation on mountain goats in alpine and low-elevation forest sites varies. Relative depths in alpine sites are largely wind determined, while those at lower elevations are most affected by conifer cover, slope, and aspect [43]. Conifer cover may benefit wintering mountain goats by intercepting and redistributing snow and providing access to browse and arboreal lichens [16]. Gilbert and Raedeke [45] summarized winter mountain goat habitat use by region and concluded that mountain goats in coastal regions occupy cliffs in dense forests, mountain goats in the Cascade Range occupy cliffs in clearcut and open forests, and mountain goats in interior regions occupy cliffs and nonforested ridges. Thus, in general, forests appear particularly important as foraging sites on winter ranges in coastal regions. Mountain goats in wet interior regions, where they occur year-round along river canyons and on cliffs interspersed among forests, may also benefit from conifer cover in winter (e.g., [17,20,43,45,57,60,108]). In southeastern Alaska, mountain goats used conifer forest on steep slopes with rock outcrops as winter range [96]. In north-central British Columbia, they used mature (141-250 years old) subalpine fir/interior white spruce forest with tall (>93.5 feet (28.5 m)) trees and high canopy closure (46-65%) during winter. In spring and summer, mountain goats used intermediate-aged (81-140 years old) forests with short (33.4-63.6 feet (10.5-19.4 m)) trees and moderate canopy closure (26-45%) [136]. At 3 sites near Ketchikan in southeastern Alaska in winter, they used sites with higher timber volume, at lower elevations, on steeper slopes, more southerly aspects, and shorter distances to cliffs than unused sites [122]. In the Stikine River drainage in northwestern British Columbia, mountain goats used rock habitats (33% of observations), open woodlands (28%), burns (24%), closed forests (13%), scrublands (2%), and grasslands (0.3%). Habitats with trees were important for cover, particularly in winter; burns for foraging, particularly in spring and fall; and rock habitats for escape terrain year-round [40].

Conversely, conifer habitats may collect more snow than other available habitats and thus not be used by

mountain goats. In the Sawatch Range, Colorado, mountain goats in alpine areas preferred fell-field, turf, meadow, marsh, and rock habitats, which were also the most abundant habitats above treeline. Rock habitats included cliffs, outcrops, scree, talus, and boulder fields. Other available habitats above treeline —willow, sparse conifer (<50% canopy cover), and dense conifer (>50% canopy cover) stands—tended to collect snow and were not used by mountain goats [1]. Increased risk of predation may also limit mountain goat use of dense conifer forests, although mountain goats often use sparse conifer stands [16].

Snowfall may not be the overriding influence in mountain goat habitat use in some areas. In the north-central Cascade Range, mountain goats used open habitats such as clearcuts, open forests, and wooded cliffs in winter, and habitat use did not appear to be related to snowfall patterns [45]. In the East Kootenay region of interior British Columbia, mountain goats wintering in areas of deep, moist snowfall did not use mature forest stands more frequently than mountain goats in areas of shallow, dry snow, even though snow depths in the shallow-snow area averaged about 60% of depths in the deep-snow area [108].

Because of the mountain goat's preference for habitats close to escape terrain, some researchers have concluded that mountain goats showed no apparent preference for any habitat as long as it occurred on steep terrain or near cliffs and talus [146]. On the Klahhane Ridge, there was no relationship between forage production and mountain goat grazing intensity or frequency. Instead, mountain goats preferred meadows close to rocky outcrops regardless of availability of preferred forage species [102]. At Caw Ridge, mountain goats did not select sites according to seasonal differences in forage biomass or peak forage protein during a 2-year study. Consequently, dispersion of nursery bands could not be explained by local differences in forage quality or quantity (Haviernick 1996 cited in [34]). Mountain goats in east-central Idaho appeared to select winter habitat primarily for its slope and snow-shedding ability and not for the availability of forage [85]. Other researchers contended that mountain goats make trade-offs between their competing needs for food and protection from predators [43,139]. For more information on this topic, see Escape terrain.

Socially subordinate individuals may be forced to use less preferred foraging sites. Overt aggressive behavior toward subordinates increases in winter when resources are limited and declines in summer when resources are abundant [74]. In the Pahsimeroi River drainage in Idaho, dominant adult females excluded subordinates from the "best" winter feeding sites (i.e., steep cliffs with shallow snow) [77]. In the Bitterroot Mountains, Montana, socially dominant adult females occurred on snow-free cliff ledges, while subordinates were on "less optimal" habitat [119]. In western Montana, the level of aggression between males and females increased when males and females were concentrated on winter range. This apparently resulted in adult males avoiding the "best" wintering areas [111]. Dominant animals also exclude subordinates from preferred sheltered microsites [85] and bedding sites [24]. Kids and older offspring associated with dominant nannies have access to foraging areas, bedding sites, sheltered microsites, and salt licks with their mothers, whereas orphaned kids or solitary young are subject to high intraspecific aggression at these sites [20,39,77,95]. As a result, the presence of a mother is hypothesized to increase survival of kids, although orphaned kids can survive [39,111].

Movement corridors: Mountain goats use habitat habitually, and trail systems in forests between cliffs are important linkages between mountain goat habitats. Within a canyon along Pinto Creek, Alberta, mountain goats traveled between cliffs using a network of trails in lodgepole pine and white spruce forests and riparian habitats [57]. In Jasper National Park, mountain goats left crags and high grasslands and traveled "long distances" through forests to access dry mineral licks [26]. Cite (personal observation cited in [24]) reported that when mountain goats crossed forested valleys, they typically used traditional

Ex022

and well-marked trails. For more information on this topic, see Habitat management.

Mountain goats may travel though unusual habitats during migration between summer and winter ranges, during dispersal, and to visit mineral licks. In the Red Butte Range in northwestern Montana, mountain goats were occasionally observed moving through burned areas with abundant windfalls and snags, dense stands of timber, and lowland valleys between ranges where there was no escape terrain [17]. Williams [142] documented mountain goat dispersal across 2.5 miles (4 km) of prairie habitat from an introduced population on Square Butte, an isolated volcanic formation in the prairies of central Montana. Klein [83] stated that bodies of water several miles across, extensive ice fields, and broad timbered valleys were barriers to mountain goat movements in Alaska [83]. However, in the Kenai Mountains, Alaska, mountain goats crossed large ice fields and major drainages when migrating between summer and winter ranges [98]. Rideout [111] reported that mountain goats swim across large rivers and lakes.

Cover requirements:

- Sheltered microsites
- Bedding and dust-bathing sites
- Birthing sites
- Lick sites

Sheltered microsites: Mountain goats live where weather is typically very harsh (high winds, low temperatures) and snow occurs 8 to 9 months of the year [24]. During periods of inclement weather, heat of day, and when bearing their young, mountain goats seek shelter in caves and under overhanging ledges and trees [19,24,62,78,140]. In southeastern Alaska, rock overhangs creating an "amphitheater" were used as shelter in winter for a "number of years" [83]. Mountain goats on Klahhane Ridge often sought shelter from rain by using krummholz or conifer forest [126]. In southeastern Alaska, Fox [43] observed that mountain goats only used sheltered microsites during the most severe winter weather (<14 °F (-10 °C) with high wind).

Protective microsites such as caves are usually limited, and mountain goats compete for them. Dominant animals utilize the "best" microsites. In Idaho, subordinate animals moved into preferred sites after hunters removed dominant animals. Because the best microsites were apparently selected for their characteristics as shelter rather than for availability of forage, food was generally thought to be limiting to mountain goats at these sites [85].

Bedding and dust-bathing sites: Before lying down, mountains goats often dig bedding sites with their front hooves [24,110]. Bedding sites are used for resting and ruminating [19,20]. All individuals in a group usually use the same areas to bed [20,24]. Bedding sites are used repeatedly by different animals [19,24]. Continual use of bedding sites over many years denudes large areas of vegetation [17,20]. Mountain goats compete for individual bedding sites. According to a review, about 36% of all aggressive interactions among mountain goats occur at resting-ruminating sites, where mountain goats attempt to displace each other to occupy the "best" bedding sites (Cote unpublished data cited in [24]).

In summer, mountain goats use some bedding sites for dust-bathing [19,20,110]. Houston and others [74] commented that it is often not possible to distinguish between bedding and dust-bathing sites. Mountain goats select bedding sites near or in escape terrain with a view of the surroundings [17,19,20,24,146]. On hot days, they frequently bed in the shade or on snowbanks [17,19,20,110]. On Klahhane Ridge in

Ex023

summer, mountain goats bedded in rocky bluffs (25%), snow (24%), bare ground (21%), and open meadows (14%). Rocky bluffs were presumably preferred for bedding because of their escape value, snow and bare ground for their thermoregulatory value, and open meadows for resting between feeding bouts [126]. In the Swan Range, Montana, 95% of mountain goats bedded in cliff habitat year-round, specifically on upper portions of rock outcrops, often with steep cliff walls at their backs. Because summer bed sites were often used to dust bathe, summer beds were often on open hillsides with loose, dry soil remote from cliffs, whereas winter beds were usually beneath overhangs and sheltered from weather [20].

Birthing sites: Pregnant females isolate themselves from other mountain goats to give birth. Birthing sites or kidding areas are typically rocky outcrops or cliffs used as escape terrain [12,24,110]. They are usually on winter ranges and are used year after year [16]. On Mt Hamell in Alberta, use of rocky habitats increased during parturition [139]. Conversely, on Caw Ridge, only 30% of parturition sites were on cliffs, probably because of the limited availability of cliffs. Rather, most birthing sites were within 300 feet (100 m) of treeline, and some were in forests [34].

Lick sites: Mineral licks used by mountain goats provide sources of minerals (e.g., sodium, magnesium, and sulfur) and buffering compounds (carbonates and clays) important to mountain goat nutrition and digestion [8]. Licks used by mountain goats may occur naturally or be man-made [8,9,19,131]. Natural licks used by mountain goats may be dry-earth or wet licks, although mountain goats appear to prefer dry-earth licks [8,61,107].

Mountain goats use licks throughout the day and night [9] and throughout the year [107,111], with use peaking during spring and summer [8,9,17,61,111,126,131]. Males and females typically use licks with similar frequency [9,107], but males generally use licks earlier in the year than females with young [61,107,111]. In southeastern British Columbia, males began using licks in April, and females with young used licks in early June [61]. In another study in a different region of southeastern British Columbia, most males visited licks from early May to late June, and most females visited licks from early June to mid-July [107]. In Colorado, male mountain goats used man-made licks 2 weeks earlier than females [131]. Female lick use appears to be delayed by parturition [9,61].

Mountain goats frequently travel long distances from summer ranges in alpine habitats to reach licks, which are often at low elevation [107,110]. To access licks, they generally travel along traditional trails [107], which often traverse large forested areas. Mountain goats often use rocky bluffs within the forests, from which they make periodic excursions to lick sites [9,61,107]. In the East Kootenay region, mountain goats moved up to 10.7 miles (17.3 km) to visit licks [107]. In the Gore Range, Colorado, mountain goats traveled up to 8 miles (12 km) to access a lick [67]. Mountain goats may travel to licks multiple times each year [67,107,111]. Mountain goats in northern British Columbia traveled at least 2 miles (3 km) over 2,300 feet (700 m) elevation from their alpine foraging habitats to dry licks along streams or riverbeds that were close to steep, rocky bluffs and cliff banks [9]. In southeastern British Columbia in early spring through summer, mountain goats used high-elevation sites, feeding at and above treeline. They left these high-elevation areas beginning in May and traveled from 2 to 15 miles (3-24 km) to licks, passing through Douglas-fir forests to access low-elevation rocky bluff areas in the forests that occurred close to lick sites. Mountain goats often remained in the bluffs for several days, traveling repeatedly to the nearby lick sites [61].

FOOD HABITS:

Ex024

Diet: Along the continuum from grazers to browsers, mountain goats are classified as intermediate or mixed feeders and can switch from a diet composed primarily of grasses to one of browse [24,28]. In a review, Johnson [78] commented that the "most predictable feature of mountain goat diets is their variability". Mountain goats are generalists and usually consume foods according to availability [24,96,99]. Mountain goats eat the flowers, stalks, seeds, and pods of grasses and forbs. They eat the stems, leaves, and bark of trees and shrubs. They also eat lichens, mosses, and ferns and dig up belowground plant structures such as fern rhizomes, roots of perennial forbs, bulbs, and tubers [20,24,63,74]. Mountain goats select young, highly nutritious plant parts when available, preferring flowers, seed heads, and growing leaves or leaf blades. The proportion of browse in mountain goat diets often increases during severe winter weather or when other forage is unavailable [74].

According to a 1983 review, in summer, mountain goats consume 12% to 82% grasses, 14% to 64% forbs, 0 to 1% conifers, 0 to 70% shrubs, and 0 to 3% lichens, mosses, and ferns. In winter, they consume 1% to 90% grasses, 0 to 18% forbs, 0 to 73% conifers, 1% to 47% shrubs, and 0 to 28% lichens, mosses, and ferns [43]. A 1994 review summarized 10 studies on feeding habits of mountain goats and found that summer diets averaged 52% grasses, 30% forbs, and 16% browse. Preferred plants in summer were bluegrass (*Poa* spp.; 14%), sedge (10%), wheatgrass (Triticeae; 9%) bluebell (*Mertensia* spp.; 6%), fescue (*Festuca* spp.; 5%), hairgrass (*Koeleria* spp.; 5%), and willow (*Salix* spp.; 4%). In winter, the average diet contained less biomass from forbs (8%) and more from browse (32%). The preferred plants were fescue (18%), sedge (8%), wheatgrass (4%), bluegrass (4%), sagebrush (*Artemisia* spp.; 3%), hairgrass (1%), and willow (1%) (Laundre 1994 cited in [24]).

In winter, forage availability, and thus mountain goat diet, changes with snow depth and hardness. When snow is shallow, mountain goats paw through it to reach understory vegetation but also browse shrubs, conifers, and lichens that protrude from the snow [20,21,56]. Deep snow can limit mountain goat use of forage to that which protrudes from the snow or cause mountain goats to move to areas with shallow snow [3,21]. On ranges where windblown slopes and ridgetops are available in winter, grasses and sedges constitute a high proportion of the diet. On coastal ranges, conifers and shrubs that protrude above the snow provide most of the winter diet [99]. When forage is limited in winter, mountain goats may eat more twigs and needles of conifers, such as lodgepole pine [40], Engelmann spruce [3], subalpine fir [20,111,115], whitebark pine [111], ponderosa pine [19], common juniper (*Juniperus communis*), Rocky Mountain juniper (*J. scopulorum*) [19,20,111], western yew [20], Douglas-fir [3,19,20], western hemlock, mountain hemlock, and Alaska-cedar [41]. Stomach contents of an introduced population in the Crazy Mountains, Montana, averaged 25% conifers in winter and 13% conifers in spring, but in summer and fall conifers constituted only trace amounts of the diet [115]. In old-growth western hemlock, Alaska-cedar, and Sitka spruce forests on the Cleveland Peninsula in southeastern Alaska, mountain goat use of trees, particularly conifers, increased with increasing snow depth, while use of grasses, forbs, ferns, and shrubs decreased [41]. Brandborg [17] reported heavy use of whitebark pine and subalpine fir as "emergency forage" in years when deep snow made other forage unavailable. In Montana, mountain goats that died from malnutrition usually had large amounts of conifer needles in their stomachs [19]. In contrast, in alpine habitat in the Sawatch Range, Colorado, conifers constituted more of the mountain goat's diet during a mild winter than during a severe winter. During the severe winter, deep snow restricted mountain goats to windswept ridges resulting in increased consumption of grasses and sedges and reduced consumption of woody plants and forbs. Woody plants and forbs tended to occur in krummholz and swales that collected snow [3]. Similarly, mountain goats wintering in the Swan Range, Montana, mostly consumed grasses and sedges on windblown slopes because most shrubs were covered by deep snow and were therefore unavailable [20].

Ex025

Deep snow may be particularly deleterious to young mountain goats. Young mountain goats have difficulty pawing through deep and/or crusted snow and often feed and bed in craters pawed and utilized by older animals, particularly their mothers. Kids and yearlings were frequently observed feeding after older mountain goats had bedded following a feeding session [21]. On Klahhane Ridge, yearling mountain goats spent more time feeding and less time bedding than any other age class. Kids spent less time feeding and more time bedding than other age classes [126].

Mountain goat kid near Logan Pass, Glacier National Park, Montana. Photo courtesy of Rachelle Meyer, US Forest Service.

Use of lichens and mosses by mountain goats often increases in winter, particularly during deep snows. In old-growth forests on the Cleveland Peninsula in southeastern Alaska, lichens (e.g., witch's hair lichen (*Alectoria* spp.), bear lichen (*Usnea* spp.), and lung lichen (*Lobaria* spp.)) and mosses (e.g., feather moss (*Hylocomium* spp.), goose neck moss (*Rhytidiadelphus* spp.), and toothed sphagnum (*Sphagnum cuspidatum*)) constituted 35% of the diet when snow was <20 inches (50 cm) deep in open areas, 49% when snow was 20 to 59 inches (50-150 cm) deep, and 57% when snow was >59 inches deep [41]. Mosses and lichens constituted 60% of the winter diet in the Black Hills, South Dakota [56]. Conversely, in the Crazy Mountains, Montana, mosses, lichens, and ferns constituted 3% of the diet of an introduced mountain goat population by volume in summer, but in winter they constituted only trace amounts [115]. In the north-central Cascade Range, where mountain goats mostly used open habitats such as clearcuts and open forests in winter, mountain goats only consumed an average of 3% lichens and mosses and 6% ferns during the 2-year study; instead, they consumed mostly conifers (45%) and shrubs (22%). Lichens and mosses may be more important in mountain goat winter diets in coastal populations than in interior populations [45].

Mountain goat forage quality is highest during late spring and early summer, when rapid plant growth occurs. Forage quality declines over summer and fall as vegetation matures, and it is lowest during winter, when plants are dormant. Forage quantity is greatest in midsummer and most limited during winter, when mountain goat distribution is constrained by deep snow and mountain goats feed on a less diverse, fixed quantity of dormant plants [74]. Winter forage abundance is often considered most limiting to mountain goat populations (e.g., [17,71]), but spring weather or timing of access to new plant growth

Ex026

in spring may be more important than winter conditions (see Weather) (Festa-Bianchet personal communication cited in [94]).

Water: Mountain goats drink water and eat snow [40,110,126]. Water is not a limiting factor on most mountain goat ranges because springs, snow, and abundant run-off from melting snowbanks are usually available year-round [16,17,19,83,90]. However, water availability may restrict mountain goat movements and habitat selection in warm, dry southern parts of the species' distribution [16,78]. In the Pasayten Wilderness, northern Cascade Range, Anderson [6] observed daily movements to water. Lack of water in July caused mountain goats to move to areas with water [6].

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
Information on state- and province-level protection status of animals in the United States and Canada is available at NatureServe, although recent changes in status may not be included.

MANAGEMENT CONSIDERATIONS:

- **Population status and threats**
- **Habitat management**
- **Population management**

Population status and threats:

Population status: Mountain goats declined in much of their historic range due to overhunting following the arrival of European immigrants. In the mid-1900s, mountain goats were reintroduced in parts of their native range where they had been extirpated in Alaska, Idaho, Montana, Washington, and Alberta [24,34]. Throughout the 1900s mountain goats were also introduced in some areas outside of their known historical range: on Baranof, Chichagof, and Kodiak islands in Alaska; on the Olympic Peninsula in Washington; in the San Juan, Gore, and Collegiate ranges in Colorado; in the Wallowa Mountains in Oregon; in the Greater Yellowstone area of Montana and Wyoming and in other parts of central and south-central Montana; in parts of southern Idaho such as along the Salmon River; in the Black Hills region of South Dakota; in several mountain ranges in northeastern Utah; and in the Ruby Mountains, northeastern Nevada [24,34,89,110]. Mountain goats were introduced to these areas for trophy hunting [110].

Mountain goats introduced outside the species' native range have thrived on many sites because predators are absent, range conditions are good, and climates are relatively mild [24]. Introduced mountain goats in Olympic National Park affect native ecosystems by creating bedding and dust-bathing sites that disturb soil and vegetation over large areas and by changing the abundance and composition of plant communities by foraging on preferred species [102,116,117]. Because of their negative impacts on nonnative range in Olympic National Park, managers have attempted to reduce or eliminate mountain goat populations there [76]. According to a 2007 review, little is known about mountain goat's relationship to bighorn (*Ovis canadensis*), Kenai Dall (*O. dalli kenaiensis*), or Stone (*O. dalli stonei*) sheep in areas where both species are native, but some introduced populations of mountain goats are suspected to compete for forage or habitat with bighorn sheep populations [28,34].

Ex027

Threats: Threats to mountain goat populations include overharvesting, particularly of females; increased human disturbance in formerly isolated habitats; reduction in forage quantity and quality because of successional changes in habitats from fire exclusion; habitat fragmentation due to human land uses, habitat succession, and climate change that may isolate populations; and tree removal in forested winter range (see Habitat management) [15,34,146]. To address these issues, Wisdom and others [146] recommended the following management practices: 1) reducing human activities in mountain goat habitats, particularly where mountain goat populations are static or declining, specifically by regulating the frequency and height of low-flying aircraft over mountain goat herds; 2) restoring quality and quantity of forage, where forage has declined because of successional changes, by thinning forest understories and using prescribed fire to improve forage and provide corridors between isolated herds; and 3) reducing fragmentation in historical ranges by maintaining connectivity among mountain goat habitats.

Human disturbance: Mountain goats are sensitive to human disturbance [24,34]. They may habituate to human disturbance in some areas, but where disturbance is unpredictable, mountain goats tend to be alarmed by disturbance [34,138]. Potentially adverse effects of disturbance on mountain goats included altered movements, range abandonment, increased vulnerability to predation, increased human access for hunting, and increased stress. High stress levels associated with disturbance have been suggested as a cause of decreased birth and recruitment rates and reduced winter survival in mountain goat populations. High stress levels may also cause a reduction in an individual's ability to fend off parasites, bacterial infections, and other diseases. Malnutrition and mineral deficiency—specifically selenium deficiency—can deleteriously affect mountain goats, especially when compounded by additional stresses [79,135,140].

A 1998 review of human disturbance on mountain goats concluded that human disturbance, such as aircraft and motor vehicle use, on mountain goat winter ranges is rare due to the steepness, ruggedness, and low snow accumulations of mountain goat winter habitats. However, the author noted that the use of helicopters, in particular, may pose a threat to mountain goat populations [138]. Helicopter recreation, helicopter logging, or fire control operations by aircraft may alter mountain goat behavior and time budgets [22,34,40,46,97]. Disturbance may be particularly detrimental in winter and during kidding [40,94,138]. Many researchers recommended a 1 mile (2 km) disturbance-free buffer around mountain goat habitat [22,34,40,138]. In Wenatchee National Forest, Washington, during a July lightning-caused wildfire, helicopters and fixed-wing aircraft maintained buffers of 500 feet (150 m) from birthing sites due to concerns that overflights would disturb mountain goats during kidding; no impacts were noted on mountain goats when this technique was used [97].

Mountain goat populations may be adversely affected by logging, road building, and mineral, coal, gas, and oil development [99,138]. Chadwick [20] found that mountain goats in western Montana either used logged areas less frequently than before logging or abandoned them completely. He found that mountain goats emigrated 3 miles (5 km) following disturbance from road building, and these mountain goats failed to return to disturbed sites 2 years after logging ended. Wright (1977 cited in [78]) reported that mountain goats on Barometer Mountain in the Cascade Range left their winter range and traveled to summer range early as a result of logging activity, but they returned to their winter range the following fall. In 1975, Rideout and Hoffman [110] reported that mountain goat populations in Idaho and Montana declined due to disturbance during and following road construction that resulted in increased human access. On Caw Ridge in Alberta, mountain goats abandoned a site while coal-mine exploration crews were working nearby [34]. In the Stikine River drainage, mountain goats abandoned summer ranges and relocated 1 to 2 miles (1-3 km) upstream after onset of hydroelectric exploration [40]. In the Sawtooth Range in

northwestern Montana, declines in adult females and kids were associated with seismic activity caused by energy exploration in mountain goat habitat during 7 years (R= -0.85, P<0.05 for both variables) [79].

Succession: Mountain goats are "superb colonizers". They readily adapt to new habitats following transplants, and they readily colonize newly created habitats after disturbance [135]. Early-successional stages in forests and subalpine communities created by fire and other disturbances such as frequent, downslope movement of snow, ice, rocks, and water provide important mountain goat foraging sites [21,78]. Festa-Bianchet and Cote [34] surmised that mountain goats are well adapted to take advantage of disturbances where resource availability changes over time, citing the mountain goat's ability to twin when conditions are favorable and its strong tendency to disperse. The authors noted that mountain goat's life history strategy presents a "somewhat paradoxical mixture of traits" including those adapted to seral, frequently changing habitats (ability to twin, strong tendency to disperse) and those typical of species occupying very stable environments (late age of maturity, low reproductive effort) [34].

Mountain goats may rely on both primary succession (as a result of receding glaciers and snowfields) and secondary succession (as a result of fire, avalanches, and logging) to create suitable habitat [81,133,135,146]. Disturbances in alpine and subalpine habitats include frost heaving; wind blasting; extreme variation in snowpack; herbivory and associated trampling; avalanches; and fire. Subalpine grasslands burn occasionally, but since 80% to 90% of subalpine plant biomass is underground, fire does not affect the structure of subalpine grasslands greatly [94].

Drought periods in subalpine grasslands are associated with tree establishment. Typically, deep snow accumulates in meadows, and late snowmelt leaves meadows with a growing season too short for tree establishment, but extended drought (20 years) apparently allows for tree establishment.

In subalpine parklands, fire exclusion has contributed to changes in habitat structure and function. During wet climatic cycles, reduced fire frequency can lead to tree islands coalescing and parklands succeeding to closed forest. In subalpine parklands, fires are most likely to occur during dry periods on warm, dry southern aspects and steep slopes [5]. Fire in subalpine parklands may increase areas of alpine grassland [86]. Once burned, these sites are slowly reinvaded by trees [5] and become less suitable for mountain goats over time [94].

According to a 2000 review, mountain goats use all seral stages within forests except for the stem exclusion stage of montane and lower montane forests [146]. Mountain goat forage is abundant in early-seral forest, decreases in midsuccession, and increases again in late succession [43]. Mountain goats also use plant communities on ledges and fell fields that tend to be stable and self-perpetuating [21]. In the interior Columbia Basin ecosystem, declining mountain goat habitat in the Lower Clark Fork region was due to broad-scale, total loss of old-growth forests of ponderosa pine as well as declines in the stand initiation stage of lodgepole pine and Engelmann spruce-subalpine fir forests. In the Upper Clark Fork region, declines in mountain goat habitat were due primarily to loss of late-seral Douglas-fir and ponderosa pine forests [146].

Climate change: Because weather affects mountain goat population dynamics, global climate change may potentially affect mountain goat populations [15,34]. Global climate change is predicted to increase fall and winter precipitation in the range of mountain goats, resulting in greater snow accumulations. However, increased temperatures predicted by global climate change will probably result in more rain and less snow in winter, shorter duration of snow cover, a prolonged growing season, and an increase in

Ex029

the upper limits of plant growth as glaciers and snowfields recede [13]. As snowfields recede, food availability for mountain goats may increase [94,133], or conversely, food availability may decrease due to increased tree encroachment into subalpine and alpine habitats preferred by mountain goats [13,101,113]. Increased tree encroachment may fragment alpine habitats used by mountain goats. This could result in mountain goat populations becoming increasingly isolated from one another, making dispersal more difficult and individual herds becoming smaller and more vulnerable to losses from wildfires, severe winter weather, or diseases and parasites [93,94,133,135].

Habitat management: Logging can have both positive and negative effects on mountain goats. Overstory removal can increase forage productivity in areas where fire exclusion has reduced the extent of open habitats. However, logging may reduce winter cover and loss of cover could increase snow depth locally, thus making forage unavailable in logged sites in winter [43,78,146]. Logging also increases human access to mountain goat habitat through road construction, and this has led to increased hunting mortality in some herds [20,78]. Except along travel corridors between ranges and to mineral licks, the effects of logging on mountain goat habitats may be restricted to areas within approximately 1,600 feet (500 m) of escape terrain [43].

Logging impacts may benefit mountain goats because of increased postlogging forage production. In the north-central Cascade Range, mountain goat forage abundance was greatest in clearcuts and least in forested habitats [45]. Because mountain goats foraged in clearcuts, clearcutting was suggested as a means of improving habitat for mountain goats in South Dakota [12]. Mountain goats also foraged in logged areas in south-coastal British Columbia in winter [130]. In Washington, they foraged in clearcuts when "sufficient" old-growth forest was left around the clearcut perimeter [78].

Logging impacts could be negative because of loss of forage and cover and because of disturbance and vulnerability resulting from increased human access [20,108]. High canopy cover in forests may benefit mountain goats by reducing snow depths on the ground and thus reducing mountain goat's energetic costs. Mature forests can be important sources of browse and lichens (see Diet). Forested buffers around escape terrain may also provide protection against disturbance [144]. Mountain goats that use low-elevation habitats in winter, such as those in coastal regions, may be most affected by logging [108,140]. In southeastern Alaska in winter, most (55%) mountain goats preferred forests with commercial timber (>8 thousand board feet (mbf)/acre), whereas only 5% of mountain goats preferred noncommercial forest stands (<8 mbf/acre), and no mountain goats preferred unforested areas [120]. Chadwick [20] found that mountain goats in western Montana either used logged areas less frequently than before logging or abandoned them completely.

Johnson [78] recommended that mountain goats have access to a variety of habitats to meet their needs. In coastal British Columbia, mountain goats commonly used old (>80 years) forests in winter, although some did not do so. Mountain goats often used early-seral forests (<40 years). Most (64%) early-seral forests used by mountain goats established after wildfires; the remaining early-seral forests established after logging (16%), site-preparation burning (4%), and unknown disturbances. Mountain goats spent the rest of their time in alpine habitats, particularly in large avalanche tracks. Because site fidelity was high in mature and old-growth forests, the authors recommended maintaining a high proportion of mature and old-growth forests in mountain goat winter ranges. Nonetheless, the authors suggested that logging small portions of mountain goat winter range through thinning or group selection may provide more abundant summer forage and more winter forage in low snowfall years, particularly on good snow-shedding areas [130]. In areas of extensive forests with cliff habitat in Washington, small clearcuts were considered

beneficial for mountain goats, but a buffer of uncut forest was recommended to provide cover in cliff habitats with no overstory cover [78].

Several researchers recommended identifying key winter ranges, travel corridors, mineral licks, and birthing sites to protect the sites from logging activities; minimizing human-related disturbances, including logging, near mountain goat winter range; restricting logging to snow-free periods; closing logging roads to minimize access to mountain goat habitats; and maintaining logging rotations long enough to reestablish dense forest canopies and understories [16,78,99]. In southeastern Alaska, Fox [43] concluded that sites >1,600 feet (500 m) from escape terrain were mostly unused by mountain goats except during travel between wintering sites. Thus, direct effects of logging in areas >1,600 feet away from cliffs were considered restricted to factors that potentially change energy expenditures required during travel. These factors include large amounts of slash and increased snow depths in early-seral forests that could hinder movements [43]. Researchers recommended that forested travel corridors between wintering sites be kept intact because fragmented wintering habitat may concentrate mountain goats in habitat where they may be more vulnerable to gray wolf predation [99]. Johnson [78] also recommended avoiding mountain goat travel routes during logging. Fox [43] recommended leaving buffers of mature forest around travel routes in forests in southeastern Alaska to prevent snow accumulation along travel routes. In contrast, Boyd and others [16] recommended reducing conifer cover in forested travel corridors to enhance visibility for mountain goats and thus decrease predation risk. Poole and others [107] speculated that logging or burning areas around lick sites may either benefit mountain goats by opening habitat or, conversely, may cause mountain goats to abandon a lick due to loss of cover. Rice [109] suggested that land managers should make accommodations for high annual variability in habitat use within and among populations.

Population management: Mountain goats are hunted in most areas of their range [24,34,110]. In 1975, Rideout and Hoffman [110] reported that mountain goats were primarily hunted as trophy animals and not for meat. Mountain goats, particularly females, are vulnerable to overhunting [24,35,53,85,124]. Characteristics making mountain goats vulnerable to overhunting include late age at first reproduction; low birth rate; high frequency of reproductive pauses in females; low kid and yearling survival; and the likelihood of orphaned kids dying during winter [17,35,78]. A 2007 review noted that longevity was apparently the most important component of lifetime reproductive success in mountain goats. Hunting reduces life expectancy and increases mortality of prime-aged mountain goat adults, an age class that normally has very high survival [34]. A model using 12 populations in Alberta found that adult survival, particularly of females 5 years and older, had the greatest potential to influence population changes of mountain goats over time [53]. Because mountain goats rely on longevity to increase lifetime reproductive success, hunting mortality that reduces life expectancy is likely to be detrimental to population growth [34]. Harvest of mature females has led to declines in native mountain goat populations [34,53,124]. Native mountain goat populations appear more vulnerable to high hunting rates than introduced populations, in part because introduced populations show a younger age of primiparity and a higher frequency of twinning than native populations [99]. Recovery of mountain goat populations from overharvesting can be prolonged and often confounded by severe winter weather and predation [99,135]. For more information, see Reproduction and development.

FIRE EFFECTS AND MANAGEMENT

SPECIES: Oreamnos americanus

- DIRECT FIRE EFFECTS
- INDIRECT FIRE EFFECTS
- FIRE REGIMES
- FIRE MANAGEMENT CONSIDERATIONS

DIRECT FIRE EFFECTS:
As of this writing (2010), no observations of direct fire mortality of mountain goats were recorded in available literature. Kelsall and others [80] concluded that because mountain goats live primarily on treeless alpine rangelands, direct fire mortality is "unlikely". However, Toweill [133] observed few mountain goats along a portion of the lower South Fork Salmon River in Idaho that burned in a wildfire about 10 years prior to the study. Because the burn appeared to be good habitat for mountain goats, the author speculated that direct mortality during the fire was substantial, and without a colonizing source of mountain goats, the habitat remained "near vacant". However, no prefire census of the mountain goat population was conducted [133].

General observations suggest that mountain goats occasionally use areas during and soon after fire. A yearling male mountain goat in the Swan Range, Montana, was observed at a lick while slash-burning and road-building occurred nearby [20].

INDIRECT FIRE EFFECTS:
Mountain goat populations respond directly to fire-caused changes in cover and food. Fire's occurrence and its impacts on mountain goat populations apparently vary between alpine and forest habitats [78]. In general, the literature regarding fire effects in alpine and subalpine mountain goat ranges suggests that fire increases mountain goat forage availability and diversity, particularly herbs and shrubs important in the diet, and reduces tree encroachment, potentially for long periods. Thus, fire in alpine and subalpine habitats may lead to increases in mountain goat populations [78,99,132]. However, in low and midelevation forests, fire may reduce important mountain goat forage and cover, particularly on winter rangelands [60]. The effects of fire on mountain goat habitats are not thoroughly understood but likely depend upon prefire mountain goat population density, the plant communities affected, the type of fire, postfire vegetation growth rates, and adjacent habitats. Most reports are anecdotal, use small sample sizes, or include no controls and/or replicates, so results presented here should be interpreted with caution.

Mountain goats use burned areas throughout their range. In Banff and Jasper National Parks, Alberta, mountain goats used grass-sedge communities in burned areas on south-facing slopes [38]. In southwestern Idaho near McCall, mountain goats were commonly observed in a 3-year-old burn in lower Big Creek [133]. In the Stikine River drainage in northwestern British Columbia, they used 10- to 20-year-old burns 24% of the time. Burns were particularly important as mountain goat foraging areas in spring and fall [40]. In the Red Butte Range, Montana, mountain goats wintered in an area burned about 30 years prior to the study that was "covered by various associations of shrubs, grasses and weeds, with a scattering of dwarf alpine trees" [18]. Mountain goats also traveled 0.5 mile (0.8 km) through burned habitat with abundant windfalls and snags [17]. Mountain goats in the Sapphire Mountains, Montana, used a salt lick in an area that was burned in a wildfire about 50 years prior to the study and was never reforested [111]. In coastal British Columbia, mountain goats commonly used burned habitats, but the authors speculated that use of burned habitat may decline in winter due to the deep snow in burns [130].

Mountain goat populations may decrease immediately following fire due to loss of winter forage and

cover, increase as postfire herb and shrub communities develop and forage becomes more abundant, and then decrease due to forest succession. In southwestern Idaho near Nampa, a summer wildfire burned through forested habitat and into adjacent grasslands with scattered shrubs and trees that occurred throughout cliff areas used by mountain goats. The mountain goat population apparently declined the spring following the fire [133], probably due to a loss of winter forage. However, other researchers reported use of burns soon after fire (Miller 1984 unpublished report cited in [49]).

Several researchers reported increased mountain goat populations from about 4 to 18 years following fire. Mountain goat populations increased following a wildfire on Chopaka Mountain in north-central Washington [78]. Prior to the fire, the mountain goat population was very small, apparently due to marginal rangeland. The mountain goat population "irrupted" after the fire, and in postfire year 12 the mountain goat population peaked at 250 individuals. The population increase was attributed to the creation of early-seral plant communities with abundant forage. The mountain goat population then declined, reaching its lowest point 41 years after the fire (King personal communication cited in [78]). On Baldy Ridge in the Olympic Mountains, Lack (1962 unpublished field notes cited in [73]) reported that mountain goats heavily grazed grasses throughout several burned areas; one burn was 12 years old, another was 23 to 46 years old, and the 3rd was at least 63 years old. Houston [73] noted that mountain goat populations on Baldy Ridge declined over 37 years as forest cover increased. After the Penticton Creek fire in south-central British Columbia, an unhunted mountain goat herd expanded its range into the burned area. The herd increased from <20 individuals prior to the fire to a peak of 45 individuals in postfire year 18. Thirty-two years after the fire, the herd had declined to 28 individuals, and 35 years after the fire, the herd had 20 individuals. The authors stated that the herd apparently declined because habitat that was opened up by the fire had succeeded to closed-canopy lodgepole pine forests that were not suitable for mountain goats [49]. In central Idaho, wildfire on alpine and subalpine areas increased forage for mountain goats and apparently resulted in increased mountain goat populations by postfire year 4, but observations were confounded by increased visibility of mountain goats and thus detection by observers [132,133]. Mountain goat's ability to increase following fire led Johnson [78] to suggest that they "obviously evolved with periodic fires and seem to have benefited from their occurrence" historically.

Mountain goat populations may increase following fire because fire sets back forest succession and increases forage abundance and plant species diversity [78]. Along Lake Chelan in the Cascade Range of central Washington, a 5- to 6-year-old burned area provided "good forage conditions" for mountain goats reintroduced into native range near the area. The authors speculated that abundant forage in the burn may have been the reason the released mountain goats persisted in the burn [36]. On Mt Hamell in Alberta, many of the grasslands used by mountain goats were created by fires, with little postfire conifer regeneration [139]. In coastal British Columbia, burned areas "appeared to attract goats", and mountain goats used second-growth forests created by fire more frequently than expected. The authors noted that mountain goats used logged but unburned habitats very little. Most second-growth forests used by mountain goats were 20 to 40 years old. The authors surmised that mountain goats used the burns because of increased forage quantity and/or quality and because the burns were snow-free during winter [130]. On Mt Wardle in Kootenay National Park, British Columbia, a fire burned a conifer forest up to 7,005 feet (2,135 m). Much of the mountain goat winter range, which extended from about 4,000 to 8,500 feet (1,220-2,590 m), occurred in the burned area (Debock 1970 cited in [80]). Debock (personal communication cited in [80]) speculated that had it not been for the fire, mountain goats might not have occurred on the mountain. On winter range at 4,000 to 5,000 feet (1,200-1,500 m) elevation in the Selkirk Range of northern Idaho, seral shrub communities, which were the most important foraging sites for mountain goats in winter, had been kept in early succession by a fire that occurred approximately 20 years

prior to the study and by avalanches [17]. Shortly after a wildfire near Sitkum Creek, British Columbia, mountain goats occurred throughout the burned area. Fifteen years after the fire, they avoided parts of the burn that had succeeded to forest but used burned areas at the base of cliffs where vegetation regrowth was slower (Miller 1984 unpublished report cited in [49]). The mountain goat herd at Sitkum Creek did not increase following the fire, possibly because population density was very low prior to the fire due to overhunting and "there were probably too few goats present to take much advantage of the burn" [49].

Some researchers reported that mountain goats are likely little affected by fire because fire is unlikely to occur in their habitat [33,37,62,148]. A 1987 review of fire effects in western Montana forests stated that mountain goats are likely "relatively impervious" to fire effects because they usually occur above fire-prone forest areas in alpine and subalpine zones and on steep, rocky slopes. However, the authors acknowledged that fire that does occur in subalpine and alpine habitats may create favorable mountain goat rangelands [37]. Other researchers reported that although fire occurred in mountain goat habitats, it had little influence on mountain goat populations. In 1964, Flook [38] noted that mountain goats used burned areas dominated by grasses and sedges in Banff and Jasper National Parks, Alberta, but concluded that "fire is of little importance in creating habitat" for this species. He considered most mountain goat rangelands to be perpetuated by climate or geological erosion rather than by fire. In 1977, Chadwick [21] observed that "recent" fires in Glacier National Park and the Swan Mountains disturbed some portions of mountain goat winter ranges but did not "appear to be a major influence" on mountain goat populations.

Fire may be detrimental to mountain goat populations in areas where mountain goats use mature forests for forage and cover. The effects may be particularly deleterious to winter ranges [16]. In southern interior and coastal mountain goat populations in British Columbia, fire was considered detrimental to mountain goats because it removed forage and snow-shedding tree canopies on winter ranges [60]. Boyd and others [16] agreed that fire in interior mountain goat winter ranges may be detrimental to mountain goat populations because sparse stands of trees and shrubs are used as forage and shelter from weather [16].

Although fire may increase some mountain goat forage species, it may decrease others. In Pacific Coast maritime forests, mountain goats consume salmonberry (*Rubus spectabilis*), which sprouts and grows rapidly in the first years after fire, although severe fires may reduce sprouting [91]. In the Red Butte Range of Montana, grouse whortleberry (*Vaccinium scoparium*) constituted 96% of the mountain goat winter diet and 49% of available vegetation [18]. Following low- or moderate-severity fires that do not kill the shallow rhizomes, grouse whortleberry sprouts quickly. Because the rhizomes occur in duff or at the duff-soil interface, severe fires can eliminate this shrub from a site [114,123]. For more information regarding fire effects on mountain goat forage, see FEIS reviews for species of interest.

FIRE REGIMES:
Fire regimes in mountain goat habitats vary across the species' distribution. Mountain goat habitats in the Rocky Mountains are characterized by large, treeless alpine areas, whereas mountain goat habitats in the Cascade Range include few alpine communities. Most of the alpine zone on the Pacific Coast in British Columbia and Alaska is occupied by glaciers, snowfields, bare rocks, and talus slopes, and fire is uncommon because of lack of fuels [78]. Fire's infrequency in alpine habitats caused several researchers to comment that fire was likely to have little effect on mountain goat populations [33,37,62,148]. However, mountain goats occur in habitats with short (e.g., subalpine woodland and montane and subalpine grasslands) to long (e.g., Sitka spruce-western hemlock and mountain hemlock) fire-return intervals and in those with understory fir regimes (e.g., Rocky Mountain Douglas-fir (*Pseudotsuga*

menziesii var. *glauca*)), mixed fire regimes (e.g., whitebark pine-lodgepole pine and grand fir (*Abies grandis*)-lodgepole pine-western larch (*Larix occidentalis*)-Douglas fir), and stand-replacement fire regimes (e.g., lower and upper subalpine fir-Engelmann spruce and mountain grassland).

In Washington, mountain goats occur in mountain hemlock, Pacific silver fir, subalpine fir, and alpine larch forests and in heath habitats. Mountain hemlock forests are typically moist; historically, fires were generally infrequent and stand-replacing, occurring at 400- to 800-year intervals. Fire in Pacific silver fir stands was infrequent due to the relatively short summers, high humidity, and high precipitation associated with these forests. Fire-return intervals were reported to be as long as 500 years. When fires occur in Pacific silver fir stands, they are typically stand-replacing owing to the buildup of abundant fuels. Subalpine fir forests at high elevation generally experience high-severity, stand-replacing fires at intervals of 100 years or more. Subalpine fir forests at low elevation often have more frequent, less severe fires than those at high elevation. Subalpine fir habitats in subalpine zones burn infrequently because of discontinuous fuels, broken, rocky terrain, and moist, cold environments in adjacent uplands. Stand-replacing fire is rare in alpine larch habitats because of abundant cliff, talus, and rock sites with little or no fuels. Fires are usually restricted to the immediate vicinity of the lightning-struck tree. In heath habitats, fires are infrequent because heath is interspersed with rock and wetlands, and because the sites have short growing seasons, low-statured plants, moist soils, and relatively cold temperatures. However, heath stands may burn during periods of severe drought [84]. For more information on fire regimes in mountain goat habitats in Washington, see Kovalchik and Clausnitzer [84].

In Montana, mountain goats occur in cold, moist upper subalpine and timberline habitats. These habitats are "cold, moist, rocky, snowbound, unproductive, and otherwise fire resistant". Upper subalpine and timberline habitats generally experience stand-replacing fires at intervals of 200 years or more. Stand-replacing fires are most likely to occur in these habitats during drought, when crown fires develop in the forests below and burn uphill. Vegetation growth following fires is usually slow because of the extremely short growing season and cold climate. Mountain goats also occur in lower subalpine habitats. Historically, periodic (30- to 130-year intervals) low- to moderate-severity fire and infrequent stand-replacement fire occurred, depending upon plant species composition, soil moisture, topography, weather, and past fire. In Douglas-fir habitats, frequent (5-45 years) low- or moderate-severity fires maintained open forest stands and grasslands favorable to mountain goats. Mountain goats occur in lodgepole pine forests above 7,500 feet (2,300 m) that historically had stand-replacing fires at 300- to 400-year intervals. In low-elevation lodgepole pine forests, stand-replacing fire occurred at <100-year to 300-year intervals [37]. For more information regarding fire regimes in mountain goat habitats in the northern Rocky Mountains, see Arno [7]. The Fire Regime Table summarizes characteristics of fire regimes for vegetation communities in which mountain goats may occur. Follow the links in the table to documents that provide more detailed information on these fire regimes. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

Fire exclusion during the 1900s resulted in increased density of trees in formerly open stands, reducing mountain goat forage quantity and quality. This has caused mountain goat rangeland deterioration and loss of quality habitat throughout the species' range [14,78,145]. Some grasslands used by mountain goats are the result of past fires, and fire exclusion has resulted in the lack of new grassland development in some areas [139]. Without periodic fire, seral grasslands often become dominated by conifers [113]. Fire exclusion has increased fuel loads in many mountain goat habitats, potentially leading to increased frequency and/or severity of fires [78], which could benefit mountain goat populations.

Ex035

FIRE MANAGEMENT CONSIDERATIONS:
Mountain goats use fire-created habitats, and mountain goat populations often increase after fire (see Indirect Fire Effects). This suggests that using prescribed fire to remove dense forest stands and increase grasses and shrubs may benefit mountain goats [99]. Some researchers suggested that prescribed fire may be used to improve mountain goat forage [12,14]. In western Washington, where dense forest stands offer poor habitat for mountain goats, Johnson [78] suggested that prescribed fire could be used to reduce dense conifers in patches and increase early-successional species used as forage near rocky terrain. In eastern Washington, where conifer stands are sparse, habitat is dominated by grasses and shrubs, and conditions are dry, he suggested using prescribed fire to increase shrub density via sprouting and to stimulate grass production. Houston and others [69] suggested using prescribed fire to increase the carrying capacity of mountain goat winter rangelands on the Olympic National Forest. Wisdom and others [145] recommended increasing the quantity and quality of mountain goat forage in the interior Columbia Basin, where succession caused forage reductions, by using prescribed fire to restore historical fire regimes and vegetation patterns.

Based upon expert opinion, prescribed fire should be used in or adjacent to good mountain goat winter range, such as on south-facing slopes along steep ledges, cliffs, or rock outcrops [78]. Foster and Rahs [40] recommended prescribed fires in areas close to steep escape terrain to create early-seral plant communities for mountain goats, but they cautioned that small islands of conifers should be protected within the burn perimeter to provide cover. Taylor and others [130] suggested that fires near winter range on sites with snow-shedding characteristics may be particularly beneficial for mountain goats. Johnson [78] considered elevation an important criterion in selecting sites suitable for use of prescribed fire in mountain goat habitats. He suggested that prescribed fires in Washington be set at elevations no higher than 6,000 feet (2,000 m) because vegetation growth is slow at higher elevations and soils at high elevations are usually fragile and can be sterilized by a "hot" fire [78].

Although often recommended, prescribed fire has been infrequently applied in mountain goat habitats. Techniques for burning under prescription to improve bighorn sheep subalpine rangelands (e.g., [11,147]) may also improve mountain goat rangelands because these species' diets and rangelands often overlap (e.g., [28,137]). For more information, see the FEIS review of bighorn sheep.

Some researchers advocate that wildfires in mountain goat habitats be allowed to burn [14,133]. Toweill [133] stated that allowing wildfires within mountain goat habitats would reduce tree encroachment on subalpine and alpine meadows and would likely promote sprouting in shrubs important in mountain goat diets. Possibly a combination of prescribed fires and wildfires for resource benefit combined with population management techniques, such as hunting restrictions, may be needed to increase mountain goat populations.

Some researchers caution that wildland fire may be detrimental to mountain goat populations in areas where mountain goats use mature forests for forage and cover [16,60]. In northwestern British Columbia, a conifer forest close to a canyon rim was important mountain goat winter range. The authors recommended planting conifers in large areas burned by a wildfire 10 to 20 years prior to the study to increase cover for mountain goats [40]. Prescribed burning and its associated human activities in mountain goat range may be harmful to mountain goat populations in the short term by increasing stress levels and altering movements and behaviors (see Human disturbance) [97].

Ex036

APPENDIX: FIRE REGIME TABLE

SPECIES: Oreamnos americanus

The following table provides fire regime information that may be relevant to mountain goat habitats. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

Fire regime information on vegetation communities in which mountain goats may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [88], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Pacific Northwest Southwest Great Basin Northern and Central Rockies

Pacific Northwest

- Northwest Grassland
- Northwest Woodland
- Northwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northwest Grassland					
Alpine and subalpine meadows and grasslands	Replacement	68%	350	200	500
	Mixed	32%	750	500	>1,000
Northwest Woodland					
Subalpine woodland	Replacement	21%	300	200	400
	Mixed	79%	80	35	120
Northwest Forested					

Ex037

Sitka spruce-western hemlock	Replacement	100%	700	300	>1,000
Douglas-fir-western hemlock (dry mesic)	Replacement	25%	300	250	500
	Mixed	75%	100	50	150
Douglas-fir-western hemlock (wet mesic)	Replacement	71%	400		
	Mixed	29%	>1,000		
Mountain hemlock	Replacement	93%	750	500	>1,000
	Mixed	7%	>1,000		
Pacific silver fir (low elevation)	Replacement	46%	350	100	800
	Mixed	54%	300	100	400
Pacific silver fir (high elevation)	Replacement	69%	500		
	Mixed	31%	>1,000		
Subalpine fir	Replacement	81%	185	150	300
	Mixed	19%	800	500	>1,000
Mixed conifer (eastside dry)	Replacement	14%	115	70	200
	Mixed	21%	75	70	175
	Surface or low	64%	25	20	25
Mixed conifer (eastside mesic)	Replacement	35%	200		
	Mixed	47%	150		
	Surface or low	18%	400		
Spruce-fir	Replacement	84%	135	80	270

Ex038

	Mixed	16%	700	285	>1,000

Southwest

- Southwest Grassland
- Southwest Shrubland
- Southwest Woodland
- Southwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southwest Grassland					
Montane and subalpine grasslands	Replacement	55%	18	10	100
	Surface or low	45%	22		
Southwest Shrubland					
Mountain-mahogany shrubland	Replacement	73%	75		
	Mixed	27%	200		
Southwest Woodland					
Bristlecone-limber pine (Southwest)	Replacement	67%	500		
	Surface or low	33%	>1,000		
Southwest Forested					
Ponderosa pine-Douglas-fir (southern Rockies)	Replacement	15%	460		
	Mixed	43%	160		
	Surface or low	43%	160		
Aspen with spruce-fir	Replacement	38%	75	40	90

Ex039

	Mixed	38%	75	40	
	Surface or low	23%	125	30	250
Lodgepole pine (Central Rocky Mountains, infrequent fire)	Replacement	82%	300	250	500
	Surface or low	18%	>1,000	>1,000	>1,000
Spruce-fir	Replacement	96%	210	150	
	Mixed	4%	>1,000	35	>1,000

Great Basin

- Great Basin Grassland
- Great Basin Shrubland
- Great Basin Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Great Basin Grassland					
Mountain meadow (mesic to dry)	Replacement	66%	31	15	45
	Mixed	34%	59	30	90
Great Basin Shrubland					
Mountain shrubland with trees	Replacement	22%	105	100	200
	Mixed	78%	29	25	100
Curlleaf mountain-mahogany	Replacement	31%	250	100	500
	Mixed	37%	212	50	
	Surface or low	31%	250	50	
Great Basin Forested					

Ex040

Ponderosa pine-Douglas-fir	Replacement	10%	250		≥1,000
	Mixed	51%	50	50	130
	Surface or low	39%	65	15	
Douglas-fir (warm mesic interior)	Replacement	28%	170	80	400
	Mixed	72%	65	50	250
Aspen with conifer (high elevations)	Replacement	47%	76	40	
	Mixed	18%	196	10	
	Surface or low	35%	100	10	
Spruce-fir-pine (subalpine)	Replacement	98%	217	75	300
	Mixed	2%	>1,000		
Aspen with spruce-fir	Replacement	38%	75	40	90
	Mixed	38%	75	40	
	Surface or low	23%	125	30	250

Northern and Central Rockies

- Northern and Central Rockies Grassland
- Northern and Central Rockies Shrubland
- Northern and Central Rockies Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northern and Central Rockies Grassland					
Mountain grassland	Replacement	60%	20	10	

Ex041

	Mixed	40%	30		
Northern and Central Rockies Shrubland					
Mountain shrub, nonsagebrush	Replacement	80%	100	20	150
	Mixed	20%	400		
Northern and Central Rockies Forested					
Ponderosa pine (Northern Great Plains)	Replacement	5%	300		
	Mixed	20%	75		
	Surface or low	75%	20	10	40
Ponderosa pine (Black Hills, low elevation)	Replacement	7%	300	200	400
	Mixed	21%	100	50	400
	Surface or low	71%	30	5	50
Ponderosa pine (Black Hills, high elevation)	Replacement	12%	300		
	Mixed	18%	200		
	Surface or low	71%	50		
Ponderosa pine-Douglas-fir	Replacement	10%	250		≥1,000
	Mixed	51%	50	50	130
	Surface or low	39%	65	15	
Western redcedar	Replacement	87%	385	75	≥1,000
	Mixed	13%	>1,000	25	
Douglas-fir (xeric interior)	Replacement	12%	165	100	300
	Mixed	19%	100	30	100
	Surface or low	69%	28	15	40

Ex042

Douglas-fir (warm mesic interior)	Replacement	28%	170	80	400
	Mixed	72%	65	50	250
Douglas-fir (cold)	Replacement	31%	145	75	250
	Mixed	69%	65	35	150
Grand fir-Douglas-fir-western larch mix	Replacement	29%	150	100	200
	Mixed	71%	60	3	75
Mixed conifer-upland western redcedar-western hemlock	Replacement	67%	225	150	300
	Mixed	33%	450	35	500
Western larch-lodgepole pine-Douglas-fir	Replacement	33%	200	50	250
	Mixed	67%	100	20	140
Grand fir-lodgepole pine-larch-Douglas-fir	Replacement	31%	220	50	250
	Mixed	69%	100	35	150
Persistent lodgepole pine	Replacement	89%	450	300	600
	Mixed	11%	>1,000		
Whitebark pine-lodgepole pine (upper subalpine, Northern and Central Rockies)	Replacement	38%	360		
	Mixed	62%	225		
Lower subalpine lodgepole pine	Replacement	73%	170	50	200
	Mixed	27%	450	40	500
Lower subalpine (Wyoming and Central Rockies)	Replacement	100%	175	30	300

Ex043

Upper subalpine spruce-fir (Central Rockies)	Replacement	100%	300	100	600

*Fire Severities—
Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [55,87].

REFERENCES:

1. Adams, Layne G.; Bailey, James A. 1980. Winter habitat selection and group size of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. In: Northern wild sheep and goat council: Proceedings of the 2nd biennial symposium; 1980 April 23-25; Salmon, ID. NWSGC2. Cody, WY: Northern Wild Sheep and Goat Council: 465-481. [80409]

2. Adams, Layne G.; Bailey, James A. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. Journal of Wildlife Management. 46(4): 1003-1009. [80311]

3. Adams, Layne G.; Bailey, James A. 1983. Winter forages of mountain goats in central Colorado. The Journal of Wildlife Management. 47(4): 1237-1243. [68332]

4. Adams, Layne G.; Masteller, Mark A.; Bailey, James A. 1982. Movement and home range of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. In: Bailey, James A.; Schoonveld, Gene G., eds. Northern wild sheep and goat council: Proceedings of the 3rd biennial symposium; 1982 March 17-19; Fort Collins, CO. NWSGC3. Cody, WY: Northern Wild Sheep and Goat Council: 391-405. [81140]

5. Agee, James K.; Smith, Larry. 1984. Subalpine tree reestablishment after fire in the Olympic Mountains, Washington. Ecology. 65(3): 810-819. [6102]

6. Anderson, Niilo A. 1940. Mountain goat study: Progress report. Biological Bulletin No. 2. Seattle, WA: State of Washington Department of Game. 20 p. [80295]

7. Arno, Stephen F. 1980. Forest fire history in the Northern Rockies. Journal of Forestry. 78(8): 460-465. [11990]

8. Ayotte, Jeremy B.; Parker, Katherine L.; Arocena, Joselito M.; Gillingham, Michael P. 2006. Chemical composition of lick soils: functions of soil ingestion by four ungulate species. Journal of Mammalogy. 87(5): 878-888. [78499]

9. Ayotte, Jeremy B.; Parker, Katherine L.; Gillingham, Michael P. 2008. Use of natural licks by four species of ungulates in northern British Columbia. Journal of Mammalogy. 89(4):

Ex044

1041-1050. [78554]

10. Bailey, James A. 1991. Reproductive success in female mountain goats. Canadian Journal of Zoology. 69: 2956-2961. [80315]

11. Bentz, Jerry A.; Woodard, Paul M. 1988. Vegetation characteristics and bighorn sheep use on burned and unburned areas in Alberta. Wildlife Society Bulletin. 16(2): 186-193. [15276]

12. Benzon, Ted A.; Rice, Leslie A. 1988. Mountain goat status, Black Hills, South Dakota. In: Samuel, Bill, ed. Northern wild sheep and goat council: Proceedings of the 6th biennial symposium; 1987 April 11-15; Banff, AB. NWSGC6. Cody, WY: Northern Wild Sheep and Goat Council: 168-183. [80403]

13. Bjork, Robert G.; Molau, Ulf. 2007. Ecology of alpine snowbeds and the impact of global change. Arctic, Antartic, and Alpine Research. 39(1): 34-43. [80232]

14. Blood, Donald A. 2000. Mountain goat in British Columbia: ecology, conservation and management. Victoria, BC: Ministry of Environment, Lands and Parks, Wildlife Branch. 6 p. [80281]

15. Bowman, William D.; Cairns, David M.; Baron, Jill S.; Seastedt, Timothy R. 2002. Islands in the sky: alpine and treeline ecosystems of the Rockies. In: Baron, Jill S., ed. Rocky Mountain futures: An ecological perspective. Washington, DC: Island Press: 183-202. [45450]

16. Boyd, Raymond J.; Cooperrider, Allen Y.; Lent, Peter C.; Bailey, James A. 1986. Ungulates. In: Cooperrider, Allen Y.; Boyd, Raymond J.; Stuart, Hanson R., eds. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Department of the Interior, Bureau of Land Management: 519-564. [10856]

17. Brandborg, Stewart M. 1955. Life history and management of the mountain goat in Idaho. Wildlife Bulletin No 2. Boise, ID: Idaho Department of Fish and Game. 142 p. [80273]

18. Casebeer, Robert L. 1948. A study of the food habits of the mountain goat (Oreamnos americanus missoulae) in western Montana. Missoula, MT: Montana State University. 178 p. Thesis. [80235]

19. Casebeer, Robert L.; Rognrud, Merle J.; Brandborg, Stewart. 1950. The Rocky Mountain goat in Montana. Pittman-Robertson Federal Aid Project 1-R. Wildlife Bulletin No. 5. Helena, MT: Montana Department of Fish, Wildlife, and Parks, Restoration Division. 107 p. [80503]

20. Chadwick, Douglas H. 1973. Mountain goat ecology-logging relationships in Bunker Creek drainage of western Montana. Job final report: Research Project No. W-120-R-3, 4. Helena, MT: Montana Fish and Game. 262 p. [Missoula, MT: University of Montana. Thesis]. [80296]

Ex045

21. Chadwick, Douglas H. 1977. Ecology of the Rocky Mountain goat in Glacier National Park and the Swan Mountains, Montana. Final Report. West Glacier, MT: U.S. Department of the Interior, National Park Service, Glacier National Park. 54 p. [19359]

22. Cote, Steeve D. 1996. Mountain goat response to helicopter disturbance. Wildlife Society Bulletin. 24(4): 681-685. [80343]

23. Cote, Steeve D. 2000. Dominance hierarchies in female mountain goats: stability, aggressiveness and determinants of rank. Behaviour. 137(11): 1541-1566. [80345]

24. Cote, Steeve D.; Festa-Bianchet, Marco. 2003. Mountain goat (Oreamnos americanus). In: Feldhamer, George A.; Thompson, Bruce C.; Chapman, Joseph A., eds. Wild mammals of North America: Biology, management, and conservation. 2nd ed. Baltimore, MD: The Johns Hopkins University Press: 1061-1075. [81256]

25. Coupe, R.; Stewart, A. C.; Wikeem, B. M. 1991. Engelmann spruce--subalpine fir zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 223-236. [81059]

26. Cowan, I. McTaggart; Brink, V. C. 1949. Natural game licks in the Rocky Mountain national parks of Canada. Journal of Mammalogy. 30: 379-387. [80297]

27. Cowan, Ian McTaggart; McCrory, Wayne. 1970. Variation in the mountain goat, Oreamnos americanus (Blainville). Journal of Mammalogy. 51(1): 60-73. [80299]

28. Dailey, Thomas V.; Hobbs, N. Thompson; Woodard, T. N. 1984. Experimental comparisons of diet selection by mountain goats and mountain sheep in Colorado. Journal of Wildlife Management. 48(3): 799-806. [80350]

29. Danby, Ryan K.; Slocombe, D. Scott. 2005. Regional ecology, ecosystem geography, and transboundary protected areas in the St. Elias Mountains. Ecological Applications. 15(2): 405-422. [80351]

30. Dane, Benjamin. 2002. Retention of offspring in a wild population of ungulates. Behaviour. 139(1): 1-21. [80352]

31. DeLong, C.; Annas, R. M.; Stewart, A. C. 1991. Boreal white and black spruce zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 237-250. [81060]

32. Dice, Lee R. 1923. Mammal associations and habitats of the Flathead Lake region, Montana. Ecology. 4(3): 247-260. [65287]

33. Edwards, R. Y. 1954. Fire and the decline of a mountain caribou herd. The Journal of Wildlife Management. 18(4): 521-526. [8394]

34. Festa-Bianchet, Marco; Cote, Steeve D. 2007. Mountain goats: Ecology, behavior, and conservation of an alpine ungulate. Washington, DC: Island Press. 280 p. [80231]

Ex046

35. Festa-Bianchet, Marco; Urquhart, Martin; Smith, Kirby G. 1994. Mountain goat recruitment: kid production and survival to breeding age. Canadian Journal of Zoology. 72: 22-27. [24005]

36. Fielder, Paul C.; Keesee, Barry G. 1988. Results of a mountain goat transplant along Lake Chelan, Washington. Northwest Science. 62(5): 218-222. [80354]

37. Fischer, William C.; Bradley, Anne F. 1987. Fire ecology of western Montana forest habitat types. Gen. Tech. Rep. INT-223. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 95 p. [633]

38. Flook, Donald R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. In: Crisp, D. J., ed. Grazing in terrestrial and marine environments: A symposium of the British Ecological Society: Proceedings; 1962 April 11-14; Bangor, UK. No. 4. Oxford: Blackwell: 119-128. [15688]

39. Foster, Bryan R.; Rahs, Engel Y. 1982. Implications of maternal separation on overwinter survival of mountain goat kids. In: Bailey, James A.; Schooneveld, Gene, eds. Northern wild sheep and goat council: Proceedings of the 3rd biennial symposium; 1982 March 17-19; Fort Collins, CO. NWSGC3.Cody, WY: Northern Wild Sheep and Goat Council: 351-363. [81142]

40. Foster, Bryan R.; Rahs, Engel Y. 1985. A study of canyon-dwelling mountain goats in relation to proposed hydroelectric development in northwestern British Columbia, Canada. Biological Conservation. 33: 209-228. [80356]

41. Fox, Joseph L.; Smith, Christian A. 1988. Winter mountain goat diets in southeast Alaska. Journal of Wildlife Management. 52(2): 362-365. [19254]

42. Fox, Joseph L.; Streveler, Gregory P. 1986. Wolf predation on mountain goats in southeastern Alaska. Journal of Mammmalogy. 67(1): 192-195. [80964]

43. Fox, Joseph Larkin. 1983. Constraints on winter habitat selection by the mountain goat (Oreamnos americanus) in Alaska. Seattle, WA: University of Washington. 147 p. Disseration. [80224]

44. Geist, Valerius. 1964. On the rutting behavior of the mountain goat. Journal of Mammalogy. 45: 551-568. [80303]

45. Gilbert, Brian A.; Raedeke, Kenneth J. 1992. Winter habitat selection of mountain goats in the North Tolt and Mine Creek drainages of the north central Cascades. In: Emmerich, John; Hepworth, Bill, eds. Northern wild sheep and goat council: Proceedings of the 8th biennial symposium; 1992 Apr 27-May 1; Cody, WY. NWSGC 8. Cody, WY: Northern Wild Sheep and Goat Council: 305-324. [80829]

46. Goldstein, Michael I.; Poe, Aaron J.; Cooper, Erin; Youkey, Don; Brown, Bridget A.; McDonald, Trent L. 2005. Mountain goat response to helicopter overflights in Alaska. Wildlife Society Bulletin. 33(2): 688-699. [80360]

Ex047

47. Gross, J. E.; Kneeland, M. C.; Reed, D. F.; Reich, R. M. 2002. GIS-based habitat models for mountain goats. Journal of Mammalogy. 83(1): 218-228. [80361]

48. Guiguet, C. J. 1951. An account of wolverine attacking mountain goat. The Canadian Field-Naturalist. 65(5): 187. [68399]

49. Gyug, Les W. 2006. Mountain goat population and harvest assessment in the Okanagan Region. Penticton, BC: British Columbia Ministry of Environment, Okanagan Region. 30 p. Available online: http://www.env.gov.bc.ca/wildlife/wsi/reports/4219_WSI_4219_RPT2.PDF [2010, December 10]. [80268]

50. Hamel, S.; Cote, S. D. 2007. Habitat use patterns in relation to escape terrain: are alpine ungulate females trading off better foraging sites for safety? Canadian Journal of Zoology. 85: 933-943. [80365]

51. Hamel, Sandra; Cote, Steeve D.; Festa-Bianchet, Marco. 2010. Maternal characteristics and environment affect the costs of reproduction in female mountain goats. Ecology. 91(7): 2034-2043. [81031]

52. Hamel, Sandra; Cote, Steeve D.; Gaillard, Jean-Michel; Festa-Bianchet, Marco. 2009. Individual variation in reproductive costs of reproduction: high-quality females always do better. Journal of Animal Ecology. 78: 143-151. [80364]

53. Hamel, Sandra; Cote, Steeve D.; Smith, Kirby G.; Festa-Bianchet, Marco. 2006. Population dynamics and harvest potential of mountain goat herds in Alberta. Journal of Wildlife Management. 70(4): 1044-1053. [81325]

54. Hamel, Sandra; Gaillard, Jean-Michel; Festa-Bianchet; Cote, Steeve D. 2009. Individual quality, early-life conditions, and reproductive success in contrasted populations of large herbivores. Ecology. 90(7): 1981-1995. [80363]

55. Hann, Wendel; Havlina, Doug; Shlisky, Ayn; [and others]. 2010. Interagency fire regime condition class (FRCC) guidebook, [Online]. Version 3.0. In: FRAMES (Fire Research and Management Exchange System). National Interagency Fuels, Fire & Vegetation Technology Transfer (NIFTT) (Producer). Available: http://www.fire.org/niftt/released /FRCC_Guidebook_2010_final.pdf. [81749]

56. Harmon, Wendell H. 1944. Notes on mountain goats in the Black Hills. Journal of Mammmalogy. 25(2): 149-151. [81014]

57. Harrison, Donna G. 1999. Distribution and movements of canyon-dwelling mountain goats along Pinto Creek, Alberta. Prince George, BC: University of Northern British Columbia. 96 p. Thesis. [81026]

58. Hayden, James A. 1984. Introduced mountain goats in the Snake River Range, Idaho: characteristics of vigorous population growth. In: Hoefs, Manfred, ed. Northern wild sheep and goat council: Proceedings of the 4th biennial symposium; 1984 April 30-May 3; Whitehorse, YT. NWSGC 4. Cody, WY: Northern Wild Sheep and Goat Council: 94-119.

[81139]

59. Haynes, Lisa A. 1992. Mountain goat habitat of Wyoming's Beartooth Plateau: implications for management. In: Emmerich, John; Hepworth, Bill, eds. Northern wild sheep and goat council: Proceedings of the 8th biennial symposium; 1992 Apr 27-May 1; Cody WY. NWSGC 8. Cody, WY: Northern Wild Sheep and Goat Council: 325-339. [80401]

60. Hebert, D. M.; Turnbull, W. G. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. In: Samuel, William; Macgregor, W. G., eds. Proceedings, 1st international mountain goat symposium; 1977 February 19; Kalispell, MT. Victoria, BC: Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch: 126-146. [81030]

61. Hebert, Daryl; Cowan, I. McTaggart. 1970. Natural salt licks as a part of the ecology of the mountain goat. Canadian Journal of Zoology. 49: 605-610. [80304]

62. Hibbs, L. Dale. 1966. A literature review of mountain goat ecology. GFP-R-S-8. Denver, CO: Colorado Department of Fish and Parks. 23 p. [80274]

63. Hjeljord, Olav. 1973. Mountain goat forage and habitat preference in Alaska. Journal of Wildlife Management. 37(3): 353-362. [16004]

64. Holmes, Eli. 1988. Foraging behaviors among different age and sex classes of Rocky Mountain goats. In: Samuel, Bill, ed. Northern wild sheep and goat council: Proceedings of the 6th biennial symposium; 1987 April 11-15; Banff, AB. NWSGC 6. Cody, WY: Northern Wild Sheep and Goat Council: 13-25. [81020]

65. Hope, G. D.; Mitchell, W. R.; Lloyd, D. A.; Erickson, W. R.; Harper, W. L.; Wideem, B. M. 1991. Interior Douglas-fir zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 153-166. [81054]

66. Hope, G. D.; Mitchell, W. R.; Lloyd, D. A.; Harper, W. L.; Wikeem, B. M. 1991. Montane spruce zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 182-194. [81057]

67. Hopkins, Anne; Fitzgerald, James P.; Chappell, Alex; Byrne, Gene. 1992. Population dynamics and behavior of mountain goats using Elliott Ridge, Gore Range, Colorado. In: Emmerich, John; Hepworth, Bill, eds. Northern wild sheep and goat council: Proceedings of the 8th biennial symposium; 1992 April 27-May 1; Cody, WY. NWSGC 8. Cody, WY: Northern Wild Sheep and Goat Council: 340-356. [80402]

68. Hornocker, Maurice G.; Hash, Howard S. 1981. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology. 59(7): 1286-1301. [68358]

69. Houston, D. B.; Hoffman, R. A.; Olson, R. W.; Moorhead, B. B. 1994. Mountain goat management in Olympic National Park. In: Houston, Douglas B.; Schreiner, Edward G.;

Ex049

Moorhead, Bruce B., eds. Mountain goats in Olympic National Park: biology, and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service: 189-208. [80911]

70. Houston, D. B.; Robbins, C. T.; Stevens, V. 1989. Growth in wild and captive mountain goats. Journal of Mammmalogy. 70(2): 412-416. [81024]

71. Houston, D. B.; Stevens, V. 1988. Resource limitation in mountain goats: a test by experimental cropping. Canadian Journal of Zoology. 66: 228-238. [80367]

72. Houston, D. B.; Stevens, V.; Moorhead, B. B. 1994. Demography. In: Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B., eds. Mountain goats in Olympic National Park: biology, and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service: 71-83. [80228]

73. Houston, D. B.; Stevens, V.; Moorhead, B. B. 1994. History, distribution, and abundance. In: Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B., eds. Mountain goats in Olympic National Park: biology, and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service: 48-70. [80907]

74. Houston, D. B.; Stevens, V.; Schreiner, E. G. 1994. Habitat relations, social behavior, and physiological ecology. In: Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B., eds. Mountain goats in Olympic National Park: biology, and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service: 84-97. [80942]

75. Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B., eds. 1994. Mountain goats in Olympic National Park: biology and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service. 296 p. [80939]

76. Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B.; Olson, Richard W. 1991. Mountain goat management in Olympic National Park: a progress report. Natural Areas Journal. 11(2): 87-92. [16850]

77. Hutchins, Michael; Geist, Valerius. 1987. Behavioural considerations in the management of mountain-dwelling ungulates. Mountain Research and Development. 7(2): 135-144. [80370]

78. Johnson, Rolf L. 1983. Mountain goats and mountain sheep of Washington. Biological Bulletin No. 18. Federal Aid Project W-88-R. Olympia, WA: Washington Department of Game. 196 p. [80506]

79. Joslin, Gayle. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain Front. In: Joslin, Gayle, ed. Northern wild sheep and goat council: Proceedings of the 5th biennial symposium; 1986 April 14-17; Missoula, MT.

Ex050

NWSGC 5. Helena, MT: Northern Wild Sheep and Goat Council: 253-271. [80404]

80. Kelsall, John P.; Telfer, E. S.; Wright, Thomas D. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian North: a review and selected bibliography. Occasional Paper No. 32. Ottawa, ON: Fisheries and Environment Canada, Canadian Wildlife Service. 58 p. [8403]

81. Kessell, Stephen R. 1976. Wildland inventories and fire modeling by gradient analysis in Glacier National Park. In: Proceedings, Montana Tall Timbers fire ecology conference and Intermountain Fire Research Council fire & land management symposium; 1974 October 8-10; Missoula, MT. No. 14. Tallahassee, FL: Tall Timbers Research Station: 115-162. [6480]

82. Ketcheson, M. V.; Braumandl, T. F.; Meidinger, D.; Utzig, G.; Demarchi, D. A.; Wikeem, B. M. 1991. Interior cedar--hemlock zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 167-182. [81056]

83. Klein, David R. 1953. A reconnaissance study of the mountain goat in Alaska. Fairbanks, AK: University of Alaska. 121 p. Thesis. [80272]

84. Kovalchik, Bernard L.; Clausnitzer, Rodrick R. 2004. Classification and management of aquatic, riparian, and wetland sites on the National Forests of eastern Washington: series description. Gen. Tech. Rep. PNW-GTR-593. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 354 p. [53329]

85. Kuck, Lonn. 1977. The impacts of hunting on Idaho's Pahsimeroi mountain goat herd. In: Samuel, William; Macgregor, W. G., eds. Proceedings, 1st international mountain goat symposium; 1977 February 19; Kalispell, MT. Victoria, BC: Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch: 114-125. [80543]

86. Kuramoto, R. T.; Bliss, L. C. 1970. Ecology of subalpine meadows in the Olympic Mountains, Washington. Ecological Monographs. 40(3): 317-347. [62888]

87. LANDFIRE Rapid Assessment. 2005. Reference condition modeling manual (Version 2.1), [Online]. In: LANDFIRE. Cooperative Agreement 04-CA-11132543-189. Boulder, CO: The Nature Conservancy; U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior (Producers). 72 p. Available: http://www.landfire.gov /downloadfile.php?file=RA_Modeling_Manual_v2_1.pdf [2007, May 24]. [66741]

88. LANDFIRE Rapid Assessment. 2007. Rapid assessment reference condition models, [Online]. In: LANDFIRE. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Lab; U.S. Geological Survey; The Nature Conservancy (Producers). Available: http://www.landfire.gov/models_EW.php [2008, April 18] [66533]

89. Laundre, John W. 1991. Mountain goats in Yellowstone: the horns of a dilemma? Park Science. 11(3): 8-9. [19296]

Ex051

90. Lentfer, Jack W. 1955. A two-year study of the Rocky Mountain goat in the Crazy Mountains, Montana. Journal of Wildlife Management. 19(4): 417-429. [80505]

91. Lyon, L. Jack; Hooper, Robert G.; Telfer, Edmund S.; Schreiner, David Scott. 2000. Fire effects on wildlife foods. In: Smith, Jane Kapler, ed. Wildland fire in ecosystems: Effects of fire on fauna. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 51-58. [44448]

92. Mainguy, Julien; Cote, Steeve D.; Coltman, David W. 2006. Rutting behaviours of male mountain goats in relation to age. In: Pybus, Margo; Wishart, Bill, eds. Northern wild sheep and goat council: Proceedings of the 15th biennial symposium; 2006 April 2-6; Kananaskis, AB. NWSGC 15. Cody, WY: Northern Wild Sheep and Goat Council: 169. Abstract. [80330]

93. Mainguy, Julien; Worley, Kirsty; Cote, Steeve D.; Coltman, David W. 2007. Low MHC DRB class II diversity in the mountain goat: past bottlenecks and possible role of pathogens and parasites. Conservation Genetics. 8: 885-891. [80338]

94. Martin, Kathy M. 2000. Wildlife in alpine and subalpine habitats. In: Johnson, David H.; O'Neil, Thomas A., managing directors. Wildlife-habitat relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press: 239-260. [80539]

95. Masteller, Mark A.; Bailey, James A. 1987. Agonistic behavior among mountain goats foraging in winter. Canadian Journal of Zoology. 66: 2585-2588. [80373]

96. Meehan, William R. 1974. The forest ecosystem of southeast Alaska: 4. Wildlife habitats. Gen. Tech. Rep. PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 32 p. [13479]

97. Murphy, Heather. 1991. Fires and imperiled species. Women in Natural Resources. 13(2): 11. [19295]

98. Nichols, Lyman. 1985. Mountain goat fidelity to given areas by season and seasonal movements. Final report. Federal Aid in Wildlife Restoration: Project No. W-21-1, W-21-2, W-22-1, W-22-2, and W-22-3. Job 12.5R. Period covered: 1 July 1979 - 30 June 1984. Juneau, AK: Alaska Department of Fish and Game, Division of Game. 72 p. [80253]

99. Peek, James M. 2000. Mountain goat. In: Demarais, Stephen; Krausman, Paul R., eds. Ecology and management of large animals in North America. Upper Saddle River, NJ: Prentice Hall: 467-490. [80233]

100. Pelletier, Fanie; Mainguy, Julien; Cote, Steeve D. 2009. Rut-induced hypophagia in male bighorn sheep and mountain goats: foraging under time budget constraints. Ethology. 115: 141-151. [80376]

101. Pettorelli, Nathalie; Pelletier, Fanie; van Hardenberg, Achaz; Festa-Bianchet, Marco; Cote, Steeve D. 2007. Early onset of vegetation growth vs. rapid green-up: impacts on juvenile mountain ungulates. Ecology. 88(2): 381-390. [80378]

102. Pfitsch, W. A.; Bliss, L. C. 1985. Seasonal forage availability and potential vegetation

limitations to a mountain goat population, Olympic National Park. The American Midland Naturalist. 113(1): 109-121. [62887]

103. Pojar, J.; Klinka, K.; Demarchi, D. A. 1991. Coastal western hemlock zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 95-112. [81067]

104. Pojar, J.; Klinka, K.; Demarchi, D. A. 1991. Mountain hemlock zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 113-124. [81065]

105. Pojar, J.; Stewart, A. C. 1991. Alpine tundra zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 263-273. [81062]

106. Pojar, J.; Stewart, A. C. 1991. Spruce--willow--birch zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 251-262. [81061]

107. Poole, Kim G.; Bachmann, Karl D.; Teske, Irene E. 2010. Mineral lick use by GPS radio-collared mountain goats in southeastern British Columbia. Western North American Naturalist. 70(2): 208-217. [80380]

108. Poole, Kim G.; Stuart-Smith, Kari; Teske, Irene E. 2009. Wintering strategies by mountain goats in interior mountains. Canadian Journal of Zoology. 87: 273-283. [80804]

109. Rice, Clifford G. 2008. Seasonal altitudinal movements of mountain goats. Journal of Wildlife Management. 72(8): 1706-1716. [80258]

110. Rideout, Chester B.; Hoffmann, Robert S. 1975. Oreamnos americanus. Mammalian Species. 63: 1-6. [80291]

111. Rideout, Chester Bernard. 1974. A radio telemetry study of the ecology and behavior of the mountain goat in western Montana. Lawrence, KS: University of Kansas. 146 p. Dissertation. [80262]

112. Risenhoover, Kenneth L.; Bailey, James A. 1985. Relationships between group size, feeding times, and agonistic behavior of mountain goats. Canadian Journal of Zoology. 63: 2501-2506. [80383]

113. Rochefort, Regina M.; Little, Ronda L.; Woodward, Andrea; Peterson, David L. 1994. Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. Holocene. 4: 89-100. [80950]

114. Romme, William H.; Bohland, Laura; Persichetty, Cynthia; Caruso, Tanya. 1995. Germination ecology of some common forest herbs in Yellowstone National Park, Wyoming, U.S.A. Arctic and Alpine Research. 27(4): 407-412. [26049]

115. Saunders, Jack K., Jr. 1955. Food habits and range use of the Rocky Mountain goat in

Ex053

the Crazy Mountains, Montana. Journal of Wildlife Management. 19(4): 429-437. [484]

116. Schreiner, E. G.; Houston, D. B. 1994. Synthesis of herbivory. In: Houston, Douglas B.; Schreiner, Edward G.; Moorhead, Bruce B., eds. Mountain goats in Olympic National Park: biology, and management of an introduced species. Scientific Monograph NPS/NROLYM /NRSM-94/25. Denver, CO: U.S. Department of the Interior, National Park Service: 186-188. [81141]

117. Schreiner, E.; Woodward, A. 1994. Study documents mountain goat impacts at Olympic National Park. Park Science. 14(2): 23-25. [24225]

118. Singer, Francis J.; Doherty, Jonathan L. 1985. Movements and habitat use in an unhunted population of mountain goats, Oreamnos americanus. The Canadian Field-Naturalist. 99(2): 205-217. [80271]

119. Smith, Bruce L. 1976. Ecology of Rocky Mountain goats in the Bitterroot Mountains, Montana. Missoula, MT: University of Montana. 203 p. Thesis. [80277]

120. Smith, Christian A. 1986. Bi-level analysis of habitat selection by mountain goats in coastal Alaska. In: Joslin, Gayle, ed. Northern wild sheep and goat council: Proceedings of the 5th biennial symposium; 1986 April 14-17; Missoula, MT. NWSGC 5. Helena, MT: Northern Wild Sheep and Goat Council: 366-380. [80408]

121. Smith, Christian A. 1986. Rates and causes of mortality in mountain goats in Southeast Alaska. Journal of Wildlife Management. 50(4): 743-746. [80386]

122. Smith, Christian A. 1994. Evaluation of a multivariate model of mountain goat winter habitat selection. In: Pybus, Margo; Wishart, Bill, eds. Northern wild sheep and goat council: Proceedings of the 9th biennial symposium; 1994 May 2-6; Cranbrook, BC. NWSGC 9. Cody, WY: Northern Wild Sheep and Goat Council: 159-165. [80334]

123. Smith, Jane Kapler; Fischer, William C. 1997. Fire ecology of the forest habitat types of northern Idaho. Gen. Tech. Rep. INT-GTR-363. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 142 p. [27992]

124. Smith, Kirby G. 1988. Factors affecting the population dynamics of mountain goats in west-central Alberta. In: Samuel, Bill, ed. Northern wild sheep and goat council: Proceedings of the 6th biennial symposium; 1987 April 11-15; Banff, AB. NWSGC 6. Cody, WY: Northern Wild Sheep and Goat Council: 308-329. [80319]

125. Steen, O.; Demarchi, D. A. 1991. Sub-boreal pine--spruce zone. In: Meidinger, Del; Pojar, Jim, eds. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests: 195-208. [81076]

126. Stevens, Victoria. 1979. Mountain goat (Oreamnos americanus) habitat utilization in Olympic National Park. Seattle, WA: University of Washington. 106 p. Thesis. [80397]

127. Stevens, Victoria. 1983. The dynamics of dispersal in an introduced mountain goat population. Seattle, WA: University of Washington. 202 p. Dissertation. [80399]

Ex054

128. Swenson, Jon E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absaroka Mountains, Montana. Journal of Wildlife Management. 49(4): 837-843. [80974]

129. Swenson, Jon E. 1986. Reproductive response of the Absoroka mountain goat population to an experimental reduction. In: Joslin, Gayle, ed. Northern wild sheep and goat council: Proceedings of the 5th biennial symposium; 1986 April 14-17; Missoula, MT. NWSGC 5. Helena, MT: Northern Wild Sheep and Goat Council: 71-75. [80320]

130. Taylor, Shawn; Wall, Wayne; Kulis, Yolanta. 2006. Habitat selection by mountain goats in south coastal British Columbia. In: Pybus, Margo; Wishart, Bill, eds. Northern wild sheep and goat council: Proceedings of the 15th biennial symposium; 2006 April 2-6; Kananaskis, AB. NWSGC 15. Cody, WY: Northern Wild Sheep and Goat Council: 141-157. [80389]

131. Thompson, Richard W. 1982. Mountain goat sodium dynamics in the Eagles Nest Wilderness, Colorado. In: Bailey, James A.; Schooneveld, Gene, eds. Northern wild sheep and goat council: Proceedings of the 3rd biennial symposium; 1982 March 17-19; Fort Collins, CO. NWSGC 3. Cody, WY: Northern Wild Sheep and Goat Council: 207-231. [80337]

132. Toweill, Dale E. 2004. Mountain goat status and management in Idaho. In: Heimer, Wayne; Toweill, Dale; Hurley, Kevin, eds. Northern wild sheep and goat council: Proceedings of the 14th biennial symposium; 2004 May 15-22; Inside Passage, AK. NWSGC 14. Cody, WY: Northern Wild Sheep and Goat Council: 115-130. [80390]

133. Toweill, Dale E. 2004. Mountain goat surveys and inventories--Progress report. Project W-170-R-28. Study 1, Job 5. July 1, 2003 to June 30, 2004. Boise, ID: Idaho Department of Fish and Game. 77 p. [80965]

134. Toweill, Dale E. 2008. Status of mountain goats and bighorn sheep and their management in Idaho. In: Smith, Thomas S.; Miller, Julie, eds. Northern wild sheep and goat council: Proceedings of the 16th biennial symposium; 2008 April 27-May 1; Midway, UT. NWSGC 16. Cody, WY: Northern Wild Sheep and Goat Council: 4-6. [80321]

135. Toweill, Dale E.; Gordon, Steve; Jenkins, Emily; Kreeger, Terry; McWhirter, Doug. 2004. A working hypothesis for management of mountain goats. In: Heimer, Wayne; Toweill, Dale; Hurley, Kevin, eds. Northern wild sheep and goat council: Proceedings of the 14th biennial symposium; 2004 May 15-22; Inside Passage, AK. NWSGC 14. Cody, WY: Northern Wild Sheep and Goat Council: 5-45. [80324]

136. Turney, Laurence; Roberts, Anne-Marie. 2004. Non-alpine habitat use and movements by mountain goats in north-central British Columbia. In: Heimer, Wayne; Toweill, Dale; Hurley, Kevin, eds. Northern wild sheep and goat council: Proceedings of the 14th biennial symposium; 2004 May 15-22; Inside Passage, AK. NWSGC 14. Cody, WY: Northern Wild Sheep and Goat Council: 47. Abstract. [80323]

137. Varley, Nathan C. 1994. Summer-fall habitat use and fall diets of mountain goats and bighorn sheep in the Absoroka Range, Montana. In: Pybus, Margo; Wishart, Bill, eds.

Ex055

Northern wild sheep and goat council: Proceedings of the 9th biennial symposium; 1994 May 2-6; Cranbrook, BC. NWSGC 9. Cody, WY: Northern Wild Sheep and Goat Council: 131-138. [80333]

138. Varley, Nathan. 1998. Winter recreation and human disturbance on mountain goats: a review. In: McCarthy, John; Moore, Fay, compilers. Northern wild sheep and goat council: Proceedings of the 11th biennial symposium; 1998 Apr 16-20; Whitefish, MT. NWSGC 11. Cody, WY: Northern Wild Sheep and Goat Council: 7-13. [80335]

139. von Elsner-Schack, Irmgard. 1986. Habitat use by mountain goats, Oreamnos americanus, on the eastern slopes region of the Rocky Mountains at Mount Hamell, Alberta. Canadian Field-Naturalist. 100: 319-324. [19293]

140. Welch, Sarah J. 1991. Human disturbance and habitat use patterns of the mountain goats (Oreamnos americanus) on White Chuck Mountain, Washington. Seattle, WA: University of Washington. 101 p. Thesis. [22509]

141. White, Kevin S. 2006. Seasonal and sex-specific variation in terrain use and movement patterns of mountain goats in southeastern Alaska. In: Pybus, Margo; Wishart, Bill, eds. Northern wild sheep and goat council: Proceedings of the 15th biennial symposium; 2006 April 2-6; Kananaskis, AB. NWSGC 15. Cody, WY: Northern Wild Sheep and Goat Council: 183-193. [80328]

142. Williams, James S. 1999. Compensatory reproduction and dispersal in an introduced mountain goat population in central Montana. Wildlife Society Bulletin. 27(4): 1019-1024. [80387]

143. Wilson, Don E.; Reeder, DeeAnn M., eds. 2005. Mammal species of the world: A taxonomic and geographic reference, [Online]. 3rd ed. Baltimore, MD: Johns Hopkins University Press. 2,142 p. In: Databases. Washington, DC: Smithsonian National Museum of Natural History, Department of Vertebrate Zoology, Division of Mammals (Producer). Available: http://vertebrates.si.edu/mammals/msw/ [69038]

144. Wilson, Steven F. 2002. Assessing the feasibility of effectiveness monitoring for mountain goat winter ranges in forested areas of British Columbia. In: Brundige, Gary, ed. Northern wild sheep and goat council: Proceedings of the 13th biennial symposium; 2002 April 23-27; Rapid City, SD. NWSGC 13. Cody, WY: Northern Wild Sheep and Goat Council: 194-207. [80392]

145. Wisdom, Michael J.; Holthausen, Richard S.; Wales, Barbara C.; Hargis, Christina D.; Saab, Victoria A.; Lee, Danny C.; Hann, Wendel J.; Rich, Terrell D.; Rowland, Mary M.; Murphy, Wally J.; Eames, Michelle R. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia basin: broad-scale trends and management implications. Volume 1--overview. In: Quigley, Thomas M., ed. Interior Columbia Basin Ecosystem Management Project: scientific assessment. Gen. Tech. Rep. PNW-GTR-485. Vol. 1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1-156. [3 volumes]. [66654]

Ex056

146. Wisdom, Michael J.; Holthausen, Richard S.; Wales, Barbara C.; Hargis, Christina D.; Saab, Victoria A.; Lee, Danny C.; Hann, Wendel J.; Rich, Terrell D.; Rowland, Mary M.; Murphy, Wally J.; Eames, Michelle R. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia basin: broad-scale trends and management implications. Volume 2--group level results. In: Quigley, Thomas M., ed. Interior Columbia Basin Ecosystem Management Project: scientific assessment. Gen. Tech. Rep. PNW-GTR-485. Vol. 2. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 157-434. [3 volumes]. [66653]

147. Woodard, Paul M.; Van Nest, Terry. 1990. Winter burning bighorn sheep range--a proposed strategy. Forestry Chronicle. October: 473-477. [14619]

148. Wright, Henry A.; Bailey, Arthur W. 1982. Fire ecology: United States and southern Canada. New York: John Wiley & Sons. 501 p. [2620]

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Ex057

Original Article

APPENDIX B

Range Expansion and Population Growth of Nonnative Mountain Goats in the Greater Yellowstone Area: Challenges for Management

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ABSTRACT Population growth and range expansion of nonnative species can potentially disrupt ecosystem function or add conservation value to an area, and evaluation of possible impacts can be a challenge for managers. Nonnative populations of mountain goats (*Oreamnos americanus*) are present in the Greater Yellowstone Area (GYA) in the U.S. states of Idaho, Montana, and Wyoming because of historical introduction events, but their population trend and range have not been assessed across the area. We used 6,701 location records from 1947 to 2015 to map mountain goat distribution and evaluate, in a descriptive manner, range overlap with native bighorn sheep (*Ovis canadensis*). We analyzed 136 survey counts using the Exponential Growth State–Space model to estimate population trends and abundance. Mountain goats dispersed 50–85 km from introduction sites to occupy all mountain ranges in the northern GYA and 30–40 km to occupy new areas in the southern GYA. Mountain goat numbers increased in nearly all count units, with the strongest growth rates estimated in areas more recently colonized. Using moderate detection probability (0.70), we estimated approximately 2,355 mountain goats in the GYA. Although not tested in our analysis, the gradual range expansion and population growth rates were consistent with density-dependent processes observed in other introduced large herbivores and demonstrate that mountain goats can successfully disperse over unsuitable locales to colonize new areas. Therefore, we expect mountain goat populations will continue to expand into unoccupied mountain ranges that contain significant numbers of bighorn sheep unless specific management actions are implemented to address their population growth. © 2016 The Wildlife Society.

KEY WORDS alpine, bighorn sheep, invasive species, mountain goats, *Oreamnos americanus*, *Ovis canadensis*, population management, ungulate.

The spread of nonnative species is a growing and pervasive conservation challenge world-wide. When nonnative species become invasive they can cause disruptions to ecosystem function and may result in local or global extinction of native biota (Mooney and Hobbs 2000, Lodge et al. 2006). Perhaps the best-known example of such a phenomenon in the Greater Yellowstone Area (GYA) in the U.S. states of Idaho, Montana, and Wyoming, is the introduction and proliferation of lake trout (*Salvelinus namaycush*) in Yellowstone Lake, which has caused a near collapse of the native Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) population, with subsequent impacts on many other native aquatic and terrestrial species (Koel et al. 2005, Gresswell

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and Tronstad 2013, Middleton et al. 2013). Other nonnative species in the GYA causing substantial impacts on ecological processes or presenting management and policy challenges for natural resource agencies include the bacteria *Brucella abortus* that causes the disease brucellosis in wild ungulates and domestic cattle (Treanor et al. 2013), and the fungal pathogen *Cronartium ribicola* that is contributing to a major die-off of whitebark pine (*Pinus albicaulis*) throughout much of the ecosystem (Olliff et al. 2013). However, not all nonnative species disrupt ecological processes and harm native species (Davis et al. 2011, Vaterý et al. 2013); in some situations, nonnative species may augment ecosystem services and have conservation value (Schlaepfer et al. 2011, Strong and Leroux 2014). Thus, natural resource managers need to carefully evaluate the potential and realized impacts of nonnative species before establishing management strategies and initiating control actions that are often difficult to execute, expensive, and potentially controversial (Davis et al. 2011).

The mountain goat (*Oreamnos americanus*) is native to northwestern North America, with its natural range primarily in coastal and inland mountains west of the continental divide. The species' range at the time of European settlement of North America extended from southern Alaska, USA, and along the Pacific Coast of Canada, including the Northwest and Yukon Territories, Alberta, and British Columbia, Canada, and into the northwestern United States, including Oregon, Washington, western Montana, and western Idaho (Côté and Festa-Bianchet 2003, Matthews and Heath 2008). During the early to mid-1900s, state wildlife agencies transplanted mountain goats outside their native range to increase hunting opportunities. These introductions have generally been successful, with nonnative populations now established in in the states of Wyoming, Colorado, Utah, South Dakota, and Nevada, as well as within new areas in Alaska, Alberta, Washington, Idaho, and Montana (Côté and Festa-Bianchet 2003).

Although establishment and expansion of nonnative mountain goat populations have been embraced by most state wildlife agencies, there are some concerns that nonnative mountain goats may degrade fragile native alpine and subalpine plant communities. Most notable have been the studies conducted in Olympic National Park in Washington that demonstrated high densities of nonnative mountain goats impacted soils, created dust wallows, and affected alpine plant communities, including endemic and rare species (Houston et al. 1994). These studies prompted the National Park Service to initiate a capture–relocation program to reduce or eliminate mountain goats from much of the park. The program removed 407 animals during 1981–1989, but was terminated when the remaining concentrations of mountain goats were in terrain deemed too hazardous for helicopter captures to continue and the agency could not identify other socially acceptable mechanisms to complete the task (Houston et al. 1994).

More recently, wildlife and public lands managers have become concerned about expanding mountain goat populations in the GYA (Laundré 1994). Although mountain goats may have been part of the fauna in the GYA region during the Pleistocene, reviews of archeological, paleontological, and historical records suggest that mountain goats were no longer present or were extremely rare in the region 10,000 years prior to European settlement of North America (Laundré 1990, Schullery and Whittlesey 2001). During the 1940s and early 1950s, 158 mountain goats were released at 7 sites in the mountains of the northern GYA. Twelve mountain goats were also introduced into the southern GYA at 2 sites in Idaho during the late 1960s and early 1970s. These introduced populations of mountain goats expanded their range, causing concern about potential effects on native species, particularly bighorn sheep (*Ovis canadensis*; Varley and Varley 1996, Lemke 2004).

From European settlement until the 1930s, the number and distribution of bighorn sheep substantially declined because of market hunting, habitat loss, and diseases introduced by domestic animals. Protective regulations, habitat conservation, and active restoration efforts over the past 75 years have resulted in a modest recovery of the species (Buechner 1960, Krausman and Bowyer 2003). However, periodic catastrophic die-offs and poor recruitment caused by the effects of domestic animal pathogens continue to be prevalent throughout the species' contemporary distribution (Monello et al. 2001, George et al. 2008, Besser et al. 2012, Cassirer et al. 2013). In addition, many populations tend to be small and isolated, increasing their susceptibility to stochastic events and extirpation (Berger 1990). Thus, bighorn sheep are considered a species of great conservation concern.

There is potential for both exploitative and interference competition between mountain goats and bighorn sheep, because both species occupy alpine and subalpine habitats and have similar diets when evaluated at a coarse scale (grasses, forbs, browse; Laundré 1994), with some indication of less dietary overlap at the plant species level for sympatric populations (Pallister 1974, Stewart 1975). Although records of direct interactions between the 2 species are scarce, observations of >100 interactions between nonnative mountain goats and native bighorn sheep in Colorado suggest mountain goats are more likely to displace bighorn, but that most interactions are benign (Reed 1986). There is also the potential that nonnative mountain goats may pose a disease threat to bighorn sheep because many species of helminths are common to both species (Samuel et al. 1977) and mountain goats may host respiratory pathogens that cause pneumonia epizootics and chronic poor lamb recruitment in bighorn populations (Garde et al. 2005).

The various natural resource agencies across the GYA have different policies that address management of mountain goats as a nonnative species. Yellowstone National Park has well-established populations (Lemke 2004) and natural resource personnel are actively engaged in research to determine potential impacts on native plant and animal resources (Aho 2012, White et al. 2013). Grand Teton National Park is currently assessing strategies to manage the small population of mountain goats that recently became established in the park because of concerns that they could

impact the park's nonmigratory bighorn sheep population that occupies isolated high-elevation ridges (U.S. Department of the Interior, National Park Service 2015). Bighorn sheep are classified as a sensitive species for all the National Forest System lands in the GYA, which typically gives them priority for conservation over nonnative species such as mountain goats (U.S. Department of Agriculture, Forest Service 2005). Wildlife management agencies in Montana, Idaho, and Wyoming are interested in maintaining populations of both species. However, the Wyoming Game and Fish Department is interested in maintaining mountain goat populations in areas with minimal impact to bighorn sheep and discouraging their expansion into areas with robust native bighorn sheep populations.

In an initial effort to gain ecological insight into the issues surrounding nonnative mountain goats in the GYA, including potential competition with bighorn sheep, these natural resource agencies collaborated to merge resources, expertise, and data on mountain goats and bighorn sheep to document current distribution, population trends, and abundance. Lemke (2004) described the introduction and colonization of mountain goats in the northern GYA, provided a benchmark for mountain goat abundance and distribution in this region, and predicted an increase in population size in Yellowstone National Park. Since then, 10 years of additional count, demographic, and location data were collected across the GYA by management agencies. These data provide an opportunity to analyze population dynamics and describe the distribution and expansion of mountain goats across the GYA. The objectives of this study were to 1) aggregate all historical location information for mountain goats and bighorn sheep to describe the distribution of both species across the GYA; 2) coalesce data from mountain goat population surveys and analyze trends in each count unit; and 3) synthesize count data to estimate overall abundance of mountain goats in the GYA region.

STUDY AREA

The GYA is a mountainous area that encompasses approximately 9,200,000 ha within Montana, Idaho, and Wyoming (McIntyre and Ellis 2011); contains one of the largest ecologically intact complexes in the United States; and represents the largest intact temperate ecosystem in the world (Keiter and Boyce 1991). For the purposes of this study, the GYA was defined to include the Madison, Gallatin, Absaroka, and Beartooth mountain ranges in Montana; the Beartooth, Absaroka, Gros Ventre, Wind River, and Teton mountain ranges in Wyoming; and the Snake River mountain range that straddles the Wyoming–Idaho border (5,911,596 ha). Elevation ranges from approximately 1,200 m to 4,210 m (McIntyre and Ellis 2011). Many different entities served as land managers in the GYA, with the federal government managing more than half (67%) of the area and encompassing most high-elevation areas (McIntyre and Ellis 2011). The majority of federal land was managed by the U.S. Forest Service (48% of the GYA) and National Park Service (11% of the GYA; McIntyre and Ellis 2011), including Yellowstone National Park (898,317 ha), Grand Teton National Park (125,471 ha), and John D. Rockefeller, Jr. Memorial Parkway (9,622 ha; National Park Service 2011). The GYA encompassed 11 designated wilderness areas (~1,678,300 ha) and nonwilderness National Forest System lands, within the Beaverhead–Deerlodge, Bridger–Teton, Caribou–Targhee, Custer–Gallatin, and Shoshone National Forests (McIntyre and Ellis 2011). Other federal land-management agencies in the GYA included the U.S. Bureau of Land Management (7.0%), U.S. Fish and Wildlife Service (0.5%), U.S. Bureau of Reclamation (0.1%), and Natural Resources Conservation Service (0.1%; McIntyre and Ellis 2011). Approximately 27% of the GYA consisted of private land that is primarily located in lower elevations (McIntyre and Ellis 2011). State agencies managed 4.2% of the area, followed by Native American (1.8%), nongovernmental organizations (0.03%), and city lands (0.02%; McIntyre and Ellis 2011).

METHODS

Developing Databases for the GYA

We aggregated mountain goat and bighorn sheep location data and mountain goat population survey data into standardized databases to describe the distributions of both species across the GYA and estimate population trends of mountain goats. Data were obtained from the Montana Department of Fish, Wildlife and Parks, Yellowstone National Park, Idaho Department of Fish and Game, Wyoming Game and Fish Department, Grand Teton National Park, Montana State University, University of Wyoming, private wildlife consulting businesses, and theses or dissertations from regional universities. In addition to locations from aerial and ground surveys, we collected harvest data, radiocollar data, and opportunistic observations documented by park visitors and hunters. We captured spatial data ranging from points with only geographic names to points described with geographic coordinates obtained using Global Positioning System units. We used all observations of mountain goats and bighorn sheep to develop a map of their distribution in the GYA using the ArcMap module of ArcGIS 10.1.

Analysis of Population Trend

Data used in the population trend analyses were obtained by management agencies through periodic minimum count surveys for mountain goats completed between July and October. Mountain goat surveys in the GYA were conducted by state management biologists using hunting district boundaries, as well as National Park Service biologists within Yellowstone National Park. Surveys were conducted through aerial counts from helicopters and fixed-wing aircraft, ground counts, and combinations of these survey methods. These surveys did not utilize a rigorous sampling scheme, but instead represented the best attempts by individual biologists at surveying all areas within each count unit that were considered mountain goat habitat and where animals had been observed on previous surveys. It is likely that over the time series for each count unit, the areas

searched changed as distribution of animals expanded. Data recorded included the location of each group observed, total number of animals, sex–age composition (if possible), and normally a narrative describing the date of survey, survey effort (survey platform and time spent), general areas searched, and a qualitative evaluation of the flying or observation conditions. Age classifications of observed animals were used to calculate a dependent juvenile (kid) per adult ratio with mountain goats classified as yearlings included in the adult category.

Population survey data were available for 15 hunting districts in Montana, including 324–328 and 362 in the Madison Range; 314 in the Gallatin Range; 323 and 329–330 in the Absaroka Range; and 316, 514, and 517–519 in the Beartooth Range (Fig. 1). Wyoming hunting districts included Unit 1 in the Beartooth Range, Unit 2 in the Snake River Range, and Unit 3 in the Absaroka Range (Fig. 1). The Snake River Range in Idaho was encompassed by Hunting District 67 (Fig. 1). Mountain goat movement patterns across these GYA count units remain relatively unknown, and consequently, population trends were analyzed by count unit rather than biological population.

We used restricted maximum likelihood parameter estimates derived from Exponential Growth State–Space analysis to estimate the growth rate (λ) of mountain goats within count units defined by management biologists. This technique adequately accounts for unequal intervals in the time series and both process and sampling variation, performing well with a minimum of 5 data points over a 10-year time series (Humbert et al. 2009). This model accepts an input of abundance data that proportionally capture change in population size during time intervals of variable length (Humbert et al. 2009); thus, data gaps in the individual time series of count data are accommodated with this analytical technique. Therefore, Exponential Growth State–Space was an appropriate analysis tool for our data sets, because the time series for each count unit exceeded the minimum recommended, and potential variability in minimum counts caused by environmental variation and detection probability variation were addressed though computations involved in the analysis.

We censored some count data that were potentially not representative of population trends using the following specific criteria before analysis: poor survey conditions; the survey was not a trend count; no mountain goats were observed; or the regional biologist designated the count as poor because of less than optimal survey conditions. Survey technique (e.g., aerial, ground) can significantly affect population survey data (Gilbert and Grieb 1957), so we considered this variable when evaluating survey data for each count unit. We used aerial surveys in lieu of ground counts when available because they generally provide better detection of animals, cover more area, and are considered effective at monitoring population trends (Bender et al. 2003, Festa-Bianchet and Côté 2008). However, we used ground counts when aerial data were not available, when the ground count was higher (thus, assuming a more accurate count), or when management biologists recommended the use of a ground count over an aerial count. We did not use in the analysis counts designated as poor by biologists because of less than optimal survey conditions. We aggregated Montana Hunting Districts 514, and 517–519 in the Beartooth Range for analysis because the area biologist indicated that there is movement among the units and the hunting districts were generally surveyed during the same time period. We also aggregated Wyoming Hunting District 1 in the Beartooth Range and District 3 in the Absaroka Range for analysis because they were surveyed as a unit during the same time period. We could not analyze the 2 mountain goat count units located in the Madison Range in the western GYA for population trends because of limited count data.

Evaluating Recruitment Using Age Composition Data

Certain age or sex classes may be underestimated when a small portion of a population is classified or the majority of observed animals cannot be classified, which can result in biased estimates of population composition (Samuel et al. 1992). Therefore, we only estimated the age composition (kids/100 adults) of mountain goats during surveys when >75% of the observed animals were classified. The minimum number of animals used to calculate age ratios was 22.

Estimating Abundance Within the GYA

We combined the survey data from all count units to estimate the number of mountain goats currently within the GYA. To provide a consistent basis for this estimate, we selected the count for each count unit that was from the most recent year and not censored prior to Exponential Growth State–Space analysis to include in the regional estimate. We aggregated mountain goat count units by geographic region within the GYA as follows: West (MT Hunting Districts 314, 324–328, and 362); North (MT Hunting Districts 316, 323, 329–330, 514, 517–519); East (WY Hunt Areas 1 and 3); South (ID Hunt Area 67 and WY Hunt Area 2); and Yellowstone National Park. We also adjusted the aggregated counts for each geographic region to account for detection probability or visibility bias, which is a common problem for surveys where it is difficult to observe all animals present (Williams et al. 2002). We used potential detection probabilities of low (0.55), moderate (0.70), and high (0.90), which encompasses the range of detection probabilities reported in the literature for mountain goat aerial surveys (Gonzalez-Voyer et al. 2001, Rice et al. 2009).

RESULTS

Distribution

We compiled 23,972 bighorn sheep observations from 1937 to 2015 and 6,701 mountain goat observations from 1947 to 2015 in the GYA (Fig. 2). These data illustrate the expansion of mountain goats from the initial 9 introduction sites into the surrounding mountain ranges in both the northern and southern portions of the GYA. In approximately 65 years since mountain goats were released at 7 sites in Montana, they have dispersed 50–85 km and established populations in all the mountain ranges of the northern GYA. Within Yellowstone National Park, mountain goats are primarily

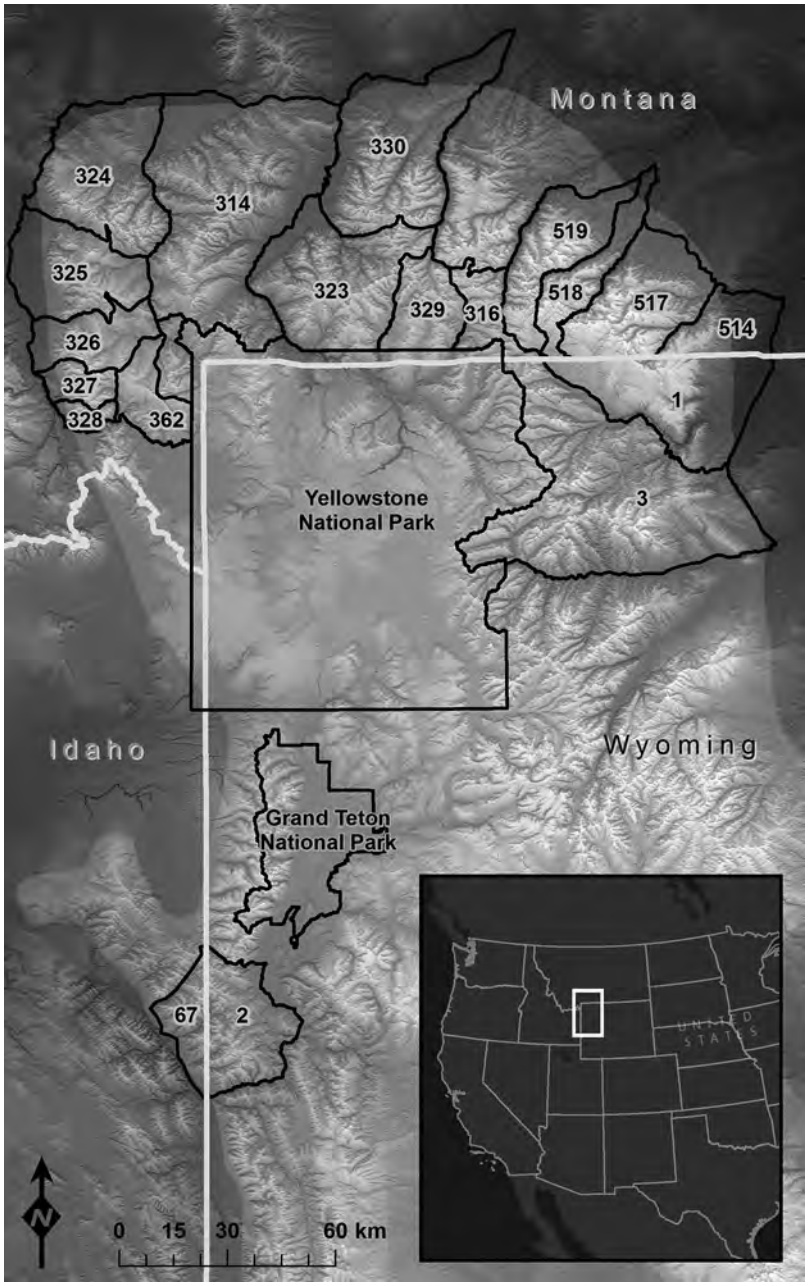

Figure 1. Mountain goat hunting districts and national park boundaries in the Greater Yellowstone Area in the states of Idaho, Montana, and Wyoming, USA, during 2014.

concentrated in the northeast and northwestern corners, with some smaller patches of occupied mountainous habitat in the north-central portion. Although bighorn sheep are patchily distributed in the northern portion of the GYA, mountain goats are sympatric with bighorn sheep in all occupied ranges.

In the southern portion of the GYA, mountain goats were released at 2 sites in the Snake River Range. The animals at the westernmost site apparently did not survive, but the release at the eastern site was successful. In the ensuing 45 years, this population has expanded its distribution 30–40 km to the south and east into Wyoming. Although an occasional bighorn sheep is observed in the Snake River Range, the mountain goat population can be considered allopatric. This population is likely the source for animals that have been pioneering northward over the past 10–15 years into the Teton Range and Grand Teton National Park, where a small population of nonmigratory bighorn sheep occupies high-elevation ranges year-round (Courtemanch 2014; S. Dewey, Grand Teton National Park, unpublished data).

The mountain ranges that define the eastern GYA support the largest aggregation of bighorn sheep in the northern Rocky Mountains, with an estimated 5,000–7,000 animals comprising a single metapopulation complex. Mountain goats are well established in the northern Absaroka Mountains (MT 323, 329, 330), but only single and small groups of pioneering mountain goats have been sighted

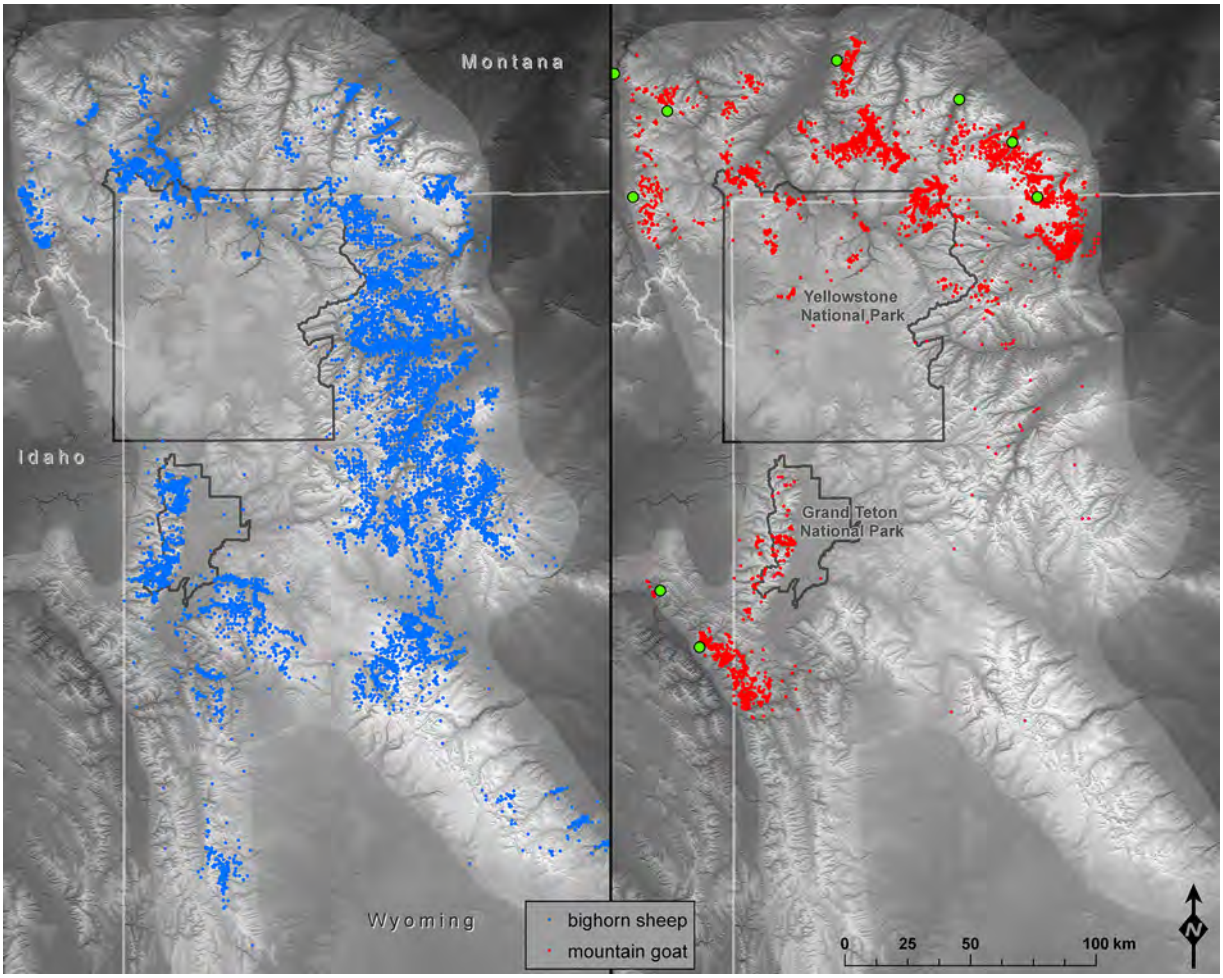

Figure 2. Current distribution of native bighorn sheep (blue) and nonnative mountain goats (red) and mountain goat introduction sites (green) in the Greater Yellowstone Area in the states of Idaho, Montana, Wyoming, USA, based on 30,673 observation records obtained primarily during inventory surveys conducted by wildlife management agencies between 1937 and 2015.

within the bighorn ranges of the southern Absaroka Mountains.

Population Trend

One-hundred fifty-nine survey counts were available for the 10 count units, but we censored 23 total counts because of only partial coverage of the survey unit (5); poor survey conditions (5); the survey was not a trend count (6); the regional biologist considered the count was poor (6); or no mountain goats were observed (1). The length of the time series for each survey area ranged from 16 to 46 years ($\bar{x} = 25$), with the longest time series realized for areas near the original introduction sites (Table 1). The number of counts that contributed to the population trend estimate for individual survey areas averaged 14 and ranged from 6 to 26. In general, the λ estimates (finite rate of increase) ranged from 1.00 to 1.20, indicating that mountain goat numbers increased in nearly all areas of the GYA. The strongest growth rates were estimated for the Gallatin Mountains (MT 314; $\lambda = 1.10$), Yellowstone National Park ($\lambda = 1.20$), and the Wyoming portion of the Snake River Range (WY 2; $\lambda = 1.08$) that have been more recently colonized, with slower rates ($\lambda = 1.00$–1.03) estimated for survey areas nearer the original introduction sites (Table 1). There was, however, considerable uncertainty in all growth rate estimates because confidence limits of the estimates were wide and included values below 1.0 for 7 of the 10 point estimates. The mean of recent kids/100 adults ratios for all count units ranged from 23 to 39.

Abundance

The most recent count data aggregated for all survey areas within the GYA provided a minimum population estimate of 1,648 mountain goats (Table 2). Approximately 82% of the estimated GYA population likely consists of descendants of the 158 animals released at 7 sites in Montana, whereas 18% of the GYA population likely consists of descendants of the 12 animals released at 2 sites in Idaho. Using a moderate value of detection probability (0.70) derived from literature on aerial surveys of ungulates in heterogeneous landscapes, the total number of mountain goats estimated in the GYA in 2014 was approximately 2,355.

DISCUSSION

Native ranges of mountain goats in North America are generally restricted to the relatively cool and moist climatic zones influenced by the North Pacific (Côté and

Table 1. Summary of demographic data and Exponential Growth State–Space (restricted max. likelihood; Humbert et al. 2009) population trend results for mountain goat count units in the Greater Yellowstone Area in Idaho (ID), Montana (MT), and Wyoming (WY), USA, during 1966–2014.

Count unit	Mountain range	Count unit area (ha)[a]	No. surveys	Time period	λ est.	λ 95% CI	Process variance	Observation error	$\bar{x}$ kids/100 ad[b]
MT 314	Gallatin	258,094	6	1997–2014	1.10	0.99–1.23	0.05	0.01	39
Yellowstone Natl. Park	Gallatin Absaroka	898,317	11	1998–2014	1.20	1.00–1.43	0.13	0.00	35
MT 323	Absaroka	131,238	26	1966–2012	1.03	0.99–1.08	0.02	0.00	33
MT 329	Absaroka	46,545	13	1993–2012	1.00	0.94–1.07	0.01	0.05	29
MT 330	Absaroka	149,939	14	1990–2011	1.03	0.97–1.09	0.00	0.28	23
MT 316	Beartooth	31,378	7	1993–2011	1.08	0.91–1.27	0.13	0.01	31
MT 514, 517–519	Beartooth	259,566	11	1977–2011	1.01	0.95–1.08	0.03	0.05	25[c]
WY 1, 3	Beartooth	386,365	18	1986–2013	1.02	1.01–1.03	0.00	0.04	31
WY 2	Snake River	75,524	14	1995–2014	1.08	1.05–1.11	0.00	0.11	25
ID 67	Snake River	31,400	16	1982–2012	1.00	0.92–1.09	0.05	0.11	30

[a] Calculated using geographic boundaries of count unit.
[b] The calculated no. of juv mountain goats (kids)/100 ad is a mean of the age classification data for the 3 most recent counts with sufficient demographic data.
[c] Calculated using winter survey data.

Festa-Bianchet 2003). However, successful establishment of mountain goats in the GYA and other sites far from strong maritime influences, such as Colorado, Nevada, Utah, and South Dakota indicate the species possesses the physiological and ecological plasticity to occupy more interior continental environments that are drier and experience more extreme temperatures. Since the initial introductions in Montana and Idaho, mountain goats have continued to colonize new areas, with approximately half of the mountainous terrain in the GYA currently occupied by mountain goats 65 years after initial releases. This relatively modest pace of range expansion suggests limited dispersal behavior and tendencies, especially when compared with the most recent mammalian reintroduction into the GYA, the wolf (*Canis lupus*), which established packs in all but one mountain range in the GYA within 5 years of the 1995–1996 reintroductions (Smith et al. 2001).

Although the rate of mountain goat range expansion in the GYA has been modest, the presence of a robust mountain goat population in the Gallatin Range (MT 314 and Yellowstone National Park) in the northwestern GYA demonstrates that mountain goats can successfully disperse over unsuitable locales to access and colonize new areas, because no animals were introduced to these mountains. Thus, the population must have been established by animals dispersing, most likely from the neighboring Madison Range (MT 324–328, 362) to the west or the Bridger Range to the north, necessitating travel across the densely forested or low-elevation valley landscapes that separate these adjacent mountain ranges. Similar dispersal movements over low-elevation unsuitable prairie landscape were noted by Williams (1999), suggesting continued range expansion in the GYA will not be dependent on the availability of contiguous suitable habitat. Lemke (2004) predicted that the population in Yellowstone National Park would increase to 200–300 mountain goats, which was consistent with our minimum estimate of 209 for the count unit.

Table 2. Estimated abundance of mountain goats in the Greater Yellowstone Area (GYA) in the states of Idaho, Montana, Wyoming, USA, in 2014 based on counts from population surveys and a range of reasonable detection probabilities.

		Detection probability		
		High	Moderate	Low
Region	Total counted	0.90	0.70	0.55
West GYA	332	369	474	604
North GYA	632	702	903	1,149
East GYA	175	194	250	318
South GYA	300	333	429	545
Yellowstone National Park	209	232	299	380
Total	1,648	1,830	2,355	2,996

The gradual range expansion of mountain goats in the GYA is likely driven by density-dependent processes similar to those noted for other introduced large herbivores where populations initially demonstrate rapid growth, but slow as densities increase and resources become limiting, forcing animals to disperse to new areas where resources are not limiting (Caughley 1970, Reynolds 1998, Larter et al. 2000). Our population growth-rate estimates support this mechanism because estimates for count units near original introduction sites were lower than those estimated for count units more recently colonized, including the Gallatin Mountains (MT 314), Yellowstone National Park, and the Wyoming portion of the Snake River Range (WY 2; Table 1). Our growth-rate estimates must be interpreted with caution, however, because estimates for 7 of 10 count units had 95% confidence intervals that spanned $\lambda = 1.00$. Wide confidence intervals were likely the result of a number of factors including the difficulty of detecting animals (Gonzalez-Voyer et al. 2001, Rice et al. 2009) and variability of survey techniques, flying conditions, and effort from one survey to the next. This interpretation is generally supported by estimates of the portion of variance attributed to observation error versus process variance for 6 of the 10 time series (Table 1). The aggressive censoring of surveys prior to the analyses undoubtedly resulted in an underestimation of the observation error realized in each time series. However, the general conclusion that mountain goat numbers have been increasing in nearly all areas of the GYA with established populations is supported by the relatively high ratios of kids to adults in all the survey areas.

Given these results, we think it is reasonable to expect that mountain goats will continue to expand their distribution into unoccupied ranges, which will result in a continuing increase in abundance unless specific management actions are implemented to limit densities and range expansion.

The presence of nonnative mountain goats in the GYA is considered beneficial by some segments of society because they are highly appreciated by wildlife watchers and popular game for hunters (Chadwick 1983, Smith 2014). Moreover, the current population of >2,000 mountain goats contribute ecological services by providing prey and carrion for a number of predators and scavengers in the ecosystem, including canids, corvids, eagles, felids, ursids, and wolverines (*Gulo gulo*). The addition of nonnative mountains goats to the GYA, however, could potentially have impacts on the alpine and subalpine environments where they reside through increasing available nitrogen, decreasing certain forage species, and soil disturbance (Houston et al. 1994, Aho 2012). Some of the largest and most demographically robust populations of bighorn sheep in the continental United States live in these areas, and mountain goats could also negatively impact bighorn sheep populations if some level of niche overlap results in competition for limited resources (Adams et al. 1982, Laundré 1990, Schullery and Whittlesey 2001, Lemke 2004). In addition, mountain goats could adversely affect the health of bighorn sheep by spreading exotic respiratory pathogens that are well-documented to cause catastrophic die-offs and poor lamb recruitment in bighorn sheep (Besser et al. 2012, Miller et al. 2012, Cassirer et al. 2013). Although there is currently inadequate ecological knowledge of mountain goats in the GYA and their potential impacts on bighorn sheep to inform appropriate policies regarding management of this nonnative species, the broad coalition of natural resource agencies and professionals involved with this initial assessment of mountain goat distribution has implemented a number of research efforts to fill these gaps (see http://www.mtbighorninitiative.com/gyamup-home.html).

MANAGEMENT IMPLICATIONS

Management authority for mountain goats occupying National Forest System lands primarily resides with state wildlife management agencies. Wyoming is evaluating increased hunting opportunities in areas of mountain goat expansion to maintain low densities. Hunting is prohibited in Yellowstone National (16 USC 26) and Grand Teton National Park except for the elk reduction program (16 USC 673). However, National Park Service (2006) policy allows for the removal of nonnative species that interfere with native wildlife or habitats if such control is prudent and feasible. Any capture and removal program in Yellowstone National Park would involve hundreds of animals and face obstacles similar to those that challenged Olympic National Park in the 1980s (Houston et al. 1994). A small population of mountain goats recently colonized Grand Teton National Park, and preventing further expansion therein would involve fewer animals, which may be more socially acceptable and reasonable to fund.

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LITERATURE CITED

Adams, L. G., K. L. Risenhoover, and J. A. Bailey. 1982. Ecological relationships of mountain goats and Rocky Mountain bighorn sheep. Northern Wild Sheep and Goat Council 3:9–22.

Aho, K. 2012. Management of introduced mountain goats in Yellowstone National Park: vegetation analysis along a mountain goat gradient. PMIS 105289. Report prepared for U.S. Department of Agriculture, Yellowstone National Park, Mammoth, Wyoming, USA.

Bender, L. C., W. L. Meyers, and W. R. Gould. 2003. Comparison of helicopter and ground surveys for North American elk *Cervus elaphus* and mule deer *Odocoileus hemionus* population composition. Wildlife Biology 9:199–205.

Berger, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4:91–98.

Besser, T. E., M. A. Highland, K. Baker, E. F. Cassirer, N. J. Anderson, J. M. Ramsey, K. Mansfield, D. L. Bruning, P. Wolff, J. P. Smith, and J. A. Jenks. 2012. Causes of pneumonia epizootics among bighorn sheep, western United States, 2008–2010. Emerging Infectious Diseases 18:406–415.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs 4.

Cassirer, E. F., R. K. Plowright, K. R. Manlove, P. C. Cross, A. P. Dobson, K. A. Potter, and P. J. Hudson. 2013. Spatio-temporal dynamics of pneumonia in bighorn sheep. Journal of Animal Ecology 82:518–528.

Caughley, G. 1970. Eruption of ungulate populations with emphasis on the Himalayan thar in New Zealand. Ecology 51:53–72.

Chadwick, D. H. 1983. A beast the color of winter: the mountain goat observed. Sierra Club, San Francisco, California, USA.

Côté, S. D., and M. Festa-Bianchet. 2003. Mountain goat. Pages 1061–1075 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Courtemanch, A. B. 2014. Seasonal habitat selection and impacts of backcountry recreation on a formerly migratory bighorn sheep population in northwest Wyoming, USA. Thesis, University of Wyoming, Laramie, USA.

Davis, M. A., M. K. Chew, R. J. Hobbs, A. E. Lugo, J. J. Ewel, G. J. Vermeij, J. H. Brown, M. L. Rosenweig, M. R. Gardener, S. P. Carroll, K. Thompson, S. T. A. Pickett, J. C. Stromberg, P. Del Tredici, K. N. Suding, J. G. Ehrenfeld, J. P. Grime, J. Mascaro, and J. C. Briggs. 2011. Don't judge species on their origins. Nature 474:153–154.

Festa-Bianchet, M., and S. D. Côté. 2008. Mountain goats: ecology, behavior, and conservation of an alpine ungulate. Island Press, Washington, D.C., USA.

Garde, E., S. Kutz, H. Schwantje, A. Veitch, E. Jenkins, and B. Elkin. 2005. Examining the risk of disease transmission between wild Dall's sheep and mountain goats, and introduced domestic sheep, goats, and llamas in the Northwest Territories. Zoonotics and Wildlife Disease 29. http://digitalcommons.unl.edu/zoonoticspub/29. Accessed 28 May 2015.

George, J. L., D. J. Martin, P. M. Lukacs, and M. W. Miller. 2008. Epidemic pasteurellosis in a bighorn sheep population coinciding with the appearance of a domestic sheep. Journal of Wildlife Diseases 44:388–403.

Gilbert, P. F., and J. R. Grieb. 1957. Comparison of air and ground deer counts in Colorado. Journal of Wildlife Management 21:33–37.

Gonzalez-Voyer, A., M. Festa-Bianchet, and K. G. Smith. 2001. Efficiency of aerial surveys of mountain goats. Wildlife Society Bulletin 29:140–144.

Gresswell, R. E., and L. M. Tronstad. 2013. Altered processes and the demise of Yellowstone cutthroat trout in Yellowstone Lake. Pages 209–225 *in* P. J. White, R. A. Garrott, and G. E. Plumb, editors. Yellowstone's wildlife in transition. Harvard University Press, Cambridge, Massachusetts, USA.

Houston, D. B., E. G. Schreiner, and B. B. Moorhead. 1994. Mountain goats in Olympic National Park: biology and management of an introduced species. U.S. Department of the Interior Scientific Monograph NPS/NROLYM/NRSM-94/25, National Park Service, Washington, D.C., USA.

Humbert, J., L. S. Mills, J. S. Horne, and B. Dennis. 2009. A better way to estimate population trends. Oikos 118:1940–1946.

Keiter, R. B., and M. S. Boyce. 1991. The Greater Yellowstone Ecosystem: redefining America's wilderness heritage. Yale University Press, New Haven, Connecticut, USA.

Koel, T. M., P. E. Bigelow, P. D. Doepke, B. D. Ertel, and D. L. Mahony. 2005. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. Fisheries 30:10–19.

Krausman, P. R., and R. T. Bowyer. 2003. Mountain sheep. Pages 1095–1115 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Larter, N. C., A. R. E. Sinclair, T. Ellsworth, J. Nishi, and C. C. Gates. 2000. Dynamics of reintroduction of an indigenous large ungulate: the wood bison of northern Canada. Animal Conservation 4:299–309.

Laundré, J. W. 1990. The status, distribution, and management of mountain goats in the Greater Yellowstone Ecosystem. NPS. U.S. Department of the Interior, National Park Service Order PX1200-8-0828, Yellowstone National Park, Mammoth, Wyoming, USA.

Laundré, J. W. 1994. Resource overlap between mountain goats and bighorn sheep. Great Basin Naturalist 54:114–121.

Lemke, T. O. 2004. Origin, expansion, and status of mountain goats in Yellowstone National Park. Wildlife Society Bulletin 32:532–541.

Lodge, D. M., S. Williams, H. J. MacIsaac, K. R. Hayes, B. Leung, S. Reichard, R. N. Mack, P. B. Moyle, M. Smith, D. A. Andow, J. T. Carlton, and A. McMichael. 2006. Biological invasions: recommendations for U.S. policy and management. Ecological Applications 16:2035–2054.

Matthews, P. E., and A. C. Heath. 2008. Evaluating historical evidence for occurrence of mountain goats in Oregon. Northwest Science 82:286–298.

McIntyre, C. L., and C. Ellis. 2011. Landscape dynamics in the Greater Yellowstone Area. Natural Resource Technical Report NPS/GRYN/NRTR-2011/506. National Park Service, Fort Collins, Colorado, USA.

Middleton, A. D., T. A. Morrison, J. K. Fortin, C. T. Robbins, K. M. Proffitt, P. J. White, D. E. McWhirter, T. M. Koel, D. Brimeyer, W. S. Fairbanks, and M. J. Kauffman. 2013. Grizzly bear predation links the loss of native trout to the demography of migratory elk in Yellowstone. Proceedings of the Royal Society B 280:20130870. doi.org/10.1098/rspb.2013.0870

Miller, D. S., E. Hoberg, G. C. Weiser, K. Aune, M. Atkinson, and C. Kimberling. 2012. A review of hypothesized determinants associated with bighorn sheep (*Ovis canadensis*) die-offs. Veterinary Medicine International 2012:1–19.

Monello, R. J., D. L. Murray, and E. F. Cassirer. 2001. Ecological correlates of pneumonia epizootics in bighorn sheep herds. Canadian Journal of Zoology 79:1423–1432.

Mooney, H. A., and R. J. Hobbs. 2000. Invasive species in a changing world. Island Press, Washington, D.C., USA.

National Park Service. 2006. Management policies 2006. U.S. Department of the Interior, Washington, D.C., USA. http://www.nps.gov/policy/mp/policies.html. Accessed 12 May 2015.

National Park Service. 2011. Listing of acreage (summary). U.S. Department of the Interior, Washington, D.C., USA. https://irma.nps.gov/Stats/DownloadFile/107. Accessed 21 Jun 2015.

National Park Service. 2015. Mountain goat management plan EA. U.S. Department of the Interior, Washington, D.C., USA. http://parkplanning.nps.gov/mountaingoat. Accessed 21 Jun 2015.

Olliff, S. T., R. A. Renkin, D. P. Reinhart, K. L. Legg, and E. M. Wellington. 2013. Exotic fungus acts with natural disturbance agents to alter whitebark pine communities. Pages 236–251 *in* P. J. White, R. A. Garrott, and G. E. Plumb, editors. Yellowstone's wildlife in transition. Harvard University Press Cambridge, Massachusetts, USA.

Pallister, G. L. 1974. The seasonal distribution and range use of bighorn sheep in the Beartooth Mountains, with special reference to the West Rosebud and Stillwater herds. Thesis, Montana State University, Bozeman, USA.

Reed, D. F. 1986. Alpine habitat selection in sympatric mountain goats and mountain sheep. Northern Wild Sheep and Goat Council 5:421–422.

Reynolds, P. E. 1998. Dynamics of range expansion of a reestablished muskox population. Journal of Wildlife Management 62:734–744.

Rice, C. G., K. J. Jenkins, and W. Chang. 2009. A sightability model for mountain goats. Journal of Wildlife Management 73:468–478.

Samuel, M. D., R. K. Steinhorst, E. O. Garton, and J. W. Unsworth. 1992. Estimation of wildlife population ratios incorporating survey design and visibility bias. Journal of Wildlife Management 56:718–725.

Samuel, W. M., W. K. Hall, J. G. Stelfox, and W. D. Wishart. 1977. Parasites of mountain goat, *Oreamnos americanus* (Blainville), of west central Alberta with a comparison of the helminths of mountain goat and Rocky Mountain bighorn sheep, *Ovis c. canadensis* Shaw. Pages 212–225 *in* W. Samuel and W. G. Macgregor, editors. Proceedings first international mountain goat symposium, 18 February 1977, Kalispell, Montana, USA. Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch, Victoria, Canada.

Schlaepfer, M. A., D. F. Sax, and J. S. Olden. 2011. The potential conservation value of non-native species. Conservation Biology 25:428–437.

Schullery, P., and L. Whittlesey. 2001. Mountain goats in the Greater Yellowstone Ecosystem: a prehistoric and historical context. Western North American Naturalist 61:289–307.

Smith, B. L. 2014. Life on the rocks: a portrait of the American mountain goat. University Press of Colorado, Boulder, USA.

Smith, D. W., K. M. Murphy, and D. S. Guernsey. 2001. Yellowstone wolf project: annual report, 2000. National Park Service YCR-NR-2001-01, Yellowstone Center for Resources, Yellowstone National Park, Mammoth, Wyoming, USA.

Stewart, S. T. 1975. Ecology of the West Rosebud and Stillwater bighorn sheep herds, Beartooth Mountains, Montana. Thesis, Montana State University, Bozeman, USA.

Strong, J. S., and S. J. Leroux. 2014. Impact of non-native terrestrial mammals on the structure of the terrestrial mammal food web of Newfoundland, Canada. PLoS ONE 9:e106264. doi:10.1371/journal.pone.0106264

Treanor, J. J., P. J. White, and R. L. Wallen. 2013. Balancing bison conservation and risk management of the non-native disease brucellosis. Pages 226–235 *in* P. J. White, R. A. Garrott, and G. E. Plumb, editors. Yellowstone's wildlife in transition. Harvard University Press, Cambridge, Massachusetts, USA.

U.S. Department of Agriculture, Forest Service. 2005. Chapter 2670: Threatened, Endangered, and Sensitive plants and animals. Forest Service manual 2600: wildlife, fish and sensitive plant habitat management. U.S. Forest Service National Headquarters, Washington, D.C., USA.

Varley, N. C., and J. D. Varley. 1996. Introductions of mountain goats in the Greater Yellowstone Ecosystem: they're here to stay or are they? Northern Wild Sheep and Goat Council 10:113–117.

Vaterý, L., H. Frits, and J.-C. Lefeuvre. 2013. Another call for the end of invasion biology. Oikos 122:1143–1146.

White, P. J., R. A. Garrott, and G. E. Plumb. 2013. The future of ecological process management. Pages 255–266 *in* P. J. White, R. A. Garrott, and G. E. Plumb, editors. Yellowstone's wildlife in transition. Harvard University Press, Cambridge, Massachusetts, USA.

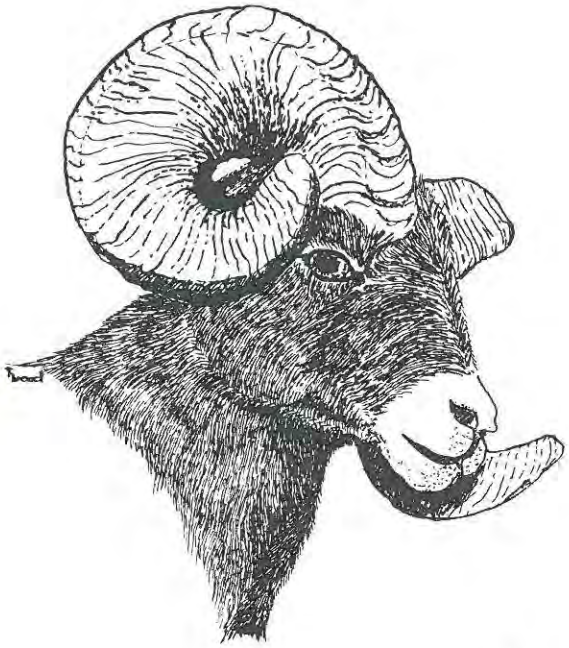
Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego, California, USA.

Williams, J. S. 1999. Compensatory reproduction and dispersal in an introduced mountain goat population in central Montana. Wildlife Society Bulletin 27:1019–1024.

Associate Editor: Blackwell.

Ex067

MOUNTAIN GOATS AND MOUNTAIN SHEEP OF WASHINGTON



by
Rolf L. Johnson

WASHINGTON
DEPARTMENT OF GAME

Ex069

MOUNTAIN GOATS AND MOUNTAIN SHEEP OF WASHINGTON

by

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PREFACE

Washington State has the largest native population of mountain goats in the contiguous United States. A pioneer study of mountain goats was initiated here more than four decades ago (Anderson, 1940). The two-year study was the first comprehensive life history work done on mountain goats in North America. The need for more data and for refined management resulted in the initiation of a new goat study in 1959 (Wadkins, 1965). This eight-year goat study evaluated population numbers and environmental factors responsible for observed goat declines. During the 1970's, goat and bighorn sheep populations in some areas of the state suffered losses dictating a need for further research on both species to solve management problems. Better survey information in particular was needed for mountain goat management.

Field work on the current sheep and goat study was initiated in 1976 as Federal Aid Project W 88 R. The study's principal objective was to determine current population status of mountain goats and mountain sheep throughout the state. This bulletin summarizes current and previous information on both montane bovids in Washington.

TERMINOLOGY

A definition of terms used in this bulletin may avoid ambiguity. I have used the terms "goat" and "mountain goat" interchangeably. In the same way, "sheep" and "mountain sheep" are used interchangeably. Where I refer to domestic goats (*Capra hircus*) or domestic sheep (*Ovis aries*), I include the word "domestic." "Nanny" refers to all adult female mountain goats and "ewe" refers to all adult female mountain sheep. Similarly, "billy" refers to an adult male mountain goat and "ram" refers to an adult male mountain sheep.

A "band" of either sheep or goats is a family-sized association interacting within a herd. A "herd" refers to sheep or goats that share specific seasonal ranges. A herd may consist of several bands of either sheep or goats. "Population" refers to all animals of the same species within a geographic area. With rare exceptions, populations are genetically isolated from one another.

TABLE OF CONTENTS

Acknowledgements ii
PREFACE iii
TERMINOLOGY iv

MOUNTAIN GOATS

INTRODUCTION 2
Historical Distribution 2
Current Distribution in Washington 5
Cascade Mountains 5
Olympic Mountains 7
Selkirk Mountains 8

GOAT HABITAT
Characteristics 9
Escape Terrain 10
Vegetation 10
Fire 10

POPULATION CHARACTERISTICS
Population Dynamics 12
Age and Sex Classification 13
Reproduction 15
Mating 15
Breeding Age 16
Kid Production 16
Population Structure 17
Age Distribution 17
Sex Ratio 24
Mortality 24
Weather 24
Natural Hazards 25
Predation 25
Parasitism 27
Harvest 28
Physical Condition 30
Food Habits 32
Chopaka Mountain Study 32
Study Area and Methods 32
Forage Consumed 33
Forage Variability 37
Summary 38
Minerals 39
Water 39
Competition 40
Interspecies Aggression 40
Forage Competition 40

Movements 42
Migration 42
Dispersal 43
Disease and Parasites 44
Diseases 44
Parasites 47

MANAGEMENT
Habitat 53
Logging, Roads, and Mining 53
Fire 55
Goat Populations 56
Restoration and Introductions 57
Trapping 58
Hunting 59
Hunter Management 59
Harvest 61
Surveys 65
Population Trends 69

SUMMARY 80

LITERATURE CITED 82

APPENDIX A. Mountain Goats Transplanted to Hooknose Mountain in Pend Oreille County, 1981 89
APPENDIX B. Mountain Goats Transplanted to Lime Mountain in Snohomish County, 1981 89
APPENDIX C. Mountain Goats Transplanted to Higgins Mountain in Skagit County, 1981 90
APPENDIX D. Mountain Goats Captured at Alpine Lookout (Nason Ridge), 1978-1980 91
APPENDIX E. Mountain Goats Captured in Olympic Mountains, 1979-1980 92
APPENDIX F. Mountain Goats Captured on Mount Chopaka, 1977-1980 93
APPENDIX G. Population Trend by Region and Management Unit 94

MOUNTAIN SHEEP

INTRODUCTION 112
Native Mountain Sheep 113
Sightings of Native Mountain Sheep in Washington 113
Evidence found indicating areas of Native Mountain Sheep Habitation 115
Bighorn losses 117
Mountain Sheep Reintroduction 118
California Bighorn 118
Rocky Mountain Bighorn 119

BIGHORN HABITAT
Characteristics 121
Vegetation 121
Escape Terrain 122
Fire 122

POPULATION CHARACTERISTICS
Population Dynamics 124
Age and Sex Classification 124
Reproduction 126
Breeding Age 127
Lambing 127
Inbreeding 128
Mortality 129
Weather 130
Predation 130
Harvest 132
Illegal Kill 133

Physical Condition 135
Body Weight 135
Kidney and Bone Marrow Fat 137

Food Habits 141
Forage Preference 141
Minerals 143
Competition 144
Cattle 144
Domestic Sheep 145
Elk 145
Deer 146
Mountain Goat 146

Movements 147
Migration 147
Emigration 147
Home Range 148

Disease and Parasites 149
Diseases 149
Lungworm Pneumonia Complex 149
Scabies 151
Bacterial Pneumonias 151
Other Diseases 152
Capture Myopathy 155
Parasites 155
Lungworms 156
Intestinal Nematodes 157
Other Parasites 157
Population Quality 158

MANAGEMENT
Reintroduction 159
Habitat 159
Present Land Management Practices in Release Area 159
Status of Other Wildlife Populations 160
Feasibility of Constructing Temporary Enclosure 160
Physical Criteria of Released Bighorns 160
Supplemental Reintroduction 160
Bighorn Population Growth 160
The First Release 161
Subsequent California Bighorn Reintroduction 164
Tucannon 164
Colockum 165
Oak Creek (Clemans Mountain) 166
Swakane Canyon 167
Umtanum 167
Klickitat River 168
Mount Hull 168
Vulcan Mountain 168
Asotin Creek - Cottonwood Creek 169
Reintroduction of Rocky Mountain Bighorns 170
Hall Mountain 170
Joseph Creek 172
Habitat Management 174
Mineral and Fossil Fuel Development 174
Logging 174
Fire 175
Ungulate Competition 175
Hunting 176
Hunter Management 176
Law Enforcement 178
Surveys 179
SUMMARY 181
LITERATURE CITED 183
APPENDIX A. Washington Trophy List 191
APPENDIX B. Washington Bighorn Sheep Harvest by Unit 192
APPENDIX C. Lamb:ewe Classification Counts of California Bighorns 193
APPENDIX D. Lamb:ewe Classification Counts of Rocky Mountain Bighorns 194
APPENDIX E. Age and Sex of California Bighorn Sheep Released at Sinlahekin, 1957 194
APPENDIX F. Age, Sex, and Weight of Rocky Mountain Bighorn Sheep Released at Hall Mountain, 1972 195
APPENDIX G. Description of Rocky Mountain Bighorns Transplanted from Hall Mountain to Joseph Creek, 1977 196
APPENDIX H. Description of Rocky Mountain Bighorns Transplanted from Lostine River in Oregon to Joseph Creek, Washington in January, 1981 196

MOUNTAIN GOATS

Ex077

INTRODUCTION

The mountain goat (*Oreamnos americanus*) is not a true goat but a mountain-dwelling antelope. Mountain goats are the only living member of the genus *Oreamnos*, and they have no close relatives living or extinct in North America. Their nearest living relative is the mountain-dwelling antelope of the Alps, the chamois (*Rupricapra rupricapra*). Other related species are found in the mountains of Asia. The mountain goat is most often differentiated from other mammals by its short, black horns and white hair giving rise to the characteristic beard, "baggy pants" and a prominent crest along neck, back and rump. While the thick hair and wooly underfur keep the mountain goat warm in winter, this animal has other unique functional adaptations. Mountain goats have extremely powerful front shoulders and broad hooves which make them premier climbers. These features enable the mountain goat to negotiate deep snow and rocky, precipitous terrain, and survive cold climates.

Although four subspecies (*Oreanmos americanus americanus, O. a. columbiae, O. a. kennedy*, and *O. a. missoulae*) were recognized at one time, Cowan and McCrory (1970) found no valid reason for recognizing subspecies within *Oreamnos americanus*.

HISTORICAL DISTRIBUTION

Ancestors of our mountain goat apparently evolved in Asia and colonized North America via the Bering land bridge about 2.5 million years ago. While extinct species of *Oreamnos* may have ranged from Yukon Territory to California, the current distribution of mountain goats is similar to historical occurrence (Johnson, 1977). A fossil mountain goat recovered from Lake Washtucna in eastern Washington indicates the environmental conditions or habitat requirements of mountain goats have changed considerably since their invasion during the Pleistocene era. This area is currently flatland and far from mountainous and forested goat range.

Native mountain goats are found in many of the mountainous areas of North America, from southeastern Alaska to south-central Washington in the coastal range and as far south as central Idaho in the Rocky Mountains. The present distribution of mountain goats is depicted in Figure 1.

Fig. 1. Distribution of mountain goats in North America.

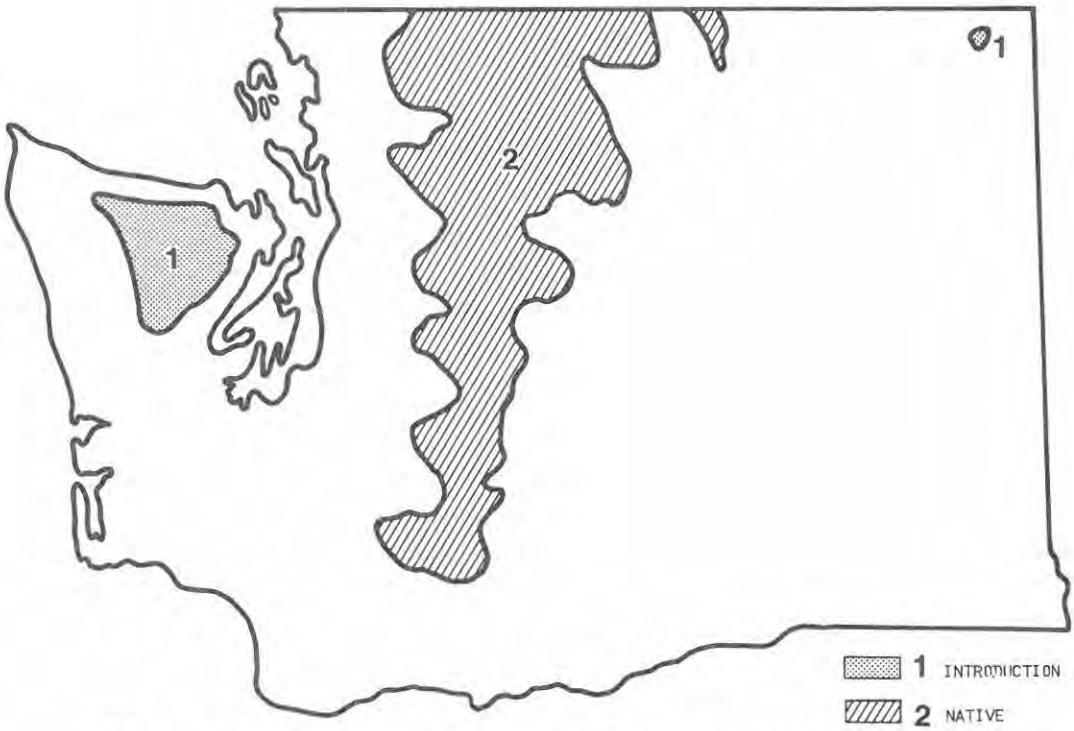

Fig. 2. Distribution of Mountain Goats in Washington State.

Mountain goats are native to the Cascade and Selkirk Mountains in Washington (Figure 2) and range over most of the same areas occupied when the first white men arrived. Reports of native mountain goats in the Cascades were documented as early as 1805 and 1806 by Lewis and Clark (Burroughs, 1961), who saw skins and blankets woven from mountain goat wool by Indians. Unfortunately Lewis and Clark used the term "goat" to refer to pronghorn antelope while "sheep" referred to mountain goats along the Columbia River. The type locality for *O. americanus* (Bailey, 1936) is described as "Cascade Range near the Columbia River in Oregon or Washington." Almost certainly these goats were taken in Washington, since Bailey (1936) indicated that there was no authentic record of mountain goat occurrence south of the Columbia River in Oregon. Dalquest (1948) believed the type locality was near Mount Adams. Historic records and other references to distribution since the turn of the century indicate that the native range of mountain goats extended throughout the Cascade Mountains from the Canadian border to Mount St. Helens and Mount Adams. Mount Chopaka, located on the eastern edge of the Cascades near the Canadian border, was historically bighorn sheep range. While a large herd of bighorns was found on Chopaka during the late 1800's, bighorn numbers declined after the turn of the century. Game Department reports indicate the sheep gradually disappeared from Chopaka about 1910-1915. No mountain goats were present when large numbers of sheep occupied Mount Chopaka. Mountain goats immigrated to Chopaka about 1910 from a resident population north of the border in British Columbia.

Goats have been reported as "seemingly a rare wanderer from outside the state" in the Selkirks of northeastern Washington (Dalquest, 1948). Taylor and Shaw (1929:31) [in Hall and Kelson (1959)] and Dice (1919:21) report the historic occurrence of mountain goats in the Blue Mountains of southeastern Washington. Dalquest (1948), however, believed that the reports of goats in the Blue Mountains by Dice (op. cit.) were erroneous. Native mountain goat populations do not currently inhabit either the Blue Mountains or Selkirk Mountains of Washington.

Harvest of mountain goats has changed considerably from their initial exploitation by Indians. Indians killed goats not only for their meat, but also for their hair and hides. Early explorers in the state found that Indians valued the wool of mountain goats for making blankets (Bailey, 1936). Salish Indians from along the Fraser River sometimes hunted goats and traded hides to tribes on the coast. Indians of the Cascades, including Skagits and Wenatchees, gathered goat wool from hillsides during the spring and summer when goats were shedding (Underhill, 1945; Collins, 1974; Thompson, 1970). Lewis and Clark discovered that Indians along the Columbia River made the skin of a goat head (with horns remaining) into a cap and valued it as an ornament (Burroughs, 1961). Indians of the Mount Baker district of Washington made a determined effort to take mountain goats; entire tribes took part in organized goat drives (Brooks, 1930). Early settlers undoubtedly also took mountain goats for their meat and hides, but the rugged terrain occupied by goats probably precluded high utilization except in accessible areas.

CURRENT DISTRIBUTION IN WASHINGTON

Cascade Mountains

Current distribution is nearly identical to historic occurrence (also shown in Figure 2). The only exception is probably on Mount St. Helens where native populations were extirpated.

Population estimates of mountain goats in the Cascade Mountains were made for the first time in 1961 (Table 1). During the recent study, trends in goat numbers have been evaluated and population estimates calculated for some units (see section entitled Population Trends).

In addition to goat populations managed by the state of Washington, four areas of the state have goat populations managed by federal agencies in the Department of Interior (Table 2). No hunting is permitted within any of the national parks but a few are probably taken on the Yakima Indian Reservation.

The North Cascades National Park was established in 1968 and consists of north and south units of the Park as well as the Ross Lake and Lake Chelan National Recreation Areas. Mountain goat hunting is permitted in the two recreation areas but closed in the park interior. Harvest statistics revealed that prior to 1968, slightly over 20 percent of the goat harvest in the state occurred within the current boundaries

Ex082

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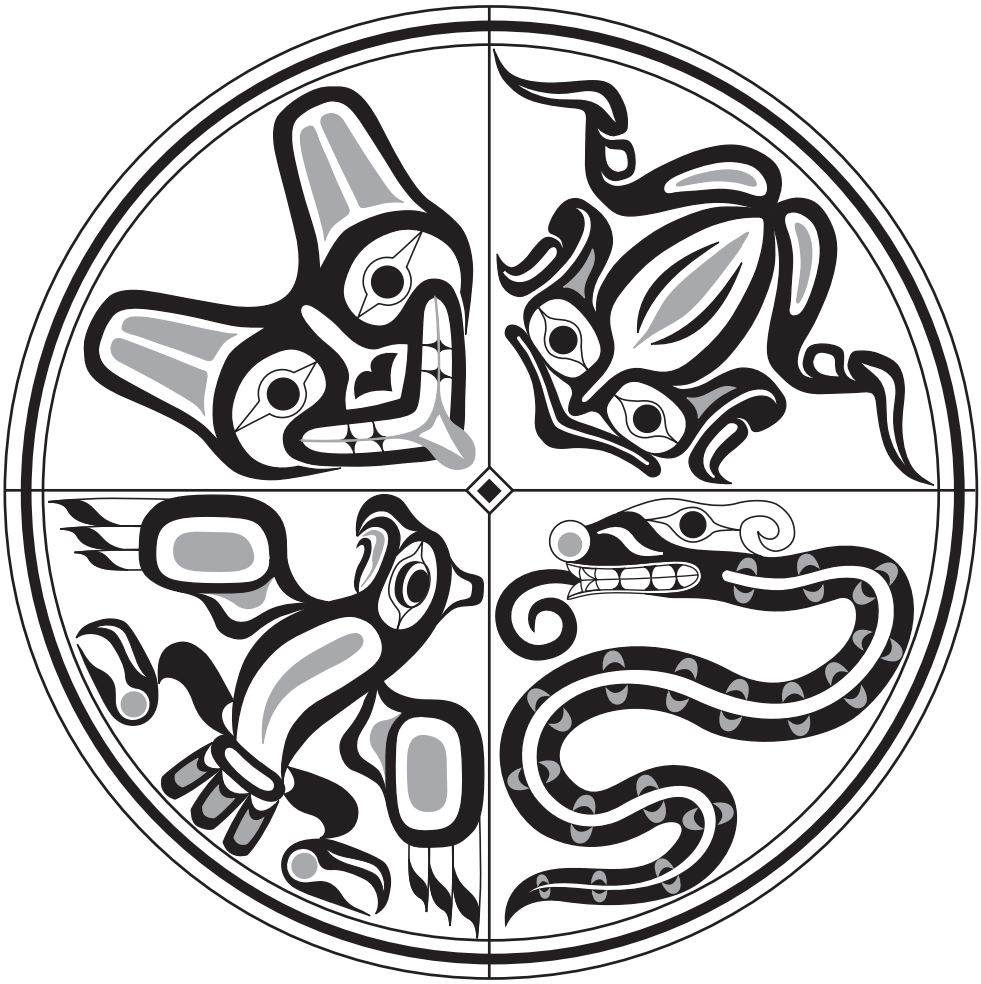

EFFECTS OF MOUNTAIN GOAT HARVEST ON HISTORIC AND CONTEMPORARY POPULATIONS

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Ex083

EFFECTS OF MOUNTAIN GOAT HARVEST ON HISTORIC AND CONTEMPORARY POPULATIONS

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ABSTRACT—Understanding population dynamics and historical declines for Mountain Goats (*Oreamnos americanus*) is challenging due to sparse data. Speculations regarding the cause of population declines have included habitat change, predation, disease, parasites, recreation impacts, and excessive harvest. Managing for recovery requires an understanding of the relative importance of the factors causing population declines. Using records of Mountain Goat harvest in selected areas of Washington State (USA), we modeled population trajectories for 7 areas with a stage-structured matrix model and compared these trajectories to recent population estimates. Our results supported the hypothesis that observed declines can be attributed primarily to the effects of harvest. We also assessed the level of harvest likely to be sustainable for Mountain Goat populations of varying sizes. Our results were sensitive to vital rates used in the model and were also influenced by population size and the proportion of harvest that is male. Generally, populations of <50 individuals should not be harvested, but larger populations (such as >100) or those where the proportion of males in the harvest is high (90 to 100%) may sustain ≤4% harvest. However, due to expected variation of vital rates among populations and years, declines may still occur with harvest at these levels and continued population monitoring is essential for hunted populations.

Key words: Cascade Range, harvest, Leslie matrices, management, Mountain Goats, *Oreamnos americanus*, population dynamics, population models, Washington

Understanding the dynamics of wild populations has been a central pursuit in wildlife management. Given intensive human use of many wild populations, detailed knowledge of population and ecological processes is crucial for management and conservation of these populations (Gordon and others 2004). The ecology of Mountain Goats (*Oreamnos americanus*) is poorly understood compared with that of other ungulates in North America (Côté and Festa-Bianchet 2003). Because of the high public profile of the species and strong interest in hunting Mountain Goats among sportsmen and by Indian tribes, a better understanding of the factors determining population levels and particularly harvest is essential.

In Washington State, Mountain Goats are native throughout the Cascade Range and were introduced in the Olympic Mountains during the 1920s (Houston and others 1991). Evident declines over the past 50 y have raised concerns about the management of this species. In 1961, the Mountain Goat population in the Cascade Range was thought to be about 8500 (excluding Mount Rainier National Park and Yakama Indian Nation lands). More recent estimates are around 3700 (4000 statewide minus 300 for the Olympics; Côté and Festa-Bianchet 2003; Happe and others 2004). However, these declines (and harvest) have been far from uniform. Whereas some areas retain substantial populations and populations are recovering in others, many areas have only remnant populations with indications of declines of ≥90% over the last 50 y.

Mountain Goat populations can be sensitive to overharvest (Côté and Festa-Bianchet 2003; Hamel and others 2006), and the acceptable harvest from native populations may be as low as 1% (Hamel and others 2006). Washington State's guidelines currently advocate permitting

Ex084

harvest of 4% of a population with a minimum population size of 50 animals (Washington Department of Fish and Wildlife 2003).

Although overharvest certainly may have played a role in apparent declines, other factors also may have been responsible. Many possible contributing factors have been reviewed by Côté and Festa-Bianchet (2003) and include disease and parasitism, disturbance caused by recreational activities, winter habitat degradation through timber harvest, predation, and loss of habitat due to conifer intrusion into alpine meadows as a result of fire suppression. Understanding the importance of these factors in population declines is a prerequisite for effective management with the goal of recovery of Mountain Goat populations.

Factors affecting Mountain Goat populations undoubtedly vary temporally and geographically, consistent with variable population trends throughout their range in Washington. However, evidence for most factors is anecdotal and not subject to retrospective analysis. Harvest effects, however, can be readily examined through modeling. The use of matrix models (Caswell 2001) is a common means of integrating information on vital rates (fecundity and survival) in analyzing population dynamics, and has application for both retrospective and prospective analysis. Following the approach that Hamel and others (2006) used for Mountain Goat populations in Alberta, we developed a generalized stage-structured matrix model to examine the hypothesis that past harvest has effected Mountain Goat populations in Washington, and to identify sustainable harvest levels.

METHODS

Study Area

Mountain Goats in the Cascade Range of Washington range in elevation from about 1150 to 2100 m in summer to about 800 to 1750 m in winter (C Rice, unpubl. data). These areas are characterized by Montane Mixed Conifer Forest, Eastside Mixed Conifer Forest, Lodgepole Pine Forest and Woodlands, Subalpine Parkland, and Alpine Grasslands and Scrublands (Johnson and O'Neil 2001). Suitable habitat for Mountain Goats is patchily distributed from the Washington-British Columbia border southward to the slopes of Mt. Adams in south-central Washington.

Harvest Records

Permit only hunting for Mountain Goats (1 Mountain Goat/permit) was established in Washington in 1948, and in 1957 permits were allocated according to 10 management units (Johnson 1983). These units were increasingly subdivided to more equally allocate hunting through 1981 when there were 40 units. Closure of units and reduced permits in open units continued from 1981 to the present.

Based on mandatory hunter reports, harvest records for Mountain Goats in Washington were obtained from 4 sources in 4 formats. From 1948–1970, reports on file with the Washington Department of Fish and Wildlife (WDFW) listed each Mountain Goat harvested by place name and drainage (along with Mountain Goat hunting unit). We used place names to determine harvest localities because unit boundaries for this period are not known. To assign coordinates to each harvest, the place names were matched against a geographic place name list (US Board on Geographic Names, undated). Where duplicates of place names occurred, the appropriate name was selected based on the watershed of the harvest report. If the place name was a creek or river, the coordinates of the headwaters were used. Based on these locations, each harvest was assigned to the appropriate hunting unit.

Mountain Goat harvest from 1971–1981 was obtained from Johnson (1983), who summarized harvest by hunting unit. For 1982–2004, harvest was recorded by unit in WDFW databases.

Population Models

Recently, Hamel and others (2006) presented a model of Mountain Goat populations based on data collected at Caw Ridge, Alberta, Canada. This was a stage-structured matrix model with 12 stages, 6 for each sex (ages 0, 1, 2, 3–4, 5–8, and ≥9 y). Hamel and others (2006) estimated vital rates (fecundity and survival) and their variability within and among years by tracking observations of marked individuals from 1993 to 2003. The model was implemented in RAMAS Metapop (Akçakaya 2002).

We followed the structure of the Hamel and others (2006) model because it was the only published assessment incorporating annual variation in vital rates for Mountain Goats. Because of the great geographic separation as

Ex085

well as climatic and ecological differences between Caw Ridge and the Cascade Range of Washington, we modified both the vital rates and their variability for our basic model by averaging rates reported in other studies. There has been no research on vital rates of Mountain Goats in the Washington Cascade Range, but data are available for an introduced population of Mountain Goats on the Olympic Peninsula of Washington (Stevens 1983; Houston and Stevens 1988).

The population dynamics of introduced Mountain Goat populations often differ from native populations (Côté and Festa-Bianchet 2003), although how long this difference persists is unclear. We found no other reports of Mountain Goat fecundity apart from that of Bailey (1991) for an introduced population in Colorado. Due to the milder climate, it is quite possible that Mountain Goats in the Cascade Range have higher vital rates than those at the interior and higher latitude Caw Ridge study area, so we averaged the rates from Caw Ridge (Hamel and others 2006), Colorado (Bailey 1991), and the Olympics (Houston and Stevens 1988); but we did not include the ''off-Klahane'' estimates from the Olympic Mountains (Stevens 1983:85) because they likely reflected early post-colonization demographics. We did not attempt to adjust for slightly different age groupings used by Bailey (1991), but directly applied his rates for 3, 4–9, and 10+ y to our basic model stages of 3–4, 5–8, and ≥9 y. Because Bailey (1991) did not specify sex of offspring, we partitioned rates according to the ratio observed at Caw Ridge for each female age class.

Cascade Range Mountain Goat populations are likely intermediate between interior and coastal ecotypes (Gilbert and Raedeke 1992). Consequently, we averaged survival rates from the Caw Ridge model (Hamel and others 2006) with those from an earlier study (1988–1992) on Caw Ridge (Smith and others 1992, for kids), Colorado (Adams and Bailey 1982, kids; Kohlmann and Bailey 1991, kids and adults), southeast Alaska (Nichols 1980, kids and yearlings; Smith 1986, yearlings and adults, harvest excluded), and the British Columbia Coast Range (Dane 2002, kids and yearlings). Except for Hamel and others (2006), these authors provided survival estimates pooled across sexes. To partition the reported rates between sexes, we allocated the pooled estimate to each sex so that the male:female ratio remained constant and equal to that of the Caw Ridge model population (Appendix A). For comparisons among models with different vital rates, we used the finite rate of population change (λ) calculated by RAMAS.

For each stage, we added the variance among vital rate estimates given above to the interannual variance (environmental stochasticity) reported by Hamel and others (2006) so that the variation in our basic model approximated pooled process and sampling variation. Thus, this variance represented the total uncertainty about vital rates for simulated populations.

Our models included initial population, vital rates, variation in vital rates (environmental stochasticity), uncertainty of vital rate estimation, demographic stochasticity, and harvest. Like Hamel and others (2006), we did not include density dependence (Côté and Festa-Bianchet 2001; Côté and others 2001), nor did we attempt to evaluate small population impacts such as inbreeding depression (O'Grady and others 2006), Allee effects (Courchamp and others 1999), or metapopulation dynamics. Although immigration and emigration of males has been reported (Stevens 1983; Côté and Festa-Bianchet 2001) and was observed in our collared Mountain Goats in Washington (n = 2, CG Rice, unpubl. data), these movements of males would have little impact on population models. Immigration and emigration by females is rare: 3 incidents in about 81 Mountain Goat years of monitoring in Alberta (Festa-Bianchet and Côté 2008); none in the Olympics (Stevens 1983); and none among our collared Mountain Goats in Washington (n = 31). Thus demographic impacts of movements beyond modeled population boundaries can be considered insignificant.

Each population was simulated with 1000 random replicates from vital rates by RAMAS Metapop with environmental variation drawn from a lognormal distribution. Each model run was initialized to a stable age distribution and demographic stochasticity was included. Several of the models had small ending populations (<50 individuals), producing model results that were not normally distributed and with average population sizes consistently much higher than the median and often above the 75th percentile.

Ex086

TABLE 1. Alternate Mountain Goat population model scenarios showing the area modeled (Model), parameter that was changed (Parameter), values that were used in the scenarios (Parameter values), and the reason for considering the alternate scenario (Rationale). Proportional vital rates were applied to both fecundity and survival.

Model	Parameter	Parameter values		Rationale
		Low	High	
Mt. Baker	Initial population	420	650	Low likelihood of initial population having supported reported harvest
Mt. Baker	Proportional vital rates	1.000	1.023	Low likelihood of initial vital rates having supported reported harvest
Penders Canyon	Harvest	78	125	Uncertainty about fall distribution of population estimated in winter
Falls Creek	Harvest	105	172	Uncertainty about fall distribution of population estimated in winter
Falls Creek	Proportional vital rates	1.000	1.045	Low likelihood of initial population having supported reported harvest
East Stevens Pass	Initial population	250	300	Low likelihood of initial population having supported reported harvest
East Stevens Pass	Proportional vital rates	1.000	1.014	Low likelihood of initial vital rates having supported reported harvest
Snoqualmie	Initial population	450	900	Low likelihood of initial population having supported reported harvest
Goat Rocks	Initial population	600	900	Low likelihood of initial population having supported reported harvest
Goat Rocks	Proportional vital rates	1.000	1.015	Low likelihood of initial vital rates having supported reported harvest

Consequently, we used the median of the model replicates as our measure of central tendency. Because RAMAS reports these percentiles only for the final year of the simulation, we ran each simulation multiple times, ending it at 5-y increments over the model period.

In addition to our basic models for each area, we examined a number of scenarios varying the initial population, estimated harvest, or vital rates depending on the uncertainties applying in each case (Table 1). In several of our simulations, population trajectories were considerably lower than corresponding population estimates, and in several models most replicates reached zero while considerable harvest occurred in subsequent years. Because of the potential for inaccuracies in initial population estimates and geographic variation in vital rates, we estimated, through iteration, both the increase in initial population and the proportional increase (Akçakaya 2002) in vital rates (factor applied to both fecundity and survival) for which the median of replicates approximated recent population estimates.

Harvest recorded or estimated (see below) for each area was assigned in the model according to the historic statewide harvest age distributions, 1959–1962 (Johnson 1983:23, kids: 0%; yearlings: 10%; age 2: 11%; age 3–4: 34%; age 4–8: 38%; and age ≥9 y: 7%; $n = 289$). Because the historic harvest distribution by sex was close to 1:1 (1948–1981, 49% males, Johnson 1983:63), harvest was allocated equally between sexes for each stage.

We selected populations for modeling (Fig. 1, Table 2) based on 3 factors: 1) the existence of historic and recent population estimates for that area; 2) ability to ascribe harvest to that area over the model period; and 3) large or moderate difference between current and historic population status.

For initial population sizes, we used approximations made by WDFW in 1961 (Wadkins 1962; reproduced by Johnson 1983) for most models. These were extrapolations from ground counts and may be considered rough estimates. Consequently, in some cases we modeled scenarios with higher initial populations when it appeared that the respective populations could not have supported the reported harvest. In some cases (for instance Mt. Baker, Goat Rocks), the 1961 areas were larger than that covered by the model. For these we reduced the 1961 estimate by an amount commensurate with our

Ex087

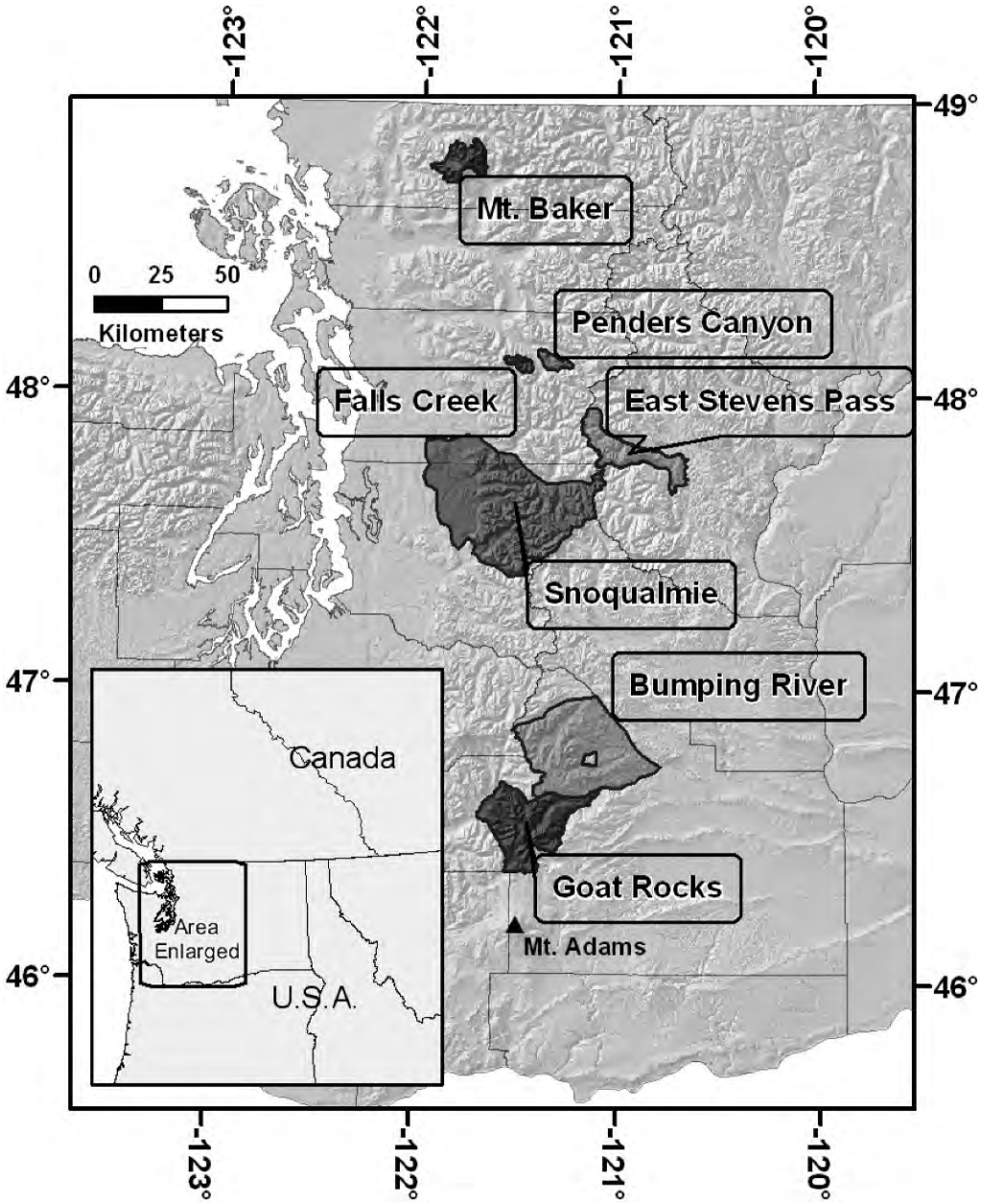

FIGURE 1. Mountain Goat population model locations in Washington State.

knowledge about current and past abundances of Mountain Goats in the respective areas. Historic population estimates for the Penders Canyon and Falls Creek models were based upon notes on Mountain Goats observed by Art Ryals during winter visits (1946–1983). These were compiled into minimum population estimates by Reed (1983, and also reported by Johnson 1983). With the exception of the Snoqualmie model, recent population estimates for all models were based on helicopter surveys (CG Rice, unpubl. data) for which we applied a preliminary sightability correction based on group size (Steinhorst and Samuel 1989):

Ex088

TABLE 2. Description of areas in Washington selected for Mountain Goat population models.

Model	Area[1] Above 1500 m	Estimated Population 1946	1961	2005	Harvest reported	Total harvest	Removals	Factors in selection
Mt. Baker	105		385–420	420	1964–1995	329		Recovered from substantial decline
Penders Canyon	18	154	72	8	1949–1991	78–125		Large decline, good historic population records
Falls Creek	3	73	31	5	1949–1994	105–172		Large decline, good historic population records
East Stevens Pass	62		250	34	1962–1990	173	27	Large decline, good harvest records
Snoqualmie	144		475	≈50	1961–1998	757		Large decline, good harvest records
Bumping River	398		475	100	1957–2005	347		Moderate decline
Goat Rocks	257		600	340	1951–2005	661		Moderate decline

[1] km^2.

$$\text{Adjusted Estimate} = \frac{1}{1+e^{0.9207-0.3885\,\text{Group Size}}}\,\text{Group Size}$$

For Snoqualmie, we have no recent population estimates, but judging from incidental observations by other resource agency personnel, a total of 50 animals was judged to be a reasonable rough estimate for this large area.

For 1948–1970, estimated Mountain Goat harvest consisted of all kills with place names in each model area (Fig. 1). Estimating harvest for 1971–2004 was more difficult for models whose area boundaries did not correspond to those of 1 or more hunting units because unit boundaries changed or because population estimates were for only a portion of the unit they were in. In such cases, we assumed that the proportion of harvest in the modeled section of the unit was the same during 1971–2004 as it was during 1948–1970 and prorated the harvest from the unit(s) overlapping the model area according to the proportion of harvest in 1948–1970 that occurred in the area being modeled. For example, for 1971–1979, the Goat Rocks Unit (then called the Packwood Unit) included the Smith Creek Unit. In 1948–1970, of the 300 Mountain Goats harvested with place names in the Packwood Unit, 287 (95.7%) had place names within the Goat Rocks Unit and 13 (4.3%) with place names in the Smith Creek Unit. So, for 1971–1979, the Goat Rocks harvest estimate was set equal to the 0.957 × the Packwood Unit estimate. There was additional uncertainty about the harvest for the Penders Canyon and Falls Creek models because the population estimates were based on winter counts, and distribution of these animals during the fall hunting season was not precisely known. Based on the movements observed by 2 GPS-collared Mountain Goats in or nearby to these areas and a subjective assessment based on terrain and the movement patterns of 44 other GPS-collared Mountain Goats elsewhere (CG Rice, unpubl. data), we developed conservative and liberal scenarios consisting of nearby and slightly more distant locations to estimate harvest according to the above procedures.

To assess levels of harvest that may be considered sustainable, we developed general models where we considered harvest of 0 to 4% of a Mountain Goat population with the proportion of that harvest being male as 0.50, 0.75, or 0.90. We did this because although historic harvest was about 50% male, recent harvest has strongly favored males (of the 72 Mountain Goats harvested 2002–2006, 89% were males), apparently in response to WDFW efforts to encourage Mountain Goat hunters to kill males. Because vital rates evidently vary geographically (Table 3) and between native and introduced populations, we considered 4 scenarios for vital rates: 1) average vital rates (as above); 2) minimum vital rates for each stage; 3) maximum vital rates for each stage from studies

TABLE 3. Fecundity (a) and survival (b) values used to calculate mean values used in the model. Standard errors are given in parentheses for mean values and for Hamel and others (2006). In the 2nd column, N = native Mountain Goat population, I = introduced population. In the survival table, Yl = yearling. For all studies except Hamel and others (2006), survival was pooled across sexes within stages; here it has been partitioned by the male:female ratio for each stage from the Caw Ridge model population.

a.

Study	Location (N or I)	Fecundity (kids per female in stage)							
		Female kids				Male kids			
		2	3–4	5–8	9+	2	3–4	5–8	9+
Hamel and others 2006	Caw Ridge, AB (N)	0.021	0.265	0.402	0.257	0.019	0.194	0.345	0.398
(S.E.)		(0.050)	(0.166)	(0.114)	(0.076)	(0.065)	(0.165)	(0.101)	(0.068)
Bailey 1991	Colorado (I)	0.000	0.300	0.382	0.208	0.000	0.220	0.328	0.322
Houston & Stevens 1988	Olympics, WA (I)	0.000	0.333	0.416	0.548	0.000	0.333	0.286	0.110
Mean		0.007	0.300	0.400	0.338	0.006	0.249	0.320	0.277
(S.E.)		(0.051)	(0.169)	(0.115)	(0.199)	(0.066)	(0.181)	(0.106)	(0.164)

b.

Study	Location (N or I)	Survival to next stage											
		Females in stage						Males in stage					
		Kid	Yl	2	3–4	5–8	9+	Kid	Y1	2	3–4	5–8	9+
Smith 1986	SE Alaska (N)		0.778	0.992	0.993	0.994	0.714		0.648	0.988	0.986	0.984	0.580
Kohlmann & Bailey 1991	Colorado (I)	0.600		0.916	0.931	0.942	0.911	0.600		0.884	0.862	0.844	0.869
Hamel and others 2006	Caw Ridge, AB (N)	0.619	0.852	0.805	0.923	0.944	0.866	0.619	0.765	0.729	0.847	0.849	0.803
(S.E.)		(0.129)	(0.153)	(0.137)	(0.062)	(0.048)	(0.084)	(0.129)	(0.201)	(0.185)	(0.104)	(0.093)	(0.284)
Dane 2002	BC Coast Range (I)	0.680	0.778					0.680	0.648				
Nichols 1980	SE Alaska (N)	0.580	0.797					0.580	0.677				
Smith and others 1992	Caw Ridge, AB (N)	0.577						0.577					
Adams & Bailey 1982	Colorado (I)	0.570						0.570					
Mean		0.604	0.801	0.904	0.949	0.960	0.830	0.604	0.684	0.867	0.899	0.892	0.751
(S.E.)		(0.135)	(0.157)	(0.166)	(0.073)	(0.057)	(0.133)	(0.135)	(0.209)	(0.226)	(0.129)	(0.123)	(0.322)

Ex089

Ex090

of native populations; and 4) maximum vital rates for each stage from all studies.

We modeled this harvest by first calculating the probability of harvest from each increment of 50 animals in a population as 50 × percent harvest/100 × proportion of harvest male (or female). So, for each 50 animals in a population exposed to 3% harvest, of which 0.9 were male, the initial estimated harvest would be 1.35 males and 0.15 females. This estimated harvest was rounded to the nearest integer to obtain the assigned harvest, with the difference between the estimated harvest and assigned harvest accumulated in successive years. So, with 1.35 males harvested/year, assigned harvest in year 1 would be 1. The estimated male harvest for year 2 would be 1.35 + 1.35 − 1 = 1.70, yielding an assigned harvest of 2. The estimated harvest for year 3 would be 1.35 + 1.70 − 2 = 1.05, yielding an assigned harvest of 1. For each sex, the assigned harvest was randomly selected from stages with ages ≥2 y. Initial populations were set at 50, 100, 200, 300, and 500, representing the range of population sizes over which harvest would likely be applied, and simulations were run for 10 y.

Sex-biased harvest was expected to affect males and female stages differently. To assess these effects, as well as those for the whole population, we saved the RAMAS final stage abundances for each replicate and evaluated the probability that the population was stable or increasing, whether the female stages were stable or increasing, and changes in the sex ratio of adults from these results.

When developing some of the population models and interpreting the results, we inspected the movements of 46 Mountain Goats throughout the Cascade Range which were fitted with GPS collars and had fix records longer than 10 mo between September 2002 and October 2007. The mean duration of tracking was 678 d (range 249 to 1535 d). The total of 138,846 fixes had intervals of 3 h (85.7%), 5 h (10.0%), or 12 h (4.3%).

RESULTS

Harvest

Of the 4719 harvest reports from 1948–1970, 2.5% did not report a location, 3.4% of the place names could not be matched meaningfully with a place name in the geographic name database, and 0.8% matched with locations outside Mountain Goat range or in Mount Rainier or Olympic National Parks. This yielded a total of 4373 harvest reports that could be assigned to a meaningful location (93% of all reported harvest).

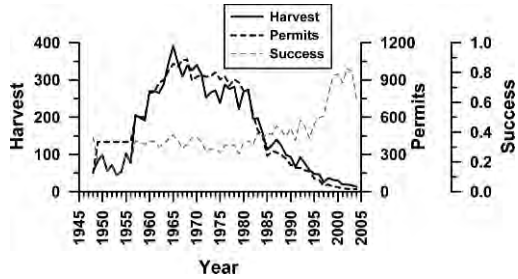

FIGURE 2. History of Mountain Goat harvest permits and success rate (harvest/permits) in Washington, 1948–2004.

Annual permits issued and total reported harvest of Mountain Goats in Washington was low (<100) before 1955, then harvest increased to between 250 and 400 animals in the 1960s and 1970s (Fig. 2). There was a substantial reduction in permits and harvest in the early 1980s, after which both steadily declined.

Models

General.—The average vital rates were often quite similar to those in the Caw Ridge model (Hamel and others 2006) with a few exceptions (Table 3, Appendix B). These exceptions were for age ≥9 y females (production of female kids was higher and production of male kids was lower than at Caw Ridge), and for age 3–4 y females (production of kids of both sexes was slightly higher). Survival of 2-y-olds of both sexes was lower in our basic model, while that of 3–4-y-olds was higher (Table 3). For our basic model, λ was 1.041 compared with 1.024 for the Caw Ridge model. Our basic model had higher standard deviations around the estimates than the Caw Ridge model (Table 3) due to the added component of sampling error, and this difference varied considerably among stages. Overall, variation (expressed as the square root of the sum of all variances) was 29% higher than for Caw Ridge in our basic model for reproduction, and 12% higher for survival.

Individual models.—The median trajectories for models with harvest indicated declining popu-

Ex091

lations, whereas those without harvest indicated increasing populations with 1 exception; the Falls Creek model with average vital rates which declined from 70 to 20 animals over the modeled period. Larger populations (250 to 900 animals) without harvest approximately doubled with average vital rates, whereas the Penders Canyon population increased only slightly from 150 to 164 animals.

With an initial population of 420 animals and average vital rates, the Mt. Baker model with harvest declined to about 20 animals by 1995 and remained low thereafter (Fig. 3). With an initial population of 650 animals, the median was near recent estimates (Fig. 3). Alternatively, proportional vital rates of 1.023 also produced the median near recent estimates.

For Penders Canyon, populations under both conservative and liberal scenarios showed steady decline over the model period, although the modeled populations tended to remain higher than population estimates (Fig. 3). Notably, the population estimates declined from 1946–1956, whereas modeled populations tended to remain near constant until the onset of regular harvest in 1964.

Modeled Falls Creek populations under both conservative and liberal scenarios generally corresponded to population estimates prior to 1970, after which they declined much more than population estimates shown in Fig. 3. Increasing vital rates by 1.045 yielded median population levels corresponding to recent surveys, but the levels remained well above all earlier counts.

Given an initial population of 250 animals, the East Stevens Pass models yielded median population levels consistently below later population estimates shown in Fig. 3. With a supposed initial population of 300 animals, modeled populations were nearly centered on later estimates, as was true with proportional vital rates of 1.014.

With an initial population of 450 animals, the Snoqualmie unit showed a precipitous decline, with the median trajectory reaching zero in 1981, well before harvest ended (Fig. 3). An initial population of 900 animals appeared to be more realistic, yielding a median final population of 51 animals. No reasonable proportional vital rates adjustment (that did not bring survival up to 1.0 for several stages) produced a median final population near 50 animals.

The median of population trajectory in the Bumping River Unit declined steadily. The median at the end of the modeled period corresponded roughly to recent population estimates from helicopter surveys as shown in Fig. 3.

The Goat Rocks modeled populations tended to decline with the median well below recent population estimates (Fig. 3). Increasing the initial population to 900 animals brought the median up to recent estimates as did a proportional vital rate of 1.015.

General models.—Without harvest, λ for the 4 scenarios were 0.958 for minimum vital rates, 1.041 for average vital rates, 1.084 for maximum vital rates for native populations, and 1.137 for maximum vital rates for all estimates. With minimum vital rates, populations had low probabilities of being stable or increasing regardless of population size or harvest rates (Fig. 4). For average vital rates, the probability of being stable or increasing increased in a nonlinear fashion with population size and percent of harvest that was male, and decreased with percent harvest (Fig. 4). For populations of 50 animals, the probabilities of being stable or increasing were below 0.50 for all average vital rate scenarios, but for larger populations this threshold was achieved for greater levels of percent harvest as the percent of harvest that was male increased (Fig. 4). For maximum vital rates from native populations, similar trends in the probability of being stable or increasing occurred, but the probabilities were higher. Given maximum vital rates, populations of all sizes and harvest scenarios had a high probability of being stable or increasing (Fig. 4). When considering only female stages, the probability of being stable or increasing was slightly higher than that of the whole population when harvest was 50% male. When harvest was 90% male, there was virtually no effect of harvest level on the probability of female stages being stable or increasing at 0.50, but there was some evidence for an effect at higher probabilities of being stable or increasing (Fig. 4).

Unlike population trajectories, the adult sex ratio was not strongly affected by population size, especially for populations $\geq$100 animals (Fig. 5), and the proportional change in sex ratio was similar among vital rate scenarios. In this

Ex092

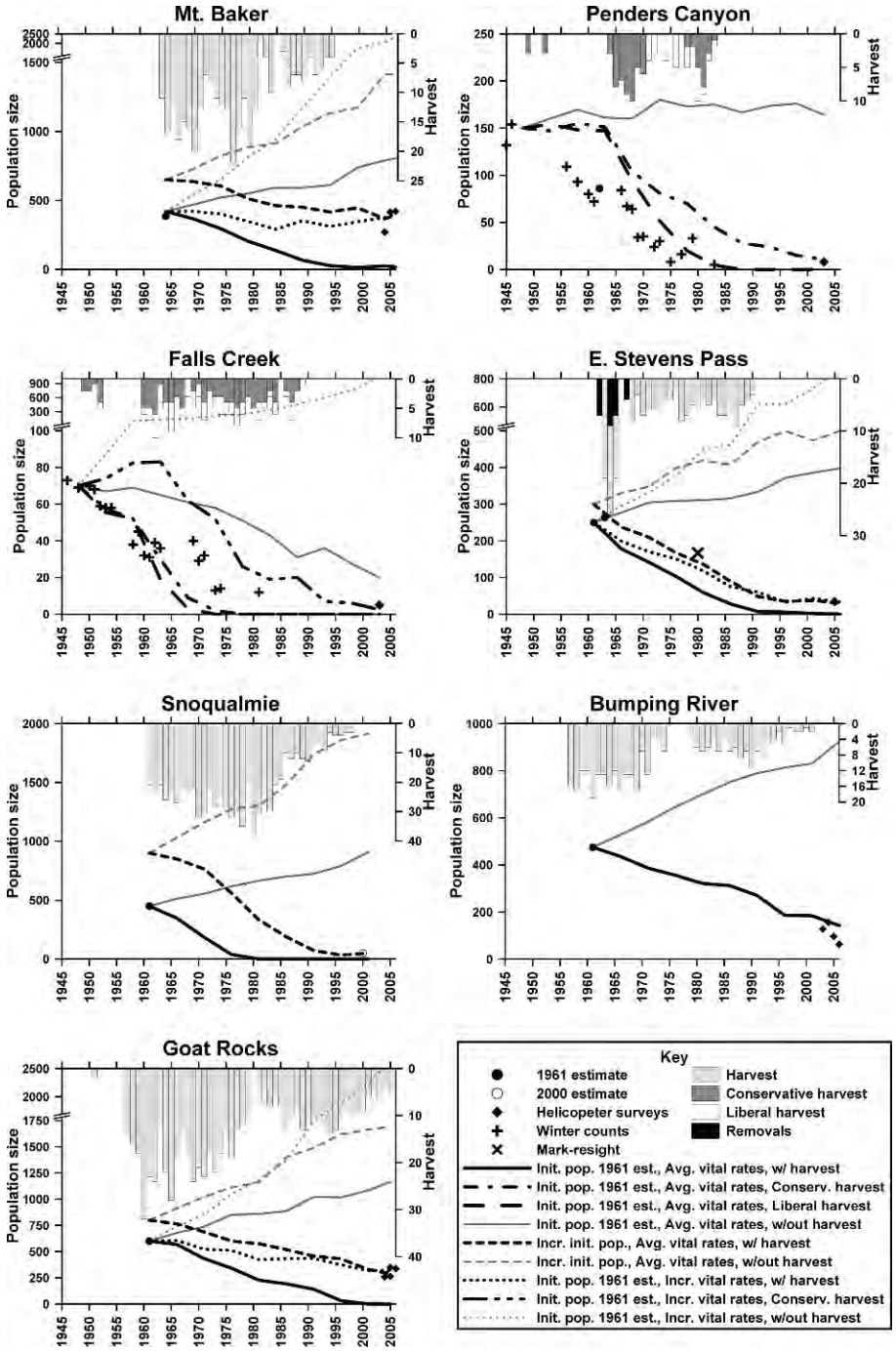

FIGURE 3. Mountain Goat median population model trajectories for 7 areas in Washington with and without harvest referenced against population estimates from 1961 Washington Department of Fish and Wildlife Estimates (all areas), 2000 estimate (Snoqualmie), helicopter surveys (all areas but Snoqualmie), Winter counts (Penders Canyon and Falls Creek), and mark-resight estimate (East Stevens Pass). Abbreviations: Init. = Initial; pop. = population; est. = estimate; Avg. = Average; w/ = With; Conserv. = Conservative; w/out = Without; Incr. = Increased. Values for increased initial populations and vital rates are in Table 1.

Ex093

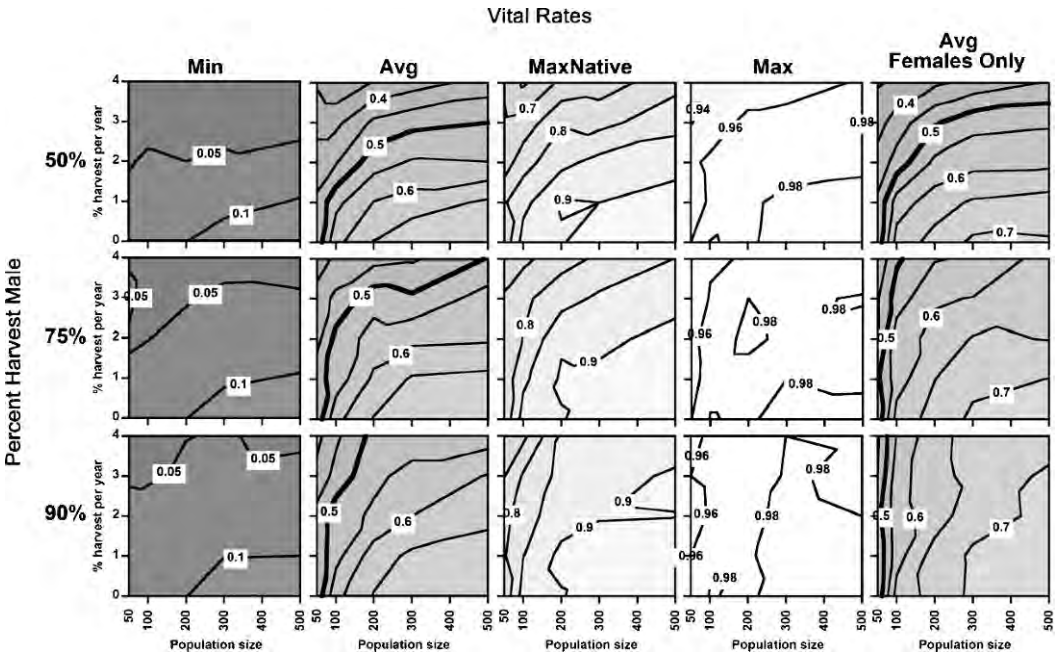

FIGURE 4. Contour graph of the probability of a Mountain Goat population remaining stable or increasing for all stages and female stages only (Avg Females Only) given: 1) the proportion of the harvest that is male, 2) population size, and 3) percent harvest for vital rates that were minimum (Min), average (Avg), the maximum for native populations (MaxNative), and maximum for all populations (Max).

context, compared with no harvest, at 4% harvest the ratio of males:females was about 20% less when the harvest was made up of 50% males, 45% less when the harvest was 75% male, and 60% less when the harvest was 90% male. Likewise, the proportion of males in each adult male stage was similar among vital rate scenarios and population sizes, but changed with percent harvest and percent of harvest that was male (Fig. 6). For example, for average vital rates with 50% of the harvest male (M), declines in the older stages (5–8 y-M and 9+ y-M) with increasing percent harvest were moderate as were increases in the younger stages (2 y-M and 3–4 y-M). These differences were much greater with 90% of the harvest male. With 4% harvest, the proportion of males in the oldest male stage (9+ y-M) declined to about 50% of that with no harvest, while males 5–8-y-old declined by about 30%. Males 3–4-y-old increased by about 16% of that with no harvest, and the proportion of youngest adult males (stage 2 y-M) approximately doubled when compared with 0% harvest (Fig. 6).

DISCUSSION

General Comments

Given the limited information on vital rates for Mountain Goats, we included estimates from introduced populations when computing our average vital rates. Notably, for survival of 2 out of 3 of the adult female stages, the highest values were from native populations (Smith 1986). Adult female survival had the highest elasticities in the Hamel and others (2006) model, so it is not surprising that the λ for our basic model was only slightly higher. Because we did not have vital rate estimates from Washington, our basic model reflects all available estimates. As such, it has general applicability and is suitable for modeling Mountain Goat populations wherever local estimates are not available.

Although density dependence has been described in several large herbivores as delayed primiparity and increased juvenile mortality (Festa-Bianchet and others 2003), this has not been described in Mountain Goats. In fact, no

Ex094

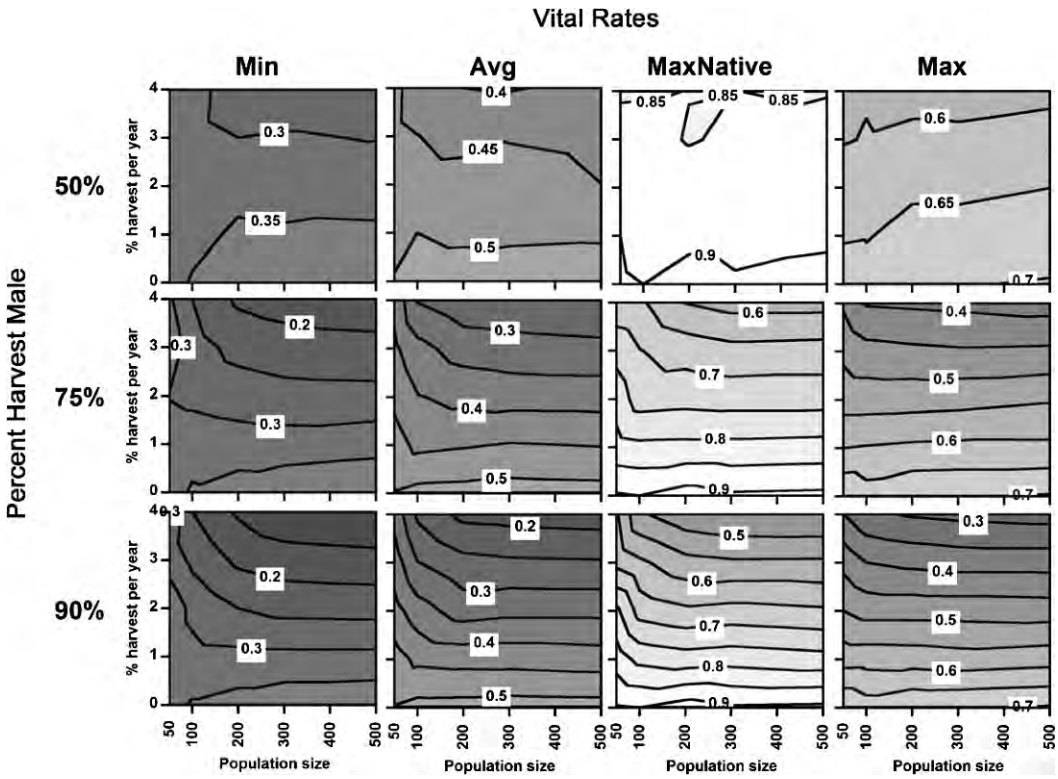

FIGURE 5. Contour graph of adult (age ≥2 y) sex ratios (males:female) of Mountain Goat populations given: 1) the proportion of the harvest that is male, 2) population size, and 3) percent harvest for vital rates that were minimum (Min), average (Avg), the maximum for native populations (MaxNative), and maximum for all populations (Max).

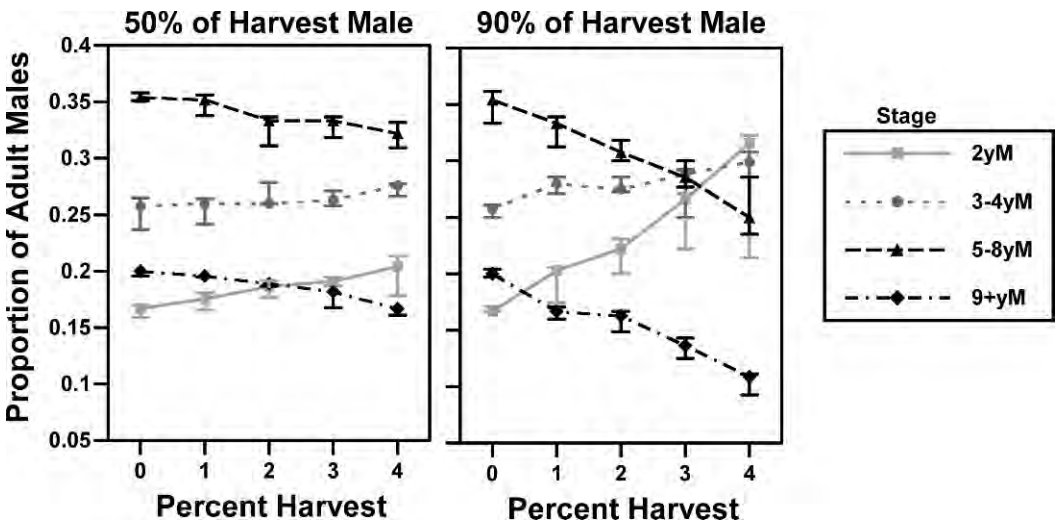

FIGURE 6. The proportion of adult male Mountain Goats in each stage of simulations using average vital rates when harvest is 50% male or 90% male. Error bars show the 90% nonparametric confidence interval of the medians across population sizes (50 to 500 animals).

Ex095

density dependent effects were detected in the Caw Ridge population despite a doubling of the population over the period of study (Côté and Festa-Bianchet 2001; Côté and others 2001; Festa-Bianchet and others 2003; Hamel and others 2006). Conversely, Kuck (1977) presented some evidence for weak inverse density dependence in a Mountain Goat population in Idaho. Forage resources are limiting for Mountain Goats primarily in winter (Hebert and Turnbull 1977), and Kuck (1977) described a system in which Mountain Goats selected winter habitats on the basis of escape terrain with dominant animals occupying the most favorable sites. After a population decline, prime escape terrain sites continued to be used while less favorable sites were not, despite the likelihood of more favorable forage conditions at the sites with poor escape terrain characteristics (Kuck 1977). Consequently, negative impacts on vegetation at favored locations remain high and may be long lasting (Wadkins 1967). Although it is probable that if Mountain Goat populations continue to decline and at some point forage resources at these sites recover, it is not known what magnitude of decline would produce this recovery, and it is likely that there would be a time lag of uncertain duration before vegetation responded at the favored sites. Given the lack of compelling evidence of density dependence in Mountain Goats and uncertainty about its magnitude and lag effects, we felt justified in excluding it from our models. While including density dependence may have prevented unrealistic increases in some model replicates, our use of the median as the measure of central tendency limited the impact of unrealistic increases in some model replicates on our interpretation.

Individual Models

When modeled over several decades, there was large variation in modeled population trajectories due to the high temporal variation in vital rates (Côté and others 2003). This precluded precise evaluation of model fit, but the differences of model trajectories between models with and without harvest were without exception substantial; and including harvest in the model usually changed realized λ from >1 to <1. Large populations modeled with 1961 population estimates and averaged vital rates tended to be comparable to (Bumping River) or below later population estimates (Mt. Baker, East Stevens Pass, Snoqualmie, and Goat Rocks). This was despite the exclusion from the models of 7.3% of harvest for 1948–1970, wounding losses, tribal harvest, kid mortality associated with female harvest mortality, uneven spatial distribution of harvest, Allee effects, or inbreeding depression; all of which would be expected to increase the impact of harvest on population levels.

Harvest may have had a greater impact in models than population estimates suggest for a variety of reasons, but we evaluated 2 potential parameters: initial population size and vital rates. Either increases (1.2–2.0 times) in initial population or increases (1.010–1.023 times) in vital rates accounted for these discrepancies. Hamel and others (2006) noted that vital rates probably differ among populations even within a confined geographic area, and therefore an increase in vital rates may be the more likely of these scenarios. However, it is unlikely that variations in vital rates are constant between fecundity and survival and among age classes as were the proportional vital rates we used for some models; but given the lack of detailed information available to construct more detailed scenarios, proportional vital rates can provide an approximate assessment of these differences. A field assessment of vital rates in Washington (and for other Mountain Goat populations) would be of great value in confirming this finding and contribute substantially to our ability to manage this species. Some of the increases in initial populations or proportional vital rates used in our models seem unrealistic. For instance, the 2-fold increase in initial population for the Snoqualmie model may be excessive. Similarly the projected 14-fold increase in the modeled population for Falls Creek with increased vital rates and no harvest would be unlikely for a Mountain Goat population. In reality, it is more likely that a combination of underestimation of initial populations and higher vital rates resulted in the final population sizes after harvest.

The Penders Canyon and Falls Creek models had the most frequent population estimates, but assigning harvest for these populations was problematic. For the Penders Canyon model, both the conservative and liberal harvest sce-

Ex096

narios resulted in declining populations for most replicates. The median of these corresponded more closely to the earlier population estimates of Ryals (Johnson 1983; Reed 1983) for the liberal scenario, while the conservative scenario yielded a median closer to recent helicopter survey results. In both scenarios, replicated runs tended to be above Ryals' counts and this was particularly evident in the decline in the counts before regular harvest commenced in 1964. It is possible that this was due to illegal harvest thought to have taken place in this area. Ryals reported finding 7 Mountain Goat carcasses in this area in 1968 (Johnson 1983:74) with the implication that this may not have been exceptional. In the Falls Creek area, both model scenarios initially tracked declines, but then declined more precipitously for nearly all replicates than did the population estimates. Increased vital rates that yielded median population levels corresponding to recent surveys were unrealistic and fit earlier population estimates very poorly. For unknown reasons, declines in both the Penders Canyon and Falls Creek populations apparently paused in the 1960s despite continuing harvest. When modeled from 1967 and 1969 respectively (not shown), these populations behaved as did other models in that they declined below recent estimates (even with conservative harvest estimates) unless vital rates were increased. In these 2 populations which declined >90%, density dependence may have been a factor.

Had many of our models tended to decline less than the actual populations, other causes of decline might have been considered to explain such a discrepancy. Because this was not the case, we think that while other factors (disease, predation, illegal harvest, winter habitat modification, conifer intrusion-fire suppression) may have played a minor role in particular areas (for instance illegal harvest of the Penders Canyon populations), their impacts were probably minor on a statewide level. For mortality from these other sources to have a comparable effect on populations as did harvest, initial populations and vital rates would need to be increased by a comparable magnitude over and above the increases already invoked, passing plausible levels with even greater frequency. While such scenarios cannot be categorically rejected, the consistent finding of declining populations exposed to historic harvest which is known to have occurred even with augmented initial populations or vital rates makes large additional increases in these parameters unlikely. We therefore conclude that past harvest was the predominant factor in population declines in these areas, and by extension, for Washington in general.

General models

The method we used to assess the impacts of harvest on hypothetical populations differed from that of Hamel and others (2006) in that simulated harvest increased when each simulation replicate increased (according to percent harvest specified), and decreased when each replicate decreased rather than remaining a constant number harvested over all replicates regardless of their changing size. This more closely matches the management scenario where harvest is increased with increasing population and decreased during population declines. Consequently, the impacts of the stated level of harvest on replicates with low population sizes would be less, resulting in a higher level of allowable harvest. However, the importance of this effect was probably less than the difference in vital rates between our models and those of Hamel and others (2006).

Our simulations indicate that the effect of harvest on populations is most pronounced for small populations, especially if a substantial proportion of the harvest is female. We evaluated the effects of percent harvest on populations by selecting a ≥50% probability of stability or increase, which equates to a <50% probability of decline. While a higher probability of stability or increase would be desirable, due to the considerable variability in population projections such a goal would be difficult to achieve. Considering that some simulated declines were small, and that continued monitoring would be expected to detect substantial declines that did occur in real populations, we judged ≥50% probability of stability or increase to be a suitable threshold. Basically, this means we decided that we could tolerate moderate declines and correct for larger declines, but would not want to manage under a scenario that favored declines over stability or increases.

It is not surprising that the probability of a population being stable or increasing is highly

Ex097

TABLE 4. Maximum percent harvest (0–4%) resulting in ≥50% probability of stable or increasing Mountain Goat population given initial population size, proportion of harvest male, and average (Avg), maximum for native populations (MaxNative), and maximum (Max) vital rates and for all stages, and female stages only (Female Stages). (Maximum percent harvest was always zero for minimum vital rates and the same for all stages and female stages for MaxNative and Max vital rates).

		All stages			
Population	% harvest male	Avg	MaxNative	Max	Avg female stages only
50	50	0	4	4	0
50	75	0	4	4	0
50	90	0	4	4	0
100	50	1	4	4	1
100	75	2	4	4	3
100	90	2	4	4	4
200	50	2	4	4	2
200	75	3	4	4	4
200	90	4	4	4	4
300	50	2	4	4	3
300	75	3	4	4	4
300	90	4	4	4	4
500	50	3	4	4	3
500	75	4	4	4	4
500	90	4	4	4	4

dependent on its vital rates. However, interpretation of the results using the maximum and minimum rates warrants some caution. Apart from the Caw Ridge rates, most of those we included were based on a few years of study (5 to 10 y) and <200 animals. Hence, sampling and inter-annual variation may have resulted in more extreme values than would have been obtained from studies of longer duration and of more animals. That the average rates we used were fairly similar to those from Caw Ridge supports the possibility that this was the case and that most Mountain Goat populations are, over the long term, closer to the average than the maximum and minimum rates would seem to indicate. Nevertheless, given the limited amount of information available on Mountain Goat vital rates these minimum and maximum rates bracket the potential variation among populations.

For average vital rates, a population of 50 animals would not be expected to sustain any harvest regardless of the percent of the harvest that is male. Despite a theoretic λ of 1.041, populations of 50 animals had a median realized λ of 0.994 due to stochastic effects. With higher than average vital rates, a population of 50 animals could sustain harvest, but a population with high vital rates would be expected to increase, in which case it would seem prudent to allow it to do so rather than subject it to harvest.

Also for average vital rates, harvest of 4% has a probability of the population being stable or increasing ≥0.5 only for large populations, and only then if it is largely male. However, the probability of the female stages achieving a probability ≥0.5 of being stable or increasing is true for populations ≥200 animals if the harvest is 70% male, and for populations ≥100 animals if the harvest is 90% male. In many of these cases, the total population would be expected to decline, but the female stages would not.

Although harvest that is biased toward males increases the probability of a population being stable or increasing, whether one considers the total population or only the female stages, it can have substantial effects on population structure. This was true for both the sex ratio of adults and the age structure of males. Milner and others (2007) recently reviewed impacts of such changes for a variety of ungulates which can lead to lower fecundity, delayed conception and hence lower body weight and survival of offspring, and reduced condition of males. The extent to which these factors may impact Mountain Goat populations is unknown, but they warrant consideration when harvest management favors males.

Conclusions

An important implication of the finding that past harvest accounts for population declines is

Ex098

that the prospects for recovery are good if populations are sufficiently protected. The exception to this is small populations, where we agree with Hamel and others (2006) that populations <50 animals are prone to decline. Where only remnants of former populations exist, or where Mountain Goats have been locally extirpated, supplementation or reintroduction may be a necessary part of recovery. In cases where recovery to former population levels is desired, harvest at any given level reduces the probability of the population increasing and should be zero or at least lower than indicated by our results.

Our simulations indicated a complex interaction between acceptable harvest, vital rates, population size, and proportion of harvest that is male. Given assessments of these elements, managers may use Table 4 to guide decisions about the harvest of Mountain Goats. Because these thresholds are based on a 50% probability of the population remaining stable or increasing, and due to expected variability of vital rates among populations, there is a reasonable possibility that populations may decline under such management. Hence, we concur with Hamel and others (2006) and Côté and Festa-Bianchet (2003) that continual monitoring is an essential feature of Mountain Goat population management where harvest is allowed.

ACKNOWLEDGMENTS

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LITERATURE CITED

ADAMS LG, BAILEY JA. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. Journal of Wildlife Management 46:1003–1009.

AKÇAKAYA HR. 2002. RAMAS Metapop: Viability Analysis for Stage Structured Metapopulations. Version 4.0. Setauket, NY: Applied Biomathematics. 185 p.

BAILEY JA. 1991. Reproductive success in female mountain goats. Canadian Journal of Zoology 69: 2956–2961.

CASWELL H. 2001. Matrix Population Models: Construction, Analysis, and Interpretation. Sunderland, MA: Sinauer Associates. 717 p.

CÔTÉ SD, FESTA-BIANCHET M. 2001. Birthdate, mass and survival in mountain goat kids: effects of maternal characteristics and forage quality. Oecologia 127:230–238.

CÔTÉ SD, FESTA-BIANCHET M. 2003. Mountain goat. In: Feldhamer GA, Thompson B, Chapman J, editors. Wild mammals of North America: biology, management and conservation. Second edition. Baltimore, MD: Johns Hopkins University. p 1061–1075.

CÔTÉ SD, FESTA-BIANCHET M, SMITH KG. 2001. Compensatory reproduction in harvested mountain goat populations: a word of caution. Wildlife Society Bulletin 29:726–730.

COURCHAMP F, CLUTTON-BROCK T, GRENFELL B. 1999. Inverse density dependence and the Allee effect. Trends in Ecology and Evolution 14:405–410.

DANE B. 2002. Retention of offspring in a wild population of ungulates. Behaviour 139:1–21.

FESTA-BIANCHET M, CÔTÉ SD. 2008. Mountain Goats. Ecology, Behavior, and Conservation of an Alpine Ungulate. Washington D.C.: Island Press. 265 p.

FESTA-BIANCHET M, GAILLARD J-M, COTE SD. 2003. Variable age structure and apparent density dependence in survival of adult ungulates. Journal of Animal Ecology 72:640–649.

GILBERT BA, RAEDEKE KJ. 1992. Winter habitat selection of mountain goats in the north Tolt and Mine Creek drainages of the North Central Cascades. Proceedings of the Northern Wild Sheep and Goat Council 8:305–324.

GORDON IJ, HESTER AJ, FESTA-BIANCHET M. 2004. The management of wild large herbivores to meet economic, conservation and environmental objectives. Journal of Applied Ecology 41:1021–1031.

HAMEL S, CÔTÉ SD, SMITH KG, FESTA-BIANCHET M. 2006. Population dynamics and harvest potential of mountain goat herds in Alberta. Journal of Wildlife Management 70:1044–1053.

*HAPPE PJ, JENKINS KJ, BEIRNE KF, ALBRIGHT MW, BACCUS WT, OLSON RW. 2004. Mountain goat census in the Olympic Mountain Range, July 2004. Olympic National Park. Available from: Olympic National Park, 600 East Park Avenue, Port Angeles, WA 98362–6798.

HEBERT DM, TURNBULL WG. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. In: Samuel W, Macgregor WG, editors. Proceedings of the First International Mountain Goat Symposium, Kalis-

* Unpublished

Ex099

pell, Montana. Victoria, BC: Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch. p 126–146.

HOUSTON DB, STEVENS V. 1988. Resource limitation in mountain goats: a test by experimental cropping. Canadian Journal of Zoology 66:228–238.

HOUSTON DB, MOORHEAD BB, OLSON RW. 1991. Mountain goat population trends in the Olympic Mountain Range, Washington. Northwest Science 65:212–216.

JOHNSON RL. 1983. Mountain goats and mountain sheep of Washington. Washington Department of Game Biological Bulletin No. 18. 196 p.

JOHNSON DH, O'NEIL TA. 2001. Wildlife-Habitat Relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press. 736 p.

KOHLMANN SG, BAILEY JA. 1991. Population ecology of introduced mountain goats. Transactions of the Congress of the International Union of Game Biologists 18:583–585.

KUCK L. 1977. The impact of hunting on Idaho's Pahsimeroi mountain goat herd. In: Samuel W, Macgregor WG, editors. Proceedings of the First International Mountain Goat Symposium, Kalispell, Montana. Victoria, BC: Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch. p 114–125.

MILNER JM, NILSEN EB, ANDREASSEN HP. 2007. Demographic side effects of selective hunting in ungulates and carnivores. Conservation Biology 21:36–47.

NICHOLS L. 1980. Mountain goat management technique studies. Alaska Department of Fish and Game W-17-9, W-17-10, and W-17-11.

O'GRADY JJ, BROOK BW, REED DH, BALLOU JD, TONKYN DW, FRANKHAM R. 2006. Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. Biological Conservation 133:42–51.

REED PL. 1983. Effects of forest management on the vegetative cover of mountain goat winter range on the west slope of the north Washington Cascades [thesis]. Seattle, WA: University of Washington. 122 p.

SMITH CA. 1986. Rates and causes of mortality in mountain goats in southeast Alaska. Journal of Wildlife Management 50:743–746.

SMITH KG, URQUHART MA, FESTA-BIANCHET M. 1992. Preliminary observations of timing and causes of mountain goat kid mortality in west central Alberta. Proceedings of the Northern Wild Sheep and Goat Council 8:293–304.

STEINHORST RK, SAMUEL MD. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415–425.

STEVENS V. 1983. The dynamics of dispersal in an introduced mountain goat population [dissertation]. Seattle, WA: University of Washington. 202 p.

US BOARD ON GEOGRAPHIC NAMES. undated: WA_DECI.TXT. Geographic Names Information System. Available online at geonames.usgs.gov/domestic/download_data.htm. (accessed 10 April 2006).

WADKINS LA. 1962. Goat management study. Washington Department of Game W-66-R-3.

WADKINS LA. 1967. Goat Management Study, Population Studies. Washington Department of Game W-66-R-6.

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE. 2003. Game management plan. Olympia, WA: Washington Department of Fish and Wildlife. 136 p.

Submitted 7 November 2008, accepted 26 January 2009. Corresponding Editor: Clayton Apps.

APPENDIX A

Partitioning survival estimates pooled across sexes. For each age class, survival was partitioned so as to maintain a constant male:female ratio equal to that of the Caw Ridge model (Hamel and others 2006). This calculation is for female survival.

$$m_r = \frac{m_F}{m_M}$$

$$m_M = \frac{m_F}{m_r}$$

$$m_F p_F + m_M p_M = m_{FM}$$

$$m_F p_F + \frac{m_F}{m_r} p_M = m_{FM}$$

$$m_F = \frac{m_{FM}}{p_F + \frac{p_M}{m_r}}$$

$$s_F = 1 - m_F$$

$$s_F = 1 - \frac{1 - s_{FM}}{p_F + \frac{p_M}{\left(\frac{1 - s_{FHamel}}{1 - s_{MHamel}}\right)}}$$

where :

m = mortality, s = survival

m_r = mortality ratio

s_F = female survival, m_{FM} = mortality of males and females (pooled)

p_F = proportion of females in population (for each stage)

s_{MHamel} = survival of males in Hamel et al. 2006

Ex100

APPENDIX B

Matrix population model parameters for Mountain Goats: minimum vital rates (Min), average (Avg), maximum of native population (MaxNative), and maximum for all populations (Max). The constant standard deviation (StdDev) is from Hamel and others (2006).

Stages		Vital Rate				
From	To	Min	Avg	MaxNative	Max	StdDev
Reproduction						
2 y-F	Kids F	0.000	0.007	0.021	0.021	0.050
2 y-F	Kids M	0.000	0.006	0.019	0.019	0.065
3–4 y-F	Kids F	0.265	0.300	0.265	0.333	0.166
3–4 y-F	Kids M	0.194	0.249	0.194	0.333	0.165
5–8 y-F	Kids F	0.382	0.400	0.402	0.416	0.114
5–8 y-F	Kids M	0.286	0.320	0.345	0.345	0.101
9+ y-F	Kids F	0.208	0.338	0.257	0.548	0.076
9+ y-F	Kids M	0.110	0.277	0.398	0.398	0.068
Survival						
Kids F	1 y-F	0.570	0.604	0.680	0.680	0.129
Kids M	1 y-M	0.570	0.604	0.680	0.680	0.129
1 y-F	2 y-F	0.778	0.801	0.852	0.852	0.153
1 y-M	2 y-M	0.648	0.684	0.765	0.765	0.201
2 y-F	3–4 y-F	0.805	0.904	0.992	0.992	0.137
2 y-M	3–4 y-M	0.729	0.867	0.988	0.988	0.185
3–4 y-F	3–4 y-F	0.480	0.493	0.516	0.516	0.045
3–4 y-F	5–8 y-F	0.443	0.455	0.477	0.477	0.042
3–4 y-M	3–4 y-M	0.431	0.457	0.502	0.502	0.075
3–4 y-M	5–8 y-M	0.416	0.441	0.484	0.484	0.072
5–8 y-F	5–8 y-F	0.707	0.720	0.746	0.746	0.046
5–8 y-F	9+ y-F	0.156	0.240	0.249	0.249	0.015
5–8 y-M	5–8 y-M	0.693	0.733	0.808	0.808	0.091
5–8 y-M	9+ y-M	0.151	0.160	0.176	0.176	0.020
9+ y-F	9+ y-F	0.714	0.830	0.866	0.911	0.084
9+ y-M	9+ y-M	0.580	0.751	0.803	0.869	0.284

Ex101

Status of the Science

On Questions that Relate to BLM Plan Amendment Decisions and Peninsular Ranges Bighorn Sheep
Updated March 14, 2001

Table of Contents

A. Causal Links Between Mortality, Fecundity, Survival and Land Uses 3

B. Disturbance Response of Bighorn Sheep 3
- **1. Generalized sheep response to human disturbance 3**
- **2. Generalized response of bighorn to recreation use 3**
- **3. Effects of Recreation Use Relative to Season 4**
- **4. Effect of Position of Disturbance Relative to Reaction of Bighorn 4**
- **5. Bighorn Response Relative to Distance at Encounter 4**
- **6. Bighorn Response to Domestic Dogs 4**
- **7. Bighorn Response to Hiking 5**
- **8. Response of Bighorn to Roads 5**
- **9. Response of Bighorn to Human Disturbance at Watering Areas 5**
- **10. Bighorn Response to Cattle Grazing 6**
- **11. Bighorn Response to Wild Horses 6**
- **12. Bighorn Response to Helicopters 6**

C. Habitat and Population Management Concerns and Issues 6
- **1. Loss of Connectivity: 6**
- **2. Response to Artificial Water Sources: 6**
- **3. Potential Effects of Fire Suppression: 7**

D. Study Area Characteristics: 7
- **Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. 2000. Can mountain sheep and humans coexist? In prep. 10pp. 7**
- **Hamilton, K., Holl, S. A., and Douglas, C. L. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel mountains, California. Desert Bighorn Council Transactions. 26: 50-55. ..... 7**
- **MacArthur, R. A., V. Geist, R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46: 351-358. ..... 8**
- **Papouchis, C.M., F. J. Singer, W. Sloan. 2000. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. In press. 8**
- **Purdy, K. G. and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: the Pusch Ridge Wilderness case. Desert Bighorn Council Transactions 25: 1-5. ..... 8**

Disclaimer: 8

Literature Cited 9

A. Causal Links Between Mortality, Fecundity, Survival and Land Uses

The cause and effect relationships between human disturbance and bighorn sheep populations are not well understood. General information and systematic research studies are lacking. Most studies have focused on one aspect of disturbance (generally sheep responses to human encounters) while few have clear ties to population level effects, known levels of human use, or historic factors influencing response of bighorn sheep to disturbance (King and Workman 1986).

Factors suggested as contributors to bighorn population declines includes roads, trails, housing developments, and fire suppression (Etchberger et al. 1989, Krausman et al. 2000, Kelly and Krausman et al. 2000). Some of the evidence appears to conflict (Kelly and Krausman 2000). Between 1991 and 1996, 34% of adult bighorn mortalities in the northern Santa Rosa Mountains were directly attributed to the effects of urbanization. Five sheep were killed by automobiles, 5 by eating toxic plants, and 1 by strangulation in a wire fence (Bighorn Institute 1997). Conversely, lamb productivity at a construction site in Nevada did not depart from the average productivity measured since 1969 (Leslie and Douglas 1980). The authors were concerned however that recruitment may have been affected (Leslie and Douglas 1980). In addition, the same study did find that 9 of 17 marked ewes abandoned historical watering sites for alternate sites in apparent response to construction activity (Leslie and Douglas 1980).

The present population size of peninsular bighorn sheep argues for action, in combination with further study, to ensure recovery. Given the current level of knowledge and publicly-available data, the potential for population effects resulting from management actions will largely be inferential based on judgments made from literature and data on the indirect effects of human activities on bighorn sheep populations.

The following literature review summarizes some of the more important literature on the impacts to bighorn sheep.

B. Disturbance Response of Bighorn Sheep

1. Generalized sheep response to human disturbance

Many authors have found that human disturbance can alter habitat use and activity patterns of bighorn sheep (e.g., Van Dyke et al. 1983, Miller and Smith 1985, King and Workman 1986, Etchberger et al. 1989, Papouchis et al. 2000). Population declines (Van Dyke et al. 1983, Etchberger et al. 1989, Harris 1992), shifts in habitat use (Van Dyke et al. 1983), interruption of seasonal migration routes (Ough and deVos 1984), has been linked to human disturbance. Disturbance is often tied to recreation use and urban interface issues. Timing and location of recreation in bighorn habitat, the distance between sheep and humans, and the presence of domestic dogs has a role in the impact of human activities on bighorn sheep.

2. Generalized response of bighorn to recreation use

Many researchers have illustrated that sheep exhibit a response to recreational activities. MacArthur et al. (1979 and 1982) found that bighorn sheep exhibited elevated heart rates in response to the presence of people, especially when people were approaching with a dog or from over a ridge. Miller and Smith (1985) found that bighorn had a stronger adverse reaction to 1 or 2 humans on the ground than to parked vehicles or a light airplane circling overhead. Papouchis et al. (2000) found that bighorn sheep had a greater flight response to hikers than to mountain bikers or cars. King and Workman (1986) noted that responses may be more severe in areas where animals have historically been exposed to relatively high levels of human activity. In addition, the history of hunting bighorn sheep may be an important variable to consider when evaluating the impacts of human disturbance in bighorn habitat (King and Workman 1986, see also Hansen

1970, Geist 1971, Horesji 1976). Krausman et al. (2000) postulate that human recreation was a contributing factor in the decline of bighorn sheep in three southwest populations.
However, not all researchers agree that recreation has a detrimental effect on bighorn sheep. Hamilton et al. (1982) found that there was no difference in levels of sheep disturbance when heavy use recreation areas were compared to light use recreation areas in the San Gabriel Mountains of California. However, they also noted that sheep avoided using a salt lick while humans were in the vicinity. Hicks and Elder (1979) found that recreation users had no negative effect on bighorn sheep in the Sierra Nevada; however, they cautioned land managers to monitor the amount of recreation and to instigate or continue to regulate recreation use in bighorn habitat.

3. Effects of Recreation Use Relative to Season

Timing of recreation use relative to the life cycle of bighorn sheep is important. Impacts to ewes that are pregnant or lactating can have the most deleterious effects (Geist 1971, Light and Weaver 1973, King and Workman 1986, Wagner and Peek 1999). Flight responses can be very severe when ewes are with young lambs. King and Workman (1986) and Wehausen (1980) documented a heightened awareness to human activity when lambs were present. Ewes with lambs tend to remain close to dependable water sources (Leslie and Douglas 1980, McCarty and Bailey 1994) with density and proximity to water increasing during the summer months (BLM 1980, Blong and Pollard 1968). Travel corridors between lambing areas and watering areas are also important and disruption could impede access to important resources (Ough and deVos 1984, Van Dyke et al. 1983).

4. Effect of Position of Disturbance Relative to Reaction of Bighorn

Research has shown that bighorn sheep exhibit a stronger, adverse reaction to humans approaching from above them than humans approaching from below (MacArthur et al. 1982, Hicks and Elder 1976, Geist 1971). Approaching from over a ridge may limit escape options for bighorn sheep. MacArthur et al. (1982) found that sheep withdrew when a human was approaching from over a ridge (> 50 meters away) 27.6% of the time but withdrew only 3.6 % of the time when approached from a road not above the bighorn.

5. Bighorn Response Relative to Distance at Encounter

Response based on distance between the bighorn and the source of disturbance has been generally documented. Both flight and cardiac responses seem to be stimulated between about 50 and 100 meters (Holl and Bleich 1983, MacArthur et al. 1982, Miller and Smith 1985). The exception is helicopter disturbance where the distance is above 400 meters (Bleich et al. 1994). The distance at which sheep become aware of the disturbance can also affect how far they move away from the disturbance (Miller and Smith 1985). Distance alone is a poor predictor of behavioral response to disturbance. Responses are variable and group size and gender compositions are also important factors (Miller and Smith 1985).

6. Bighorn Response to Domestic Dogs

Bighorn sheep evolved with canine predators (Geist 1971) and thus react very strongly to domestic dogs. Disturbance of bighorn by dogs causes heart rate increases and flight response (MacAruthur et al. 1979, MacArthur et al. 1982, Purdy and Shaw 1981). Sheep will remain nervous and alert for up to 30 minutes following a dog encounter, responding to subtle stimuli with otherwise evoked no response (MacArthur et al. 1982). Goodson et al. (1999) noted that the elimination of camping and dogs in important sheep habitat resulted in a reduction in the effects of human disturbance to bighorn.

7. Bighorn Response to Hiking

Researchers have shown that bighorn sheep exhibit a response to hikers (e.g., Hicks and Elder 1979, Miller and Smith 1985, Papouchis et al. 2000). Miller and Smith (1985) found that sheep had a strong reaction (immediate flight response) to the presence of 1 or 2 humans on foot (38% and 49% of the total responses respectively). MacArthur et al. (1982) also found that sheep had a strong behavioral and cardiac response when approached from over a ridge by a human or a human with a dog. In addition, Hamilton et al. (1982) found that sheep avoided using areas while humans were present but were not permanently displaced by hikers. Bighorn behavior was modified to avoid human interactions at salt licks or waterholes, visiting each earlier or later in the day when humans were not present (Campbell and Remington 1981, Hamilton et al. 1982). The level of response seems to be affected by a number of factors such as direction of approach (I.e., from above, across a ridge, below, or level) or the presence or absence of a dog (MacArthur et al. 1982), levels of previous disturbance and the history of hunting (King and Workman 1986), composition of the bighorn group (i.e., presence of ewes with lambs) (Wehausen 1980, Miller and Smith 1985, King and Workman 1986), and the size of the group of sheep (Berger 1978, Miller and Smith 1985). Papouchis (2000) found a more frequent flight response from hiking disturbance than from mountain biking or vehicles. Conversely, Hamilton et al. (1982) did not detect any significant difference in bighorn distribution between heavily-used and lightly-used recreation areas. Hicks and Elder (1976) concluded that foot trails did not affect sheep movement on summer range in the Sierra Nevada mountains. To date, research has not established a link between hiking and population level effects on bighorn sheep.

Studies indicate that roads adversely impact bighorn sheep by inducing flight, causing mortality, elevating heart rate, and fragmenting habitat by cutting off traditional movement corridors. Roads impede movement between habitat patches (Cunningham 1982, Ough and deVos 1984).
Back country roads that receive low use may have little or no effect on bighorn sheep, but other roads have caused bighorn to alter traditional migration routes (Van Dyke et al.1983, Ough and deVos 1984). Stress responses can occur and flight responses are possible. MacArthur et al. (1982) found that 8.8% of vehicle passes in sheep habitat elicited an increase in heart rate, which the authors interpreted as a stress response. In addition, they found that flight responses were induced in only 0.9% of those vehicle passes (MacArthur et al. 1982). Papouchis et al. (2000) reported that the average distance maintained from a road increased along heavily used roads that went through remote areas. Human use of a road along or through lambing, bedding, or watering areas eliminates the solitude and security for bighorn (Van Dyke et al. 1983, Jorgensen 1974). Cunningham and deVos (1992) found that ewes with home ranges bisected by a state highway had a 24% probability of being killed while crossing the highway. MacArthur (1979) found that ewe heart rates increased decreased as distance from roads increased and that at less than 200 meters from the road heart rates were elevated above average.

9. Response of Bighorn to Human Disturbance at Watering Areas

Bighorn sheep typically range within 2 miles of free water (Geist 1971, Van Dyke et al. 1983) and are highly dependent upon reliable water sources especially during the hot season (BLM 1980). Bighorn activity has been found to decrease on days when vehicle use interrupts access to water (Jorgensen 1974). Constant or frequent human use (e.g., cross country travel, camping, off-road vehicles) at or near water sources, particularly during the summer months, may adversely affect sheep and may cause them to abandon the water source in favor of less disturbed areas (Blong 1967, DeForge 1972, Cunningham 1982, Miller and Smith 1985). Leslie and Douglas (1980) recorded alterations in behavior and movement coincident with construction activity near a sheep water source.

10. Bighorn Response to Cattle Grazing

"Cattle grazing can be detrimental to bighorn sheep populations, either through direct competition for forage or water, or through vegetation changes in response to cattle grazing" (reviewed by McQuivey 1978 and Jones 1980 *in* USFWS 2000). In addition, Goodson et al. (1999) found that bighorn sheep used areas less after intensive cattle grazing.

11. Bighorn Response to Wild Horses

Competition between feral horses and bighorn sheep has not been extensively studied. However, increasing horse populations were reported to coincide with decreasing bighorn Populations in the Silver Peak Range of Nevada (McQuivey 1978). Coates and Schemitz (1994 *in* USFWS 2000) suggested that association with feral horse herds may result in increased foraging efficiency for bighorn rams because rams may spend less time watching for predators and more time foraging. However, the overall fitness of these rams was not examined. Goodson et al. (1999) noted an increase in sheep use of an area after the feral horse herd was reduced.

12. Bighorn Response to Helicopters

"Helicopter surveys may adversely affect populations of mountain sheep…by altering the movement, habitat use, and foraging efficiency of sheep so that survivorship or reproduction is reduced" (Stockwell 1991 *in* Bleich et al. 1994). Bighorn can respond so dramatically to helicopter use that it may override other factors affecting sheep movement (Bleich et al. 1990, Bleich et al. 1994). Sheep do not habituate or become sensitized to repeated helicopter flights (Bleich et al. 1994). MacArthur et al. (1982) reported no heart rate responses in bighorn sheep to helicopters above 400 meters in altitude. Helicopter flights at 90-250 meters above the ground increased the heart rate in ewes 2.5 - 3 times above normal. Bleich et al. (1994) found that radio collared bighorn moved significantly farther following a helicopter survey than on the day prior to a survey. Helicopter overflights may also reduce foraging efficiency during winter (Harris 1992). Miller and Smith (1985) recommended that helicopter flights be kept at over 100 meters above ground level to minimze impacts to bighorn sheep.

C. Habitat and Population Management Concerns and Issues

1. Loss of Connectivity:

Anecdotal and genetic evidence suggests potential for historic connections between peninsular bighorn sheep and bighorn to the north (Boyce et al. 1997, Guitierrez-Espleleta et al. 1998, Boyce et al. 1999). Urban development along the floor of the Coachella Valley, Highways 111 and 74, and Interstates 10 and 8, may prevent movement of sheep and reduce genetic mixing which otherwise may have occurred when bighorn crossed the desert flats between ranges (Leslie and Douglas 1980, Bleich et al. 1990, Bleich et al. 1996,). This lack of connectivity and genetic exchange may have long term implications for both persistence, recolonization, and the maintenance of fitness and population viability (Berger 1990).

2. Response to Artificial Water Sources:

It has been suggested that water is a major limiting factor to abundance of peninsular bighorn sheep in the Santa Rosa Mountains (Blong 1967, BLM 1980). Bighorn abandoned the Magnesia Spring water source as development encroached and began using a new water source in nearby Bradley Canyon (Blong 1967). It has been suggested that bighorn sheep summer use areas could be extended by providing artificial water sources in portions of the range lacking reliable water sources (Blong 1967, Leslie and Douglas 1980, BLM 1980).

3. Potential Effects of Fire Suppression:

Bighorn sheep rely on keen vision to detect predators (Geist 1971, Wakelyn 1987, Risenhoover Bailey (1985) and avoid areas of dense vegetation that obscure visibility (Geist 1971, McCann 1956, Oldemeyer et al. 1971, Risenhoover and Bailey 1980). Wakelyn (1987) and Risenhoover and Bailey (1985) found that foraging efficiency was reduced in bighorn sheep foraging in dense cover. It has been suggested that visual obscurity has a measurable impact on habitat use and range expansion by bighorn sheep (Ough and deVos 1984, Risenhoover and Bailey 1985, Fairbanks, et al. 1987, Wakelyn 1987). Fire suppression has been identified as a major cause of change in vegetation density in the western United States (Miller and Wigand 1994, Miller 1999) and has been causally related to habitat avoidance and abandonment by bighorn sheep (Shannon et al. 1978, Risenhoover and Bailey 1985, Etchberger et al. 1989, Bleich et al. 1997, Andrew 1994).

D. Study Area Characteristics:

Each research study included in this literature review has a unique design and study area. These unique characteristics increase the difficulty in isolating causal factor which represent the relationship between observed population trends and the nature and amount of disturbance. Variables assessed include the amount of habitat available to the bighorn, herd size (Van Dyke et al. 1983, Berger 1990, Harris 1992), connectivity to other population groups (Leslie and Douglas 1980) and differences in the type or amount of human use. The synopses provided below are taken from a few of the studies cited in this review to provide a contextual framework.

Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. 2000. Can mountain sheep and humans coexist? In prep. 10pp.

> This paper reviews population declines in bighorn sheep in three areas in the southwest: the Sandia Mountains, New Mexico, the Santa Catalina Mountains, Arizona, and the Northern Santa Rosa Mountains, California. Similarities exist among the study areas, including similar vegetation associations, steep slopes and cliffs, canyons, and washes which characterize bighorn habitat in each range. Each of the areas assessed are adjacent to human habitation. The Sandia Mountains are near Albuquerque, NM, the Santa Catalina mountains are adjacent to Tucson, AZ and include the Pusch Ridge Wilderness, and the Santa Rosa mountains are adjacent to Palm Springs, CA. Human disturbance was examined using human population growth and recreation in sheep habitat as an index to disturbance. Differences among these populations include the subspecies of bighorn sheep present (Sandia Mountains - Rocky Mountain bighorn sheep), native vs. introduced population (Sandia Mountains bighorn introduced in 1939 and 1941), and amount of bighorn habitat identified (Sandia Mountains 40 km^2, Santa Catalina mountains 20 km^2, Northern Santa Rosa Mountains not available).

Hamilton, K., Holl, S. A., and Douglas, C. L. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel mountains, California. Desert Bighorn Council Transactions. 26: 50-55.

> This study examined the effects of recreation activities on bighorn sheep in the San Gabriel mountains of southern California. Two trails crossing summer bighorn sheep range were used to assess whether high numbers of hikers were influencing habitat use by bighorn sheep. Trail use by hikers was monitored in August 1980 and June through September 1991 using time lapse cameras, direct observation, and trail registers.

MacArthur, R. A., V. Geist, R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46: 351-358.

This study was conducted at the Sheep River Wildlife Sanctuary in Alberta, Canada. There is a gravel road that runs through the Sheep River valley and bighorn sheep may be exposed to 25-30 vehicles per hour during peak recreational use. The authors implanted heart monitors in 8 bighorn sheep to assess physiological effects of human disturbance on bighorn sheep. Disturbance was induced by researchers walking toward the sheep from a vehicle, sitting in a parked vehicle, or approaching with a dog on a leash.

Papouchis, C.M., F. J. Singer, W. Sloan. 2000. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. In press.

Situated in a remote area of Canyonlands National Park, Utah, this study assessed the impacts of recreation activities on desert bighorn sheep. Behavioral responses of bighorn sheep to hikers, mountain bikers, and vehicles were recorded to address two contradictory hypotheses: 1) bighorn sheep will avoid or abandon habitat when humans are present, 2) bighorn sheep will habituate to predictable human activities or may compensate by using alternate habitat away from the disturbance. Field assistants initiated 98% of the hiking disturbance trials, 24% in high-use areas and 77% in low-use areas. Recreational use was disproportionate across the types of use, hikers (9%), mountain bikers (67%), and vehicles (24%).

Purdy, K. G. and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: the Pusch Ridge Wilderness case. Desert Bighorn Council Transactions 25: 1-5.

The Pusch Ridge Wilderness is located near Tucson, Arizona and in 1980 received approximately 34,000 visitors. Photoelectric trail traffic counters, unmanned registration stations, voluntary survey forms, telephone surveys, and direct observations were used to assess recreation use patterns and the response of bighorn sheep to human disturbance.

Disclaimer: Caution should be exercised when making inference from case studies to other sites or situations. Circumstances are rarely identical and often are very different. For example, the Pusch Ridge Wilderness receives more than 1,000,000 visitors use days per year and is surrounded by urban development, whereas in the San Jacinto and Santa Rosa Mountains urban encroachment is confined to the north side of the range west of Thermal and visitor use levels are much lower. In Canyonlands National Park hiking is a less common form of recreation than it is in the San Jacinto and Santa Rosa mountains. Urban encroachment was not a factor in the Hicks and Elder study from 1976 whereas in the San Jacinto and Santa Rosa mountains urbanization plays a major role. In the San Gabriel mountains, the large urban expanse of Los Angeles does not encroach directly on sheep habitat, but the large L.A. population supplies many visitors to the mountains. Differences exist between most of the case studies cited in this review. Caution should be used when comparing these case studies to bighorn sheep and human interactions in the Peninsular Ranges.

Literature Cited

Andrew, N. G. 1994. Demography and habitat use of desert-dwelling mountain sheep in the east Chocolate Mountains, Imperial County, California. MS thesis. University of Rhode Island. 135pp.

Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Behavioral Ecology and Sociobiology 4: 91-99.

Berger, J. 1990. Persistence of different sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4: 91-98.

Bighorn Institute, 1997. Bighorn Institute -Year End Report to the California Department of Fish and Game, Sacramento.

Bleich, V. C., J.D. Wehausen, and S.A. Holl. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4: 383-390.

Bleich, V. C., R. T. Bowyer, A. M. Pauli, M. C. Nicholson, and R. W. Anthes. 1994. Mountain sheep Ovis canadensis and helicopter surveys: Ramifications for conservation of large mammals. Biological Conservation 70 : 1-7.

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353-373 *in* Metapopulations and Wildlife Conservation. D.R. McCullough, ed. Island Press, Washington, D.C. 429pp.

Bleich, V.C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs. No. 134. The Wildlife Society. 50pp.

Blong, B. 1967. Desert bighorn and people in the Santa Rosa Mountains. The Wildlife Society Transactions. California-Nevada Section. Pages 66-70.

Blong, B. and W. Pollard. 1968. Summer water requirements of desert bighorn in the Santa Rosa Mtns., Calif., in 1965. California Fish and Game 54 : 289-296.

Boyce, W.M., P.W. Hedrick, N.E. Muggli-Cockett, S. Kalinowski, M.C.T. Penedo, and R. R. Ramey, II. 1997. Genetic variation of major histocompatibility complex and microsatellite loci: a comparison in bighorn sheep. Genetics 145: 421-433.

Boyce, W. M., R. R. Ramey II, T. C. Rodwell, E. S. Rubin, and R. S. Singer. 1999. Population subdivision among desert bighorn sheep (*Ovis canadensis)* ewes revealed by mitochondrial DNA analysis. Molecular Ecology 8: 99-106.

Bureau of Land Management. 1980. Santa Rosa Mountains Wildlife Habitat Management Plan: A Sikes Act Plan. Riverside District Office. 56 pp + app.

Campbell B. and R. Remington. 1981. Influence of construction activities on water-use patterns of desert sheep. Wildlife Society Bulletin 9: 63-65.

Cunningham, S. C. 1982. Aspects of the ecology of Peninsular desert bighorn sheep (Ovis canadensis cremnobates) in Carrizo Canyon, California. M. S. thesis. Arizona State University, Tempe. 76 pp.

Cunningham and J.C. deVos. 1992. Mortality of mountain sheep in the Black Canyon area of northwest Arizona. Desert Bighorn Council Transactions 36 : 27-29.

DeForge, J. R. 1972. Man's invasion into the bighorn's habitat. Desert Bighorn Council 16 :112-116.

Etchberger, R. C., P. R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in the Pusch Ridge Wilderness, Arizona. Journal of Wildlife Management 53 : 902-907.

Fairbanks, W. S., J. A. Bailey, and R. S. Cook. 1987. Habitat use by a low-elevation, semi-captive bighorn sheep population. Journal of Wildlife Management 51: 912-915.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. The University of Chicago Press. Chicago and London. 383 pp.

Guitierrez-Espeleta, G. A., S. T. Kalinowski, W. M. Boyce, and P. W. Hedrick. 1998. Genetic variation in desert bighorn sheep. Desert Bighorn Council Transactions 42: 1-10.

Goodson, N. J., D. R. Stevens, K. McCoy, J. Cole. 1999. Effects of river based recreation and livestock grazing on desert bighorn sheep on the Navajo Nation. Second North American Wild Sheep Conference April 6-9, 1999 Reno, NV.

Hamilton, K., S. A. Holl, C. L. Douglas. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel Mountains, California. Desert Bighorn Council Transactions 26 : 50-55.

Hansen, C. G. 1980. The desert bighorn: its life history, ecology, and management *in* G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370 pp.

Harris, L. K. 1992. Recreation in mountain sheep habitat. Ph. D. Dissertation. University of Arizona, Tucson. 156pp.

Hicks, L. L. and J. M. Elder. 1976. Human disturbance of Sierra Nevada bighorn sheep. Journal of Wildlife Management 43 : 909-915.

Holl, S. A. and V. C. Bleich. 1983. San Gabriel mountain sheep: biological and management considerations. USDA Forest Service San Bernadino National Forest. Administrative Report 136pp.

Horesji, B. L. 1976. Suckling and feeding behavior in relation to lamb survival in bighorn sheep (*Ovis canadensis canadensis* Shaw). Ph.D. Dissertation University of Calgary, Alberta. 265pp.

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering site. Desert Bighorn Council Transactions 18 : 18-24.

Kelly, K. A. and P. R. Krausman. 2000.

King, M. M. and G. W. Workman. 1986. Response of desert bighorn sheep to human harassment: management implications. Transactions 51st North American Wildlife and Natural Reource Conference.

Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. 2000. Can mountain sheep and humans coexist? In prep.

Leslie, D. M., Jr., and C. L. Douglas. 1980. Human disturbance at water sources of desert bighorn sheep. Wildlife Society Bulletin 8 : 284-290.

Light, J. T., and R. Weaver. 1973. Report on bighorn sheep habitat study in the area for which an application was made to expand the Mt. Baldy winter sports facility. USDA Forest Service Cajon Ranger District, San Bernadino National Forest. 39 pp.

MacArthur, R.A., R.H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Canadian Journal of Zoology 57 : 2010 - 2021.

MacArthur, R. A. , V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351-358.

McCarthy, M. C. and J. A. Bailey. 1994. Habitat requirements of desert bighorn sheep. Special report No. 69. Colorado Division of Wildlife, Denver, CO.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Department of Fish and Game, Biological Bulletin No. 6. 81 pp.

Miller, M. E. 1999. Use of historical aerial photography to study vegetation change in the Negrito watershed, southwestern New Mexico. Southwestern Naturalist 44: 121-137.

Miller, G. D. and E. L. Smith. 1985. Human activity in desert bighorn habitat: what disturbs sheep? Desert Bighorn Council Transactions 1985 : 4-7.

Miller, R. F. and P. E. Wigand. 1994. Holocene changes in semiarid pinyon-juniper woodlands: Response to climate, fire, and human activities in the U.S. Great Basin. Bioscience 44: 465-476.

Oldemeyer, J. L., W. J. Barmore, and D. L. Gilbert. 1871. Winter ecology of bighorn sheep in Yellowstone National Park. Journal of Wildlife Management 35: 257-269.

Ough, W. D. and J. C. deVos. 1984. Intermountain travel corridors and their management implications for bighorn sheep. Desert Bighorn Council Transactions 28 : 32-36.

Papouchis, C. M., F. J. Singer, and W. Sloan. 2000. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. Pages 364 - 391 *in* Singer, F. J. and M. A. Gudorf. Restoration of bighorn sheep metapopulations in and near 15 national parks: conservation of a severely fragmented species. USGS Open File Report 99-102, Midcontinent Ecological Science Center, Fort Collins, CO.

Purdy, K. G. and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: The Pusch Ridge Wilderness case. Desert Bighorn Council Transactions 25: 1-5.

Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. Journal of Wildlife Management 49: 797-804.

Shannon, N.H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. Journal of Wildlife Management 39: 387-401.

U. S. Fish and Wildlife Service. 1992. Endangered and Threatened Wildlife and Plants: Proposed rule to list the Peninsular Ranges population of the desert bighorn sheep as endangered. Federal Register 57(90) : 19837 - 19843.

U.S. Fish and Wildife Service. 2000. Recovery plan for bighorn sheep in the Peninsular Ranges, California. U.S. Fish and Wildlife Service Portland, OR. xv + 251pp.

Van Dyke, W. A., A. Sands, J. Yoakum, A. Polenz, and J. Blaisdell. 1983. Wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon: bighorn sheep. USDA Forest Service and USDI Bureau of Land Management General Technical Report PNW-159. 37pp.

Wagner, G. D. Wagner and J. M. Peek. Activity patterns of Rocky Mountain bighorn ewes in central Idaho. Second North American Wild Sheep Conference April 6-9, 1999 Reno, NV.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51: 904-912.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. PhD dissertation. University of Michigan. 243 pp.

Ex113

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Conflicts in National Parks: A Case Study of Helicopters and Bighorn Sheep Time Budgets at the Grand Canyon

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ABSTRACT

Wildlife in numerous national parks of the United States experience frequent overflights by aircraft. Such activities may disturb wildlife populations. We analysed time budgets for desert bighorn sheep Ovis canadensis nelsoni *in the presence and absence of helicopter overflights at Grand Canyon National Park (GCNP) to determine the extent to which food intake may be impaired. Bighorn were sensitive to disturbance during winter (43% reduction in foraging efficiency) but not during spring (no significant effect). This seasonal difference may have arisen because the sheep were farther from helicopters during the spring after they had migrated to lower elevations. Further analyses indicated a disturbance distance threshold of 250–450 m. The conservation implications of these results are discussed.*

INTRODUCTION

As habitats become fragmented, the importance of national parks as refugia for wildlife increases. In many US national parks the popularity of

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Ex114

sightseeing via private and commercial aircraft has increased with the demand for outdoor recreation. Because aircraft have varying impacts on large ungulates (MacArthur *et al.*, 1979, 1982; Krausman & Hervert, 1983; Miller & Smith, 1985; Krausman *et al.*, 1986), the goals of sightseeing via aircraft and the maintenance of undisturbed wildlife populations may be incompatible.

Bighorn sheep at Grand Canyon National Park (GCNP) experience heavy helicopter traffic, with estimates ranging from 15 000 to 42 000 flights per year (R. Ernenwein, pers. comm., 1987; ADOT, 1991, respectively). Helicopter traffic is expected to double by 1995 and triple by 2010 (ADOT, 1991). Although few data exist regarding its influence on wildlife populations at GCNP, such data are needed to allow mitigation of potential negative impacts.

The behavior of wildlife has been used to assess the influence of human activities (Hicks & Elder, 1979; Berger *et al.*, 1983; King & Workman, 1986). Because large ungulates devote much time to feeding, foraging behavior and time budgets may be important parameters to evaluate disturbances. Bighorn sheep spend up to 7 h a day feeding (Stockwell, 1989), and may require 1 h of rumination for every hour of active feeding (Belovsky & Slade, 1986). The amount of time allocated to foraging is influenced by a variety of environmental and social variables including forage quality and density, and group size (Berger *et al.*, 1983). The coefficient of foraging efficiency measures the relationship between feeding and scanning, and has been applied to a wide variety of topics including the costs and benefits of sociality (Berger, 1978; Knight & Knight, 1986; Stacey, 1986), habitat utilization (Risenhoover & Bailey, 1985; Warrick & Krausman, 1987) and human disturbance (Berger *et al.*, 1983; King & Workman, 1986). Long-term disturbances may lead to acute or chronic reduction in foraging efficiency (Berger *et al.*, 1983; King & Workman, 1986). In this paper we examine the extent to which helicopter overflights affect the time budgets of bighorn sheep and determine the threshold of distance sufficient to cause disturbance.

STUDY AREA AND METHODS

We observed bighorn sheep between November 1985 and July 1986 in the central region of GCNP in Hermit, Horn, Monument and Salt Canyons. Observations were limited to sheep occurring in the upper strata of the Grand Canyon—Supai, Hermit Shale and Toroweap strata (Fig. 1). Thirty-five sheep were counted during a survey from the rim in the vicinity of the study site in September 1987 (Stockwell, 1989). This group represents a small portion of the total population at Grand Canyon. The distribution of

Ex115

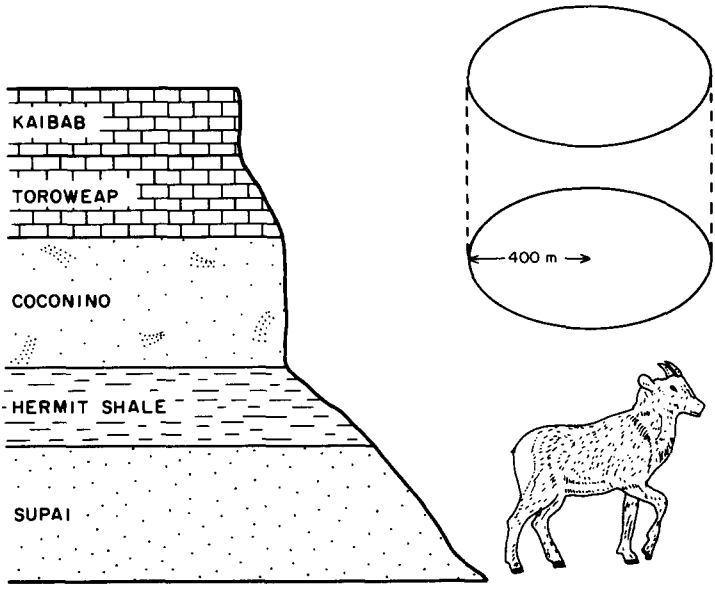

Fig. 1. A schematic cross-section of the strata of Grand Canyon in which animals were observed. Bighorn occupied the Supai, Hermit Shale and Toroweap strata, and occasionally were observed on the rim. During the spring bighorn migrated to lower elevations and did not use the Toroweap stratum. The cylinder represents the relationship between helicopter overflights and their relative proximity to bighorn occupying various strata of the canyon. Helicopters were considered to be overhead if they were flying at rim level or lower and were within 400 m horizontal distance.

bighorn throughout GCNP appears to be patchy and the population size is not known (Stockwell, 1989).

Data collection

Individual animals were located by scanning side canyons with spotting scopes (20–45 ×) from the rim of the Grand Canyon. Upon locating bighorn sheep, data were collected via scan sampling and focal animal sampling (Altmann, 1974). During each 15-min scan sample, data were collected on date, location, group size, group composition and activity patterns of all band members. Observations generally lasted 2 to 3 h.

Animals were classified according to Geist (1971), but class one males and male yearlings were grouped together. Lambs less than six months old were not included for analyses of group size, activity pattern or foraging efficiency data.

Sheep were categorized as either resting (lying down) or active. The total hours of daily activity were determined following the methodology outlined by Hansen (1984) and analysed by season.

Focal animal sampling (Altmann, 1974) was used to record data only on

Ex116

active animals for 300-s periods, using a micro-recorder and later transcribed onto data forms. Foraging bouts were analysed for animals that were in view and active for more than 180 s (≥60% of the bout). Animals were considered active if they engaged in any of the following three activities—foraging (*F*): animal's head down in a foraging or searching position, or animal foraging with neck extended into a tall bush; head up (*HU*): animal's head was up (vigilance and scanning were included here); walking (*W*): movement between two different activity patterns. If walking occurred between two foraging bouts, it was included with *F* unless the animal was vigilant while walking, or if more than five consecutive seconds were allocated to walking.

A foraging efficiency index (FE) was calculated by dividing *F* by the sum of *F* and *HU*, and multiplying by 100 (Berger *et al.*, 1983). Foraging efficiency is an index of time allocated to feeding or searching for food relative to time spent scanning; it is not intended to convey information about assimilation efficiency.

Sheep in a group were observed systematically to avoid potential observer bias. Foraging bouts were recorded for females first, rams second and juveniles last. Furthermore, selection procedure was standardized by beginning at the right side of the band and proceeding toward the left. To decrease pseudoreplication, only one foraging bout was recorded for each animal on a given day.

Data were collected when helicopters were flying overhead and when helicopters were absent. Observations during which helicopters were audible but not overhead were omitted.

Helicopters were visually determined to be overhead if they were flying at the canyon's rim level or lower and were within a horizontal distance of 400 m (Fig. 1). The flight generally originated (or terminated) at rim level and gradually descended below (or ascended to) the rim. Most helicopters flew at altitudes which corresponded with levels between the rim and the top of the Coconino stratum as they flew over the band (Fig. 1). Thus, for bighorn occupying the Toroweap, Hermit Shale and Supai strata, helicopters were generally 50–200 m, 100–450 m and 250–700 m distant, respectively. These values overlap because of the variable altitude flown. Although crude, this measure provides the best possible estimate of helicopter proximity, because monitoring the behavior of the bighorn and the simultaneous path of the helicopter was not possible.

Analyses

We partitioned data into two seasons, winter (October–February) and spring–summer (March–July), which corresponded to bighorn sheep

Ex117

migrations. Bighorn used upper portions of the canyon during winter, but they migrated to lower strata at the commencement of lambing in March, and the upper Toroweap stratum was virtually unused until August (Stockwell, 1989). The migration also appeared to be related to the lack of free water in the Toroweap stratum (Stockwell, 1989).

Foraging efficiency data were transformed by arcsin transformation and then analysed by two-way ANOVA to examine possible seasonal and other interactive effects. Except where noted, one-tailed t-test was used in all pairwise comparisons.

Helicopter presence may be correlated with weather (e.g. helicopters usually flew during calm conditions), yet precipitation had no interactive effect with helicopter overflights on foraging efficiency ($F < 0{\cdot}01, n = 307, p = 0{\cdot}970$). Therefore data obtained under various weather conditions were included in the analyses.

Although foraging bouts in the absence of helicopters were recorded during all diurnal hours, in the presence of helicopters they were recorded only between 0700 and 1100 h, and 1300 and 1700 h. Therefore we compared foraging bouts in the presence or absence of helicopters during these time periods only.

When the foraging efficiencies of treatment and control groups were significantly different, the reduction in foraging efficiency was determined by using the control group as a standard. For instance, if the mean foraging efficiencies of treatment and control animals were 60% and 80%, respectively, treatment animals were considered to be 25% less efficient than the control animals.

RESULTS AND DISCUSSION

Seasonal patterns in activity

Bighorn were active 6·9 h/day during the winter and 6·4 h/day during the spring (Fig. 2(a) and (b)). During winter, they were active throughout the day, but activity was greatest in the morning, late afternoon and evening (Fig. 2(a)). Within each 1-h time period at least 50% of the animals observed were active. During spring, most activity occurred in early morning and late evening (Fig. 2(b)). Other studies have also shown that bighorn sheep reduce activity in the middle of the day (Chilelli & Krausman, 1981; Hansen, 1984).

Time budgets

Data for all animals were combined because helicopter overflights had no interactive effect with age and sex classes of bighorn (males, females and

Ex118

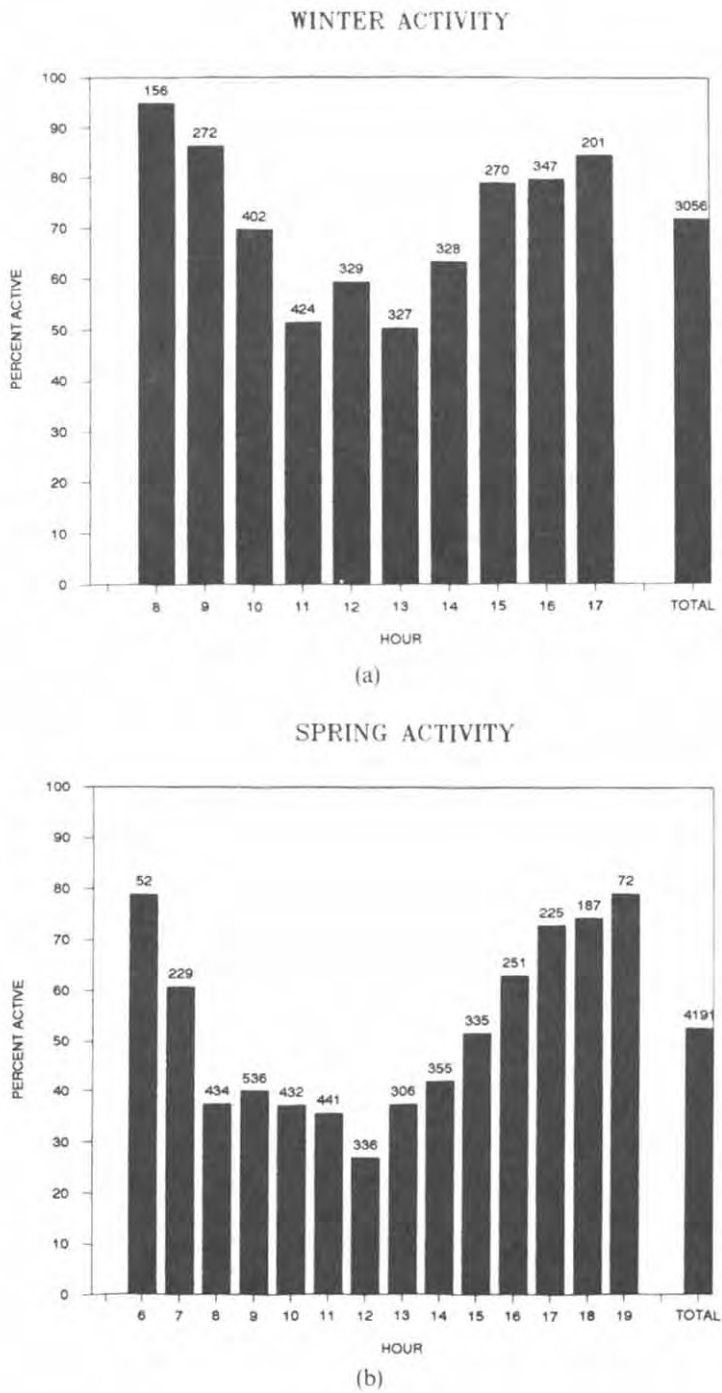

Fig. 2. The diurnal activity patterns of bighorn sheep in winter (a) and spring (b). One point was assigned for each animal during each 15-min scan sample.

lambs older than six months) ($F = 0{\cdot}52$, $n = 297$, $p = 0{\cdot}593$). The presence or absence of helicopters also had no interactive effect with group size (group sizes 1–4, 5–8, 9–13) on foraging efficiency ($F = 1{\cdot}81$, $n = 268$, $p = 0{\cdot}166$).

Helicopters had a seasonal effect on foraging efficiency ($F = 6{\cdot}64$, $n = 320$, $p = 0{\cdot}01$). During winter bighorn foraged 43% less efficiently in the presence of helicopters, $FE = 42{\cdot}7\% \pm 7{\cdot}8$ ($n = 16$) (mean $\pm$ SEM), than when they were absent, $FE = 74{\cdot}6\% \pm 1{\cdot}7$ ($n = 160$) ($t = 4{\cdot}83$, $p < 0{\cdot}001$). During spring helicopters had no effect on foraging efficiency, which averaged $79{\cdot}3\% \pm 4{\cdot}6$ ($n = 24$) and $84{\cdot}2\% \pm 2{\cdot}0$ ($n = 120$) in the presence and absence of helicopters, respectively ($t = 1{\cdot}42$, $p = 0{\cdot}079$).

Because group size influences bighorn foraging behavior (Berger, 1978) and varies seasonally in other areas (Leslie & Douglas, 1979; Chilelli & Krausman, 1981), the seasonal relationship reported here could be related to variation in group size. However, group sizes did not differ between seasons for either undisturbed desert bighorn ($t = 0{\cdot}52$, $p = 0{\cdot}607$ (2-tailed p), $n = 254$) or for sheep foraging in the presence of helicopters ($t = 0{\cdot}64$, $p = 0{\cdot}529$ (2-tailed p), $n = 34$).

Proximity of disturbance

Helicopters were closer to bighorn sheep during winter than spring because bighorn used the Toroweap stratum in winter. Thus the seasonal relationship may have been related to differences in the relative proximity of helicopters between seasons, indicating a possible threshold in disturbance distance. To address this possibility, the data were analysed by strata, holding season constant.

Helicopter overflights had no interactive effect with strata usage on foraging efficiency in winter ($F = 0{\cdot}23$, $n = 169$, $p = 0{\cdot}63$) or in spring ($F = 2{\cdot}52$, $n = 140$, $p = 0{\cdot}115$). Nevertheless, because effects may be subtle we also examined (1) treatment and control bighorn foraging efficiencies within each stratum; (2) inter-strata foraging efficiencies of control bighorn; and, if no difference existed between these groups, (3) inter-strata foraging efficiencies of treatment bighorn.

Winter

Winter strata comparisons were limited to Toroweap and Hermit Shale bighorn because few bands were observed in the Supai stratum. Within-stratum comparisons showed that helicopters had a significant effect on the foraging behavior of both Toroweap bighorn ($t = 4{\cdot}04$, $p < 0{\cdot}001$) and Hermit Shale bighorn ($t = 2{\cdot}8$, $p = 0{\cdot}003$) (Table 1).

Inter-strata comparisons revealed that in the absence of helicopters, sheep in the Hermit Shale foraged more efficiently than animals in the Toroweap

Ex120

TABLE 1
The Influence of Proximity of Helicopters on Bighorn Foraging Efficiency, during Winter

	Control	*Treatment*[a]
Toroweap bighorn	71·8 ± 2·7 (51) a*	35·1 ± 11·1 (7) b
Hermit shale bighorn	76·6 ± 2·2 (103) c	50·2 ± 12·2 (8) b

[a] Helicopters were within 50–200 m and 100–450 m of bighorn in the Toroweap and Hermit Shale strata, respectively.
* Groups with the same letter are not significantly different from each other.

($t = -1{\cdot}93$, $p = 0{\cdot}056$) (2-tailed p) (Table 1), suggesting possible habitat differences between these two strata. Therefore inter-strata comparison of experimental bighorn is not justified. Because helicopters influenced the foraging behavior of bighorn sheep within each stratum, a disturbance distance could not be determined.

Spring

Spring comparisons were limited to bighorn occupying the Hermit Shale and Supai strata, because the Toroweap stratum was virtually unused by bighorn during this period. The within-stratum comparisons also illustrate that only bighorn closest to helicopters were sensitive to disturbance. Hermit Shale bighorn foraged 17% less efficiently in the presence of helicopters than when helicopters were absent ($t = 1{\cdot}91$, $p = 0{\cdot}03$) (Table 2). In contrast, foraging efficiencies were similar for Supai bighorn irrespective of the presence of helicopters ($t = -0{\cdot}35$, $p = 0{\cdot}366$) (Table 2).

Inter-strata comparisons of control bighorn revealed similar foraging rates for bighorn in the Hermit Shale and Supai ($t = 0{\cdot}90$, $p = 0{\cdot}370$) (2-tailed p) (Table 2). This justifies an inter-strata comparison of the foraging efficiencies of bighorn in the presence of helicopters. In the presence of helicopter overflights, foraging efficiencies for Hermit Shale and Supai bighorn were 71·3% ± 9·1 ($n = 11$) and 89·5% ± 2·0 ($n = 11$), respectively ($t = -1{\cdot}40$, $0{\cdot}05 < p < 0{\cdot}10$).

TABLE 2
The Influence of Proximity of Helicopters on Bighorn Foraging Efficiency, during Spring

	Control	*Treatment*[a]
Hermit shale bighorn	86·0 ± 2·4 (66) a*	71·3 ± 9·1 (11) b
Supai bighorn	82·2 ± 3·5 (52) ac	89·5 ± 2·0 (11) c

[a] Helicopters were within 100–450 m, and 250–700 m for bighorn in the Hermit Shale and Supai strata, respectively.
* Groups with same letter are significantly different from each other.

Ex121

Because only those sheep using the Toroweap or Hermit Shale strata were disturbed by helicopters, these results indicate a disturbance distance threshold of 250–450 m. Other studies have also shown that the degree of disturbance is a function of proximity to the stimulus (Altmann, 1958; Berger *et al.*, 1983; Krausman & Hervert, 1983; Knight & Knight, 1984; Miller & Smith, 1985; Krausman *et al.*, 1986). Physiological data also report this relationship. Heart rates of Rocky Mountain bighorn *O. c. canadensis* did not respond to high-flying aircraft (>400 m), but those exposed to low-flying aircraft (90–250 m) ran and incurred up to a 3·5-fold increase in heart rate (MacArthur *et al.*, 1979, 1982).

Implications

If bighorn do not habituate to helicopters, the impacts will be cumulative; as the frequency of flights increases, so will impacts, which would be most severe in winter.

An animal may compensate for an energy loss by foraging longer if time is not limiting. However, ruminants require sufficient time to consume and ruminate large quantities of food. During winter, time constraints may be acute because bighorn were active approximately 69% of the daylight hours (Stockwell, 1989), and additional time may be required for rumination since bighorn often ruminate while lying down. Therefore additional compensatory activity may have an important influence on the total time budget of Grand Canyon bighorn.

Determining the average number of helicopters a bighorn may experience is problematic because helicopter traffic is spatially and temporally variable, and the distribution of bighorn at GCNP is not well documented. Following this study, the Federal Aviation Administration adopted Special Federal Aviation Regulation (SFAR) 50–2 on 1 November 1988, which created flight-free zones and flight corridors (Mazzu, 1990). This has effectively concentrated helicopter traffic over designated regions, which now may experience as many as 15 helicopter flights/hour during the fall (Mazzu, 1990). How these flight corridors overlap with areas occupied by bighorn throughout the park is not known; however, bighorn inhabit the strata below one flight corridor (Dragon Corridor) which experiences the heaviest helicopter traffic in the park (Stockwell, 1989; Mazzu, 1990).

Although helicopters caused a notable reduction in foraging efficiency, the long-term effects of such modified behavior are difficult to assess. Under ideal conditions one may design an experiment to compare the reproductive rates of populations exposed to varying levels of helicopter overflights while controlling for other variables. However, environmental factors that influence lamb survival are poorly understood (DeForge & Scott, 1982;

Ex122

DeForge *et al.*, 1982), and the control of such variables in free-ranging populations will always remain difficult. Therefore, time budgets offer an alternative method for the determination of potential impacts of human activities on wildlife populations.

In summary, our data indicate that helicopter overflights alter the foraging behavior of desert bighorn—impacts which may be minimized by either restricting the number of flights or by regulating the flight altitudes of helicopters.

Restricting the number of flights during the winter appears to be a good strategy because impacts on bighorn foraging occurred only in winter. However, potential impacts may also occur during spring if helicopters haze bighorn during lambing. Although the frequency of such events is not known, at least one incident of hazing bighorn has been reported at Grand Canyon (Steve Carothers, pers. comm.).

Flights could also be restricted during specified periods of the day, especially in the spring when bighorn are most active during early morning and late afternoon. During winter, helicopters would be likely to encounter active sheep during all hours since at least 50% of the animals were active during every hour.

Alternatively, current regulations of helicopter flight altitudes could be modified to reduce impacts on bighorn. Current altitude regulations vary throughout GCNP, but generally helicopters must fly 152·4 m (500 ft) above the south rim; however, such altitudes are often below the north rim of the canyon. Because our data indicate a disturbance distance of approximately 250–450 m, impacts would be minimized if helicopters were to fly no nearer to bighorn habitat than 500 m.

The information reported here illustrates how time budget data may be used to mitigate impacts in national parks. Such an approach should prove useful in other areas where conflicts between human activities and wildlife populations may exist. As the demand for outdoor recreation continues to increase, data on potential human-induced impacts will become essential to mitigate possible long-term impacts.

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Ex123

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REFERENCES

ADOT (Arizona Department of Transportation) (1991). Master plan for Grand Canyon National Park Airport. Arizona Department of Transportation, Phoenix.

Altmann, J. (1974). Observational study of behavior: sampling methods. *Behaviour*, **49**, 227–67.

Altmann, M. (1958). The flight distance in free-ranging big game. *J. Wildl. Manage.*, **22**, 207–9.

Belovsky, G. E. & Slade, J. B. (1986). Time budgets of grassland herbivores: body size similarities. *Oecologia Berl.*, **70**, 53–62.

Berger, J. (1978). Group size, foraging and anti-predator ploys: an analysis of bighorn sheep decisions. *Behav. Ecol. Sociobiol.*, **4**, 91–100.

Berger, J., Daneke, D., Johnson, J. & Berwick, S. H. (1983). Pronghorn foraging economy and predator avoidance in a desert ecosystem: implications for the conservation of large mammalian herbivores. *Biol. Conserv.*, **25**, 193–208.

Chilelli, M. & Krausman, P. R. (1981). Group organization and activity patterns of desert bighorn sheep. *Desert Bighorn Council Trans.*, **25**, 17–24.

DeForge, J. R. & Scott, J. E. (1982). Ecological investigations into high lamb mortality. *Desert Bighorn Council Trans.*, **26**, 65–76.

DeForge, J. R., Jessup, D. A., Jenner, C. W. & Scott, J. E. (1982). Disease investigations into high lamb mortality of desert bighorn sheep in the Santa Rosa Mountains, California. *Desert Bighorn Council Trans.*, **26**, 76–81.

Geist, V. (1971). *Mountain Sheep: A Study in Behavior and Evolution.* University of Chicago Press, Chicago, IL.

Hansen, M. C. (1984). Activity patterns of bighorn sheep on the Sheldon National Wildlife Refuge. *Desert Bighorn Council Trans.*, **28**, 14–17.

Hicks, L. L. & Elder, J. M. (1979). Human disturbance of Sierra Nevada bighorn sheep. *J. Wildl. Manage.*, **43**, 909–15.

King, M. M. & Workman, G. W. (1986). Response of desert bighorn sheep to human harassment: management implications. *Trans. N. Amer. Wildl. Nat. Resour. Conf.*, **51**, 74–85.

Knight, R. L. & Knight, S. K. (1984). Responses of wintering bald eagles to boating activity. *J. Wildl. Manage.*, **48**, 999–1004.

Knight, S. K. & Knight, R. L. (1986). Vigilance patterns of bald eagles feeding in groups. *Auk*, **103**, 263–72.

Krausman, P. R. & Hervert, J. J. (1983). Mountain sheep responses to aerial surveys. *Wildl. Soc. Bull.*, **11**, 372–5.

Ex124

Krausman, P. R., Leopold, B. D. & Scarbrough, D. L. (1986). Desert mule deer response to aircraft. *Wildl. Soc. Bull.*, **14**, 68–70.

Leslie, D. M. Jr & Douglas, C. L. (1979). Desert bighorn sheep of the River Mountains, Nevada. *Wildl. Monogr.*, **66**, 1–56.

MacArthur, R. A., Johnston, R. H. & Geist, V. (1979). Factors influencing heart rate in free ranging bighorn sheep: a physiological approach to the study of wildlife harassment. *Can. J. Zool.*, **57**, 2010–21.

MacArthur, R. A., Geist, V. & Johnston, R. H. (1982). Cardiac and behavioral responses of mountain sheep to human disturbance. *J. Wildl. Manage.*, **46**, 351–8.

Mazzu, L. (1990). Fall 1989 aircraft monitoring program, final report. United States Department of the Interior, National Park Service, Grand Canyon National Park, Arizona.

Miller, G. & Smith, E. L. (1985). Human activity in desert bighorn habitat: what disturbs sheep? *Desert Bighorn Council Trans.*, **29**, 4–7.

Risenhoover, K. L. & Bailey, J. A. (1985). Foraging ecology of mountain sheep: implications for habitat management. *J. Wildl. Manage.*, **49**, 797–804.

Stacey, P. B. (1986). Group size and foraging efficiency in yellow baboons. *Behav. Ecol. Sociobiol.*, **18**, 175–87.

Stockwell, C. A. (1989). The behavior of desert bighorn at Grand Canyon National Park: implications for conservation. MS thesis, Northern Arizona University, Flagstaff, AZ.

Warrick, G. D. & Krausman, P. R. (1987). Foraging behavior of female mountain sheep in western Arizona. *J. Wildl. Manage.*, **51**, 99–104.

Ex125

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Ex126

Mountain goat responses to helicopter disturbance

Steeve D. Côté

Abstract Mountain goat (*Oreamnos americanus*) responses to helicopter traffic were investigated at Caw Ridge (Alberta) from June to August 1995. A population of 109 marked individuals inhabited the ridge during the study. As measured by their overt responses, mountain goats were disturbed by 58% of the flights and were more adversely affected when helicopters flew within 500 m. Eighty-five percent of flights within 500 m caused the goats to move >100 m; 9% of the flights >1,500 m away caused the goats to move similar distances. Helicopter visibility and height above ground, number of goats in the group, group type (bachelor or nursery), and behavior of groups just prior to helicopter flights did not appear to influence reactions of goats to helicopters. Helicopter flights caused the disintegration of social groups on ≥5 occasions and resulted in 1 case of severe injury to an adult female. Based on these observations, restriction of helicopter flights within 2 km of alpine areas and cliffs that support mountain goat populations is recommended.

Key words behavior, disturbance, helicopter, mountain goat, *Oreamnos americanus*

Helicopters commonly are used in wildlife management and industrial development activities (Klein 1971, Miller and Gunn 1980, Thompson and Baker 1981). Exploration for petroleum and natural gas on the eastern slopes of the Canadian Rocky Mountains have relied heavily on helicopters for the past 40 years (Penner 1988). Such exploration often requires numerous flights in the same area because ground operations (e.g. slashing, drilling, placing geophones) need aerial assistance (Joslin 1986). Thus, wild animals in the vicinity are frequently exposed to helicopter flights.

Effects of aircraft overflights on the behavior of bighorn sheep (*Ovis canadensis*; MacArthur et al. 1979, Krausman and Hervert 1983, Stemp 1983, Bleich et al. 1990, 1994; Stockwell et al. 1991), caribou (*Rangifer tarandus*; McCourt et al. 1974, Calef et al. 1976, Miller and Gunn 1979, Gunn and Miller 1980, Gunn et al. 1983, Valkenburg and Davis 1983, Harrington and Veitch 1991), mountain goat (Foster and Rahs 1983) and muskoxen (*Ovibos moschatus*; Miller and Gunn 1979, 1980; Miller et al. 1988) have been reported. In most cases, reports show an inverse relationship between intensity of responses and altitude of a helicopter above animals. Close-range flights typically elicit strong negative responses in ungulates, but few studies have investigated effects of horizontal distance of aircraft to the animals (Miller and Gunn 1979, Foster and Rahs 1983, Stockwell et al. 1991). There is no evidence that wild un-

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gulates habituate to repeated helicopter overflights (Miller and Gunn 1980, Bleich et al. 1990). Though mountain goats are believed to be sensitive to human disturbance (Pendergast and Bindernagel 1977, Joslin 1986), few attempts have been made to record their responses to helicopter overflights systematically (Geist 1971, Foster and Rahs 1983).

The goals of this study were to determine whether low-flying helicopters modified mountain goat behavior and to provide data for guidelines on the use of helicopters in mountain goat habitats. I evaluated goat responses to distance from the helicopter, direct sighting of the aircraft, helicopter height above the animals, group size, group type and pre-flight activity.

Study area

This study was conducted at Caw Ridge (54°N, 119°W) in west-central Alberta, Canada. The study area is a gently rolling mountain complex in the front range of the Rocky Mountains. The mountain goat population used about 21 km^2 of alpine tundra and open subalpine spruce (*Picea engelmanii*) forest, ranging in elevation from 1,750 to 2,170 m with timberline at about 1,900 m. The area includes only a few short cliff faces and does not have extensive steep escape terrains. A more detailed description of the study area is provided by Festa-Bianchet et al. (1994).

Methods

A mountain goat population of 109 animals (98 marked), including 9 adult males, 43 adult females, eight 2-year-old males, ten 2-year-old females, 2 yearling males, 13 yearling females, and 24 kids inhabited the ridge during the study. Fourteen animals were fitted with radiocollars to facilitate locating groups. I tried to find and observe each goat at least once a week. Priority of observation was given to the groups that had not been observed for the longest period of time. I used spotting scopes (15 x 45X) to sample goat behavior from the ground at distances ranging from 200 to 700 m. Observations reported here extended from 26 June to 26 August 1995 with peak flying activities occurring between 15 July–5 August. Exploration companies used 2 types of helicopters: Bell-206B turbo (n = 18 flights) and Bell-212 (twin engine; n = 57 flights). I observed helicopter flights opportunistically with no control over when and where helicopters flew.

For each flight, I noted the date, time, helicopter model (206 or 212), and whether the aircraft was carrying a drill (in a net), or not. I recorded group size, group type (bachelor [adult male(s) only], nursery [including adult females, juveniles, and kids]), behavior of animals immediately prior to the flight (active or bedded) and goat responses to the flight. I also visually estimated helicopter height above the ground (<100 m or >100 m) and evaluated the shortest horizontal distance between goat groups and a helicopter (<500 m, 500–1,500 m or >1,500 m) using topographic maps. Flights at <100 m above ground generally represented helicopters working on cut lines while those at >100 m represented flights occurring between lines or base camp. I considered flights at <500 m as the first category of horizontal distance sampling because they were generally over goat alpine habitats. Most of the flights at >500 m occurred over forests. Finally, I determined whether the aircraft was visible to the animals.

Mountain goats that continued their activities during the preflight period, or were alert for <2 minutes or moved <10 m, were classified as not disturbed or lightly disturbed (a single category for analysis). Alert goats stood, raised their ears, and usually looked towards the approaching helicopter. Goats that moved 10–100 m or were alert >2 and <10 minutes were considered moderately disturbed. Goats that walked or ran >100 m or were alert for >10 minutes were considered greatly disturbed. I recorded group responses rather than individual responses because events happened too quickly to observe animals individually. Consequently, I did not distinguish individual responses of marked goats. I considered that a group changed its behavior when at least 1/2 of the individuals did so. In >90% of cases, >75% of animals in a group reacted similarly.

Preliminary G tests were used to compare frequency distributions of goat reactions to helicopter model (206 vs. 212) and presence or absence of a sling (Sokal and Rohlf 1981). Because neither variable affected goat reactions to helicopters (P = 0.3), I pooled data from all flights and used log-linear analysis to assess the

effects of remaining variables and interaction terms on goat responses. I controlled for distance effect when analyzing the other variables because cell counts were unbalanced for close and distant helicopters. All analyses were conducted with S-Plus 3.3 (StatSci, a division of Mathsoft, Inc. 1995, Seattle, Wash.).

Results

Responses of 84 groups to helicopters were observed on 74 occasions. Twenty-nine different groups were sampled. Mean group size was 45 (SD = 41) animals. Individual goats often moved between groups. I usually recorded 1 group response/day, but occasionally I sampled the same group >1 time/day. For these cases, I waited until the goats had recovered their normal activity before recording a new response. Furthermore, there was no difference between goat reaction to the first flight of the day and subsequent flights (n = 81, G = 0.39, 2 df, P = 0.8), indicating that the effects of flights occurring in the same day were likely independent.

Over the entire study, 42% of mountain goat groups observed during helicopter flights were considered lightly disturbed, 26% were moderately disturbed, and 32% were greatly affected by the presence of the helicopter.

The distance between the helicopter and the animals was the most important factor affecting goat behavior. Mountain goats were greatly disturbed by 85% of helicopter flights <500 m compared to only 9% of flights >1500 m (Table 1). All flights <500 m caused at least a moderate reaction, and 63% of flights >1500 m were classified as not disturbing or lightly disturbing.

Once I accounted for the effect of distance of goats from a helicopter, then direct sighting of the helicopter and height above ground, group size, group type (nursery or bachelor group) and behavior of goats before a helicopter flight had no significant effect on goat reactions ($0.14 < P < 0.98$). No interaction terms of the above variables significantly affected the response of goats ($P > 0.4$). However, some cell counts were low and therefore may have precluded detecting differences.

Helicopter traffic caused a group to split up on 5 occasions (7% of flights). Once, a 2-year-old male was grazing about 50 m from a nursery group of 10 individuals when a helicopter suddenly appeared at <200 m. The young male ran >1 km in the opposite direction of the nursery group. Several flights occurred in the hours following the incident, and the young male never returned to his group but joined another group of 91 individuals 2.5 days later. Two other nursery groups were separated by helicopter flights: a herd of 90 goats and a group of 4 females, 2 juvenile males and 3 kids. They both split roughly in half (4–5 and 44–46) and reassembled 28 hours and 8 hours later, respectively. Two different male groups (1 with 2 individuals and 1 with 3) separated for ≥2 days following helicopter approaches.

On another occasion, a helicopter approached a herd of 54 goats and flew along side of them at a distance of approximately 100 m. The entire group immediately fled to a rocky cliff situated <150 m. A marked 3-year-old female broke her right hindleg during the incident. After her injury, she was separated from the main group periodically for ≥70 days.

Table 1. Influence of helicopter distance on mountain goat responses to helicopter flights at Caw Ridge, Alberta, June–August 1995.

	Mountain goat reaction[a]			
Distance	Light	Moderate	Great	P
<500 m	0	3	17	0.0002
500–1,500 m	0	3	4	
>1,500 m	34	15	5	

[a] Mountain goats that continued their activities during the preflight period or were alert for <2 minutes or moved <10 m were classified as lightly disturbed. Goats that moved 10–100 m or were alert >2 and <10 minutes were considered moderately disturbed. Goats that walked or ran >100 m or were alert for >10 minutes were considered greatly disturbed.

Discussion

For 1/3 of the flights, animals reacted to the aircraft by assuming alert and standing behavior for >10 minutes or moving >100 m. A typical reaction began with the animal standing and raising its ears while looking in the direction of the helicopter. If the helicopter approached, the animal would run to safer terrain such as a cliff and face the helicopter. Mountain goats rely on rocky cliffs for security (Geist 1971, Fox and Streveler 1986). Once goats reached a cliff, they habitually did not go further. This escape behavior had an important implication in the context of petroleum and natural gas exploration which required repeated flights in the same area. Usually such activities included flying along cut lines slinging new drills and collecting the ones just used. Because goats tended to remain in nearby cliffs, instead of escaping some distance away, they were exposed to stress from helicopter disturbance for a prolonged period of time. Therefore, when the escape terrain was close to the cut line, a helicopter could remain in the

vicinity of the goats for several hours. In these situations, I noted panic behavior with animals staying alert for several hours without attempting to forage.

Prolonged disturbance could have severe consequences on daily energy intake of goats, especially for kids and nursing females, because seismic operations are normally conducted during the lactation period. Furthermore, reaction to helicopters can increase energy expenditure, reduce fat accumulation, or change animal physiological condition (MacArthur et al. 1979), factors that may affect survival or reproduction (Calef et al. 1976, Joslin 1986, Harrington and Veitch 1991).

In our study, the distance between mountain goat groups and the helicopter was the most important factor affecting their behavior. Goats appeared to be more sensitive to helicopter traffic than other open-terrain ungulates; 37% of flights at >1500 m caused at least a moderate reaction. Foster and Rahs (1983) found mountain goats were affected by flights within 1 km, the recommended flight distance from caribou and muskox (Miller and Gunn 1979), and responded beyond the disturbance distance threshold of 250-450 m observed for desert bighorn sheep (Stockwell et al. 1991).

Extensive studies on caribou and muskoxen found no evidence that exposure to helicopter harassment caused any injuries or herd splintering, but mentioned the potential impact of these factors (Jonkel et al. 1975, Calef et al. 1976, Miller and Gunn 1979, 1980). The group splinterings I observed suggest that mountain goats may be more sensitive to disturbance than other ungulates and that special care should be taken in the management of this species.

Management implications

In view of the intensity of petroleum and natural gas exploration and other activities requiring heavy helicopter traffic, the following recommendations should be considered within mountain goat range in the Rocky Mountains.

Helicopters should remain ≥2 km away from goat herds. Seismic lines should not be created in goat habitats such as alpine tundra, cliffs and open forest close to timberline. A practical guideline would be to establish a buffer zone of 2 km around alpine areas and cliffs known to support mountain goat populations, and to direct aerial traffic away from goat alpine habitat to minimize disturbance. In cases where helicopters must infringe on goat habitats, aircraft should stay ≥300 m above ground level and not land on treeless ridges (Calef et al. 1976, Miller and Gunn 1979).

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Literature cited

Bleich, V. C., R. T. Bowyer, A. M. Pauli, R. L. Vernoy, and R. W. Anthes. 1990. Responses of mountain sheep to helicopter surveys. Calif. Fish and Game 76:197-204.

Bleich, V. C., R. T. Bowyer, A. M. Pauli, M. C. Nicholson, and R. W. Anthes. 1994. Mountain sheep (*Ovis canadensis*) and helicopter surveys: ramifications for the conservation of large mammals. Biol. Conserv. 70:1-7.

Calef, G. W., E. A. DeBock, and G. M. Lortie. 1976. The reaction of barren-ground caribou to aircraft. Arctic 29:201-212.

Festa-Bianchet, M., M. Urquhart, and K. G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. Can. J. Zool. 72:22-27.

Foster, B. R., and E. Y. Rahs. 1983. Mountain goat response to hydroelectric exploration in Northwestern British Columbia. Environ. Manage. 7:189-197.

Fox, J. L., and G. P. Streveler. 1986. Wolf predation on mountain goats in southeastern Alaska. J. Mammal. 67:192-195.

Geist, V. 1971. Mountain sheep. Univ. Chicago Press, Chicago, Ill. 383pp.

Gunn, A., and F. L. Miller. 1980. Responses of Peary caribou cow-calf pairs to helicopter harassment in the Canadian high Arctic. Proc. Int. Reindeer/Caribou Symp. 2:497-507.

Gunn, A., F. L. Miller, R. Glaholt, and K. Jingfors. 1983. Behavioral responses of barren-ground caribou cows and calves to helicopters on the Beverly herd calving ground, Northwest Territories. Proc. North Am. Caribou Workshop 1:10-14.

Harrington, F. H., and A. M. Veitch. 1991. Short-term impacts of low-level jet fighter training on caribou in Labrador. Arctic 44:318-327.

Jonkel, C. J., D. R. Gray, and B. Hubert. 1975. Immobilizing and marking wild muskoxen in Arctic Canada. J. Wildl. Manage. 39:112-117.

Joslin, G. 1986. Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain front. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:253-269.

Klein, D. R. 1971. Reaction of reindeer to obstructions and disturbances. Science 173:393-398.

Krausman, P. R., and J. J. Hervert. 1983. Mountain sheep responses to aerial surveys. Wildl. Soc. Bull. 11:372-375.

MacArthur, R. A., R. H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Can. J. Zool. 57:2010-2021.

McCourt, K. H., J. D. Feist, D. Doll, and J. J. Russell. 1974. Reactions of caribou to aircraft disturbance. Pages 183-208 *in* R. D. Jakimchuk, ed. Disturbance studies of caribou and other mammals in the Yukon and Alaska, 1972. Arct. Gas Biol. Rep. Ser. Vol. 5. 246pp.

Miller, F. L., and A. Gunn. 1979. Responses of Peary caribou and muskoxen to helicopter harassment. Can. Wildl. Serv. Occas. Pap. No. 40. 90pp.

Miller, F. L., and A. Gunn. 1980. Behavioral responses of muskox herds to simulation of cargo slinging by helicopter, Northwest Territories. Can. Field-Nat. 94:52-60.

Miller, F. L., A. Gunn, and S. J. Barry. 1988. Nursing by muskox calves before, during, and after helicopter overflights. Arctic 41:231-235.

Penner, D. F. 1988. Behavioral response and habituation of mountain goats in relation to petroleum exploration at Pinto Creek, Alberta. Proc. Bienn. Symp. North. Wild Sheep and Goat Council 6:141-158.

Pendergast, B., and J. Bindernagel. 1977. The impact of exploration for coal on mountain goats in Northeastern British Columbia. Pages 64-73 *in* W. Samuel and W. G. Macgregor, eds. Proc. First Int. Mountain Goat Symp., Kalispell, Mont.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. Second ed. W. H. Freeman and Co., San Francisco, Calif. 859pp.

Stemp, R. E. 1983. Responses of bighorn sheep to environmental factors and harassment. M.Sc. Thesis, Univ. Calgary, Alberta. 314pp.

Stockwell, C. A., G. C. Bateman, and J. Berger. 1991. Conflicts in National Parks: a case study of helicopters and bighorn sheep time budgets at the Grand Canyon. Biol. Conserv. 56:317-328.

Thompson, B. C., and B. W. Baker. 1981. Helicopter use by wildlife agencies in North America. Wildl. Soc. Bull. 9:319-323.

Valkenburg, P., and J. L. Davis. 1983. The reaction of caribou to aircraft: a comparison of two herds. Proc. North Am. Caribou Workshop 1:7-9.

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Ex131

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The effect of radio-collar weight on survival of migratory caribou

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Ex132

Note

The Effect of Radio-Collar Weight on Survival of Migratory Caribou

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ABSTRACT Radio transmitters are widely used in wildlife management; therefore, it is essential to assess any effects that they may have on animal survival. We compared the survival of 269 randomly selected adult migratory caribou (*Rangifer tarandus*) fitted with either light very high frequency or heavy Argos satellite collars during the same period. Heavy collars reduced annual survival of caribou in a declining population with generally poor body condition by about 18%. Accurate estimates of survival are crucial for management decisions and possible effects of collars should be considered when calculating estimates. © 2014 The Wildlife Society.

KEY WORDS *Cervidae*, radio transmitter weight, *Rangifer tarandus*, satellite/VHF collars, survival, Ungava caribou.

Radio transmitters embedded in collars, backpacks, or ear tags are widely used in animal ecology and management to study habitat use (Massé and Côté 2013), behavior (Bleich et al. 1997), and survival (Fuller 1989). A crucial assumption often made, but rarely tested, is that the transmitter does not alter the behavior or vital rates of the subject (Bank et al. 2000, Venturato et al. 2009). Although all possible measures are normally taken by wildlife managers to minimize the risks associated with capture and wearing a radio transmitter, some detrimental effects may still persist for some species. Guidelines for the use of radio transmitters are often ambiguous and rarely species-specific. One frequently cited guideline is that they should weigh less than 3% of body mass of the animal instrumented (Kenward 2001), but the basis for that guideline is unclear. Regardless of the weight of radio transmitters, it is essential to consider their potential undesired effects, which may lead to biased vital rate estimates and erroneous management decisions. Although some studies have identified effects of radio transmitters on animal behavior (Brooks et al. 2008), mass loss (Legagneux et al. 2013), reproductive success (Demers et al. 2003), or survival (Swenson et al. 1999), much is still unknown and several results appear contradictory (e.g., Godfrey and Bryant 2003).

The size and weight of the radio transmitter, the species studied, and individual characteristics may affect the response to the radio transmitter. For example, heavier devices are more likely to have a negative impact than light ones (Brooks et al. 2008, Venturato et al. 2009). In addition, younger individuals may be more affected than adults (Cypher 1997, Swenson et al. 1999). Migratory species such as greater snow goose (*Anser caerulescens atlanticus*) or caribou (*Rangifer tarandus*) that travel hundreds or thousands of kilometers each year may be particularly susceptible to the effects of collars (Demers et al. 2003, Haskell and Ballard 2007), because the energetic costs of long migrations exacerbate the burden of wearing a transmitter.

Although technological advances have reduced the size and weight of radio transmitters, demand for newer and better tools has led to added functions, such as global positioning system (GPS) engines, 2-way communication, geofencing and proximity sensors, longer battery life, or onboard cameras, adding bulk and weight to the devices. Our objective was to evaluate the effect of radio-collar weight on survival of migratory caribou. We compared survival of adult females ($\geq$2 years old) wearing a light very high frequency (VHF) collar (514 g) to that of females wearing a heavy satellite collar (1.63 kg) in a herd in northern Québec and Labrador over 5 years. Although these types of collars were consistently used throughout the 1990s, satellite collars used on migratory caribou today weigh approximately 500 g.

STUDY AREA

The range of the Rivière-George caribou herd extends over several thousand square kilometers in northern Québec and Labrador (Boulet et al. 2007). Over the last few decades, the herd's demography has changed. Estimated at about 60,000 caribou in 1963 (Des Meules and Brassard 1964), the herd

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experienced several decades of growth and was above 500,000 individuals for about 15 years, peaking in the late 1980s and early 1990s (Crête et al. 1996, Bergerud et al. 2008). The Rivière-George herd was photo censused at 823,375 individuals (±102,000) in 1993 (Couturier et al. 1996). It then declined to about 27,600 (±2,760) individuals in 2012 (Québec and Newfoundland-Labrador governments, unpublished data; Fig. 1). The recent decline was associated with poor body condition, likely due to overgrazing of the summer range and more extensive movements (Couturier et al. 1990, Crête and Huot 1993).

METHODS

Collar Data

In 1986, the governments of Québec and Newfoundland-Labrador initiated a satellite-monitoring program using Telonics (Mesa, AZ) Argos ST-3 satellite collars (hereafter satellite collars) on migratory caribou, mostly adult females. Animals were captured at various times of the year, mainly by net-gunning from a helicopter but also by boat at river crossings. The VHF and satellite collars were fitted on adult females (≥2-year olds) and both collar types provided large adjustment range so the fit on caribou neck was comparable. The Argos satellite collars used during our study provided a better fit than earlier versions of GPS satellite collars. Collar type did not differ between capture techniques and females to be fitted with each type of collar were selected randomly. Several new adults were captured and collared each year, maintaining a representative age structure of collared animals (Table 1). Actual age was not determined. Battery life for VHF collars was longer (4–9 years) than for satellite collars (2.5 years), but individuals with both collar types were consistently recaptured and fitted with new collars prior to the end of battery life. Observers monitored VHF radio-collars from fixed-wing aircraft or helicopter (see Crête et al. 1996). The herd's range was covered 6–8 times/year, with at least 1 field session between January and March over the winter range. We assumed that the chance of detecting live or dead individuals during these flights did not differ, because large proportions of the herd's range were covered during most flights. Some individuals with VHF collars may have died outside of these more frequented zones and were therefore not detected as deceased. Recent data, however, suggest that such bias, if present, was small. In 2011 and 2012, we found that the probability of finding a satellite collar in mortality mode using only the VHF was very similar to the probability of detecting mortality from functioning satellite collars. During this period, several satellite collars malfunctioned and could only be found using VHF transmitters. Out of 33 collar malfunctions of adult females, 3 were found dead and 30 alive, suggesting a survival rate of 91%, compared to 90% for individuals with functioning satellite collars (S. Rivard, Ministère des ressources naturels du Québec, personal communication). For VHF collars, mortality was determined using pulse rate of VHF frequency as the beats per minute (BPM) were higher (average 187 BPM) for collars in mortality mode than for those in active mode (average 49 BPM). Satellite monitoring provided the mortality date and location of each individual every ±5 days. For both VHF and satellite collars, mortalities were determined by visiting the presumed mortality site and locating evidence such as bones, fur, or blood on the collar. Unfortunately, in most cases exact time and cause of mortality was not determined because the carcass was visited up to a few months after death. We analyzed annual survival of caribou fitted with VHF and satellite collars in 1991–1994 and in 2000. The VHF collars were substituted for satellite collars after 1995, but many VHF collars were deployed prior to the 2001 aerial census (Couturier et al. 2004). A total of 195 adult females (>2 years) with VHF collars and 96 with satellite collars were monitored over these 5 years. The weight of the 2 collar types differed substantially; VHF collars weighed 514 g, whereas Argos ST-3 satellite collars weighed 1.63 kg.

Table 1. Number of new and active radio-collared caribou as well as number of mortalities between 1991–1994 and 2000 for caribou equipped with very high frequency (VHF) and satellite (Telonics Argos ST-3) collars from the Rivière-George herd.

	VHF collars	Satellite collars
Number of new radio-collared caribou		
1991	12	26
1992	10	2
1993	26	9
1994	9	14
2000	74	7
Number of active radio-collared caribou		
1991	76	29
1992	65	20
1993	67	23
1994	16	28
2000	74	22
Number of mortalities		
1991	15	10
1992	13	5
1993	12	8
1994	0	9
2000	9	7

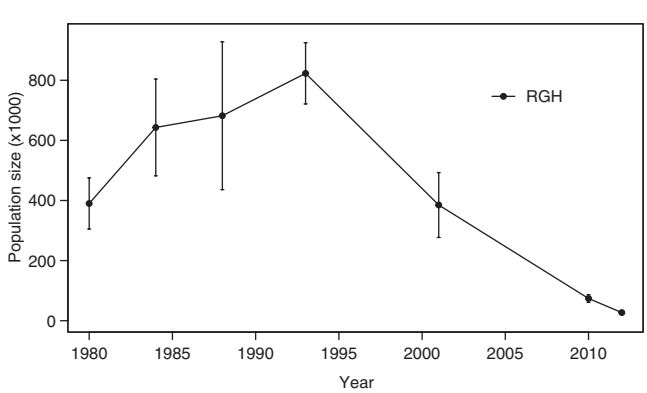

Figure 1. Population estimates from aerial censuses, with 95% confidence intervals when available, for the Rivière-George migratory caribou herd (RGH) in northern Québec and Labrador between 1980 and 2012. Note that the confidence interval in 2012 is too small to be seen on the graph.

Estimation of Survival Parameters

We compared survival of adult females over a biological year, 1 June to 31 May, according to collar type during the same period. We included individuals as of their first full year of monitoring (collared no later than 30 Jun) to eliminate potential biases due to the duration of monitoring during the first year. We censored individuals with satellite collars that were lost because of collar malfunction after the last transmission. However, we found no relation between collar malfunction and fate, as we explained above. We used a known-fate model in Program MARK version 6.1 (White and Burnham 1999) to estimate annual survival. We compared a general time-dependent model ($S_{g\times t}$, where S is survival, g is collar type and t is time), a simple time-dependent model (S_t) and a model with only collar type as the independent variable (S_g) and used the corrected Akaike's Information Criterion (AIC_c) to select the best model (White and Burnham 1999). We tested goodness-of-fit of each multistate dataset using Program U-Care version 2.3.2 (Choquet et al. 2009).

RESULTS

Females from the Rivière-George herd equipped with VHF collars had much higher annual survival rates (86%; $\hat{c} < 1$, SD = 9.79) than females with satellite collars (68.4%; $\hat{c} < 1$, SD = 5.78; Fig. 2) between 1991 and 1994 and in 2000. The best model included only collar type as an independent variable (95% CI = −1.4, upper 95% CI = −0.4), with no support for a time effect (Table 2).

DISCUSSION

We directly tested the effect of collar weight and size by comparing individuals with light and heavy collars that experienced the same pursuit, capture, and handling procedures during the same time period and over the same range. We found no difference in the locations of captures according to collar type. Our results suggested that heavy collars may reduce survival in migratory caribou. The average difference in point estimates of annual survival between individuals equipped with light VHF collars and those with heavy satellite collars was 17.7% (yearly range 5–32%) over 5 years. Only collar weight and size differed between these 2 groups. Survival of animals equipped with light VHF collars may be lower than survival of uncollared caribou, but we had no way to explore this possibility.

Although body condition measurements were not taken on captured individuals during this period, the herd was declining during the study period because of, in part, poor body condition in the late 1980s and early 1990s (Crête and Huot 1993; Couturier et al. 2009*a*, 2009*b*, 2010). Furthermore, the herd range had increased considerably during this period, resulting in annual migrations of over 1,000 km, likely decreasing body condition (Couturier et al. 2009*a*, 2010). This suggests that during a population decline, when demographic parameters such as survival and reproduction are already diminished, the added weight of a collar, even within the suggested <3% of total body mass (Kenward 2001), may have important implications. Although the satellite collars only weighed approximately 1.6% of the body mass of an adult female caribou (80–100 kg; Couturier et al. 2009*a*), compared to approximately 0.5% for the VHF collars, this difference was apparently enough to decrease survival during a population decline. In addition to the detrimental effect of weight, the size or shape of the collar may contribute to the cumulative effect of wearing a heavier radio collar. Although older caribou may be more affected by the added weight of a collar, age estimates of collared individuals were not available. The constant annual addition of newly marked random individuals of both collar types, however, should have maintained an age structure representative of the overall population for both collar groups. Thus, survival rate of animals fitted with each type of collar should not be biased by age. Further research with known age animals, however, is needed to address this question. Since 2000, caribou in the herd are no longer equipped with heavy collars. Recent satellite collars weigh approximately 500 g, similar to the weight of the VHF collars in this study.

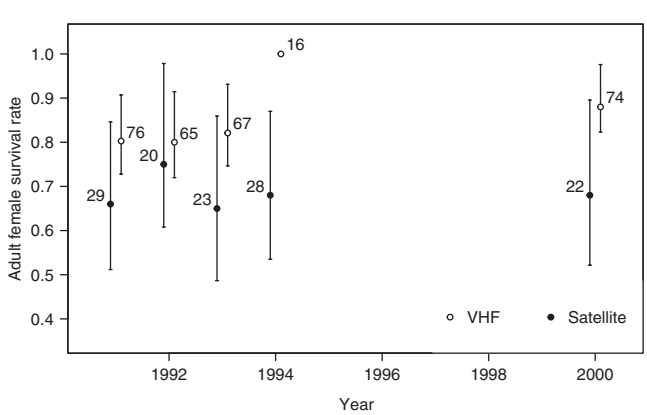

Figure 2. Annual survival rates with 95% confidence intervals of adult female caribou from the Rivière-George herd equipped with either light very high frequency (VHF) or heavy satellite collars (Argos) between 1991 and 2000. The number of individuals is indicated for each year.

MANAGEMENT IMPLICATIONS

Given the potential impact of satellite collars on individual survival, studies using heavy transmitter collars, for example, those including a video camera, should quantify the effect of these devices on survival, especially when body condition may be low. Ignoring this potential impact may bias results and lead to inappropriate management decisions. For example, an underestimate of adult female survival by only 5% (we found >15%) in migratory caribou demographic models will lead to an underestimate of projected population size by approximately 20% after only 5 years (A.L. Rasiulis, Université Laval, unpublished data). Such bias may lead to the establishment of inappropriate harvest strategies in management plans. We underscore, however, that potential effects of radio collars on individuals did not affect population demography, because a very small proportion (<0.0005%) of caribou carried radio collars during our study. Our results suggest that the interaction between collar

Table 2. Model selection results, based on Akaike's Information Criterion corrected for small sample sizes (AIC_c), for analyses examining adult female caribou survival (*S*) as a function of time and collar type in the Rivière-George herd, 1991–1994 and 2000; we considered 3 models.

Model[a]	AIC_c	ΔAIC_c	AIC_c weights	Model likelihood	No. of parameters	Deviance
S (collar)	423.3	0	0.98	1	2	194.42
S (collar × time)	431.4	8.1	0.02	0.0174	10	185.8
S (time)	439.7	16.4	0.00	0.0003	5	204.67

ΔAIC_c refers to the difference in AIC_c between the most supported and the given model.
[a] Collar = collar type, either very high frequency (VHF) or satellite; time = we considered each biological year (1 Jun to 31 May) as 1 occasion.

weight and individual body condition should also be considered.

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LITERATURE CITED

Bank, M. S., W. L. Franklin, and R. J. Sarno. 2000. Assessing the effect of radiocollars on juvenile guanaco survival. Oecologia 124:232–234.

Bergerud, A. T., S. N. Luttich, and L. Camps. 2008. The return of caribou to Ungava. McGill-Queen's University Press, Montréal, Québec, Canada.

Bleich, V. C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs 134:1–50.

Boulet, M., S. Couturier, S. D. Côté, R. D. Otto, and L. Bernatchez. 2007. Integrative use of spatial, genetic, and demographic analyses for investigating genetic connectivity between migratory, montane, and sedentary caribou herds. Molecular Ecology 16:4223–4240.

Brooks, C., C. Bonyongo, and S. Harris. 2008. Effects of global positioning system collar weight on zebra behavior and location error. Journal of Wildlife Management 72:527–534.

Choquet, R., J.-D. Lebreton, O. Gimenez, A.-M. Reboulet, and R. Pradel. 2009. U-CARE: utilities for performing goodness of fit tests and manipulating capture–recapture data. Ecography 32:1071–1074.

Couturier, S., J. Brunelle, D. Vandal, and G. St-Martin. 1990. Changes in the population dynamics of the George River caribou herd, 1976–87. Arctic 43:9–20.

Couturier, S., R. Courtois, H. Crépeau, L.-P. Rivest, and S. Luttich. 1996. Calving photocensus of the Rivière George caribou herd and comparison with an independent census. Rangifer, Special Issue 9:283–296.

Couturier, S., D. Jean, R. Otto, and S. Rivard. 2004. Démographie des troupeaux de caribous migrateurs-toundriques (*Rangifer tarandus*) au Nord-du-Québec et au Labrador. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'aménagement de la faune du Nord-du-Québec and Direction de la recherche sur la faune, Québec, Québec, Canada. [In French.]

Couturier, S., S. D. Côté, J. Huot, and R. D. Otto. 2009*a*. Body condition dynamics in a northern ungulate gaining fat in winter. Canadian Journal of Zoology 87:367–378.

Couturier, S., S. D. Côté, R. D. Otto, R. B. Weladji, and J. Huot. 2009*b*. Variation in calf body mass in migratory caribou: the role of habitat, climate, and movements. Journal of Mammalogy 90:442–452.

Couturier, S., R. D. Otto, S. D. Côté, G. Luther, and S. P. Mahoney. 2010. Body size variations in caribou ecotypes and relationships with demography. Journal of Wildlife Management 74:395–404.

Crête, M., and J. Huot. 1993. Regulation of a large herd of migratory caribou: summer nutrition affects calf growth and body reserves of dams. Canadian Journal of Zoology 71:2291–2296.

Crête, M., S. Couturier, B. J. Hearn, and T. E. Chubbs. 1996. Relative contribution of decreased productivity and survival to recent changes in the demographic trend of the Rivière George caribou herd. Rangifer, Special Issue 9:27–36.

Cypher, B. L. 1997. Effects of radiocollars on San Joaquin kit foxes. Journal of Wildlife Management 61:1412–1423.

Demers, F., J.-F. Giroux, G. Gauthier, and J. Bêty. 2003. Effects of collar-attached transmitters on behavior, pair bond and breeding success of snow geese (*Anser caerulescens atlanticus*). Wildlife Biology 9:161–170.

Des Meules, P., and J. M. Brassard. 1964. Inventaire préliminaire du Caribou (*Rangifer tarandus caribou*) d'un secteur de la Côte-Nord et du secteur Centre de l'Ungava, Printemps 1963. Pages 187–218 *in* Ministère du Tourisme, de la Chasse et de la Pêche, editor. Travaux en cours en 1963. Report no. 3, Service de la faune, Québec, Québec. [In French.]

Fuller, T. K. 1989. Population-dynamics of wolves in North-Central Minnesota. Wildlife Monographs 1–41.

Godfrey, J. D., and D. M. Bryant. 2003. Effects of radio transmitters: review of recent radio-tracking studies. Pages 83–95 *in* M. Williams, compiler. Conservation applications of measuring energy expenditure of New Zealand birds: assessing habitat quality and costs of carrying radio transmitters. Science for Conservation 214.

Haskell, S. P., and W. B. Ballard. 2007. Modeling the western Arctic caribou herd during a positive growth phase: potential effects of wolves and radiocollars. Journal of Wildlife Management 71:619–627.

Kenward, R. E. 2001. A manual for wildlife radio tagging. Academic Press, London, United Kingdom.

Legagneux, P., A.-A. Simard, G. Gauthier, and J. Bêty. 2013. Effect of neck collars on the body condition of migrating greater snow geese. Journal of Field Ornithology 84:201–209.

Massé, A., and S. D. Côté. 2013. Spatiotemporal variations in resources affect activity and movement patterns of white-tailed deer (*Odocoileus virginianus*) at high density. Canadian Journal of Zoology 91:252–263.

Swenson, J. E., K. Wallin, G. Ericsson, G. Cederlund, and F. Sandegren. 1999. Effects of ear-tagging with radio transmitters on survival of moose calves. Journal of Wildlife Management 63:354–358.

Venturato, E., P. Cavallini, P. Banti, and F. Dessì-Fulgheri. 2009. Do radio collars influence mortality and reproduction? A case with ring-necked pheasants (*Phasianus colchicus*) in Central Italy. European Journal of Wildlife Research 55:547–551.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120–139.

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Ex136

Diversity

Troubling issues at the frontier of animal tracking for conservation and management

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Developments in electronic tagging and tracking, including biotelemetry and biologging, have provided unprecedented insight into the ecology of wild animals (Cooke et al. 2004) and revealed hidden movement patterns, habitat associations, animal–environment interactions, and mortality rates for even the most cryptic of species (Hussey et al. 2015; Kays et al. 2015). Natural history, ecology (including movement ecology), conservation, and resource management have all benefitted from the application of this technology. Yet, as use of electronic tagging in research and public awareness of this technology has increased, a number of troubling and unanticipated issues have emerged. We submit that these issues need to be addressed proactively by the diverse range of people involved in animal-tracking studies—manufacturers, funders, researchers, and animal-care committees. Ignoring these issues may have serious negative consequences for individual animals, animal populations, conservation, and the future use, regulation, and public perception of electronic tracking. We recount examples of such issues in freshwater, marine, and terrestrial realms. We did not consider issues related to the effects of capturing and fitting animals with tracking devices; these are discussed at length elsewhere (e.g., Wilson & McMahon 2006; Cooke et al. 2013).

Animal tracking can reveal animal locations (sometimes in nearly real-time), and these data can help people locate, disturb, capture, harm, or kill tagged animals. In Minnesota (U.S.A.), some anglers petitioned for access to movement data derived from electronic tagging of northern pike (*Esox lucius*) to aid in fish capture (Grover 2001). The petitioners argued that the data should be publicly available because it was publicly funded, even though the study goal was not to improve recreational catch rates. Although their attempts failed, the case highlights perceptions among some stakeholders regarding their right to data. Similarly, tracking data were misused in a shark-culling program in western Australia (Meeuwig et al. 2015). Researchers tagged imperiled white sharks to study their spatial ecology and inform conservation planning. The tagged sharks were also used as warning systems at beaches. The agency that granted the research permits had access to the tagging data as part of the permitting requirements. However, these data were then used to locate and kill tagged animals to allegedly reduce human–wildlife conflict (Meeuwig et al. 2015). Similar scenarios may occur in other areas where human–wildlife conflict is related to livelihoods (e.g., predator attacks on livestock). In an era where open and transparent data are trending (Roche et al. 2015) and often a requisite of funding agencies, it is important for researchers and funding bodies to accept and acknowledge responsibility for the consequences of public access to electronic-tagging data.

Also troubling is that members of the public have acquired tracking equipment for nonresearch purposes, such as photography or wildlife viewing. The frequent exposure of animals to people can habituate them to human interaction, which at minimum alters the animal's natural behavior, thus negatively influencing research findings. Such interactions also contribute

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Ex137

to human–wildlife conflict and the potential euthanasia of an animal. After photographers used telemetry to track animals tagged by researchers and managers, Parks Canada implemented a public ban on VHF radio receivers in Banff National Park, Alberta (http://www.pc.gc.ca/apps/scond/Cond_E.asp?oID=24602&oPark=100092). Given that many researchers use social media and other forms of outreach to share information with the public and that research results are often freely available online, it is necessary to increase the curation, stewardship, and security of electronic-tagging information, including tag codes, coding schemes, and receiver–station locations and share data in forms that do not facilitate abuse. In India, attempts were made to hack GPS collar information from endangered Bengal tigers in a case of "cyber poaching" (http://www.computerworld.com/article/2475200/cybercrime-hacking/cyber-poaching-hacking-gps-collar-data-to-track-and-kill-endangered-tigers.html). The attempts were unsuccessful but revealed an unanticipated potential negative outcome of a conservation tracking program.

Nonresearchers could also purchase and deploy their own tags. Such actions are not well regulated, and most management agencies are ill-prepared to respond (Pope 2001). In some jurisdictions, scientific-collection permits and animal-care protocols may be needed (especially in developed countries), so this activity could be regulated. Many researchers may consider the costs of capturing and fitting electronic tagging equipment to animals as so prohibitive that the public could be dissuaded from exploiting the technology. However, researchers strive for statistically valid sample sizes (dozens or hundreds of tags). For the public, a single tagged animal (e.g., consider the Judas goat used for predator control [e.g., Lennox et al. 2016]) could be used to track and harm untagged animals.

We anticipate malicious attempts to derail telemetry studies or distort study findings. For example, intentional deployment of duplicate tag codes could preclude the ability of researchers to discern real detections or know what they are tracking. For some technologies (e.g., r-code acoustic telemetry), it is possible to deploy so many tags such that the receiving systems cannot decode tags, rendering a receiver disfunctional. Although telemetry terrorism may seem far-fetched, some fringe groups and industry players may have incentives for doing so. Such interference may affect data quality and put animals in jeopardy. Dynamic marine-protected areas (DMPAs) are used to protect vulnerable marine biodiversity and require diligent tracking for their implementation (Game et al. 2009). If tracking data used to outline the spatial and temporal boundaries of a DMPA are corrupted, animals could be exposed to harm (e.g., ship strikes) or exploitation at a critical period in their life history. Speculation in the media suggests that hunters may target tagged wolves from Yellowstone National Park to interfere with research (https://www.outsideonline.com/1913831/out-bounds-death-832f-yellowstones-most-famous-wolf). Moreover, although tag codes are classified, websites operated by some wolf-persecution groups provide strategies for figuring out tag codes.

A negative public perception of tagging and tracking could result in protest or cessation of research. For example, a minority of aboriginal fishers in the Fraser River watershed (Canada) regard the tagging of wild Pacific salmon (Nguyen et al. 2015) as "playing with food," which is offensive to their culture. In general, however, there is a surprisingly high level of support (or indifference to) for telemetry among these aboriginal fishers (Nguyen et al. 2012). In Pangnirtung (Canada), members of an Inuit community were sufficiently concerned that telemetry tags and receivers would scare away culturally important wildlife that research was temporarily suspended. Although the study was resumed with a positive impact for the management of the community fishery (Hussey et al. 2017), community concerns over telemetry tracking of animals are still prevalent across the Arctic and in many other indigenous communities. Some members of the community believe that acoustic transmitters would allow marine mammals to find and consume tagged animals (Cunningham et al. 2014) or contribute to noise pollution and disrupt natural behavior of marine wildlife (Erbe et al. 2016). In Australia wildlife managers have speculated that acoustic tags on sharks could provide an early warning of predation risk to marine mammals. Sharks might then feed on alternative prey, including people (http://www.perthnow.com.au/news/western-australia/wa-shark-study-questions-affect-of-tagging-on-animals-feeding-ability/news-story/535c6d51fa06b293d0addb17cd7d9c27). In the Bahamas, divers are attempting to remove satellite tags from sharks, especially when biofouling organisms are attached (Hammerschlag et al. 2014). In the United States, visitors to national parks have raised concerns about tagged wildlife detracting from the "wilderness" experience (Mech & Barber 2002). Wildlife photographers often object to any form of external tagging (Hammerschlag et al. 2014). It is possible, however, as publics become more accustomed to tagging studies and their value that norms and thus acceptance of tagging may change.

At present, researchers have little guidance about how to evaluate and respond to these perceptions and criticisms from stakeholders. In the worst-case scenario, fear of criticism means important science remains undone or proceeds with less-than-ideal tools or research design (Frickel et al. 2010). To counter these issues, we argue that greater research on the human dimensions of animal tracking is needed, including research on public perceptions and attitudes toward research needs, animal welfare, and data stewardship. A social science approach could be used to identify areas of accommodation and

compromise among researchers and interested parties (Hess 2015). Given the regional, ecological, and cultural variability across research settings, case studies with qualitative methods (e.g., interviews, participant observation) are essential for uncovering and addressing multiple stakeholder perspectives and concerns.

We identified issues that must be considered if animal-tracking science is to continue to contribute meaningfully to animal conservation and management (Cooke 2008) and devised suggestions that may help facilitate this: cocreation of the research agenda to obtain partner buy-in; include stakeholders in the research (e.g., animal capture, tagging, and tracking); share information on the technology through workshops; provide project updates to partners and stakeholders via avenues that reach different segments of the population; create a data-sharing policy that clearly articulates who has access to what type of data and how it can be used; ensure data are secure; encourage the telemetry industry to help prevent instances of sabotage or exploitation; encourage regulators to develop clear and enforceable policies and regulations that limit the ability of the public to use telemetry tools for activities that are inconsistent with the mission of management agencies; listen to and consider stakeholder concerns; create opportunities for stakeholders (e.g., telemetry industry, regulators, and researchers) to come together to discuss issues of mutual concern; encourage telemetry practitioners to work closely with human dimensions researchers to identify stakeholder concerns and barriers to use or application of telemetry; and learn from and share successes and mistakes.

Failure to adopt more proactive thinking about the unintended consequences of electronic tagging could lead to malicious exploitation and disturbance of the very organisms researchers hope to understand and conserve. We suggest that electronic tracking manufacturers, researchers, managers, and stakeholders have joint discussions about their responsibilities so that use of tagging equipment and data is consistent with the foundations of animal conservation and management. The onus is on researchers to take a leadership role in this effort to illuminate the tenebrous frontier of animal tracking and to engage with other partners in a proactive manner.

Acknowledgments

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Literature Cited

Cooke SJ. 2008. Biotelemetry and biologging in endangered species research and animal conservation: relevant to regional, national and IUCN Red List threat assessments. Endangered Species Research **4:**165–185.

Cooke SJ, Hinch SG, Wikelski M, Andrews RD, Wolcott TG, Butler PJ. 2004. Biotelemetry: a mechanistic approach to ecology. Trends in Ecology & Evolution **19:**334–343.

Cooke SJ, Nguyen VM, Murchie KJ, Thiem JD, Donaldson MR, Hinch SG, Brown RS, Fisk A. 2013. To tag or not to tag: animal welfare, conservation and stakeholder considerations in fish tracking studies that use electronic tags. Journal of International Wildlife Law & Policy **16:**352–374.

Cunningham KA, Hayes SA, Rub AMW, Reichmuth C. 2014. Auditory detection of ultrasonic coded transmitters by seals and sea lions. Journal of the Acoustical Society of America **135:**1978–1985.

Erbe C, Reichmuth C, Cunningham K, Lucke K, Dooling R. 2016. Communication masking in marine mammals: a review and research strategy. Marine Pollution Bulletin **103:**15–38.

Frickel S, Gibbon S, Howard J, Kempner J, Ottinger G, Hess DJ. 2010. Undone science: charting social movement and civil society challenges to research agenda setting. Science, Technology and Human Values **35:**444–473.

Game ET, Bode M, McDonald- Madden E, Grantham HS, Possingham HP. 2009. Dynamic marine protected areas can improve the resilience of coral reef systems. Ecology Letters **12:**1336–1346.

Grover JZ. 2001. One cast beyond - the public's right to know - radiotelemetry. In-Fisherman **26:**18–22.

Hammerschlag N, Cooke SJ, Gallagher AJ, Godley BJ. 2014. Considering the fate of electronic tags: user responsibility and interactions with stakeholders and other scientists when encountering tagged aquatic animals. Methods in Ecology and Evolution **11:**1147–1153.

Hess DJ. 2015. Publics as threats? Integrating science and technology studies and social movement studies. Science as Culture **24:**69–82.

Hussey NE, et al. 2015. Aquatic animal telemetry: a panoramic window into the underwater world. Science **348**. DOI: 10.1126/science.125564.

Hussey NE, et al. 2017. Movements of a deep-water fish: establishing marine fisheries management boundaries in coastal Arctic fisheries. Ecological Applications. DOI: 10.1002/eap.1485.

Kays R, Crofoot MC, Jetz W, Wikelski M. 2015. Terrestrial animal tracking as an eye on life and planet. Science **348**. DOI: 10.1126/science.aaa2478.

Lennox RJ, Blouin-Demers G, Rous AM, Cooke SJ. 2016. Tracking invasive animals with electronic tags to assess risks and develop management strategies. Biological Invasions **18:**1219–1233.

Mech LD, Barber SM. 2002. A critique of wildlife radio-tracking and its use in national parks. Technical report, U.S. National Park Service, Biological Resources Management Division, Fort Collins, Colorado.

Meeuwig JJ, Harcourt RG, Whoriskey FG. 2015. When science places threatened species at risk. Conservation Letters **8:**151–152.

Nguyen VM, Raby GD, Hinch SG, Cooke SJ. 2012. Aboriginal fisher perspectives on use of telemetry technology to study adult Pacific salmon. Knowledge and Management of Aquatic Ecosystems **406:**8.

Pope KL. 2001. Anglers tagging and marking fish: provincial and state fishery agency views. Fisheries **26:**23–27.

Wilson RP, McMahon CR. 2006. Measuring devices on wild animals: what constitutes acceptable practice? Frontiers in Ecology and the Environment **4:**147–154.

Olympic National Park
Washington

Ex139

US Department of the Interior
National Park Service

Draft Mountain Goat Management Plan / Environmental Impact Statement

2017

UNITED STATES DEPARTMENT OF THE INTERIOR – NATIONAL PARK SERVICE

MOUNTAIN GOAT MANAGEMENT PLAN / ENVIRONMENTAL IMPACT STATEMENT

Lead Agency: National Park Service, US Department of the Interior
Cooperating Agencies: USDA Forest Service, Washington Department of Fish and Wildlife

This *Draft Mountain Goat Management Plan / Environmental Impact Statement* (plan/EIS) for Olympic National Park (the park) evaluates the impacts of a range of alternatives for managing exotic mountain goats on the Olympic Peninsula in a manner that reduces impacts on park resources while reducing potential public safety issues associated with the presence of mountain goats. Upon conclusion of the plan/EIS and decision-making process, the alternative selected for implementation will become the mountain goat management plan, which will specifically address the issue of mountain goats within the park and in areas of the adjacent Olympic National Forest. The National Park Service (NPS) (at Olympic National Park) worked in cooperation with the Washington Department of Fish and Wildlife (WDFW), and the United States Department of Agriculture (USDA) Forest Service (Olympic, Mt. Baker-Snoqualmie, and Okanogan-Wenatchee National Forests) to prepare this plan/EIS.

This plan/EIS evaluates the impacts of the no-action alternative (alternative A) and three action alternatives (alternatives B, C, and D). Alternative A would involve full implementation of the 2011 *Mountain Goat Action Plan* including management of individual mountain goats in visitor use areas according to a continuum of mountain goat-human interactions. Specific management could range from hazing to lethal removal of hazardous mountain goats. Alternative B would focus exclusively on the capture of mountain goats within the park and on adjacent Olympic National Forest lands followed by transfer of ownership to the WDFW and release on National Forest System (NFS) lands at Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forests (North Cascades national forests). Translocation would be conducted at the discretion of WDFW to NFS lands in the North Cascades where mountain goats are native and supplementation of the existing population would further mountain goat conservation efforts (e.g., improve genetic diversity and enhance demographic vigor to depleted populations). Alternative C would use lethal removal to significantly reduce or eliminate mountain goats from the park and adjacent Olympic National Forest lands. Alternative D (preferred alternative) would use a combination of capture and translocation and lethal removal to reduce or eliminate mountain goats from the park and adjacent Olympic National Forest lands. Capture and translocation would take place wherever safe and feasible. Once a point of diminishing returns for capture operations is reached, management would continue using lethal removal activities. This plan/EIS analyzes impacts of these alternatives in detail for both the Olympic Peninsula area and NFS lands within the two national forest units located in the North Cascades Mountains that could receive mountain goats.

The review period for this plan/EIS will end 60 days after publication of the US Environmental Protection Agency Notice of Availability in the Federal Register. During the 60-day comment period, comments will be accepted electronically through the NPS Planning, Environment, and Public Comment (PEPC) website at http://parkplanning.nps.gov/olymgoat and in hard copy format delivered by the US Postal Service or other mail delivery service or hand-delivered to the address below. Written comments will also be accepted during public meetings on the plan/EIS. Comments will not be accepted by fax, email, or in any format other than those specified above. Bulk comments in any format (hard copy or electronic) submitted on behalf of others will not be accepted.

For further information, visit http://parkplanning.nps.gov/olymgoat or contact:

Olympic National Park
Mountain Goat Management Plan/EIS
600 East Park Avenue
Port Angeles, WA 98362-6798

Decision-Making Process

After reviewing and analyzing comments on the draft plan/EIS, the NPS will prepare a final plan/EIS and then issue a Record of Decision (ROD) that selects an alternative for implementation. In the event that an alternative is selected that involves removing goats (either via live capture or lethal means) from Olympic National Forest and/or translocating mountain goats to North Cascades national forests, the USDA Forest Service would have to authorize these actions on NFS lands, which could include issuing temporary closures around staging areas, capture sites, and lethal removal areas as needed, per 36 CFR 261 Subpart B, “Prohibitions in Areas Designated by Order.” Therefore,

the responsible officials for the USDA Forest Service will decide through their own records of decision whether to authorize the following actions on their respective forests:

- The responsible official for the Olympic National Forest will decide whether to authorize the NPS to use helicopters to remove mountain goats from wilderness areas in the Olympic National Forest and transport them to staging areas; and whether to authorize temporary closures associated with the NPS capture operations, and at staging areas used by the WDFW.
- The responsible officials for the Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forests will decide whether to authorize the WDFW to establish temporary closures for staging and release sites and to release mountain goats with helicopters in the wilderness areas on their respective forests.

USDA Forest Service Objection Process

Actions proposed on NFS lands under this plan/EIS constitute activities that implement land management plans for the USDA Forest Service and are subject to the agency's pre-decisional objection process at 36 CFR 218 Subparts A and B. The objection process occurs prior to the Forest Service making a final decision (signing a ROD) and will include circulation of the final EIS and draft decision document (ROD). Legal notices to initiate the objection period will be published in the newspapers of record for the three national forests following publication of the Notice of Availability of the final EIS; objections will be submitted to the respective forests at that time.

The opportunity to provide comments to establish eligibility to object under 36 CFR 218 ends when the public comment period on this draft plan/EIS ends, as discussed above. Only those individuals who submit timely and specific written comments (36 CFR 218.2) regarding the proposed project or activity during the public comment period are eligible to file an objection (36 CFR 218.24(b)(6)). It is the responsibility of all individuals and organizations to ensure that their comments are received in a timely manner. For issues to be raised in objections, they must be based on previously submitted, specific, written comments regarding the proposed project or activity and must be attributed to the objector. For objection eligibility, each individual or representative from each entity submitting timely and specific written comments regarding the proposed project or activity must either sign the comments or verify identity upon request (36 CFR 218.24(b)(8)).

Ex142

National Park Service
US Department of the Interior

Olympic National Park
Washington

DRAFT MOUNTAIN GOAT MANAGEMENT PLAN / ENVIRONMENTAL IMPACT STATEMENT

2017

Ex143

Executive Summary

EXECUTIVE SUMMARY

This *Mountain Goat Management Plan / Environmental Impact Statement* (plan/EIS) analyzes the impacts that could result from a continuation of current management of an exotic mountain goat population on the Olympic Peninsula (the no-action alternative) by the National Park Service (NPS) and United States Department of Agriculture (USDA) Forest Service, as well as the impacts that could result from three action alternatives. The plan/EIS describes the reasons the NPS is taking action at this time and evaluates a range of alternatives for the management of exotic mountain goats on the Olympic Peninsula, as well as the associated actions proposed by the Washington Department of Fish & Wildlife (WDFW) to translocate mountain goats to National Forest System (NFS) lands in the North Cascade Mountains should an alternative involving translocation be implemented. Two separate project areas are being evaluated in this plan/EIS: (1) areas of Olympic National Park and Olympic National Forest, where exotic mountain goats could be reduced, which comprise the area referred to as the Olympic Peninsula; and (2) areas in the Mt. Baker-Snoqualmie National Forest and Okanogan-Wenatchee National Forest where mountain goats could be translocated, which comprise the area referred to as the North Cascades national forests.

PURPOSE OF TAKING ACTION

The purpose in taking action is to allow the NPS to reduce or eliminate impacts on park resources from exotic mountain goats, while reducing potential public safety issues associated with the presence of mountain goats in the park.

NEED FOR ACTION

Mountain goats are not native to the Olympic Peninsula. They were introduced to the Olympic Mountains prior to the establishment of the national park, and have since colonized the entire range, with the majority of the population residing within the park (Noss et al. 2000). The original need to manage this exotic species was an ecological concern related to the impacts that mountain goats impose on natural resources at the park, particularly sensitive vegetation communities (NPS 1995; Houston, Schreiner, and Moorhead 1994). New concerns were raised in 2010 when a visitor was fatally gored by a mountain goat while hiking on a park trail. Mountain goats have a high affinity for salts and natural sources of salt occur within their native range. There are no natural sources of salt in the Olympic Mountains, and mountain goats have learned to seek salts from humans. In areas with high levels of visitor use within the park and national forest, mountain goats have become conditioned to the extent that they are a nuisance and may be hazardous to visitors. The Olympic National Park *Mountain Goat Action Plan*, included as appendix A, addresses mountain goat behavior and seeks to minimize the potential for hazardous mountain goat-human encounters. This action plan focuses on the management of individual mountain goats that have been identified as potentially hazardous (appendix A). Additional planning and compliance is needed to address overall management of the mountain goat population on the Olympic Peninsula.

There is also a need to remove mountain goats from adjacent lands in the Olympic National Forest because mountain goats in these areas are part of a population that moves between the Olympic National Forest and Olympic National Park. As in the national park, mountain goats cause soil erosion, impact native plant communities, and occupy habitat for native species in the national forest. As a result of these concerns, a plan/EIS is needed to address the impacts of exotic mountain goats in the park and in the adjacent Olympic National Forest, which would include the interference with natural processes, native species, natural habitats, and impacts on visitor use and safety.

OBJECTIVES IN TAKING ACTION

Objectives are "more specific statements of purpose that provide additional bases for comparing the effectiveness of alternatives in achieving the desired outcomes of the action" and represent a refinement of the purpose of this plan/EIS. All alternatives selected for detailed analysis must meet all objectives to a large degree and resolve the purpose of and need for action. The following objectives relate to the management of mountain goats on the Olympic Peninsula:

- Develop a scientifically based method for the management of exotic mountain goat populations in an extensive mountainous wilderness area.
- Reduce or eliminate impacts on sensitive environments and unique natural resources from mountain goats in the park and in Olympic National Forest.
- Reduce or eliminate the potential for visitor safety issues associated with mountain goats in the park.
- Further public understanding of the Olympic high elevation ecosystems and native species and the ecology and conservation of mountain goats in their native range.
- Protect the International Biosphere Reserve and World Heritage Site designations of Olympic National Park and preserve the integrity of these designations.
- Protect the wilderness character of designated park wilderness and wilderness in Olympic National Forest.
- Work cooperatively with co-managers of mountain goats or habitats in Washington State (USDA Forest Service, WDFW, and tribes).
- Support the wildlife management objectives of cooperating agencies and tribes, to the extent practicable, with respect to mountain goats.
- Provide opportunities to reestablish or augment sustainable native mountain goat populations in suitable mountain goat habitat on NFS lands in the North Cascades national forests.

ISSUES RELATING TO THE PROJECT

Issues associated with mountain goats on the Olympic Peninsula are primarily related to visitor safety and the unique vegetation of the Olympic Mountains. Because many of the areas inhabited by mountain goats are popular destinations for park and national forest visitors, both in the frontcountry (e.g., Hurricane Ridge) and backcountry (e.g., Glacier Meadows), there is high potential for mountain goat-human interactions. Most notable are areas where mountain goats are habituated to human presence and have become conditioned to seeking salts and other minerals from humans. Mountain goats can be a nuisance along trails and around wilderness campsites where they persistently seek salt and minerals from human urine, packs, and sweat on clothing. They often paw and dig areas on the ground where hikers have urinated or disposed of cooking wastewater. The nature of mountain goat-human interactions can vary widely, such as humans observing mountain goats from several hundred meters away across a ridge, mountain goats approaching visitors, hazing events and hazardous interactions such as the October 2010 fatality.

Through herbivory and wallowing behaviors, mountain goats have directly and indirectly affected the vegetation in the Olympic Mountains. Changes in the relative abundance of plant species have been observed as a result of mountain goat herbivory; this has altered competitive interactions among plant species. Wallowing by mountain goats has impacted plant species as a result of soil disturbance and

subsequent creation of mineral substrates for colonization by disturbance-oriented plant species. As the mountain goat population on the Olympic Peninsula increased prior to live capture operations in the 1980s, changes in vegetation were substantial, and the status of rare plant populations became a concern.

ISSUES AND IMPACT TOPICS

The issues described above form the basis for identifying impact topics that can be used to organize the analysis of effects of mountain goats and the management actions being considered. Table ES-1 details the impact topics that are discussed and analyzed in the plan/EIS.

TABLE ES-1. SUMMARY OF IMPACT TOPICS

Impact Topic	Reason for Analysis
Mountain Goats	On the Olympic Peninsula, any proposed management of mountain goats in this plan/EIS would have direct impacts on mountain goats. For the North Cascades national forests, impacts on mountain goats are analyzed as part of the wildlife topic. Any proposed management activities would have only beneficial impacts on mountain goats.
Wilderness Character	The congressionally designated Daniel J. Evans Wilderness was established in 1988 and comprises about 95% of the park. Adjacent to the park on Olympic National Forest are five wilderness areas. The NPS and USDA Forest Service are responsible for preserving wilderness character, defined by the 1964 *Wilderness Act* as "…the combination of biophysical, experiential, and symbolic ideals that distinguish wilderness from other lands." On the Olympic Peninsula, the presence of exotic mountain goats in wilderness, and their impacts on native species from grazing and wallowing results in adverse impacts on the natural quality of designated wilderness in Olympic National Park and Olympic National Forest. Additionally, any proposed management activities, such as the use of aircraft and firearms to remove mountain goats, could result in impacts on the untrammeled, undeveloped, and opportunities for solitude or primitive and unconfined recreational qualities of wilderness character. For the North Cascades national forests, impacts on wilderness character are also analyzed because proposed management activities, in particular the use of aircraft to translocate mountain goats, could impact the untrammeled and undeveloped qualities of wilderness character.
Wildlife and Wildlife Habitat, Including Special-Status Species	The Olympic Peninsula is home to a variety of native fish, birds, and other wildlife throughout its diverse habitats, including several endemic species due to its isolated biogeographic history. Similarly, the North Cascades national forests are home to an abundant and diverse assemblage of native fauna. On the Olympic Peninsula, mountain goats represent a source of competition that impacts certain native wildlife species and their habitat. Wildlife could be impacted by mountain goat management activities including hazing, aversive conditioning, capture, and lethal removal actions, the use of staging areas and associated site preparation, and aircraft or vehicular traffic. For the North Cascades national forests, impacts on wildlife are also analyzed because proposed management activities to translocate mountain goats would have the potential to impact wildlife, including sensitive and management indicator species.

Impact Topic	Reason for Analysis
Vegetation, Including Special-Status Plant Species	Mountain goats occupy high-elevation alpine and subalpine vegetation communities at or above treeline. The summer range of mountain goats is composed primarily of subalpine meadows, fragile alpine herbaceous communities, and sparsely vegetated scree and rock slopes. Mountain goats damage vegetation and destabilize soils through herbivory, trampling, and wallowing behaviors. On the Olympic Peninsula, the removal of mountain goats would reduce adverse impacts on native vegetation. For the North Cascades national forests, impacts on vegetation are also analyzed because translocation activities could result in the removal of vegetation at staging areas and the disturbance of vegetation at mountain goat release sites.
Threatened or Endangered Species	Several species that are federally listed under the *Endangered Species Act* (ESA), or their designated critical habitat, could be impacted by proposed mountain goat management activities, such as the use of aircraft or firearms. On the Olympic Peninsula, two species that could be impacted are the northern spotted owl and marbled murrelet, both listed as threatened. For the North Cascades national forests, impacts on threatened or endangered species are also analyzed because proposed management activities associated with staging areas and release sites, such as the use of aircraft, could impact six threatened or endangered species. These species includes the northern spotted owl (threatened), marbled murrelet (threatened), grizzly bear (threatened), Canada lynx (threatened), gray wolf (endangered), and wolverine (candidate).
Acoustic Environment	The natural soundscape in the Olympic Mountains is a special resource to park and national forest visitors. The park is one of the best examples of a natural soundscape found anywhere in the national park system and includes natural sounds that are part of the biological or physical resources of the park. On the Olympic Peninsula, any proposed mountain goat management activities, specifically the use of aircraft and firearms, would result in noise that could in turn impact visitors, wildlife, and wilderness character within the park and national forest. For the North Cascades national forests, although the proposed translocation of mountain goats would have similar impacts on the acoustic environment, those impacts are addressed within the context of the analysis of impacts on wildlife, wilderness character, and visitor use and experience.
Soils	Mountain goats cause soil disturbance and erosion by wallowing, trailing, and trampling. On the Olympic Peninsula, alpine and subalpine soils tend to be shallow, poorly developed, and fragile, making them sensitive to disturbance. Any proposed management that would reduce or eliminate mountain goats from areas with sensitive soils would result in beneficial impacts on soils. For the North Cascades national forests, impacts on soils are not analyzed because the translocation of mountain goats to their native range will not contribute adverse impacts on soils.
Archeological Resources	Mountain goat wallowing behavior has the potential to degrade or destroy archeological resources in the park and in national forests. On the Olympic Peninsula, only about one percent of the park has been systematically inventoried for archeological resources, although results from this work indicate that there are thousands of archeological sites within the project area. Mountain goat wallowing has had an adverse effect on both documented and undocumented archeological resources in the Olympic Mountains. For the North Cascades national forests, impacts on archeological resources are not analyzed because there are no known cultural, historic, or archeological resources within the project area that would be disturbed as a result of actions related to mountain goat restoration.

Impact Topic	Reason for Analysis
Visitor Use and Experience	Potential activities associated with the management of mountain goats, specifically the use of aircraft and firearms, would generate intermittent loud noises that could disrupt visitor activities and enjoyment of natural soundscapes. Proposed management activities could result in the temporary closure of areas. On the Olympic Peninsula, visitors to the park and adjacent national forest have indicated that the presence of habituated mountain goats deters them from hiking on trails, while other visitors have indicated that the presence of mountain goats in the Olympic Mountains enhances the visitor experience. The reduction or elimination of mountain goats could reduce recreational mountain goat hunting opportunities in the national forest. For the North Cascades national forests, impacts on visitor use and experience are also analyzed because future visitors would observe mountain goats more frequently and hunting opportunity would be increased due to increased mountain goat populations.
Visitor and Employee and Safety	The presence of mountain goats in the park and in the national forest can present threats to visitor and employee safety. On the Olympic Peninsula, many of the areas that mountain goats inhabit are hiking and camping destinations for visitors and thus, there is potential for mountain goat-human interactions. There have been attacks by mountain goats, although attacks are rare. Interactions between mountain goats and humans can range from neutral, to nuisance, to hazardous. For the North Cascades national forests, impacts on visitor and employee safety are also analyzed because translocated mountain goats would inhabit areas that are also popular destinations for national forest visitors, thus increasing the potential for interactions between mountain goats and humans.

ALTERNATIVES CONSIDERED

The alternatives considered include a required "no-action" alternative and three action alternatives that were developed by the interagency planning team, which included federal and state agencies, and through feedback received during the public scoping process. The three action alternatives analyzed in this plan/EIS meet, to a large degree, the management objectives and address the purpose of and need for action. The alternatives are briefly described below.

Alternative A: No Action

Under the no-action alternative, options for the management of mountain goats on the Olympic Peninsula would be limited to those actions outlined in the park's *Mountain Goat Action Plan* (appendix A), which are focused on preventing unacceptable mountain goat behavior. Management would be set up according to a continuum of mountain goat-human interactions and the appropriate park response to each. Common management activities under alternative A would include foot patrols, evaluation of mountain goat-human interactions, possible area closures, and use of nuisance animal control tools, including hazing and up to lethal removal. The frequency of management activities under alternative A would vary depending on the level of mountain goat-human interaction observed at a given time. The long-term duration of management activities would continue indefinitely, and may increase in frequency and intensity, because the mountain goat population within the park and national forest would continue to increase.

Elements Common to All Action Alternatives (Alternatives B, C, and D)

The action alternatives described below (alternatives B, C, and D) include several management elements that would be used to reach the goal of substantially reducing or eliminating mountain goats on the

Olympic Peninsula. Some elements are common to all three action alternatives and include the use of helicopters for access and transporting mountain goats, area closures for safety, and various interpretive tools to provide information and education to the public under an enhanced public outreach program. These are described in more detail below.

Interpretive Tools. Under all action alternatives, park and national forest staff would provide information and educational opportunities to the public through interpretive programs and visitor interactions regarding the management of mountain goats on the Olympic Peninsula. Public outreach would be enhanced to increase the public's awareness of the current mountain goat situation, and detailed information would be provided regarding impending mountain goat management activities or areas of potential closures in the park and national forest.

Helicopters. Under all action alternatives, helicopter operations would take place during two separate 2-week management periods in a given year: once in mid- to late July, and the second in late August to mid-September. Helicopters would be used for both capture and translocation, and lethal removal, operating up to a maximum of 12 days during each period, and a maximum of 8 hours per day. Flight paths would be determined by weather (clouds and winds), but in general, helicopters would take the most efficient routes between staging areas and mountain goat habitat.

Area Closures. Under all action alternatives, there would potentially be temporary area closures within both the park and national forest during management activities, which include capture and translocation and lethal removal operations. In general, trails and campgrounds would remain open to the public in both backcountry and frontcountry areas as long as management personnel determine it is safe to do so. As applicable for each alternative, closures would include areas near ongoing management activities and immediately surrounding staging areas. There would be no parkwide or forest-wide closures, and no area closures would be permanent.

Staging Areas. Under all action alternatives, staging areas would be required for mobilization of staff and equipment during management activities. The use of helicopters to access remote areas of the park and national forest would require a safe and accessible space for taking off, landing, and refueling. Five staging areas have been identified, with three sites in the northern part of the park and two sites on Olympic National Forest lands, beyond the southeastern boundary of the park.

Baiting. It is likely that salt blocks could be placed in remote areas of the park and national forest to attract mountain goats to suitable areas for carrying out management activities. Baiting areas would either be located away from public use areas or closed to public access to minimize mountain goat-human conflicts.

Lethal Removal. Under all action alternatives, there would be the potential for lethal removal of mountain goats. The timing and duration of lethal removal would vary dramatically for each action alternative. Lethal removal would be used as the only approach for mountain goat management under alternative C, but would be a secondary management approach under alternative D. Shotguns and high-powered rifles would be used for lethal removal actions. Ammunition would be non-toxic. Personnel involved, which could include NPS or other federal personnel, state personnel, or trained volunteers, would have the appropriate skills and proficiencies in the use of firearms to maximize public safety, including experience in the use of firearms for the removal of wildlife. Any lethal action would be completed as humanely as possible. Under all alternatives, mountain goats that sustain life-threatening injury during management activities would be dispatched as quickly as possible to minimize suffering.

Animal Welfare Tools and Considerations. The NPS would strive to use the most humane techniques possible for animal capture, transport, and handling to maximize individual animal welfare and health.

Translocation activities would be conducted in accordance with established WDFW translocation protocols; and when conducting lethal removal using firearms, consideration would be given to the choice of firearm and shot placement to ensure the humaneness of the action.

Research and Monitoring. Under all alternatives, research and monitoring activities would take place opportunistically based on available funding. Possible research and monitoring efforts could involve management efficacy analysis and mountain goat population studies. Mountain goat population surveys would be conducted in a manner similar to the no-action alternative.

Carcass Handling and Disposal. Under all action alternatives, mountain goat carcasses resulting from management activities could be left in the field, but relocated away from trails, campsites, or where visible from areas with high visitor use. If feasible, mountain goats that have been killed could be donated for processing and human consumption. Carcasses could be provided to the Skokomish Indian Tribe or other willing recipients who may wish to obtain hides and horns.

Alternative B: Capture and Translocation

Under alternative B, mountain goats would be captured within the park and in the adjacent Olympic National Forest, followed by transfer of ownership to WDFW and translocation to areas of the Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forests (North Cascades national forests), where mountain goats are native and augmentation of the existing populations would further mountain goat conservation. Mountain goats would be captured over the course of up to 3 to 5 years, with most activity in years 1 and 2. Capture operations would occur during two 2-week management periods per year: once in mid- to late July, and once in late August to mid-September. Captured mountain goats would be transported by helicopter to one of five staging areas for transfer to WDFW. WDFW would then translocate mountain goats in crates to the North Cascades national forests.

Capture and translocation under alternative B would most likely involve approximately 50% of the 725 mountain goats projected to occupy the Olympic Mountains by 2018. However, the number of mountain goats captured and translocated could be more or less, depending on capture success and the ability of WDFW to receive and translocate mountain goats. Following the 5-year initial management period, maintenance activities would consist of periodic capture and translocation efforts focused in areas of high visitor use, or areas experiencing high levels of resource damage, in order to reduce impacts by the remnant mountain goat population and to keep the mountain goat population at a reduced level.

Alternative C: Lethal Removal

Under alternative C, lethal removal using shotguns or high-powered rifles would be used to reduce or eliminate mountain goats from the park and adjacent Olympic National Forest. Mountain goats would not be translocated under this alternative. Specific management activities for the lethal removal of mountain goats would include helicopter- and ground-based use of firearms. Park staff and other approved personnel, including trained volunteers, would access areas on foot that are accessible, but in more remote areas, a helicopter would be used for lethal removal activities. Following lethal removal, mountain goat carcasses would remain on the landscape but would be moved from areas of high visitor use.

Initial lethal removal actions would involve removing as many mountain goats as possible from the Olympic Peninsula. It is expected that approximately 90% of the projected 2018 mountain goat population, or approximately 625 to 675 mountain goats, could be removed during the initial management phase and whose carcasses would be left on the landscape. Maintenance activities under alternative C would involve opportunistic ground- and helicopter-based lethal removal throughout the summer and fall seasons as personnel, funding, weather, and accessibility of targeted mountain goats allow. Maintenance

activities would be prioritized in proximity to areas of high visitor use and areas experiencing high levels of resource damage.

The timing and duration of the initial management phase under alternative C would be 3 to 5 years, with most activity occurring in years 1 to 3. Lethal removals would be conducted only if necessary in years 4 and 5. Helicopter-based operations would occur within the same 2-week management periods as described for alternative B, and ground-based lethal removal would take place opportunistically at any time during the year as needed.

Alternative D: Combination of Capture and Translocation and Lethal Removal (Preferred Alternative)

Under alternative D, initial management would involve the capture and translocation of as many mountain goats as possible, similar to alternative B, followed by a switch to lethal removal, similar to alternative C. Initial management activities under alternative D could last 3 to 5 years, with most of the activity in years 1 to 4. Some lethal removal could occur as early as the second capture bout in year 1, but only for those mountain goats that are determined to be uncatchable. The timing and duration of capture and translocation operations within a year would be the same 2-week management periods as described for alternative B. Translocation operations under alternative D would be identical to those described for alternative B.

Similar to alternative C, it is anticipated that initial management under alternative D would remove approximately 90% of the mountain goat population, or approximately 625 to 675 mountain goats, and carcasses of those mountain goats that are lethally removed would be left on the landscape. It is anticipated that the success rate for capturing mountain goats would diminish over time and management would likely switch to almost exclusively lethal removal during year 3 or year 4 of the initial management, but could begin as early as year 2. By year 5, most mountain goats encountered would be lethally removed.

ENVIRONMENTAL CONSEQUENCES

This document evaluates the impacts that would result from the proposed mountain goat management alternatives. The analysis used methods and assumptions that follow Council on Environmental Quality (CEQ) and US Department of the Interior regulations and guidance found in the 2015 NPS National Environmental Policy Act (NEPA) Handbook. A summary of the environmental consequences is provided below for each alternative, and a full analysis for each impact topic is evaluated in chapter 4.

Alternative A: No Action

Olympic Peninsula

Impacts under the no-action alternative would occur from potential management activities and from the continued presence of exotic mountain goats on the Olympic Peninsula. The management activities under this alternative would seek to address undesirable mountain goat-human interactions and thus, would occur infrequently and be of short duration, over an indefinite period. Direct, short-term, adverse impacts to wilderness character; wildlife and wildlife habitat, including special-status species; threatened or endangered species; acoustic environment; and visitor use and experience could result from hazing activities and associated human presence, although greater impacts would occur on the rare occasion that required mountain goat capture or lethal removal. However, impacts would be minimal for most affected resources because any disturbance or changes would be of limited duration and intensity. Under the no-

action alternative, impacts would occur over an indefinite period from the continued presence and growth of the mountain goat population, including from mountain goat-human interactions and due to mountain goat behaviors such as browsing, grazing, wallowing, trailing, and trampling. Although there would be some beneficial impacts on visitor use and experience from continued wildlife viewing opportunity, the increasing presence of mountain goats would continue to threaten visitor safety. In comparison to the action alternatives, the continued habitat degradation, alteration of forage resources, and soil disturbance due to the no-action alternative would have greater long-term, adverse impacts on the natural quality of wilderness character; wildlife and wildlife habitat, including special-status species; threatened or endangered species; soils; and archeological resources. The continued abundance of mountain goats would also likely have substantial adverse impacts on vegetation, including special-status plant species, through herbivory, trampling, and soil disturbance, which affects the relative abundance of plant species, alters interspecific competition, and degrades habitat for sensitive subalpine and alpine plant communities. As the mountain goat population continues to grow under the no-action alternative, these adverse impacts would expand geographically and in intensity.

North Cascades National Forests

Alternative A would have no impacts in the North Cascades national forests.

Alternative B: Capture and Translocation

Olympic Peninsula

During the first 3 to 5 years of initial management under alternative B, temporary adverse impacts would affect most resources analyzed due to capture and translocation activities, and associated preparation and use of staging areas. These impacts would occur intermittently each year during the two 2-week management periods. Management activities, including the use of aircraft, vehicles, and other equipment would produce direct, adverse impacts on the acoustic environment. In turn, the noise associated with these activities would have direct, periodic adverse impacts on the following resources: mountain goats; wilderness character; wildlife and wildlife habitat, including special-status species; threatened or endangered species; visitor use and experience; and visitor and employee safety. Increased human presence under alternative B, as well as handling of mountain goats, would further disturb mountain goats; wilderness character; wildlife and wildlife habitat, including special-status species; vegetation, including special-status plant species; and threatened or endangered species. Restrictions on public access or area closures during mountain goat capture and translocation activities, although temporary and localized, would adversely impact wilderness character and visitor use and experience. Most of these direct impacts would be temporary and intermittent, therefore the overall impact would be minimal; however, there would be substantial impacts on wilderness character from the noise associated with helicopter use at staging areas. These adverse impacts would progressively diminish in duration and intensity, as the need for management activities declines as the mountain goat population is decreased.

Maintenance activities under alternative B would have the same adverse, direct impacts as described for the initial management phase, although they would only occur periodically every few years. The capture and removal of mountain goats would have an adverse effect on the local mountain goat population because it would result in a large decrease in numbers, although mountain goats would remain in certain areas and be likely to rebound after initial management activities cease. However, assuming that maintenance activities are able to keep the mountain goat population at a lower level, alternative B would result in beneficial impacts on most resources, including substantial benefits to wildlife and wildlife habitat, including special-status species; vegetation, including special-status plant species; and soils due to reduced pressure on these resources by mountain goats. These beneficial impacts would continue for an extended duration. Adverse effects of the remaining mountain goat population from browsing, grazing,

wallowing, trailing, and trampling would continue indefinitely in certain areas of the Olympic Mountains, impacting the natural quality of wilderness character; wildlife and wildlife habitat, including special-status species; threatened or endangered species; soils; and archeological resources. Thus, the implementation of alternative B would produce fewer beneficial impacts on natural resources than alternatives C or D because those alternatives would eliminate a much larger number of mountain goats. The removal of mountain goats would have no long-term impact on the acoustic environment. Likewise, adverse impacts on visitor use and experience, and visitor and employee safety would continue under alternative B due to potential human interactions with any remaining mountain goats. For the visitor whose experience is enhanced by the ability to view mountain goats, minimal adverse impacts would result because although the mountain goat population would be reduced, there would still be a population present to view.

North Cascades National Forests

The translocation of mountain goats to the North Cascades national forests would have short-term, direct adverse impacts on all resources analyzed, although long-term, beneficial impacts are believed to outweigh those more immediate impacts. As on the Olympic Peninsula, the primary source of direct impacts would be from helicopter use, human presence, and other activities associated with preparing and using staging areas and release sites. There would be short-term, adverse impacts on the untrammeled and undeveloped qualities of wilderness character, as well as opportunities for solitude within wilderness areas. Impacts on wildlife, including special-status species, would include their displacement or disturbance, which could adversely affect the survival of some individuals; however, these effects would be limited in area and duration during management actions. Likewise, for several federally threatened or endangered species, including grizzly bear, Canada lynx, gray wolf, and wolverine an effects determination was made that proposed actions *may affect, but would not likely adversely affect* their survival and recovery. However, an effects determination was made that proposed translocation activities are *likely to adversely affect* the northern spotted owl and marbled murrelet because unknown nesting individuals near staging sites could be disturbed by helicopters and other human activity. Furthermore, adverse impacts on vegetation would occur during preparation of staging areas and release sites, but these effects would be limited to small areas and vegetation would recover following management activities. There would also be some short-term, adverse effects on visitor use and experience in the North Cascades national forests due to noise and sight of helicopters, as well as temporary closures of a few roads and trails. Lastly, adverse impacts on visitor and employee safety would occur due to risks associated with staging and release activities and increased future potential for human-mountain goat interactions.

Augmenting the mountain goat populations in the North Cascades national forests would have lasting beneficial effects on the viability of this Regional Forester Sensitive wildlife species through increased genetic diversity and enhanced demographic vigor to depleted populations. The natural quality of wilderness would be improved over the long term as a result of the mountain goat relocation as this would move these ecosystems toward their historical ecological condition. For other wildlife species and vegetation resources, management activities are unlikely to have any indirect or long-term, adverse impacts. The increased abundance of mountain goats would produce beneficial, lasting impacts on visitor use and experience due to increased opportunity to view native wildlife and possibly increased mountain goat hunting opportunity in the future from the translocation of mountain goats.

Alternative C: Lethal Removal

Olympic Peninsula

During the first 3 to 5 years of initial management under alternative C, temporary adverse impacts would affect most resources analyzed due to lethal removal actions, and associated preparation and use of

staging areas. These direct impacts would occur intermittently each year during the two 2-week management periods. The preparation and use of staging areas would result in adverse impacts on the same resources as described above under alternative B. Unlike alternative B, the duration of these impacts would be less frequent, and less intense because fewer helicopter flights to and from staging areas would be required because mountain goats would not be captured and translocated. Also, the impacts under alternative C would occur over a relatively shorter time frame because lethal removal would be a more efficient method to remove mountain goats. Adverse impacts on mountain goats on the Olympic Peninsula would be more substantial than under alternative B because of the number that would be lethally removed. Also, the use of firearms for lethal removal activities would produce additional noise and disturbance, which would further impact mountain goats; wilderness character; wildlife and wildlife habitat, including special-status species; vegetation, including special-status plant species; threatened or endangered species; visitor use and experience; and visitor and employee safety. The impacts from potential public access restrictions or area closures would be similar as under alternative B. Lastly, the presence of a large number of mountain goat carcasses on the landscape would have short-term benefits on scavenging wildlife, but would adversely impact the untrammeled quality of wilderness character. Overall, similar to alternative B, most direct adverse impacts of management activities under alternative C would be temporary and intermittent, and would diminish as increasing numbers of mountain goats are lethally removed. Maintenance activities under alternative C would have the same adverse, direct impacts as describe above for the initial management phase. However, such impacts would be more intermittent and less intense than those under alternative B because a much smaller number of mountain goats are expected to remain on the Olympic Peninsula after initial management.

After completion of management activities under alternative C, there would be long-term, beneficial impacts on most resources due to reduced impacts from exotic mountain goats. This alternative would also produce those benefits more quickly and to a larger degree than under alternative B. Some of the beneficial impacts would be substantial, including those to soils; wildlife and wildlife habitat, including special-status species; archeological resources; and visitor use and experience. One exception is that the lethal removal of mountain goats from the park would have a significant and permanent adverse impact on mountain goats on the Olympic Peninsula. These impacts would likely continue indefinitely because any mountain goats remaining on the landscape would be too few for the population to rebound. Beneficial impacts on visitor use and experience would result from the reduced potential for visitors to encounter mountain goats or to be inconvenienced by area closures related to the presence of conditioned or aggressive mountain goats. There would also be long-term, adverse impacts on visitor use and experience for those visitors that value seeing mountain goats in the Olympic Mountains.

North Cascades National Forests

Alternative C would have no impacts in the North Cascades national forests.

Alternative D: Combination of Capture and Translocation and Lethal Removal (Preferred Alternative)

Olympic Peninsula

Impacts associated with management of mountain goats under alternative D would include a combination of the impacts described under alternatives B and C. As described above for those alternatives, the initial management phase of mountain goat management activities would result in temporary adverse impacts on most resources from both capture and translocation operations and lethal removal actions. The preparation and use of staging areas would result in adverse impacts from aircraft, vehicle, and other equipment noise; direct disturbance from human activity; safety issues; and temporary limitations on public access in some

areas. The impacts associated with lethal removal activities would include disturbance from aircraft and firearm noise and the presence and disturbance of ground crews and would be concentrated during the final 2 years of initial management. The potential for adverse impacts would decrease substantially after management changes from capture and translocation to lethal removal activities, because lethal removal activities would require less helicopter flight time and fewer human resources. The resources affected include mountain goats; wilderness character, including opportunities for solitude and unconfined recreation; wildlife and wildlife habitat, including special-status species; vegetation, including special status plant species; threatened or endangered species; acoustic environment; visitor use and experience; and visitor and employee safety. Most of the adverse impacts would be temporary, intermittent, and minimal.

As described for alternative C, alternative D would result in long-term, beneficial impacts on most resources, including substantial beneficial impacts on the natural quality of wilderness, wildlife and wildlife habitat, including special-status species; vegetation, including special-status plant species; archeological resources; and soils, as a result of the removal of the majority of adverse impacts on these resources by mountain goats. The beneficial impacts would likely continue indefinitely because any mountain goats remaining on the landscape would be too few for the population to rebound. Long-term, beneficial impacts on visitor use and experience would result from the reduced potential for visitors to encounter mountain goats or to be inconvenienced by area closures related to the presence of conditioned or aggressive mountain goats. There would also be long-term, adverse impacts on visitor use and experience for those visitors that value seeing mountain goats in the Olympic Mountains.

North Cascades National Forests

Alternative D would have the same impacts in the North Cascades national forests as alternative B.

Table of Contents

Chapter 1: Purpose of and Need for Action 1

Introduction 1
Purpose of Taking Action 1
Need for Action 1
Objectives in Taking Action 2
Mountain Goats on the Olympic Peninsula 2
Cooperating Agencies and the Decision-Making Process 3
Impacts Associated with Mountain Goats at Olympic National Park 4
NPS Management Policies Regarding Removal of Exotic Species 4
Park Background 5
Project Areas Evaluated for Impacts 8
Issues and Impact Topics 8

Chapter 2: Alternatives 23

Introduction 23
Overview of Alternatives 23
Alternative A: No Action 32
Elements Common to All Action Alternatives (Alternatives B, C, and D) 35
Alternative B: Capture and Translocation 43
Alternative C: Lethal Removal 51
Alternative D: Combination of Capture and Translocation and Lethal Removal (Preferred Alternative) 53
How Alternatives Meet Objectives 55
Alternatives Considered but Dismissed from Further Analysis 55
Mitigation Measures 60
National Park Service Preferred Alternative 68
Environmentally Preferable Alternative 68

Chapter 3: Affected Environment 71

Introduction 71

Part One – Olympic Peninsula 71

General Project Setting 71
Mountain Goats 72
Wilderness Character 75
Wildlife and Wildlife Habitat, Including Special-Status Species 82
Vegetation, Including Special-Status Plant Species 88
Threatened or Endangered Species 93
Acoustic Environment 97
Soils 99
Archeological Resources 100
Visitor Use and Experience 102
Visitor and Employee Safety 107

Part Two – North Cascades National Forests Area 112

Project Setting 112
Wilderness Character 112
Wildlife, Including Sensitive and Management Indicator Species 113
Vegetation 117
Threatened or Endangered Species 117
Visitor Use and Experience 121
Visitor and Employee Safety 122

Chapter 4: Environmental Consequences 125

Introduction 125
General Methodology for Assessing Impacts 125
General Analysis Methodology and Assumptions 125

Part One – Impacts on Resources and Values of the Olympic Peninsula 127

Cumulative Impacts 127
Mountain Goats 133
Wilderness Character 137
Wildlife and Wildlife Habitat, Including Special-Status Species 146
Vegetation, Including Special-Status Plant Species 157
Threatened or Endangered Species 164
Acoustic Environment 174
Soils 187
Archeological Resources 191
Visitor Use and Experience 197
Visitor and Employee Safety 207

Part Two – Impacts on Resources and Values of the North Cascades National Forests 215

Wilderness Character 217
Wildlife, Including Sensitive and Management Indicator Species 222
Vegetation 226
Threatened or Endangered Species 228
Visitor Use and Experience 233
Visitor and Employee Safety 238
Unavoidable Adverse Impacts 241
Sustainability and Long-Term Management 242
Irreversible and Irretrievable Commitment of Resources 243

Chapter 5: Consultation and Coordination 245

History of Public Involvement 245
Agency Consultation 246
Tribal Treaties and Consultation 248
List of Recipients of the Plan / Environmental Impact Statement 248
List of Preparers and Consultants 249

References 253

Glossary 271

Index 277

Appendices

Appendix A: 2011 Olympic National Park *Mountain Goat Action Plan*

Appendix B: Olympic National Park Mountain Goat Management Continuum

Appendix C: USDA Forest Service Aquatic Conservation Strategy

Appendix D: Olympic, Mt. Baker-Snoqualmie, and Okanogan-Wenatchee National Forests Forest Plan Standards and Guidelines

Appendix E: Olympic National Park Minimum Requirements Analysis

Appendix F: Olympic, Mt. Baker-Snoqualmie, and Okanogan-Wenatchee National Forests Minimum Requirements Analysis

Appendix G: USDA Forest Service Special-Status Species for the Olympic, Mt. Baker-Snoqualmie, and Okanogan-Wenatchee National Forests (Wildlife, Fish, and Plants)

Appendix H: Federally Listed Species (*Endangered Species Act*) and USDA Forest Service Special-Status Species for the North Cascades National Forests (Wildlife and Plants)

Appendix I: Consultation Letter with Washington State Historic Preservation Office

Appendix J: Consultation Letter with US Fish and Wildlife Service

Tables

Table 1. Summary of Alternatives and their Management Elements 24

Table 2. Summary of Staging and Release Sites in the North Cascades National Forests and Corresponding Helicopter Trips Needed 47

Table 3. Summary of How Alternatives Meet Project Objectives 57

Table 4. Project Design Criteria for the Olympic National Forest 64

Table 5. Project Design Criteria for the North Cascades National Forests 66

Table 6. State-Listed Wildlife Species in Olympic National Park 84

Table 7. Vegetation Zones of the Olympic Peninsula 89

Table 8. State-Listed Plant Species in Olympic National Park 92

Table 9. Federally Listed Wildlife Species in the Olympic Peninsula Project Area 93

Table 10. Common Noise Levels and their Effects on the Human Ear 98

Table 11. Existing Ambient Sound Conditions in Olympic National Park, January–March, 2010 98

Table 12. 2015 Monthly Visitation in Olympic National Park 102

Table 13. 2015 Monthly Visitation in Olympic National Park by Area 104

Table 14. Reports of Mountain Goat-Human Interactions in Olympic National Park by Area 109

Table 15. Frequency and Type of Mountain Goat-Human Interaction in Olympic National Park 109

Table 16. Federally Listed and Candidate Wildlife Species in the North Cascades National Forests 118

Table 17. Past, Present, and Reasonably Foreseeable Future Actions and Potential Resources Affected in the Olympic Peninsula Area 128

Table 18. Distance of Staging Areas to Designated Wilderness 140

Table 19. Reduction in Listening Area and Alerting Distance Due to Increases in Ambient Sound Levels 176

Table 20. Past, Present, and Reasonably Foreseeable Future Actions and Potential Resources Affected in the North Cascades National Forests 216

Figures

Figure 1. Project Area on the Olympic Peninsula 9

Figure 2. Project Area in the North Cascades National Forests 10

Figure 3. Northern Staging Areas in Olympic National Park 37

Figure 4. Southern Staging Areas in Olympic National Forest 38

Figure 5. Projected Mountain Goat Density, Staging Areas, and Potential Flight Path Areas on the Olympic Peninsula 41

Figure 6. Example of Salt Block Site 42

Figure 7. Staging Areas and Release Sites in the North Cascades National Forests 49

Figure 8. Wilderness in Olympic National Park and Olympic National Forest 81

Figure 9. Vegetation Zones on the Olympic Peninsula 90

Figure 10. Critical Habitat and Potential Habitat for Northern Spotted Owl and Marbled Murrelet on the Olympic Peninsula 95

Figure 11. Map of Project Area on the Olympic Peninsula Showing Visitor Use Areas and Facilities 103

Figure 12. Sweets Staging Area 168

Figure 13. Mt. Ellinor Staging Area 169

Figure 14. Hamma Hamma Staging Area 170

Figure 15. Representative Helicopter Flight Paths and Potential Impacts on the Acoustic Environment of the Olympic Peninsula 182

Acronyms

ACETA	Aerial Capture, Eradication and Tagging of Animals
AGL	above ground level
APHIS	Animal & Plant Health Inspection Service
CEQ	Council on Environmental Quality
dBA	A-weighted decibel
ESA	*Endangered Species Act*
NEPA	*National Environmental Policy Act*
NFS	National Forest System
NPS	National Park Service
PEPC	NPS Planning, Environment, and Public Comment Website
plan/EIS	Mountain Goat Management Plan / Environmental Impact Statement
ROD	record of decision
SHPO	State Historic Preservation Office
USDA	US Department of Agriculture
USFWS	US Fish and Wildlife Service
WDFW	Washington Department of Fish & Wildlife

Ex162

Chapter 1:

Purpose of and Need for Action

CHAPTER 1: PURPOSE OF AND NEED FOR ACTION

INTRODUCTION

This *Mountain Goat Management Plan / Environmental Impact Statement* (plan/EIS) for Olympic National Park (the park) analyzes the impacts that could result from a continuation of current management of an exotic mountain goat population on the Olympic Peninsula (the no-action alternative), as well as the impacts that could result from three action alternatives.

This plan/EIS analyzes the impacts that could result from the no-action alternative and three action alternatives that involve lethal removal and/or translocation of nonnative mountain goats from the Olympic Peninsula.

This chapter describes the reasons the National Park Service (NPS) is taking action at this time to evaluate a range of alternatives for the management of exotic mountain goats in the park, and the subsequent actions by the Washington Department of Fish & Wildlife (WDFW) on National Forest System (NFS) lands in the North Cascades national forests. Two separate project areas are being evaluated in this plan/EIS: (1) areas of Olympic National Park and Olympic National Forest where exotic mountain goats could be reduced, which comprise the area referred to as the Olympic Peninsula; and (2) areas in the Mt. Baker-Snoqualmie National Forest and Okanogan-Wenatchee National Forest where mountain goats could be translocated, which comprise the area referred to as the North Cascades national forests.

PURPOSE OF TAKING ACTION

The purpose in taking action is to allow the NPS to reduce or eliminate impacts on park resources from exotic mountain goats (*Oreamnos americanus*), while reducing potential public safety issues associated with the presence of mountain goats in the park.

NEED FOR ACTION

Mountain goats are not native to the Olympic Peninsula. They were introduced to the Olympic Mountains prior to the establishment of the national park, and have since colonized the entire range, with the majority of the population residing within the park (Noss et al. 2000). The original need to manage this exotic species was an ecological concern related to the impacts that mountain goats impose on natural resources at the park, particularly sensitive vegetation communities (NPS 1995; Houston, Schreiner, and Moorhead 1994). New concerns were raised in 2010 when a visitor was fatally gored by a mountain goat while hiking on a park trail. Mountain goats have a high affinity for salts and natural sources of salt occur within their native range. There are no natural sources of salt in the Olympic Mountains, and mountain goats have learned to seek salts from humans. In areas with high levels of visitor use within the park and national forest, mountain goats have become conditioned to the extent that they are a nuisance and may be hazardous to visitors. The Olympic National Park *Mountain Goat Action Plan,* included as appendix A, addresses mountain goat behavior and seeks to minimize the potential for hazardous mountain goat-human encounters. This action plan focuses on the management of individual mountain goats that have been identified as potentially hazardous (appendix A). Additional planning and compliance is needed to address overall management of the mountain goat population on the Olympic Peninsula.

There is also a need to remove mountain goats from adjacent lands in the Olympic National Forest because mountain goats in these areas are part of a population that moves between the Olympic National Forest and Olympic National Park. As in the national park, mountain goats cause soil erosion, impact

native plant communities, and occupy habitat for native species in the national forest. As a result of these concerns, a plan/EIS is needed to address the impacts of exotic mountain goats in the park and in the adjacent Olympic National Forest, which would include the interference with natural processes, native species, natural habitats, and impacts on visitor use and safety.

OBJECTIVES IN TAKING ACTION

Objectives are "more specific statements of purpose that provide additional bases for comparing the effectiveness of alternatives in achieving the desired outcomes of the action" (NPS 2015e). Objectives presented below represent a refinement of the purpose of this plan/EIS and are focused primarily on objectives for Olympic National Park, although these would help meet the purpose and need for the Olympic National Forest areas that are adversely affected by mountain goats. All alternatives selected for detailed analysis must meet all objectives to a large degree and resolve the purpose of and need for action. Objectives for managing exotic mountain goats must be grounded in the enabling legislation, purpose, significance, and mission goals of the park, and must be compatible with the direction and guidance provided in the strategic plan, natural resources management plan, master plan, or other management guidance for the park. Any plan the park and cooperating agencies develop must be consistent with the laws, policies, and regulations that guide the NPS. The following objectives relate to the management of exotic mountain goats on the Olympic Peninsula:

- Develop a scientifically based method for the management of exotic mountain goat populations in an extensive mountainous wilderness area.
- Reduce or eliminate impacts on sensitive environments and unique natural resources from mountain goats in the park and in Olympic National Forest.
- Reduce or eliminate the potential for visitor safety issues associated with mountain goats in the park.
- Further public understanding of the Olympic high-elevation ecosystems and native species, and the ecology and conservation of mountain goats in their native range.
- Protect the International Biosphere Reserve and World Heritage Site designations of Olympic National Park and preserve the integrity of these designations.
- Protect the wilderness character of designated park wilderness and wilderness in Olympic National Forest.
- Work cooperatively with co-managers of mountain goats or habitats in Washington State (US Department of Agriculture (USDA) Forest Service, WDFW, and tribes).
- Support the wildlife management objectives of cooperating agencies and tribes, to the extent practicable, with respect to mountain goats.
- Provide opportunities to reestablish or augment sustainable native mountain goat populations in suitable mountain goat habitat on NFS lands in the North Cascades national forests.

MOUNTAIN GOATS ON THE OLYMPIC PENINSULA

Mountain goats are a native species in the State of Washington but are not native on the Olympic Peninsula. Approximately 12 mountain goats were introduced to the Olympic Peninsula near Lake Crescent from 1925 to 1929, prior to establishment of the national park. By the early 1980s, the mountain goat population in the park had grown to more than 1,000 individuals, with mountain goats distributed in

high-elevation habitats throughout the Olympic Peninsula (Houston, Moorhead, and Olson 1986). The highest density population was on Klahhane Ridge and included more than 200 mountain goats. The park implemented a series of live capture operations from 1981 to 1989, translocating 407 mountain goats to other mountain ranges throughout several western states (Houston et al. 1991). An additional 119 mountain goats were legally harvested during sport hunting seasons outside the park and 3 known mountain goats were illegally harvested in the park between 1983 and 1997. A second survey, conducted in July 1990 following the cessation of the NPS capture and translocation program, produced an estimate of 389 goats (Jenkins et al. 2012). Live capture operations were halted in 1990 for several reasons, including employee safety, animal safety, and changing Department of the Interior rules concerning helicopter landing techniques (NPS 1995). Subsequent surveys were conducted in 1994, 1997, and 2004, during a period in which no mountain goats were removed from the Olympic Mountains (Jenkins et al. 2012). A survey conducted in 2011 revealed that the population started increasing sometime between 2004 and 2011. Most recently, a 2016 survey revealed that the population has continued to increase to an estimated 625 mountain goats, with an 8% average annual rate of increase from 2004 to 2016. At this growth rate, there could be approximately 725 mountain goats on the Olympic Peninsula by 2018 (Jenkins et al. 2016).

Following the 2010 visitor fatality, the NPS developed the 2011 *Mountain Goat Action Plan* (appendix A) to provide guidance for addressing mountain goat behavior issues and minimizing the potential for hazardous encounters between mountain goats and humans. In 2015, a continuum for classifying and responding to mountain goat-human interactions was developed during a "Managing Animal Behavior" workshop attended by the Olympic National Park biologists (appendix B). Potential management actions identified in the continuum range from tracking mountain goat behavior to lethal removal of conditioned and aggressive mountain goats and are described in detail in appendixes A and B.

COOPERATING AGENCIES AND THE DECISION-MAKING PROCESS

The NPS is the lead agency for this planning process, whereas the USDA Forest Service and WDFW are participating as cooperating agencies. Management of mountain goats in Washington State is the primary responsibility of WDFW, but the USDA Forest Service is responsible for managing the vast majority of their habitat outside of Olympic National Park on both the Olympic Peninsula and in the North Cascades national forests (see FS 1991, FSM 2600). The NPS has jurisdiction over actions on NPS lands; however, NPS must also consider the impacts of its actions on other agencies' lands. The USDA Forest Service has jurisdiction over the Olympic National Forest lands and must provide NPS and WDFW with permission to engage in certain proposed mountain goat management activities on its lands. The USDA Forest Service also manages lands in the North Cascades national forests, where WDFW proposes to translocate mountain goats depending on the alternative ultimately selected in this plan/EIS.

After reviewing and analyzing comments on the draft plan/EIS, the NPS will prepare a final plan/EIS and then issue a record of decision (ROD) that selects an alternative for implementation. In the event that an alternative is selected that involves removing goats (either via live capture or lethal means) from Olympic National Forest and/or translocating mountain goats to North Cascades national forests, the USDA Forest Service would have to authorize these actions on NFS lands, which could include issuing temporary closures around staging areas, capture sites, and lethal removal areas as needed, per 36 CFR 261 Subpart B. Therefore, the responsible officials for the USDA Forest Service will decide through their own records of decision whether to authorize the following actions in their respective forests:

- The responsible official for the Olympic National Forest will decide whether to authorize the NPS to use helicopters to remove mountain goats from wilderness areas in the Olympic National Forest and transport them to staging areas; and whether to authorize temporary closures associated with the NPS capture operations, and at staging areas used by the WDFW.

- The responsible officials for the Mt. Baker-Snoqualmie and Okanogan-Wenatchee National Forests will decide whether to authorize the WDFW to establish temporary closures for staging and release sites and to release mountain goats with helicopters in the wilderness areas in their respective forests.

IMPACTS ASSOCIATED WITH MOUNTAIN GOATS AT OLYMPIC NATIONAL PARK

Issues associated with mountain goats at the park are primarily related to visitor safety and the unique vegetation at the park.

Issues associated with mountain goats at the park are primarily related to visitor safety and the unique vegetation at the park. Because many of the areas inhabited by mountain goats are popular destinations for park visitors, both in the frontcountry (e.g., Hurricane Ridge) and backcountry (e.g., Royal Basin), there is a high potential for mountain goat-human interactions within the park. Most notable are areas where mountain goats are habituated to human presence and have become conditioned to seeking salts and other minerals from humans. Mountain goats can be a nuisance along trails and around wilderness campsites where they persistently seek salt and minerals from human urine, packs, and sweat on clothing. They often paw and dig areas on the ground where hikers have urinated or disposed of cooking wastewater. The nature of mountain goat-human interactions in the park can vary widely, such as humans observing mountain goats from several hundred meters away across a ridge, mountain goats approaching visitors, and hazardous interactions such as the October 2010 fatality (appendix A).

Through their herbivory and wallowing behaviors, exotic mountain goats have directly and indirectly affected the vegetation within the park. Changes in the relative abundance of plant species have been observed as a result of mountain goat herbivory; this has altered competitive interactions among plant species. Wallowing by mountain goats has impacted plant species within the park as a result of soil disturbance and subsequent creation of mineral substrates for colonization by disturbance-oriented plant species. As the mountain goat population in the park increased prior to live capture operations in the 1980s, changes in vegetation were substantial, and the status of rare plant populations became a concern (Houston, Schreiner, and Moorhead 1994).

Mountain goat wallow site

NPS MANAGEMENT POLICIES REGARDING REMOVAL OF EXOTIC SPECIES

Section 4.4.4.2 of NPS *Management Policies 2006* states that "all exotic plant and animal species that are not maintained to meet an identified park purpose will be managed—up to and including eradication—if (1) control is prudent and feasible, and (2) the exotic species: interferes with natural processes and the perpetuation of natural features, native species or natural habitats; or disrupts the genetic integrity of native species; or disrupts the accurate presentation of a cultural landscape; or damages cultural resources; or significantly hampers the management of park or adjacent lands; or poses a public health hazard as

APPENDIX E: OLYMPIC NATIONAL PARK MINIMUM REQUIREMENTS ANALYSIS

Updated March 2017

Olympic National Park

Wilderness Project Proposal Form and Minimum Requirements Worksheet

PART ONE: Wilderness Project Proposal Information

Project Originator(s):	Christina Miller
Division:	Superintendent's (Planning and Compliance Office)
MRW Preparer:	Christina Miller
Date:	December 14, 2016 (Revised March 6, 2017)
PEPC #:	49246
What is the <u>issue</u> or <u>problem</u> to be solved?	The presence of exotic mountain goats in Olympic National Park (the park).
What is the underlying need for the project?	Mountain goats are not native to the Olympic Peninsula. They were introduced to the Olympic Mountains prior to the formation of the park, and have since colonized the entire range, with the majority of the population residing within the park (Noss et al. 2000). The original need to manage this exotic species was driven by ecological concerns related to the impacts that mountain goats impose on natural resources at the park, particularly sensitive vegetation communities (NPS 1995; Houston, Schreiner, and Moorhead 1994). New concerns were raised in 2010 when a visitor was fatally gored by a mountain goat while hiking on a park trail. Mountain goats have a high affinity for salts and natural sources of salt within their native range. There are no natural sources of salt in the Olympic Mountains and mountain goats have learned to seek salts from humans. In high visitor use areas within the park, mountain goats have become habituated to the point that they are a nuisance and may be hazardous to park visitors. The Olympic National Park Nuisance and Hazardous Animal Management Plan includes the *Mountain Goat Action Plan*, which addresses mountain goat behavior and seeks to minimize the potential for hazardous goat-human encounters. This action plan focuses on the management of individual mountain goats which have been identified as potentially hazardous. Additional planning and compliance is needed to address overall management of the mountain goat population within the park. As a result of the above stated concerns, and based on National Park Service (NPS) policy, a plan/EIS has been developed to address the impacts of exotic mountain goats in the park, which includes the interference with natural processes, native species, and

	natural habitats and impacts to visitor safety. The plan/EIS analyzed four alternatives. While, based on impact analysis section in Chapter 4 of the plan/EIS, Alternative C (lethal removal only) was determined to have the least amount of impacts on overall wilderness character (only due to less frequent and shorter duration of maintenance activities), the planning team determined that Alternative D (combination of capture and translocation and lethal removal) within plan/EIS would provide the park with best direction for the overall management of exotic mountain goats. This determination was made during an IDT workshop with the project's Cooperating Agencies. A process was followed that identified whether and to what extent each alternative in the draft plan/EIS addressed the plan's seven objectives as identified on page 2 of the plan/EIS, one of which was, "Protect the wilderness character of Olympic National Park." A preferred alternative is the alternative that "would best accomplish the purpose and need of the proposed action while fulfilling [the NPS] statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors" (2015 NPS NEPA Handbook). These factors were also taken into consideration. Thus only the no action and preferred alternatives are considered in this minimum requirement analysis.
Location (attach map and/or photos):	See figures 1 and 2 in the plan/EIS.
Is resolution of this issue addressed in an approved NEPA document: Categorical Exclusion (CE); Environmental Assessment, Finding of No Significant Impact (FONSI); or Environmental Impact Statement, Record of Decision (ROD)? If so, please name:	The resolution of this issue is currently being addressed in the Olympic National Park Mountain Goat Management Plan/Draft Environmental Impact Statement (plan/EIS).
What would happen if the need were not met? (NO ACTION)	If the need were not met, exotic mountain goats would remain within the park, would likely increase in population numbers, and would continue to adversely affect the natural quality of wilderness character. The mountain goats would also continue to adversely affect opportunities for solitude or a primitive and unconfined type of recreation (through incessantly seeking salts from humans) and possibly also the undeveloped quality of wilderness character (through the use of helicopters or the use of guns or other prohibited uses/means to capture or lethally remove nuisance mountain goats).

Wilderness Minimum Requirement Analysis (MRA)
STEP ONE: Determine if action is necessary or appropriate

1	Is the resolution of this issue covered by an existing Wilderness Plan or other NEPA decision document that includes wilderness minimum requirement considerations?	Answer: Yes____ No __X___
	Yes → Implement action as approved No → Continue PPF/MRA	If "Yes" provide name of document and approval date:
2	Has Superintendent determined this is an emergency in accordance with law & policy?	Answer: Yes____ No __X__
	No →	Yes, Follow approved emergency SOPs/management plans. If they do not exist or have not gone through MRA, continue MRA.
3	List guidance provided in law and policy for resolution of the issue	See Management Policies Chapter 6, Director's Order #41 and other applicable laws, policies and directives. Add additional policy guidance as appropriate.

WILDERNESS MINIMUM REQUIREMENT

Wilderness Act of 1964 – Section 2(a) In order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition, it is hereby declared to be the policy of the Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness. For this purpose there is hereby established a National Wilderness Preservation System to be composed of federally owned areas designated by Congress as "wilderness areas", and these shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness; and no Federal lands shall be designated as "wilderness areas" except as provided for in this Act or by a subsequent Act.

Wilderness Act of 1964 - Prohibition Of Certain Uses Section 4(c) Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area.

NPS Management Policies 2006, § 6.3.5 Minimum Requirement

All management decisions affecting wilderness must be consistent with the minimum requirement concept. This concept is a documented process used to determine if administrative actions, projects, or programs undertaken by the Service or its agents and affecting wilderness character, resources, or the visitor experience are necessary, and if so how to minimize impacts. The minimum requirement concept will be applied as a two-step process that determines whether the proposed management action is appropriate or necessary for administration of the area as wilderness and does not cause a significant impact to wilderness resources and character, in accordance with the Wilderness Act; and the techniques and types of equipment needed to ensure that impacts on wilderness resources and character are

minimized.

In accordance with this policy, superintendents will apply the minimum requirement concept in the context of wilderness stewardship planning, as well as to all other administrative practices, proposed special uses, scientific activities, and equipment use in wilderness. The only exception to the minimum requirement policy is for eligible areas that the Service has not proposed for wilderness designation. However, those lands will still be managed to preserve their eligibility.

When determining minimum requirements, the potential disruption of wilderness character and resources will be considered before, and given significantly more weight than, economic efficiency and convenience. If a compromise of wilderness resources or character is unavoidable, only those actions that preserve wilderness character and/or have localized, short-term adverse impacts will be acceptable.

Although park managers have flexibility in identifying the method used to determine minimum requirement, the method used must clearly weigh the benefits and impacts of the proposal, document the decision-making process, and be supported by an appropriate environmental compliance document. Parks must develop a process to determine minimum requirement until the plan is finally approved. Parks will complete a minimum requirement analysis on those administrative practices and equipment uses that have the potential to impact wilderness resources or values. The minimum requirement concept cannot be used to rationalize permanent roads or inappropriate or unlawful uses in wilderness.

Administrative use of motorized equipment or mechanical transport will be authorized only

- if determined by the superintendent to be the minimum requirement needed by management to achieve the purposes of the area, including the preservation of wilderness character and values, in accordance with the Wilderness Act; or
- in emergency situations (for example, search and rescue, homeland security, law enforcement) involving the health or safety of persons actually within the area.

Such management activities will also be conducted in accordance with all applicable regulations, policies, and guidelines and, where practicable, will be scheduled to avoid creating adverse resource impacts or conflicts with visitor use.

While actions taken to address search and rescue, homeland security and law enforcement issues are subject to the minimum requirement concept, preplanning or programmatic planning should be undertaken whenever possible to facilitate a fast and effective response and reduce paperwork.

For more detailed guidance, see Director's Order #41 and the National Wilderness Steering Committee Guidance Paper #3: "What Constitutes the Minimum Requirements in Wilderness?"

ADDITIONAL POLICY GUIDANCE AS APPROPRIATE

NPS Management Policies 2006, § 4.4.4.2 Removal of Exotic Species Already Present – All exotic plant and animal species that are not maintained to meet an identified park purpose will be managed – up to and including eradications – if (1) control is prudent and feasible, and (2) the exotic species

- interferes with natural processes and the perpetuation of natural features, native species or natural habitats, or
- disrupts the genetic integrity of native species, or
- disrupts the accurate presentation of a cultural landscape, or
- damages cultural resources, or
- significantly hampers the management of park or adjacent lands, or
- poses a public health hazard as advised by the U.S. Public Health Service (which includes the Centers for Disease Control and the NPS public health program), or
- creates a hazard to public safety.

Executive Order 13112, "Invasive Species" – The NPS is required to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause.

4	Is resolution of this issue necessary or appropriate to meet wilderness management objectives or the requirements of other laws, policies and directives? Yes → 5 No → Do not proceed with action	Answer: Yes __X__ No____ Explain: Please see Section 3 above in regard to the Wilderness Act and additional policy guidance.
5	Can the issue be resolved through visitor education? Yes → Carry out visitor education No → 6	Answer: Yes____ No__X__ Explain: Visitor education alone would not eradicate the exotic mountain goats. The population of exotic mountain goats that currently exists within the park is estimated to be 500 individuals. Visitors are currently asked to assist in hazing activities if/when mountain goats are within range of visitors. Hazing activities (e.g., shouting, throwing rocks) are merely an attempt to create a negative association/fear of humans by mountain goats in an effort to encourage goats to refrain from approaching humans. Hazing activities do not remove exotic species from park lands.
6	Can the issue be resolved through actions outside of wilderness? Yes → Conduct actions outside wilderness No →	Answer: Yes____ No__X__ Explain: The exotic mountain goats reside within the Daniel J. Evans Wilderness as well as within adjacent U.S. Forest Service (USDA Forest Service) wilderness areas: Buckhorn, The Brothers, and Mount Skokomish.

I have reviewed this project proposal and have determined that it meets the overall goals of Olympic National Park and can be included in my divisional work plan. I have designated a project coordinator below to represent my division and present the proposal to the Compliance Council.		
Project Manager:		
Division Chief Signature:		Date:
Next step: **Contact the Planning & Compliance Office to schedule the issue for discussion by the Olympic National Park Compliance Council.**		
I have reviewed this project proposal and have determined that the proposed management action is appropriate or necessary for administration of the park, if in wilderness it is appropriate and necessary for the administration of the area as wilderness, in accordance with the Wilderness Act. I recommend that alternatives be developed to ensure that actions taken would not cause a significant impact to wilderness resources or character, and to develop techniques and types of equipment needed to ensure that impacts on park resources and values, and wilderness		

resources and character are avoided or minimized. Complete Part Two (next page).		
Deputy Superintendent:		Date:

PART TWO: Evaluate Alternatives, as appropriate determine the minimum tools, techniques and actions that would effectively resolve the issue while avoiding or minimizing adverse effects.

8	Describe in detail alternative ways to resolve the issue (include use of minimum tools as appropriate) Note: Alternatives described in other compliance documents that address this issue may be referenced. If minimum requirement considerations were not included, develop below for projects affecting wilderness.	Questions to answer for each alternative: • What is proposed? • Does the proposed action involve new construction or repair/rehab to existing structures/utilities/assets? • Does the project take place in the same location/footprint/trench used before, or in a previously undisturbed area? • Would the project involve ground disturbance (cut or fill)? If so, how many cubic yards and where will materials be deposited (both temporarily and permanently)? If fill materials are taken, identify the specific site fill taken from and if the materials are native to the park. How would fill be "stored"? • How much excavation would be necessary (quantify by width, length, depth, cubic feet, number or lines, etc.) • Would the proposal involve work in or near a known archeological site or other historic property? • Would a staging area be required? If so, identify staging area(s), include map, what type of materials and/or equipment and for how long? What would be the estimated square footage of the staging are? • How/where would construction debris be disposed of? • How much surface area would be disturbed, cleared, or denuded of vegetation (quantify by square footage, # of trees removed, etc.) • Would the project involve any geologic or hydrologic features/alter stream courses, surface or ground water flow? • Would the proposal involve structures, fill, or discharge into water (example: bridge crossing, boardwalk, gravel, culverts, etc.)? • Would the proposal affect water quality or quantity? • What changes would occur in land/facility use? • What changes would occur to traffic flow or visitor circulation? • Would the proposal require aerial operations? • Would the proposal alter visitor services, activities, or experiences? • Where would the action take place? • When would the action take place? • What design and standards would apply? • What methods, tools and techniques would be used? • How long would it take to complete the action? • What mitigation would be taken to minimize action impacts on park resources and values, and

		wilderness resources and character (where applicable)?

Alternative 1: No action
• **What is proposed?** o Under the no action alternative (Alternative A in the plan/EIS), options for the management of mountain goats in the park would be limited to those actions outlined in the *Mountain Goat Action Plan* which was revised by an NPS workgroup in 2015. The goal of the action plan is "that mountain goats in the park exhibit natural behaviors consistent with other portions of their range, to not have those natural behaviors altered by human use of their habitats (i.e., become habituated or conditioned), and to minimize the potential for hazardous mountain goat-human encounters." Unacceptable mountain goat behaviors include the following: Failing to retreat when coming in sight of people; allowing people to approach within 150 feet; approaching and following people on trails or at camp or rest sites; aggressively seeking out areas where humans urinate and consuming soil and vegetation where human urine is deposited; making contact with clothing or equipment, chewing gear, seeking salt; displaying aggressive postures or behavior to people when encountered on or off trail; attacking and making contact with humans. o Management under the *Mountain Goat Action Plan*, and therefore under Alternative 1, would be an integrated effort between all park divisions with an emphasis on preventing unacceptable mountain goat behavior. Management according to the action plan is set up according to the continuum of mountain goat-human interactions and the appropriate park response. o The management actions include the following, listed in order of increasing intensity, based on an increasing (worsening) classification of goat behavior (i.e., as goats become more habituated or aggressive): ▪ Providing informational material to visitors. ▪ Posting regulatory signs (no feeding, minimum distance, advice on urine deposits, etc.). These signs would be posted at trailheads and bulletin boards. Very few would be in the wilderness. ▪ Recording observations on daily logs and turn in to the wildlife manager when the page is full or at the end of the season. ▪ Filling out goat incident forms and turning them in to the district ranger and wildlife manager. ▪ Posting higher level regulatory and warning signs. These signs would be posted at trailheads and bulletin boards. Very few would be in the wilderness. ▪ Informing the Wildlife Incident Team of developing situations. ▪ Hazing goats in the area(s) that are exhibiting habituated behavior. Recording hazing actions and goat responses. Hazing actions include, but are not limited to; yelling, throwing rocks, banging hiking sticks, hitting habituated animals with projectiles propelled via sling shot and paint ball gun (CO2 charges) and rubber slugs and bean bag rounds propelled by a shot gun. ▪ Increasing staff patrols in the area(s), marking animals with paint balls; hazing goats exhibiting unacceptable behavior during regular patrols. ▪ Increasing outreach to visitors about habituated and conditioned goats. ▪ Evaluating the need for area closure(s) and implementing the closure(s) if needed. ▪ Dedicating trained staff to implement hazing for several days, and marking goats encountered and target hazing on goats exhibiting unacceptable behavior during regular patrols. ▪ Continuing more intensive patrols when the trail is opened to assess goat response to hazing. ▪ Contacting park dispatch and inform Wildlife Incident Team of incident. ▪ Closing trails for longer durations. ▪ Marking goats in the area, consider the use of permanent marks (ear tag or radio collar). ▪ Patrolling closed trail(s) for several days to assess efficacy of aversive conditioning

(not in uniform).
    - Consider lethal removal.
    - Conduct lethal removal.
  - Management elements that could be employed under alternative A are as follows:
    - **Interpretive Tools -** Park staff would continue to provide information and warnings regarding hiking safely with mountain goats, and educational opportunities to the public through interpretive programs and visitor interactions regarding the management of mountain goats in the park. Interpretation would include efforts to increase the public's awareness of the current mountain goat situation within the park and on the Olympic Peninsula, as well as associated management activities.
    - **Nuisance Control -** In the *Mountain Goat Action Plan*, aversive conditioning consists of immediate and short-term hazing activities intended to modify mountain goat behavior and to drive mountain goats away from visitor use areas. Under the no-action alternative, nuisance control tools would vary from hazing actions, such as shouting and throwing rocks at mountain goats, to lethal removal (by shooting) as described above under management actions.
    - **Access -** Park staff would primarily access mountain goat management areas on foot. Management activities under the no-action alternative would take place primarily in high visitor use areas that are accessed via hiking, but could also occur in more remote areas utilizing helicopters as needed to complete necessary management actions such as in emergency response (i.e., response to an attack by a goat – get staff in there quickly; haul out.)
    - **Park Closures -** It would occasionally be necessary to close *areas of the park for hazing activities associated with the no-action alternative. Often when hazing, park staff work to involve park visitors in the process of shouting and throwing rocks at the mountain goats. If it is determined that lethal removal actions are required for a habituated mountain goat, then that particular *area of the park would be temporarily closed for the duration of the process. Closures for management may last from a few hours to a few weeks. *Area is going to vary based on how well we understand just where the goat or goats in question are roaming, and where the interactions may occur. It can be as small as on top of Victor Pass (as was the case in the 2010 fatality), to the upper Royal Basin (as was the case in 2011) to the whole 7 Lakes Basin if we have an attack by an unmarked goat in that area.
    - **Firearms (Lethal Removal) -** Under the no-action alternative, there would be the potential for lethal removal of mountain goats. This would involve using firearms such as high-powered rifles for the removal of mountain goats that have exhibited habitual aggressive behavior or have presented a clear threat to human safety. As necessary, park staff would be involved with lethal removal activities, including the field activities directly related to the reduction efforts (assisting with enforcing temporary closures of management area, patrolling, shooting, carcass handling). Contracted sharpshooters or designated hunters (e.g. volunteers who have gone through training and are approved by the NPS) would also likely be involved with lethal removal activities. Each individual's role would be identified prior to reduction and could include any of the actions noted above. The process for identifying mountain goats for lethal removal is described above under management actions. Specific protocols for lethal removal under the no-action alternative are described in the *Mountain Goat Action Plan*. Carcasses may be left in place or hauled out via helicopter for necropsy.

- **Does the proposed action involve new construction or repair/rehab to existing structures/utilities/assets?**
  - No
- **Does the project take place in the same location/footprint/trench used before, or in a previously undisturbed area?**
  - Hazing and marking would continue to occur throughout the mountain goat range.
  - If the management action leads to lethal removal, this could occur in or outside of previously disturbed areas. This could entail the use of helicopter for sharpshooting and the on-the-ground removal (moving the goat to an area outside of immediate public sight (>100m and out of sight) – some areas may be visible but unsafe to access; or on-the-ground operations to assist with removal by helicopter). The same footprint as before – which is potentially the entirety of mountain goat range – however this one is a little awkward as there is no ground

disturbance associated with our actions – however there is with the goat's activities.

- **Would the project involve ground disturbance (cut or fill)? If so, how many cubic yards and where will materials be deposited (both temporarily and permanently)? If fill materials are taken, identify the specific site fill taken from and if the materials are native to the park. How would fill be "stored"?**
    - This project does not involve cut or fill ground disturbance. The signs would not be on posts, and therefore no holes would be dug.
- **How much excavation would be necessary (quantify by width, length, depth, cubic feet, number or lines, etc.)**
    - None
- **Would the proposal involve work in or near a known archeological site or other historic property?**
    - Exotic mountain goat management activities could occur in or near known archeological sites or other historic property.
- **Would a staging area be required? If so, identify staging area(s), include map, what type of materials and/or equipment and for how long? What would be the estimated square footage of the staging are?**
    - Staging areas could be utilized for lethal removal operations if it is determined that a necropsy would be needed on the goat. Staging areas would mainly be used for helicopter operations for approximately one day for goat removal. Staging areas would be determined based on the location of the incident and would be located outside of wilderness and likely be identified in existing visitor parking areas (such as Hurricane Hill and Deer Park as identified in the plan/EIS for the preferred alternative) or in Sweets Meadow (where there's a currently designated helicopter landing area outside of wilderness in the Elwha Valley).
- **How/where would construction debris be disposed of?**
    - N/A
- **How much surface area would be disturbed, cleared, or denuded of vegetation (quantify by square footage, # of trees removed, etc.)**
    - None to very little if there's a need to move (by dragging) a lethally removed goat out of sight of visitors/out of high use areas. The disturbance to vegetated areas would be trampling.
- **Would the project involve any geologic or hydrologic features/alter stream courses, surface or ground water flow?**
    - No
- **Would the proposal involve structures, fill, or discharge into water (example: bridge crossing, boardwalk, gravel, culverts, etc.)?**
    - No
- **Would the proposal affect water quality or quantity?**
    - No
- **What changes would occur in land/facility use?**
    - None
- **What changes would occur to traffic flow or visitor circulation?**
    - If area closures are implemented, visitors would not be able to enter those areas/hike those trails. If there is a need to conduct a lethal removal operation, those areas would be closed to visitor use and parking areas utilized as staging areas would also be closed to visitor use. These closures would be temporary, only long enough to conduct the operation.
- **Would the proposal require aerial operations?**
    - If it is determined that a necropsy is necessary on a lethally removed goat, then a helicopter may be utilized to facilitate in the physical removal of the goat from an area to the frontcountry for the procedure.
- **Would the proposal alter visitor services, activities, or experiences?**
    - If area closures are implemented, visitors would not be able to enter those areas/hike those trails. If there is a need to conduct a lethal removal operation, those areas would be closed to visitor use and parking areas utilized as staging areas would also be closed to visitor use. These closures would be temporary, only long enough to conduct the operation.
- **Where would the action take place?**
    - Wherever there are human-goat encounters occurring – both in wilderness and frontcountry areas.
- **When would the action take place?**

- The timing of management actions would be based on the need for action, but would likely occur primarily during times of high visitor use within the park when there is greater potential for mountain goat-human interactions.

- **What design and standards would apply?**
  - Helicopter safety, developed in a Helicopter Safety Plan, as well as staff and visitor safety protocols.
- **What methods, tools, and techniques would be used?**
  - Signs, hazing, staff patrols, area/trail closures, paint ball marking of goats, firearms to lethally remove goats, helicopter to remove goats requiring necropsy.
- **How long would it take to complete the action?**
  - The frequency of management actions would vary depending on the level of mountain goat-human interactions observed at a given time within the park. If mountain goat-human interactions are occurring often, then the frequency of management activities would increase. The short-term duration of management activities would vary depending on mountain goat responses to management activities. If management activities are effective, then the duration may last long enough to only haze the mountain goat out of an area. If mountain goats are not responsive to management activities, then the duration could increase to longer than one week or would occur sporadically throughout the spring and summer as mountain goats change their seasonal areas of concentrated use. The long-term duration of management activities would continue indefinitely into the future because the mountain goat population within the park would continue to increase.
- **What mitigation would be taken to minimize action impacts on park resources and values, and wilderness resources and character (where applicable)?**
  - Research and monitoring activities would continue opportunistically according to current park operations and based on available funding. Park staff would continue to collect information on the population of mountain goats in the park including topics such as goat population levels and visitor interactions. Annual aerial monitoring would continue as funding allows.
  - Lethal removal would occur by foot vs. helicopter when and where possible.
  - Public notification of activities affecting wilderness would be provided, and appropriate information would be distributed at visitor centers.
  - Duration and geographic scope of actions and disturbances would be minimized in wilderness areas.
  - The tool that would cause the least amount of disturbance to wilderness would be used for all management actions.
  - “Leave No Trace” principles would be applied to all management actions.
  - Helicopter operations would not be conducted within a minimum of 500 feet from marbled murrelet and northern spotted owl habitat.
  - Helicopter flight paths to and from staging areas would be designed to minimize noise impacts to wildlife and visitors to the greatest practical extent.
  - Area closures in the immediate vicinity of mountain goat hazing and lethal removal operations would minimize noise impacts to backcountry visitors.
  - Previously agreed upon travel corridors and flight altitudes for helicopters would be used during operations.
  - Contractors and other project workers would properly store and dispose of food and garbage while working on site.
  - Staging areas would be located in areas that are previously disturbed, and would necessitate the least amount of affect to wildlife and wildlife habitat.
  - Lead-free ammunition would be used for lethal removal activities to prevent contamination.
  - Project staff would be properly trained regarding adherence to safety protocols identified in the Olympic National Park *Mountain Goat Action Plan*.

Alternative 2:

- **What is proposed?**
  - Alternative 2 (Alternative D in the plan/EIS – the Preferred Alternative) would utilize a combination of capture and translocation and lethal removal tools to reduce (to the point that the population cannot survive) or eliminate mountain goats from the park. Under this alternative approximately 90% of the projected 2018 mountain goat population, or approximately 625 to 675 mountain goats would be removed. Approximately 10% of the

mountain goat population would remain following initial management, or between 50 and 100 mountain goats based on the projected 2018 population size. These goats would be subject to maintenance activities of ground- and helicopter-based lethal removal in proximity to areas of high human use.

- The specific management elements and actions that could be used for capture and translocation are as follows:
  - **Personnel Access** – Management activities for capture and translocation would involve several tools for accessing remote areas. Park staff would access backcountry areas via foot in order to bait and trap mountain goats. Fixed-wing aircraft or helicopters could be used to identify areas for aerial capture operations. Helicopters would be used to facilitate capture of mountain goats and to transport them to specific staging areas for transfer of ownership to the Washington Department of Fish and Wildlife (WDFW).
  - **Capturing Mountain Goats** – Mountain goats would be captured either through the use of helicopter capture operations or ground-based capture techniques followed by transport to specified staging areas via helicopter for transfer to WDFW. WDFW would then translocate mountain goats using a combination of trucks and helicopters.
  - Each year, for 3-5 years, there would be a maximum of two 2-week operations (occurring in July and in August or September) of 8 flight hours per day. There may be up to 2 helicopters in the air at one time, weather and funding dependent (this is the maximum, the actual likelihood is much less).
- Capture and translocation would occur in most areas prior to direct reduction activities.
- Once a point of diminishing returns for capture operations is reached, management would continue using lethal removal activities.
- There would be a desired eventual population goal of zero mountain goats within the park. The desired population goal may be difficult to obtain; however, the intent of the action would be to reduce the population to a level where maintenance activities (e.g., shooting goats if and when they re-occur – activities can be either ground hunting or aerial operations) would prevent the population from rebounding to pre-reduction numbers.
- When goats become too difficult to capture, the park would switch to lethal removal. In this alternative, it is anticipated that the majority (90-100%) of operations in year 1 would be live capture. In year 2, as the mountain goats get sparser and more wary, situations would develop where the crew (of about 6 staff in two helicopters; and 99% of the operations would be in wilderness) would encounter goats that are obviously uncatchable – either in areas where it was determined in the prior year to be unworkable terrain, or when a goat that has been involved in prior capture attempts and is extremely elusive. In those situations, mountain goats would be removed lethally. It is estimated that in year 2 the majority of the mountain goats would be live captured, but a lower percentage than in year 1 (60-70% live capture, 30-40% lethal removal). In year 3, for the first capture period, the park would try to conduct live captures, but it is estimated that the success rate would be low and a greater portion of the mountain goats would be lethally removed (20-30% capture, 70-80% lethal removal). In the last operations period of year 3, almost all of the mountain goats encountered would be lethally removed. The park would continue mountain goat capture operations as long as it is safe and feasible, and there are still areas available to receive mountain goats. The switch to lethal removal may be made at the end of year 2.
- Maintenance activities (as explained above) under this alternative would be prioritized in areas of high visitor or mountain goat use and areas experiencing high levels of resource damage, and would primarily be done through lethal removal.
- Interpretive Tools:
  - Park staff would provide information and educational opportunities to the public through interpretive programs and visitor interactions regarding the management of mountain goats in the park.
  - Interpretation would include efforts to increase the public's awareness of the current mountain goat situation within the park and on the Olympic Peninsula, as well as about management activities that would be undertaken under this alternative.
  - Interpretive tools could include enhanced outreach to media outlets, expanded website resources, additional backcountry notices, and informational handouts. These signs would be posted at trailheads and bulletin boards. Very few would be in the wilderness.

- Park Closures:
  - There would be the potential for closing limited park areas while undertaking various management actions including lethal removal and capture operations (there's the potential to close 7 Lakes, Lake of the Angels, and Klahanne for ~5-12 days, not all at once; or there may be no closures at all); and Hurricane Hill would be closed while that staging area is in use and Deer Park Campground may be closed while the Deer Park staging area is in use. Park closures would include areas within the vicinity of active management activities and surrounding staging areas.
  - No parkwide closures would occur.
  - Closures in specific areas could last for several days while management activities are taking place. The closure schedule and geographic areas impacted by closures would be coordinated with the Wilderness Information Center that issues wilderness use permits to ensure that no permits are issued for areas undergoing management activities. Closures would also be coordinated with wilderness and law enforcement rangers, volunteer staff, and all other park staff that could potentially be working in closed areas.
- Staging Areas:
  - The use of helicopters would be required to access remote areas of the park and would require space for taking off and landing. Space for animal care and handling would also be required for capture and translocation activities and would include areas to unload mountain goats from slings, receive veterinary care and process (unload from sling, subdue, examine, treat any illnesses or wounds, gather biological samples and morphometric samples, tag and/ or collar, hydrate, place in shade in box until transported), and to load into vehicles for transport for translocation.
  - Staging areas would not be located in designated wilderness, but would be located on previously disturbed areas and would be used for management action mobilization of staff and equipment.
  - Areas for aircraft landing would be located adjacent to mountain goat handling areas, and would be located far enough away to maintain safety.
  - Potential staging areas have been identified and include Deer Park, Hurricane Hill parking area and potentially the overflow parking lot, and Sweets Field (alternate) in the park, and Hamma Hamma and the Mt. Ellinor Trailhead in ONF.
  - The use of staging areas would rotate to those areas closest to where management actions would occur.
  - Some minor improvement to staging areas (e.g., ground leveling and grading, removal and trimming of vegetation, and treatment for noxious weeds) may be required; however it would all occur within the existing footprint of the disturbed area and outside of designated wilderness.
  - The NPS would not be responsible for staging area improvements on USDA Forest Service property.
- Baiting:
  - Salt blocks may be placed in remote areas of the park to attract mountain goats to suitable areas for carrying out management activities. Research has demonstrated that pre-baiting with salt and trace mineral blocks up to one year prior to removal actions can significantly increase effectiveness. Locations would be identified to provide for the greatest efficacy of either capture or lethal removal actions depending on the alternative being implemented. Areas would either be located away from public use areas or closed to public access to minimize human-mountain goat conflicts. The maximum number of areas would be five. Salt blocks would be placed in impermeable containers to prevent salt from leaching into soils and would be removed once management activities are complete to limit effects to other wildlife species.
- Firearms:
  - High-powered rifles would be used in all lethal actions. Personnel involved, which could include NPS or other federal personnel, state personnel, or authorized agents would have the appropriate skills and proficiencies in the use of firearms to maximize public safety, including experience in the use of firearms for the removal of wildlife. Any lethal action would be completed as humanely as possible. Under all alternatives, mountain goats injured during management activities would be

dispatched as quickly as possible to minimize suffering. The specific management elements and actions that could be used for the lethal removal of mountain goats are as follows: Helicopters and fixed-wing aircraft would be used to access areas where goats need to be dispatched and high-powered firearms would be used to dispatch mountain goats in and adjacent to the park.

- Animal Welfare:
  - The NPS would adhere to guidelines from the American Veterinary Medical Association on euthanasia of animals to ensure that management actions are conducted as humanely as possible to minimize mountain goat suffering. When capturing mountain goats for translocation, management actions would be designed to maximize the humane treatment of animals including capturing nannies with dependent young together in order to enhance the likelihood of survival. NPS would use a variety of techniques to improve the survival rates of nannies with dependent young. These include but are not limited to: trapping nannies with young in clover traps and transporting them together to holding areas, if young did not enter traps they could be caught adjacent to nannies with either net guns or immobilized with drugs. When using helicopters the same techniques could be used and every effort made to secure the dependent young with the nannies, this could be done by separating nannies with young during pursuit and keeping the groups together and then using net guns to capture both animals in one net. If using drugs then similar techniques would be applied; capturing the nannies first and then young as they stayed near the immobilized adult or once the adult is caught pursuing the dependent young. If drive traps are used they would be implemented following the methods described by Smith 2010. Nannies and their young will be transported together. When using lethal removal with firearms, consideration would be given to the choice of firearm, non-lead ammunition, and shot placement to ensure the humaneness of the action.
- Carcass Handling and Disposal:
  - Mountain goat carcasses resulting from management activities would be left in the field but would be relocated away from trails, campsites, or where visible from high visitor use areas. If feasible, carcasses could be provided to the Skokomish Indian Tribe to obtain hides and horns.

- **Does the proposed action involve new construction or repair/rehab to existing structures/utilities/assets?**
  - No
- **Does the project take place in the same location/footprint/trench used before, or in a previously undisturbed area?**
  - Capture and lethal removal actions will take place range-wide – see comments on the no action alt for this question
  - If the management action leads to lethal removal, this could occur in or outside of previously disturbed areas. This could entail the use of helicopter for sharpshooting and the on-the-ground removal (moving the goat to an area outside of immediate public site; or on-the-ground operations to assist with removal by helicopter).
- **Does the project take place in the same location/footprint/trench used before, or in a previously undisturbed area?**
  - Hazing and marking would continue to occur throughout the mountain goat range.
  - If the management action leads to lethal removal, this could occur in or outside of previously disturbed areas. This could entail the use of helicopter for sharpshooting and the on-the-ground removal (moving the goat to an area outside of immediate public sight (>100m and out of sight) – some areas may be visible but unsafe to access or on-the-ground operations to assist with removal by helicopter).
- **Would the project involve ground disturbance (cut or fill)? If so, how many cubic yards and where will materials be deposited (both temporarily and permanently)? If fill materials are taken, identify the specific site fill taken from and if the materials are native to the park. How would fill be "stored"?**
  - This project does not involve cut or fill ground disturbance. Signs would not be placed on posts, and therefore not holes would need to be dug.
- **How much excavation would be necessary (quantify by width, length, depth, cubic feet, number or lines, etc.)**

- None
- **Would the proposal involve work in or near a known archeological site or other historic property?**
  - Exotic mountain goat removal activities could occur in or near known archeological sites or other historic property.
- **Would a staging area be required? If so, identify staging area(s), include map, what type of materials and/or equipment and for how long? What would be the estimated square footage of the staging are?**
  - Staging areas for capture and lethal removal operations are described above. They would not be in wilderness
- **How/where would construction debris be disposed of?**
  - N/A
- **How much surface area would be disturbed, cleared, or denuded of vegetation (quantify by square footage, # of trees removed, etc.)**
  - None to very little if there's a need to move (by dragging) a lethally removed goat out of sight of visitors/out of high use areas. The disturbance to vegetated areas would be trampling.
- **Would the project involve any geologic or hydrologic features/alter stream courses, surface or ground water flow?**
  - No
- **Would the proposal involve structures, fill, or discharge into water (example: bridge crossing, boardwalk, gravel, culverts, etc.)?**
  - No
- **Would the proposal affect water quality or quantity?**
  - No
- **What changes would occur in land/facility use?**
  - None
- **What changes would occur to traffic flow or visitor circulation?**
  - If area closures are implemented, visitors would not be able to enter those areas/hike those trails. If there is a need to conduct a lethal removal operation, those areas would be closed to visitor use and parking areas utilized as staging areas would also be closed to visitor use. These closures would be temporary, only long enough to conduct the operation.
- **Would the proposal require aerial operations?**
  - Translocation operations require aerial operations. Lethal removal operations would also require aerial operations. If it is determined that a necropsy is necessary on a lethally removed goat, then a helicopter may also be utilized to facilitate in the physical removal of the goat from an area to the frontcountry. Each year there would be a maximum of two 2-week operations (in July and in August or September) of 8 flight hours per day. There may be up to 2 helicopters in the air at one time, weather and funding dependent (this is the maximum, the actual likelihood is much less).
- **Would the proposal alter visitor services, activities, or experiences?**
  - If area closures are implemented, visitors would not be able to enter those areas/hike those trails. If there is a need to conduct a lethal removal operation, those areas would be closed to visitor use and parking areas utilized as staging areas would also be closed to visitor use. These closures would be temporary, only long enough to conduct the operation.
- **Where would the action take place?**
  - The translocation and lethal removal operations would take place in areas where goats are located.
- **When would the action take place?**
  - For two weeks during the month of July or August/September for at least 2-3 years, depending on the success of the capture and translocation operations.
- **What design and standards would apply?**
  - Helicopter safety, developed in a Helicopter Safety Plan, as well as staff and visitor safety protocols.
- **What methods, tools, and techniques would be used?**
  - Nuisance control measures: Nuisance control measures would be employed minimally as needed on a case-by-case basis and the specific actions would be the same range from hazing to lethal removal as identified under the no action alternative.
  - Interpretive tools: Increased interpretation including media outreach and website resources,

detailed information provided regarding areas of potential closure.

- Access tools: Hiking into and out of areas for ground-based capture operations; helicopter use to drop off equipment (e.g., nets), to capture mountain goats in remote areas and to transport them out to staging areas for transfer to WDFW for translocation to receiving locations; hiking into and out of areas for ground-based lethal removal; helicopter or fixed-wing airplane use for lethal removal of mountain goats from the air.
- Tools for capturing mountain goats: Ground-based capture methods including drop nets, foot snares, darting, and clover traps; air-based capture methods including net guns and darting; as applicable, use of methods in 351DM2-351DM3 “Aerial Capture, Eradication and Tagging of Animals (ACETA) Handbook” (DOI 1997).
- Park closure tools: Short-term closures of limited areas for ground capture, hazing, and lethal removal actions; short-term closures of areas surrounding staging areas for takeoff and landing of helicopters (outside of wilderness).
- Baiting tools: Salt blocks could be used as a tool to attract mountain goats for capture.
- Lethal removal firearms: Lethal dispatch of mountain goats injured during management activities, as well as in the lethal removal of non-injured goats in the park.
- Animal welfare tools and considerations: All humane management methods and regulations would be taken into consideration and implemented as applicable.

- **How long would it take to complete the action?**
  - Approximately two to three years for initial capture and translocation actions and then another year or two for lethal removal, or occurring as needed until the goat population is at zero.
- **What mitigation would be taken to minimize action impacts on park resources and values, and wilderness resources and character (where applicable)?**
  - Research and monitoring activities would take place opportunistically based on available funding. Possible research and monitoring efforts could involve management efficacy analysis and mountain goat population studies. Mountain goat population surveys would be conducted in a similar nature as under the no-action alternative.
  - Helicopter staging area preparation, if necessary, would occur prior to the proposed action, preferably during the early to late fall, unless otherwise agreed.
  - Project staff would coordinate flight schedules and paths with Naval Air Station Whidbey Island to ensure operations on Olympic Peninsula and in the north cascades forests do not interfere with active military training routes.
  - When possible, helicopter overflight paths would avoid highly developed areas and residences.
  - During management activities at staging areas, staging areas that are not already behind gates would be otherwise secured.
  - Capture and translocation efforts would strive to minimize stress and to protect the welfare of individual animals, including attempts to keep nannies and kids together.
  - Public notification of activities affecting wilderness would be provided, and appropriate information would be distributed at visitor centers.
  - Project staff would access wilderness areas via foot or by riding stock where possible, without risking life or limb. This would be considered for travel to sites accessible by trail or non-technical cross-country travel (e.g. without the use of crampons, ice axes, rope or other specialized equipment).
  - Foot travel would be considered for both baiting mountain goats ahead of time and during the capturing operational period, to limit trammeling and impeding solitude/primitive recreation from helicopter operations. Capture sites to be considered for primitive travel of personnel include, but are not limited to, Marmot Pass in the Buckhorn Wilderness and Wilderness portions of Mount Ellinor, Mount Skokomish Wilderness.
  - Duration and geographic scope of actions and disturbances would be minimized in wilderness areas.
  - The tool that would cause the least amount of disturbance to wilderness would be used for all management actions.
  - “Leave No Trace” principles would be applied to all management actions.
  - Motorized equipment would be use on approved roads only.
  - Helicopter operations would not be conducted within a minimum of 500 feet from marbled murrelet and northern spotted owl habitat.
  - Helicopter flight paths to and from staging areas would be designed to minimize noise

impacts to wildlife and visitors to the greatest practical extent.

- Area closures in the immediate vicinity of mountain goat capture, lethal removal, and release operations would minimize noise impacts to backcountry visitors.
- Previously agreed upon travel corridors and flight altitudes for helicopters would be used during operations
- Contractors and other project workers would properly store and dispose of food and garbage while working on site.
- Staging areas would be located in areas that are previously disturbed, and would necessitate the least amount of affect to wildlife and wildlife habitat.
- Lead-free ammunition would be used for lethal removal activities to prevent contamination.
- Exotic invasive plant management measures would be taken.
- Vegetation removal would be minimized near staging areas as necessary to facilitate flight paths and safe operating procedures.
- If any individual spotted owl or marbled murrelet is observed during project operations, a wildlife biologist would be notified and measures to minimize or eliminate take would be applied.
- Previously agreed upon travel corridors and flight altitudes for helicopters would be used during operations.
- At staging areas, restoration activities would be conducted, such as soil aeration and restoration and erosion control structures (if needed) to reverse the effects of compaction.
- At staging areas, removal of loose rock in pits would be minimized as necessary, but would be required for safe helicopter operation.
- If subsurface archaeological evidence or previously unidentified cultural resources are located during implementation of the project, activities would cease pending an evaluation of cultural eligibility by a qualified archaeologist, who would determine appropriate mitigation measures. Project staff would fulfill its consultation requirements in accordance with 36 CFR 800.11.
- Staging areas would be surveyed if ground disturbing activities are required. These would go through Washington State Historic Preservation Office review prior to implementation and use.
- Temporary and limited road closures during translocation of goats to release sites would be required on FR 1550 and FR 49. This would result in closure of the La Rush/Bear Lake and Curry Gap Trails while translocation staging is taking place. This may occur during two periods in two-week intervals (mid-July and late August/early September).
- Project vehicles would maintain a speed at or below 15 mph along particular roads.
- A traffic control plan would be developed for USDA Forest Service Road 2419 and USDA Forest Service Road 2500 prior to implementation. Involvement with federal law enforcement officials would be needed.
- A communication plan would be developed by the NPS, USDA Forest Service and WDFW that would include information on the ecological purpose and need of the activity and any area closures for visitors. News releases, signage, website, and other forms of communication would be prepared well in advance.
- Project staff would be properly trained regarding adherence to safety protocols identified in the Olympic National Park *Mountain Goat Action Plan*.

9	Evaluate the impacts of each alternative	Potential impacts to evaluate under <u>each</u> alternative: • Wilderness character effects • Effects on natural resources • Cultural resources considerations • Social/recreational/experiential effects • Societal/political effects • Health/safety concerns • Economic/timing/sustainability considerations

Alternative 1: No Action

Wilderness character effects (untrammeled, natural, undeveloped, solitude or a primitive & unconfined type of recreation)

Positive effects:

- Untrammeled: None; the goat population would be intentionally manipulated under this alternative – hazing and marking would continue as would the lethal removal of nuisance goats.
- Natural: The number of goat carcasses introduced into the natural environment would be less than Alternative 2, thus there would be less scavengers feeding on carcasses and altering their normal behavior. This alternative also involves less aircraft use and less high-powered rifle use, thus reducing impacts on the natural soundscape.
- Undeveloped: Under the no action alternative there wouldn't be as much helicopter use as under alternative 2 for capture and translocation operations, as well as for lethal removal operations.
- Solitude or a Primitive & Unconfined Type of Recreation: Under the no action alternative there wouldn't be as much aircraft use as under alternative 2 for capture and translocation operations, as well as for lethal removal operations. There would be less management restrictions on visitors (i.e., area closures) due to goat removal activities than in Alternative 2.

Negative effects:

- Untrammeled: Aversive conditioning to modify goat behavior would continue, as would lethal removal of goats.
- Natural: Non-native mountain goats would still be present within the park and therefore would continue to have a negative effect on the natural quality of wilderness character. See Chapter 4 in the PLAN/EIS, specifically the impacts to wilderness/wilderness character for more detailed information.
- Undeveloped: There would be helicopter use from lethal removal operations in line with protocols in the *Mountain Goat Action Plan* as part of the park's Hazard and Nuisance Animal Plan, Helicopters would also be used for annual aerial monitoring. Paintball marking, permanent markers on goats including ear tags and radio collars would be used.
- Solitude or a Primitive & Unconfined Type of Recreation: Under this alternative, while there wouldn't be as much helicopter use as under Alternative 2, there would still be some helicopter use adversely affecting opportunities for solitude. There would still be some areas closed to visitor access during hazing or lethal removal.

Effects on natural resources

Positive effects: The number of goat carcasses introduced into the natural environment would be less than Alternative 2, thus there would be less scavengers feeding on carcasses and altering their normal behavior. This alternative also involves less aircraft use and less high-powered rifle use, thus reducing impacts on the natural soundscape.

Negative effects: Mountain goats would continue to directly compete for forage resources with native wildlife species and would continue to degrade habitat used by other wildlife species. As the mountain goat population continues to grow, it would increase the potential for heavier, sustained browsing and grazing on plant communities in existing mountain goat summer and winter range within the park and on adjacent national forest land. Additionally, it is expected that mountain goat habitat use and associated herbivory could expand over a larger area. Grazing pressure would be especially likely to intensify in areas of habitat preferentially selected by goats, such as rocky outcrops and cliffs, leading to increased impacts on plant communities in those habitats. Olympic subalpine and alpine plant communities are particularly sensitive to soil disturbance, therefore, soil disturbance associated with wallowing or rutting behavior would be expected to compound the impacts on vegetation associated with herbivory. The use of helicopters and/or firearms during lethal removal activities may cause short-term disturbance of some wildlife species causing them flee or flush their habitat. Mountain goats would continue to disturb sensitive alpine and subalpine soils by wallowing, trailing, and trampling. These behaviors would continue to remove and eliminate surface rocks and vegetation, exposing the sensitive mineral soils beneath. Over time, these impacts would expand geographically and would increase in intensity as the mountain goat population continues to grow and disperse. Considering the slow development of these sensitive soils, it is likely that they would be unable to recover in the near future resulting in long-term impacts to soils.

Cultural resources considerations

Positive effects: No salt blocks would be placed that would attract goats and have the potential for goat disturbance on any cultural resources that may be present.

Negative effects: Under the no-action alternative, the park would continue nuisance control activities such as lethal removal and hazing of mountain goats exhibiting unacceptable behavior but these management activities are not anticipated to slow the projected growth of the mountain goat population. Instead, the population is expected to increase under the no-action alternative. This increase would result in a higher likelihood of impacts to archeological resources from wallowing, trailing and trampling behaviors. These impacts would expand geographically and in intensity as the population grows and disperses. Impacts to archeological sites in the project area would therefore be adverse and permanent in nature.

Social/recreational/experiential effects

Positive effects: Mountain goats would continue to be present in alpine and subalpine areas of the park and national forest where they are currently found, and may both increase in number and expand their habitat use to additional areas. The likelihood that visitors to the backcountry could encounter mountain goats would persist and could potentially increase. Long-term beneficial impacts would result for visitors whose experience is enhanced by the presence of mountain goats. Long-term beneficial impacts would also result for hunters in Olympic National Forest (ONF), since mountain goats would continue to be available for hunting and the likelihood of harvesting a goat may increase with an increase in population. Visitors' experiences would not be affected by aircraft conducting goat operations during July for 3-5 years.

Negative effects: Mountain goats would continue to be present in alpine and subalpine areas of the park and national forest where they are currently found, and may both increase in number and expand their habitat use to additional areas. The likelihood that visitors to the backcountry could encounter mountain goats would persist and could potentially increase. Long-term adverse impacts would result for visitors who do not wish to encounter goats because of safety concerns or other reasons. Intermittent access restrictions and trail closures due to reports of negative human-mountain goat interactions would likely continue and could possibly become more frequent or widespread, resulting in long-term adverse impacts to visitor use and experience. Visitors would be adversely affected by helicopter and firearm noise disturbances during instances that warrant lethal removal of nuisance goats.

Societal/political effects

Positive effects: Some visitors, local citizens, and interest groups enjoy seeing the goats; these groups would be more amenable to having only nuisance goats being lethally removed as under the no action alternative rather than all goats being translocated and others lethally removed as in Alternative 2. Individuals or groups with values that hold that an individual animal's right to life outweigh non-native species lethal removal would be more amenable to this alternative over Alternative 2.

Negative effects: Some visitors and local citizens are very frightened of the goats, especially after the death of a local area resident who was hiking in 2010, and want the goats completely removed from the park. Under the no action alternative, no goats would be removed from the park with exception of those that become nuisance animals and then are lethally removed.

Health/safety concerns

Positive effects: The no action alternative would not have near as many helicopter flights as Alternative 2 and therefore would have a lesser risk of helicopter-related safety issues. Interpretive and educational materials would continue to be distributed to the public at NPS and USDA Forest Service visitor facilities, and would be made available online. Signage would continue to be placed at trailheads, and NPS and USDA Forest Service would continue to conduct outreach to visitors regarding mountain goat safety and proper reporting of mountain goat interactions. These actions would somewhat mitigate the potential for adverse impacts on visitor safety, but would not eliminate it.

Negative effects: Under the no-action alternative, the continued presence of mountain goats in Olympic National Park and adjacent areas of Olympic National Forest would result in a long-term visitor safety risk because the potential would remain for negative interactions between humans and mountain goats. Trail closures and access restrictions would be implemented as necessary in the event of a conflict between a goat and a visitor. Over time, the increase of the mountain goat population and potential expansion of mountain goat distribution would offset the beneficial effects of outreach, education, and access restrictions. Overall, the no-action alternative would have long-term adverse impacts on visitor safety.

There would be potential under the no-action alternative for injuries to NPS and USDA Forest Service employees and contractors during mountain goat management actions such as monitoring, aversive conditioning/hazing, animal marking, lethal removal of hazardous goats, and other mountain goat management activities. Actions associated with mountain goat management could at times involve the use of helicopters through dangerous high elevation terrain as well as the use of firearms in backcountry areas, which would present additional safety risks. The potential for employee accidents and injuries would be mitigated through proper training of staff and adherence to safety protocols identified in the Olympic National Park *Mountain Goat Action Plan* (NPS 2011a). Employee safety risks would persist in the long term, however, because mountain goats would remain in the Olympic Mountains indefinitely. Additionally, the continued growth of the mountain goat population and potential expansion of distribution in the long term would be likely to increase the need for aversive conditioning and lethal removal activities, which could exacerbate risks to employee safety. As a result, the no-action alternative could have long-term adverse effects on employee safety.

Economic/timing/sustainability considerations

Positive effects: The no action alternative requires less financial resources to manage goats than Alternative 2.

Negative effects: The park does not have the level of fiscal and staffing resources to fully implement the *Mountain Goat Action Plan*. There are also costs associated with the on-going removal of nuisance animals and with revegetation efforts (in areas where wallowing has greatly affected vegetation resources).

Alternative 2:

Wilderness character effects (untrammeled, natural, undeveloped, solitude or a primitive & unconfined type of recreation)

Positive effects:

- Untrammeled: A federally-authorized action would occur (removal of non-native mountain goats) that would manipulate the biophysical environment to help restore its natural conditions.
- Natural: Removing non-native mountain goats from the park would support the recovery of natural conditions (soils and endemic plants) of the park, as well as remove a vector for non-native species dispersal on the Olympic Peninsula.
- Undeveloped: Helicopters and firearms would be used for goat capture and translocation as well as for lethal removal operations.
- Solitude or a Primitive & Unconfined Type of Recreation: With the goats eventually removed from the park, visitors may feel less concerned about recreating in the park, especially in areas where goats are currently known to inhabit.

Negative effects:

- Untrammeled: A federally-authorized action would occur (removal of non-native mountain goats) that would manipulate the biophysical environment. Direct human intervention from the air for goat capture operation would be done through either the use of immobilizing drugs or net guns, delivered from a helicopter; ground-based capture methods would include baiting, drop nets, foot snares, and darting. Direct human intervention from lethal removal operations would include firearms and goat carcasses resulting from lethal reduction would be left in the field unless located near trails, campsites, or where visible from high visitor use areas.
- Natural: Noise from helicopter and firearm use, as well as increase and concentrated staff presence may disturb wildlife. Salt block may be used to bait goats and may also attract other

wildlife. See Chapter 4 in the plan/EIS, specifically the impacts to wilderness/wilderness character for more detailed information.

- Undeveloped: Use of helicopters and firearms for goat capture and translocation as well as lethal removal operations. Salt blocks would be placed, possibly up to a year in advance of capture events.
- Solitude or a Primitive & Unconfined Type of Recreation: Use of helicopters and firearms during capture and translocation as well as lethal removal operations would create noise disturbances and may disrupt visitor solitude; and area closures would have a negative impact on unconfined recreation.

Effects on natural resources

Positive effects: Mountain goat removal by capture and translocation as well as by lethal removal would allow natural resources and processes to return to pre-goat conditions to the extent practicable given current climate conditions. With the removal of goats there would be no damage to soils and endemic plants due to wallowing. With the removal of goats there would be less competition for habitat and food sources with other, native or endemic species. In the long term, the substantial reduction in the mountain goat population and the dispersal of the small number of goats that may remain in the ecosystem would result in much lower pressure on alpine and subalpine plant communities from goat herbivory. Lethal removal from aircraft would not have adversely affect vegetation.

Negative effects: Baiting with salt blocks could be used to concentrate mountain goats for easier capture, and these salt blocks could attract other unintended wildlife such as deer. Air-based capture operations could involve the use of drugs or net guns to immobilize mountain goats which would have disturbance effects on other wildlife due to noise. Ground-based capture operations could involve drop nets, foot snares, and darting which would also disturb other wildlife due to increased presence of humans and human activity. Once captured, mountain goats would be subdued by animal handlers at which point they may or may not be sedated for transport. While capture efforts would strive to minimize stress and to protect the welfare of individual animals (including attempts to keep nannies and kids together), there is potential for injury and death of animals from accidents and stress resulting from these capture efforts. Management activities in mountain goat habitat under Alternative 2 would also involve some level of lethal removal of mountain goats using firearms. Hunting and the use of firearms is prohibited in the national park and therefore are not normal sounds wildlife are used to, therefore, noise from firearm use could cause disturbance to wildlife. The use of aircraft in mountain goat habitat would produce sound that could impact wildlife causing them to temporarily disperse or retreat into dens. Short-term adverse impacts to vegetation from management activities in mountain goat habitat under alternative B would result from trampling or crushing of vegetation associated with management personnel entering mountain goat habitat on foot and handling of captured mountain goats on the ground. These impacts would be intermittent, localized, would occur most frequently during the initial phase of reduction, and would not be substantial.

Cultural resources considerations

Positive effects: The removal of mountain goats would eliminate the occurrence of wallowing in the park which has unearthed previously unknown archeological sites and would remove the potential to disturb any other unknown archeological sites in the future.

Negative effects: Capture and translocation activities could occur where known or unknown archeological sites are present. Baiting, such as the use of salt blocks, would likely be used to attract mountain goats to suitable areas for carrying out management activities. There is the potential for baiting to impact archeological sites if salt blocks are placed in locations where sites are present. Mountain goats would be attracted to these areas and could trample archeological materials near the bait. However, given the low density of archeological resources and the small areas where the bait would be placed, there is a low potential for these impacts to occur. Previously unknown archeological sites could be inadvertently disturbed or damaged.

Social/recreational/experiential effects

Positive effects: With the goats eventually removed from the park, visitors may feel less concerned about recreating in the park, especially in areas where goats are currently known to inhabit.

Negative effects: Use of helicopters and firearms during capture and translocation as well as lethal removal operations would create noise disturbances and may disrupt visitor experience; and area closures would have a negative impact on visitor use and experience. Some visitors enjoy seeing the goats and may be disappointed if goats are removed entirely from the park.

Societal/political effects

Positive effects: Some visitors and local citizens are very frightened of the goats, especially after the death of a local area resident who was hiking in 2010, and want the goats completely removed from the park.

Negative effects: Some visitors, local citizens, and interest groups enjoy seeing the goats; these groups would not want to see the goats removed from the park. Individuals or groups with values that hold that an individual animal's right to life outweigh non-native species lethal removal would be more amenable to this alternative over Alternative 2.

Health/safety concerns

Positive effects: Under Alternative 2, areas where active capture and removal operations are ongoing would be temporarily closed to park visitors. NPS park rangers would patrol public areas to ensure compliance with park closures and public safety measures. The public would be notified of closures in advance. Information regarding mountain goat management activities would be available at visitor centers and posted on the park's website to inform the public of mountain goat management actions. Capture and translocation of mountain goats within the park and adjacent areas of Olympic National Forest would be carried out only by qualified, properly trained NPS employees and contractors. Employees would apply safety training and awareness measures designed to reduce safety risks, including adherence to safety protocols outlined in the Olympic National Park *Mountain Goat Action Plan* (NPS 2011a). The greatest potential for adverse impacts to employee and visitor safety under Alternative 2 would be in the short term, during initial capture and translocation activities. In the long term, with a reduced population size, the potential for hazardous interactions between humans and mountain goats would be substantially reduced, resulting in long-term beneficial impacts on visitor safety. The frequency with which employees would need to engage in aversive conditioning, animal marking, and other activities used to manage dangerous goats would also decrease, resulting in beneficial impacts on employee safety. While occasional mountain goat management actions would be necessary over the long term to maintain the mountain goat population as close to zero as possible, these activities would be expected to take place on an increasingly infrequent basis.

Negative effects: Short-term adverse impacts on employee safety could result from potential injuries (kicks, bites, stabbing with horns) that may occur during handling of live goats during capture. Helicopter-based capture operations would present risk of accidents or injuries to NPS employees and contractors during capture and translocation efforts. If an accident occurred, the adverse impact to employee safety could be substantial, even catastrophic; however, the likelihood of an accident occurring is considered to be minimal. NPS employees and contractors taking part in helicopter-based operations would be highly trained and qualified, and required to observe proper safety protocol.

Economic/timing/sustainability considerations

Positive effects: With the removal of goats completely from the park, over the long-term this action would save the park significantly from having to hire seasonal staff each year to perform hazing actions to implement the *Mountain Goat Action Plan*.

Negative effects: The costs over the 3-5 years or more to implement this project are substantial in the short-term but would provide greater long-term benefits in costs, resource protection, and visitor and staff safety.

10	**After approval by the Deputy Superintendent to proceed, update the PPF/MRA with input provided by the Compliance Council and/or the Interdisciplinary Planning Team (IDP) and provide an electronic copy to the Planning and Compliance Office to initiate park internal review and comment.** **Comments due by:_____**

Wilderness Specialist Comments:

Comments have been integrated throughout.

Reviewed by: ____**Ruth Scott**_____ **Date:**__**8-14-16/12-14-16**_____

After the established review period, contact the Planning and Compliance Office to schedule a discussion of your issue at a park Compliance Council meeting to recommend a preferred alternative and complete the review process.

11	Select the alternative that will most effectively resolve the issue while having the least overall adverse impact on park resources & values and wilderness resources, character and the visitor experience		*Note:* When selecting the preferred alternative for actions in wilderness, the potential disruption of wilderness character and resources will be considered before, and given significantly more weight than, economic efficiency and convenience. If a compromise of wilderness resources or character is unavoidable, only those actions that preserve wilderness character and/or have localized, short-term adverse impacts will be acceptable.

Preferred alternative: 2 (PLAN/EIS Alternative D)

Describe rationale for selecting this alternative including how it meets minimum requirement guidelines and how impacts to wilderness will be minimized and mitigated (if applicable). Also, describe the safety risks and the preventive/mitigation measures that would be implemented:

Alternative 2 has short-term negative impacts to all qualities of wilderness character, however, the long-term beneficial impacts far outweigh the short-term negative, while meeting NPS Management Policies 2006 Removal of Exotic Species (section 4.4.4.2) management requirements. Alternative 2 was selected as the preferred alternative because, over the long-term, it has less negative impacts and greater beneficial impacts to wilderness character, specifically, the natural quality of wilderness character. This alternative would remove a non-native species; would help the restoration of soils and endemic plant species; and would reduce competition for forage and habitat between a non-native and native wildlife species. This alternative would also have greater long-term beneficial impacts on the undeveloped quality of wilderness character as there would be less need for helicopter flights and the use of firearms for lethal removal of nuisance goats for the long-term. Additionally, Alternative 2 would also have greater long-term beneficial impacts on opportunities for solitude and unconfined types of recreation as with the removal of mountain goats there would be less need for area closures for lethal removal of nuisance goats, less need for hazing operations, and no need for visitors to avoid areas of the park due to their fear of goats.

There are safety risks involved with Alternative 2 and these include potential injuries (kicks, bites, stabbing with horns) that may occur during handling of live goats during capture. Helicopter-based capture operations would present some risk of accidents or injuries to NPS employees and contractors during capture and translocation efforts. If an accident occurred, the adverse impact to employee safety could be substantial and could result in death; however, the likelihood of an accident occurring is considered to be minimal. NPS employees and contractors taking part in helicopter-based operations would be highly trained and qualified, and required to observe proper safety protocol. Areas where active capture and removal operations are ongoing would be temporarily closed to park visitors. NPS park rangers would patrol public areas to ensure compliance with park closures and public safety measures. The public would be notified of closures in advance. Information regarding mountain goat management activities would be available at visitor centers and posted on the park's website to inform the public of mountain

goat management actions. Capture and translocation of mountain goats within the park and adjacent areas of Olympic National Forest would be carried out only by qualified, properly trained NPS employees and contractors. Employees would apply safety training and awareness measures designed to reduce safety risks, including adherence to safety protocols outlined in the Olympic National Park *Mountain Goat Action Plan* (NPS 2011a). The greatest potential for adverse impacts to employee and visitor safety under Alternative 2 would be in the short term, during initial capture and translocation activities. In the long term, with a reduced population size, the potential for hazardous interactions between humans and mountain goats would be substantially reduced, resulting in long-term beneficial impacts on visitor safety. The frequency with which employees would need to engage in aversive conditioning, animal marking, and other activities used to manage nuisance goats would also decrease, resulting in beneficial impacts on employee safety. While occasional mountain goat management actions would be necessary over the long term to maintain the mountain goat population as close to zero as possible, these activities would be expected to take place on an increasingly infrequent basis.

The plan/EIS analyzed four alternatives. While, based on impact analysis section in Chapter 4 of the plan/EIS, Alternative C (lethal removal only) was determined to have the least amount of impacts on overall wilderness character (only due to less frequent and shorter duration of maintenance activities), the planning team determined that Alternative D (Alternative 2 in this MRA - combination of capture and translocation and lethal removal) within plan/EIS would provide the park with the best direction for the overall management of exotic mountain goats. This determination was made during an IDT workshop with the project's Cooperating Agencies. A process was followed that identified whether and to what extent each alternative in the draft plan/EIS addressed the plan's seven objectives as identified on page 2 of the plan/EIS, one of which was, "Protect the wilderness character of Olympic National Park." A preferred alternative is the alternative that "would best accomplish the purpose and need of the proposed action while fulfilling [the NPS] statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors" (2015 NPS NEPA Handbook). These factors were also taken into consideration.

Reviewed by: _____ **Date**_____

Wilderness Specialist

Leadership Team Comments on Preferred Alternative (recommendation to Superintendent for final review and approval)

Administration Division comments/recommended mitigations:

Reviewed by Administrative Officer: _____ **Date**_____

Interpretation Division comments/recommended mitigations:

Reviewed by Chief of Interpretation: _____ **Date**_____

Cultural Resources comments/recommended mitigations (include next steps for compliance with NHPA, other applicable cultural resource law/policy):

Reviewed by Section 106 Specialist: _____ **Date**_____

Visitor and Resource Protection Division comments/recommended mitigations:

Reviewed by Chief Ranger: _____ **Date**_____

Facilities Management Division comments/recommended mitigations:

Reviewed by Chief of Facilities Mgmt:_____ **Date**_____

Natural Resources Division comments/recommended mitigations:

T & E Species Determination of Effect (No Effect (NE), Not Likely to Adversely Affect (NLAA), Likely to Adversely Affect (LAA):

- **Bull Trout:**_____
- **Marbled Murrelet:**_____
- **Northern spotted owl:**_____
- **Other:**_____

Reviewed by Chief of NRM: _____ **Date**_____

Compliance Pathway Determination:

Categorical Exclusion: _____ **EA:** _____ **PLAN/EIS:** ____X____

Recommended by Env. Protection Specialist:_____ **Date:**_____

Approved by:

_____ _____

Superintendent **Date**

APPENDIX F: OLYMPIC, MT. BAKER-SNOQUALMIE, AND OKANOGAN-WENATCHEE NATIONAL FORESTS MINIMUM REQUIREMENTS ANALYSIS

United States Department of Agriculture

Draft Minimum Requirements Analysis

Mountain Goat Removal from Olympic National Forest Wilderness Areas

Forest Service	Olympic National Forest	Hood Canal Ranger District	September 2016

Responsible Official:
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Mountain Goat Removal from Olympic National Forest Wilderness Areas

Purpose

This minimum requirements analysis is an assessment of proposed administrative actions associated with the removal of mountain goats, affecting Olympic National Forest Wilderness Areas. This analysis is a mandatory procedure, required by the Wilderness Act of 1964, to determine whether the proposed restricted activities are appropriate methods or actions for achieving the desired land management objectives in wilderness. Discussion of advantages or disadvantages of the proposed mountain goat removal project are beyond the scope of this inquiry.

Introduction

Olympic National Park proposes the elimination of the mountain goat (*Oreamnos americanus*) populations in the Olympic Mountains. Mountain goats are not locally indigenous to the Olympic peninsula (Festa-Bianchet, Côté 2012, 11-12). Populations primarily reside in Olympic National Park (Noss et al. 2000). However, groups range from the Olympic Wilderness in the park into neighboring The Brothers, Buckhorn, Colonel Bob, Mount Skokomish, and Wonder Mountain Wilderness areas, in Olympic National Forest. Mountain goat migration between National Park Service and Forest Service lands necessitates cooperative management action.

The proposed administrative actions on wilderness areas affect the "biophysical, experimental, and symbolic ideals" described as *wilderness character* (Landres et al. 2005, iii). Wilderness character qualities include the following distinct attributes:

- Untrammeled—areas essentially unhindered and free from human manipulation
- Natural—areas with ecological systems largely separate from direct human influence
- Undeveloped—areas restrict permanent improvements and are unoccupied
- Solitude or Unconfined Recreation—provides outstanding opportunities for solitude or primitive types of unconfined travel for the purposes of enjoyment
- Other features of Value—areas may contain other features of value that enhances wilderness character.

Wilderness character attributes derive from the Wilderness Act. While the qualities are not specifically mentioned in the law, these qualities are foundational to wilderness management decision-making.[1]

[1] Wilderness Act of 1964. Section 4 (b): "Except as otherwise provided in this Act, each agency administering any area designated as wilderness shall be responsible for preserving the wilderness character of the area and shall so administer such area for such other purposes for which it may have been established as also to preserve its wilderness character."

Wilderness character attributes on Olympic National Forest potentially impacted include: *untrammeled*—manipulation of herbivore populations by translocating or culling the species; *natural*—direct human influence to the environment with the original introduction of mountain goats in the early 20th century; *solitude*—actions involve helicopters and other modern technology creating noise and visual impacts, detracting from visitor's experience of the primitive landscape; and *Other features of Value*—specifically, the unique and significant ecological value of the alpine ecosystem, the introduced mountain goat's primary habitat.

The intent of this minimum requirements analysis is to show, through a transparent process, trade-offs to wilderness character qualities that are likely to result on the forest (Cole and Yung 2010, 8-9). This document is a determination that 'prohibited uses' by the Wilderness Act, including helicopters and other and motorized equipment, meet the minimum necessary requirement for accomplishing the administrative goals for the project. It considers whether the utilization of non-compliant activities and methods in Wilderness are warranted and are concurrent with directives in Forest Service Manual 2320.

Background

The alpine ecosystems on the Olympic Peninsula is distinctive, resulting from areas relative geographic isolation. The Olympic Mountains are surrounded by open ocean, the Strait of Juan de Fuca, Hood Canal and a broad coastal plain. The region was further isolated during the Holocene by glaciers. The region is, in effect, a biotic island. As a result, the ecosystem hosts flora and fauna found nowhere else in the world (NPS PMIS 2016). At least sixteen animals and eight plant species or species or subspecies are only found on the Olympic Peninsula. Examples include the Olympic Marmot, Olympic pocket gopher and Olympic milkvetch (NPS PMIS 2016). As a result of these scientific and scenic values, portions of Olympic National Park are designated as both an International Biosphere Reserve and a World Heritage site (UNESCO 2016a; UNESCO 2016b).

Mountain goats, first introduced in 1920 on the Olympic Peninsula, have since colonized most of the suitable high-country habitat in the Olympic Mountains. Long-term inventorying and monitoring studies show the non-indigenous mountain goats have a significant impact to the local alpine environment, as the largest herbivore (NPS DEIS 2016). The mountain goat population reached a peak of over 1000 goats in the early 1980's and was reduced to about 300 goats in the 1980's through live capture (in the National Park) and hunting (in the National Forest). In June of 2016, an aerial survey conducted by Olympic National Park and Washington Department of Fish and Wildlife estimated the mountain goat population greater than 600, increasing at approximately eight percent a year (National Park Service unpublished data). Statistical models show, with 95 percent confidence level, between 53 and 89 individuals in Olympic National forest. The preferred estimate is 59 mountain goats (USGS, Olympic Field Station unpublished analysis, September 2016).

The mountain goat population's impact to fragile alpine ecosystems is significant, according to the Park Service draft mountain Goat management plan. Their browsing, trampling and wallowing behavior impact delicate skeletal soils and rare plants, ultimately degrading wilderness character values (NPS PMIS 2016).

Olympic National Park and Washington Department of Fish and Wildlife recommend the use helicopters for the following actions:

- Capture live mountain goats and haul via nets to locations outside of Wilderness
- Facilitate the lethal removal of mountain goats as a platform for sharpshooters
- Transport of personnel and equipment to accomplish operations in a safe and timely manner

In the initial phase of the operation, healthy mountain goats will be captured and transported by truck to sites on the Mount Baker-Snoqualmie and Okanogan-Wenatchee National Forests in the North Cascades. The translocation activities will occur in six operational episodes. Two, twelve-day periods in the summer months, over three years, 2018 through 2020. Proposed lethal removal of certain mountain goats is also estimated to take three years, as well. The project may possibly be extended for two additional years, 2021 through 2022 (NPS DEIS 2016).

Are the actions necessary in Wilderness?

The proposed actions are deemed necessary because mountain goat primary summer range on the Olympic Peninsula is within wilderness boundaries (Overflight survey, 2016). Mountain goats range outside of wilderness areas during winter months (Rice 2008). However, removal operations are only feasible while the animals are utilizing their summer range for the following reasons:

- Locating and capturing or shooting the animals is not possible when they are dispersed under canopy, below the timberline in non-wilderness areas. The animals are elusive and extremely difficult to locate.
- They should be captured during the time of year when they experience the least amount of environmental stress for successful translocation (Harris and Steele 2014).
- Capture or lethal removal only taking place in the Olympic Wilderness (NPS jurisdiction) will have no lasting effect since mountain goats will recolonize from the NFS wilderness areas. Multi-agency collaboration is required for success to meet agency objectives.

Options outside of Wilderness

Mountain goat populations range fluidly between Forest and Park wilderness areas. Their summer range is in wilderness alpine areas, as stated above. The Mount Washington group (approximately 31 individuals surveyed in 2012) in the vicinity of Mount Elinor and Mount Washington is, at times, an exception. The southeast face of the ridge where the group forages is outside the Mount Skokomish Wilderness. All other groups require capturing or lethal removal in wilderness areas.

Helicopter staging on forest

All proposed staging sites for helicopter and ground transportation operations are outside of wilderness areas. Overflights to and from the capture areas has the potential of

impacting wilderness character quality of Solitude. However, activities at staging areas pose no long-term affects to wilderness.

Helicopter staging areas requires a large space for taking off and landing as well as an adequate area for veterinary examination, containing the goats in portable pens, and room for transport vehicles. The staging areas also require adequate access, via an improved road, for moving the mountain goats from the forest to North Cascades release sites.

Hamma Hamma Gravel Pit

This administrate site, historically used for excavating and staging road-building materials, is located south of the Brothers Wilderness. The site is accessed by a gated spur drive, branching from the paved Hamma Hamma Road. The gravel pit is close in proximity to multiple mountain goat groups, both on Forest and in the Park.

Upper Mount Ellinor trailhead and FS Road 2419

This is a high-use public access point to the summit of Mount Ellinor, bordering the Mount Skokomish Wilderness. The 1.6 mile trail gains 2,444 feet of elevation from the parking lot to the summit. It is accessed from the paved State Route 119 to a gravel spur from FS Road 24. There are multiple points of access to the Mount Ellinor trailhead, both by designated trails and user-built trails from roads. System trails accessing the trailhead include number 812.1, 812.2, 827, 827.1 and 827.2. A compete closure of the trailhead to use as a helicopter staging area could be achieved by barricading FS Road 2419 at the junction of FS Road 24. The trailhead is within a mile of the largest group of mountain goats on the Forest on Mt. Ellinor and Mt. Washington.

Time constraints

The seasonal requirement for both capturing and translocating mountain goats is between July and early September. Capture operations will tentatively occur for twelve days in July and an additional twelve days in September. Time constraints are a primary factor in this analysis in several ways: the project must occur during the warmer/low-snow season when avalanche conditions make it safe for the goat team to be in the area, and when the goats are more readily accessible for capture.

Wilderness capture locations

The Olympic National Forest contains five designated Wilderness areas, totaling 88,256 acres. Established by the Washington State Wilderness Act of 1984, Public Law 98-339, these areas are contiguous with the Olympic Wilderness located in the National Park. The majority of the mountain goats are in the National Park, with about 12% in National Forest Wilderness.

The Brothers Wilderness

The Brothers Wilderness, totaling 16,682 acres, is located south of Buckhorn Wilderness and north of Mt. Skokomish Wilderness, between the Dosewallips and Hamma Hamma Rivers. There is abundant mountain goat habitat in the vicinity of The Brothers Peaks, elevation 6,866 feet, and Mount Jupiter, 5,701 to the north. There are seventeen miles of established trails within the wilderness. The 2016 survey estimates seven individual mountain goats in the group. They range in the vicinity of a popular climbing route to the

summit of South Brothers Peak. Removal of goats is a high priority in this area (USFS 2016d).

Buckhorn Wilderness

Buckhorn Wilderness totals 44,258 acres, and is divided into northern and southern management units by the Dungeness River and an access road system. The smaller northern portion, drained by the Gray Wolf River, descends from higher mountainous terrain with abundant mountain goat habitat. There are 59 miles of trail provide hiking, backpacking, and stock access to the Buckhorn Wilderness (approximately eleven miles in the North Unit and 48 miles in the South Unit). The Gray Wolf River trailhead and the Slab Camp trailhead provide access to the North Unit. Main access points to the South Unit include the Upper Dungeness trailhead, Tubal Cain trailhead, Upper Big Quilcene trailhead, Mt. Townsend trailhead, Tunnel Creek trailhead, and Little Quilcene trailhead (USFS 1993a). High elevations host a small mountain goat groups. The 2016 survey located three animals in four survey areas (mostly in Olympic Wilderness, adjacent to the forest). These groups are a lower priority for removal.

Colonel Bob Wilderness

The Colonel Bob Wilderness, 11,961 acres, is located in the south boarder of the Olympic Wilderness near Quinault Lake. Terrain is steep, rising from 1,300 feet to 4,509 feet in less than a mile. Colonel Bob Wilderness has three access points: the Ziegler Creek trailhead, Pete's Creek trailhead, and Fletcher Canyon trailhead. There are twelve miles of established trails that accesses the sub-alpine reaches of the management unit (USFS 2016b). While there is suitable mountain goat habitat in the wilderness, only one verified identified male mountain goat has been documented (2015). Mountain goat management activities are not a priority for the area.

Mount Skokomish Wilderness

Skokomish Wilderness, 13,015 acres, is southeast of the Olympic Wilderness. The wilderness is primarily accessed from the south from the Lake Cushman area, having the highest concentrated recreational use on the Forest. The wilderness hosts the largest groups of mountain goats on the Forest. The mountain goat groups range in the vicinity of Mounts Washington, Rose, Ellinor, and Jefferson Peak to Mount Pershing and from Mount Lincoln north to Mount Skokomish at 6,434 feet in elevation, on the northern boundary of the wilderness. There are twelve miles of established trails in the wilderness. Access to the southern boundary of the wilderness is from the Mount Rose and Mount Ellinor trails, the highest use in the forest. The interior of the wilderness is accessed from the Hamma Hamma River drainage on from the steep the Mildred Lakes Trail (SFS 2016c). The 2016 helicopter survey identified forty mountain goats, the largest population of mountain goats in the Forest. Removal of goats is this wilderness is the highest priority.

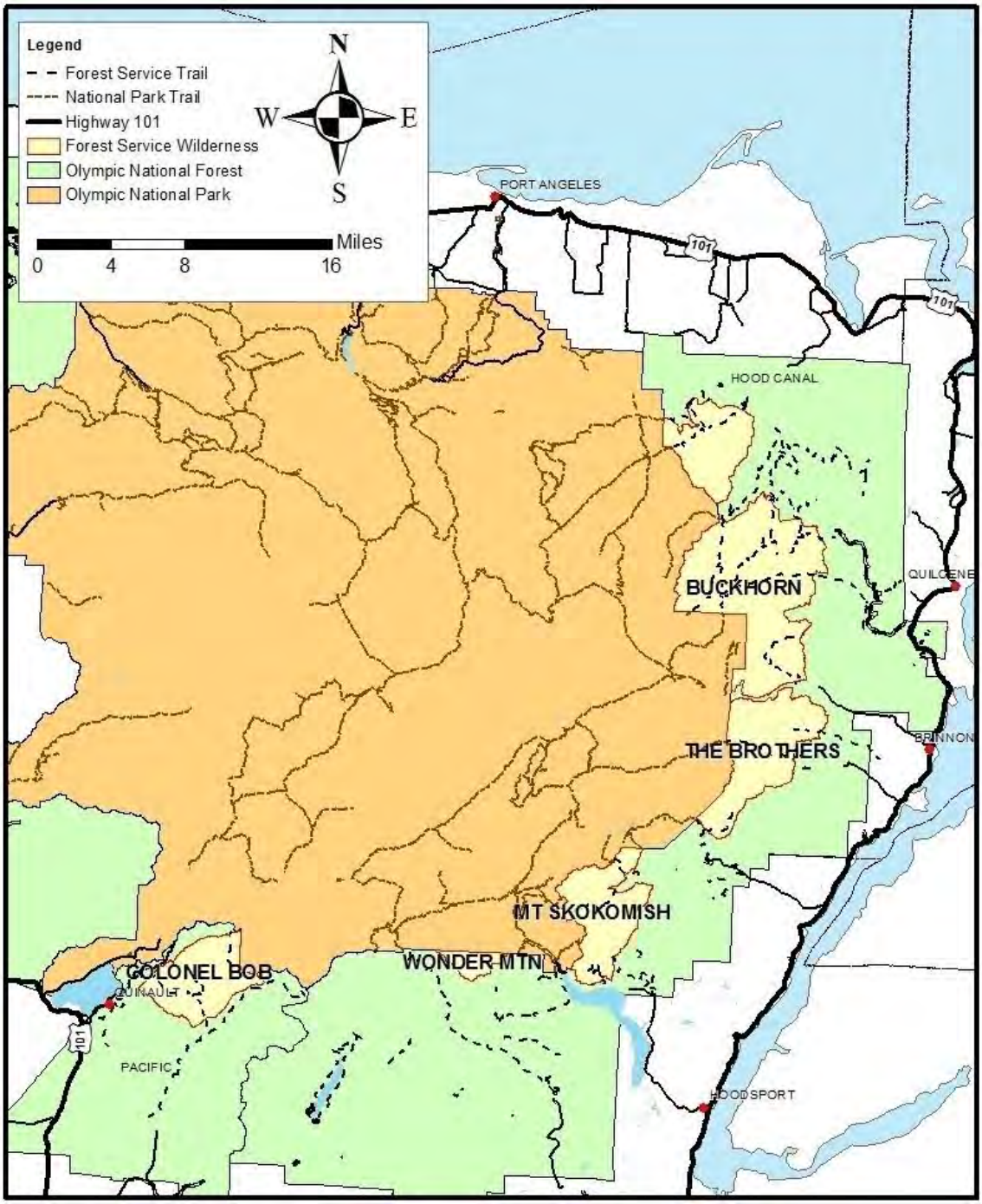
Wonder Mountain Wilderness

The 2,349 acre Wonder Mountain Wilderness is one of the smallest wildernesses in the Western United States (USFS 1993d). It is located on the southwestern side of the forest, east of Colonel Bob Wilderness and west of Lake Cushman. Wonder Mountain Wilderness rises from 1,740 feet to the 4,758 foot summit of Wonder Mountain. This wilderness is unique within Olympic National Forest because there are no established trails in the wilderness. The two main access roads to Wonder Mountain Wilderness have seasonal

closures from October 1 to April 30, to protect wildlife (USFS 2016e). The mountain goat population is unknown, making action in this area a low priority.

Olympic National Forest wilderness areas

An overview of the five wilderness areas potentially affected by the proposed actions, including removal of mountain goats by capturing and/or lethal removal are as follows (listed clockwise): Buckhorn, The Brothers, Mount Skokomish, Wonder Mountain, and Colonel Bob.



Criteria for determining necessity

Wilderness character

Administrative actions, or abstaining from actions, affects the untrammeled, natural, solitude or unconfined recreation as well as other features of value, specifically the ecological integrity of the wilderness areas. According to the proposal, ecological intervention actions are necessary to lessen negative effects to biotic communities resulting from introduction of the non-indigenous species. While outcomes to the wilderness areas are not predictable, removal of mountain goats is likely to have tangible long-term affects to the alpine and subalpine reaches for each of the wilderness areas.

Trade-offs include both the immediate potential negative effects of *trammeling* from helicopter landings and the potential for visual and noise disturbances, impeding the individuals' *solitude* experience. In addition, expected is long-term trammeling, since current management of the mountain goat population involves direct manipulation of the natural environment. However, there are long-term potential positive effects to the overall quality of the alpine ecosystem by intervening in ecological processes directly caused by the recent introduction of the non-indigenous species. In addition, negative habituated mountain goat and human interactions pose safety concerns. There is also the potential for future short-term recreational use limitations.

Desired outcomes include revegetation of heather, grasses and other alpine plant communities heavily impacted from mountain goat browsing and wallowing behavior, especially in areas where no natural salt is available and goats seek human-created salt. More subjective results include greater opportunities for visitor solitude and primitive recreation. Currently, mountain goat management activities impede on visitors' solitude from daily patrols monitoring conditioned mountain goats in wilderness to the occasional lethal removal of animals, as an extreme measure.

Minimum activity

As proposed, the administrative actions necessary to achieve the wilderness objective requires the use of methods and equipment noncompliant with wilderness regulations. Therefore, the minimum activity to bring about the desired management outcomes should be considered. This analysis considers whether essential methods for the capture, lethal removal and translocation activities are the minimum activity.

Policies and guidance

Valid existing rights or special provisions of wilderness legislation

Provisions in the Wilderness Act of 1964, Sec. 2 (c) (4) and Sec. 4 (d) (8), prohibits proposed actions, exclusive of meeting Wilderness Act "minimum requirements."
There are no known valid existing rights that the proposed actions infringes upon in the Olympic National Forest Wilderness areas, as referenced in the Washington State Wilderness Act of 1984, Public Law 98 through 339.

Requirements of other legislation

National Park Service is preparing a Mountain Goat Management Plan and an associated Draft Environmental Impact Statement addresses the requirements of the Environmental Policy Act of 1970. Alternatives outlined in the draft management plan influence the need for actions to take place in wilderness. Additionally, consultation for the Endangered Species Act of 1973 is addressed by the lead agencies, Olympic National Park and Washington Department of Fish and Wildlife. Forthcoming Biological Assessments associated with the proposed actions are likely to be concurrent with wilderness management objectives since mountain goats are not locally ingenious. Their ecological impacts may affect both threatened and endangered species as well as wilderness character qualities.

Agency directives and other requirements

Policies and Guidelines for Fish and Wildlife Management in National Forests and Bureau of Land Management Wilderness (United States Forest Service, Bureau of Land Management and International Association of Fish and Wildlife agencies, June 2006). Referenced in Forest Service Manual (2323.32 (5)) Policy.

> This document is intended as a framework for projects in Wilderness between state Fish and Game agencies and the BLM and Forest Service. In section F. 'Project Implementation,' subheading 1.) Use of Motorized Equipment' it states that mechanized equipment can be used "only if these devices are necessary to meet the minimum requirements for the administration of the area as wilderness or are specifically permitted by other provisions of the Act".

Forest Service Manual (FSM) 2326, Use of Motorized Equipment or Mechanical Transport in Wilderness

FSM 2326.1(5)

> Guidelines cites conditions under which the use of motorized and/or mechanized equipment use may be approved in wilderness. Directives specify conditions meeting minimum needs for protection and administration of the area as wilderness. These include:
>
> a) A delivery or application problem necessary to meet wilderness objectives cannot be resolved within reason through the use of non-motorized methods.
>
> b) An essential activity is impossible to accomplish by non-motorized means because of such factors as time or season limitations, safety, or other material restrictions.

Components of activities

Olympic National Park's proposed activities are grouped into the following steps. Specific details are covered in later sections under the *Alternatives* description.

- Transporting equipment and personnel by helicopter from remote landing sites to capture locations. Loads transported both inside the aircraft requiring a complete

landing and by external cargo net dropped to the location using a long line and remote hook.

- Teams of personnel capture mountain goats, one at a time. This occurs in open terrain, primarily along ridgelines and rocky outcrops. Loading the immobilized animal into a cargo net and attaching the load to the helicopter via a cable. Flying the goat to the staging area.
- Culling mountain goat groups using helicopters as a sharpshooting platform and to transport sharpshooter.

Capturing operations originate from two staging areas, to facilitate faster processing times. Mountain goats are captured, transported and processed at one time. Two stations are required because of the large spatial extent of mountain goat habitat, the dispersed nature of mountain goat groups, and the tendency for localized poor flying weather during summer months. Proposed staging areas are outside of wilderness. However, flight paths to and from staging areas may require flights below the 2000 feet above ground level recommendation, to minimize noise and visual impacts to recreationalists and affected wildlife.

Capture and translocation occur in most areas prior to culling mountain goats. Staff anticipate most, if not all, operations in the first year are live capture and transport. In the second year, more than half of operations are expected to be live capture. However, staff considers shooting habituated, unhealthy or difficult to access animals. In the final years, staff will conduct live captures, but then shift to a majority of lethal removal towards the end of the operational period.

Description of alternatives

Proposed activities on National Forest lands will be carried out by the lead organizations, Olympic National Park and Washington Department of Fish and Wildlife. Specific operational information is taken nearly verbatim from the Park's Draft "Wilderness Project Proposal Form and Minimum Requirements Worksheet" May 5, 2016, since they are the responsible agency. While proposed project details originate from materials provided by Olympic National Park, the selection of alternatives and the subsequent analysis herein is independent.

Olympic National Forest is considering three alternatives (two action and one no-action alternative) addressing the wilderness minimum requirements of the project:

- Alternative 1.) Helicopters for both mountain goat handling and transportation.
    - Helicopters utilized to capture and/or shoot mountain goats.
    - Fixed-wing aircraft will be used as spotting planes, for the purpose of locating groups of mountain goats. No landing of this type of aircraft will occur.
    - Helicopters utilized to transport for crew and equipment to remote sites in alpine areas.
    - Mineral salt blocks are used to bait goats at alpine capture locations.

- Alternative 2.) Helicopters combined with pack stock.
    - All mountain goat capture, handling and personnel operations utilize helicopters and fixed-wing aircraft as in alternative 1.).
        - Pack stock utilized to help facilitate the transport of equipment and gear to the nearest point along access trails. Teams of climbers carry equipment cross-country to the base of climbing routes. Climbers then use non-mechanical rigging apparatus to haul equipment to capture locations.
        - Mineral salt blocks are used to bait goats at alpine capture locations.

- Alternative 3.) No-action alternative. All operations in wilderness areas occur without engaging in restricted activities, such as using mechanized transport or equipment.

Alternative 1.) Helicopters for mountain goat handling and transportation

Proposed management elements and actions likely used for capture and translocation are as follows.

Transportation

Management activities for capture and translocation involve several modes of transportation for accessing remote areas in wilderness.

- Fixed-wing aircraft or helicopters are used to identify areas for aerial capture operations.
- Helicopters utilized to mobilize support equipment to spike camps near capture locations.
- Helicopters utilized to demobilize spike camp equipment at remote locations.
- Helicopters used to transport capture teams and other support staff to and from remote wilderness sites.

Capturing mountain goats

Mountain goats are captured utilizing helicopters as well as ground-based capture techniques. Immobilized mountain goats are placed individually in nets or slings to be transported by belly hook or long line by the helicopter to specified staging areas.

- Ground-based capture methods including drop nets, foot snares, darting, and clover traps
- Air-based capture methods including net guns and darting following guidelines in 351DM2-351DM3 “Aerial Capture, Eradication and Tagging of Animals (ACETA) Handbook” (DOI 1997).
- Helicopters land both external cargo nets and physically touchdown at remote locations to move the animals.

Forest area closures

Limited areas of the Forest, inside and outside of designated Wilderness, would be temporarily closed while lethal removal and capture operations take place. Visitor use locations and roads in vicinity of staging areas are closed for safety.

- Where closures are implemented, visitors are prohibited from entering wilderness sites by trail, route or cross country travel.
- Closures would also be coordinated with wilderness and law enforcement officers and all other forest staff working nearby.
- Closures may be in effect for several days.
- Forest-wide closures do not occur.

Baiting mountain goats

Mineral salt lick blocks placed to attract mountain goats to suitable locations for greater efficacy for either capture or lethal removal actions.

- Preferred locations for salt licks are distant from public use areas or difficult to access to lessen human and mountain goat interactions.

Alternative 2.) Helicopters combined with pack stock

Proposed management elements and actions for the capture and translocation by helicopter are identical to Alternative 1. However, activities such as moving personnel and equipment for support occur by foot or riding and pack stock. Stock travel on designated trails and routes. Under this alternative, staff access mountain goat groups on foot using trails and extensive cross country travel.

- Off-trail areas are accessed by backpack and climbing teams. In many locations high-angle climbing techniques will be utilized.
- Some capture locations require multiple day expeditions, transferring equipment from one camp to another at higher elevations.

Capture teams require additional equipment, primarily for camping. Equipment is designed or retrofitted to be broken down to be carried by backpackers, or in some cases stock animals. Some sites may take multiple days for travel.

Alternative 3.) No-action alternative

Under the no-action alternative, options for the management of mountain goats in wilderness remain the same. Activities affecting wilderness character are limited to disturbances to future management activities associated with controlling human-mountain goat interactions. The frequency of management actions is dependent on the level of mountain goat-human interactions.

Research and monitoring activities would continue on the forest in wilderness areas. Staff continues to collect demographic and other information. Annual aerial monitoring with helicopters and fixed-wing aircraft continues.

Aerial activities

Guidance on low-level flights over designated wilderness are recommendations. All aircraft are requested to maintain a minimum altitude of 2,000 feet above the ground surface of Wilderness. There is no statutory requirements except that noise from aircraft can be considered harassment of wildlife (16 USC 742j-1; 50 CFR Part 19).

The following table shows the number of estimated helicopter landings in wilderness, under the proposed action alternatives. A landing is the touching down of any part of the airship, including external loads suspended from longlines or other apparatus, in Wilderness. Data is taken from 2012 mountain goat survey, organized by geographic location.[2] Sums are the number of landings possible, based on the observed number of individual mountain goats. The actual number of mountain goat group complexes, with few or no sightings, is likely to be greater than the number observed.

Capturing requires no more than three landings per individual and each lethal removal requires zero to one wilderness landing under Alternative 1.) Under Alternative 2.), two landings are estimated for the capture of each individual, assuming that is physically possible to access some of the locations by foot. The number of flights for lethal removal will stay the same for this alternative. Wilderness landing estimates for alternatives was provided by Olympic National Park managers at interagency internal scoping meeting May 4, 2016). The number of landings, in both options, is assumed to be less since multiple animals can be removed in a given location from one crew flight.

Estimated helicopter landings in wilderness

Mt. Goat Group Complex	Priority 1 through 5	No. Observed	Landings for translocation	Landings for lethal removal	Landings for translocation	Landings for lethal removal
			Alternative 1.)		Alternative 2.)	
Copper Mt.	5	2	6	2	4	2
Mt. Washington	1	31	93	31	62	31
Flapjack—Skokomish	4	6	18	6	12	6
Mt. Bretherton	5	0	0	0	0	0
The Brothers	2	5	15	5	10	5
Mt. Jupiter	2	0	0	0	0	0
Constance—Townsend	2	4	12	4	8	4
Royal—Fricaba	4	0	0	0	0	0
Tyler—Baldy	3	0	0	0	0	0
Total Flights			144	48	96	48

[2] Copper Mountain group; Mount Washington group; Flapjack—Skokomish complex, includes Flapjack Lakes, Mt Gladys, Mt. Henderson, Mt. Skokomish groups. Mt. Bretherton group; The Brothers group; Mt. Jupiter group; Mt. Constance—Townsend complex, includes Harrison Lake, Mt. Constance, Tunnel Creek, Warrior, Charlia Lakes, The Gargoyles, Marmot Pass, Buckhorn, Silver Lake, Copper Creek and Mt. Townsend Groups; Royal—Fricaba complex, includes Mt. Fricaba, Royal Lake and Royal Creek Groups. The Tyler Peak—Baldy complex includes, the Baldy and Tyler Peak Groups.

Discussion

Compared is the observed population in each complex by priority for removal (1 through 5); distance to staging area; and, the anticipated number goats to capture. For comparison, the table shows number of flights for both translocation and lethal removal. Numbers in red indicate lethal removal. The right four columns show the number of flights for each action alternative.

Affects to wilderness character

The scope and scale of the mountain goat removal activities necessitates careful consideration of untrammeled, undeveloped, natural, solitude/unconfined recreation, and other features of value, essential to the character of the five Olympic National Forest wilderness areas. The Wilderness Act identifies other features having significant ecological, geological, scientific, educational, scenic or historical value. No lasting impacts are expected to incur to geological, educational, scenic or historical wilderness features.

Translocating Olympic peninsula mountain goats benefits ecological management efforts to repopulate endemic populations in North Cascade wilderness areas, while removing a non-native species on the Olympic Peninsula, also a significant factor to the mountain goat management plan. North Cascades populations are unlikely to rebound nor maintain a healthy genetic variability (Harris and Steele 2014).

The following sections compare the three alternatives within the framework of five wilderness character elements. Information is organized into the following matrixes.

Untrammeled wilderness character elements

Untrammeled	*Affected primarily by the forces of nature. Unhindered and free from modern human control or manipulation*
Alternative 1)	Short-term: Landing of helicopters, the use of dart and net guns and other mechanized equipment constitute modern human manipulation. Long-term: Removing an established species manipulates the environment.
Alternative 2)	Short-term: Landing of helicopters, the use of dart and net guns and other mechanized equipment constitute modern human manipulation. Using stock lessens dependence on helicopters for the operation. Long-term: Same as above. Removing an established species manipulates the environment.
Alternative 3)	Managers continue to control human-mountain goat interactions through hazing and other activities.

Undeveloped and natural wilderness character elements

Undeveloped	*Primeval character and influence, essentially without improvements and without permanent human occupation*
Alternative 1)	Short-term: Salt lick attractants are a temporary improvement. They may draw other wildlife to the site, altering local species composition. Long-term: Activities will not result in permanent improvements or sign of human occupation of the wilderness.
Alternative 2)	Short-term: Same as above. Salt lick attractants are a temporary improvement. They may draw other wildlife to the site, altering local species composition. Long-term: Same as above. Activities will not result in permanent improvements or sign of human occupation of the wilderness.
Alternative 3)	No change from the current condition.

Natural	*Preserve natural ecological systems which are substantially free from the effects of modern civilization*
Alternative 1)	Removal of an introduced species may, ultimately, benefit endemic species and have a positive impact to the ecosystem.
Alternative 2)	Same as above. Removal of an introduced species may, ultimately, benefit endemic species and have a positive impact to the ecosystem.
Alternative 3)	No change from the current condition. A large ungulate introduced into the ecosystem remains.

Solitude and other features of value wilderness character elements

Solitude/ Unconfined Recreation	*Provides outstanding opportunities for solitude or primitive and unconfined recreation*
Alternative 1)	Short-term: Some visitors may have their experience of solitude degraded by the presence of a helicopter for the duration of the project. Visitors may see or hear helicopters flying over wilderness and hovering to release the sling loads or drop off equipment and personnel. Long-term: Solitude impeded by continuous need to manage mountain goat-human interactions through visitor education and the use of hazing devices such as air horns or paintball guns.
Alternative 2)	Short-term: Some visitors may have their experience of solitude degraded by the presence of a helicopter for the removal portion of the operation. However, there are significantly less flights for the duration of the project disrupting fewer visitors for less time. Feelings of solitude are lessened where visitors come into contact with large pack stings and spike camps. The extent of time the crew would be camped is less than two weeks. Long-term: Solitude impeded by continuous need to manage mountain goat-human interactions through visitor education and the use of hazing devices such as air horns or paintball guns.
Alternative 3)	Solitude impeded by continuous need to manage mountain goat-human interactions through visitor education and the use of hazing devices such as air horns or paintball guns.

Other Features of Value	*Wilderness areas "may also contain ecological, geological, or other features of scientific, educational, scenic, or historical use" unique to the wilderness area*
Alternative 1)	Impact to fragile alpine ecosystems from mountain goats is eliminated. Ecosystem impacts from the non-indigenous species to soils, plants and other wildlife is eliminated.
Alternative 2)	Same as above. Impact to fragile alpine ecosystems from mountain goats is eliminated. Ecosystem impacts from the non-indigenous species to soils, plants and other wildlife is eliminated.
Alternative 3)	Human-caused impacts from mountain goats continue to affect the ecological integrity

Other factors for consideration

Other factors considered are the proposed activities role in maintaining or perpetuating traditional skills such as stock packing; project costs and economic constraints for attaining

the desired administrative outcome; and, lastly, safety for both the general public and for employees.

Maintaining traditional skills

Traditional skills are not utilized with the use of helicopters. However, Alternative 2.) utilizes pack stock for portions of the operation, employing traditional skills, not often practiced in Olympic National Forest.

Economic costs

As proposed, Olympic National Forest does not directly contribute to the cost of the operation, except for time for the preparation of planning documents, as outlined in a memorandum of understanding between the agencies for mountain goat management.

While there are no direct costs incurred by the Forest Service, economic information is included in this minimum requirements analysis is provided as an overview of costs for the proposed actions. Overall economic costs of the multi-year proposed action, including all aspects of the translocation project on the Olympic Peninsula and in the Northern Cascades, is $1,600,000. Of this cost, Washington Department of Fish and Wildlife is contributing $461,000 (NPS PMIS 2016). If the total population is estimated to be 600 individuals, then the cost for both translocating and lethal removal is $2,667 per individual. The proportion of cost for the National Park Service and Washington Department of Fish and Wildlife on Olympic National Forest is approximately $157,353 (based on the 2016 estimate of 59 mountain goats).

Cost differences for actions outlined in alternative 2.), the use of pack stock for a portion of the operations are not calculated. However, it can be assumed that it would be significantly greater since it would lengthen the overall time needed to attain the management goals. Note that areas not accessible by trail are extremely difficult to access and take multiple days to reach sites.

Safety of visitors and workers

Risk of injury is significant due to the work environment. Mountain goats live in extremely rough and inaccessible terrain, at high elevations. Hazards include, snowfields, cliffs, difficult route-finding under canopy and unstable montane weather. Access to capture sites may involve traversing ridges or other alpine features such as ice fields. Likewise, helicopter transport in mountainous terrain is hazardous. Challenges include poor weather for flying, erratic winds and temperature fluctuations. Landing and taking off from remote sites involves risk. Risk to visitors, agency personnel, or contractors, associated with implementing either of the action alternatives is substantial.

The significant trade-offs between the two action-alternatives is the length of exposure to potentially catastrophic activities versus the severity of an accident from operations more dependent on helicopters. The use of climbing parties and pack and saddle stock may lessen fight times and exposure to air accidents but significantly increases the time personnel are engaged in other risky activities such as alpine fourth and fifth class aid climbing. Mitigation actions to decrease risk include providing information to the public and temporary area closure or employing ‘best practices,’ for helicopter operations and for cross-country travel.

The no-action alternative 3.), poses no direct safety hazard for managers that impede wilderness character elements.

Conclusion

The long-term impacts of mountain goats on the Olympic peninsula are significant. Removal of mountain goats is essential to the overall ecological integrity of Wilderness areas on the Olympic Peninsula. Removal activities solely in Olympic National Park likely will have no lasting impact on the mountain goat population since they can recolonize from forest service lands. Specifically, the no-action alternative on forest service lands will not mitigate ecological impacts to multiple wilderness character elements. Therefore, the two action alternatives meet priorities to preserve, unhindered, the unique assemblage of alpine and subalpine flora and fauna on Olympic National Forest.

After considering the options for this project, Alternative 1.) is consistent with Forest Service Manual directives for minimum requirements to accomplish wilderness management objectives. There are no feasible non-motorized methods that could be used to transfer goats from remote sites to the staging areas. Alternative 2.) is not feasible for most mountain goat group locations due to difficult cross-country access by foot. Pack stock cannot access most areas of mountain goat habitat. It is not possible for teams of workers to carry the necessary equipment for the operation over steep and hazardous terrain, due to costs, safety and time constraints.

Solitude in these areas would be affected by the presence of helicopters. However, these impacts are temporary and last only two weeks of each year of operation. Furthermore, the activities are dispersed over a large geographic area.

Olympic National Forest determines there is no reasonable or safe, non-motorized or mechanized alternatives for the project to proceed. The timing, scope and scale of activities justifies the use of mechanized equipment in wilderness, as minimum requirements to meet wilderness management objectives.

Recommendations

The Forest recommends to the National Park Service and Washington Department of Fish and Wildlife, to implement the project as proposed, with similar activities as outlined in Alternative 1.): Helicopters for mountain goat handling and transport. Where feasible, crews may also access capture sites via foot or horseback. Helicopters may be used for transporting personnel and equipment.

The following methods or actions are recommended to be incorporated into the project design criteria, to limit degradation to wilderness character:

- Washington Department of Fish and Wildlife is strongly encouraged to issue as many fall mountain goat hunting permits, as possible, to the general public. This action is contingent upon a Record of Decision in favor of implementing the proposed action alternatives in the Olympic National Park, Draft Mountain Goat Management Plan. Any

animals removed from the forest prior to, and during implementation, will limit flights and operational time, impacting wilderness character.

- Staff access wilderness areas via foot or riding stock where possible, without risking life or limb. This shall be considered for travel to sites accessible by trail or non-technical cross-country travel (e.g. without the use of crampons, ice axes, rope or other specialized equipment).
    - Foot travel shall be considered for both baiting mountain goats ahead of time as well as during the capturing operational period, to limit trammeling and inhibiting solitude/primitive recreation from helicopter flights.
    - Capture sites to be considered for primitive travel of personnel include, but are not limited to, Marmot Pass in the Buckhorn Wilderness and Wilderness portions of Mount Ellinor, Mount Skokomish Wilderness.
- Bait mountain goats, whenever possible, to lure them outside of Forest Service wilderness boundaries.

Approved: _____DRAFT_____ Date: _____DRAFT_____

Reta Laford
Forest Supervisor
Olympic National Forest

References

Cole, David N., and Laurie Yung, eds. Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change. Island Press, 2012.

Festa-Bianchet, Marco, and Steve D. Côté. Mountain goats: ecology, behavior, and conservation of an alpine ungulate. Island Press, 2012: 11-12.

Harris, Richard B. and B. Steele. 2014. Factors predicting success of mountain goat reintroductions. Northern Wild Sheep and Goat Council 19:17-35.

Landres, Peter; Boutcher, Steve; Merigliano, Linda; Barns, Chris; Davis, Denis; Hall, Troy; Henry, Steve; Hunter, Brad; Janiga, Patrice; Laker, Mark; McPherson, Al; Powell, Douglas S.; Rowan, Mike; Sater, Susan. 2005. Monitoring selected conditions related to wilderness character: a national framework. Gen. Tech. Rep. RMRS-GTR-151. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Noss, R.F., R. Graham, D.R. McCullough, F.L. Ramsey, J. Seavey, C. Whitlock, and M.P. Williams. 2000. Review of scientific material relevant to the occurrence, ecosystem role, and tested management options for mountain goats in Olympic National Park. U.S. DOI contract #14-10-0001-99-C-05. May 30, 2000.

NPS DEIS 2016. National Park Service, Olympic National Park, Mountain goat management plan/Environmental Impact Statement. Internal draft, June 2016.

NPS PMIS 2016. National Park Service. Project Management Information System. PMIS 226113, Implement selected alternative for Olympic National Park mountain goat management plan and EIS. Olympic National Park, Pacific West Region

Rice, Clifford G. 2008. Seasonal altitudinal movements of mountain goats. Journal of Wildlife Management 72(8):1706-1716

Rice, Clifford G. 2012. Survey of mountain goats in Olympic National Forest. Washington Department of Fish and Wildlife. Internal document. http://wdfw.wa.gov/publications/00008/

UNESCO 2016a. United Nations Educational, Scientific and Cultural Organization, MAB Programme, Biosphere Reserve Information, United States of America, OLYMPIC

http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=all&code=USA+17

UNESCO 2016b. United Nations Educational, Scientific and Cultural Organization. Culture. World Heritage Centre. World Heritage List. http://whc.unesco.org/en/list/151

USFS 1993a. Wilderness Implementation Schedule, Buckhorn Wilderness. Olympic National Forest.

USFS 1993b. Wilderness Implementation Schedule, Mount Skokomish Wilderness. Olympic National Forest.

USFS 1993c. Wilderness Implementation Schedule, The Brothers Wilderness. Olympic National Forest.

USFS 1993d. Wilderness Implementation Schedule, Wonder Mountain Wilderness. Olympic National Forest.

USFS 2016a. Buckhorn Wilderness. http://www.fs.usda.gov/recarea/olympic/recreation/recarea/?recid=77834

USFS 2016b. Colonel Bob Wilderness. http://www.fs.usda.gov/recarea/olympic/recreation/recarea/?recid=78488

USFS 2016c. Mount Skokomish Wilderness. http://www.fs.usda.gov/recarea/olympic/recreation/recarea/?recid=78489

USFS 2016d. The Brothers Wilderness. http://www.fs.usda.gov/recarea/olympic/recreation/recarea/?recid=78494

USFS 2016e. Wonder Mountain Wilderness. http://www.fs.usda.gov/recarea/olympic/recreation/recarea/?recid=78493

Ex217

Jessie Chase <jmchase@utah.gov>

Fwd: EA example

Rusty Robinson <rustyrobinson@utah.gov>
To: Jessie Chase <jmchase@utah.gov>

Mon, Sep 11, 2017 at 3:11 PM

——— Forwarded message ———
From: **Rusty Robinson** <rustyrobinson@utah.gov>
Date: Fri, Mar 31, 2017 at 10:48 AM
Subject: Fwd: EA example
To: Riley Peck <rileypeck@utah.gov>, Dale Liechty <dalelliechty@utah.gov>

——— Forwarded message ———
From: **Manders, Pamela - FS** <pmanders@fs.fed.us>
Date: Wed, Mar 29, 2017 at 1:47 PM
Subject: EA example
To: Rusty Robinson <rustyrobinson@utah.gov>

I am not sure if this will help or not. It has a lot of track changes but it shows all the work that the Salmon Challis forest did working with IFGD

Thank you for your help.

By the way delete all your email that you do not want to keep before once we go to the public everything can be requested by the public. So clean everything up that you do not want to go out.

I delete everything and clean out my trash daily.

Thanks again

Pamela Manders
Fish and Wildlife Manager

Forest Service

Uinta-Wasatch-Cache National Forest

p: 801-999-2167
f: 801-253-8118
pmanders@fs.fed.us

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–
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Utah Division of Wildlife Resources
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rustyrobinson@utah.gov

–

Ex218

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UDWR_data Info.docx
323K

Ex219

Jessie Chase <jmchase@utah.gov>

Fwd: good morning

Rusty Robinson <rustyrobinson@utah.gov>
To: Jessie Chase <jmchase@utah.gov>

Mon, Sep 11, 2017 at 3:07 PM

——— Forwarded message ———
From: **Manders, Pamela - FS** <pmanders@fs.fed.us>
Date: Thu, Jun 1, 2017 at 11:57 AM
Subject: RE: good morning
To: Rusty Robinson <rustyrobinson@utah.gov>

Thank you so much. Much appreciated.

Pamela Manders
Fish and Wildlife Manager

Forest Service

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From: Rusty Robinson [mailto:rustyrobinson@utah.gov]
Sent: Thursday, June 01, 2017 10:47 AM
To: Manders, Pamela - FS <pmanders@fs.fed.us>
Subject: Re: good morning

Hi Pam,

1. The WAFWA Wild Sheep Working Group has suggested guidelines for pathogen surveillance. They are 10% of the population or 10-15 animals. Target quantities for both species fall within these guidelines. Link to the document is below.

http://www.wafwa.org/Documents%20and%20Settings/37/Site%20Documents/Working%20Groups/Wild%20Sheep/Most%20Recent%20WSWG%20Meeting%20Info/DMV%20Wild%20Sheep%20Strategy%20Jan%202017.pdf

2. No action would likely not result in more aerial surveys. We would simply continue to monitor.

Hope this helps.

PS We have been working on a position statement on mountain goats. We will send it to you shortly, likely just in email form.

Thanks,

Rusty

Ex220

On Thu, Jun 1, 2017 at 9:29 AM, Manders, Pamela - FS <pmanders@fs.fed.us> wrote:

Rusty,

We were going through the comments from the OGC attorney and I have a couple of questions for you.

1. The collection of 20 goats and 10 sheep, Where did the numbers come from? Is that the minimum number to complete the study? Is it out of the management plans? Can you help me to understand where those numbers came from?

2. Second question: If the study does not go through looking at the no action alternative would you have to increase the flights over the wilderness areas from 2-3 years to once a year to help study the wildlife populations., More helicopter fly overs.

Thanks Pam

Pamela Manders
Fish and Wildlife Manager

Forest Service

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Rusty Robinson
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Utah Division of Wildlife Resources

Ex221

Salt Lake City, UT 84114
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nistyrobinson@utah.gov

Ex222

Jessie Chase <jmchase@utah.gov>

Fwd: Unpublished Data

Rusty Robinson <rustyrobinson@utah.gov>
To: Jessie Chase <jmchase@utah.gov>

Mon, Sep 11, 2017 at 3:03 PM

——— Forwarded message ———
From: **Manders, Pamela - FS** <pmanders@fs.fed.us>
Date: Wed, Aug 9, 2017 at 2:45 PM
Subject: RE: Unpublished Data
To: Rusty Robinson <rustyrobinson@utah.gov>

Perfect

Pamela Manders
Fish and Wildlife Manager

Forest Service

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From: Rusty Robinson [mailto:rustyrobinson@utah.gov]
Sent: Wednesday, August 09, 2017 2:42 PM
To: Manders, Pamela - FS <pmanders@fs.fed.us>
Subject: Unpublished Data

Hi Pam,

Here is the info you requested for the unpublished data citation.

–

Rusty Robinson
Bighorn Sheep/Mountain Goat Biologist
Utah Division of Wildlife Resources
Salt Lake City, UT 84114
(385) 368-1128
rustyrobinson@utah.gov

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–

Rusty Robinson
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Utah Division of Wildlife Resources
Salt Lake City, UT 84114

Ex223

Jessie Chase <jmchase@utah.gov>

Fwd: Summary Data

Rusty Robinson <rustyrobinson@utah.gov>
To: Jessie Chase <jmchase@utah.gov>

Mon, Sep 11, 2017 at 3:03 PM

——— Forwarded message ———
From: **Rusty Robinson** <rustyrobinson@utah.gov>
Date: Wed, Aug 9, 2017 at 2:42 PM
Subject: Re: Summary Data
To: "Manders, Pamela - FS" <pmanders@fs.fed.us>

Just sent it. Looks good. Let me know if you need anything else.

On Wed, Aug 9, 2017 at 2:02 PM, Manders, Pamela - FS <pmanders@fs.fed.us> wrote:

I am going to send you this summary of the data. Review it and send in a new email and that is what I will use for the unpublished data.

Okay

Understand.

Then I will delete the other reports

Thanks Pam

Pamela Manders
Fish and Wildlife Manager

Forest Service

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Caring for the land and serving people

From: Rusty Robinson [mailto:rustyrobinson@utah.gov]
Sent: Wednesday, August 09, 2017 9:55 AM
To: Manders, Pamela - FS <pmanders@fs.fed.us>
Subject: Re: Wildlife Report Edits

Here is an unpublished disease profile for mountain goats and one example for bighorn sheep. Is this what you needed? Will these be public documents now? I think we would prefer that they stay in house if possible.

Rusty

On Wed, Aug 9, 2017 at 8:01 AM, Manders, Pamela - FS <pmanders@fs.fed.us> wrote:

Thank you so much. Can you send me the write up for the unpublished data when you get a chance. Thank you so much. Very much appreciated.

Have a great day

Pamela Manders

Ex224

Fish and Wildlife Manager

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From: Rusty Robinson [mailto:rustyrobinson@utah.gov]
Sent: Monday, August 07, 2017 9:29 AM
To: Manders, Pamela - FS <pmanders@fs.fed.us>
Subject: Wildlife Report Edits

Hi Pam,

Sorry, I wasn't able to get to this until now. I made a few edits.

Thanks,

Rusty

--

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Ex225

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Ex226

UTAH MOUNTAIN GOAT
STATEWIDE MANAGEMENT PLAN

UTAH DIVISION OF WILDLIFE RESOURCES
DEPARTMENT OF NATURAL RESOURCES

UTAH DIVISION OF WILDLIFE RESOURCES
STATEWIDE MANAGEMENT PLAN FOR MOUNTAIN GOAT

I. PURPOSE OF THE PLAN

A. General

This document is the statewide management plan for mountain goats in Utah. The plan will provide overall guidance and direction to Utah's mountain goat management program. The plan assesses current information on mountain goats, identifies issues and concerns relating to mountain goat management in Utah, and establishes goals and objectives for future mountain goat management programs. Strategies are also outlined to achieve the goals and objectives. This plan will be used to help determine priorities for mountain goat management and provide the overall direction for management plans on individual mountain goat management units throughout the state.

B. Dates Covered

The statewide mountain goat plan was approved by the Utah Wildlife Board on June 4, 2013 and will be in effect for 5 years from that date (Dates covered: June 2013 – June 2018).

II. SPECIES ASSESSMENT

A. Natural History

Mountain goats (*Oreamnos amreicanus*) are not true goats as the name suggests, but share the family Bovidae with true goats (*Capra* spp.), gazelles (*Gazella* spp.) and cattle (*Bos* spp.). They are in the subfamily Caprinae along with 32 other species including sheep (*Ovis* spp.) and muskoxen (*Ovibos* spp.). Mountain goats are the only living species in the genus *Oreamnos*.

Mountain goat males, females, and young are known as billies, nannies, and kids, respectively. Kids are born after a gestation period of approximately 190 days most often as singles, but twins are not uncommon. Kids are normally born in mid-May to early-June. Compared to similarly sized ungulates, mountain goats have a surprisingly late age of first reproduction. In established populations, females often do not give birth until 4 or 5 years old (Festa-Bianchet et al. 1994). In newly translocated populations, females can reproduce as early as 2 or 3 years old (Bailey 1991, Festa-Bianchet and Cote 2008).

Like many ungulates, mountain goats put on weight and fat reserves during the spring and summer months for use during winter. As such, weights vary greatly depending on when they are taken. In late summer, a typical mature male will weigh about 175-225 pounds. Females are smaller and typically average between 125 and 150 pounds. Both males and females continue to gain body mass until about 6 years old when they are considered fully grown. The maximum life span of mountain goats is typically around 15 years old for males and 18–20 years old for females (Festa-Bianchet and Cote 2008).

Both male and female mountain goats have horns. For both sexes, horn growth begins at birth and the vast majority of horn growth occurs during the first 3 years of life. Horn growth for mature adult goats (4+) is minimal. There is little sexual dimorphisms exhibited in mountain goats. Horn length of males and females is similar, but male horns tend to be 10-20% thicker at the base than females (Festa-Bianchet and Cote 2008).

The mating period for mountain goats peaks in mid-November and individual females come into estrus for about 2 days. During this time, males seek out females in estrus and defend them from other males. Unlike most ungulates where males fight by clashing or locking horns or antlers, mountain goats have an antiparallel fighting style. During these interactions, males circle each other with each goats head aligned with the others rump. Outside the mating season, males and females remain segregated.

B. Management

1. DWR Regulatory Authority

The Utah Division of Wildlife Resources presently operates under authority granted by the Utah Legislature in Title 23 of the Utah Code. The Division was created and established as the wildlife authority for the state under Section 23-14-1 of the Code. This Code also vests the Division with its functions, powers, duties, rights, and responsibilities. The Division's duties are to protect, propagate, manage, conserve, and distribute protected wildlife throughout the state.

The Utah Division of Wildlife Resources is charged to manage the state's wildlife resources and to assure the future of protected wildlife for its intrinsic, scientific, educational, and recreational values. Protected wildlife species are defined in code by the Utah Legislature.

2. Population Status

Mountain goats currently inhabit several mountain ranges in Utah including numerous peaks along the Wasatch Front, Uinta Mountains, and Tushar Mountains (Figure 1). All populations are the result of introductions; the first of which occurred in 1967 when 6 mountain goats (2 billies, 4 nannies) were released in the Lone Peak area (Table 1). Within Utah, 24 separate transplant events have occurred and 185 mountain goats have been released. Initial transplants used mountain goats from Olympic National Park in Washington as the source herd. After those transplanted herds became established, they became source herds for future transplants. The Tushar Mountains population has been the most common Utah source herd because of its rapidly growing population and relative ease of accessibility. As a result of the transplants, mountain goat populations in Utah have steadily increased since 1967 to their current population of more than 2000 estimated animals (Figure 2).

3. Past and Current Management

In Utah, mountain goat populations are surveyed via helicopter every 2-3 years (Table 2). During these flights, biologists survey all potential mountain goat habitat in August or September and classify all observed animals as billies, nannies, or kids. Previous studies have shown that

sightability is usually around 80-85% for mountain goats (Rice et al. 2009). In addition to the helicopter surveys, most biologists conduct ground-based or fixed-wing classification counts on units during years when they are not surveyed with a helicopter. This provides biologists with data on annual production and greatly improves our population models for those units.

Mountain goats are managed as an once-in-a-lifetime species in Utah. The first mountain goat hunt in Utah was held on Lone Peak in 1981 where 1 permit was issued. Since 1981, permits have steadily increased as populations of mountain goats increased reaching a high of 175 in 2012 (Table 3). From 1981 to 2012, a total of 1231 permits have been issued resulting in the harvest of 1176 mountain goats (794 billies, 382 nannies). Success rates for mountain goats in Utah are high and average 97%. In 2012, mountain goat hunting was allowed on 11 of the 12 areas where goats are present. The only unit without hunting was the Central Mountains - Loafer Mountain/Mount Nebo Unit, where mountain goats were initially transplanted in 2007. On the Beaver and Ogden units, where we are attempting to control goat populations, we have issued nanny-only permits in addition to any-goat permits. These permits require taking an online course to help differentiate males from females. On units where population control is not needed, any goat permits have been issued to harvest any adult goat. Historically, 79 percent of mountain goat hunters with any-goat permits have harvested billies. The average age of mountain goats harvested in Utah is 4.4 years old in 2012 (Table 4). Demand for permits is extremely high making these permits difficult to draw (Table 5). In 2012, a total of 7999 hunters applied for the 161 public draw permits available resulting in drawing odds of 1 in 50.

C. Habitat

Mountain goats are obligate occupants of the highest alpine environments in Utah. Elevations of up to 13,000 feet are frequented in summer, and winter habitat may be high as 12,000 feet on windblown ridges of some units. Exposed, precipitous cliffs are an essential component of mountain goat habitat. Mountain goats typically prefer sites that are close to escape terrain with an intermediate slope typically between 20 and 50 degrees (Gross et al. 2002). Suitable sites encompass most aspects of mountain goat habitat needs including escape terrain, feeding sites, and birthing and nursery areas.

Food habits of goats are extremely variable among different geographic populations. In general, summer diets are typically dominated by succulent grasses and forbs. Winter diets may include a much higher browse or shrub component, and may even include Ponderosa pine, lodgepole pine, or alpine fir. Other components of goat habitat that may be locally important include mineral licks and dusting areas used to alleviate heat or ectoparasite load.

III. ISSUES AND CONCERNS

A. Native Status

The native status of mountain goats in Utah is debatable and subject to controversy. An analysis of available information is included as an appendix to this document (Appendix A). Regardless of their native status to Utah, they are certainly native to the North American continent and the Northern Rocky Mountains. The DWR's position is that mountain goat habitat exists in Utah, as

indicated by the success of introduced populations. As such, the DWR believes mountain goats are a valuable addition to our wildlife resource diversity and are a legitimate part of our modern Utah faunal landscape. As with any other ungulate species in our now pervasively human-altered ecosystem, they require pro-active management.

B. Habitat Impacts

Given the fragile nature of alpine habitats, mountain goat utilization of the available forage must be closely monitored. Although goat densities are typically low, local areas may exhibit heavier use and cause resource damage. If mountain goat use is demonstrated to be excessive, the Division must work cooperatively with the Forest Service to manage goat populations to acceptable numbers. As part of this plan, target population sizes for individual goat herd units will be reviewed for existing management units or developed for new units. Public input, cooperation with the Forest Service, and habitat monitoring data will all be used to determine the target population size.

In addition to their direct utilization of forage, the creation of dust bowls by mountain goats has been identified as a potential habitat concern. In Olympic National Park, large concentrations of goats have created extensive dusting areas. However, this occurred in an unmanaged and unhunted population, and those goat densities have never been observed outside the Park. As such, it is likely that this issue only arises in unregulated populations. Under most conditions, goats disturb far less area than that observed in Olympic National Park. Where localized disturbance occurs, it is considered normal goat behavior. Comparable disturbance is observed at elk wallows and on bighorn sheep lambing and wintering cliffs, even at low population densities. Livestock use of salt blocks or water developments can also result in similar disturbance on a larger scale.

C. Disease

Little information is available relative to disease in mountain goats (Cote and Festa-Bianchet 2003). However, there are some documented occurrences of disease that may be of concern for mountain goats in Utah including contagious ecthyma, Johnes disease, and respiratory pneumonia. Contagious ecthyma is a highly contagious parapox virus that causes blister-like sores to form on the face and muzzle of infected animals. The virus can lay dormant in soil for long periods of time and enters the host through skin abrasions. Lesions can be extremely painful causing an animal to not feed, leading to emaciation and ultimately death. It is believed that mountain goats may suffer severely from this disease with documented outbreaks resulting in deafness, blindness, and ultimately death (Samuel et al. 1975). Lesions typically last about 2-4 weeks after which an animal may recover. This disease has been observed in domestic sheep flocks for over 200 years (Lance et al. 1981).

Between 1972 -1978, the Colorado Division of Wildlife collected several bighorn sheep and a sympatric mountain goat carcass with lesions consistent with infection from the bacteria *Mycobacterium avium*, commonly referred to as Johnes disease or paratuberculosis (Williams et al. 1979). Mountain goats are believed to be highly susceptible to the disease, leading to severe gastrointestinal distress, emaciation, dry or rough hair coat, and death (Williams et al. 1983).

The disease primarily affects lambs and transmission of the disease may occur *in utero* or in the first few months of life through ingestion of contaminated food, water, dust, or feces (Kimberling 1988). This disease is most commonly associated with cattle; however adult sheep, goats, and llamas can be carriers (Garde et al. 2005).

Respiratory pneumonia associated with *pasteurella* spp. and *mannheimia* spp. of bacterium have been reported sporadically in mountain goats, but large scale die-offs have rarely been documented (Garde et al 2005). Several strains of the bacteria are carried as common commensals in the upper respiratory tract. Transmission of these bacteria can occur through direct contact or aerosolization (Garde et al. 2005). In 2010, the Nevada Department of Wildlife documented a pneumonia related die-off in mountain goats and sympatric bighorn sheep in the Ruby Mountains (Peregrine Wolff, personal communication Nevada Department of Wildlife). Other concerns include myopathy that may result from selenium deficiency (Cote and Festa-Bianchet 2003) and possibly some parasites such as lungworm.

D. Predation

Predation does not seem to be a limiting factor to mountain goat population growth in Utah. This is likely due to the absence of many mountain goat predators from Utah. Festa-Bianchet and Côté (2008) found that grizzly bears (*Ursus arctos*), wolves (*Canis lupus*) and cougars (*Puma concolor*) were the most effective predators of mountain goat in British Columbia. Cougars are potential predators of mountain goats in Utah, but are more likely to target easier prey such as mule deer, elk, and bighorn sheep. If predation is shown to be an issue on a particular unit, the DWR can increase predator hunting pressure in specific areas or establish a predator management plan for that unit.

E. Wilderness and Park Management

Many wilderness areas in Utah currently have populations of goats resulting from transplant efforts. These areas include the High Uintas, Lone Peak, Mt. Olympus, Twin Peaks, and Mt. Timpanogos. In order to properly manage mountain goat populations in these areas, it is critical that biologists have all possible management tools available to them if needed. These include but aren't limited to the use of aircraft for surveys, transplants (captures and releases), and research projects. Any future wilderness designations or park expansions should also allow for these activities. The Division must continue to work cooperatively with the U.S. Forest Service to ensure the proper management of mountain goats in these areas.

F. Competition with Bighorn Sheep

Mountain goats and Rocky Mountain bighorn sheep typically occur in broadly similar habitats, at similar elevations, and consume many of the same forages. Thus, the potential exists for competition between these two species, particularly when seasonal habitat overlap occurs (Hobbs et al. 1990, Laundre 1994, Gross 2001). However, even where both are present, resource partitioning appears to minimize conflicts (Laundre 1994). Specifically, there is enough disparity in site selection, seasonal use, and forage preference such that range overlap does not

result in as much direct competition as expected when each species' habitat requirements are considered separately.

In Utah, sympatric bighorn sheep and goat populations are found only in the eastern Uinta Mountains and to a lesser extent along the Wasatch Front. In this area, the abundance of alpine habitat combined with the low densities of mountain goats and bighorn sheep, greatly minimizes any interspecies competition. Range overlap of mountain goats and bighorn sheep does not currently occur in other areas of Utah, largely due to domestic and wild sheep disease issues that prohibit wild sheep. In some areas, there is also a general lack of suitable bighorn sheep wintering areas.

G. Poaching

Poaching of mountain goats is less common than other ungulate species due to the remote nature of their habitat. There are some documented cases of mountain goat poaching in Utah, but they are rare. Poaching likely has no population level effect, but does reduce hunting opportunity for law abiding hunters. Mountain goat populations are small and due to their low reproductive rate, only a small proportion of the population can be harvested. With less than 200 permits currently issued, one poached animal is proportionately a large loss in opportunity.

Most poaching cases of mountain goats occur when a hunter with a female-only permit mistakenly identifies an animal and accidentally harvest a male. Typically, the hunters report their mistake, but this situation can lead to overharvesting males if this becomes too prevalent. Other poaching incidents usually occur when a hunter cannot access the goat he shot due to the rugged terrain or the animal was damaged from falling after it was shot. The Division investigates all reported poaching cases. The high profile nature of mountain goats and their limited distribution adds concern to these investigations.

H. Transplants

All of the mountain goat populations that currently exist in Utah are a result of transplants. Although mountain goats can pioneer to new areas when densities are sufficiently high, transplants continue to be the preferred method used to establish new mountain goat populations and supplement existing ones. Mountain goat transplants in Utah have typically been successful provided the habitat on the site is suitable and a sufficient number of goats have been released. Although most suitable mountain goat habitat in Utah is already occupied, several potential sites for new transplants still exist (Table 6). Additionally, some existing units may need to be augmented to bolster population growth. It is critical that the Division work closely with the U.S. Forest Service to ensure the success of any future relocation efforts. Careful monitoring of vegetation will be needed to make sure habitat damage is not occurring and to alleviate any concerns.

There are a number of mountain goat populations in Utah that could serve as source herds for augmentation or to start new populations within Utah or for other states. On many of these populations, wilderness designated lands are one of the largest barriers to catching animals. The

Division and U.S. Forest Service will need to work cooperatively to determine the suitability of helicopter access for possible transplant projects.

IV. USE AND DEMAND

In Utah mountain goats are one of the easier to draw permits for an once-in-a-lifetime species, likely due to the extremely rugged terrain they inhabit. Even so, the demand for these permits is still high and far exceeds permit supply. In Utah for 2012, applications exceeded available permits by 29:1 for residents and 222:1 for nonresidents. Applications for both resident and nonresidents have increased every year since the initiation of Utah's draw system. In recent years, draw odds have improved because the growing populations have allowed the DWR to issue more permits while still providing a quality hunting experience.

In addition to hunting, viewing mountain goats is one of the most exhilarating and memorable experiences available to users of high alpine areas in Utah. The closeness of some of Utah's mountain goat populations to the Wasatch front helps contribute to the interest of wildlife viewers in watching mountain goats. Public perception of goat viewing opportunities is overwhelmingly positive, and the Watchable Wildlife events for mountain goats are some of the most popular events hosted by the DWR. The Division's goal is to foster and promote these opportunities wherever possible and enable people to see this unique species.

V. CONCLUSION

Mountain goats personify the high lonesome reaches of western North America. Goats are adapted to live in the highest, coldest, snowiest and most precipitous reaches of our classic western mountain ranges. The image of a solitary goat on a ridiculously narrow rock ledge on a seemingly inaccessible cliff is one that once seen is never forgotten. For nearly 50 years, the Division of Wildlife Resources has carefully managed Utah's mountain goat populations so herds are productive and balanced with available habitat. The Division plans to continue this management approach, while also establishing new mountain goat populations where possible. This will allow the Division to expand both hunting and viewing opportunities for mountain goats while ensuring their long-term viability in Utah.

VI. STATEWIDE MANAGEMENT GOALS AND OBJECTIVES

A. Population Management Goal: Establish optimum populations of mountain goats in all suitable habitat within the state.

Objective 1: Increase mountain goat populations within the state as conditions allow. Once unit objectives are established, bring all populations to objective.

Strategies:

a. Develop or revise all management plans for individual units making sure to include population goals and objectives.
b. Survey all herd units by helicopter every 1–3 years to monitor population size and composition.
c. Use population or sightability models to determine the relationship between population surveys and population size.
d. Harvest nannies from populations where habitat damage is occurring due to high goat densities or where populations are above objective.
e. Augment existing populations where needed to improve herd distribution, link small populations, and improve genetic diversity (Table 6).
f. Transplant mountain goats to establish new populations in accordance with Utah Code 23-14-21 (Table 6).
g. Participate in research efforts to monitor adult and kid survival and determine reasons for poor kid recruitment and population declines.
h. Support law enforcement efforts to reduce illegal taking of mountain goats.

B. Habitat Management Goal: Provide good quality habitat for healthy populations of mountain goats.

Objective: Maintain or improve sufficient mountain goat habitat to allow herds to reach population objectives.

Strategies:

a. Identify mountain goat habitats and work with land managers to protect and enhance these areas.
b. Assist land management agencies in monitoring mountain goat habitat.
c. Work with land managers to minimize and mitigate loss of mountain goat habitat.
d. Inform and educate the public concerning the needs of mountain goats.

C. Recreation Goal: Provide high quality opportunities for hunting and viewing of mountain goats.

Objective 1: Increase hunting opportunities as populations allow while maintaining high quality hunting experiences.

Strategies:

a. Recommend any-goat permits to harvest 5%–15% of the counted population. Populations that have slow rates of growth or are stable should be harvested near the low end of the range, whereas populations with rapid growth potential should be

harvested near the top end of the range.

b. Recommend nanny goat permits in accordance with population objectives.
c. Use subunits to maximize hunting opportunities and improve hunter distribution.
d. When feasible, use multiple seasons to maximize hunting opportunities and minimize hunter conflicts.
e. Maintain high hunter success (>90%) on all units.

Objective 2: Increase public awareness and expand viewing opportunities of mountain goats.

Strategies:

a. Evaluate existing public viewing areas and identify potential new sites.
b. Install interpretive signs in mountain goat areas for public information.
c. Produce written guides or brochures to help educate the public and provide viewing opportunities which will not impact mountain goats.
d. Continue and expand mountain goat viewing events for interested publics.

Figure 1. Mountain goat distribution, Utah 2013.

Figure 2. Mountain goat population trends, Utah 1975–2012.

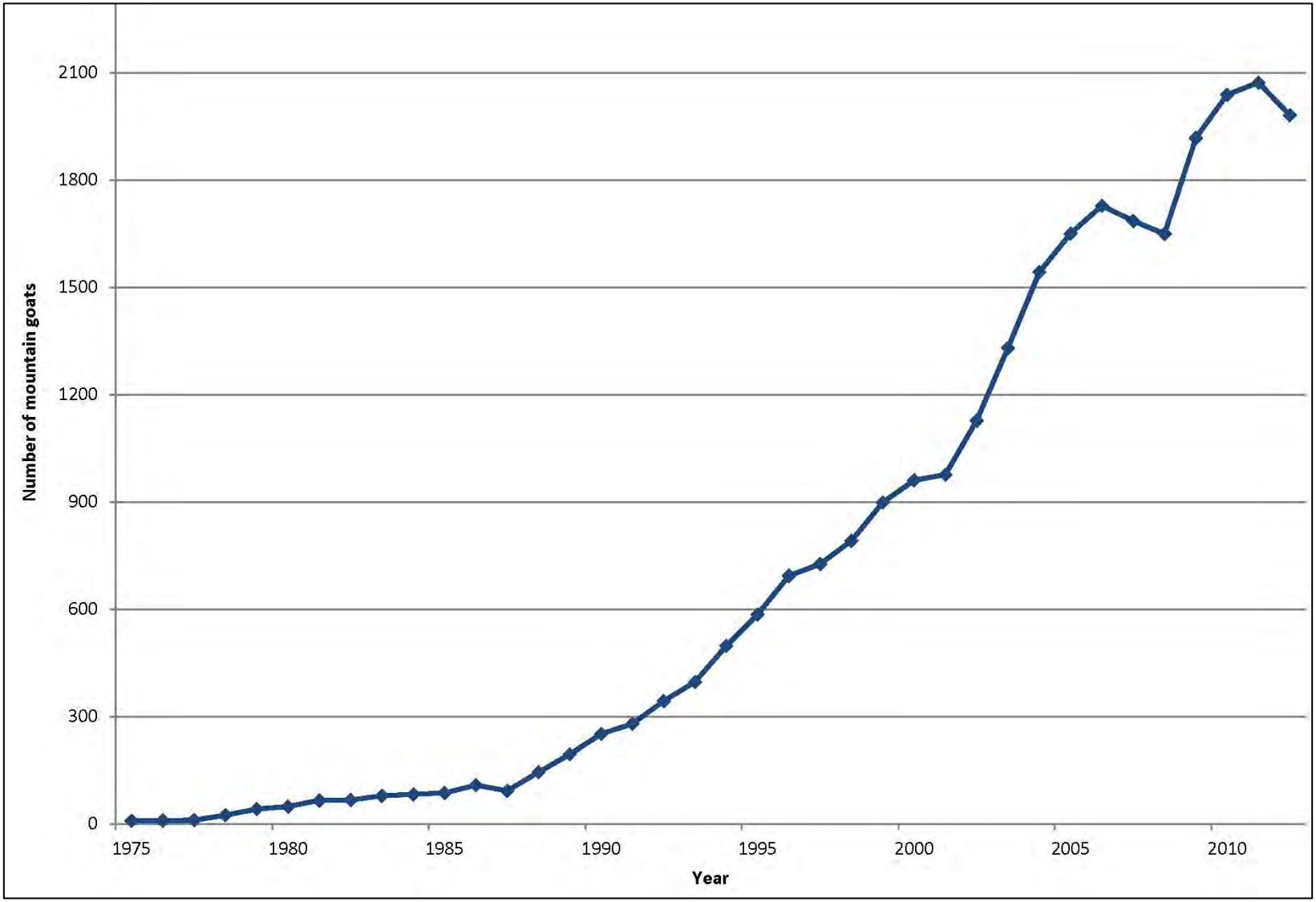

Table 1. History of mountain goat transplants, Utah 1967–2012.

Unit #	Unit	Area released	Year	# of mountain goats released				Source
				Total	Billies	Nannies	Kids	
3	Ogden	Willard Peak	1994	5	1	4	0	Lone Peak, UT
3	Ogden	Willard Peak	2000	4	—	—	—	Provo Peak, UT
7	Kamas	Bald Mountain, Uintas	1987	7	2	5	0	Lone Peak, UT
7	Kamas	Bald Mountain, Uintas	1988	16	—	—	—	Olympic NP, WA
8 / 9	North Slope/South Slope	Whiterocks Canyon, Uintas	1989	9	5	4	0	Olympic NP, WA
8 / 9	North Slope/South Slope	Whiterocks Canyon, Uintas	1989	1	1	0	0	Kamas, UT
8 / 9	North Slope/South Slope	Whiterocks Canyon, Uintas	1992	13	4	9	0	Lone Peak, UT
8 / 9	North Slope/South Slope	Chepeta Lake, Uintas	1996	7	1	6	0	Tushar Mountains, UT
8 / 9	North Slope/South Slope	Liedy Peak, Uintas	1996	3	0	3	0	Tushar Mountains, UT
8 / 9	North Slope/South Slope	Marsh Peak, Uintas	1996	5	1	4	0	Tushar Mountains, UT
8 / 9	North Slope/South Slope	Brown Duck Peak, Uintas	1997	7	1	6	0	Tushar Mountains, UT
8 / 9	North Slope/South Slope	South Fork of Rock Creek, Uintas	1997	5	1	4	0	Tushar Mountains, UT
8 / 9	North Slope/South Slope	Center Park, Uintas	2000	8	0	6	2	Tushar Mountains, UT
8 / 9	North Slope/South Slope	Jefferson Park, Uintas	2000	9	2	7	0	Tushar Mountains, UT
16	Central Mountains	Loafer Mountain	2007	20	5	15	0	Tushar Mountains, UT
17	Wasatch Mountains	Lone Peak	1967	6	2	4	0	Wantachee, WA
17	Wasatch Mountains	Mount Olympus	1981	10	3	4	3	Olympic NP, WA
17	Wasatch Mountains	Mount Olympus	1981	4	0	2	2	Unknown
17	Wasatch Mountains	Mount Timpanogos	1981	10	4	6	0	Olympic NP, WA
17	Wasatch Mountains	Provo Peak	1989	7	2	5	0	Olympic NP, WA
17	Wasatch Mountains	Provo Peak	1990	5	1	4	0	Mount Timpanogos, UT
22	Beaver	Tushar Mountains	1986	6	1	5	0	Lone Peak, UT
22	Beaver	Tushar Mountains	1986	1	1	0	0	Mount Timpanogos, UT
22	Beaver	Tushar Mountains	1988	17	—	—	—	Olympic NP, WA
—	Idaho	Lemhi Mountains	2007	24	5	18	1	Tushar Mountains, UT

Table 2. Mountain goat trend counts by unit, Utah 2003–2012.

Unit	Year established	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Beaver	1986	128	133	153	140	180	133	206	—	240	—
Central Mountains, Loafer Mountain	2007	—	—	—	—	20*	—	—	—	—	26
Central Mountains, Nebo	2007	—	—	—	—	—	—	—	—	—	22
Kamas / Chalk Creek	1987	—	34	—	24	—	37	108	—	91	—
North / South Slope, High Uintas Central	1989	—	183	—	228	—	153	210	—	197	—
North / South Slope, High Uintas East	1996	—	139	—	166	—	95	81	—	89	—
North / South Slope, High Uintas Liedy Peak	1996	—	96	—	111	—	58	77	—	41	—
North / South Slope, High Uintas West	1987	—	131	—	169	—	236	294	—	440	—
Ogden, Willard Peak	1994	—	105	151	72	183	115	193	218	252	—
Wasatch Mountains, Box Elder Peak	1967	—	50	—	—	57	—	—	54	—	30
Wasatch Mountains, Lone Peak	1967	—	165	—	—	68	—	—	67	—	13
Wasatch Mountains, Provo Peak	1989	—	88	—	—	95	—	—	104	—	79
Wasatch Mountains, Timpanogos	1981	—	109	—	—	113	—	—	118	—	64

*Initial transplant

Table 3. Mountain goat harvest statistics, Utah 1981–2012.

Year	Permits issued	Billy harvest	Nanny harvest	Total harvest	Hunters afield	Success rate (%)	Mean days hunted
1981	1	1	0	1	1	100	2
1982	1	0	1	1	1	100	2
1983	3	3	0	3	3	100	4.3
1984	4	2	1	3	4	75	4
1985	3	3	0	3	3	100	5.3
1986	4	2	2	4	4	100	6.5
1987	4	3	1	4	4	100	3.8
1988	4	3	1	4	4	100	3.5
1989	5	4	1	5	5	100	3.6
1990	6	4	0	4	6	67	4.8
1991	6	3	3	6	6	100	7
1992	8	8	0	8	8	100	5.8
1993	7	6	1	7	7	100	4.3
1994	10	10	0	10	10	100	—
1995	12	10	2	12	12	100	—
1996	19	16	2	18	19	95	4.2
1997	19	17	2	19	19	100	—
1998	19	18	0	18	19	95	3.5
1999	20	18	2	20	20	100	—
2000	29	19	9	28	29	97	3.2
2001	30	21	9	30	30	100	—
2002	36	25	10	35	36	97	—
2003	41	32	9	41	41	100	2.3
2004	46	31	15	46	46	100	2.6
2005	68	42	21	63	65	97	3.5
2006	94	48	38	86	93	92	3.3
2007	96	55	36	91	96	95	3.3
2008	95	58	30	88	93	95	2.9
2009	108	77	30	107	107	100	2.8
2010	115	70	41	111	114	97	3.0
2011	143	91	42	133	142	94	3.4
2012	175	94	73	167	174	96	2.6

Table 4. Mountain goat average age of harvest, Utah 2005–2012.

Management unit	Average age								3-year average
	2005	2006	2007	2008	2009	2010	2011	2012	
Beaver	6.1	6.2	5.2	5.5	4.3	4.9	4.9	5.0	4.9
Kamas/Chalk Creek	6.5	3.5	5.0	5.5	—	4.6	6.5	3.3	4.8
North / South Slope, High Uintas Central	4.0	3.3	4.8	4.4	—	5.8	4.0	3.6	4.5
North / South Slope, High Uintas East	10.0	2.7	6.8	4.5	6.0	5.0	11.0	7.0	7.7
North / South Slope, High Uintas Liedy Peak	6.0	4.5	2.5	4.3	4.0	3.5	3.8	7.5	4.9
North / South Slope, High Uintas West	4.8	2.8	4.8	3.3	3.6	3.0	4.8	4.8	4.2
Ogden, Willard Peak	2.5	3.7	4.7	3.5	3.2	3.7	4.1	3.9	3.9
Wasatch Mountains, Box Elder Peak	4.0	3.7	3.0	6.0	5.0	9.0	—	6.0	7.5
Wasatch Mountains, Lone Peak	6.0	3.4	4.2	1.0	3.0	10.0	3.0	3.5	5.5
Wasatch Mountains, Provo Peak	4.0	—	3.0	5.3	4.0	5.8	4.0	4.0	4.6
Wasatch Mountains, Timpanogos	4.5	5.0	7.3	4.0	4.0	6.4	4.5	3.0	4.6
Statewide average	5.3	3.9	4.8	4.3	3.7	4.7	4.5	4.4	4.3

Table 5. Resident and nonresident drawing odds of obtaining mountain goat hunting permits, Utah 1998–2012.

Year	Residents			Nonresidents		
	Applicants	Permits	Odds	Applicants	Permits	Odds
1998	568	18	1 in 31.6	44	1	1 in 44
1999	748	20	1 in 37.4	93	1	1 in 93
2000	904	24	1 in 37.7	142	2	1 in 71
2001	1103	27	1 in 40.9	194	2	1 in 97
2002	1505	33	1 in 45.6	244	2	1 in 122
2003	1793	37	1 in 48.5	275	3	1 in 92
2004	2072	40	1 in 51.8	333	3	1 in 111
2005	2384	59	1 in 40.4	464	5	1 in 93
2006	2747	83	1 in 33.1	660	6	1 in 110
2007	3351	84	1 in 39.9	683	5	1 in 137
2008	3405	83	1 in 41.0	732	7	1 in 105
2009	3577	91	1 in 39.3	2869	9	1 in 319
2010	3911	97	1 in 40.3	3194	10	1 in 319
2011	4005	118	1 in 33.9	3446	11	1 in 313
2012	4220	144	1 in 29.3	3779	17	1 in 222

Table 6. Potential mountain goat transplant sites by region, Utah 2013.[1]

Region	Unit	Transplant Site	Transplant Type
Central	Central Mountains	Loafer Mountain	Augmentation
	Central Mountains	Mount Nebo	Augmentation
	Wasatch Mountains	Box Elder Peak	Augmentation
	Wasatch Mountains	Lone Peak	Augmentation
	Wasatch Mountains	Provo Peak	Augmentation
	Wasatch Mountains	Timpanogos	Augmentation
	West Desert	Deep Creek Mountains	Initial transplant
Northeastern	North / South Slope	High Uintas East	Augmentation
	North / South Slope	High Uintas Liedy Peak	Augmentation
Northern	Cache	Wellsville Mountains	Augmentation
	Ogden	Farmington Peak	Initial transplant
	Ogden	Ogden Peak	Augmentation
Southeastern	La Sal	La Sal Mountains	Initial transplant
Southern	Mount Dutton	Mount Dutton	Augmentation

[1] In accordance with Utah Code 23-14-21.

Literature Cited

Bailey, J. A. 1991. Reproductive success in female mountain goats. Canadian Journal of Zoology 69:2956–2961.

Cote, S. D. and M. Festa-Bianchet. 2003. Mountain Goat. Pages 1061–1075 *in* G. A. Feldhammer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America, Biology, Management, and Conservation, 2nd edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Festa-Bianchet, M. and S. D. Cote. 2008. Mountain Goats. Island Press, Washington DC, USA.

Festa-Bianchet, M., M. Urquhart, and K. G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. Canadian Journal of Zoology 72:22–27

Garde, E., S. Kutz, H. Schwantje, A. Vietch, E. Jenkins, and B. Elkin. 2005. Examining the risk of disease transmission between wild Dall's sheep and mountain goats, and introduced domestic sheep, goats, and llamas in the Northwest Territories. Other publications in Zoonotics and Wildlife Disease, University of Nebraska-Lincoln 29: 1–139.

Gross, J. E. 2001. Evaluating effects of an expanding mountain goat population on native bighorn sheep: a simulation model of competition and disease. Biological Conservation 101:171–185.

Hobbs, N. T., J. A. Bailey, D. F. Reed, and M. W. Miller. 1990. Biological criteria for introductions of large mammals: using simulation models to predict impacts of competition. Transactions of the 55th North American Wildlife and Natural Resources Council 1990:620–632.

Kimberling, C. V. 1988. Jensen and Swift's Diseases of Sheep. Lea & Febiger, Philadelphia, Pennsylvania, USA.

Lance, W., W. Adrian, and B. Widhalm. 1981. An epizootic of contagious ecthyma in Rocky Mountain bighorn sheep in Colorado. Journal of Wildlife Diseases 17: 601–603.

Laundre, J. W. 1994. Resource overlap between mountain goats and bighorn sheep. Great Basin Naturalist 54:114–121.

Rice, C. G., K. J. Jenkins, and W. Y. Chang. 2009. A sightability model for mountain goats. Journal of Wildlife Management 73:468–478.

Samuel. W. M., G. A. Chalmers, J. G. Stelfox, A. Loewen, and J. J. Thomsen. 1975. Contagious ecthyma in bighorn sheep and mountain goat in western Canada. Journal of Wildlife Diseases 11:26–31.

Williams, E. S., T. R. Spraker, and G. G. Schoenfeld. 1979. Paratuberculosis (Johne's Disease) in bighorn sheep and a Rocky Mountain goat in Colorado. Journal of Wildlife Diseases 15: 221–227.

Williams, E.S., S. P. Snyder, and K. L. Martin. 1983. Pathology of spontaneous and experimental infection of North American wild ruminants with *Mycobacterium paratuberculosis*. Veterinary Pathology 20:274–291

Appendix A

MOUNTAIN GOATS IN UTAH: AN OVERVIEW

History

The mountain goat of western North America is one of two known members from the genus *Oreamnos*. The other member of the genus, *Oreamnos harringtoni*, is extinct. The closest extant relative is the chamois of Europe. Because of the harsh sites that mountain goats inhabit, the fossil record is not extensive. The genus likely derived from parent stock in Asia and entered North America sometime during the Pleistocene. It was likely completely isolated from that parent stock by the late Pleistocene (18,000 years ago).

During and since the Pleistocene, the distribution and status of goat populations likely varied widely since mountain goats specialized to occupy a narrow range of habitats. These habitats are tied closely to alpine cliffs, which means any glacial encroachment or retreat would have likely changed habitat suitability on all mountain ranges in western North America. This would have also caused an altitudinal shift in habitats within individual mountain ranges. During the full glacial period of the late Pleistocene, Harrington's mountain goats were present farther south than any mountain goats live today. This is documented by fossils recovered from the San Josecito Cave site, in Nuevo Leon, Mexico, at an altitude of 2300 meters. There were likely no goats present in much of Canada and Alaska because suitable cliff sites were buried by glaciers. With the end of the Pleistocene and the associated glacial retreat, suitable habitats for mountain goats would have become available northward and upward from the southern terminus in Mexico. As these habitat changes progressed, Utah would have provided a major pathway for goat redistribution from south to north. The central mountain ranges of Utah, along with the Rocky Mountains of Colorado, would have provided appropriate habitats for goat redistribution in response to changing climate. A strong case can be made that Utah would have been intermediate between both extremes. Given the variety and extent of mountain ranges through the length of the state, habitat at some elevation could have been provided during most if not all of the Pleistocene, and evidence from fossil sites in nearby areas support that premise. Pleistocene goat remains have been identified from the Smith Creek Cave site on the Utah-Nevada border near Baker, Nevada; at three sites in the Laramie Mountains in southeastern Wyoming; and at Rampart Cave and the Stanton site along the Colorado River corridor in northern Arizona. As conditions became warmer and drier in the Intermountain region after the Pleistocene, a dramatic restructuring of goat distributions could have occurred.

Recent Distribution

The distribution of mountain goats at the time of European contact with western mountain ranges is very poorly documented. This is likely a byproduct of the remote habitats used by mountain goats. Given the climatic conditions of the past 200 years, goat habitat would have been limited to the highest and most inaccessible alpine expanses in the Intermountain region. Only in Alaska and Northwest Canada would goats have been found near the valleys and basins that provided access for Europeans. Even early trappers would have been unlikely to encounter goats in their normal pursuit of beaver, since goats persist yearlong at high elevations in most ranges.

By the early part of the 20th century, European settlement and an interest in wildlife had set the stage for increasing recorded knowledge of the status and distribution of goats. By mid-century, a well documented analysis of goat distributions had emerged. A Forest Service report that was published in the Twelfth Biennial Report of the Fish and Game Commissioner of the State of Utah in 1917-1918, estimated 25 mountain goats on the Wasatch Forest. This figure was listed in addition to mountain sheep numbers. The Wasatch Forest at that time also included the Uinta Mountains; site locations, unfortunately, were not listed. A separate report from a District Ranger in Kamas stated that both mountain sheep and goats were present in the High Uintas. By the middle of the 20th century no native goat populations were known to persist in Utah, Colorado, Nevada, or Wyoming.

Currently, however, there are populations of mountain goats in all these states. All are the result of introductions of goats by state wildlife departments during the last 50+ years. Many, if not all, of these populations are healthy and viable, indicating that these populations all occupy habitat suitable for mountain goats. The status of these areas at the time of European settlement is not fully known.

The Intermountain Region Since the Pleistocene

The most recent glacial age ended about 14,000 years ago, and the interglacial period that we currently occupy had gained primacy. Conditions became significantly warmer and in many cases drier. Mountain goat habitat, which once existed as far south as Mexico was no longer suitable. The progression from full glacial advance to present day conditions was far from linear. Small scale returns to colder and snowier conditions occurred as recently as the 1800's. During the Middle Holocene, there was a period of several thousand years (from about 7,000 to 4,500 years ago) when climatic conditions were substantially warmer and probably drier than those today. Data indicate this period was pervasive enough that the Great Salt Lake may have been nearly dry.

Based on our knowledge of goat habitat requirements and climatic conditions in the early Holocene, goats could have found suitable habitat in many mountain ranges of Utah and the Intermountain area after the end of glaciation. These habitats were likely similar to those present today, though perhaps more extensive, given the cooler temperatures. During the Middle Holocene, however, the dramatic warming would have shifted goat habitat much higher on occupied mountain ranges. Data from the Snowbird Bog pollen sites indicate that timberline may have been 1000 feet or more higher in altitude than that found today. Given the observed altitudinal depth of current habitats, this compression would have eliminated suitable sites on most Intermountain ranges, and restricted those found in larger and more northerly ranges. Thus goat populations surviving after the Pleistocene in high elevation habitats may have been eliminated or restricted.

Since that period, however, conditions have reverted to a cooler and wetter pattern. Suitable goat habitat exists on many mountain ranges in Utah and surrounding states, as demonstrated by the survival of transplanted populations. If these ranges were devoid of goats at the time of European contact, why had goats not re-colonized there? Certainly goat populations had

followed the ebb and flow of glacial periods for perhaps millions of years. However, one new factor was inserted at the end of the Pleistocene; humans. Humans became for the first time a member of the North American ecosystem. After that time, aboriginal people were widespread and important modifiers of both vegetative and animal communities. Although the extent and type of modifications are debated, the conclusion of nearly all recent research has been that impacts by aboriginal people were greater than previously thought. Some of the most obvious and dramatic impacts would have been extensive and widespread burning, transportation of propagules of plant species beyond the range of "natural" movement, and manipulation or even elimination of populations and even species of large vertebrates.

It is known that goats were contemporaneous with aboriginal hunters at the end of the Pleistocene. The loss of goats during the Holocene may have been directly aided by opportunistic hunting of goats. It is well documented that native peoples hunted mountain sheep in alpine areas throughout the Intermountain area. Goats would have been an appropriate alternative prey item for these big game hunters.

Whatever the extent of this aboriginal pressure, it is obvious that recolonization of suitable habitats by goats had to be accomplished through the barrier of a thriving culture of big game hunters. These big game hunters likely only killed goats opportunistically, since their survival was dependent upon the vast array of other ungulates available to them. Given their highly selective habitat requirements, relatively low densities, and low fecundity, it would have been difficult for goats to recolonize these now suitable habitats. Currently, with a vast ocean of human habitation surrounding islands of goat habitat, the prospects for natural expansion of goat populations, except for unoccupied habitats immediately adjacent to existing populations, is unlikely.

An interesting footnote to this scenario can be added for the current status of moose. This species has since the turn of the century greatly extended its range southward into the Intermountain Area. The prospects for moose pioneering after the Pleistocene should have been as poor as for goats in the face of a thriving big game hunting culture. However, the encroachment of Europeans eliminated the two prime predators of moose - wolves and aboriginal big game hunters. After the turn of the century, wildlife laws and enforcement reduced the killing of moose by early settlers. As such, moose, with their higher mobility and broader habitat requirements than mountain goats, were able to colonize areas far to the south of what had been considered its historically occupied range.

***Oreamnos* speciation**

The relationship between the two known species of *Oreamnos* (Harrington's goat and mountain goat) warrants some discussion. Essentially, the largest difference between the two species is size. Harrington's goat is up to 30% smaller than the existing mountain goat species and has minor skull variances. This difference is derived from skulls from a few well-documented sites in Arizona, Mexico, California, and Nevada. Overall, though, the fossil record is poor because of the low probability of preservation in the harsh sites frequented by goats. The existing fossils all came from protected cave sites which are rare. Nearly all such sites are from isolated areas at the southern extreme of past mountain goat range and were likely in areas isolated from other

goat populations after the end of the Pleistocene. Caution must be exercised in projecting the importance of a character such as relative size in assessing its evolutionary significance and the relationship between the two *Oreamnos* species. Body size may be one of the most labile of morphological traits, especially in extremes of climatic conditions. Purdue and Reity (1993) have demonstrated tremendous shifts in body size in white-tailed deer during the past 4,400 years in Georgia and South Carolina. They consider climate changes with resultant habitat quality to be the driving factor for this change. They indicate that body size tends to be quite responsive to changes in certain environmental factors that in turn serve as the ultimate source of selection. This is dramatically demonstrated by ungulates on islands, which may frequently be dwarfed in response to reduced food resources.

A careful consideration of these factors will generate caution in inferring about the relationship between *O. harringtoni* and *O. americanus*. The fossil records are non-existent between isolated southerly sites and the range of "modern" goats. It is possible that the Harrington population documented by cave sites were "islands" by the late Pleistocene. Kurten (1980) postulates that Harrington's goat was in fact an extension of *O. americanus* that became isolated at the end of the Pleistocene, and body size would have been driven by limited resources. Since their habits were probably like those of modern goats, they would have been subjected to resource limitations in their peripheral occurrences.

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UTAH BIGHORN SHEEP
STATEWIDE MANAGEMENT PLAN

UTAH DIVISION OF WILDLIFE RESOURCES
DEPARTMENT OF NATURAL RESOURCES

UTAH DIVISION OF WILDLIFE RESOURCES
STATEWIDE MANAGEMENT PLAN FOR BIGHORN SHEEP

I. PURPOSE OF THE PLAN

A. General

This document is the statewide management plan for bighorn sheep in Utah. The plan will provide overall guidance and direction to Utah's bighorn sheep management program. The plan assesses current information on bighorn sheep, identifies issues and concerns relating to bighorn sheep management in Utah, and establishes goals and objectives for future bighorn management programs. Strategies are also outlined to achieve goals and objectives. The plan will be used to help determine priorities for bighorn management and provide the overall direction for management plans on individual bighorn units throughout the state.

B. Dates Covered

The statewide bighorn sheep plan was approved by the Utah Wildlife Board on June 4, 2013 and will be in effect for 5 years from that date (Dates covered: June 2013 – June 2018).

II. SPECIES ASSESSMENT

A. Natural History

Bighorn sheep are found in western North America from central British Columbia to Mexico and from California to the Dakotas and are one of the most impressive large mammals in North America. They are named for the massive horns grown by the males of the species. Horns grow throughout life and typically reach maximum size at 8 to 10 years of age. Females also have horns that are similar in size to yearling males. Males, females, and young of the year are called rams, ewes, and lambs respectively. Rams normally separate themselves from groups of ewes and lambs, except during the breeding season, which occurs from mid October to early December. During that time, rams engage in impressive head butting clashes to establish dominance. Gestation is about 180 days. Lambs, which are nearly always singles, are born in mid April to early June.

Bighorn sheep are native to Utah. Archeological evidence indicates they were well known to the prehistoric inhabitants of Utah, since bighorns are depicted in pictographs and petroglyphs more than any other form of wildlife. Historical records of the first white men in the state also confirm the presence of bighorns. Father Escalante noted in his journal as he crossed the Colorado River in Utah - "through here wild sheep live in such abundance that their tracks are like those of great herds of domestic sheep" (Rawley 1985). Explorers, trappers, pioneers and settlers also recorded numerous observations of bighorn sheep throughout the state. Rocky Mountain bighorns *(Ovis canadensis canadensis)* are generally recognized to have inhabited northern and central Utah, whereas desert bighorns *(Ovis canadensis nelsoni)* were found in southern Utah. California bighorns *(Ovis canadensis californiana)* historically inhabited portions of the Great Basin in Nevada and Idaho. Although it is not known conclusively whether or not California bighorns

inhabited Utah, recent studies indicate there is no genetic or taxonomic distinction between Rocky Mountain and California bighorns (Ramey 1993). Thus, they should both be considered the same subspecies (Rocky Mountain bighorn sheep). Some mixing and interbreeding of Rocky Mountain and desert bighorns likely occurred where their ranges converged in Utah, making a clear distinction of historic ranges difficult.

Native populations of Rocky Mountain bighorn sheep were nearly extirpated following pioneer settlement. A few scattered sightings of bighorns persisted in northern Utah as late as the 1960's. Factors contributing to their demise included competition with domestic livestock for forage and space, vulnerability to domestic livestock-borne diseases, habitat conversions away from native grasslands towards shrub lands due to excessive grazing and fire suppression, and unregulated hunting (Shields 1999).

Utah's desert bighorn sheep populations also struggled to survive civilization. Whereas some herds suffered early extirpation, others remained relatively unexploited until the 1940's and 1950's, when uranium was discovered on the Colorado Plateau. By the 1960's, only a small population of desert bighorns remained in Utah along the remote portions of the Colorado River. Desert bighorn populations were thought to have declined for the same reasons previously described for Rocky Mountain bighorns.

B. Management

1. DWR Regulatory Authority

The Utah Division of Wildlife Resources (DWR) presently operates under authority granted by the Utah Legislature in Title 23 of the Utah Code. The Division was created and established as the wildlife authority for the state under Section 23-14-1 of the Code. That Code also vests the Division with its functions, powers, duties, rights, and responsibilities. The Division's duties are to protect, propagate, manage, conserve, and distribute protected wildlife throughout the state.

The Utah DWR is charged to manage the state's wildlife resources and to assure the future of protected wildlife for its intrinsic, scientific, educational, and recreational values. Protected wildlife species are defined in code by the Utah Legislature.

2. Population Status

Rocky Mountain and California Bighorns

Rocky Mountain and California bighorns currently exist in the northern half of the state (Figure 1). The current statewide population estimate for Rocky Mountain bighorns in Utah managed by DWR is nearly 2200 sheep and has shown an increasing trend over the past 15 years (Figure 2). Of the total population, approximately 770 are considered California bighorn sheep and are found on Antelope Island, the Newfoundland Mountains, and the Stansbury Mountains. Utah currently has 12 distinct populations of Rocky Mountain and California bighorn sheep, all of which are the result of transplant efforts. Six of these populations are showing increasing trends, 3 are stable, and 3 are showing declining trends or have low numbers of sheep (Table 1). One

population, North Slope-Goslin Mountain was culled in 2009 due to disease issues and concerns about the disease spreading to nearby herds. Initial indications show that this effort was successful, and efforts will likely be made to attempt to reestablish this population in the future. In addition to the DWR managed herds, populations of Rocky Mountain bighorn sheep populations are also found in Dinosaur National Monument and on Ute tribal lands in northeastern Utah.

Desert Bighorn

Desert bighorns inhabit the slickrock canyon areas of southern Utah (Figure 1). Significant populations occur across the Colorado Plateau including the San Rafael Swell and throughout the Colorado River and its many tributaries. The current population estimate for desert bighorns in Utah managed by DWR is 2000 sheep and has been relatively stable for the past 10 years (Figure 2). Utah currently has 12 distinct populations of desert bighorn sheep. Of those 12, 3 are showing increasing trends, 4 are stable, and 5 are showing declining trends or have low numbers of sheep (Table 2). In addition to those herds, desert sheep populations also occur in Arches, Canyonlands, Capital Reef, and Zion National Parks, and on Navajo tribal lands.

3. Population Surveys

In Utah bighorn sheep populations are surveyed via helicopter every 2–3 years (Table 1, Table 2). During these flights, biologists survey all potential bighorn sheep habitat during the peak of the rut in late October to December depending on the management unit. All observed animals are counted and classified as ewes, lambs, and rams, with rams being further classified as Class I (2.5 years old), II (2.5–5.5 years old), III (6.5–7.5 years old), or IV (8.5+ years old) according to Geist. Previous studies have shown that sightability on bighorn sheep populations varies between 60-70%, depending on the unit and conditions. In addition to the helicopter surveys, many bighorn sheep populations in Utah have radio-collared animals. These collars allow biologist to monitor annual survival and movements. The collars also allow biologists to locate animals and collect ground classification data in years without helicopter surveys. In conjunction with Brigham Young University, Utah State University, Utah Foundation for North American Wild Sheep (FNAWS), and Sportsmen for Fish and Wildlife (SFW), DWR has conducted and participated in many bighorn sheep research projects. Findings from those research projects have greatly improved the current knowledge of bighorn sheep and have improved management practices.

4. Hunting

Bighorn sheep are managed as an once-in-a-lifetime species in Utah. The first hunt for bighorn sheep in Utah was held in 1967 for the desert subspecies on the San Juan Unit (Table 3). A total of 10 permits were issued, 9 hunters went afield, and all 9 harvested rams. The first hunt for Rocky Mountain bighorns in Utah was in 1991 on the Book Cliffs Rattlesnake Unit. Two permits plus 1 high-bid permit were issued and all 3 hunters harvested rams. Since the initial hunts, bighorn sheep permits have generally been increasing. The highest number of desert bighorn sheep tags issued in Utah was in 2011 when 54 permits were issued. For Rockies, the highest number of tags was issued in 2012 with 40 permits being issued. From 1967 to 2012, a

total of 1378 people hunted bighorn sheep (324 Rocky Mountain, 1054 desert) resulting in the harvest of 1182 bighorn sheep (321 Rocky Mountain, 861 desert). Success rates for bighorn sheep in Utah are high and average 99% for Rockies and 82% for deserts. Demand for bighorn sheep permits is extremely high, and demand is increasing faster than supply (Table 4, Table 5). The odds of drawing a bighorn sheep permit are worse than any other species in Utah. In 2012, a total of 20,009 hunters applied for the 71 public draw permits available resulting in drawing odds of 1 in 283.

5. Transplants

Utah DWR, in partnership with local conservation groups including FNAWS, SFW, and the Wild Sheep Foundation, has been involved in an aggressive program to restore bighorn sheep to their native habitat for over 40 years. Extensive efforts have been made to reintroduce and supplement populations of both Rocky Mountain and desert bighorn sheep (Table 6, Table 7). Rocky Mountain bighorns were first reintroduced into the state near Brigham City in 1966, whereas desert bighorns were first reintroduced in Utah in 1973 in Zion National Park. Since restoration efforts began, over 1000 Rocky Mountain bighorn sheep (including 190 California bighorn sheep) and over 850 desert bighorns have been released in areas of historical habitat. Most desert bighorn transplants have been successful, whereas there have been some failures of Rocky Mountain bighorn transplants. Although the exact reasons behind the transplant failures are unknown, disease issues, predation, and not moving enough animals have all been hypothesized as potential reasons.

C. Habitat

Bighorn sheep are uniquely adapted to inhabit some of the most remote and rugged areas in Utah. They exist in some of the most hostile climatic conditions ranging from the hot, dry canyonlands of southern Utah to the cold, snowy alpine regions of Utah's northern mountains. Bighorns are sometimes referred to as a wilderness species because of the naturally remote and inaccessible areas they inhabit. Bighorns prefer open habitat types with adjacent steep rocky areas for escape and safety. Habitat is characterized by rugged terrain including canyons, gulches, talus cliffs, steep slopes, mountaintops, and river benches (Shackleton et al. 1999). The diet of mountain sheep is comprised primarily of grasses and forbs, although sheep may also utilize shrubs depending on season and availability. Most Rocky Mountain bighorns have seasonal migrations with established winter and summer ranges, whereas desert bighorns generally do not migrate. Extensive historical bighorn habitat occurs throughout Utah. However, not all habitat is currently suitable for reestablishment of bighorn populations. Vegetative changes, human encroachment, and continued domestic sheep grazing make some areas unsuitable for bighorn restoration. Habitat management practices include conversions of domestic sheep grazing permits, vegetative treatments, and water developments. Utah FNAWS and other conservation groups have been extremely helpful in negotiating, funding, and participating in habitat projects.

III. ISSUES AND CONCERNS

A. Disease

Parasites and diseases are a major concern for bighorn sheep management in Utah. Parasites such as those that cause Psoroptic mange (Boyce and Weisenberger 2005) and respiratory diseases such as those caused by Pasteurellosis have resulted in large-scale population declines in short periods of time (Jessup 1985, Foreyt 1990).

Pasteurellacae are a wide array of bacteria that have been associated with respiratory disease, death, and reduced fecundity in bighorn sheep (Miller et al. 2012). Currently, there are 23 known Pasteurellacae isolates from bighorn sheep, and of these, 3 appear to be associated with severe disease. These include *Pasteurella multocida*, *Mannheimia haemolytica* (formerly *P. haemolytica*) and *Bibersteinia trehalosi* (formerly *P. trehalosi*). Within each species there are several biovariants and subtypes that may be further classified by virulence, or ability to produce leukotoxin, which may cause enzyme production, cell lysing, and extensive tissue damage during a pneumonia event (Miller et al. 2012).

Pasteurella multocida is the most widely distributed of the 3 genera and has been associated with epidemic disease outbreaks in both domestic and wild mammals. *P. multocida* is rarely found or isolated from bighorn sheep and is not typically linked to disease outbreaks. However, it has been associated with large die-offs of Rocky Mountain bighorn sheep in the Hells Canyon area of Idaho, Washington, and Oregon (Weiser et al. 2003) and Colorado (Spraker et al. 1984). *P. multocida* was one of the primary isolates from bighorn sheep collected during an all ages pneumonia die-off in Utah's Goslin Mountain bighorn sheep herd during winter 2010.

Mannheimia haemolytica and *P. trehalosi* appear to be the genera that primarily affect both wild and domestic ruminants and are the most studied in bighorn sheep. Both can cause pneumonia or septicemia; however, they are also considered common commensal organisms in the upper respiratory tract. As commensal organisms, they likely act as opportunistic pathogens to animals under environmental stress or with lowered immunities (Foryet and Jessup 1982, U-C Davis 2007).

Other bacterium such as *Mycoplasma* spp. that have been associated with respiratory disease in many different mammal and avian species, including domestic sheep (Weiser et al, 2012), may contribute or lead to pneumonia events in bighorn sheep by allowing the overgrowth of Pasteurellacae (Besser et al. 2008, Dassanyake et al. 2010, Besser et al. 2012, Weiser et al. 2012). For example, research in bighorn sheep that were exposed to leukotoxin producing *M. haemolytica* did not develop fatal respiratory disease until after exposure to *M. ovipneumonia* (Dassanayake et al. 2010).

As mentioned above, many mammals can carry one or more of these bacterium as commensal flora in their upper respiratory system (Dunbar et al 1990, Miller 2001, U-C Davis 2007). Exposure of naïve bighorn sheep to domestic sheep and goats carrying strains of these bacteria can have devastating results and examples of epizootic outbreaks of respiratory disease in relation to contact with domestic sheep or goats exist in the literature (Jessup 1985, Foreyt 1990,

Martin et al. 1996, Rudolph et al. 2003). Conversely, respiratory disease attributed to Pasteurellosis has occurred in the apparent absence of contact with domestic sheep or goats. The cause of those die-offs have been attributed to various forms of stress including overcrowding, poor nutrition, human disturbance, loss of habitat, weather conditions, infection with parasites such as lungworm (*Protostrongylus* spp) or mites (*Psoroptes ovis)* (Lange et al. 1980, DeForge 1981, Foreyt and Jessup 1982, Spraker et al. 1984, Clark and Jessup 1992, Bunch et al. 1999, Monello et al. 2001).

It is believed that wild sheep to wild sheep interactions may also lead to respiratory disease when exposure of naïve bighorn sheep to other bighorn sheep carrying different strains of bacterium occurs (Monello et al. 2001, Weiser et al. 2003, U-C Davis 2007). Therefore proximity of bighorn sheep to domestic sheep grazing areas and the connectivity of habitats between other herds and seasonal ranges play a critical role in management of respiratory disease (Monello et al. 2001). For those reasons it is critical for future management that we understand the distribution and dynamics of disease and their pathogens in Utah bighorn sheep.

Because of the aforementioned disease concerns, the Western Association of Fish and Wildlife Agencies (WAFWA) Wild Sheep Working Group published the "Recommendations for Domestic Sheep and Goat Management in Wild Sheep Habitat" in 2007. Those guidelines clearly outline steps that should be taken by state wildlife agencies, federal land management agencies, wild sheep conservation organizations, domestic sheep and goat producers/permittees, and private landowners to reduce conflicts between wild sheep and domestic sheep and goats. The guidelines were updated in 2010 and once again in 2012. The 2012 WAFWA Wild Sheep Working Group recommendations for state wildlife agencies can be found in Appendix A of this plan. The complete and most updated version of the guidelines can be found at http://www.wafwa.org/html/wswg.shtml.

The Utah Division of Wildlife Resources recognizes the economic importance of the domestic sheep industry, and it is not the intent of this plan or the UDWR to force domestic sheep operators off of their ranges or out of business. Rather, the intent is to look for opportunities that will protect bighorn sheep populations while working with the domestic sheep industry. Utah FNAWS has been instrumental in resolving bighorn/domestic sheep issues, and their efforts have resulted in protection of many bighorn sheep populations by reducing the potential for the transmission of disease.

Response and control of a disease outbreak will be conducted using standardized current protocols for sampling and testing (Foster 2004, WAFWA Wildlife Health Committee (WHC), UC-Davis 2007). Accurate cause of death should be determined through a full necropsy when possible. All bighorn sheep that are exhibiting signs or symptoms of illness should be considered for removal from the population and the impacts of stressors on populations experiencing a disease outbreak should be determined and if possible lessened. The isolation of an affected sheep herd from other unaffected sheep herds should also be ensured.

B. Predation

Predators have played an important role in the evolution and development of adaptive strategies

in bighorn sheep (Geist 1999). However, predation can be a serious limiting factor to bighorn herd establishment or expansion. In some states excessive predation has resulted in substantial herd reductions (Wehausen 1996, Creeden and Graham 1997, Rominger et al. 2004). Mountain lions are the most significant predators of bighorns in Utah. Coyotes, bobcats, and golden eagles may occasionally take bighorn sheep but are not considered to be a serious threat to bighorn sheep herds.

Mountain lion populations should be managed at levels which will allow for the establishment of viable bighorn populations and allow bighorn population objectives to be met. That may require removal of mountain lions which are negatively impacting bighorn populations until herds are well established. In established small herds where mountain lion harvest is typically low or non-existent because of topography and access, a consistent effort to improve mountain lion harvest opportunity may need to be considered. These efforts could include not closing sheep units to harvest (i.e., no quotas) and maintaining a liberal policy of removing lions on sheep units when there is opportunity. In some cases, the use of USDA Wildlife Services or other contracted personnel may also be needed to help control cougar populations. Bighorn sheep unit management plans and predator management should specify conditions for predator management in bighorn areas.

C. Habitat Degradation or Loss

Bighorn habitat can be degraded, fragmented, or lost to a variety of causes including human disturbance, mineral development, and natural succession. Reductions in the quality or quantity of habitat can result in corresponding losses to bighorn populations (Deforge 1972, Hamilton et al. 1982). Human disturbance in bighorn sheep habitat is an increasing concern in many areas of Utah. Those disturbances include outdoor recreation activities such as off-road vehicle use, mountain biking, river running, and others. Bighorn sheep may change use areas and abandon certain habitats because of those disturbances. Human disturbance is also thought to be a possible stress inducer, which may lead to disease problems in some populations (DeForge 1981, Bunch et al. 1999).

Mineral development in bighorn habitat, if not properly regulated and mitigated, can result in direct loss of habitat. Mineral exploration for oil, gas, uranium, and other minerals has been extensive in bighorn areas. Habitat managers for the Bureau of Land Management and U.S. Forest Service need to carefully monitor and regulate those activities to avoid impacts on bighorn sheep.

Plant succession can also dramatically affect habitat quality. Encroachment by pinyon-juniper and other shrubs has resulted in the fragmentation and loss of large expanses of bighorn habitat. Vegetative treatments including fire management can restore and improve bighorn habitat to its condition prior to settlement times.

D. Wilderness and Park Management

Administration of wilderness areas and national parks has presented problems for bighorn sheep managers in some states (Arizona Game and Fish 1989 and Bleich 1999). Utah currently has a

good working relationship with federal land management agencies, which has allowed and promoted good bighorn sheep management programs. Future wilderness designation and park expansions should specifically allow for activities required for proper management of bighorn populations including the use of aircraft for surveys, transplants, research projects, and the ability to access and maintain water developments constructed specifically for bighorn sheep. It is critical to the future of bighorn sheep in those areas to maintain the use of those valuable management tools.

E. Poaching

Although poaching is not a problem for overall bighorn populations, it can have a detrimental effect on hunter harvest opportunities. Bighorn sheep are highly prized by hunters and legal hunting permits are difficult to obtain. Bighorns often inhabit very remote areas which are difficult to monitor and patrol. Thus, the incentives and opportunities for poaching exist.

F. Competition

Competition for forage and space by domestic livestock, feral animals, and other wild ungulates can impact bighorn populations (Bailey 1980). Competition is most likely to occur in crucial habitats such as winter ranges and lambing areas and during periods of extreme weather such as droughts or heavy snow. Competition with livestock for forage is minimal for most bighorn populations in Utah since bighorns utilize steep, rugged terrain generally not used by livestock. However, some feral animals, such as burros and goats, and some wild ungulates may use the same ranges as bighorn sheep making competition possible. Bighorn habitat should be monitored to assure proper range management and minimize competition.

G. Transplants

Transplanting bighorn sheep is a primary tool for restoration and management of bighorn populations. All bighorn sheep transplants in Utah will be done in accordance with Utah Code 23-14-21. Several issues need to be considered prior to releasing bighorns in new areas or into existing herds, and those issues are clearly stated in the 2012 WAFWA guidelines (Appendix A). Bighorns should only be released in areas where there is a good probability of success as determined by GIS modeling and habitat evaluations. Furthermore, a disease profile should be established for the source stock and any existing herds where those sheep may be released. Sufficient numbers should be released to assure genetic diversity and to help new herds reach self-sustaining levels as soon as possible. Additionally, source stocks should come from the nearest available source with similar habitat and disease profiles as the release site animals.

Utah has 32 units/subunits for bighorn sheep that serve as potential augmentation or reintroduction sites for bighorn sheep (Table 8). All suitable bighorn sheep habitat found within those units/subunits will be available for augmentation/reintroduction. The exact release site for transplanted sheep depends on accessibility and weather conditions and will be determined closer to the time of release.

Currently, the DWR obtains bighorn sheep for transplants from source herds within Utah as well

as surrounding western states and Canadian provinces. As Utah's bighorn sheep populations continue to grow, the DWR will work towards transplanting more sheep from Utah populations and reduce the reliance on sheep coming from out of state, with the ultimate goal of only using Utah bighorn sheep populations with known disease profiles as transplant source herds. This practice will also be important to minimize the number of bighorn sheep in thriving populations. Monello et. al (2001) found that 88% of pneumonia induced die-offs occurred at or within 3 years of peak population estimates. By using growing bighorn populations in Utah as source herds, the DWR will minimize the risk introducing a new disease to naïve populations and decrease the chances of having population die offs in both source and release herds.

As part of the reintroduction/transplant program within Utah, all bighorn sheep brought into Utah from other states will be tested for pathogens and antibodies for disease and must meet health requirements established by UDWR and the state veterinarian for the Utah Department of Agriculture and Food. All bighorn sheep relocated from source herds within the state will also be monitored for those same diseases to prevent the introduction of disease into wild or domestic sheep populations. Moreover, to prevent disease introduction, only wild sheep herds with known disease profiles will serve as source stock for intra and inter-jurisdictional transplants. The mixing of wild sheep from various sources will be evaluated and current protocols for sampling, testing, and responding to disease outbreaks will be used as a standard for Utah transplants (Foster 2004, WAFWA Wildlife Health Committee (WHC), UC-Davis 2007).

For all sheep used in relocation efforts, nasal and oro-pharyngeal swabs will be collected to test for *Pasteurella* spp. and *Mycoplasma* spp. Additionally, blood samples will be collected for brucellosis testing, antibody testing for various diseases of concern, and serum banking. Sheep used for all relocation efforts will be treated with the appropriate antibiotics, wormers, and vaccinations prior to release. Sheep exhibiting signs or symptoms of Psoroptic mange or contagious ecthyma will not be relocated and, instead, will be released at their capture site.

IV. USE AND DEMAND

Bighorn sheep are considered one of the most sought after and highly prized big game animals in North America. Demand for bighorn sheep hunting opportunities far exceeds the current availability of hunting permits (Table 4, Table 5). Currently in Utah, applications exceed available permits by 124:1 for residents and 2376:1 for nonresidents. Additionally, applications for both resident and nonresidents have increased every year since the initiation of Utah's draw system.

Great demand also exists for information concerning bighorn sheep and bighorn viewing opportunities. Many people who have no interest in hunting bighorns are very interested in learning more about bighorn sheep and observing them in the wild. Informational programs and viewing opportunities currently offered for bighorn sheep include DWR sheep viewing days and guided hikes at Antelope Island State Park.

Finally, public interest and legal mandates require management of bighorn sheep for their intrinsic value. Bighorn sheep are an important part of fragile ecosystems throughout Utah and should be properly managed regardless of recreational uses.

V. CONCLUSION

A fitting conclusion to this section of the plan is found in the book *Mountain Sheep of North American* by Raul Valdez and Paul Krausman (1999). It states:

> **"***Mountain sheep, like all other native fauna and flora, are part of the structure and heritage of North America. Despite all of the efforts exerted toward their conservation, wild sheep face a precarious future. They are an ecologically fragile species, adapted to limited habitats that are increasingly fragmented. Future conservation efforts will only be successful if land managers are able to minimize fragmentation. According mountain sheep their rightful share of North America and allowing them to inhabit the wilderness regions they require is a responsibility all Americans must shoulder. It is our moral and ethical obligation never to relent in the struggle to ensure their survival."*

VI. STATEWIDE MANAGEMENT GOALS AND OBJECTIVES

A. Population Management Goal: Establish optimum populations of bighorn sheep in all suitable habitat within the state.

Objective 1: Increase bighorn sheep populations within the state as conditions allow and bring all populations to at least the minimum viable level of 125 bighorns.

Strategies:

a. Develop or revise management plans for individual units with population goals and objectives. During unit plan development, all affected cooperative agencies and sheep grazing permittees shall be invited to take part in the decision making process.
b. Survey all herd units by helicopter every 2–3 years to monitor population size and composition.
c. Use population or sightability models to determine the relationship between population surveys and population size.
d. Augment existing populations where needed to improve herd distribution, link small populations, and improve genetic diversity (Table 8).
e. Transplant bighorn sheep to establish new populations in accordance with Utah Code 23-14-21 (Table 8).
f. Develop an annual transplant plan based on availability of bighorn sheep, release sites, and consistent with Table 8.
g. Reduce bighorn numbers in specific areas of concentration through trapping and transplanting programs to help reduce potential for disease problems.
h. In areas where transplants are not an option, explore the possibility of establishing ewe hunts to help reduce population densities or remove sheep in areas of high risk of contracting disease.
i. Establish a monitoring rotation for all bighorn sheep herds to establish background disease profiles for each herd. This information will be used to determine overall herd health and the compatibility of each herd for transplants.
j. Continue to document instances of interaction between wild sheep and domestic sheep and goats so that it allows conflicts to be evaluated and dealt with in a timely manner.
k. Follow established guidelines for dealing with domestic sheep and goats that wander into bighorn sheep units.
l. Participate in research efforts to find solutions to disease problems and low lamb survival.
m. Initiate predator management as specified in predator and bighorn sheep unit management plans. On remote or hard to access units, USDA Wildlife Services or other contracted personnel may be needed to help reduce cougar numbers.
n. Support law enforcement efforts to reduce illegal taking of bighorn sheep.

B. Habitat Management Goal: Provide good quality habitat for healthy populations of bighorn sheep.

Objective: Maintain or improve sufficient bighorn sheep habitat to allow herds to reach population objectives.

Strategies:

a. Identify crucial bighorn sheep habitats and work with land managers and private

landowners to protect and enhance these areas.

b. Assist land management agencies in monitoring bighorn sheep habitat.
c. Work with land managers to minimize and mitigate loss of bighorn habitat due to human disturbance and development.
d. Initiate vegetative treatment projects to improve bighorn habitat lost to natural succession or human impacts.
e. Encourage land management agencies to use fire as a management tool to improve bighorn sheep habitat. When possible, allow fires that can have beneficial effects for bighorn sheep to burn.
f. Improve or maintain existing water sources and develop new water sources as needed to improve distribution and abundance of bighorn sheep.
g. Support research and monitoring efforts to evaluate bighorn sheep use of water sources to ensure the water sources are having the desired effect.
h. Work with land management agencies and private landowners to implement agency guidelines for management of domestic sheep and goats in bighorn areas similar to those proposed by the WAWFA Wild Sheep Working Group.
i. Support conservation groups' efforts to pursue conversions of domestic sheep grazing allotments by working with willing permittees in bighorn areas to minimize the risk of disease transmission.
j. Inform and educate the public concerning the needs of bighorn sheep including the effects of human disturbance and the need for habitat improvements.

C. Recreation Goal: Provide high quality opportunities for hunting and viewing bighorn sheep.

Objective 1: Increase hunting opportunities as populations allow while maintaining high quality hunting experiences.

Strategies:

a. Recommend permit numbers based on 12-15% of the counted ram population (yearling and older) or 30-40% of the counted rams 6 years of age or older.
b. When feasible, use subunits and multiple seasons to maximize hunting opportunities, distribute hunters, and minimize hunter conflicts.
c. Recommend hunting seasons to provide maximum recreational opportunity while not imposing on DWR management needs.
d. Maintain high hunter success rates (> 90%) and/or high hunter satisfaction on all units.
e. Monitor size and age class of all harvested rams.

Objective 2: Increase public awareness and expand viewing opportunities of bighorn sheep.

Strategies:

a. Evaluate existing public viewing areas and identify potential new sites.
b. Install interpretive signs in bighorn sheep areas for public information.
c. Produce written guides or brochures to help educate the public and provide viewing opportunities which will not impact bighorn sheep.
d. Continue and expand bighorn sheep viewing events for interested publics.

Figure 1. Current management units and bighorn sheep habitat/distribution, Utah 2013.

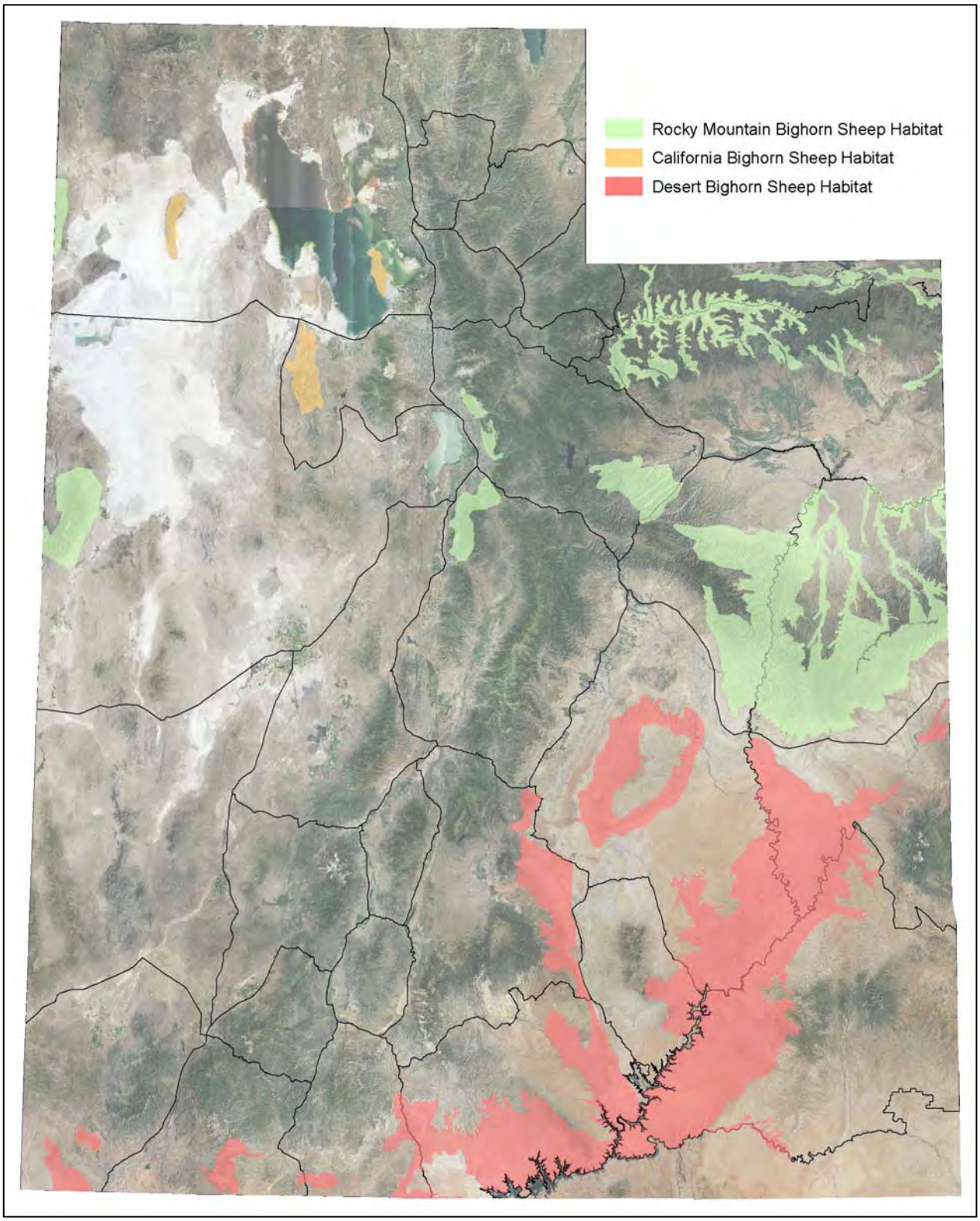

Figure 2. Statewide bighorn sheep population trends, Utah 2013.

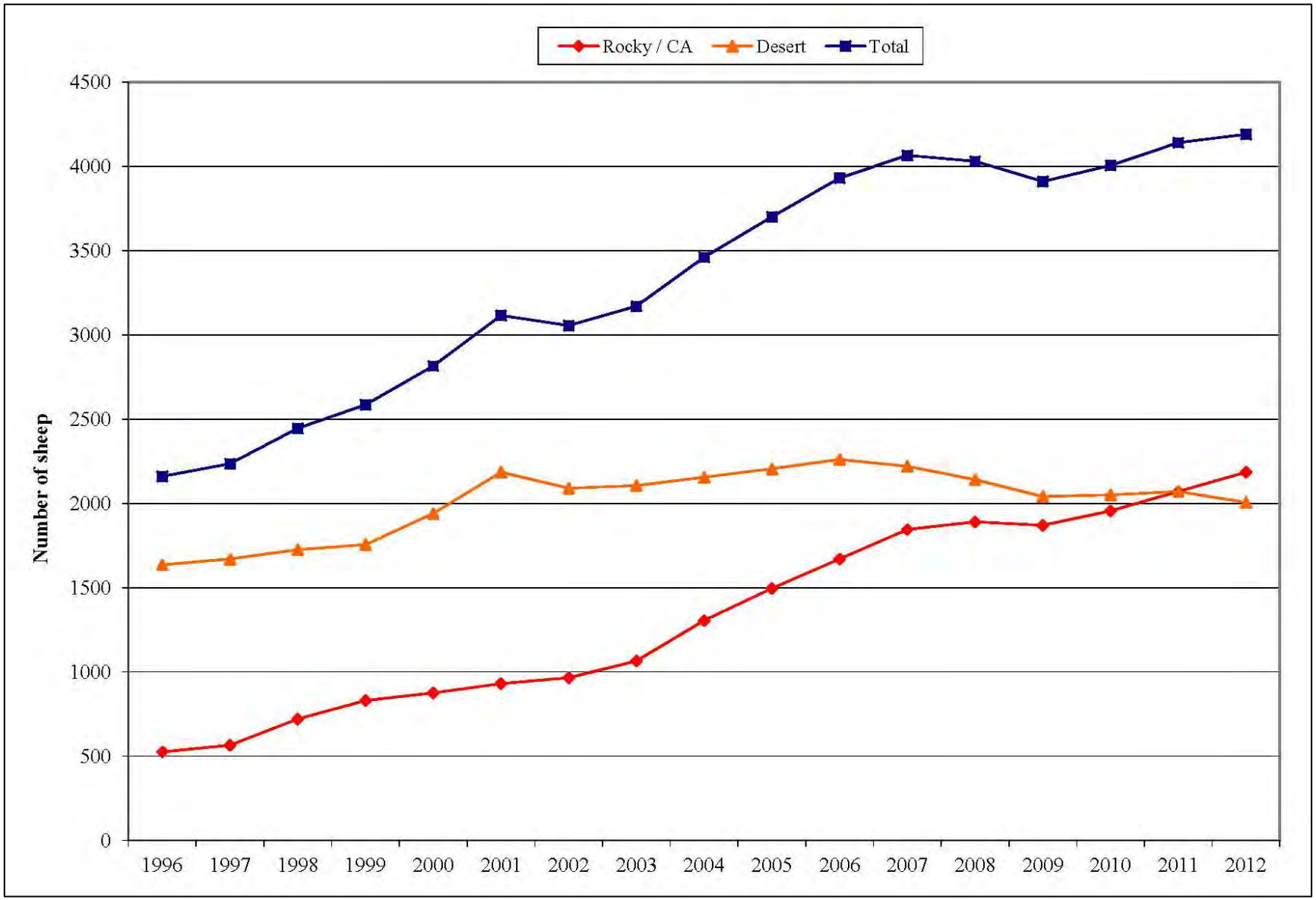

Table 1. Trend counts for Rocky Mountain and California bighorn sheep populations managed by UDWR, Utah 2007-2012.

Unit #	Unit name	2007	2008	2009	2010	2011	2012
1	Box Elder, Antelope Island	190	—	125	—	—	164
1	Box Elder, Newfoundland Mountains	135	—	173	—	—	198
8	North Slope, Bare Top Mountain	84	99	76*	104	72*	52*
8	North Slope, Goslin Mountain	79	33	0**	—	—	—
8	North Slope, Sheep Creek	37	53	32*	55	48*	61*
8	North Slope, Carter Creek/Red Canyon	27	20	32*	40	36*	39*
10	Book Cliffs, Rattlesnake	235	—	174	—	182	—
11	Nine Mile, Bighorn Mountain	346	—	384	—	418	—
16	Central Mountains, Nebo	35	26	22	—	—	—
17	Wasatch Mountains, Timpanogos	51	45	49	—	—	—
17	Wasatch Mountains, Provo Peak	41	12	7	—	—	—
17	Wasatch Mountains, Avintaquin	—	—	35	—	30	—
18	Oquirrh-Stansbury, Stansbury Mountains	70	137	—	—	—	163

*Incomplete count
**Population culled due to disease issues

Table 2. Trend counts for desert bighorn sheep populations managed by UDWR, Utah 2007-2012.

Unit #	Unit name	2007	2008	2009	2010	2011	2012
12	San Rafael, Dirty Devil	—	115	—	67	—	66
12	San Rafael, North	167	150	—	—	86	101
12	San Rafael, South	259	—	183	—	220	—
13	La Sal, Potash	—	105	—	118	—	69
14	San Juan, Lockhart	—	59	—	46	—	40
14	San Juan, North	—	—	—	17	—	13
14	San Juan, South	—	122	—	57	—	39
15	Henry Mountains, Little Rockies	—	54	—	24	—	63
26	Kaiparowits, Escalante	—	115	—	87	—	71
26	Kaiparowits, East / West	110	—	139	—	200	—
29	Zion	—	—	131	—	200	—
30	Pine Valley, Beaver Dam	38	23	—	73	—	72

Table 3. Summary of bighorn sheep hunting opportunities, Utah 1967–2012.

Year	Rocky Mountain Bighorns		Desert Bighorns	
	Hunters afield	Rams harvested	Hunters afield	Rams harvested
1967	No hunt	—	9	9
1968	No hunt	—	10	3
1969	No hunt	—	10	6
1970	No hunt	—	10	4
1971	No hunt	—	10	1
1972	No hunt	—	8	1
1973	No hunt	—	No hunt	—
1974	No hunt	—	No hunt	—
1975	No hunt	—	5	2
1976	No hunt	—	10	4
1977	No hunt	—	25	10
1978	No hunt	—	23	7
1979	No hunt	—	18	3
1980	No hunt	—	19	10
1981	No hunt	—	18	5
1982	No hunt	—	11	6
1983	No hunt	—	10	9
1984	No hunt	—	14	5
1985	No hunt	—	15	12
1986	No hunt	—	14	10
1987	No hunt	—	12	7
1988	No hunt	—	15	12
1989	No hunt	—	12	10
1990	No hunt	—	15	12
1991	3	3	13	10
1992	3	3	11	10
1993	6	6	17	17
1994	6	6	19	18
1995	6	6	30	30
1996	6	5	29	28
1997	3	3	29	28
1998	5	5	31	31
1999	4	4	32	31
2000	9	9	33	33
2001	12	12	30	30
2002	13	12	40	39
2003	13	13	44	43
2004	12	12	42	40
2005	13	13	40	39
2006	20	19	41	37
2007	22	22	45	40
2008	27	27	41	39
2009	28	28	41	37
2010	34	34	50	46
2011	37	37	54	46
2012	42	42	49	41

Table 4. Drawing odds of obtaining a Rocky Mountain bighorn sheep permit, Utah 1998–2012.

Year	Residents			Nonresidents		
	Applicants	Permits	Odds	Applicants	Permits	Odds
1998	283	3	1 in 94.3	0	0	—
1999	332	3	1 in 110.7	0	0	—
2000	414	6	1 in 69.0	0	0	—
2001	568	11	1 in 51.6	0	0	—
2002	831	10	1 in 83.1	0	0	—
2003	1063	10	1 in 106.3	932	1	1 in 932.0
2004	1166	9	1 in 129.6	0	0	—
2005	1354	11	1 in 123.1	0	0	—
2006	1793	15	1 in 119.5	0	0	—
2007	2192	16	1 in 137.0	1131	1	1 in 1131.0
2008	2381	21	1 in 113.4	1015	1	1 in 1015.0
2009	2547	21	1 in 121.3	4323	1	1 in 4323.0
2010	2828	25	1 in 113.1	4776	2	1 in 2388.0
2011	3205	26	1 in 123.3	5001	2	1 in 2500.5
2012	3603	30	1 in 120.1	5400	2	1 in 2700.0

Table 5. Drawing odds of obtaining a desert bighorn sheep permit, Utah 1998–2012.

Year	Residents			Nonresidents		
	Applicants	Permits	Odds	Applicants	Permits	Odds
1998	866	22	1 in 39.4	712	2	1 in 356.0
1999	1033	25	1 in 41.3	1026	2	1 in 513.0
2000	1292	27	1 in 47.9	1320	2	1 in 660.0
2001	1473	26	1 in 56.7	1583	2	1 in 791.5
2002	1997	33	1 in 60.5	2118	3	1 in 706.0
2003	2253	35	1 in 64.4	2266	3	1 in 755.3
2004	2653	32	1 in 82.9	3139	3	1 in 1046.3
2005	3051	32	1 in 95.3	3731	3	1 in 1243.7
2006	3467	33	1 in 105.1	3897	3	1 in 1299.0
2007	3814	35	1 in 109.0	4201	3	1 in 1400.3
2008	3827	33	1 in 116.0	3599	2	1 in 1799.5
2009	4042	33	1 in 122.5	5592	2	1 in 2796.0
2010	4386	40	1 in 109.7	6004	3	1 in 2001.3
2011	4367	39	1 in 112.0	6124	3	1 in 2041.3
2012	4607	36	1 in 128.0	6480	3	1 in 2160.0

Table 6. History of Rocky Mountain and California bighorn sheep transplants, Utah 1966–2013.

Unit #	Release Unit / Area	Year	# Released	Source
1	Box Elder, Antelope Island	1997	23	Kamloops, BC
1	Box Elder, Antelope Island	2000	6	Winnemucca NV
1	Box Elder, Newfoundland Mountains	2001	15	Antelope Island, UT
1	Box Elder, Newfoundland Mountains	2001	20	Antelope Island, UT
1	Box Elder, Newfoundland Mountains	2003	16	Antelope Island, UT
1	Box Elder, Newfoundland Mountains	2008	18	Antelope Island, UT
1	Box Elder, Pilot Mountain	1987	24	Basalt, CO
1	Box Elder, Pilot Mountain	1993	2	Bare Top Mountain., UT
1	Box Elder, Pilot Mountain	1998	13	Wells, NV
1	Box Elder, Pilot Mountain	1998	19	Contact, NV
3	Ogden, Box Elder Canyon	1966	14	Whiskey Basin, WY
3	Ogden, Box Elder Canyon	1966	20	Waterton, AB
3	Ogden, Box Elder Canyon	1969	12	Banff, AB
3	Ogden, Box Elder Canyon	1970	14	Banff, AB
8	North Slope, Bare Top Mountain	1983	19	Whiskey Basin, WY
8	North Slope, Bare Top Mountain	1984	17	Whiskey Basin, WY
8	North Slope, Sheep Creek	1989	21	Whiskey Basin, WY
8	North Slope, Sheep Creek	2000	6	Almont Triangle, CO
8	North Slope, Hoop Lake	1989	23	Whiskey Basin, WY
8	North Slope, Carter Creek / S Red Canyon	2000	10	Almont Triangle, CO
8	North Slope, Carter Creek / S Red Canyon	2001	18	Basalt, CO
8	North Slope, Carter Creek / S Red Canyon	2003	6	Desolation Canyon, UT
8	North Slope, Goslin Mountain	2005	34	Thompson Falls, MT
8	North Slope, Goslin Mountain	2007	42	Bonner, MT
10	Book Cliffs, Hill Creek	1970	9	Whiskey Basin, WY
10	Book Cliffs, Hill Creek	1973	12	Alberta, Canada
10	Book Cliffs, Hill Creek	1998	44	Kaleden, BC
10	Book Cliffs, Hill Creek	1998	20	Fowler, CO
11	Nine Mile, Bighorn Mountain	1993	26	Estes Park, CO
11	Nine Mile, Bighorn Mountain	1995	28	Georgetown, CO
11	Nine Mile, Jack Creek	2000	15	Bare Top Mountain., UT
11	Nine Mile, Jack Creek	2002	15	Sula, MT
11	Nine Mile, Trail Canyon	2009	40	Green River, UT
16	Central Mountains, Nebo	1981	27	Whiskey Basin, WY
16	Central Mountains, Nebo	1982	21	Whiskey Basin, WY
16	Central Mountains, Nebo	2004	18	Augusta, MT
16	Central Mountains, Nebo	2007	25	Augusta, MT
17a	Wasatch Mountains, Timpanogos	2000	25	Rattlesnake, UT
17a	Wasatch Mountains, Timpanogos	2001	10	Hinton, AB
17a	Wasatch Mountains, Timpanogos	2002	9	Sula, MT
17a	Wasatch Mountains, Timpanogos	2007	20	Sula, MT
17a	Wasatch Mountains, Timpanogos	2007	18	Forbes, CO
17a	Wasatch Mountains, Provo Peak	2001	22	Hinton, AB
17a	Wasatch Mountains, Provo Peak	2007	10	Sula, MT / Augusta, MT
17c	Wasatch Mountains, Lake Canyon	2009	30	Augusta, MT
17c	Wasatch Mountains, Indian Canyon	2009	30	Augusta, MT
18	Oquirrh-Stansbury, Stansbury Mountains	2005	12	Antelope Island, UT
18	Oquirrh-Stansbury, Stansbury Mountains	2006	44	Antelope Island, UT
18	Oquirrh-Stansbury, Stansbury Mountains	2008	36	Antelope Island, UT
19	West Desert, Deep Creek Mountains	1984	16	Whiskey Basin, WY
19	West Desert, Deep Creek Mountains	1989	14	Whiskey Basin, WY

Table 7. History of desert bighorn sheep transplants, Utah 1966–2013.

Unit #	Release Unit / Area	Year	# Released	Source
12	San Rafael, Dirty Devil	1991	22	North San Rafael, UT
12	San Rafael, Dirty Devil	1994	15	Potash, UT
12	San Rafael, Dirty Devil	1996	17	Potash, UT
12	San Rafael, Dirty Devil	2003	25	San Rafael, South, Chimney Cyn, UT
12	San Rafael, Dirty Devil	2007	15	San Rafael, South, UT
12	San Rafael, Dirty Devil	2007	15	Escalante, Steven's Canyon, UT
12	San Rafael, Maze (CNP)	1983	23	Island in the Sky, CNP, UT
12	San Rafael, Maze (CNP)	1985	2	Canyonlands NP, UT
12	San Rafael, North	1979	12	San Juan Unit, UT
12	San Rafael, North	1982	11	Island in the Sky, CNP, UT
12	San Rafael, North	1986	6	Canyonlands NP, UT
12	San Rafael, North	1986	18	Canyonlands NP, UT
12	San Rafael, North	1988	10	Coal Wash, UT
12	San Rafael, North Wash	1996	21	South San Rafael, UT
12	San Rafael, North Wash	1997	13	Escalante, UT
12	San Rafael, South	1983	12	Island in the Sky, CNP, UT
12	San Rafael, South	1984	16	Potash, UT
12	San Rafael, South	1985	12	Island in the Sky, CNP, UT
12	San Rafael, South	1997	4	Escalante, UT
12	San Rafael, South	1998	6	Escalante, UT
13	La Sal Potash	1991	10	Potash, UT
13	La Sal, Arches National Park	1985	6	Canyonlands NP, UT
13	La Sal, Arches National Park	1986	19	Canyonlands NP, UT
13	La Sal, Dolores Triangle	1979	7	San Juan Unit, UT
13	La Sal, Dolores Triangle	1990	20	River Mountains, NV
14	San Juan, Johns Canyon	2008	19	San Juan, South, Hite, UT
14	San Juan, Johns Canyon	2008	11	La Sal, Potash, Crystal Geyser, UT
14	San Juan, Johns Canyon	2013	16	Big Bend, Moab, UT
14	San Juan, North	1998	6	Escalante, UT
14	San Juan, North	1999	12	Lake Mead, NV
14	San Juan, North	1999	13	Lake Mead, NV
15	Henry Mountains, Little Rockies	1985	18	Canyonlands NP, UT
15	Henry Mountains, Little Rockies	1985	12	Red Canyon / White Canyon, UT
25/26	Capitol Reef National Park	1984	21	Island in the Sky, CNP, UT
25/26	Capitol Reef National Park	1985	10	Canyonlands NP, UT
25/26	Capitol Reef National Park	1996	20	Island in the Sky, CNP, UT
25/26	Capitol Reef National Park	1997	20	Island in the Sky, CNP, UT
26	Kaiparowits, East	1980	20	Cataract/White Canyons, UT
26	Kaiparowits, East	1982	12	Canyonlands NP, UT
26	Kaiparowits, East	1993	13	Escalante, UT
26	Kaiparowits, East	1995	17	Escalante, UT
26	Kaiparowits, East	2009	20	Lake Mead, NV
26	Kaiparowits, East	2012	25	River Mountains, NV
26	Kaiparowits, East	2012	25	Muddy Mountains, NV

Table 7. History of desert bighorn sheep transplants, Utah 1966–2013 (cont.).

Unit #	Release Unit / Area	Year	# Released	Source
26	Kaiparowits, Escalante	1975	4	Gypsum Canyon, UT
26	Kaiparowits, Escalante	1976	12	Gypsum Canyon, UT
26	Kaiparowits, Escalante	1978	7	Cataract Canyon, UT
26	Kaiparowits, Escalante	1986	4	Canyonlands NP, UT
26	Kaiparowits, Escalante	1995	6	Escalante, UT
26	Kaiparowits, Escalante	1998	7	Escalante, UT
26	Kaiparowits, Escalante	1995	18	Escalante, UT
26	Kaiparowits, West	1995	21	Black Mountains, AZ
26	Kaiparowits, West	1995	2	Escalante, UT
26	Kaiparowits, West	1999	21	Lake Mead, AZ
26	Kaiparowits, West	2000	20	Lake Mead, NV
26	Kaiparowits, West	2006	20	Fallon, NV
26	Kaiparowits, West	1995	2	Escalante, UT
26	Kaiparowits, West	1996	20	Lake Mead, NV
29	Zion	2013	19	Zion, UT
29	Zion National Park	1973	12	Lake Mead, NV
30	Pine Valley, Beaver Dam	1994	25	Lake Mead, AZ

Table 8. Potential bighorn sheep transplant sites. Utah 2013.[1] All suitable bighorn sheep habitat within the following units/subunits will be considered for augmentation/reintroduction.

Rocky Mountain / California Bighorn Sheep

Augment existing populations/management units to meet population management objectives, including:

Book Cliffs
Central Mountains – Nebo
Ninemile – Range Creek
North Slope – Summit, Three Corners, West Daggett
Oquirrh-Stansbury – Stansbury Mountains
Wasatch Mountains – Avintaquin, Rocky Canyon, Timpanogos
West Desert – Deep Creek Mountains

Reintroduction areas to establish new populations:

Beaver – Mineral Mountains
Book Cliffs – South
Fillmore – Oak Creek
South Slope – Diamond Mountain, Vernal, Yellowstone

Desert Bighorn

Augment existing populations/management units to meet population management objectives, including:

San Rafael – Dirty Devil, North, South
San Juan – Lockhart, North, South
Henry Mountains
La Sal – Potash, Dolores Triangle
Kaiparowits – East, Escalante, West
Paunsaugunt – Paria River
Zion
Pine Valley

Reintroduction areas to establish new populations:

Paunsaugunt
San Juan – San Juan River

[1] In accordance with Utah Code 23-14-21.

Literature Cited

Arizona Game and Fish Department. 1989. Arizona Wildlife Views. September 1989.

Bailey, J. A. 1980. Desert bighorn forage competition and zoogeography. Wildlife Society Bulletin 8:208–216.

Besser, T. E., E. F. Cassier, K. A. Potter, J. VanderSchalie, A. Fischer, and D. P. Knowles. 2008. Association of *Mycoplasma ovipneumonia* infection with population-limiting respiratory disease in free-ranging Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Journal of Clinical Microbiology 46:423–430.

Besser, T. E., M. A. Highland, K. Baker, E. F. Cassrier, N. J. Anderson, J. M. Ramsey, K. Mansfield, D. L. Bruning, P. Wolff, J. B. Smith, and J. A. Jenks. 2012. Causes of pneumonia epizootics among bighorn sheep, Western United States, 2008–2010. Emerging Infectious Diseases 18:406–414.

Boyce, W. M., and M. E. Weisenberger. 2005. The rise and fall of Psoroptic scabies in bighorn sheep in the San Andreas Mountains, New Mexico. Journal of Wildlife Diseases 41: 525–531.

Bleich, V. C. 1999. Impacts of wilderness management on wildlife conservation: some case histories of conflict. 2nd North American Wild Sheep Conference Proceedings.

Bunch, T. D., W. M. Boyce, C. P. Hibler, W. R. Lance, T. R. Spraker, and E. S. Williams. 1999. Diseases of North American wild sheep. Pages 209–237 *in* R. Valdez and P. R. Krausman, editors. Mountain Sheep of North America. University of Arizona Press, Tuscon, Arizona, USA.

Clark, R. K., and D. A. Jessup. 1992. The health of mountain sheep in the San Andres Mountains, New Mexico. Desert Bighorn Council Transactions 36:30–35.

Creeden, P. J., and V. K. Graham. 1997. Reproduction, survival, and lion predation in the Black Ridge/Colorado National Monument desert bighorn herds. Desert Bighorn Council Transactions 41:37–43.

Dassanayake, R. P., S. Shaanthalingam, C. N. Herndon, R. Surbramaniam, P. K. Lawrence, J. Bavananthasivam, E. F. Cassirer, G. J. Haldorson, W. J. Foreyt, F. R. Rurangirwa, D. P. Knowles, T. E. Besser, and S. Srikumaran. 2012. Mycoplasma ovipneumonia can predispose bighorn sheep to fatal Mannheimia haemolytica pneumonia. Veterinary Microbiology 145:354–359.

DeForge, J. R. 1972. Man's invasion into the bighorn's habitat. Desert Bighorn Council Transactions 16:112–116.

_____. 1981. Stress: changing environments and the effects on desert bighorn sheep. Desert Bighorn Council Transactions 25:15–16.

Dunbar, M. R., A. C. S. Ward, and G. Power. 1990. Isolation of *Pasteurella haemolytica* from tonsilar biopsies of Rocky Mountain bighorn sheep. Journal of Wildlife Diseases 26:210–213.

Foreyt, W. J. 1990. Pneumonia in bighorn sheep: effects of *Pasteurella haemolytica* from domestic sheep and effects on survival and long-term reproduction. Biennial Symposium of the Northern Wild Sheep and Goat Council 7:92–101.

_____, and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. Journal of Wildlife Diseases 18:163–168.

_____, V. Coggins, and P. Fowler. 1990. Psoroptic scabies in bighorn sheep in Washington and Oregon. Biennial Symposium of the North American Wild Sheep and Goat Council 7:135–142.

Foster, C. L. 2004. Wild sheep capture guidelines. Proceedings of the North American Wild Sheep and Goat Council 14:211–282.

Geist, V. 1999. Adaptive strategies in mountain sheep. Pages 192–208 *in* R. Valdez and P. R. Krausman, editors. Mountain Sheep of North America. University of Arizona Press, Tuscon, Arizona, USA.

Hamilton, K., S. A. Holl, and C. L. Douglas. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel Mountains, California. Desert Bighorn Council Transactions 26:50–55.

Jessup, D. A. 1985. Diseases of domestic livestock which threaten bighorn sheep populations. Desert Bighorn Council Transactions 29:29–33.

Lange, R. E., A. V. Sandoval, and W. P. Meleney. 1980. Psoroptic scabies in bighorn sheep (*Ovis canadensis mexicana*) in New Mexico. Journal of Wildlife Diseases 16:77–82.

Martin, K. D., T. Schommer, and V. L. Coggins. 1996. Biennial Symposium of the Northern Wild Sheep and Goat Council 10:72–77.

Miller, D. S., G. C. Weiser, A. C. S. Ward, M. L. Drew, and P. L. Chapman. 2012. Pasteurellacae isolate from bighorn sheep (Ovis Canadensis) from Idaho, Oregon, and Wyoming. American Journal of Veterinary Research 73:1024–1028.

Miller, M. W. 2001. Pasteurellosis. Pages 330–339 *in* E. S. Williams and I. K. Barker, editors. Infectious Diseases of Wild Mammals. Iowa State University Press, Ames, Iowa, USA.

Monello, R. J., D. L. Murray, and E. F. Cassirer. 2001. Ecological correlates of pneumonia epizootics in bighorn sheep herds. Canadian Journal of Zoology 79:1433-1441.

Ramey, R. R. 1993. Evolutionary gentics and systematics of North American mountain sheep: implications for conservation. Dissertation, Cornell University, Ithaca, New York, USA.

Rawley, E. V. 1985. Early records of wildlife in Utah. Publication number 86-2. Division of Wildlife Resources, Department of Natural Resources, Salt Lake City, Utah, USA.

Rominger, E. M., H. A. Whitlaw, D. L. Weybright, W. C. Dunn, and W. B. Ballard. 2004. The influence of mountain lion predation on bighorn sheep translocations. Journal of Wildlife Management 68:993–999.

Rudolph, K. M., D. L. Hunter, W. J. Foryet, E. F. Cassirer, R. B. Rimler, and A. C. S. Ward. 2003. Sharing of *Pasteurella* species between free ranging bighorn sheep and feral goats. Journal of Wildlife Diseases 39:897–903.

Shackleton, D. M., C. C. Shank, and B. M Wikeem. 1999. Rocky Mountain and California bighorns. Pages 78–138 *in* R. Valdez and P. R. Krausman, editors. Mountain Sheep of North America. University of Arizona Press, Tuscon, Arizona, USA.

Shields, W. 1999. Rocky Mountain bighorns - Utah. Pages 108–111 *in* D. E. Toweill and V. Geist, editors. Return of Royalty - Wild Sheep of North America. Boone and Crocket Club and Foundation for North American Wild Sheep, Missoula, Montana, USA.

Spraker, T. R., C. P. Hibler, G. G. Schoonveld, and W. S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. Journal of Wildlife Diseases 20:319–327.

U-C Davis. 2007. Respiratory disease in mountain sheep: Knowledge gaps and future research. University of California - Davis, Wildlife Health Center. Pp. 1–24.

Valdez, R. and P. R. Krausman. 1999. Description, distribution, and abundance of mountain sheep in North America. Pages 3–22 *in* R. Valdez and P. R. Krausman, editors. Mountain Sheep of North America. University of Arizona Press, Tuscon, Arizona, USA.

Wehausen, J. D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite mountains of California. Wildlife Society Bulletin 24:471–479.

Weiser, G. C., W. J. DeLong, J. L. Paz, B. Shafii, W. J. Price, and A. C. S. Ward. 2003. Charactierization of *Pasteurella multocida* associated with pneumonia in bighorn sheep. Journal of Wildlife Diseases 39:536–544.

Weiser, G. C., M. L. Drew, E. F. Cassirer, and A. C. S. Ward. 2012. Detection of Mycoplasma ovipneumonia and M. arginini in bighorn sheep using enrichment culture coupled with genus-and-species-specific polymerase chain reaction. Journal of Wildlife Diseases 48:449–453.

Western Association of Fish and Wildlife Agencies Wild Sheep Working Group. 2007. Recommendations for domestic sheep and goat management in wild sheep habitat.

_____. 2012. Recommendations for domestic sheep and goat management in wild sheep habitat.

APPENDIX A. WAFWA Wild Sheep Working Group "Recommendations for Domestic Sheep and Goat Management in Wild Sheep Habitat"

Recommendations to WAFWA Agencies

- Historic and suitable but currently unoccupied wild sheep range should be identified, evaluated, and compared against currently-occupied wild sheep distribution and existing or potential areas where domestic sheep or goats may occur.

- Risk assessments should be completed at least once per decade (more often if warranted) for existing and potential wild sheep habitat. These assessments should specifically identify where and to what extent wild sheep could interface with domestic sheep or goats, and the level of risk within those areas.

- Following completion of site or herd-specific risk assessments, any translocations, population augmentations, or other restoration and management strategies for wild sheep should minimize the likelihood of association between wild sheep and domestic sheep or goats. Agencies should:

    - Avoid translocations of wild sheep into areas with no reasonable likelihood of effective separation from domestic sheep or goats.

    - Re-evaluate planned translocations of wild sheep to historical ranges as potential conflicts, landscape conditions, and habitat suitability change.

    - Recognize that augmentation of a wild sheep herd from discrete source populations poses a risk of pathogen transfer (CAST 2008) and thus, only use source stock verified as healthy through a proper health assessment (WAFWA 2009) for translocations. Source herds should have extensive health histories and be regularly monitored to evaluate herd health. Wild sheep managers should evaluate tradeoffs between anticipated benefits such as demographic, behavioral and genetic interchange, and the potential consequences of mixing wild sheep from various source herds.

    - Develop and employ mapping or modeling technology as well as ground based land use reviews prior to translocations to compare wild sheep distribution and movements with distribution of domestic sheep or goats. If a translocation is implemented and association with domestic sheep or goats occurs, or is likely to occur beyond an identified timeframe or pre-determined geographic area, domestic sheep or goat producers should be held harmless.

- The higher the risk of association between wild sheep and domestic sheep or goats, the more intensively wild sheep herds should be monitored and managed. This is particularly important when considering "new" vs. "augmented" wild sheep populations.

    - Site-specific protocols should be developed when association with domestic sheep or goats is probable. For example, decisions concerning percentage of translocated wild

sheep that must be radio-collared for achieving desired monitoring intensities should in part, be based upon the subsequent level of risk of association with domestic sheep or goats.

- Intensive monitoring provides a mechanism for determining proximity of wild sheep to domestic sheep or goats and for evaluating post-release habitat use and movements.

- Budgets for wild sheep translocation projects should include adequate funding for long-term monitoring.

- Wild sheep managers should identify, analyze, and evaluate the implications of connectivity and movement corridors between largely insular herds comprising a meta-population against opportunities for increased association with domestic sheep or goats. Analyses should include distribution and continuity (Mack 2008) among populations of wild sheep and the anticipated frequency of movement among or within wild sheep range. In doing so, the benefits of genetic interchange and its resultant implications for population viability, must be weighed against the risks of disease transmission (Bleich et al. 1990), especially if dispersing or wandering wild sheep could travel across domestic sheep or goat grazing allotments or trailing routes, private land holdings or other areas where the potential transfer of endemic pathogens from an infected wild herd to a naïve herd could occur.

- Removal of wild sheep known, or suspected to have closely associated with domestic sheep or goats is considered to be an effective management tool. Atypical movements by wild sheep can heighten risk of association with domestic sheep or goats. Additional measures to achieve effective separation should be implemented if such association occurs. However, removal of wild sheep from occupied, normally-anticipated wild sheep range is not always the best management option. Continuous risk of association exists during active grazing seasons when domestic sheep or goats are grazed within normally-anticipated wild sheep range. Thus, removal of individual wild sheep is an ineffective method for maintaining separation, and has potentially negative consequences for population viability. Removal of wild sheep should occur only after critical evaluation and further implementation of measures designed to minimize association and enhance effective separation.

- Wild sheep populations should have pre-determined population objectives, and should be managed at agreed-upon densities to minimize the potential for dispersal. Because some dispersal occurs regardless of population density, some risk of association is always present if domestic sheep or goats are within range of dispersing wild sheep.

- Agencies should develop a written protocol to be implemented when association between wild sheep and domestic sheep or goats is confirmed. Notification requirements, appropriate response and post-contact monitoring options for both domestic sheep and goats and dispersing or wandering wild sheep should be included. Moreover, wildlife agencies should collaborate with agricultural agencies, land management agencies, producers and permittees, grazing industry representatives, and wild sheep advocates to develop an effective, efficient, and legal protocol to be implemented when feral or abandoned domestic sheep or goats threaten to associate with wild sheep but for which no owner can be identified. Written

protocol examples are provided in Appendix B (British Columbia Fish, Wildlife and Habitat Management Branch) and Appendix C (Wyoming Game and Fish Department).

- Wildlife agencies should develop databases as a system to report, record, and summarize association between wild sheep and domestic sheep or goats and its outcome; the WAFWA WSWG website (http://www.wafwa.org/html/wswg.shtml) would be a logical host. Further, wildlife managers and federal/crown land managers should encourage prompt reporting by the public of observed proximity between wild sheep and domestic sheep or goats.

- Wild sheep managers should coordinate with local weed or pest management districts, or other applicable agencies or organizations involved with weed or vegetation management, to preclude the use of domestic sheep or goats for noxious weed or vegetation control in areas where association with wild sheep is likely to occur. Agencies should provide educational information and offer assistance to such districts regarding disease risks associated with domestic sheep or goats. Specific guidelines (Pybus et al. 1994) have already been developed and implemented in British Columbia, and are available at: http://www.for.gov.bc.ca/hfp/publications/00006/.

- Specific protocols for sampling, testing prior to translocation, and responding to disease outbreaks should be developed and standardized to the extent practical across state and federal jurisdictions. Several capture and disease-testing protocols have been developed and are available to wild sheep managers (Foster 2004, UC-Davis 2007, WAFWA 2009). Protocols should be reviewed and updated as necessary by the WAFWA Wildlife Health Committee (WHC) and presented to WAFWA Directors for endorsement. Once endorsed, agencies should implement the protocols, and the WHC should lead an effort to further refine and ensure implementation of said protocols.

- Agencies should coordinate and pool resources to support the ongoing laboratory detection and interpretation of important diseases of wild sheep. Furthermore, wild sheep managers should support data sharing and development and use of standardized protocols (WAFWA 2009). Interagency communication between wildlife disease experts such as the WAFWA Wildlife Health Committee (WHC) should be encouraged to enhance strategies for monitoring, managing and improving health of wild sheep populations through cooperative efforts.

- Wild sheep management agencies should develop educational materials and outreach programs to identify and interpret the risk of association between wild sheep and domestic sheep or goats for producer groups, owners of small and large farm flocks, animals used for packing and 4-H animals. In some cases, regulation may be necessary to maintain separation.

Adaptive Wild Sheep Disease Management Venture (DMV) Strategy

January 2017

Western Association of Fish and Wildlife Agencies, Wild Sheep Working Group

Background

Respiratory disease remains the biggest impediment to restoring and sustaining bighorn sheep populations with a west-wide survey documenting 175 die-off incidents from the 1970s through 2014. These disease events involved 17of the 20 jurisdictions and the loss of over 14,000 adult bighorn. Over 75 herds experienced 3 or more years of poor lamb recruitment post disease event with over 20 herds having 10 or more years. In 2015, the Wild Sheep Disease Management Venture (DMV) was established by the Western Association of Fish & Wildlife Agencies (WAFWA) Wild Sheep Working Group (WSWG) to identify management challenges associated with these respiratory disease events and collaboratively develop solutions to these challenges.

The DMV accepts that *Mycoplasma ovipneumoniae* (*M. ovi*) is a primary causative agent driving epidemic respiratory disease (i.e. pneumonia) in bighorn sheep. Additional bacteria including *Pasteurellaceae*, viruses, and other emerging factors (e.g., paranasal sinus tumors), likely contribute to the severity of disease in individuals or herds. Initial spillover of *M. ovi* occurs via contact with domestic sheep or goats (which commonly carry *M. ovi* without experiencing signs of disease), and can subsequently be circulated within and between populations by wild sheep or mountain goats. Following spillover into a bighorn herd several different outcomes have been documented, ranging from little to no impact on health and recruitment to epizootic pneumonia, followed by years of lamb deaths caused by pneumonia. This variable pattern has defined the key question for the DMV: ***What contributes to this variation in herd response to respiratory disease and how can management actions improve herd performance?***

Mission and Objectives

To aid jurisdictions in addressing this key question the mission of the DMV is to work collaboratively to:

- **Improve and speed collective learning on respiratory disease and herd response**
- **Be a source of guidance and expertise**
- **Be a clearinghouse for information sharing among jurisdictions and researchers**
- **Facilitate the evaluation of adaptive management actions**
- **Encourage jurisdictions to explore new management actions**
- **Seek funding to support enhanced monitoring and adaptive management trials**
- **Summarize outcomes of management actions and identify those that have the most promise of improving herd performance**

The DMV seeks to use the collective resources from all jurisdictions to strengthen the power of inference to find solutions to wild sheep disease challenges. The efforts of the DMV are similar to models used in emerging disease management where actions are developed to "reduce the harm" to herds already exposed to disease agents and promote herd health and productivity. The current vision is for the DMV to have an initial 5-year life (see Appendix A). The hope is that

through strong participation, successes, and funding opportunities, the DMV will continue beyond 5 years in providing support and promoting communication in its continued mission.

Process and Methods

The DMV will assist jurisdictions in assessing candidate herds for monitoring and possible adaptive management actions. A flowchart was developed (see Appendix B) to help visualize the interaction/relationships of herd history, disease risk, herd size and performance, and pathogen testing/exposure. This can be used in assigning "candidate" herds to categories to assess variables for standard monitoring or for consideration in adaptive management trials.

The DMV will provide guidance for conducting enhanced herd monitoring (see Appendix C) and to identify variables that may contribute to a herd's initial and long term response to pathogens and associated disease factors. It will also provide information and assistance to implement and evaluate adaptive management actions that potentially improve population performance in herds negatively impacted by respiratory disease.

The DMV will develop publications such as a web-based newsletter, fact sheets, email blasts, literature reviews or white papers to synthesize findings from monitoring and adaptive management trials, and pertinent research related to respiratory disease and herd response.

Enhanced Monitoring

In support of the DMV mission, jurisdictions are encouraged to conduct an enhanced level of monitoring of demographics, pathogens, and other associated factors on selected candidate herds (see Appendix C). This will greatly assist in information sharing and collective learning. Due to staff, funding, and access limitations, it is understood that not every candidate herd will undergo enhanced monitoring. In these situations, the DMV encourages continuing baseline monitoring and will seek funding to assist these efforts. General trends and highlights from monitoring efforts west wide will be summarized and shared annually. After 5 years of monitoring, the DMV proposes to analyze all jurisdictional data and information using generalized linear mixed models to identify correlations between performance variables (e.g., population growth rate, lamb recruitment, etc.) and predictive variables (e.g., *M. ovi* strain type , time since outbreak, secondary pathogens, herd substructure, etc.). Finally, the DMV proposes to model the probability of *M. ovi* elimination and herd recovery using the above predictive variables.

Adaptive Management Actions

Jurisdictions are encouraged to identify appropriate candidate herds for adaptive management actions that: 1) hasten elimination of pathogens from the herd, 2) prevent the spread of the pathogen to adjacent uninfected herds, 3) improve herd performance despite continued evidence of primary respiratory pathogen infections, or 4) evaluate risk of translocating animals from herds which are infected with identical strains of pathogens. Enhanced monitoring (see Appendix C) will be used to evaluate the cost/benefit, logistics, practicality and success of each action. The exploration of other adaptive management actions is encouraged.

APPENDIX A – DMV Strategy Timeline

Time period	What to Ask Jurisdictions for	What to Give back to Jurisdictions
Year 1	• List of herds by revised list of categories • Data for Frances' JWM manuscript	• General Summary - Assessment of herd information gathered through Google Survey • Suggested additional suite of tools/management actions • Updated Health Guidelines; include justification of archiving samples • Frances et al. JWM Bighorn Pneumonia Manuscript will be finalized and submitted
Year 2 – 5	• Agency participation in enhanced monitoring • Agency participation in management actions	• Assessment of the suite of actions and summarize/distribute • Develop Best Mgmt Practices, web-based communications, specific reviews, white papers, training videos, and workshops • Management Actions Guidelines

APPENDIX B – Herd Categories and Flowchart

Herd categories are identified based on disease event history, herd size, and performance:

1. Disease event with an initial population decline, followed by persistent or variable annual lamb mortality, resulting in below expected lamb recruitment and a stagnant/declining population.
2. Disease event with little or no initial population decline and herd recovery to pre-disease event levels or higher
3. Disease event with little or no initial population decline, followed by persistent or variable annual lamb mortality, resulting in below expected lamb recruitment and a stagnant/declining population.
4. Healthy herd with low risk of disease transmission
5. Healthy herd with high risk of disease transmission
6. No known disease event but stagnant/declining population.

Display a conceptual flowchart on herd history, size, performance, disease risk, pathogens sampled, and pathogen detection.

APPENDIX C - Suggested Enhanced Monitoring Guidelines

Parameter	Examples of Methods	Desired Frequency	Rationale
Population Estimate	Reconstructive, Integrated Population, Mark-Resight or Sightability, or Minimum Count using helicopter and/or ground surveys	**Annual**	Needed to document and detect changes in population trends.
Lamb Recruitment	Lamb to Ewe ratios at least 4 months post-parturition based on composition surveys from helicopter and/or ground	**Annual**	Most consistent long-term metric collected by jurisdictions
Lamb Survival	Observe lambs born to marked (e.g., radio-collared) ewes after birth and again no later than 4 months from ground, camera, or fixed wing HR imagery surveys. Radio mark new-born lambs and monitor cause-specific mortality.	**Annual** to document timing of lamb loss	Lamb pneumonia mortality peaks within 4 months of birth; lamb mortality ≥6 months post parturition may be more reflective of predation or weather.
Adult Survival	Monitor radio-collared (VHF or GPS) animals or derive from population estimate	**Annual**; minimum of 10 animals per gender	Detect large changes in adult survival due to pneumonia events.
Movements and Herd substructure	GPS collared adults, widely distributed throughout herd so as to capture substructure. Alternatively, VHF collars may give sense of substructure.	**Daily** -GPS collars; suggest minimum of 10 ewes and 5 rams	Pathogen transmission is sensitive to sub-structuring and contact patterns within a herd.
Pathogen Surveillance	At a minimum, collect samples recommended in 2014 WAFWA Herd Heath Monitoring Document. Nasal and tonsil swabs; blood; feces. Attempt to sample across herd substructure groups. Passive sampling of skulls for sinus tumors.	**Every other year**, 10% of herd or 10-15 animals. **Annual** opportunistic sampling of mortalities and hunter harvest.	Targeted sampling provides detection, and in some cases estimates of prevalence, for key pathogens as well as estimates for how these change over time.
Nutritional Status	Body condition through BCS Palpation, body weight, or ultrasound body fat	During all captures.	Gives point estimate of nutritional condition.
Genetic structure	Fecal, tissue, horn-shavings, or blood collection	Bank a minimum of 15 samples per herd	Genetic diversity, connectivity, MHC, disease-specific loci
Habitat or abiotic factors	Habitat or related indices/metrics, stressors, deficiencies, climate/weather events	Annually or other appropriate timing	May be tied to herd resiliency, resistance, or susceptibility to disease

APPENDIX D– Adaptive Management Actions

Proposed Actions

1. Selective Test and Cull - Test (nasal swab PCR) and cull *M. ovi*-shedders to reduce the number or eliminate all *M. ovi* shedders from the herd, to prevent *M. ovi* infection of lambs and improve lamb survival. Jurisdictions may choose to use a different pathogen metric other than *M. ovi*. detected through PCR

    a. Test and identify 75% or more of ewes 2 years or older at least once.
    b. Resample all animals that test positive.
    c. Cull or remove ewes that test positive twice.
    d. Test and monitor at least 25 or 50%, whichever is less, of ewes in a separate control population.
    e. Assess productivity and lamb survival in treatment and control herd in a manner that will allow detection of pneumonia related mortality.
    f. If pneumonia in lambs is detected following culling, retest ewes and cull positive animals.
    g. Schedule: Years 1 and 2: Test, treat and monitor herds; Year 3 and 4: Monitor; Year 5: Monitor and retest herds.

2. Depopulation - Remove all animals from a poor performing herd. Repopulate after the original source of disease transmission is removed.
    a. To ensure complete depopulation; consider using "Judas" animals (radio collared) and monitor for association with remaining sheep.
    b. Conduct thorough aerial and ground surveys to ensure no sheep remain; consider thermal imaging infrared and/or high definition camera surveys to locate any remaining sheep.
    c. Reintroduced sheep should all have visible markings, and all adults should be radio-collared.
    d. Conduct enhanced monitoring for minimum of 3 and ideally-5 years post-reintroduction to document herd performance and to confirm that no original animals remain or other unmarked immigrants are present.
    e. Any original animals or immigrants that are located within the repopulated herd area should be removed and tested for disease.

3. Translocation of animals with identical strains of *M. ovi* or other primary pathogen: With greater risk of disease transmission among wild sheep herds, translocations must now involve a more critical evaluation to ensure they do not extend the current distribution of *M. ovi* or unknowingly spread a *M. ovi* strain that may cause a different herd response in the recipient herd area compared to the source herd.

    a. Both source and recipient animals should have identical strains (defined as an exact match on 4 gene locus sequencing as performed at the Washington Animal Disease Diagnostic Lab.) for all PCR positive animals.

DMV Strategy

b. Herd performance and pathogen profiles must be known for both source and recipient populations within 1 year of the translocation and all handled animals will be marked.
c. Neither the source nor recipient herd areas should have a domestic sheep, goat, or wild sheep herd nearby or within 32 km that poses a risk of *M. ovi* transmission that possesses a different strain type.
d. All translocated adult animals should be collared.
e. Enhanced monitoring should continue for a minimum of 3 and ideally 5 years post-translocation

<u>Consider Additional Management Actions:</u>

Nonselective culls – ewe hunts

"Breakup" herds – actions to disperse/distribute/hazing

Fertility Control to reduce herd densities

WILDERNESS ACT MINIMUM REQUIREMENTS ANALYSIS[1]

Project Title: **Middle Fork Zone Elk Monitoring**

Minimum Requirements Analysis Step 1: Determination

Determine if Administrative Action is Necessary

Description of the Situation
What is the situation that may prompt administrative action?

The Idaho Department of Fish and Game (IDFG) lacks information to detect elk population changes and causes in the Frank Church River of No Return Wilderness (FC-RONRW). This lack of information impedes IDFG's ability to determine appropriate state wildlife management response, including harvest regulation, to dramatic elk herd declines in the FC-RONRW. This lack of information also impedes IDFG's ability to coordinate with the U.S. Forest Service (USFS) to respond appropriately to corresponding degradation to FC-RONRW wilderness character related to the elk herds' decline.

The State of Idaho, through IDFG and the Idaho Fish and Game Commission (Commission), has jurisdiction and responsibility for managing wildlife across Idaho, including monitoring wildlife and regulating hunting, fishing, and trapping. The Wilderness Act, Central Idaho Wilderness Act, and IDFG's 2010 Memorandum of Understanding with USFS recognize the State of Idaho as the primary management authority for wildlife in the FC-RONRW.

FC-RONRW elk herds, along with related primitive hunting and other non-consumptive recreational activities, are of great historic significance both statewide and nationally, and fundamental to the FC-RONRW's wilderness character. *See, e.g.,* U.S. Senate, Subcom. on Parks, Recreation, and Renewable Resources, 96 S. Hrg. 30 (1979). Since 2002, FC-RONRW elk populations have dramatically declined. In 2002, the Middle Fork Elk Zone population estimate was 7,485; in 2011 it was 4,229, a 43% decline, with additional decline likely since 2011 (IDFG 2014). Significant portions of this decline appear related to excessive predation following federal reintroduction of wolves into the FC-RONRW in the mid-1990s; in addition to wolves, elk are also subject to predation pressures from black bears and mountain lions. Adding to the complexity of IDFG's management of elk in the FC-RONRW is a decline in habitat conditions from invasive, non-native plant species and the impacts of historic and recent fire regimes.

The State's Elk Management Plan (IDFG 2014) establishes population objectives for elk throughout Idaho. For the Middle Fork Elk Zone (Game Management Units 20A, 26, and 27, which are wholly or partially within the FC-RONRW), the objectives are for 3,850-5,750 adult females, 390-810 adult males, and 690-1,030 total antlered males. In 2011, IDFG estimated 3,341 adult females, 276 adult males, 462 total antlered males, with additional declines likely since 2011 (IDFG 2014).

[1]In preparing this analysis, IDFG used the general format of the federal Minimum Requirements Decision Guide (MRDG) to facilitate coordination pursuant to the IDFG-USFS Memorandum of Understanding (2010).

IDFG's hunter participation and success data indicate the quantity and quality of elk hunting in the Middle Fork Zone has also declined significantly. The Commission has already eliminated cow tags and put a cap on the total number of hunters that can use the Middle Fork Zone. In the Middle Fork Zone, elk hunter participation decreased from 2,075 hunters in 2002 to 917 hunters in 2014, a 56% loss of this type of wilderness recreation participation. The Commission will need to further restrict harvest if elk population targets cannot be maintained or achieved, but IDFG lacks information to provide appropriate recommendations for such restrictions.

IDFG establishes management goals and monitoring requirements for individual species through Commission-approved management plans. The State Elk Management Plan establishes management objectives to meet a variety of public needs, including hunting recreation and associated economic benefits. IDFG monitors elk populations to obtain data so that IDFG may make informed and effective wildlife management decisions and recommend to the Commission appropriate harvest seasons and rules.

IDFG currently faces several challenges to its elk monitoring program across the State, the most significant of which is increased variability in adult and calf survival. Historically, most adult elk and a large percentage of calves observed during winter aerial surveys survived until June, thus providing a reliable estimate of adult numbers and calf recruitment. Previous monitoring programs, including estimating populations through aerial surveys once every 5 to 10 years, were adequate to monitor elk demographics when populations were stable or increasing.

Previous monitoring programs are not adequate to support decision making where herds are declining or prone to increased variability in annual survival. After the federal reintroduction of wolves to the landscape, elk population dynamics became more erratic. For example, adult survival rates recently observed in the Lolo Zone varied from 71% to 84%; survival of 6-month old calves from winter capture varied from 9% to 73% (Pauley and Zager 2011). The assumption that a large percentage of individuals counted in winter surveys would ultimately survive until June is no longer valid in elk zones, such as the Lolo Zone and Middle Fork Zone in the FC-RONRW, where wolf densities are medium to high.

To address this lack of information, IDFG began implementing a statewide elk survival and cause-specific mortality data collection effort in late 2014 through statistically based deployment of satellite collars. IDFG strategically selected zones for collar deployment as representative of the various habitat and predator complexes found throughout Idaho. As it does with any use of low-altitude flight operations statewide because of inherent risks, IDFG evaluated data needs and optional data collection methods related to helicopter use for the deployment of radiocollars to support this effort.

IDFG's data collection includes an annual estimate of population rate of change. IDFG will use an integrated population model (IPM) to combine population count data (population estimate as well as demographic information), harvest data, survival data, and other types of data into a comprehensive analysis. This modeling procedure allows for variable quality data to be combined such that all data can contribute to the relative quality (variability) of the dataset. This Bayesian statistical analysis can provide estimates of vital rates (survival and reproduction), as well as population estimates on an annual basis, not just every 5 years. The data needed to fully inform and calibrate the model includes: survival of calves and adult females, harvest, and periodic population estimates. In backcountry areas where populations are volatile, estimates of cow/calf ratios in January are also important to fully inform the IPM.

Options Outside of Wilderness
Can action be taken outside of wilderness that adequately addresses the situation?

☐ YES	**STOP – DO NOT TAKE ACTION IN WILDERNESS**
☒ NO	**EXPLAIN AND COMPLETE STEP 1 MINIMUM REQUIREMENTS ANALYSIS**

Explain:

Monitoring outside the FC-RONRW is inadequate to support state wildlife management decisions, including regulation of harvest, within the FC-RONRW. Monitoring outside the FC-RONRW is also inadequate to assess the condition of wilderness character.

As described in the prior section, winter aerial elk sightability surveys, conducted previously over the FC-RONRW once every 5 to 10 years, are no longer adequate to support IDFG's decision needs. To fully inform and calibrate an integrated population model, IDFG identified six zones wholly outside of designated wilderness areas for gathering radiocollar monitoring data (Figure 1). These zones, however, are not representative of the apparent distinctions regarding elk population vital rates related to unique conditions within the vast FC-RONRW. The Middle Fork Elk Zone (Figure 2) represents elk populations within the FC-RONRW and important traditional backcountry hunting areas where harvest of elk and predators is lower than in more accessible areas.

IDFG has identified data needs specific to the FC-RONRW to evaluate and determine appropriate wildlife management actions to address significant declines in the FC-RONRW's elk herds. Although IDFG has obtained some information from elk and other big game animals going across the wilderness boundary, the FC-RONRW is sufficiently large that there are populations of both species that remain wholly or mostly within the FC-RONRW. IDFG requires additional data to address the large geographic hole in its data set. Without more accurate demographic data and vital statistics, IDFG is unable to adequately determine whether it has established appropriate and sustainable regulation of harvest and other wildlife management objectives and actions for this area.

FC-RONRW's wilderness character appears to have been degraded with significant declines in elk populations, in conjunction with increased predation pressure and habitat degradation from invasive weeds. Wilderness character could also be further harmed if IDFG's harvest regulations and other management decisions are not well aligned with the actual numbers, distribution, and demographics of elk and species that prey on elk (wolves, black bears and mountain lions) within the FC-RORNRW.

Based on available data, IDFG hypothesizes that elk survival rates and predator-prey interactions (*e.g.,* predation rates and vulnerability) are different inside the FC-RONRW than outside of it. IDFG has data (from radiocollaring and other marking of animals outside of the FC-RONRW) that elk, mule deer, and bighorn sheep from at least 8 GMUs outside of the wilderness boundary migrate into the wilderness for a portion of their required annual use area. IDFG does not know, however, what proportion of each subpopulation uses the FC-RONRW. In addition, IDFG expects survival to be relatively unique in the FC-RONRW because of: limited human influence; habitat conditions affected by granitic soils, and fire regimes; relatively low elk reproductive success (lower pregnancy rates, lower neonate survival, and winter calf survival); and higher vulnerability to predation. The proportion of elk wintering in the FC-

RONRW and migrating out for summer range is also unclear. IDFG has monitored neonatal calves captured in the Stanley and Challis areas that have migrated into the FC-RONRW, but there is little understanding regarding the proportion of animals for which this occurs. As is generally true statewide, historic and recent fire regimes and the presence of invasive species and multiple predators add to the complexity of understanding and managing elk populations inside the FC-RONRW.

Relationship to FC-RONRW Management Plan

IDFG's data collection is consistent with USFS' FC-RONRW Management Plan (2003, with May 22, 2009 Errata) (FC-RONRW Plan). The FC-RONRW Plan states that ungulate populations and habitat conditions will be monitored for baseline information and changes in baseline, and includes the ratio of males, females, and young in wild ungulate populations as a monitoring indicator. FC-RONRW Plan at 2-28; 3-3.

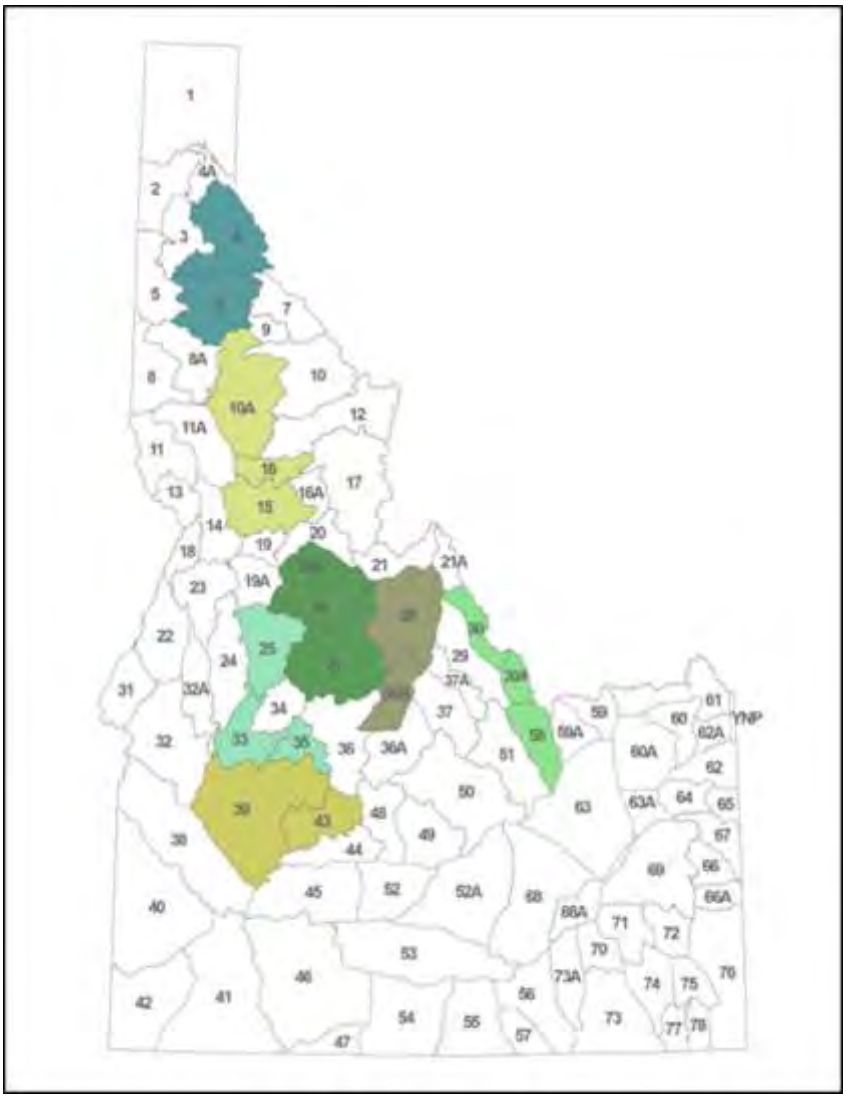

Figure 1. GMUs selected for elk survival estimation for inclusion into integrated population models

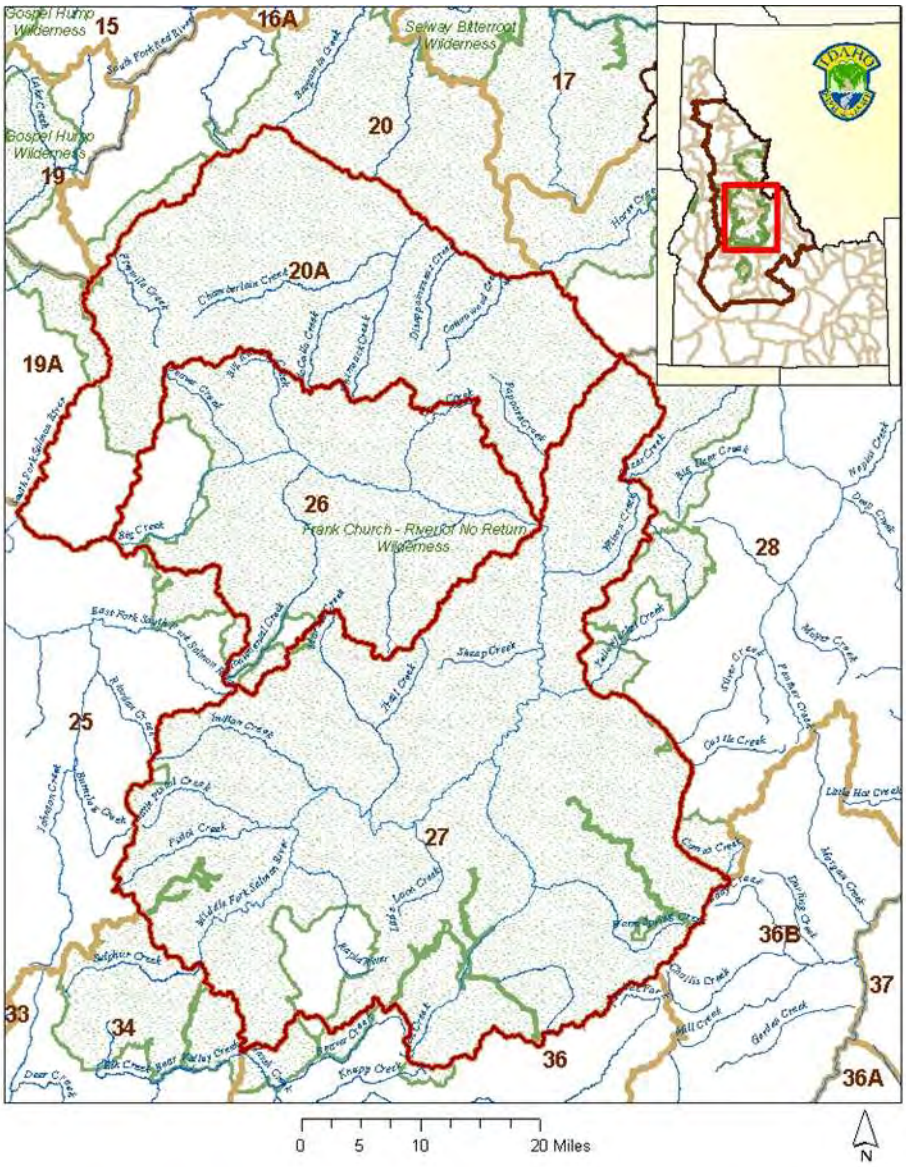

Figure 2. Middle Fork Elk Management Zone depicting the elk radiocollar project area

Criteria for Determining Necessity
Is action necessary to meet any of the criteria below?

A. Valid Existing Rights or Special Provisions of Wilderness Legislation

Is action necessary to satisfy valid existing rights or a special provision in wilderness legislation (the Wilderness Act of 1964 or subsequent wilderness laws) that ***requires*** *action? Cite law and section.*

☒ YES ☐ NO

Explain:

Monitoring of elk herds in the FC-RONRW is necessary to satisfy and support the State of Idaho's proper exercise of its wildlife management jurisdiction and responsibilities, which are recognized under the Wilderness Act and Central Idaho Wilderness Act. Without appropriate monitoring data, IDFG cannot make informed harvest and other wildlife management decisions within the FC-RONRW.

State Jurisdiction and Responsibilities

The Wilderness Act specifies in Section 4(d)(8), *"Nothing in this Act shall be construed as affecting the jurisdiction or responsibilities of the several States with respect to wildlife and fish in the national forests."* Similarly, The Central Idaho Wilderness Act of 1980 (Public Law 96-312) states in Section 7(c): *"As provided in paragraph 4(d)(8) of the Wilderness Act, nothing in this Act shall be construed as affecting the jurisdiction or responsibilities of the State of Idaho with respect to wildlife and fish in the national forests in Idaho."*

Pursuant to Idaho's Wildlife Policy, as set forth in Idaho Code Section 36-103(a), it is the State's authority, jurisdiction, and obligation to preserve, protect, perpetuate and manage wildlife in Idaho and to ensure that wildlife is only taken so as to preserve, protect, and perpetuate such wildlife, and provide for the citizens of this state and, as by law permitted to others, continued supplies of such wildlife for hunting, fishing and trapping.

Idaho Code Section 36-103(b) requires flexible management and appoints a Commission to administer fish and wildlife policies in the State: *"Because conditions are changing and in changing affect the preservation, protection, and perpetuation of Idaho wildlife, the methods and means of administering and carrying out the state's policy must be flexible and dependent on the ascertainment of facts which from time to time exist and fix the needs for regulation and control of fishing, hunting, trapping, and other activity relating to wildlife, and because it is inconvenient and impractical for the legislature of the state of Idaho to administer such policy, it shall be the authority, power and duty of the fish and game commission to administer and carry out the policy of the state in accordance with the provisions of the Idaho fish and game code. The commission is not authorized to change such policy but only to administer it."* Idaho Code Sections 36-102 and 36-104 grant administration of the State's statutory mission to the Commission and IDFG.

In addition, Idaho law requires state licensing of outfitters and guides (Idaho Code, Title 36 Chapter 21 and Title 6 Chapter 12). The Wilderness Act allows for outfitting and guiding as a commercial service in designated wilderness "*to the extent necessary for activities which are proper for realizing the recreational or other wilderness purposes of the area."* Outfitted and guided hunting is authorized in the

FC-RONRW. In accordance with state administrative rules, IDFG issues an allotment of tags for big game hunting to licensed outfitters based on the biological information on status of big game herds. The monitoring action is necessary to determine the proper allotment of these tags in conjunction with other big game tags.

Both the Wilderness Act and the Central Idaho Wilderness Act recognize the State of Idaho's independent wildlife management authority and jurisdiction in designated wilderness. A key component of IDFG's management program is to monitor populations of big game species, including elk, to ensure these species are preserved, protected, perpetuated and managed, and in such a way as to provide continued supplies for consumptive use.

B. Requirements of Other Legislation

Is action necessary to meet the requirements of other federal laws? Cite law and section.

☒ YES ☐ NO

Explain:

National Forest Management Act (NFMA)

Under the National Forest Management Act of 1976 (Public Law 94-588; 16 U.S.C. 1600 *et seq.*), USFS must comply with requirements incorporated into the relevant approved forest management plan. The FC-RONRW Plan has been incorporated into the Salmon-Challis National Forest Land and Resource Management Plan (Salmon-Challis Forest Plan). Chapter 3 of the FR-RONRW Plan includes monitoring direction that USFS is required to follow.

IDFG conducts monitoring in designated wilderness under independent state wildlife management authorities, recognized by Congress as being unaffected by the applicable Wilderness Acts. In addition, without IDFG's monitoring data, USFS will not have data necessary to fulfill its obligations under the FC-RONRW Plan to determine appropriate management measures and to ensure the compatibility of the reintroduction of historically native predatory species with the FC-RONRW Plan and IDFG species management plans. FC-RONRW Plan at 2-27, 3-1, 3-3.

The FC-RONRW Plan recognizes the importance of wild ungulate populations to the area and its wilderness character, with both wildlife indicators relating to these populations: (1) percent of forage utilization on selected transects within seasonally important wild ungulate habitats and (2) ratio of males, females, and young in wild ungulate populations. FC-RONRW Plan at 2-28; 3-3.

The FC-RONRW Plan also states, "Habitat and population conditions and trends of both game and nongame fish and wildlife species inhabiting the wilderness will be monitored," (FC-RONRW Plan at 2-28), and if areas of degradation are detected, appropriate management actions will be taken (FC-RONRW Plan at 3-1).

The FC-RONRW Plan states that wild ungulate populations in the wilderness area are stable or slowly increasing (FC-RONRW Plan at 2-25). However, conditions have changed and this is no longer true. As previously discussed, the area's elk populations have dramatically declined since 2002.

The Salmon-Challis Forest Plan is due for revision pursuant to the NFMA. This revision depends on an updated assessment of the conditions on the Forest. Elk monitoring data in the FC-RONRW will support the forest plan revision effort.

Executive Order (EO) 13443

On August 16, 2007, President Bush signed EO 13443 directing Federal agencies to facilitate the expansion and enhancement of hunting opportunities and the management of game species and their habitat. Among other things, the EO requires agencies to:

- evaluate the effects of agency actions on trends in hunting participation;
- consider the economic and recreational values of hunting in agency actions;
- manage wildlife and habitats on public lands in a manner that expands and enhances hunting opportunities; and
- work collaboratively with State governments to manage and conserve game species and their habitats and in a manner that respects State management authority over wildlife resources.

As public land, the FC-RONRW is within the scope of the Order. Monitoring in the FC-RONRW to evaluate and respond to apparently distinct elk population conditions is necessary to manage game species and habitat in a manner that expands and enhances hunting opportunities. It is also necessary for coordination between USFS and IDFG in the management and conservation of game species and their habitats, respectful of Idaho's wildlife management authority.

Federal Requirements for Coordination with States

Elk monitoring is necessary to meet other requirements for federal agency coordination and cooperation with states on wildlife management issues. For example, 36 C.F.R. 241.2 requires USFS to cooperate with state fish and game departments to formulate plans for securing and maintaining desirable populations of wildlife species. Monitoring data is a fundamental component in the development and implementation of wildlife management plans.

C. Wilderness Character

Is action necessary to preserve one or more of the qualities of wilderness character, including: Untrammeled, Undeveloped, Natural, Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation, or Other Features of Value?

UNTRAMMELED

☒ YES ☐ NO

Explain:

The necessity for action to preserve Untrammeled and Natural Qualities is interrelated; see consolidated discussion under "Natural" below.

UNDEVELOPED

☐ YES ☒ NO

Explain: Action is not necessary regarding the undeveloped character of the FC-RONRW.

NATURAL

☒ YES ☐ NO

Explain:

Wolves were extirpated from the lands now identified as the FC-RONRW decades before its designation. The federal government chose to manipulate populations through the reintroduction of wolves to the FC-RONRW in 1995 and 1996 instead of achieving recovery through natural migration. (FWS 1994[2]). Subsequent abrupt predator population growth and expansion, in combination with habitat degradation from invasive, non-native plant species, do not appear to have resulted in a naturally functioning ecosystem that incorporates the effects of traditional hunting activities (as described in the next section).

Previous monitoring programs are not adequate to support IDFG's decision making in the FC-RORNRW. Elk herds in the FC-RONRW have declined due to poor recruitment (*i.e.,* calf survival to age one) and increased variability in annual survival. Without accurate data as to population demographics, vital statistics, and causes of mortality, IDFG cannot determine whether harvest regulation and other wildlife management actions, as well as actions USFS may take related to habitat degradation, are appropriate and sustainable to effectively address elk population declines. Without accurate information on causes of decline and population response to management actions, IDFG's actions may either be ineffective or inadvertently cause further degradation to the untrammeled and natural qualities of wilderness character instead of mitigating it.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

☒ YES ☐ NO

Explain:

Traditional elk hunting (and related opportunities for solitude of primitive and unconfined recreation) is a recognized component of the FC-RONRW's wilderness character. Part of the appeal of the experience is the challenge and solitude that backcountry hunting in the FC-RONRW provides. Hunter participation and success data indicate that the quantity and quality of hunting in the FC-RONRW has declined substantially. IDFG has already eliminated cow elk harvest and put a cap on the total number of hunters that can use the Middle Fork Elk Zone for hunting bull elk. IDFG will have to further restrict hunting in the FC-RONRW if elk population targets cannot be maintained/achieved, or if IDFG is unable to accurately monitor and predict changes in elk populations. Such restrictions and regulation adversely affect the experience of freedom in wilderness, and declining elk numbers adversely affect backcountry hunting and other recreational experiences. Action is necessary to protect the solitary or primitive and unconfined hunting and other recreational opportunities that are an important component of the FC-RONRW's wilderness character.

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[2] The federal 1994 environmental impact statement significantly overestimated projected elk population numbers in Central Idaho in comparison to actual population estimates made 10 and 15 years after wolf introduction (*see* FWS 1994 at 4-35 to 4-39).

OTHER FEATURES OF VALUE

☐ YES ☒ NO

Explain: Action is not necessary to protect other features of value within the FC-RONRW.

Step 1 Decision
Is administrative action necessary in wilderness?

Decision Criteria

A.	Existing Rights or Special Provisions	☒ YES	☐ NO
B.	Requirements of Other Legislation	☒ YES	☐ NO
C.	Wilderness Character		
	Untrammeled	☒ YES	☐ NO
	Undeveloped	☐ YES	☒ NO
	Natural	☒ YES	☐ NO
	Outstanding Opportunities	☒ YES	☐ NO
	Other Features of Value	☐ YES	☒ NO

Is administrative action necessary in wilderness?

☒ YES **EXPLAIN AND PROCEED TO STEP 2**

☐ NO **STOP – DO NOT TAKE ACTION IN WILDERNESS**

Explain:

Elk monitoring is necessary for the proper exercise of state wildlife management jurisdiction and responsibilities as they relate to administration of the FC-RONRW. Elk populations in the FC-RONRW have declined dramatically. Backcountry/wilderness elk hunting is an important and historic component of the solitude, primitive, and unconfined recreation character of the FC-RONRW. Hunter participation and success data indicate that the quantity and quality of hunting in the FC-RONRW is declining. Because of changed conditions resulting from increased variability in adult and calf survival, aerial surveys alone are now inadequate to detect elk population changes and causes.

Without accurate demographic data, vital statistics, and mortality cause inforamtion for elk, IDFG cannot determine whether established harvest regulations and other management actions are appropriate and sustainable for this area or how to effectively address elk population declines. Monitoring elk outside the FC-RONRW, and aerial surveys alone do not provide adequate information to address unique conditions within the FC-RONRW. Data from within the wilderness are necessary to inform management decisions and to respond appropriately to elk population declines in the FC-RONRW.

Data collected would provide important information on current ecology and predator-prey relationships in the FC-RONRW. Monitoring is also needed to coordinate with USFS to respond appropriately to apparent degradation to wilderness character related to the elk herds' decline. Data would also address monitoring and condition assessment required by USFS' FC-RONRW Plan.

Minimum Requirements Analysis Step 2

Determine the Minimum Activity

Other Direction

*Is there "special provisions" language in legislation (or other Congressional direction) that explicitly **allows** consideration of a use otherwise prohibited by Section 4(c)?*

AND/OR

Has the issue been addressed in agency policy, management plans, species recovery plans, or agreements with other agencies or partners?

☒ YES	**DESCRIBE OTHER DIRECTION BELOW**
☐ NO	**SKIP AHEAD TO TIME CONSTRAINTS BELOW**

Describe Other Direction:

As discussed above, both the Wilderness Act and the Central Idaho Wilderness Act recognize the State of Idaho's independent jurisdiction and responsibilities under state law for wildlife management in designated wilderness. A key component of Idaho's jurisdiction and responsibilities is the monitoring of big game populations, including elk, to ensure these species are preserved, protected, perpetuated and managed, and in such a way as to provide continued supplies for consumptive use. IDFG's use of aircraft for monitoring and other fish and wildlife management actions in the proper exercise of its jurisdiction and responsibilities is consistent with the Wilderness Act and Central Idaho Wilderness Act. For additional information regarding the use of aircraft in general in the FC-RONR Wilderness, see the "wilderness character" discussion under Alternative 1.

State of Idaho's Species Management Plans

In addition to statutory direction, wildlife management in Idaho is implemented following direction established in State species management and predation management plans. State management plans are approved by the Commission; these plans establish management goals and monitoring requirements for individual species.

The Idaho Elk Management Plan 2014-2024[3] states: *"Population monitoring is the backbone of IDFG's elk management program. Monitoring provides wildlife managers with information to evaluate management goals and allows informed decision making. Monitoring should include an estimate of population size, as well demographic information such as age and sex ratios."* This plan establishes management objectives to meet a variety of public needs, including hunting and other wildlife-based

[3] The Idaho Elk Management Plan is available at: http://fishandgame.idaho.gov/public/wildlife/planElk.pdf

recreation. As an example, the Elk Management Plan establishes population objectives for the Middle Fork Elk Zone of 3,850-5,750 adult females, 390-810 adult males, and 690-1,030 total antlered males (IDFG 2014). Elk monitoring will also provide data necessary for supporting the adaptive framework of the Predation Management Plan for the Middle Fork Zone (2014).[4]

Memorandum of Understanding

In June 2010, IDFG and USFS' Intermountain and Pacific Northwest Regions signed an MOU regarding agency commitments, responsibilities, and areas of cooperation and coordination relative to terrestrial and aquatic species conservation programs on National Forest System (NFS) lands. The MOU recognizes there is a mutual benefit for the agencies to work together for the common purpose of developing, maintaining, and managing fish and wildlife resources, associated habitats, and other related resources on NFS lands. Excerpts of the MOU are included below:

III. [USFS] shall:

A. Recognize [IDFG] as the agency with the primary authority, jurisdiction, and responsibility to manage, control, and regulate fish and wildlife populations on NFS lands….

C. Coordinate with and involve [IDFG] in a timely manner in developing goals, objectives, management areas, standards and guidelines, and monitoring that affect fish and wildlife habitat and related recreation in Forest Resource and Land Management Plans, amendments and revisions to those plans, and in subsequent fish, wildlife, plant, and habitat management and conservation activities.

D. Respond to requests from [IDFG] for use of National Forest improvements, facilities, equipment, pack and saddle stock, aircraft and services as would be used in wildlife work, provided they are not currently being used by [USFS]….

F. Cooperate with [IDFG], when requested, and to the extent feasible, in fish and wildlife population surveys and harvest data collection.

G. Cooperate with [IDFG] to ensure that the appropriate level of environmental analysis is completed when State activities on NFS land require [USFS] authorization or there are other Federal actions implicated which triggers requirements for compliance with NEPA and other federal environmental laws. [USFS] need not prepare environmental analyses under NEPA or other laws for actions undertaken solely by the State where no federal action or funding by [USFS] is required….

I. Cooperate in the development and implementation of new analytical techniques, habitat inventories and evaluation procedures, and ecosystem and habitat type mapping….

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[4] The Predation Management Plan related to elk in the Middle Fork Zone is available at: http://fishandgame.idaho.gov/public/wildlife/planMiddleForkPredation.pdf

IV. [IDFG] shall:

A. Recognize [USFS] as the agency responsible for the management of NFS lands in Idaho and the fish and wildlife habitat on these lands.
B. Coordinate with and provide information and assessments to [USFS] concerning [IDFG] objectives, plans, programs, and policies for fish, wildlife, and related recreation on [USFS] administered lands….
F. Assist, as [IDFG] deems appropriate, in preparation of environmental analyses under NEPA and other federal laws and regulations that may be required when there is a [USFS] action or decision associated with State fish and wildlife management actions on NFS lands….
G. Cooperate with [USFS] in fish and wildlife population surveys and collection of harvest data to the extent possible.
H. Involve [USFS] in the development of state wildlife planning documents, seek comments on these documents, and coordinate actions on NFS lands directed by these documents.
I. Cooperate with [USFS] in the design and implementation of wildlife and fish management programs and actions on NFS lands.

FC-RONRW Plan

USFS completed its FC-RONRW Plan in 2003. The FC-RONRW plan includes direction to USFS for the management of fish and wildlife resources, including monitoring and research proposals. Pertinent excerpts include:

Conditions Chapter 2, Fish and Wildlife Resources, Section VIII

B. Desired Future

The [FC-RONRW] land, lakes, and streams provide a variety of consumptive (i.e., hunting and fishing) and non-consumptive (i.e., viewing, photography) recreation opportunities. Wilderness managers cooperate with fish and wildlife management agencies to emphasize native species and their habitats. Managers will favor fish and wildlife resources when they resolve or eliminate identified conflicts between recreational uses and fish and wildlife populations or habitats….

D. Objectives

1. The [FC-RONRW] serves as a refuge for native threatened, endangered, proposed, and sensitive species. It protects existing remnant populations that inhabit the FC-RONR Wilderness and provides natural habitats for reintroduced native species. Wilderness managers evaluate effects of all human activities on fish and wildlife species to reduce or eliminate potential conflicts, restore populations and maintain quality habitats in a natural condition.

2. Biological opinions, watershed biological assessments and letters of concurrence from NOAA Fisheries and U.S. Fish and Wildlife Service will be followed. [IDFG] Species Management Plans and U.S. Fish and Wildlife Service Recovery Plans will be supported.

3. Recreation/wildlife conflicts will be evaluated and seasonal use restrictions will be initiated as needed to eliminate measurable problems.

E. Standards and Guidelines - Wildlife

1. Reintroduction or supplemental transplanting of native wildlife species will be permitted only when analysis shows that:

b. Populations of native species reduced or eliminated by human activity will be restored;

c. Reintroduction of historically native predatory species is compatible with goals and objectives of this Wilderness Plan, [IDFG], and the U.S. Fish and Wildlife Service; and

d. Significant values of the [FC-RONRW] will not be impaired.

4. Salting, supplemental minerals and nutrients, or supplemental feeding of wildlife is prohibited….

F. Monitoring

Habitat and population conditions and trends of both game and non-game fish and wildlife species inhabiting the Wilderness will be monitored.

Indicators

1. Percent of forage utilization on selected transects within seasonally important wild ungulate habitats.

2. Ratio of males, females, and young in wild ungulate populations.

Forest Service Manual

Although not binding on State monitoring and management activities, the Forest Service Manual (FSM), Section 2323.32 outlines [USFS] policies regarding fish and wildlife management in wilderness:

1. *Recognize that States have jurisdiction and responsibilities for the protection and management of wildlife and fish populations in wilderness. Cooperate and work closely with State wildlife and fish authorities in all aspects of wildlife and fish management. Base any [USFS] recommendation to State wildlife and fish agencies on the need for protection and maintenance of the wilderness resource. Recognize wilderness protection needs and identify any needed requirements in coordination efforts and in cooperative agreements with State agencies….*

Although IDFG's activities are conducted under State wildlife management authority and are in the nature of monitoring rather than research activity, some of the FSM statements regarding research provide insight to USFS' considerations for monitoring. For example, FSM 2323.37 provides direction for wildlife and fish research*:*

Wildlife and fish research is an appropriate activity in wilderness. In all cases, research shall be conducted in such a way as to minimize any adverse impacts on the wilderness resource or its users….

1. Research methods that temporarily infringe on the wilderness character may be used, provided the information sought is essential for wilderness management and alternative methods or locations are not available.

2. Scientific sampling of wildlife and fish populations is essential to the management of natural populations in wilderness.

3. Capturing and inconspicuous marking of animals, including radio telemetry, is permitted.

Time Constraints

What, if any, are the time constraints that may affect the action?

The following time constraints apply to those alternatives that consider radiocollaring animals:

- Adult female elk could be captured anytime from December to March.
- Elk calves should be collared by January 15 of each year to accurately track mortalities.
- For operational effectiveness and less disturbance to elk, helicopter-based radiocollar operations should occur in winter to early spring when elk are concentrated.

Winter to early spring aircraft activities would avoid the major air traffic congestion associated with existing landing strips during high-use recreational periods during summer and fall.

Components of the Action

What are the discrete components or phases of the action?

Component 1:	Transportation of personnel and equipment to the project site
Component 2:	Monitoring technique(s)
Component 3:	Equipment used and transportation of personnel while monitoring
Component 4:	Staging and lodging
Component 5:	Condition of the site after the project
Component 6:	Length of project

Minimum Requirements Analysis Step 2: Alternatives

Alternative 1: 10-year Elk Radiocollaring (IDFG Planned Action)

Description of the Alternative
What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

IDFG would collect data through deployment of satellite collars on elk in the Middle Fork Zone. IDFG would use data to inform and calibrate an integrated population model (IPM) for elk in wilderness for harvest regulation and other state management decisions. For adequate precision/accuracy, IDFG would collect survival data over a 10-year time period to evaluate annual survival under a representative range of conditions, such as those associated with fluctuations in weather patterns over time.

IDFG would perform radiocollaring during the winter months. Winter is the optimal time for capture because elk are in larger groups and are more concentrated on open shrub winter range. This is also a time when recreational use and other air traffic and landings are minimal and typically associated only with developed private inholdings.

IDFG would bring equipment and personnel needed for radiocollaring into the FC-RONRW using existing public and State-owned airstrips (or private airstrips with owner permission)[5]. Base camps for end-of-day landing and staging would be at existing airstrips and non-federal landing sites on in-holdings (e.g. Taylor Ranch, Whitewater Ranch, Lower Loon, and Mormon Ranch). Fueling points for helicopter activity would be at existing airstrips and non-federal in-holdings or other non-wilderness locations. Fuel would be pre-positioned prior to conducting flight operations.

IDFG estimates that helicopters would be flown a total of approximately 5 consecutive days each of the first two years of the project, and 3 days in each subsequent years. The days of operation would occur during winter from December 1 through March 30. Each capture event would typically include two landings: one to capture and offload personnel and one to retrieve personnel.[6]

Capture methods would follow published protocols using a helicopter and either a netgun or immobilizing darts depending on terrain and habitat. Netgunning is most efficient in open terrain where biologists have the ability to stop and restrain the animal at a selected location, which is safer for both the animal and helicopter crew and minimizes helicopter time. Darting would be used in forested terrain that precludes netgun use. Darting requires maintaining visual contact with the animal after darting, generally

[5] Throughout the document, any reference to use of private airstrips assumes obtaining prior permission.
[6] USFS counts landings as anytime equipment (such as a net) or people are offloaded from a helicopter (36 CFR 261.18), or as anytime one or more helicopter skids touch ground.

5 minutes, before the animal is fully anesthetized. Individual animals can be lost or injured using either technique; netgunning results in about 2% injury rate and darting results in about 3% injury. Handling and care of the darted animals is managed under standard operating procedures developed by the University of Idaho Animal Care and Use Committee. At the time of radiocollaring, IDFG would collect information from adult females as to nutritional condition through various techniques (*e.g.,* ultrasound, body scoring, and blood samples).

All captured animals would be radiocollared with GPS satellite collars. These collars would automatically send information to IDFG's computer systems, thus limiting the need for future overflights to locate collared animals. IDFG would conduct overflights for collars whenever a mortality or a dropped collar is indicated. Collars would be retrieved by personnel on foot after landing at the nearest public, State, or private airstrip.

IDFG would use a stratified random sampling design to capture elk in proportion to their distribution on winter ranges. Each GMU is stratified into subunits based on low, medium or high winter elk densities. Figure 3 illustrates stratification across GMU 27, one of the three GMUs located in the Middle Fork Zone. IDFG would seek to sample all high-density subunits, and to sample medium- and low-density subunits at a rate of approximately 50% (targeting medium-density subunits). IDFG would calculate the number of elk required in each of the density strata and randomly capture cows and calves up to the target number. Calves should be collared by January 15 of each year to accurately track mortalities. For monitoring to be statistically valid, IDFG needs to collar 30 calves each year. Adult females could be captured anytime from December to March. A sample size of 60 adult females is needed for statistical precision; IDFG would collar 30 adult females in each of the first two years to achieve this objective. Thereafter, IDFG would collar adult females as necessary to replace individuals that die, taking into account replacement by collared calves that survive to age one to become adults.

For collaring, a processing team of 2-3 personnel would exit the helicopter while the pilot maintains either a hover or a "toe-in" (the front of the skids touch the ground). The full hover is the more common exit and is safer--the skid cannot get caught under vegetation under the snow and the blades are farthest from the ground. Personnel would re-enter the helicopter in the same fashion after the animal is processed. Elk would be anesthetized with Carfentanil and reversed with Naltrexone.

Multiple captures would occur each day. Elk congregate in groups while on their winter range. The helicopter would move from group to group, attempting to capture 1-2 animals from each. Once disturbed, elk tend to retreat to timbered areas for a short time period. Thus, the helicopter would only make a pass or two over a group in any given day. Once a group has retreated, the helicopter would move on to another group and then another group, etc. In that way, multiple elk from multiple groups could be captured and collared on a single day.

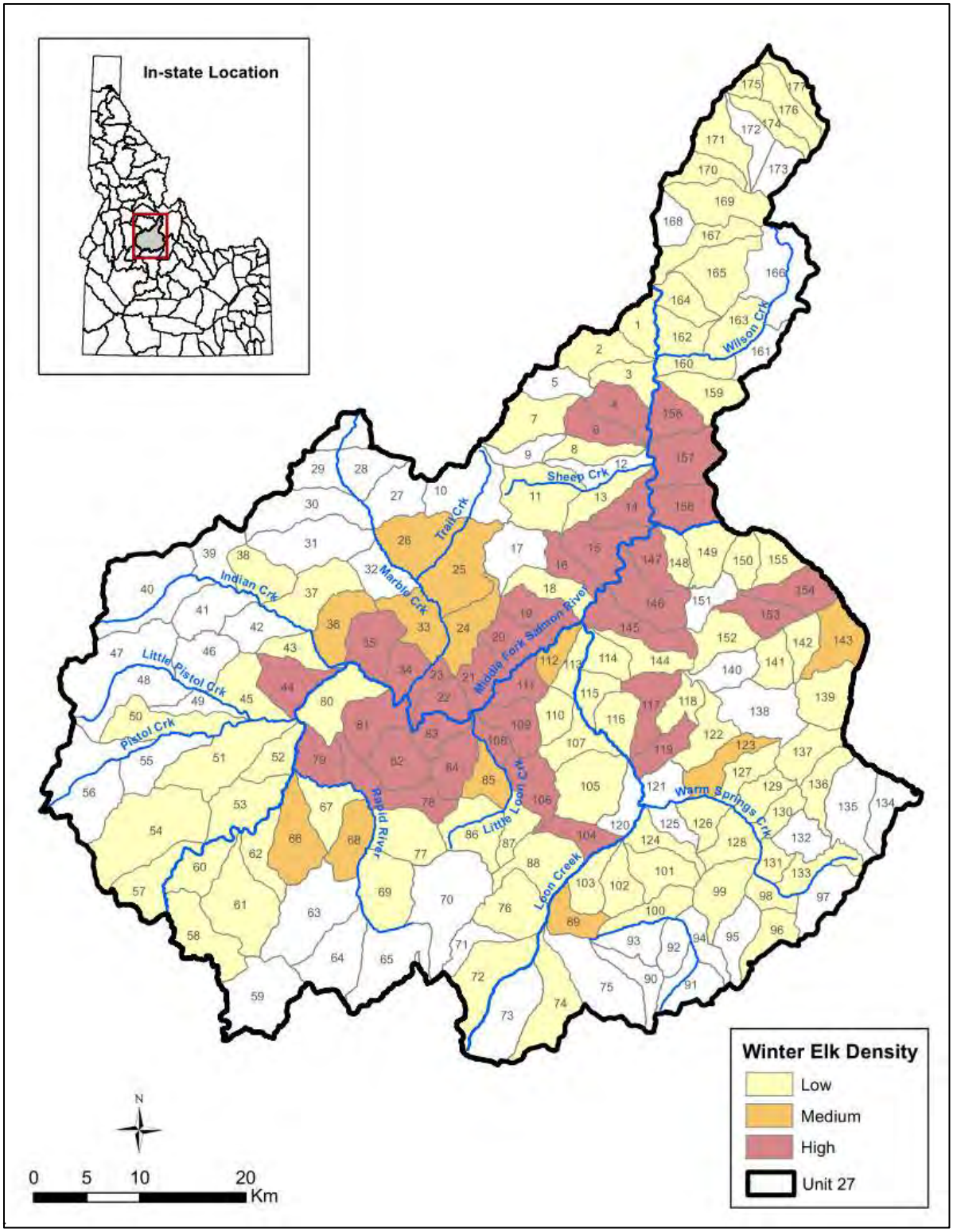

Figure 3. Winter elk density in GMU 27

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
1	Transportation of personnel and equipment to the project site	Equipment and personnel will travel into the wilderness via public, state, or private airstrips.
2	Monitoring technique(s)	IDFG will radiocollar elk via helicopter, offloading 1-3 team members to process and radiocollar each netted or darted animal. Monitoring will include 120 estimated landings in each of years 1 & 2 and 70 per year thereafter (800 over 10 years). IDFG will monitor survival and movements via satellite download of radiocollar data.
3	Equipment used and transportation of personnel while monitoring	Collars would automatically upload information to IDFG computers without need for overflights. Personnel would retrieve dropped collars or collars indicating mortality on foot via public/State/private airstrips.
4	Staging and lodging	End-of-day landing, staging, and base camps will be at State/private in-holdings. Personnel will primarily be present only during collaring operations.
5	Condition of the site after the project	IDFG obtains adequate data to ensure wildlife harvest regulations and management actions are appropriate and consistent with elk demographics.
6	Length of project	10 years total

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

Explain:

To evaluate appropriately the effects of component activities on the qualities of wilderness character and mitigation measures, it is important to consider the unique attributes of the FC-RONRW, rather than evaluate wilderness character in the abstract. For example, the historic and ongoing use of aircraft is particularly relevant in considering an action involving the use of aircraft in the FC-RONRW.

Section 4(d)(1) of the Wilderness Act allows for the use of aircraft or motorboats to continue "where these uses have already become established" and "subject to such restrictions as the Secretary of Agriculture deems desirable." Because of unique circumstances and compromises related to the FC-RONRW, Section 7(a)(1) of the Central Idaho Wilderness Act of 1980 states, *"the landing of aircraft, where this use has become established prior to the date of the enactment of this Act* ***shall*** *be permitted to continue subject to such restrictions as the Secretary deems desirable: Provided, That the Secretary shall not permanently close or render unserviceable any aircraft landing strip in regular use on national forest lands on the date of enactment of this Act…."* (emphasis added).

USFS manages 8 airstrips for active public use in the FC-RONRW. Use of these airstrips requires no special authorization from the USFS. There are an additional 18 landing strips on non-federal in-holdings within the external boundaries of the FC-RONRW, 4 of which are owned by the State of Idaho. Use of the federal and non-federal airstrips within the FC-RONRW is considerable, particularly in summer and fall, with over 12,000 operations per year at the 8 USFS public airstrips alone (FAA aircraft operation statistics, AirNav.com). Operations at airstrips at state and private in-holdings, such as high-use sites at the Thomas Creek, Loon Creek, Flying B, Pistol Creek, Sulphur Creek, and Taylor Ranches, are likely comparable in scale.

Within the area that is now the FC-RONRW, IDFG has long used helicopters and fixed wing aircraft in the exercise of its wildlife management jurisdiction and responsibilities, conducting overflights and landing at airstrips and other locations. IDFG's aircraft use for these purposes is long-established, dating back to the 1960s (*e.g.,* aerial surveys, radiocollaring and other monitoring activities; law enforcement; and active management such as animal relocation and fish stocking).

Although USFS' minimum tool analysis guidance generally considers helicopter use as a development, a negative impact to solitude, and erosive of traditional skills, significant aircraft use is part of the baseline condition for the FC-RONRW. IDFG considers an activity to have "No Effect" if the use exists within baseline conditions, and this analysis only references impacts that potentially differ from baseline conditions.

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☒	☐
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	-1	NE
Untrammeled Total Rating		**0**		

Explain:

Under Alternative 1, helicopters would fly over and conduct landings in the Middle Fork Elk Zone (includes (GMUs 27, 26, and 20A) to capture elk according to the sample design. Helicopters disturb elk and cause them to retreat from open winter range areas into nearby timber if available. Elk typically stop their retreat within 200 meters after pursuit ends. Only one capture operation would be imposed on each group (1-3 animals captured) during collaring operations, limiting disturbance to one per year per group. Helicopters cause animals to expend energy and disrupt their activities. Helicopters may

disturb the elk's normal daily activities and may adversely affect the untrammeled character of the wilderness area. However, these effects are less disruptive, involve a smaller footprint, are of shorter duration, and more reliable in attaining the desired monitoring outcomes than any ground pursuit methods. The effects would be temporary (occurring during the period of radiocollaring activities) and would occur only during the winter/early spring periods. The effect would occur annually, for 3-5 days every year during the 10-year period.

See interrelated discussion of "Natural" quality below.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	0	NE
Undeveloped Total Rating		**0**		

Explain:

See prior discussion regarding baseline of aircraft use. IDFG's helicopter use under Alternative 1 makes no permanent impact to the undeveloped character of the FC-RORNW beyond baseline development. Helicopters would fly over and conduct brief landings off-airstrip at dispersed sites in the Middle Fork Elk Zone (includes GMUs 27, 26, and 20A) to capture elk according to the sample design, approximately 3-5 days each year during the 10-year period. Support activities would occur at existing airstrips, in-holdings and other non-wilderness sites. Helicopter use would occur during the winter period when recreational use is minimal and public aircraft operations are generally associated with developed private in-holdings.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒

5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	0	NE
Natural Total Rating		**+1**		

Explain:

Capturing and radiocollaring activities would not themselves affect the natural character of the wilderness area. Ecological processes would continue over the short and long-terms. Collected data would contribute to IDFG's understanding of the ecology of the FC-RONRW and provide specific knowledge regarding habitat use and predator-prey relationships. IDFG expects that these data will provide the information necessary to support decisions for harvest regulation and other management activities that will improve the natural character of the ecosystem (which includes traditional consumptive uses) degraded by the elk herds' decline. This information would help IDFG and USFS respond appropriately to address elk herd declines apparently related to excessive predation pressure, as well as the habitat effects of invasive, non-native plant species.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☒	☐
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	-1	NE
Solitude or Primitive & Unconfined Rec. Total Rating		**0**		

Explain:

Helicopters may adversely affect opportunities for solitude. While temporary in duration, these impacts would occur annually for 3-5 days during the 10-year period in the Middle Fork Elk Zone (includes GMUs 27, 26, and 20A). Effects would be mitigated by the activities occurring during winter, when recreational use is minimal and generally associated with flights into established airstrips and activity is typically confined near developed private in-holdings. Opportunities for primitive and unconfined recreation could be adversely impacted when helicopter operations occur. However, over the long-term, backcountry hunting would benefit from the information obtained from radiocollared animals and any associated changes in IDFG's management that result in improvements to the quality and quantity of hunting and other recreational opportunities related to elk and wildlife in general.

OTHER FEATURES OF VALUE

Explain: The project would have no effect on other features of value.

Traditional Skills

What is the effect of each component activity on traditional skills?

TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☒	☐	☐
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	0	NE
Traditional Skills Total Rating		**+1**		

Explain:

This alternative depends on mechanical equipment and motorized transport during the collaring phase. Personnel may use traditional skills during collar retrieval; personnel would be flown into the nearest public/State/private airstrip and then access the collar location on foot.

Economics

What is the estimated cost of each component activity?

COST

Component Activity for this Alternative		Estimated Cost
1	Transportation of personnel and equipment to the project site	$21,600
2	Monitoring technique(s)	$148,750
3	Equipment used and transportation of personnel while monitoring	$221,750
4	Staging and lodging	N/A
5	Condition of the site after the project	N/A
6	Length of project	(10 years)
Total Estimated Cost		**$392,100**

Explain:

The average cost estimate of $39,210/year ($392,100 over 10 years) includes: radiocollar purchase, remote data retrieval cost, transportation of crews in and out of established airstrips, and helicopter rental for capture activities. It does not include permanent personnel time or per diem. The cost estimates do not reflect change in monetary value over time.

Safety of Visitors & Workers

What is the risk of this alternative to the safety of visitors and workers? What mitigation measures will be taken?

RISK ASSESSMENT	Probability of Accident				
Severity of Accident	Frequent	Likely	Common	Unlikely	Rare
Catastrophic: Death or permanent disability	1 ☐	1 ☐	2 ☐	2 ☒	3 ☐
Critical: Permanent partial disability or temporary total disability	1 ☐	2 ☐	2 ☐	3 ☒	4 ☐
Marginal: Compensable injury or illness, treatment, lost work	2 ☐	3 ☐	3 ☐	4 ☐	4 ☒
Negligible: Superficial injury or illness, first aid only, no lost work	3 ☐	4 ☐	4 ☐	4 ☒	4 ☐
Risk Assessment	**3**				

Risk Assessment Code

1 = Extremely High Risk	**2 = High Risk**	**3 = Moderate Risk**	**4 = Low Risk**

Explain:

Pursuit and capture of animals via low-level helicopter travel and backcountry landings involves typical safety risks associated with these types of flight operations. IDFG and contractor personnel are trained and experienced in these types of activities and follow strict safety procedures to effectively manage and mitigate risks. IDFG and its contractor would also be responsible for managing operations to avoid conflicts with wilderness visitors and to avoid exposing the public to safety risks associated with the operation. Inclement winter weather is an additional risk. Capture crews would conduct operations only when conditions such as visibility and winds are within acceptable ranges. Capture crews could be exposed to immobilizing drugs used to dart animals. Personnel performing capture work, netgunning or darting, and elk handling are all certified by IDFG for these activities. Under Alternative 1, personnel would not be exposed to long periods of winter camping or associated inclement weather.

Air traffic in the Middle Fork Zone of the FC-RONR Wilderness during the summer and fall months is intense, largely due to recreational rafting and hunting activities. By conducting collaring operations during the winter months, potential interference with other flights is greatly reduced.

Risks to personnel retrieving radiocollars in the FC-RONRW may involve slips, trips, and falls and other safety risks commonly associated with hiking, camping, and associated inclement weather. Although unlikely, injuries could result in lost work (e.g., a broken arm).

Summary Ratings for Alternative 1

Wilderness Character	
Untrammeled	0
Undeveloped	0
Natural	+1
Solitude or Primitive & Unconfined Recreation	0
Other Features of Value	0
Wilderness Character Summary Rating	**+1**
Traditional Skills	
Traditional Skills	+1
Economics	
Cost	$392,100 ($39,210/yr)
Safety	
Risk Assessment	3

Minimum Requirements Analysis Step 2: Alternatives

Alternative 2: 5-year intensive survival estimation with radio collars

Description of the Alternative
What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

IDFG would collect data in the Middle Fork Elk Zone needed to establish and calibrate an integrated population model (IPM) for elk in the FC-RONRW for harvest regulation and other state management purposes.

This alternative is similar to Alternative 1, except IDFG would intensify radiocollaring activities to obtain needed precision and accuracy for survival data during a shorter-term (5-year) period. IDFG would increase total sample size to guard against demographic variance (variance due to animal behavior or sample size). Increased samples must be used in short-term studies to make sure a nonstandard survival year is adequately captured since it may be the only one.

With Alternative 2's shorter time frame, IDFG would increase sample sizes of cows and calves in years 3, 4 and 5 to provide a higher sample of adult elk to carry over after the final year of monitoring. This would increase adult elk monitoring to 7 years while only capturing in 5. IDFG would collar an additional 20 elk each year in years 3-5 of the intensive option. Based on estimated "average" survival and collar failure rates, 124 adult females might be collared at the end of year 5 to allow IDFG to collect statistically valid data for adult cow survival through years 6 and 7. This differs from the 10-year option (Alternative 1), where IDFG would just replace collars to maintain a constant 60 cows each year.

Disadvantages

A more intense 5-year radiocollar timeframe may be sufficient to understand and document adult elk vital rates. However, calf mortality and survival rates are highly variable over time, especially in regards to weather conditions (*e.g.*, summer drought and deep snow conditions). It is unlikely that IDFG can obtain representative variability in survival data in a 5-year period, upon which an extension beyond 5 years would be necessary. If the IPM does not reflect representative variability or cannot be updated and calibrated with current data, the IPM would have limited utility in providing IDFG with the information needed to manage elk populations over the long-term.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
1	Transportation of personnel and equipment to the project site	Equipment and personnel will travel into the wilderness via public, state, or private airstrips.
2	Monitoring technique(s)	IDFG will radiocollar elk via helicopter, offloading 1-3 team members to process and radiocollar each netted or darted animal. Monitoring would include 120 estimated landings in each of years 1 & 2 and 110 landings for years 3-5 (570 over 5 years) IDFG will monitor survival and movements via satellite download of radiocollar data.
3	Equipment used and transportation of personnel while monitoring	Collars would automatically upload information to IDFG computers without need for overflights. Personnel would retrieve dropped collars or collars indicating mortality on foot via public/State/private airstrips.
4	Staging and lodging	End of day landing, staging, and base camps would be at State/private in-holdings. Personnel would primarily be present only during the collaring operation.
5	Condition of the site after the project	IDFG would obtain adequate data to ensure wildlife harvest regulations and management actions are appropriate and consistent with actual elk demographics.
6	Length of project	5 years total

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☒	☐
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	-1	NE

Untrammeled Total Rating	**0**

Explain:
The evaluation of untrammeled quality is the same as described for Alternative 1, except potential disturbance to elk would be greater in years 3-5 when more collaring activity would occur, and less potential disturbance in years 6-10.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	0	NE
Undeveloped Total Rating		**0**		

Explain:
The evaluation of undeveloped quality is the same as Alternative 1, except that more collaring activity would occur in years 3-5 and no collaring activity would occur in years 6-10.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	0	NE
Natural Total Rating		**+1**		

Explain:

The evaluation of natural quality is the same as for Alternative 1, except for the reduced likelihood of achieving the desired condition of the site after the project in Alternative 2. As described above, if IDFG cannot obtain representative variability in survival or otherwise update and calibrate the IPM, the model has limited utility in providing IDFG with the information needed to appropriately manage elk populations in the FC-RORNW over the long-term.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☒	☐
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☒	☐	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	-1	NE
Solitude or Primitive & Unconfined Rec. Total Rating		**0**		

Explain:

The evaluation of solitude or primitive and unconfined recreation would be as described for Alternative 1. Potential negative impacts to solitude and primitive/unconfined recreation would be greater in years 3-5 in Alternative 2 and fewer in years 6-10. There is also a reduced likelihood of achieving the desired condition of the site after the project in Alternative 2. As described above, if IDFG cannot obtain representative variability in survival or otherwise update and calibrate the IPM, the IPM has limited utility in providing IDFG with the information needed to appropriately manage elk populations to improve site conditions for recreational opportunities in the FC-RORNW over the long-term.

OTHER FEATURES OF VALUE

Explain: The project would have no effect on other features of value.

Traditional Skills
What is the effect of each component activity on traditional skills?

TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒

2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☒	☐	☐
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	0	NE
Traditional Skills Total Rating		**+1**		

Explain:

The evaluation of traditional skills would be as described for Alternative 1, except there would likely be fewer collar retrievals as the number of collars decrease (*e.g.,* years 8-10).

Economics

What is the estimated cost of each component activity?

COST

Component Activity for this Alternative		Estimated Cost
1	Transportation of personnel and equipment to the project site	$15,300
2	Monitoring technique(s)	$119,000
3	Equipment used and transportation of personnel while monitoring	$148,250
4	Staging and lodging	N/A
5	Condition of the site after the project	N/A
6	Estimated number of landings (outside of established airstrips)	N/A
7	Length of project	N/A
Total Estimated Cost		**$282,550**

Explain:

The average cost estimate of $56,510/year ($282,550 over 5 years) includes: radiocollar purchase, remote data retrieval cost, transportation of crews in and out of established airstrips, and helicopter rental for capture activities. It does not include permanent personnel time or per diem. The cost estimates do not reflect change in monetary value over time.

Safety of Visitors & Workers
What is the risk of this alternative to the safety of visitors and workers? What mitigation measures will be taken?

RISK ASSESSMENT	Probability of Accident				
Severity of Accident	Frequent	Likely	Common	Unlikely	Rare
Catastrophic: Death or permanent disability	1 ☐	1 ☐	2 ☐	2 ☒	3 ☐
Critical: Permanent partial disability or temporary total disability	1 ☐	2 ☐	2 ☐	3 ☒	4 ☐
Marginal: Compensable injury or illness, treatment, lost work	2 ☐	3 ☐	3 ☐	4 ☐	4 ☒
Negligible: Superficial injury or illness, first aid only, no lost work	3 ☐	4 ☐	4 ☐	4 ☒	4 ☐
Risk Assessment	**3**				

Risk Assessment Code

1 = Extremely High Risk	**2 = High Risk**	**3 = Moderate Risk**	**4 = Low Risk**

Explain:

The Risk Assessment is comparable to that described in Alternative 1, except there would be a slightly increased probability of accident in Alternative 2 in years 3-5 corresponding to increase in flight operations, and a decrease in probability in years 6-10 assuming completion of those operations.

Summary Ratings for Alternative 2

Wilderness Character	
Untrammeled	0
Undeveloped	0
Natural	+1
Solitude or Primitive & Unconfined Recreation	0
Other Features of Value	0
Wilderness Character Summary Rating	**+1**

Traditional Skills	
Traditional Skills	+1

Economics	
Cost	$282,550 (56,510/yr)

Safety	
Risk Assessment	3

Minimum Requirements Analysis Step 2: Alternatives

Alternative 3: No Action (current condition)

Description of the Alternative
What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

IDFG would continue conducting aerial surveys for elk in the Middle Fork Zone once every 5-10 years. An aerial elk survey involves approximately 80 flight hours over an approximately 3-week period. IDFG would monitor elk radiocollared outside of wilderness areas that move into the FC-RONRW via satellite data download or overflight. Personnel would retrieve dropped collars and collars associated with mortalities on foot or using pack stock via public/state/private state airstrips as appropriate.

Disadvantages

This alternative fails to adequately address needs. Under this alternative, IDFG has been unsuccessful in locating and obtaining meaningful data regarding annual elk survival, cause of mortality, and predator-prey relationships in the FC-RONRW.

Data collected from aerial elk monitoring and hunter participation surveys will not provide sufficient data for IDFG to develop and calibrate an integrated population model (IPM) to support management decisions in the FC-RONRW. Although Alternative 3 obtains population estimates, it does not provide data as to causes of mortality, predator-prey relationships, and the underlying causes of changes in the elk population.

Without more accurate demographic data and vital statistics for elk in the FC-RONRW, IDFG would not be able to determine whether it has established appropriate and sustainable harvest regulation and other management actions for the FC-RONRW. Wilderness character could be negatively affected by management decisions made without additional data. Backcountry hunting, an important and historic component of the primitive and unconfined recreation character of the FC-RONRW, could remain at less than target levels, with potential for additional decline.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
1	Transportation of personnel and equipment to the project site	N/A
2	Monitoring technique(s)	IDFG would conduct aerial overflight surveys every 5-10 years for elk.
3	Equipment used and transportation of personnel while monitoring	IDFG would monitor elk via aerial overflight surveys using fixed wing aircraft and/or helicopters (without landings). IDFG would monitor elk that are radiocollared outside of wilderness areas and move into the FC-RONRW via satellite or aircraft. Dropped collars and collars associated with mortalities in the FC-RONRW would be retrieved by crews on foot or using pack stock, with use of public/state/private airstrips as appropriate.
4	Staging and lodging	N/A
5	Condition of the site after the project	No change over the current condition. IDFG would not obtain the information needed to ensure wildlife management is consistent with actual elk demographics.
6	Length of project	Indefinite

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	0	NE
Untrammeled Total Rating		**0**		

Explain:

During aerial surveys each group of elk encountered must be moved by the aircraft to obtain the correct viewing angle for age classification. However, IDFG has used aircraft for elk/deer/bighorn sheep surveys/monitoring for decades, predating wilderness designation.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	0	NE
Undeveloped Total Rating		**0**		

Explain:
See prior discussion regarding baseline of aircraft use. Aerial surveys would be used to monitor elk, and this technique would not include any additional development.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☒	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	-1	NE
Natural Total Rating		**-1**		

Explain:
The continued implementation of monitoring techniques other than radiocollaring would not impact the natural character of the wilderness area; ecological processes would not be affected by the monitoring techniques. However, if IDFG is not be able to obtain the full set of data needed to make

informed harvest regulation and other management decisions, IDFG's decisions could inadvertently negatively affect natural character by altering population numbers, species distributions, and predator-prey dynamics. Collected data would not contribute to our understanding of the ecology of the FC-RONRW and would not enhance our knowledge of predator-prey relationships.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒
2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☐	☐	☒
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☒	☐
6	Length of project	N/A	N/A	N/A
Total Number of Effects		0	-1	NE
Solitude or Primitive & Unconfined Rec. Total Rating		**-1**		

Explain:

Aerial overflights could disturb visitors and negatively affect the solitude of wilderness experiences. However, impacts would be expected to be similar to those already occurring and predating wilderness designation.

Backcountry hunting and other elk-related recreation is an important and historic form of primitive and unconfined recreation in the FC-RONRW. Under this alternative, IDFG would not be able to obtain accurate demographic data and vital statistics for elk and would not be able to determine whether it is taking appropriate wildlife management actions, including establishing appropriate and sustainable harvest regulations for the FC-RONRW. Opportunities for primitive and unconfined recreation could be negatively affected by management decisions pertaining to consumptive uses.

OTHER FEATURES OF VALUE

Explain: The project would have no effect on other features of value.

Traditional Skills
What is the effect of each component activity on traditional skills?

TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
1	Transportation of personnel and equipment to the project site	☐	☐	☒

2	Monitoring technique(s)	☐	☐	☒
3	Equipment used and transportation of personnel while monitoring	☒	☐	☐
4	Staging and lodging	☐	☐	☒
5	Condition of the site after the project	☐	☐	☒
6	Length of project	N/A	N/A	N/A
Total Number of Effects		+1	0	NE
Traditional Skills Total Rating		**+1**		

Explain:

Personnel may use traditional skills during collar retrieval; personnel would be flown into the nearest public/State/private airstrip and then access the site on foot. IDFG expects the probability of use of traditional skills to be less under this alternative where the likelihood of collar retrieval from elk collared only outside the FC-RONRW would be less.

Economics

What is the estimated cost of each component activity?

COST

Component Activity for this Alternative		Estimated Cost
1	Transportation of personnel and equipment to the project site	$6,000
2	Monitoring technique(s)	$113,500
3	Equipment used and transportation of personnel while monitoring	(incorporated above)
4	Staging and lodging	N/A
5	Condition of the site after the project	N/A
6	Length of project	N/A
Total Estimated Cost		**$119,500/year flown**

Explain:

Only an annual estimate of the cost incurred in those years in which a survey is conducted was provided for this alternative because the project does not have an end date. The estimation includes only helicopter rental, additional personnel for other monitoring methods, and transport to existing airstrips. The estimate does not include permanent personnel time or per diem. The cost estimates do not reflect change in monetary value over time.

Safety of Visitors & Workers
What is the risk of this alternative to the safety of visitors and workers? What mitigation measures will be taken?

RISK ASSESSMENT	Probability of Accident				
Severity of Accident	Frequent	Likely	Common	Unlikely	Rare
Catastrophic: Death or permanent disability	1 ☐	1 ☐	2 ☐	2 ☐	3 ☒
Critical: Permanent partial disability or temporary total disability	1 ☐	2 ☐	2 ☐	3 ☐	4 ☒
Marginal: Compensable injury or illness, treatment, lost work	2 ☐	3 ☐	3 ☐	4 ☐	4 ☒
Negligible: Superficial injury or illness, first aid only, no lost work	3 ☐	4 ☐	4 ☐	4 ☒	4 ☐
Risk Assessment	**4**				

Risk Assessment Code

1 = Extremely High Risk	**2 = High Risk**	**3 = Moderate Risk**	**4 = Low Risk**

Explain:

Risks to personnel retrieving radiocollars in the FC-RONRW may involve slips, trips, and falls and other safety risks commonly associated with hiking, camping, and associated inclement weather. Although unlikely, injuries could result in lost work (e.g., a broken arm). Because this alternative involves the retrieval of radiocollars only when animals radiocollared outside the FC-RONRW drop a collar or indicate mortality inside the FC-RONRW, IDFG expects retrieval activities to occur in the FC-RONRW less frequently than in the other two alternatives, with corresponding reduction in the probability of accident.

Summary Ratings for Alternative 3

Wilderness Character	
Untrammeled	0
Undeveloped	0
Natural	-1
Solitude or Primitive & Unconfined Recreation	-1
Other Features of Value	0
Wilderness Character Summary Rating	**-2**

Traditional Skills	
Traditional Skills	+1

Economics	
Cost	$119,500/yr flown (once every 5 yrs)

Safety	
Risk Assessment	4

Minimum Requirements Analysis Step 2: Alternatives Not Analyzed

Alternatives Not Analyzed
What alternatives were considered but not analyzed? Why were they not analyzed?

IDFG also considered the following alternatives but dismissed them from further display or analysis:

A 5-year intense radio-collaring effort in conjunction with annual aerial surveys/ground-based techniques

Use of ground-based remote cameras and aerial infrared applications for estimating elk populations are unproven techniques. The additional amount of aerial survey involved in this alternative would be infeasible from a scheduling and logistical standpoint given other statewide needs; annual aerial surveys would involve 80 flight hours over an approximately 3-week period each year (in contrast to the current frequency of every 5 to 10 years).

Techniques that Require Baiting

Capture methods involving baiting animals were not analyzed. Such methods include corral and clover traps for elk. These options could potentially adversely affect natural character if animals were to become habituated to the bait sites or alter their distributions in response to the bait. Prolonged baiting may influence elk survival and invalidate the purpose of the capture. Because baiting takes more time than darting or netgunning, it would cause prolonged disruption to animals.

Techniques that Require Herding

Capture methods involving herding animals into traps, such as drive nets, were not analyzed. Herding is more disruptive to animal groups than aerial darting. Distribution of sampled elk would be limited to within one mile of existing airstrips in open habitat and would not provide a representative sample for survival estimates. IDFG uses one mile as the upper limit that elk may be herded to a drive net to avoid adverse animal health impacts.

Ground Darting

Alternatives that include ground darting were not analyzed. Shooting a dart from a dart gun is different than shooting a rifle. A dart moves slowly and has a more arching trajectory. To be effective using a dart gun, the shooter needs to be no more than 40 yards from a target animal. This technique is unlikely to be successful on open winter range, and would result in disturbance over a considerably longer time period to a group of animals during attempts to approach them. In addition, the limitations of cross-country travel and other ground conditions make darting the appropriate number of animals over a representative geographic area infeasible.

Smaller Sample Size

IDFG needs data regarding a variety of population demographic information for elk (*e.g.,* abundance, distribution, trend, survival, mortality, etc.) to evaluate predator-prey relationships. Developing estimates for demographic information requires IDFG to follow established scientific

protocols, including adequate sampling and measurement techniques. IDFG has determined that statistically valid monitoring requires at least 30 elk calves and 60 adult females. Lesser numbers of animals would not provide sufficient data to estimate adult and calf survival rates. IDFG anticipates approximately 50% of calves will be lost between January and June due to weather, animal condition, and predation. It is necessary to collar enough calves to accurately determine mortality and survival rates as well as to determine causes of mortality. The survival rate for adult female elk is generally higher than for calves, and therefore more adult animals need to be included in the sample to attain comparable precision in survival estimates. Even if the number of radio-tagged elk could be reduced, IDFG would still consider use of helicopters as the least disruptive, most cost-effective alternative to accomplish the work.

Limit Locations of Helicopter Landings

An alternative that would limit IDFG's radiocollaring activities to the vicinity of public/state/private airstrips was not analyzed. Most elk do not winter near airstrips, which tend to be situated at the wrong aspect and elevation to support overwintering animals. Airstrips are not broadly distributed in the Middle Fork Zone and would not provide needed geographic representation across subunits. Without adequate geographic representation of the Zone, IDFG would still lack data needed to inform and calibrate its model to support harvest and other management decisions. Decisions made without such data could still negatively affect wilderness character.

Radio Collar Animals Only Outside Wilderness

See discussion regarding *Options Outside of Wilderness* at pages 3-5.

Minimum Requirements Analysis Step 2: Alternative Comparison

Alternative 1:	IDFG Planned Action (10-year radiocollaring)
Alternative 2:	5 year intensive survival estimation with radio collars
Alternative 3:	No Action (current condition)

Wilderness Character	Alternative 1		Alternative 2		Alternative 3	
	+	-	+	-	+	-
Untrammeled	+1	-1	+1	-1	0	0
Undeveloped	0	0	0	0	0	0
Natural	+1	0	+1	0	0	-1
Solitude/Primitive/Unconfined	+1	-1	+1	-1	0	-1
Other Features of Value	0	0	0	0	0	0
Total Number of Effects	+3	-2	+3	-2	0	-2
Wilderness Character Rating	**+1**		**+1**		**-2**	
Traditional Skills	Alternative 1		Alternative 2		Alternative 3	
	+	-	+	-	+	-
Traditional Skills	+1	0	+1	0	+1	0
Traditional Skills Rating	**+1**		**+1**		**+1**	
Economics	Alternative 1		Alternative 2		Alternative 3	
Cost	**$392,100 ($39,210/yr)**		**$282,550 ($56,510/yr)**		**$119,500/yr flown (once every 5 yrs)**	
Safety of Visitors & Workers	Alternative 1		Alternative 2		Alternative 3	
Risk Assessment	**3**		**3**		**4**	

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Ex328

Special Section on Mountain Sheep Management

Pneumonia in Bighorn Sheep: Risk and Resilience

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ABSTRACT Infectious disease contributed to historical declines and extirpations of bighorn sheep (*Ovis canadensis*) in North America and continues to impede population restoration and management. Reports of pneumonia outbreaks in free-ranging bighorn sheep following contact with domestic sheep have been validated by the results of 13 captive commingling experiments. However, ecological and etiological complexities still hinder our understanding and control of respiratory disease in wild sheep. In this paper, we review the literature and summarize recent data to present an overview of the biology and management of pneumonia in bighorn sheep. Many factors contribute to this population-limiting disease, but a bacterium (*Mycoplasma ovipneumoniae*) host-specific to Caprinae and commonly carried by healthy domestic sheep and goats, appears to be a primary agent necessary for initiating epizootics. All-age epizootics are usually associated with significant population declines, but mortality rates vary widely and factors influencing disease severity are not well understood. Once introduced, *M. ovipneumoniae* can persist in bighorn sheep populations for decades. Carrier females may transmit the pathogen to their susceptible lambs, triggering fatal pneumonia outbreaks in nursery groups, which limit recruitment and slow or prevent population recovery. The demographic costs of disease persistence can be equal to or greater than the impacts of the initial epizootic. Strain typing suggests that spillover of *M. ovipneumoniae* into bighorn sheep populations from domestic small ruminants is ongoing and that consequences of spillover are amplified by movements of infected bighorn sheep across populations. Therefore, current disease management strategies focus on reducing risk of spillover from reservoir populations of domestic sheep and goats and on limiting transmission among bighorn sheep. A variety of techniques are employed to prevent contacts that could lead to transmission, including limiting the numbers and distribution of both wild and domestic species. No vaccine or antibiotic treatment has controlled infection in domestic or wild sheep and to date, management actions have been unsuccessful at reducing morbidity, mortality, or disease spread once a bighorn sheep population has been exposed. More effective strategies are needed to prevent pathogen introduction, induce disease fadeout in persistently infected populations, and promote population resilience across the diverse landscapes bighorn sheep inhabit. A comprehensive examination of disease dynamics across populations could help elucidate how disease sometimes fades out naturally and whether population resilience can be increased in the face of infection. Cross-jurisdictional adaptive management experiments and transdisciplinary collaboration, including partnerships with members of the domestic sheep and goat community, are needed to speed progress toward sustainable solutions to protect and restore bighorn sheep populations. © 2017 The Wildlife Society.

KEY WORDS bighorn sheep, domestic goats, domestic sheep, *Ovis canadensis*, respiratory disease, spillover, wildlife-livestock interface.

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Infectious disease has influenced bighorn sheep (*Ovis canadensis*) population dynamics at least since the westward expansion of the United States, and plausibly since the Spanish colonization of Mexico and the American Southwest. The importance of disease in the historical decline and extirpation of bighorn sheep across much of their range from southern Canada to Mexico is unique among North American ungulates. Early naturalists described catastrophic die-offs and suggested that disease outbreaks and disappearance of wild sheep might be attributed to the introduction of domestic sheep and goats into bighorn sheep range (Brooks 1923, Grinnell 1928). Shillinger (1937) reported on an experiment in which Rocky Mountain bighorn sheep (*O. c. canadensis*), after surviving well in captivity by themselves, all died when healthy-appearing domestic sheep were introduced to the enclosure. Shillinger speculated "The only evident explanation is that some infectious organism well tolerated by the domestic sheep. . .was transferred to the wild animals with disastrous results" (Shillinger 1937:301). Since then, many more disastrous disease outbreaks have occurred in free-ranging wild sheep populations and another 12 domestic-wild sheep commingling experiments have been conducted with similar deadly results for bighorn sheep (Wehausen et al. 2011, Besser et al. 2012*a*). Together these observations have culminated in the recognition that management of bighorn sheep also involves management of pathogen transmission from domestic sheep (Council for Agricultural Science and Technology 2008, Western Association of Fish and Wildife Agencies Wild Sheep Working Group 2012, The Wildlife Society 2015).

The susceptibility of bighorn sheep to infectious agents carried by domestic sheep is not unexpected given that genetic similarity with domestic hosts is a key risk factor for pathogen spillover and associated disease-induced population declines in wildlife (Pedersen et al. 2007). The bighorn sheep is the only North American ungulate with a congeneric domesticated relative. Although species divergence occurred over a million years ago (Rezaei et al. 2010), domestic and bighorn sheep are still sufficiently similar that they can interbreed and produce viable offspring (Young and Manville 1960). Bighorn and domestic sheep and goats share lineages of immune-associated genes in the major histocompatibility complex (Gutierrez-Espeleta et al. 2001), but inherent differences in immune systems likely contribute to the disparity in effects of pathogens across species (Silflow et al. 1989, Dassanayake et al. 2009, Highland et al. 2016).

Understanding and acknowledging the importance of pathogen spillover from domestic sheep and goats has provided valuable perspective and direction for management of respiratory disease in bighorn sheep and, at the same time, has complicated it. Wildlife biologists managing bighorn sheep are now faced with an uncomfortable choice between promoting connectivity and gene flow to restore remnant populations and increasing fragmentation and limiting dispersal to reduce the risk of pathogen spillover and transmission. The impact of disease persistence in the aftermath of all-age epizootics is also a serious obstacle to population management. In this paper, we review the literature and include a synthesis of data from our respective jurisdictions and from members of the Western Association of Fish and Wildlife Agencies Wild Sheep Working Group to provide an overview of the current state of knowledge about pneumonia in bighorn sheep. We report on impacts to individuals and populations, describe current management directions, and discuss potential strategies for moving forward.

CAUSES OF PNEUMONIA IN BIGHORN SHEEP

Pneumonia in bighorn sheep is a microbiologically complex disease, and many diverse bacteria are detected in the lungs of fatally affected animals, including pathogens that cause pneumonia and other diseases in livestock such as *Mannheimia haemolytica*, *Pasteurella multocida*, and *Fusobacterium necrophorum.* Some of these pathogens are toxigenic and lethal to captive bighorn sheep in experimental trials (Foreyt et al. 1994, Dassanayake et al. 2009), but they do not exhibit a clear and consistent association with disease epizootics in free-ranging populations (Singer et al. 2000*b*, Weiser et al. 2003, Rudolph et al. 2007, Besser et al. 2012*b*, Shanthalingam et al. 2016). Over time, paradigms of disease etiology have shifted, reflecting the diversity of pathogens and nonpathogenic agents detected in the lungs of pneumonic bighorn sheep. Suspected causes have ranged from lungworm infection (*Protostrongylus* spp.) to leukotoxin positive Pasteurellaceae, to a multi-factorial respiratory disease complex (Besser et al. 2013). Much attention has focused on virulent Pasteurellaceae bacteria where problems with accurate detection and classification have also complicated efforts to establish an association with pneumonia outbreaks in wild sheep (Angen et al. 2002, Walsh et al. 2012, Miller et al. 2013, Shanthalingam et al. 2014, Walsh et al. 2016).

In 2006, by applying culture-independent methods to high-quality samples of the lung microbiome obtained from free-ranging bighorn lambs in early stages of disease, researchers discovered that *Mycoplasma ovipneumoniae* was the pathogen that first invaded the lungs and predisposed affected animals to polymicrobial pneumonia (Besser et al. 2008). This pathogen does not act alone but appears to be a necessary agent for initiating epizootics. Further research is needed on the role of co-infection by known and perhaps as yet unrecognized pathogens as well as other factors that may contribute to disease outcomes by affecting transmission, carriage, and immunity (Dassanayake et al. 2010, Besser et al. 2012*b*, Fox et al. 2015, Wolff et al. 2016). Clarity on the significance of these interactions will help provide a more complete understanding of the variation observed in the course of infection and disease. We focus our discussion of microbial etiology on *M. ovipneumoniae* because, based on the experimental and empirical data which we review here, it currently presents the most parsimonious and well-supported model for a primary agent of bighorn sheep respiratory disease. For this reason it is also an important focus for management.

M. ovipneumoniae better meets Hill's (1965) causal criteria relevant to infectious diseases: strength of association,

temporality, plausibility, experimental evidence, and analogy than any competing proposed etiology (Besser et al. 2013). *M. ovipneumoniae* also fulfills Koch's postulates (Evans 1976, Walker et al. 2006) for a primary causal agent, with minor modifications. The strong association with disease (i.e., Koch's first postulate) is one of the most convincing lines of evidence for *M. ovipneumoniae*. Besser et al. (2013) detected *M. ovipneumoniae* in all free-ranging bighorn sheep populations affected by pneumonia epizootics where samples were available for testing ($n = 36$) and 91% (29/32) of bighorn sheep populations unaffected by pneumonia lacked evidence of exposure. Pneumonia outbreaks were associated with introduction of *M. ovipneumoniae* in $\geq$10 previously unexposed free-ranging bighorn sheep populations where testing was done before and after the epizootic (Besser et al. 2008, Bernatowicz et al. 2016; M. Cox, Nevada Department of Wildlife, unpublished data; J. Kanta, South Dakota Game, Fish, and Parks, unpublished data; J. Shannon, Utah Division of Wildlife, unpublished data; L. Jones, U.S. Fish and Wildlife Service, unpublished data). Limited information also suggests that free-ranging Dall's sheep (*Ovis dalli*) in Alaska and bighorn sheep populations in northern Alberta where bacterial pneumonia epizootics are not reported, have not been exposed to *M. ovipneumoniae* (Zarnke and Soren 1989, Besser et al. 2013).

Equally compelling, in 2 recent experiments 5 of 6 bighorn sheep survived when commingled with domestic sheep in the absence of *M. ovipneumoniae* (Besser et al. 2012*a*, Kugadas 2014). In contrast, virtually no (2%) bighorn sheep survived in 12 previous commingling experiments with domestic sheep, including only 1 of 26 in 4 experiments where presence of *M. ovipneumoniae* was reported or could be confirmed retrospectively (Foreyt and Jessup 1982; Foreyt 1989, 1990; Lawrence et al. 2010; Table S1, available online in Supporting Information).

Although Koch's second postulate (i.e., isolation of the agent in pure culture; Walker et al. 2006) has been repeatedly fulfilled, the ability of those cultures to reproduce the disease in healthy bighorn sheep (i.e., Koch's third postulate) is limited, perhaps because of virulence attenuation during cultural passage (Gilmour et al. 1979, Niang et al. 1998*a*, Besser et al. 2008). However, nasal washes from *M. ovipneumoniae*-colonized domestic sheep, treated to remove any detectable viable bacterial species other than *Mycoplasma*, do reproduce the disease in healthy bighorn sheep and the challenge strain of *M. ovipneumoniae* can be recovered from the pneumonic lungs of the affected animals, thereby fulfilling postulate 4 (i.e., re-isolation of the originally inoculated pathogen; Besser et al. 2014).

Many *Mycoplasma* spp. are host-specific, and the host range of *M. ovipneumoniae* is considered to be limited to Caprinae (Nicholas et al. 2008). Respiratory disease following infection with *M. ovipneumoniae* also has been reported in captive Dall's sheep and other wild Caprinae, including mountain goats (*Oreamnos americanus*), and muskox (*Ovibos moschatus*; Black et al. 1988, Handeland et al. 2014, Wolff et al. 2014). In a recent National Animal Health Monitoring System survey, Sheep 2011, the Animal and Plant Health Inspection Service tested up to 16 adult females each in 453 randomly selected domestic sheep flocks from across the United States for *M. ovipneumoniae* nasal carriage and serum antibody. Most flocks (88%) tested positive for carriage (as determined by polymerase chain reaction [PCR] on nasal swabs). Larger operations were more likely to be PCR positive and all flocks with $\geq$500 adult females were PCR positive (USDA Aphis Veterinary Services 2015). Less extensive surveys of domestic goats reported 37.5–88% of flocks to be PCR positive on nasal swabs. Larger flocks were more likely to be positive for carriage (Heinse et al. 2016; Table S2, available online in Supporting Information). A host-specific pathogen commonly carried by domestic sheep and goats is consistent with the high mortality observed in captive bighorn sheep when commingled with domestic sheep but not when commingled with non-Caprinae livestock including cattle, horses, and llamas (Foreyt 1992, Foreyt and Lagerquist 1996, Besser et al. 2012*a*).

Additional evidence for *M. ovipneumoniae* as an epidemic agent is the transmission of 1 (or occasionally 2) multi-locus sequence types (strains) within an outbreak and a diversity of strains across outbreaks (Besser et al. 2012*b*, Cassirer et al. 2017). These strains of *M. ovipneumoniae* also link the all-age epizootics to the recurrent lamb pneumonia epizootics that follow (Cassirer et al. 2017). Strains detected in domestic sheep differ from those detected in domestic goats, suggesting host adaptation and coevolution within old world Caprinae (Maksimović et al. 2017). This divergence also provides a means for inferring the host species of origin.

CHARACTERISTICS OF RESPIRATORY DISEASE IN INDIVIDUALS

The diverse histopathologic lesions observed in experimental and naturally occurring bighorn sheep pneumonia, range from those typical of *Mycoplasma* infections (lymphocytic cuffing around airways and hypertrophy of the bronchial respiratory epithelium) to the often more dramatic and severe hemorrhagic, edematous, and necrotic lesions resulting from secondary bacterial infections (Miller 2001, Besser et al. 2008, Wood et al. 2017). This polymicrobial pneumonia is thought to occur when *M. ovipneumoniae* binds to and degrades the cilia of the trachea and bronchi, resulting in disruption of the mucociliary escalator (Niang et al. 1998*c*), the physiologic process for clearing bacteria from the lower respiratory tract. The impaired host immune defenses then allow inhaled opportunistic pathogens to establish multiple simultaneous infections of lung tissues with often fatal results.

The clinical course of bighorn sheep pneumonia may appear dramatic and short, but evidence from naturally occurring and experimental infection indicates that subclinical disease exists for several days to several weeks prior to development of obvious symptoms (Besser et al. 2008, Besser et al. 2014, Cassirer et al. 2017). This delay presumably represents the time required for *M. ovipneumoniae* to infect the airways and disrupt the mucociliary escalator. The latent period has important implications for management because animals might appear healthy for several weeks following

infection. By the time disease is evident, *M. ovipneumoniae* and other pneumonia pathogens already could be widespread in the population, even in individuals that still look healthy.

The original focus of *M. ovipneumoniae* research was infection in domestic sheep and goats where it is documented as an important, and probably under-diagnosed, cause of pneumonia in lambs and kids (Lin et al. 2008, Rifatbegović et al. 2011). Differences in the disease across host species suggest potential focal areas for research that may reveal why the disease is so devastating in wild sheep (Table 1). Higher nasal carriage rates ($\chi^2_1 = 35.49$, $P < 0.001$) and lower antibody prevalence in domestic sheep ($\chi^2_1 = 33.78$, $P < 0.001$; Table 1, Table S2) are consistent with an evolved tolerance of *M. ovipneumoniae*, defined as the ability to shed high levels of a pathogen with minimal morbidity or mortality (Råberg et al. 2009). Bighorn sheep resist infection and react to *M. ovipneumoniae* exposure with dramatic humoral immune responses, which could reduce carriage (Table 1), but also might trigger an auto-immune reaction. Such a reaction has been described in domestic lambs that develop respiratory disease associated with *M. ovipneumoniae* infection (Niang et al. 1998*b*). Robust bighorn sheep immune responses may also contribute to their disease.

Although *M. ovipneumoniae* may be associated with early pneumonia in domestic lambs (Bottinelli et al. 2017), juvenile domestic sheep are usually resistant to *M. ovipneumoniae* prior to weaning. Lambs born in persistently infected flocks often become infected during their third month of life (Table S3, available online in Supporting Information). Bighorn lambs are apparently completely susceptible to infection from birth (Besser et al. 2013), despite the similar magnitude and timing of passive transfer of maternal immunity in both species (Herndon et al. 2011, Highland 2016). Passively transferred bighorn sheep antibodies might not protect from colonization or it could be that other forms of immunity are more important than the maternally transferred antibody-mediated immune response in defending the host from this pathogen (Plowright et al. 2013).

Table 1. Comparison of *M. ovipneumoniae* infection in domestic and bighorn sheep, USA, 1999–2016.

	Bighorn sheep	Domestic sheep
Infection outcome—naïve adults[a]	Bronchopneumonia	No disease
Infection outcome—lambs[a]	Bronchopneumonia 20–100% mortality	Coughing syndrome <2% mortality
Age of lambs at initial infection[a]	<1 week	Usually 8–12 weeks
Prevalence of carriage[b]	Low (median 22%)	High (median 56%)
Seroprevalence[c]	High (median 67%)	Low (median 30%)
Strain diversity within populations[d]	Usually 1	Usually many

[a] Alley et al. (1999); Besser et al. (2008, 2014); Cassirer et al. (2013); USDA (2011).
[b] Samples ($n = 1{,}267$) from 40 bighorn sheep populations in California, Idaho, Nevada, Oregon, Utah, and Washington and 47 domestic sheep flocks ($n = 2{,}508$ samples) in 13 states across the United States (USDA Aphis 2015).
[c] Samples ($n = 1{,}589$) from 42 bighorn sheep populations in California, Idaho, Nevada, Oregon, Utah, and Washington and 37 domestic sheep flocks ($n = 323$ samples) across the United States (USDA Aphis 2015).
[d] Parham et al. (2006), Cassirer et al. (2017).

Domestic sheep herds usually harbor multiple strains of *M. ovipneumoniae* simultaneously (Thirkell et al. 1990; Ionas et al. 1991*a*, *b*; Parham et al. 2006). Therefore, intensive sampling and strain typing are required to confirm or rule out individual flocks as a source of *M. ovipneumoniae* transmission to bighorn sheep populations. In contrast, 1 or occasionally 2 strains appear to predominate in bighorn sheep populations (Cassirer et al. 2017). Immune response to *M. ovipneumoniae* is apparently strain-specific in both species, but disease outcomes of cross-strain infection are more severe in bighorn sheep (Alley et al. 1999, Felts et al. 2016, Justice-Allen et al. 2016, Cassirer et al. 2017).

PNEUMONIA IN BIGHORN SHEEP POPULATIONS

Die-Off Events

Many, if not most, bighorn sheep populations in the lower 48 states have endured all-age pneumonia die-offs (Western Association of Fish and Wildife Agencies Wild Sheep Working Group 2012). These epizootics are the most obvious and dramatic manifestation of disease in bighorn sheep populations. During pneumonia outbreaks when animals are clinically ill, disease agents such as *M. ovipneumoniae* and Pasteurellaceae, usually transmitted through direct contact, may become airborne for short distances (Dixon et al. 2002, Besser et al. 2014). Pathogens can spread rapidly and expose nearly all individuals to infection (Bernatowicz et al. 2016, Ramsey et al. 2016, Cassirer et al. 2017). Severe, high mortality epizootics can ultimately cause extirpation or functional extinction of populations (Singer et al. 2000*b*); however, most pneumonia outbreaks do not kill entire populations. We estimated a median population decline of 48% (range = 5–100%) in 82 bighorn sheep disease events reported in 7 states and 2 provinces (Fig. 1, Table S4). Causes of the considerable divergence in mortality rates are not well understood but might be explained by heterogeneity in host immunity, pathogen virulence, and patterns of contact and transmission (Hobbs and Miller 1992).

We detected 28 different strains of *M. ovipneumoniae* in 45 bighorn sheep populations tested in 6 western states (Fig. 2B,C; Tables S5 and S6, available online in Supporting Information), each of which likely represents a separate spillover event that caused an all-age epizootic when first introduced. Domestic sheep and domestic goat *M. ovipneumoniae* lineages were both detected in bighorn sheep populations, but most strains detected in bighorn sheep fell within the domestic sheep clade (Kamath et al. 2016, Cassirer et al. 2017; Fig. 2C).

Clusters of the same strain in inter-connected populations, such as those along the border of Idaho, Oregon, and Washington in Hells Canyon, USA; in the Pancake Range

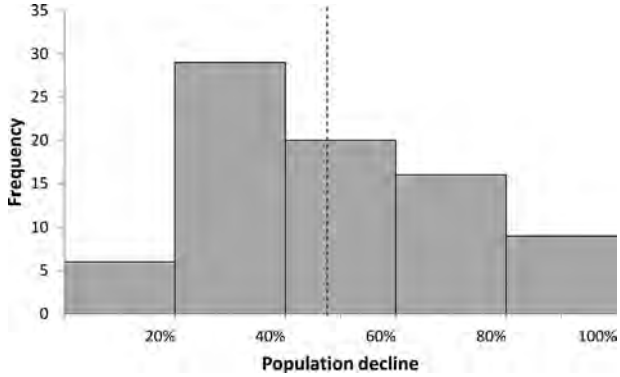

Figure 1. Population declines reported after pneumonia events in bighorn sheep populations in Alberta and British Columbia, Canada; and Idaho, Montana, Nebraska, Nevada, North Dakota, Oregon, Utah, and Washington, USA, 1978–2016. Dashed line represents median mortality of 48% in 82 pneumonia events. Data provided by state and provincial agencies and the Western Association of Fish and Wildlife Agencies Wild Sheep Working Group.

metapopulation of south-central Nevada, USA; and in the southern Nevada metapopulation (Fig. 2B), likely reflect a multiplier effect on a single spillover event when carrier bighorn sheep spread the pathogen across neighboring populations over time.

Multiple strains of *M. ovipneumoniae* observed within a single bighorn sheep population (Fig. 2B) often represent sequential pathogen invasion events. When a new strain is introduced into a population with ongoing infection, it may replace the existing strain or eventually fade out. Retrospective analysis in the intensively sampled Hells Canyon metapopulation demonstrated a pattern of sequential spillovers and strain replacement or fadeout (Cassirer et al. 2017). Additional data and genomic analyses will be useful for confirming relationships among strains within and between populations and for more rigorous modeling of the ancestral phylogeny and transmission dynamics.

Pathogen Persistence

In 6 states (i.e., California, Idaho, Nevada, Oregon, Utah, and Washington), 63% of 155 populations where infection status is known, have been exposed to *M. ovipneumoniae*, including most native (never extirpated) herds (Fig. 2A). Exposure, as determined by the presence of *M. ovipneumoniae*-specific antibodies, indicates that at least some members of the population have been infected during their lifetime. Exposure does not confirm ongoing shedding, but infection is often maintained in exposed populations by (generally) asymptomatic carriers (Plowright et al. 2016, Cassirer et al. 2017).

Persistently infected populations have a high likelihood of prolonged periods of disease in juveniles and occasionally adults. High rates of pneumonia-induced lamb mortality (20–100%) between 4 and 14 weeks of age are common and reduce recruitment, limiting population growth or causing declines when combined with other mortality factors (Ryder et al. 1992, Enk et al. 2001, Smith et al. 2014, Smith et al. 2015). Some populations rebound (Coggins and Matthews

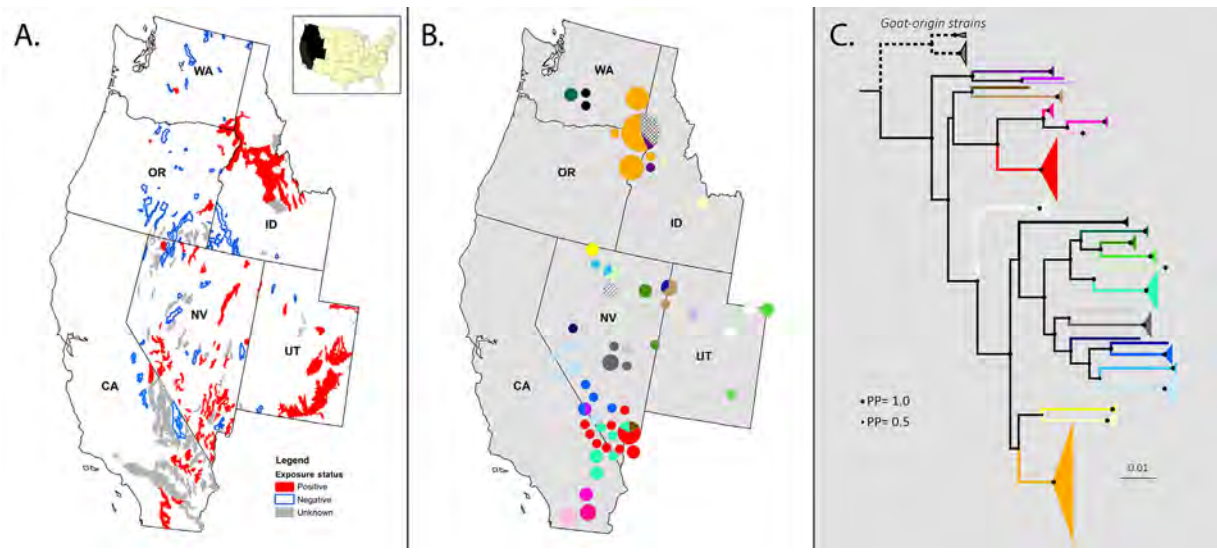

Figure 2. Exposure status and strain types of *Mycoplasma ovipneumoniae* detected in bighorn sheep populations in Washington, Oregon, Idaho, Utah, California, and Nevada, USA. A) Exposure of bighorn sheep populations to *M. ovipneumoniae*, 1999–2016. We assigned exposure based on results of blood serum samples ($n \geq 10$ from each population) submitted to the Washington Animal Disease and Diagnostic Laboratory for *M. ovipneumoniae*-specific serum antibody testing. Populations were classified as positive if antibodies were detected in at least one sample. Populations were classified as negative if no antibodies were detected from $\geq$15 samples. B) Spatial distribution of 28 *M. ovipneumoniae* genotypes (strains) obtained from bighorn sheep, 1984–2016. Each strain type is identified by a different color (domestic sheep origin, $n = 26$) or hatching (domestic goat origin, $n = 2$). Strains of the same color represent well-supported monophyletic clusters (posterior probability, PP > 0.95) with 99.7% to 100% sequence identity (as in panel C). In general, strains that are shades of the same colors are more closely related than strains of different colors. Pie charts indicate the proportional composition of strain types found at a given location over the entire time period of sampling. Chart size is relative to sample size. C) Bayesian majority rule consensus phylogeny of *M. ovipneumoniae* strains derived from bighorn sheep, with colors corresponding to strains shown in panel B. We based phylogenetic analyses on multilocus sequence typing data from 4 genetic loci (16S, IGS, *rpoB*, *gyrB*). Node support is reported as PP, with circle size relative to value (only PP > 0.60 shown). Scale bar indicates genetic distance in units of nucleotide substitutions per site. Dashed line represents the *M. ovipneumoniae* lineage derived from domestic goats.

1992, Jorgenson et al. 1997), but in others there is no trend towards recovery for decades (Manlove et al. 2016). In these cases, the demographic costs of pathogen persistence can outweigh the effects of the initial epizootic. Persistently infected populations also pose a disease risk for adjacent herds and, if they are used as source stock for translocations, moving carriers can inadvertently spread infection over long distances.

Chronically infected populations occasionally experience years with no evidence of disease in juveniles or adults. In approximately 20% of years following all-age disease epizootics in Hells Canyon, lamb survival was high and similar to that observed in unexposed populations (Cassirer et al. 2013). These sporadic disease fadeouts may be due to a delay or failure of *M. ovipneumoniae* transmission to susceptible lambs, as opposed to local pathogen extirpation, because pneumonia epizootics recur in subsequent years. A single or even several years with apparently healthy rates of lamb survival is not necessarily a harbinger of pathogen fadeout and population recovery (Manlove et al. 2016).

Social behavior likely plays an important role in determining the patterns of pneumonia epizootics and disease fadeout. Males are more likely to be directly associated with spillover and spread within and across populations during all-age outbreaks simply because they have larger home ranges and make more long distance movements (DeCesare and Pletscher 2006, O'Brien et al. 2014, Borg et al. 2016). However, dam-lamb and lamb-lamb interactions may be the most important routes of transmission in persistently infected populations (Manlove et al. 2017). Population substructure seems to protect some nursery groups from pathogens (Manlove et al. 2014) perhaps because no carrier dams are present. However, substructuring also might decouple contact rates and associated pathogen transmission from population size. If contact rates remain high as populations decline, transmission may never drop below the threshold required for pathogen extinction. This form of frequency-dependent transmission is common in social animals, and allows disease to persist at low population sizes. This can ultimately lead to host extirpation especially when combined with other stochastic events affecting small populations (de Castro and Bolker 2005).

MONITORING POPULATIONS FOR INFECTION AND DISEASE

All-age pneumonia epizootics are usually readily detected by observations of sick and dying sheep where populations are being actively monitored or are easily observed. However, low mortality outbreaks and epizootics in small and remote populations may be overlooked and underreported. Bighorn sheep also die from other diseases and not all sheep with clinical signs of respiratory disease (for example coughing) have pneumonia. Necropsy and laboratory testing are recommended when animals die from unknown causes, or when pneumonia is suspected. Pneumonia epizootics should be considered as a plausible cause when there is a sudden decline in a bighorn sheep population, particularly if followed by low recruitment.

Outside of all-age outbreaks, juvenile survival, particularly during the first 4 months of life, is the best demographic indicator of health status in bighorn sheep populations. Poor survival to weaning, (~4 months of age; Festa-Bianchet 1988), is the most sensitive signal of pneumonia-induced mortality in lambs. In Hells Canyon, there was a 100% probability of pneumonia being detected when survival to weaning was <50% (Cassirer et al. 2013, Manlove et al. 2016; Fig. 3A); however, this relationship might differ in areas with higher rates of non-disease-related neonatal mortality. Recruitment of juveniles as yearlings and population trend are less clear and specific metrics for classification of health status. Although most populations are stable or decline slowly during periods of persistent infection, pneumonia also might be present when lamb:female ratios at 9–12 months (recruitment) are ≤0.30 (Fig. 3A), even if populations are stable or slightly increasing (Fig. 3B, Table S7 available online in Supporting Information).

Diagnostic testing procedures for respiratory disease are continually changing as technology advances and knowledge of the disease and disease agents evolve. Comprehensive testing guidelines for wild sheep produced by the Western Association of Fish and Wildlife Agencies Wildlife Health Committee (2015) provide a good recent overview for a broad array of pathogens. Sampling for *M. ovipneumoniae* should be a part of any bighorn sheep health surveillance protocol and can also be used to monitor potential sources of domestic spillover. The most efficient diagnostic strategies for detection vary by host species and by infection stage. In acute infection (e.g., during all-age or lamb pneumonia epizootics in bighorn sheep, or in 8–16-week-old domestic lambs or kids in an enzootic flock), *M. ovipneumoniae* can be detected by PCR tests in a high proportion of animals' nasal swabs or pneumonic lung tissues. Infection status of domestic sheep and goat flocks is also best determined by PCR tests on nasal swabs. Given the high *M. ovipneumoniae* shedding prevalence in domestic sheep flocks (median 0.56; Table 1), PCR testing on swab samples from 10 adults should be sufficient (99% probability, binomial test) to detect whether *M. ovipneumoniae* is present. Repeated sampling is recommended to confirm negative status. In contrast, determining the exposure status of chronically infected bighorn sheep herds is most efficiently done by testing for serum antibodies, given the relatively high seroprevalence (median 0.67) and lower PCR prevalence in wild sheep (Table 1). Blood serum samples from 15 animals are generally adequate to determine exposure status if prevalence is ≥0.25 (99% probability, binomial test). If no antibodies are detected, the population can be considered unexposed, unless samples are collected recently after transmission, prior to immune response development. Nasal swabs from ≥18 animals should be adequate (85% probability) to detect shedding by PCR in bighorn sheep populations with *M. ovipneumoniae* prevalence of ≥0.10. Larger sample sizes may be required to account for non-detection error associated with field sampling and diagnostic testing (Walsh et al. 2016). Strain-type can be identified in PCR-positive samples. Nasal or sinus swabs can also be collected from

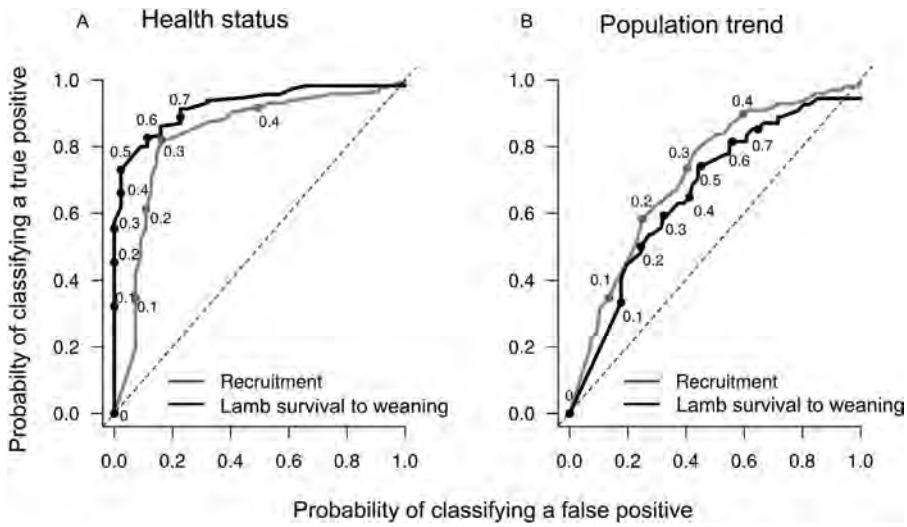

Figure 3. Receiver operating characteristic (ROC) curves identifying optimal lamb survival to weaning (black) and recruitment lamb:female ratios (gray) cut-off values for correctly classifying A) presence of pneumonia and B) declining population trend in bighorn sheep populations in Hells Canyon, Idaho, Oregon, and Washington, USA, 1997–2015 (Manlove et al. 2016). The *y* axis indicates sensitivity and the *x* axis indicates inverse specificity of lamb survival and recruitment values. A perfect predictor would have a value of 1 on the *y* axis and 0 on the *x* axis for a score of 1 AUC (area under curve). The dashed line represents values with no ability to predict categories (0.50 AUC). A) Lamb survival to weaning (AUC = 0.93) was an excellent predictor of health status and performed better than recruitment (AUC = 0.84). B) Recruitment (AUC = 0.72) was a better predictor of population trend than juvenile survival to weaning (AUC = 0.66). Optimal cut-off values for assigning presence of pneumonia were juvenile survival to weaning of <0.60 (84% accuracy) or recruitment of <0.30 lambs:female (82% accuracy). The optimal cut-off value for classifying populations as declining was recruitment of <0.20 lambs:female (69% accuracy).

fresh or frozen dead animals including heads of hunter-harvested bighorn sheep. Formalin-fixed paraffin-embedded pneumonic lung tissue blocks routinely archived by most diagnostic laboratories for histopathology also provide a DNA source for investigating historical presence and strain types of *M. ovipneumoniae* and other pathogens.

MANAGEMENT OF PNEUMONIA IN BIGHORN SHEEP

Wildlife managers and veterinarians have tried many techniques for controlling and mitigating respiratory disease in wild sheep populations, including administering antibiotics (Coggins 1988, Rudolph et al. 2007, McAdoo et al. 2010), vaccination (Cassirer et al. 2001, Sirochman et al. 2012), mineral supplementation (Coggins 2006, Sirochman et al. 2012), anthelmintic treatment (Miller et al. 2000, Goldstein et al. 2005), selective culling (Edwards et al. 2010, Bernatowicz et al. 2016, Ramsey et al. 2016), partial or complete depopulation (Cassirer et al. 1996, McFarlane and Aoude 2010, Bernatowicz et al. 2016), augmentation, and limiting population size and dispersal. The variety of methods employed, and the lack of clear successes, partially reflects past uncertainty over the causative agents and biological processes involved. The *ad hoc* nature of some of the treatments also limits broader inference. More rigorous testing of a broad ensemble of approaches for management is needed to account for the inherent challenges and variability associated with managing disease in free-ranging wildlife.

Large-scale pathogen eradication is rarely seen as a realistic goal (Klepac et al. 2013), particularly in the presence of a reservoir host, and indeed is not considered a viable option for wild sheep respiratory disease. Instead, more practical management objectives include controlling the spatial extent or prevalence of the pathogen, facilitating natural pathogen extinction, or reducing the demographic costs of infection (Wobeser 2002, Joseph et al. 2013). Attempts to manage bighorn sheep pneumonia fall broadly into 2 categories: 1) strategies that directly aim to reduce exposure and transmission such as preventing spillover, treatment with antibiotics, vaccination, targeted culling of shedders, reducing population size or density, and population eradication; and 2) strategies that aim to increase individual resistance or herd resilience, including improving nutritional condition, increasing genetic diversity, managing co-infection, or increasing or modifying spatial structuring. Some approaches (such as vaccination or density reduction) could conceivably have application in both categories.

Preventing exposure, theoretically and in practice, offers the most direct and effective method for disease control. Managing transmission is a component of disease prevention strategies for most zoonoses and other spillover diseases (Ebinger et al. 2011, Viana et al. 2014) including test and cull for brucellosis, oral vaccination for rabies, and reduction of deer density for tuberculosis (Rupprecht et al. 1986, Schmitt et al. 2002, Slate et al. 2005, Schumaker et al. 2012). However, managing transmission can be a long-term and costly endeavor. Promoting individual resistance and population resilience has theoretical and empirical support in a number of systems. In general, managing populations to maximize their individual- or herd-level resilience makes good sense (Stephen 2014). Whether increased resistance and resilience can offset the costs of an exotic pathogen like *M. ovipneumoniae*, which generally produces high mortality rates in non-adapted but otherwise robust hosts, remains to

be seen. Below, we discuss past performance and future potential of these management strategies in combating bighorn sheep pneumonia.

Preventing Spillover and Pathogen Invasion

State and federal natural resource agencies have widely instituted policies to prevent pathogen spillover by encouraging or requiring spatial separation between wild sheep and domestic sheep and goats (Western Association of Fish and Wildife Agencies Wild Sheep Working Group 2012, Bureau of Land Management 2016). Federal and state policies are informed by models, such as the USDA Forest Service's Bighorn Sheep Risk of Contact Tool (Woolever et al. 2015), which incorporate bighorn sheep space use, habitat preferences, foray probabilities, and demographics (Clifford et al. 2009, Cahn et al. 2011, Carpenter et al. 2014, O'Brien et al. 2014) to identify geographic locations with high risk of domestic-wild sheep contact. These models allow comparison of proposed management alternatives and assessment of population-level consequences for bighorn sheep. Resulting actions may take the form of closing or retiring public grazing allotments, altering their timing of use, trucking rather than trailing sheep between pastures, or changing grazing classification from domestic sheep or goats to other livestock (USDA Forest Service 2010, Bureau of Land Management 2017).

Other preventive management practices include capturing or culling escaped domestic sheep on bighorn sheep ranges and removing wild sheep observed near or commingling with domestics. Outreach efforts on private and public lands have encouraged landowner or public lands grazing permittee cooperation in double-fencing domestic sheep flocks in wild sheep habitat, using additional guard dogs, penning domestic sheep and goats at night, not turning sick sheep out to pasture, counting domestic sheep more frequently to better detect and gather strays, notifying local wildlife officials if wild sheep are observed near domestic sheep, and encouraging use of other best management practices (Western Association of Fish and Wildife Agencies Wild Sheep Working Group 2012).

We are unaware of any formal evaluation of the success of existing separation strategies in preventing new outbreaks, though the regular appearance of new *M. ovipneumoniae* strains in bighorn sheep herds suggests there is room for improvement. Nevertheless, cross-species contact mitigation efforts almost certainly play a crucial role in reducing pathogen invasion. More work is needed to assess the strengths and weaknesses of existing approaches and to devise new and better strategies for managing both domestic and wild sheep to reduce transmission risk. Efforts are currently underway to investigate the feasibility of developing and maintaining *M. ovipneumoniae*-free domestic flocks, which could help reduce the significant risk of pathogen transmission from small domestic sheep and goat herds on private lands (Sells et al. 2015, Heinse et al. 2016, Cassirer et al. 2017).

Another paradigmatic approach to preventing pathogen introduction is reducing density of wild sheep populations. Associative studies (Monello et al. 2001, Sells et al. 2015) report a positive relationship between wild sheep relative density (or population size) and risk of respiratory disease outbreaks. This relationship could mechanistically result from larger or higher density populations occupying a greater area and dispersing more widely or more often than smaller, lower density herds, with the consequence that increased density corresponds to increased contacts with neighboring domestic sheep or infected wild sheep herds (Monello et al. 2001). Evidence, however, for a density-dependent relationship in movements and dispersal in ungulates is limited and equivocal (Loison et al. 1999, Long et al. 2008) and pre-outbreak population sizes are often small (<50 to 200 animals) and do not differ from sizes of populations that remain healthy (Monello et al. 2001, Shannon et al. 2014).

Many reintroduced bighorn sheep populations experience robust or even exponential growth following initial establishment. When these populations are exposed to respiratory pathogens they often undergo die-offs followed by a prolonged period of low lamb recruitment, limiting recovery (Manlove et al. 2016). As a result, populations are often largest just prior to outbreaks, leading to a statistical, but not necessarily biological, association between population size and outbreak risk. The expected biological processes underlying a presumed density-dependent relationship are not evident, such as declining population growth rate or reduced juvenile recruitment (Jorgenson et al. 1997, Monello et al. 2001). Therefore, it is unknown whether reducing populations or keeping them small would actually mitigate risk, or whether disease outbreaks are simply associated with healthy, growing, and susceptible populations. Future work could pursue the underlying mechanisms directly and experimentally. Understanding the nature of observed associations of pneumonia and population size in bighorn sheep is needed to help minimize disease risk and maximize the number and distribution of wild sheep on the landscape.

Translocations have been widely and successfully used to increase the numbers, distribution, and genetic diversity of bighorn sheep populations (Singer et al. 2000*a*, Hogg et al. 2006, Olson et al. 2012). Translocations also present a clear risk for anthropogenically assisted pathogen introductions and opportunities for exposure at release sites (Cunningham 1996, Deem et al. 2001, Sainsbury and Vaughn-Higgins 2012, Aiello et al. 2014). Moving animals known to be positive for pneumonia pathogens into new ranges is risky (Western Association of Fish and Wildlife Agencies Wildlife Health Committee 2015). Mixing bighorn sheep from populations known to harbor pathogens with naïve animals, can and has, had poor results (Sandoval et al. 1987). Even if a pathogen is present in both source and recipient populations, immunity may not provide universal protection (Dassanayake et al. 2009, Cassirer et al. 2017). Most state, federal, and provincial agencies use health screenings to inform wild sheep translocation decisions. Careful matching of pathogen profiles, including relevant bacteria, viruses, and parasites in source, recipient, and adjacent bighorn sheep populations and selecting release sites with low risk of contact with domestic sheep and goats are important for translocation success. In practice, health surveys may be

conducted a year in advance at the herd level and with imperfect pathogen detection probabilities, resulting in uncertainty surrounding an individual's health status at the time of translocation. Furthermore, *M. ovipneumoniae* strain typing would not be expected to detect possible epitope variation resulting in immune escape, and health screenings are only as good as our knowledge of what to look for. Improved molecular-based approaches for detecting and describing pathogens and their associated virulence factors are needed. Development of rapid animal-side tests is in progress and, if successful, could also contribute to reducing disease risks posed by translocations.

Reducing Transmission During and Post-Epizootics

A number of agencies have attempted to manage active respiratory disease outbreaks. However, no management action, absent population eradication, has successfully stopped a pneumonia outbreak, and there is no evidence that any intervention has consistently reduced morbidity, mortality, or spread of disease. In part, this is due to the unplanned nature of outbreaks and the inability to randomly assign treatments and controls to matched populations to reliably test for an effect. Nevertheless, efforts to halt epizootics by administering antibiotic treatments (Sandoval et al. 1987, Coggins 1988, Rudolph et al. 2007, McAdoo et al. 2010), and by conducting random and selective culls (Cassirer et al. 1996, Edwards et al. 2010, Bernatowicz et al. 2016, Ramsey et al. 2016) have generally had mixed or negative results. In other wildlife species, depopulation has been successfully employed to prevent spread between populations, but culling zones or population segments to stop the spatial spread of epidemics have met with limited success (Wobeser 2002). Culling is rarely successful because by the time an epidemic is detectable, transmission is usually well under way; even if culling slows transmission, it is unlikely to stop it given imperfect detection of symptomatic animals, long infectious periods, ongoing contacts, and undetected animal movements within and between populations. Lack of success with antibiotics and vaccines administered during or after outbreaks may be a function of their low efficacy, targeting the wrong agent, or an inability to administer them appropriately in most free-ranging bighorn sheep populations.

Depopulation and reintroduction has occasionally been used in an attempt to manage small, particularly poorly performing herds struggling with persistent disease. Although this method may be effective when all members of the former herd are removed, significant effort is needed to ensure complete removal and that the ongoing risk of pathogen introduction is low. A current experimental management effort offering an alternative to depopulation of persistently affected populations exploits the relatively low shedding prevalence of *M. ovipneumoniae* in bighorn sheep by removing only chronic carrier females (Bernatowicz et al. 2016). The goal of this experiment is to stop the chain of transmission from dams to lambs and facilitate pathogen fade-out. If successful, this technique may be best applied to small, accessible populations, where extensive testing is feasible, and the stochastic mortality of chronic carriers may bolster an active selective removal. In general, test-and-cull success hinges on test sensitivity, animal handling opportunity, pathogen prevalence, and the duration over which management is implemented. Targeted removal works best when a few individuals are responsible for most of the transmission (Lloyd-Smith et al. 2005, Streicker et al. 2013) and may require complete eradication of these carriers. For example, although test-and-cull efforts to control brucellosis in elk (*Cervus canadensis*) successfully met goals of reducing local prevalence (Scurlock et al. 2010, Schumaker et al. 2012) they never eradicated the disease, and upon the program's cessation, prevalence rapidly increased (Wyoming Game and Fish Department 2016). Test-and-cull strategies would ideally be timed to coincide with the lowest-possible pathogen prevalence and the highest levels of immunity, although we currently do not know when those minima and maxima occur.

Managing for Resistance and Resilience

Managing disease by maximizing individual resistance or population resilience has received renewed interest, particularly in the face of continuing challenges associated with direct control of transmission. Theoretical and empirical work across humans, domestic animals, and wildlife suggests that manipulating physiological condition, genetics, or co-infection can alter rates of morbidity and mortality and reduce infection intensity, which may in turn feedback on population-level dynamics (Beldomenico and Begon 2010). However, several studies have found that tradeoffs often exist between enhancing disease resistance and controlling transmission. For example, increasing food supply can minimize parasite-induced mortality (Pedersen and Greives 2008) but may also facilitate transmission (Becker et al. 2015), managing co-infections can reduce morbidity and mortality but can also accelerate pathogen spread (Ezenwa and Jolles 2015), and metapopulation structure can enhance disease spread while simultaneously allowing higher numbers of hosts to survive (Hess 1996, McCallum and Dobson 2002).

There are numerous examples of management actions intended to bolster individual resistance and overall population performance in struggling bighorn sheep populations but little systematic evaluation as to their efficacy. For example, there is no clear evidence of a causal relationship between nutritional condition and susceptibility to respiratory disease in bighorn sheep. Certainly the many experiments in captivity show that optimally provisioned bighorn sheep still succumb at high rates upon exposure to respiratory pathogens. Disease resistance may be correlated with genetic diversity (Luikart et al. 2008, Savage and Zamudio 2011) and researchers continue to seek evidence of host genetic resistance to respiratory disease, which might be expected in herds that are demographically successful even in the presence of long-term pathogen persistence but, to date, a genetic basis has not been found for the susceptibility of wild sheep to pneumonia (Gutierrez-Espeleta et al. 2001, Boyce et al. 2011). Currently, multi-jurisdictional efforts are

underway to collect data on animal condition, genetics, and pathogens to better understand their interactions with wild sheep health.

At the population level, maximizing resilience might include promoting large, widely distributed, genetically diverse metapopulations with spatial structuring and a range of behaviors (de Castro and Bolker 2005, Hess 1996). Indeed, there is some evidence that larger wild sheep populations may experience lower rates of mortality during pneumonia epizootics and are more able to recover than their smaller counterparts (Singer et al. 2001, Cassaigne et al. 2010). Furthermore, increasing population substructure may create asynchrony in transmission across groups of animals. Although this may not prevent epizootics and could actually increase pathogen persistence at the herd or metapopulation level (Grenfell and Harwood 1997, Swinton et al. 1998, Park et al. 2002), it might buffer against simultaneous population-wide epizootics and facilitate stochastic pathogen extinction from sub-herd or population segments (Cross et al. 2005). More work is needed to determine whether or not spatial structuring shields bighorn sheep populations from the worst outcomes of disease and how population structure might affect disease persistence. Current efforts are underway on a limited basis to expedite formation of metapopulation structure by assisted colonization of adjacent range. These manipulations may be most applicable to large, healthy populations.

MANAGEMENT IMPLICATIONS

The extensive costs of pathogen introduction and transmission observed across a wide range of habitats and populations indicate that preventing spillover is the most pressing immediate priority for management of pneumonia in bighorn sheep. Collaboration by wildlife and livestock managers on research and in practice is needed to develop more effective, sustainable approaches to reduce ongoing pathogen transmission from domestic small ruminants to wild sheep. Transmission risks posed by moving bighorn sheep to expand populations are also recognized and should be mitigated before translocations are conducted. In the absence of spillover, selection on the host and the pathogen may eventually lead to a less destructive relationship between wild sheep and the bacteria involved in pneumonia. However, considerable theory suggests that evolution toward increased resistance or reduced virulence is not always expected (Alizon et al. 2009, Osnas et al. 2015). Effective tools are needed to actively restore persistently infected stagnant or declining populations. A comprehensive examination of disease dynamics across populations to better understand how recovery occurs naturally would be useful to inform management of pneumonia in exposed populations.

In the long-term, agencies will need better strategies for the management of larger interconnected bighorn sheep populations for species viability. Engaging a diversity of perspectives in the wildlife, domestic animal, and health sciences through an inter- or trans-disciplinary process could provide new directions or refine existing approaches for management of healthy, resilient populations (Choi and Pak 2007, Allen-Scott et al. 2015). Natural experiments and designed experiments conducted in an adaptive management framework can also accelerate learning about complex natural systems (Walters and Green 1997, Craig et al. 2012, Williams and Brown 2016). Interjurisdictional collaboration can greatly facilitate and, in many cases, is required for successful adaptive management. Replicated interventions with clear hypotheses, objectives, and defined expected outcomes accompanied by monitoring of treatments and controls could greatly advance understanding in the face of uncertainty and speed progress towards developing successful strategies for managing pneumonia in wild sheep.

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LITERATURE CITED

Aiello, C. M., K. E. Nussear, A. D. Walde, T. C. Esque, P. G. Emblidge, P. Sah, S. Bansal, and P. J. Hudson. 2014. Disease dynamics during wildlife translocations: disruptions to the host population and potential consequences for transmission in desert tortoise contact networks. Animal Conservation 17:27–39.

Alizon, S., A. Hurford, N. Mideo, and M. Van Baalen. 2009. Virulence evolution and the trade-off hypothesis: history, current state of affairs and the future. Journal of Evolutionary Biology 22:245–259.

Allen-Scott, L. K., B. Buntain, J. M. Hatfield, A. Meisser, and C. J. Thomas. 2015. Academic institutions and One Health: building capacity for transdisciplinary research approaches to address complex health issues at the Animal-Human-Ecosystem interface. Academic Medicine 90:866–871.

Alley, M. R., G. Ionas, and J. K. Clarke. 1999. Chronic non-progressive pneumonia of sheep in New Zealand—a review of the role of *Mycoplasma ovipneumoniae*. New Zealand Veterinary Journal 47:155–160.

Angen, O., P. Ahrens, and M. Bisgaard. 2002. Phenotypic and genotypic characterization of *Mannheimia* (*Pasteurella*) *haemolytica*-like strains isolated from diseased animals in Denmark. Veterinary Microbiology 84:103–114.

Becker, D. J., D. G. Streicker, and S. Altizer. 2015. Linking anthropogenic resources to wildlife-pathogen dynamics: a review and meta-analysis. Ecology Letters 18:483–495.

Beldomenico, P. M., and M. Begon. 2010. Disease spread, susceptibility and infection intensity: vicious circles? Trends in Ecology & Evolution 25: 21–27.

Bernatowicz, J., D. Bruning, E. F. Cassirer, R. B. Harris, K. Mansfield, and P. Wik. 2016. Management responses to pneumonia outbreaks in 3 Washington State bighorn herds: lessons learned and questions yet unanswered. Biennial Symposium Northern Wild Sheep and Goat Council 20:38–61.

Besser, T. E., E. F. Cassirer, M. A. Highland, P. Wolff, A. Justice-Allen, K. M. Mansfield, M. A. Davis, and W. J. Foreyt. 2013. Bighorn sheep pneumonia: sorting out the etiology of a polymicrobial disease. Journal of Preventive Veterinary Medicine 108:85–93.

Besser, T. E., E. F. Cassirer, K. A. Potter, K. Lahmers, J. L. Oaks, S. Shanthalingam, S. Srikumaran, and W. J. Foreyt. 2014. Epizootic pneumonia of bighorn sheep following experimental exposure to *Mycoplasma ovipneumoniae*. PLoS ONE 9:e110039.

Besser, T. E., E. F. Cassirer, K. A. Potter, J. VanderSchalie, A. Fischer, D. P. Knowles, D. R. Herndon, F. R. Rurangirwa, G. C. Weiser, and S. Srikumaran. 2008. Association of *Mycoplasma ovipneumoniae* infection with population-limiting respiratory disease in free-ranging Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Journal of Clinical Microbiology 46:423–430.

Besser, T. E., E. F. Cassirer, C. Yamada, K. A. Potter, C. N. Herndon, W. J. Foreyt, D. P. Knowles, and S. Srikumaran. 2012*a*. Survival of bighorn sheep (*Ovis canadensis*) commingled with domestic sheep (*Ovis aries*) in the absence of *Mycoplasma ovipneumoniae*. Journal of Wildlife Diseases 48:168–172.

Besser, T. E., M. A. Highland, K. Baker, E. F. Cassirer, N. J. Anderson, J. M. Ramsey, K. Mansfield, D. L. Bruning, P. Wolff, J. B. Smith, and J. A. Jenks. 2012*b*. Causes of pneumonia epizootics among bighorn sheep, Western United States, 2008-2010. Emerging Infectious Disease 18:406–414.

Black, S. R., I. K. Barker, K. G. Mehren, G. J. Crawshaw, S. Rosendal, L. Ruhnke, J. Thorsen, and P. S. Carman. 1988. An epizootic of *Mycoplasma ovipeumoniae* infection in captive Dall's sheep (*Ovis dalli dalli*). Journal of Wildlife Diseases 24:627–635.

Borg, N. J., M. S. Mitchell, P. M. Lukacs, C. M. Mack, L. P. Waits, and P. R. Krausman. 2016. Behavioral connectivity among bighorn sheep suggests potential for disease spread. Journal of Wildlife Management 81:38–45.

Bottinelli, M., C. Schnee, E. Lepri, V. Stefanetti, G. Filippini, M. Gobbi, M. Sebastianelli, P. Antenucci, E. Rampacci, M. Coletti, and F. Passamonti. 2017. Investigation on mycoplasma populations in pneumonic dairy lamb lungs using a DNA microarray assay. Small Ruminant Research 147:96–100.

Boyce, W. M., M. E. Weisenberger, M. C. Penedo, and C. K. Johnson. 2011. Wildlife translocation: the conservation implications of pathogen exposure and genetic heterozygosity. BMC Ecology 11:5

Brooks, A. 1923. The Rocky Mountain sheep in British Columbia. Canadian Field-Naturalist 37:23–25.

Bureau of Land Management. 2016. Management of domestic sheep and goats to sustain wild sheep. <https://d1cqrq366w3ike.cloudfront.net/http/DOCUMENT/SheepUSA/BLM%20Management%20of%20Domestic%20Sheep%20and%20Goats.pdf> . Accessed 14 May 2017.

Bureau of Land Management. 2017. Record of decision and approved amendment to Cottonwood Resource Management Plan for domestic sheep grazing. <https://eplanning.blm.gov/epl-front-office/projects/lup/36859/95304/115258/CottonwoodSheepAmendmentROD-508-011317.pdf >. Accessed 9 May 2017.

Cahn, M. L., M. M. Conner, O. J. Schmitz, T. R. Stephenson, J. D. Wehausen, and H. E. Johnson. 2011. Disease, population viability, and recovery of endangered Sierra Nevada bighorn sheep. Journal of Wildlife Management 75:1753–1766.

Carpenter, T. E., V. L. Coggins, C. McCarthy, C. S. O'Brien, J. M. O'Brien, and T. J. Schommer. 2014. A spatial risk assessment of bighorn sheep extirpation by grazing domestic sheep on public lands. Preventive Veterinary Medicine 114:3–10.

Cassaigne, I., R. A. Medellin, and J. A. Guasco. 2010. Mortality during epizootics in bighorn sheep: effects of intial population size and cause. Journal of Wildlife Diseases 46:763–771.

Cassirer, E. F., K. R. Manlove, R. K. Plowright, and T. E. Besser. 2017. Evidence for strain-specific immunity to pneumonia in bighorn sheep. Journal of Wildlife Management 81:133–143.

Cassirer, E. F., L. E. Oldenburg, V. L. Coggins, P. Fowler, K. M. Rudolph, D. L. Hunter, and W. J. Foreyt. 1996. Overview and preliminary analysis of a bighorn sheep dieoff, Hells Canyon 1995-96. Biennial Symposium Northern Wild Sheep and Goat Council 10:78–86.

Cassirer, E. F., R. K. Plowright, K. R. Manlove, P. C. Cross, A. P. Dobson, K. A. Potter, and P. J. Hudson. 2013. Spatio-temporal dynamics of pneumonia in bighorn sheep (*Ovis canadensis*). Journal of Animal Ecology 82:518–528.

Cassirer, E. F., K. M. Rudolph, P. Fowler, V. L. Coggins, D. L. Hunter, and M. W. Miller. 2001. Evaluation of ewe vaccination as a tool for increasing bighorn lamb survival following pasteurellosis epizootics. Journal of Wildlife Diseases 37:49–57.

Choi, B. C. K., and A. W. P. Pak. 2007. Multidisciplinarity, interdisciplinarity, and transdisciplinarity in health research, services, education and policy: 2. Promotors, barriers, and strategies of enhancement. Clinical and Investigative Medicine 30:E224–E232.

Clifford, D. L., B. A. Schumaker, T. R. Stephenson, V. C. Bleich, M. L. Cahn, B. J. Gonzales, W. M. Boyce, and J. A. K. Mazet. 2009. Assessing disease risk at the wildlife-livestock interface: a study of Sierra Nevada bighorn sheep. Biological Conservation 142:2559–2568.

Coggins, V. L. 1988. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. Biennial Symposium Northern Wild Sheep and Goat Council 6:57–64.

Coggins, V. L. 2006. Selenium supplementation, parasite treatment, and management of bighorn sheep at Lostine River, Oregon. Biennial Symposium Northern Wild Sheep and Goat Council 15:98–106.

Coggins, V. L., and P. E. Matthews. 1992. Lamb survival and herd status of the Lostine bighorn herd following a Pasteurella die-off. Biennial Symposium Northern Wild Sheep and Goat Council 8:147–154.

Council for Agricultural Science and Technology. 2008. Pasteurellosis transmission risks between domestic and wild sheep. CAST Commentary QTA2008-1, Ames, Iowa, USA.

Craig, P., C. Cooper, D. Gunnell, S. Haw, K. Lawson, S. Macintyre, D. Ogilvie, M. Petticrew, B. Reeves, M. Sutton, and S. Thompson. 2012. Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. Journal of Epidemiology and Community Health 66:1182–1186.

Cross, P. C., J. O. Lloyd-Smith, P. L. F. Johnson, and W. M. Getz. 2005. Duelling timescales of host movement and disease recovery determine invasion of disease in structured populations. Ecology Letters 8:587–595.

Cunningham, A. A. 1996. Disease risks of wildlife translocations. Conservation Biology 10:349–353.

Dassanayake, R. P., S. Shanthalingam, C. N. Herndon, P. K. Lawrence, E. F. Cassirer, K. A. Potter, W. J. Foreyt, K. D. Clinkenbeard, and S. Srikumaran. 2009. *Mannheimia haemolytica* serotype A1 exhibits differential pathogenicity in two related species, *Ovis canadensis and Ovis aries*. Veterinary Microbiology 133:366–371.

Dassanayake, R. P., S. Shanthalingam, C. N. Herndon, R. Subramaniam, P. K. Lawrence, J. Bavananthasivam, E. F. Cassirer, G. J. Haldorson, W. J. Foreyt, F. R. Rurangirwa, D. P. Knowles, T. E. Besser, and S. Srikumaran. 2010. *Mycoplasma ovipneumoniae* can predispose bighorn sheep to fatal *Mannheimia haemolytica* pneumonia. Veterinary Microbiology 145: 354–359.

de Castro, F., and B. Bolker. 2005. Mechanisms of disease-induced extinction. Ecology Letters 8:117–126.

DeCesare, N. J., and D. H. Pletscher. 2006. Movements, connectivity, and resource selection of Rocky Mountain bighorn sheep. Journal of Mammalogy 87:531–538.

Deem, S. L., W. B. Karesh, and W. Weisman. 2001. Putting theory into practice: wildlife health in conservation. Conservation Biology 15:1224–1233.

Dixon, D. M., K. M. Rudolph, M. L. Kinsel, L. M. Cowan, D. L. Hunter, and A. C. S. Ward. 2002. Viability of airborne *Pasteurella* Spp. Biennial Symposium Northern Wild Sheep and Goat Council 13:6–13.

Ebinger, M., P. Cross, R. Wallen, P. J. White, and J. Treanor. 2011. Simulating sterilization, vaccination, and test-and-remove as brucellosis control measures in bison. Ecological Applications 21:2944–2959.

Edwards, V. L., J. M. Ramsey, C. Jourdonnais, R. Vinkey, M. Thompson, N. Anderson, T. Carlsen, and C. Anderson. 2010. Situational agency response to four bighorn sheep die-offs in western Montana. Biennial Symposium Northern Wild Sheep and Goat Council 17:29–50.

Enk, T. A., H. D. Picton, and J. S. Williams. 2001. Factors limiting a bighorn sheep population in Montana following a dieoff. Northwest Science 75:280–291.

Evans, A. S. 1976. Causation and disease: the Henle-Koch postulates revisited. Yale Journal of Biology and Medicine 49:175–195.

Ezenwa, V. O., and A. E. Jolles. 2015. Opposite effects of anthelmintic treatment on microbial infection at individual versus population scales. Science 347:175–177.

Felts, B. L., D. P. Walsh, E. F. Cassirer, T. E. Besser, and J. A. Jenks. 2016. Mycoplasma ovipneumoniae cross-strain transmissions in captive bighorn sheep. Biennial Symposium Northern Wild Sheep and Goat Council 20:77–78.

Festa-Bianchet, M. 1988. Nursing behaviour of bighorn sheep: correlates of ewe age, parasitism, lamb age, birthdate and sex. Animal Behaviour 36:1445–1454.

Foreyt, W. J. 1989. Fatal *Pasteurella haemolytica* pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. American Journal of Veterinary Research 50:341–344.

Foreyt, W. J. 1990. Pneumonia in bighorn sheep: effects of *Pasteurella haemolytica* from domestic sheep and effects on survival and long-term reproduction. Biennial Symposium Northern Wild Sheep and Goat Council 7:92–101.

Foreyt, W. J. 1992. Experimental contact association between bighorn sheep, elk, and deer with known *Pasteurella haemolytica* infections. Biennial Symposium Northern Wild Sheep and Goat Council 8:213–218.

Foreyt, W. J., and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. Journal of Wildlife Diseases 18:163–168.

Foreyt, W. J., and J. E. Lagerquist. 1996. Experimental contact of bighorn sheep (*Ovis canadensis*) with horses and cattle, and comparison of neutrophil sensitivity to *Pasteurella haemolytica* cytotoxins. Journal of Wildlife Diseases 32:594–602.

Foreyt, W. J., K. P. Snipes, and R. W. Kasten. 1994. Fatal pneumonia following inoculation of healthy bighorn sheep with Pasteurella haemolytica from healthy domestic sheep. Journal of Wildlife Diseases 30:137–145.

Fox, K. A., N. M. Rouse, K. P. Huyvaert, K. A. Griffin, H. J. Killion, J. Jennings-Gaines, W. H. Edwards, S. L. Quackenbush, and M. W. Miller. 2015. Bighorn sheep (*Ovis canadensis*) sinus tumors are associated with coinfections by potentially pathogenic bacteria in the upper respiratory tract. Journal of Wildlife Diseases 51:19–27.

Gilmour, J. S., G. E. Jones, and A. G. Rae. 1979. Experimental studies of chronic pneumonia of sheep. Comparative Immunology Microbiology and Infectious Diseases 1:285–293.

Goldstein, E. J., J. J. Millspaugh, B. E. Washburn, G. C. Brundige, and K. J. Raedeke. 2005. Relationships among fecal lungworm loads, fecal glucocorticoid metabolites, and lamb recruitment in free-ranging Rocky Mountain bighorn sheep. Journal of Wildlife Diseases 41:416–425.

Grenfell, B., and J. Harwood. 1997. (Meta)population dynamics of infectious diseases. Trends in Ecology & Evolution 12:395–399.

Grinnell, G. B. 1928. Mountain sheep. Journal of Mammalogy 9:1–9.

Gutierrez-Espeleta, G. A., P. W. Hedrick, S. T. Kalinowski, D. Garrigan, and W. M. Boyce. 2001. Is the decline of desert bighorn sheep from infectious disease the result of low MHC variation? Heredity 86:439–450.

Handeland, K., T. Tengs, B. Kokotovic, T. Vikøren, R. D. Ayling, B. Bergsjø, Ó. G. SigurÐardóttir, and T. Bretten. 2014. *Mycoplasma ovipneumoniae*—a primary cause of severe pneumonia epizootics in the Norwegian muskox (*Ovibos moschatus*) population. PLoS ONE 9: e106116.

Heinse, L. M., L. M. Hardesty, and R. B. Harris. 2016. Risk of pathogen spillover from domestic sheep and goat flocks on private land. Wildlife Society Bulletin 40:625–633.

Herndon, C. N., S. Shanthalingam, D. P. Knowles, D. R. Call, and S. Srikumaran. 2011. Comparison of passively transferred antibodies in bighorn and domestic lambs reveals one factor in differential susceptibility of these species to Mannheimia haemolytica-induced pneumonia. Clinical Vaccine Immunology 18:1133–1138.

Hess, G. 1996. Disease in metapopulation models: implications for conservation. Ecology 77:1617–1632.

Highland, M. A. 2016. Comparative investigation of the immune systems of two ovine species (*Ovis aries* and *Ovis canadensis*). Dissertation, Washington State University, Pullman, USA.

Highland, M. A., D. A. Schneider, S. N. White, S. A. Madsen-Bouterse, D. P. Knowles, and W. C. Davis. 2016. Differences in leukocyte differentiation molecule abundances on domestic sheep (*Ovis aries*) and bighorn sheep (*Ovis canadensis*) neutrophils identified by flow cytometry. Comparative Immunology Microbiology and Infectious Diseases 46:40–46.

Hill, A. B. 1965. The environment and disease: association or causation. Proceedings of the Royal Society of Medicine 58:295–300.

Hobbs, N. T., and M. W. Miller. 1992. Interactions between pathogens and hosts: simulation of pasteurellosis epizootics in bighorn sheep populations. Pages 997–1006 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: populations. Elsevier Applied Science, Essex, United Kingdom.

Hogg, J. T., S. H. Forbes, B. M. Steele, and G. Luikart. 2006. Genetic rescue of an insular population of large mammals. Proceedings of the Royal Society of London B: Biological Sciences 273:1491–1499.

Ionas, G., J. K. Clarke, and R. B. Marshall. 1991*a*. The isolation of multiple strains of *Mycoplasma ovipneumoniae* from individual pneumonic sheep lungs. Veterinary Microbiology 29:349–360.

Ionas, G., N. G. Norman, J. K. Clarke, and R. B. Marshall. 1991*b*. A study of the heterogeneity of isolates of *Mycoplasma ovipneumoniae* from sheep in New Zealand. Veterinary Microbiology 29:339–347.

Jorgenson, J. T., M. Festa-Bianchet, J.-M. Gaillard, and W. D. Wishart. 1997. Effects of age, sex, disease, and density on survival of bighorn sheep. Ecology 78:1019–1032.

Joseph, M. B., J. R. Mihaljevic, A. L. Arellano, J. G. Kueneman, D. L. Preston, P. C. Cross, and P. T. J. Johnson. 2013. Taming wildlife disease: bridging the gap between science and management. Journal of Applied Ecology 50:702–712.

Justice-Allen, A. E., E. Butler, J. Pebworth, A. Munig, P. Wolff, and T. E. Besser. 2016. Strain type matters: mortality in a *M. ovipneumoniae*-positive herd in association with the detection of a divergent strain of *M. ovipneumoniae*. Biennial Symposium Northern Wild Sheep and Goat Council 20:26–27.

Kamath, P. L., P. C. Cross, E. F. Cassirer, and T. E. Besser. 2016. Genetic linkages among *Mycoplasma ovipneumoniae* strains in wild and domestic sheep and goats. Biennial Symposium Northern Wild Sheep and Goat Council 20:113.

Klepac, P., C. J. E. Metcalf, A. R. McLean, and K. Hampson. 2013. Towards the endgame and beyond: complexities and challenges for the elimination of infectious diseases. Philosophical Transactions of the Royal Society B-Biological Sciences 368:20120137. doi 10.1098/rstb.2012.0137

Kugadas, A. 2014. Growth of *Mannheimia haemolytica*: inhibitory agents and putative mechanism of inhibition. Dissertation, Washington State University, Pullman, USA.

Lawrence, P. K., S. Shanthalingam, R. P. Dassanayake, R. Subramaniam, C. N. Herndon, D. P. Knowles, F. R. Rurangirwa, W. J. Foreyt, G. Wayman, A. M. Marciel, S. K. Highlander, and S. Srikumaran. 2010. Transmission of *Mannheimia haemolytica* from domestic sheep (*Ovis aries*) to bighorn sheep (*Ovis canadensis*): unequivocal demonstration with green fluorescent protein-tagged organisms. Journal of Wildlife Diseases 46:706–717.

Lin, Y. C., R. J. Miles, R. A. Nicholas, D. P. Kelly, and A. P. Wood. 2008. Isolation and immunological detection of *Mycoplasma ovipneumoniae* in sheep with atypical pneumonia, and lack of a role for *Mycoplasma arginini*. Research in Veterinary Science 84:367–373.

Lloyd-Smith, J. O., S. J. Schreiber, P. E. Kopp, and W. M. Getz. 2005. Superspreading and the effect of individual variation on disease emergence. Nature 438:355–359.

Loison, A., J.-M. Jullien, and P. Menaut. 1999. Subpopulation structure and dispersal in two populations of chamois. Journal of Mammalogy 80:620–632.

Long, E. S., D. R. Diefenbach, C. S. Rosenberry, and B. D. Wallingford. 2008. Multiple proximate and ultimate causes of natal dispersal in white-tailed deer. Behavioral Ecology 19:1235–1242.

Luikart, G., K. Pilgrim, J. Visty, V. O. Ezenwa, and M. K. Schwartz. 2008. Candidate gene microsatellite variation is associated with parasitism in wild bighorn sheep. Biology Letters 4:228–231.

Maksimović, Z., C. De la Fe, J. Amores, Á. Gómez-Martín, and M. Rifatbegović. 2017. Comparison of phenotypic and genotypic profiles among caprine and ovine *Mycoplasma ovipneumoniae* strains. Veterinary Record 180: doi: 10.1136/vr.103699, article 179.

Manlove, K. R., E. F. Cassirer, P. C. Cross, R. K. Plowright, and P. J. Hudson. 2014. Costs and benefits of group living with disease: a case study of pneumonia in bighorn lambs (*Ovis canadensis*). Proceedings of the Royal Society B-Biological Sciences 281, article 2331.

Manlove, K. R., E. F. Cassirer, P. C. Cross, R. K. Plowright, and P. J. Hudson. 2016. Disease introduction is associated with a phase transition in bighorn sheep demographics. Ecology 97:2593–2602.

Manlove, K. R., E. F. Cassirer, R. K. Plowright, P. C. Cross, and P. J. Hudson. 2017. Contact and contagion: bighorn sheep demographic states vary in probability of transmission given contact. Journal of Animal Ecology 86:908–920.

McAdoo, C., P. Wolff, and M. Cox. 2010. Invesetigation of Nevada's 2009–2010 East Humboldt Range and Ruby Mountain bighorn dieoff. Biennial Symposium Northern Wild Sheep and Goat Council 17:51–52.

McCallum, H., and A. Dobson. 2002. Disease, habitat fragmentation and conservation. Proceedings of the Royal Society B-Biological Sciences 269:2041–2049.

McFarlane, L., and A. Aoude. 2010. Status of Goslin Unit bighorn sheep pneumonia outbreak in Utah. Biennial Symposium Northern Wild Sheep and Goat Council 17:53.

Miller, M. W. 2001. Pasteurellosis. Pages 558 *in* E. S. Williams, and I. K. Barker, editors. Infectious diseases of wild mammals. Iowa State University Press, Ames, USA.

Miller, M. W., B. M. Hause, H. J. Killion, K. A. Fox, W. H. Edwards, and L. L. Wolfe. 2013. Phylogenetic and epidemiologic relationships among Pasteurellaceae from Colorado bighorn sheep herds. Journal of Wildlife Diseases 49:653–660.

Miller, M. W., J. E. Vayhinger, D. C. Bowden, S. P. Roush, T. E. Verry, A. N. Torres, and V. D. Jurgens. 2000. Drug treatment for lungworm in bighorn sheep: reevaluation of a 20-year-old management prescription. Journal of Wildlife Management 64:505–512.

Monello, R. J., D. L. Murray, and E. F. Cassirer. 2001. Ecological correlates of pneumonia epizootics in bighorn sheep herds. Canadian Journal of Zoology 79:1423–1432.

Niang, M., R. F. Rosenbusch, J. J. Andrews, and M. L. Kaeberle. 1998*a*. Demonstration of a capsule on *Mycoplasma ovipneumoniae*. American Journal of Veterinary Research 59:557–562.

Niang, M., R. F. Rosenbusch, J. J. Andrews, J. Lopez-Virella, and M. L. Kaeberle. 1998*b*. Occurrence of autoantibodies to cilia in lambs with a 'coughing syndrome'. Veterinary Immunology and Immunopathology 64:191–205.

Niang, M., R. F. Rosenbusch, M. C. DeBey, Y. Niyo, J. J. Andrews, and M. L. Kaeberle. 1998*c*. Field isolates of *Mycoplasma ovipneumoniae* exhibit distinct cytopathic effects in ovine tracheal organ cultures. Journal of Veterinary Medicine Series A-Physiology Pathology Clinical Medicine 45:29–40.

Nicholas, R. A. J., R. D. Ayling, and G. R. Loria. 2008. Ovine mycoplasmal infections. Small Ruminant Research 76:92–98.

O'Brien, J. M., T. E. Carpenter, C. S. O'Brien, and C. M. Ccarthy. 2014. Incorporating foray behavior into models estimating contact risk between bighorn sheep and areas occupied by domestic sheep. Wildlife Society Bulletin 38:321–331.

Olson, Z. H., D. G. Whittaker, and O. E. Rhodes. 2012. Evaluation of experimental genetic management in reintroduced bighorn sheep. Ecology and Evolution 2:429–443.

Osnas, E. E., P. J. Hurtado, and A. P. Dobson. 2015. Evolution of pathogen virulence across space during an epidemic. American Naturalist 185: 332–342.

Parham, K., C. P. Churchward, L. McAuliffe, R. A. J. Nicholas, and R. D. Ayling. 2006. A high level of strain variation within the *Mycoplasma ovipneumoniae* population of the UK has implications for disease diagnosis and management. Veterinary Microbiology 118:83–90.

Park, A. W., S. Gubbins, and C. A. Gilligan. 2002. Extinction times for closed epidemics: the effects of host spatial structure. Ecology Letters 5:747–755.

Pedersen, A. B., and T. J. Greives. 2008. The interaction of parasites and resources cause crashes in a wild mouse population. Journal of Animal Ecology 77:370–377.

Pedersen, A. B., K. E. Jones, C. L. Nunn, and S. Altizer. 2007. Infectious diseases and extinction risk in wild mammals. Conservation Biology 21:1269–1279.

Plowright, R. K., K. R. Manlove, T. E. Besser, P. E. Matthews, D. Paez, K. R. Andrews, L. P. Waits, P. C. Cross, P. J. Hudson, and E. F. Cassirer. 2016. Understanding the dynamics of *Mycoplasma ovipneumoniae* carriers in a bighorn sheep population. Biennial Symposium Northern Wild Sheep and Goat Council 20:21.

Plowright, R. K., K. R. Manlove, E. F. Cassirer, P. C. Cross, T. E. Besser, and P. J. Hudson. 2013. Use of exposure history to identify patterns of immunity to pneumonia in bighorn sheep (*Ovis canadensis*). PLoS ONE 8: e61919.

Råberg, L., A. L. Graham, and A. F. Read. 2009. Decomposing health: tolerance and resistance to parasites in animals. Philosophical Transactions of the Royal Society B: Biological Sciences 364:37–49.

Ramsey, J., K. Carson, E. S. Almberg, M. Thompson, R. Mowry, E. Bradley, J. Kolbe, and C. Jourdonnais. 2016. Status of Montana bighorn sheep herds and discussion of control efforts after all-age die-offs. Biennial Symposium Northern Wild Sheep and Goat Council 20:19–37.

Rezaei, H. R., S. Naderi, I. C. Chintauan-Marquier, P. Taberlet, A. T. Virk, H. R. Naghash, D. Rioux, M. Kaboli, and F. Pompanon. 2010. Evolution and taxonomy of the wild species of the genus *Ovis* (Mammalia, Artiodactyla, Bovidae). Molecular Phylogenetics and Evolution 54:315–326.

Rifatbegović, M., Z. Maksimović, and B. Hulaj. 2011. *Mycoplasma ovipneumoniae* associated with severe respiratory disease in goats. Veterinary Record 168:565.

Rudolph, K. M., D. L. Hunter, R. B. Rimler, E. F. Cassirer, W. J. Foreyt, W. J. DeLong, G. C. Weiser, and C. S. W. Alton. 2007. Microorganisms associated with a pneumonic epizootic in Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Journal of Zoo and Wildlife Medicine 38:548–558.

Rupprecht, C. E., T. J. Wiktor, D. H. Johnston, A. N. Hamir, B. Dietzschold, W. H. Wunner, L. T. Glickman, and H. Koprowski. 1986. Oral immunization and protection of raccoons (*Procyon lotor*) with a vaccinia-rabies glycoprotein recombinant virus vaccine. Proceedings of the National Academy of Sciences 83:7947–7950.

Ryder, T. J., E. S. Williams, K. W. Mills, K. H. Bowles, and E. T. Thorne. 1992. Effect of pneumonia on population size and lamb recruitment in Whiskey Mountain bighorn sheep. Biennial Symposium Northern Wild Sheep and Goat Council 8:137–147.

Sainsbury, A. W., and R. J. Vaughn-Higgins. 2012. Analyzing disease risks associated with translocations. Conservation Biology 26:442–452.

Sandoval, A. V., A. S. Elenowitz, and J. R. Deforge. 1987. Pneumonia in a transplanted population of bighorn sheep. Desert Bighorn Council 31:18–22.

Savage, A. E., and K. R. Zamudio. 2011. MHC genotypes associate with resistance to a frog-killing fungus. Proceedings of the National Academy of Sciences 108:16705–16710.

Schmitt, S. M., D. J. O'Brien, C. S. Bruning-Fann, and S. D. Fitzgerald. 2002. Bovine tuberculosis in Michigan wildlife and livestock. Annals of the New York Academy of Sciences 969:262–268.

Schumaker, B. A., D. E. Peck, and M. E. Kauffman. 2012. Brucellosis in the Greater Yellowstone Area: disease management at the wildlife-livestock interface. Human-Wildlife Interactions 6:48–63.

Scurlock, B. M., W. H. Edwards, T. Cornish, and L. Meadows. 2010. Using test and slaughter to reduce prevalence of brucellosis in elk attending feedgrounds in the Pinedale elk herd unit of Wyoming; results of a 5-year pilot project. Wyoming Game Fish Department, Cheyenne, USA.

Sells, S. N., M. S. Mitchell, J. J. Nowak, P. M. Lukacs, N. J. Anderson, J. M. Ramsey, J. A. Gude, and P. R. Krausman. 2015. Modeling risk of pneumonia epizootics in bighorn sheep. Journal of Wildlife Management 79:195–210.

Shannon, J. M., J. C. Whiting, R. T. Larsen, D. D. Olson, J. T. Flinders, T. S. Smith, and R. T. Bowyer. 2014. Population response of reintroduced bighorn sheep after observed commingling with domestic sheep. European Journal of Wildlife Research 60:737–748.

Shanthalingam, S., A. Goldy, J. Bavananthasivam, R. Subramaniam, S. A. Batra, A. Kugadas, B. Raghavan, R. P. Dassanayake, J. E. Jennings-Gaines, H. J. Killion, W. H. Edwards, J. M. Ramsey, N. J. Anderson, P. L. Wolff, K. Mansfield, D. Bruning, and S. Srikumaran. 2014. PCR assay detects *Mannheimia haemolytica* in culture negative pneumonic lung tissues of bighorn sheep (*Ovis canadensis*) from outbreaks in the western USA, 2009–2010. Journal of Wildlife Diseases 50:1–10.

Shanthalingam, S., S. Narayanan, S. A. Batra, B. Jegarubee, and S. Srikumaran. 2016. Fusobacterium necrophorum in North American bighorn sheep (*Ovis canadensis*) pneumonia. Journal of Wildlife Diseases 52:616–620.

Shillinger, J. E. 1937. Disease relationship between domestic animals and wildlife. Transactions North American Wildlife and Natural Resources Conference 2:298–302.

Silflow, R. M., W. J. Foreyt, S. M. Taylor, W. W. Laegreid, H. D. Liggitt, and R. W. Leid. 1989. Comparison of pulmonary defense mechanisms in Rocky Mountain bighorn and domestic sheep. Journal of Wildlife Diseases 25:514–520.

Singer, F. J., C. M. Papouchis, and K. K. Symonds. 2000*a*. Translocations as a tool for restoring populations of bighorn sheep. Restoration Ecology 8:6–13.

Singer, F. J., E. Williams, M. W. Miller, and L. C. Zeigenfuss. 2000*b*. Population growth, fecundity, and survivorship in recovering populations of bighorn sheep. Restoration Ecology 8:75–84.

Singer, F. J., L. C. Zeigenfuss, and L. Spicer. 2001. Role of patch size, disease, and movement in rapid extinction of bighorn sheep. Conservation Biology 15:1347–1354.

Sirochman, M. A., K. J. Woodruff, J. L. Grigg, D. P. Walsh, K. P. Huyvaert, M. W. Miller, and L. L. Wolfe. 2012. Evaluation of management treatments intended to increase lamb recruitment in a bighorn sheep herd. Journal of Wildlife Diseases 48:781–784.

Slate, D., C. E. Rupprecht, J. A. Rooney, D. Donovan, D. H. Lein, and R. B. Chipman. 2005. Status of oral rabies vaccination in wild carnivores in the United States. Virus Research 111:68–76.

Smith, J. B., T. W. Grovenburg, K. L. Monteith, and J. A. Jenks. 2015. Survival of female bighorn sheep (*Ovis canadensis*) in the Black Hills, South Dakota. American Midland Naturalist 174:290–301.

Smith, J. B., J. A. Jenks, T. W. Grovenburg, and R. W. Klaver. 2014. Disease and predation: sorting out causes of a bighorn sheep (*Ovis canadensis*) decline. PLoS ONE 9:e88271.

Stephen, C. 2014. Toward a modernized definition of wildlife health. Journal of Wildlife Diseases 50:427–430.

Streicker, D. G., A. Fenton, and A. B. Pedersen. 2013. Differential sources of host species heterogeneity influence the transmission and control of multihost parasites. Ecology Letters 16:975–984.

Swinton, J., J. Harwood, B. Grenfell, and C. Gilligan. 1998. Persistence thresholds for phocine distemper virus infection in harbour seal (*Phoca vitulina*) metapopulations. Journal of Animal Ecology 67:54–68.

The Wildlife Society. 2015. Domestic sheep and goats disease transmission risk to wild sheep <http://wildlife.org/wp-content/uploads/2015/03/WS-DS_DiseaseTransmission_TWS-AAWV_JointStatement_APPROVED.pdf>. Accessed 14 May 2017.

Thirkell, D., R. K. Spooner, G. E. Jones, and W. C. Russell. 1990. Polypeptide and antigenic variability among strains of *Mycoplasma ovipneumoniae* demonstrated by SDS-PAGE and immunoblotting. Veterinary Microbiology 21:241–254.

U.S. Department of Agriculture [USDA]. 2011. Sheep and lamb nonpredator death loss in the United States, 2009. USDA–APHIS–VS–CEAH. USDA, Fort Collins, Colorado, USA. <https://www.aphis.usda.gov/animal_health/nahms/general/downloads/sheep_nonpred_2009.pdf>. Accessed 14 Jun 2017.

U.S. Department of Agriculture [USDA] Aphis Veterinary Services. 2015. Mycoplasma ovipneumoniae on U.S. sheep operations. Sheep 2011 Info Sheet. <https://www.aphis.usda.gov/animal_health/nahms/sheep/downloads/sheep11/Sheep11_is_Myco.pdf>. Accessed 14 May 2017.

U.S. Department of Agriculture [USDA] Forest Service. 2010. Record of decision for the: Final supplemental environmental impact statement and forest plan amendment identifying suitable rangeland for domestic sheep and goat grazing to maintain habitat for viable bighorn sheep populations. <https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5238683.pdf>. Accessed 14 May 2017.

Viana, M., R. Mancy, R. Biek, S. Cleaveland, P. C. Cross, J. O. Lloyd-Smith, and D. T. Haydon. 2014. Assembling evidence for identifying reservoirs of infection. Trends in Ecology & Evolution 29:270–279.

Walker, L., H. LeVine, and M. Jucker. 2006. Koch's postulates and infectious proteins. Acta Neuropathologica 112:1.

Walsh, D. P., E. F. Cassirer, M. D. Bonds, D. R. Brown, W. H. Edwards, G. C. Weiser, M. L. Drew, R. E. Briggs, K. A. Fox, M. W. Miller, S. Shanthalingam, S. Srikumaran, and T. E. Besser. 2016. Concordance in diagnostic testing for respiratory pathogens of bighorn sheep. Wildlife Society Bulletin 40:634–642.

Walsh, D. P., L. L. Wolfe, M. E. P. Vieira, and M. W. Miller. 2012. Detection probability and Pasteurellaceae surveillance in bighorn sheep. Journal of Wildlife Diseases 48:593–602.

Walters, C. J., and R. Green. 1997. Valuation of experimental management options for ecological systems. Journal of Wildlife Management 61:987–1006.

Wehausen, J. D., S. T. Kelley, and R. R. Ramey III. 2011. Domestic sheep, bighorn sheep, and respiratory disease: a review of experimental evidence. California Fish and Game 97:7–24.

Weiser, G. C., W. J. De Long, J. L. Paz, B. Shafii, W. J. Price, and A. C. S. Ward. 2003. Characterization of *Pasteurella multocida* associated with pneumonia in bighorn sheep. Journal of Wildlife Diseases 39: 536–544.

Western Association of Fish and Wildife Agencies Wild Sheep Working Group. 2012. Recommendations for domestic sheep and goat management in wild sheep habitat. <http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5385708.pdf>. Accessed 15 Oct 2016.

Western Association of Fish and Wildlife Agencies Wildlife Health Committee. 2015. 2014 Bighorn sheep herd health monitoring recommendations. <http://www.wafwa.org/Documents%20and%20Settings/37/Site%20Documents/Working%20Groups/Wild%20Sheep/Disease/BHS%20herd%20health%20monitoring_Final%201_3_2015.pdf>. Accessed 6 October 2016.

Williams, B. K., and E. D. Brown. 2016. Technical challenges in the application of adaptive management. Biological Conservation 195: 255–263.

Wobeser, G. 2002. Disease management strategies for wildlife. Revue Scientifique Et Technique De L Office International Des Epizooties 21: 159–178.

Wolff, P. L., T. E. Besser, D. D. Nelson, J. F. Ridpath, K. McMullen, J. Muoz-Gutierrez, M. Cox, C. Morris, and C. McAdoo. 2014. Mountain goats at the livestock-wildlife interface: a susceptible species. Biennial Symposium Northern Wild Sheep and Goat Council 19:13.

Wolff, P. L., C. Schroeder, C. McAdoo, M. Cox, D. D. Nelson, J. F. Evermann, and J. F. Ridpath. 2016. Evidence of bovine viral diarrhea virus infection in three species of sympatric wild ungulates in Nevada: life history strategies may maintain endemic infections in wild populations. Frontiers in Microbiology 7. https://doi.org/10.3389/fmicb.2016.00292, article 297.

Wood, M. E., K. A. Fox, J. Jennings-Gaines, H. J. Killion, S. Amundson, M. W. Miller, and W. H. Edwards. 2017. How respiratory pathogens contribute to lamb mortality in a poorly performing bighorn sheep (*Ovis canadensis*) herd. Journal of Wildlife Diseases 53:126–130.

Woolever, M., T. Rinkes, C. McCarthy, J. O'Brien, C. O'Brien, and S. Moss. 2015. Bighorn sheep risk of contact tool v2 user guide. FS/BLM Bighorn Sheep Working Group. <https://d1cqrq366w3ike.cloudfront.net/http/DOCUMENT/SheepUSA/Risk%20of%20Contact%20Tool%20User%20Guide%20LR.pdf> Accessed 27 Nov 2016.

Wyoming Game and Fish Department. 2016. Pinedale Elk Herd Unit (E108) Brucellosis Management Action Plan Update, April 2016. <https://wgfd.wyo.gov/WGFD/media/content/PDF/Wildlife/E108_BMAPUpdate_041916-Pinedale.pdf >. Accessed 20 Apr 2017.

Young, S. P., and R. H. Manville. 1960. Records of bighorn hybrids. Journal of Mammalogy 41:523–525.

Zarnke, R. L., and R. Soren. 1989. Serologic survey for *Mycoplasma ovipneumoniae* in free-ranging dall sheep (*Ovis dalli*) in Alaska. Journal of Wildlife Diseases 25:612–613.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's website.

Ex342

http://www.heraldextra.com/news/local/flying-sheep-dwr-transports-wildlife-via-helicopter-to-test-for/article_94056e6f-ae82-510c-a00d-47ea4897a7f1.html

FEATURED

Flying sheep: DWR transports wildlife via helicopter to test for disease

Katie England Daily Herald Jan 11, 2017

Annette Roug, left, a wildlife veterinarian for the Utah Division of Wildlife Resources, prepares to take a blood sample from a bighorn sheep Tuesday, Jan. 10, 2017, in Cedar Hills. ISAAC HALE, Daily Herald

Isaac Hale, Daily Herald

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Ex343

Photos: DWR transports wildlife via helicopter to test for disease
Jan 11, 2017

Two of the bighorn sheep who live near the mouth of American Fork Canyon had the surprise of their lives Tuesday afternoon.

A helicopter, from a company hired by the Utah Division of Wildlife Resources, captured the two female sheep, with a net gun. The animals were then transported — dangling beneath the helicopter — to a staging area just east of North Canyon Road and south of the Alpine Scenic Loop Byway in Cedar Hills.

As the blindfolded animals were gently lowered to the ground, a mixture of DWR employees and volunteers transported the sheep to a table to conduct tests.

Brett Miller, a volunteer from South Jordan, was tasked with taking the animals' temperatures every few minutes throughout the proceedings. The stress of capture, handling and noise can cause the animals' body temperatures to spike.

"Can you imagine getting strapped to a helicopter blindfolded, then land and have all these strange people poking and prodding you?" Miller asked.

Their thickly insulated winter coats trap in that extra heat, causing the animals' body temperatures to rise above normal levels.

"They have you take the temperature every few minutes while they're there, and most of the time, it's high," Miller said. Miller and other volunteers packed snow under the animals' legs to help regulate the temperature, while others held the sheep still so others could take blood and saliva samples.

Though the experience is definitely stressful for the animals being captured, the process helps the DWR gather information that helps them better manage Utah's herds of bighorn sheep.

Ex344

The DWR is in the process of trying to establish disease profiles on all the bighorn sheep herds in Utah. So far, they have tested about 80 percent of Utah's herds, said Rusty Robinson, bighorn sheep and mountain goat biologist with the DWR.

"Bighorn sheep are pretty susceptible to disease, so we're pretty concerned about that, so we've tried to get a handle on the certain pathogens that are in each individual herd, and that's going to drive our management decisions in the future," Robinson said.

Biologists use the samples taken from the sheep to test for certain pathogens that bighorn sheep are particularly susceptible to.

For instance, mycoplasma ovipneumoniae is a bacteria that can predispose bighorn sheep to respiratory infections.

"It can create a long-term, chronic issue with initial die-off," Robinson said. "Then a lot of times you will have a hard time with lamb recruitment for years to come, because the lambs will get it as soon as they're born and they don't make it."

Once they know what diseases are present in certain herds, biologists can make more informed decisions on which animals can be added to other herds, or augmented.

Once all samples are taken, the sheep are released, sporting a collar that will transmit GPS signals to biologists twice a day for several years. Despite being blindfolded throughout the process, the sheep are aware of their surroundings, Robinson said, and find their way back to their herd quickly.

Knowing the location of the sheep can help biologists learn about their movement patterns and habitat preferences. Additionally, if the sheep stops moving, biologists can find the sheep and determine the cause of death.

Ex345

Approximately 40 to 50 bighorn sheep live in the general area where the captures were taking place, Robinson estimated. Another 15 to 20 live in the Rock Canyon area, where the DWR conducted a similar capture earlier in the day.

Robinson said that some of the tests, such as those done on the saliva, can have results back as quickly as three days. Other tests, such as those done on blood, take longer to come back.

Katie England

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Ex346

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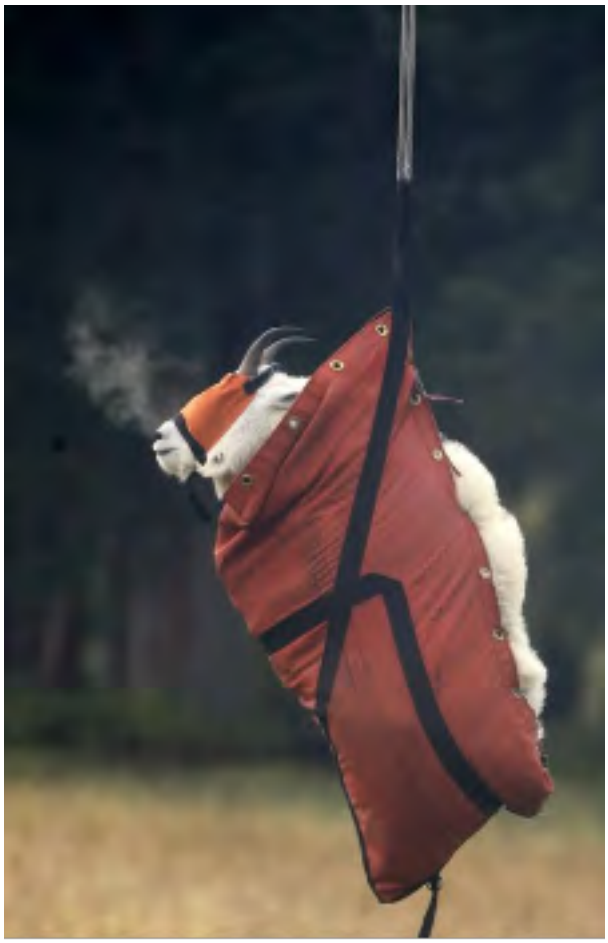
The Salt Lake Tribune

Judge rejects suit over La Sal goat introduction

National forest • Court concludes the Forest Service is still evaluating groups' call t evict non-native mountain goats.



Al Hartmann | The Salt Lake Tribune Helicopter lowers one of 50 captured mountain goats in a secure sling to the ground at a staging area in a high meadow in the Tushar Mountains east of Beaver, Utah on Tuesday September 3, 2013. Utah Division of Wildlife Resources biologists gave them a quick health check and loaded into boxes and tra for a move to new homes in South Dakota and two Utah sites.

By Brian maffly: The Salt Lake Tribune • March 04, 2017

Ex348

Sections Subscribe

A federal judge refused to order the removal of mountain goats in Utah's La Sal Mountains on Thursday, saying it is too early for the courts to interfere. The U.S. Forest Service is still formulating a decision in response to Utah's effort to establish non-native big game in alpine terrain, though the agency voiced concerns about the impact the animals could have on delicate and rare plant communities.

The decision dismisses a lawsuit brought by the Grand Canyon Trust and Utah Native Plant Society that alleged the Forest Service is failing its duty to manage habitat in deference to the state's traditional role of overseeing wildlife. The dispute arose after the Utah Wildlife Board's decision to release goats onto state-owned land that have since established a herd in the Manti-La Sal National Forest.

Federal scientists had concluded the goats would subvert the purpose of the 2,380 acre Mount Peale Research Natural Area, but the state went ahead and transplanted 20 goats from the Tushars to the La Sals in September 2013.

U.S. Magistrate Judge Paul Warner's decision will hardly put the controversy to rest since it does not affirm the goat introduction, but merely concludes the Forest Service has yet to make a decision that can be challenged in court.

"The unique intersection between federal land management and state wildlife management requires the Forest Service to work cooperatively with the states," Warner wrote. "The Forest Service did not authorize the state to release mountain goats near the Manti-La Sal National Forest. To the contrary, the Forest Service objected on numerous occasions and asked the state to delay introducing the mountain goats until more research could be conducted."

Utah was "exercising its inherent authority to regulate wildlife" when it rejected the federal request and released goats on state land.

Ex349

Sections Subscribe

"Now that the animals have migrated to some degree on federal land, the Forest Service is tasked with determining whether the goats' presence violates federal law and the existing forest plan. To achieve this task, the Forest Service has decided that it needs to gather more information," the judge wrote.

But Mary O'Brien, a botanist with the Grand Canyon Trust, said officials have all the information they need to justify ridding the La Sals of goats. Resource Natural Areas, or RNAs, are set aside as reference areas that are to be left undisturbed for scientific and educational study.

"The Forest Service has committed to removing exotic species from RNAs and at the forest level the Manti-La Sal has committed to removing exotics from Mount Peale. There is nothing clearer than that. Exotic species are to be removed," O'Brien said. "In this case [mountain goats] are highly and inevitably destructive. They are trampling, they are wallowing and it can't help up but damage the fragile and scattered alpine plants."

The deliberate introduction of a non-native animal, especially one that weighs about 175 pounds and has a habit of rolling around on soft ground, would affect th mosses, lichens and plants on 12,721-foot Mount Peale, especially in spring when soils are saturated with snowmelt, according to internal Forest Service documents entered into the court case. The goat introduction should have undergone an environmental review and been the subject of a special-use permit and the Utah Division of Wildlife Resources (DWR) should have gathered baseline vegetation data before putting goats on the ground, the groups argued.

Tony Frates of the Utah Native Plant Society saw a silver lining in the legal outcome.

"The extent of the monitoring actions that are now in place would not have

Ex350

SECTIONS Subscribe

secured without the strong intervention and concern by a number of different organizations and private citizens," he wrote in an email. "The problem is that no monitoring or other work was being done prior to the release. The 'bad guy' in this story is the Utah DWR and it is true that the Forest Service was then placed into a very awkward position."

DWR officials could not be reached Thursday, but they have previously said a grea deal of planning and study went into the goat project, developed in response to the public's desire to see big game, and the Forest Service waited until the last minute to lodge its objections.

"We have a close working relationship with the Forest Service and we would both like to see that remain intact. We were trying to address all these concerns for quit a long time," DWR Director Greg Sheehan told the Wildlife Board three years ago when it authorized the La Sal goat plan.

There were no mountain goats in Utah when the state turned six loose on Lone Peak in 1967. Today there are herds established around the Wastach, Uinta and Tushar mountains and Mount Dutton. In 2014, DWR released another 15 goats into the La Sals and today that herd numbers between 60 and 65 with a goal of reaching 200.

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