Bienn. Symp. North. Wild Sheep
and Goat Counc. 8:121-135.

DETERMINING THE FUTURE OF BIGHORN HERDS IN WILDERNESS AREAS

JAMES A. BAILEY, Department of Fishery and Wildlife Biology,
Colorado State University, Fort Collins, CO 80523

MELANIE M. WOOLEVER, Region 2, U. S. Forest Service, Box 25127,
Lakewood, CO 80255

Abstract: Outside wilderness, managers usually seek to optimize some characteristics of bighorn sheep (Ovis canadensis) herds for abundant consumptive and non-consumptive use. In contrast, the Wilderness Act of 1964 and subsequent wilderness regulations emphasize protecting natural processes in wilderness. Agency manuals appear naive regarding the dynamics of natural populations and offer inconsistent directions for maintaining these wilderness values. Processes expected in natural bighorn populations are proposed as goals for management of wilderness bighorns. Strict interpretation of the Forest Service manual could jeopardize many herds, especially in small wilderness areas. In 11 western states, there are >287 wilderness areas and 63 % are <20,250 ha (50,000 acres). Over 100 areas contain bighorn sheep. Few wilderness management plans have been completed. Consequently, policies for managing wilderness vary greatly among administrative units, especially in the Forest Service. Recommendations for managing bighorn sheep in wilderness areas include revising the Forest Service manual, designating bighorns as primary components of much wilderness, and management intervention to simulate natural processes in order to achieve the highest possible degree of naturalness in most wilderness bighorn herds. Plans should specify goals for bighorns, including reintroduction to historic range, participation in regional bighorn metapopulations, minimum acceptable levels for herd sizes and movements, and elimination of contact with domestic sheep.

In 11 western states, more than 100 designated wilderness areas contain bighorn sheep populations. In addition, there are numerous wilderness study areas with bighorn herds. Several wilderness management plans are now being developed by the U. S. Forest Service and Bureau of Land Management, and many plans will be written in the next 5-10 years. These plans will set precedents and will determine the future of many of the nation's bighorn sheep. Consequently, policies and practices for managing bighorn sheep in wilderness areas deserve abundant discussion and careful consideration.

The objectives of this paper are to (1) compare goals for optimizing bighorn sheep to goals for maximizing wilderness values of bighorn sheep; (2) illustrate some inconsistencies, confusion, and naivete in the manuals guiding wilderness management, as they apply to bighorn sheep; (3) document the current status of wilderness management, as it applies to bighorns; and (4) recommend policies and practices that

may maximize wilderness values of bighorns, yet reduce conflicts between optimization management and wilderness management of bighorn herds, especially those herds that migrate across wilderness boundaries.

We thank the following for responding to our survey of management policies and practices in wilderness areas: Ariz. BLM, S. Richardson; U.S. Forest Service, R1, A. Christensen; R3, B. Rickel, M. Ross, B. Wagenfehr, T. Skinner, D. Garcia; R4, P. Shields; R5, S. Loe, P. Rich, E. Rodriguez, K. Noland, and 2 anonymous respondents; R6, G. Silovsky. V. Bleich, G. Byrne, J. Emmerich, A. Fisher, M. Hess, G. Jense, R. Johnson, R. Lee, M. McCarthy, L. Oldenburg, J. Olterman, and W. Van Dyke identified wilderness areas containing bighorn sheep.

OPTIMIZATION MANAGEMENT OF BIGHORN SHEEP

Many, perhaps most, management plans for bighorn herds and habitats do not contain detailed statements of management goals. However, there is usually an intent to optimize one or several characteristics of the managed herd and habitat. These optimal characteristics may include:

(1) a large herd, perhaps controlled at some level believed to be the range carrying capacity, with the herd well above the minimum viable level, allowing abundant consumptive and/or non-consumptive use.

(2) a fairly stable herd size, without periodic declines or local extinctions of herd segments.

(3) high and stable levels of animal condition, reproduction, and resistance to disease.

(4) abundant, high-quality, diverse and fairly stable habitat resources, including a diversity of seasonal ranges and migration corridors accessed by periodic movements of animals.

(5) local forage resources in good condition; "excessive" use of forage does not occur, except perhaps locally in exceptional years.

(6) no contact with domestic sheep.

(7) genetic diversity is maintained by the large herd size, by immigration from nearby herds, or by occasional transplants into the herd.

WILDERNESS MANAGEMENT

The goals for wilderness areas are not consistent with all of these goals of optimization management for bighorn sheep. (While the Forest Service manual, FSM2323.35, and the Bureau of Land Management manual, BLMM8560.34.C.1, state similarly, "Objectives for the management of wildlife and fish habitat are normally compatible with the objectives for maintaining wilderness values", it is abundantly clear that optimization of a wildlife species is not a wilderness goal. For example see FSM2323.35a, 2324.22.7, BLMM8560.34.C.3.)

The Wilderness Act of 1964 defines wilderness as "an area where the earth and its community of life are untrammeled by man ...undeveloped ... without permanent improvements ... and managed so as to preserve its natural conditions." A wilderness "generally *appears* to have been affected primarily by the forces of nature, with the imprint of man's work substantially *unnoticeable*". Italics have been added to emphasize that this wording does not preclude man's works; it allows works that are not apparent. In fact, the Wilderness Act allows certain "grandfathered" uses of wilderness areas to continue, in the pre-existing manner and degree, after wilderness designation. These uses are mining and grazing, and the use of aircraft and motorboats (Keiter 1988). Also, wild horses or burros may be considered part of the natural wilderness system, although their numbers will be controlled by human intervention (BLMM8560.37.C).

The Wilderness Act and subsequent legislation (National Forest Management Act of 1976, Federal Land Policy and Management Act of 1976) emphasize the preservation of natural features, including species, and natural forces or processes in wilderness areas. Consequently, the Bureau of Land Management Manual, BLMM8560.11A, states, " BLM must foster a natural distribution of native species ... by ensuring that natural ecosystems and ecological processes continue to function." Likewise, the Forest Service seeks to "maintain wilderness in such a manner ... that plants and animals develop and respond to natural forces." (FSM2320.2.2) and to "provide an environment where the forces of natural selection and survival ... determine what numbers of wildlife species will exist." (FSM2323.31.1).

However, there is inconsistent and confusing direction for the management and maintenance of natural processes in Forest Service wilderness areas. For examples:

(1) While natural selection and survival are to determine numbers of wildlife (FSM2323.31.1), predators may be controlled to protect livestock (2323.33c), domestic sheep may be allowed to transmit serious diseases to bighorn herds (if "grandfathered in" during wilderness designation), and wildlife shall be held in balance with their habitat through public hunting or trapping (2323.35).

(2) While an objective of wilderness is to permit lightning caused fires to play, as nearly as possible, their natural ecological role in wilderness (FSM2324.21.1), prescribed ignitions may be used only to reduce unnatural buildups of fuels (2324.22.6). This may preclude use of prescribed ignitions to maintain the natural ecological roles of fire. Fortunately, the BLM Manual recognizes these other roles of fire (BLMM8560.35.3a) and allows prescribed ignitions for maintaining fire-dependent ecosystems, for sustaining a primary wilderness value, or for promoting endangered species (BLMM8560.34.C.4).

Furthermore, it is becoming clear that the idealistic goal of allowing all ecological processes to function naturally in wilderness

areas will be impossible, especially in the small areas that predominate in our wilderness system. The Forest Service admits that "absolute wilderness" is impossible and that activities including mining, grazing, visitor-use, and control of fire and pests will constrain achievement of absolute wilderness (FSM2320.6). (A neglect of the constraints imposed by small wilderness size and by boundary conflicts in this section of the Manual suggests naivete regarding natural processes in mobile wildlife populations and metapopulations.) Recognizing these limitations, the Forest Service and BLM Manuals require that human activities deviating from absolute wilderness be minimized. The manuals also allow human activities that might replace and simulate natural processes in wilderness areas. Manipulation of vegetation or wildlife habitat may be used to enhance or perpetuate the wilderness resource where natural processes have been unsuccessful, or to correct abnormal conditions resulting from human influence (BLMM8560.34.C.2-4, FSM2323.35a). However, strict interpretation of FSM2324.22.6 would indicate that prescribed ignition of fire may not be used to manipulate vegetation for these purposes. Manipulation of habitats within wilderness areas has also been delayed by the lack of completed wilderness management plans; and may be limited by a low federal priority and budget for wilderness, and by the relatively high costs and risks associated with management, especially prescribed fire, in wilderness.

It is implied that all natural processes in wildlife populations contribute to wilderness value. However, the Forest Service and BLM manuals offer few and very general examples of these processes. Fire, biotic succession, and evolution are mentioned. But the Forest Service manual provides directions that conflict with maintaining these processes, as noted above. Directions for maintaining natural ecological processes in wilderness areas are probably unclear because these processes are very diverse and complex. For example, Christensen (1988) described the great range and complexity of natural processes in plant populations.

NATURAL PROCESSES IN BIGHORN POPULATIONS

If bighorn sheep populations are to contribute as much as possible to wilderness values, then wilderness management plans must recognize and provide for the natural processes expected in natural bighorn populations. These include:

(1) variation of herd size and sex-age composition; variation of animal condition, reproduction and survival; some herds may fluctuate a great deal, others may never be large.

(2) emigration and immigration.

(3) natural selection: coevolution with dynamic populations of diseases, predators, and forage plants; adaptation to a variable physical and biotic environment through selection from a large and diverse gene pool; however, herd bottlenecks, local inbreeding incidents, re-foundering, and outbreeding from immigration may also occur in some populations.

(4) variation in range use: occasional habitat abandonment and pioneering of new ranges; some herds relatively sedentary, others migrate annually over varying distances; local impacts on forage resources vary widely among areas and years, with persistent and sometimes obvious forage impacts in zootic climax (Cayot et al. 1979) areas, such as near water sources or mineral licks, and in snow-free or thermally-attractive sites.

(5) metapopulation dynamics: some herds are core populations supporting the persistence and/or genetic diversities of other herds; some are dependant, perhaps ephemeral, satellite populations; some herds are interdependent in a patchy distribution (Bailey 1992).

(6) no contact with domestic sheep.

In pristine North America, some of this natural variation of bighorn herds has been caused by fires and biotic successions that periodically improved and degraded habitats; by occasional severe winters and periodic droughts; and possibly by epizootics that occurred because of the bighorn's marginal immune capacity (Desert Bighorn Council Technical Staff 1990). Optimization management addresses these factors. Prescribed fire is used to maintain habitats (Risenhoover et al. 1988); winter ranges are often emphasized; water supplies are maintained artificially in deserts; some diseases are treated (Miller et al. 1987); and disease-carrying domestic sheep are avoided.

Natural processes in bighorn herds are not all congruent with goals for optimizing bighorn sheep, listed above. Many bighorn herds migrate across wilderness boundaries, so herds are often managed by agencies with conflicting goals. Conflicts between state and federal agencies have resulted (Sizer and Carr 1989, Bleich et al. 1991). However, federal regulations leave little, if any, room for compromising wilderness objectives. Where there are conflicting decisions or choices, "the wilderness resource is the overriding value" and this value "shall dominate over other considerations" (FSM2320.6, 2320.3.1). Where objectives for managing wildlife habitat are incompatible with wilderness character or values, the requirements for maintaining wilderness values take precedence (FSM2320.35, BLMM8560.34.C.1).

Smaller wilderness areas will experience a lower frequency of lightning caused fires that may be necessary to maintain bighorn ranges and migration corridors. Small and narrow wilderness areas also have a large ratio of boundary to area. As a result, most natural fires will be suppressed in these wildernesses due to the high risks of fire leaving the areas (FSM2324.21.2 and .22.6d, BLMM8560.35.A1). In addition, fire suppression outside wilderness will reduce the frequency of natural fires entering wilderness. The resulting lack of fire could gradually diminish the amount of early-successional habitats beneficial to bighorns (and other early-successional species). It could also allow fuels to accumulate, producing very infrequent, but very large, fires. For bighorns, a long period with few fires would cause gradual population decline and increasing sedentariness. Such a population may

decline to the size of non-viability and disappear. If the population survives, it may expand rapidly in response to an infrequent, very large, fire. These possibilities of sedentariness, extirpation, or boom-and-bust fluctuations, are probably not natural in most wilderness areas.

A small wilderness may not contain the diversity of habitat resources that a pristine, mobile bighorn herd once used. Some of the once-used habitat diversity (including water sources or mineral licks) may, or may not, persist outside the small wilderness. Habitat diversity provides a wildlife population with options for responding to, and compensating for, adverse environmental variation, particularly adverse weather such as drought or severe winter. A bighorn herd unable to use a diversity of habitat resources would fluctuate more widely in response to environmental variation. For small herds, these fluctuations may result in loss of genetic diversity or extirpation. Both the excess fluctuations and the possible extirpation may be unnatural.

The natural processes listed above occurred in pristine North America when bighorn sheep were much more abundant and more continuously distributed than today. Bighorn herds and ranges have contracted for several reasons, including fire suppression in the Rocky Mountains (Wakelyn 1987, Cunningham 1991), and other human-caused impacts upon desert environments, especially upon water sources (McCutchen 1981:174-176). Many natural processes of bighorn populations will not occur, or will be limited in degree, within small, isolated wilderness areas. This may lead to extirpation of bighorn herds from these areas, unless limited unnatural human intervention is used to compensate for the small size and restricted habitat diversity of many wildernesses. If wilderness managers fail to recognize this dilemma, and pursue a purist non-intervention policy, many bighorn herds may slowly decline, become unnaturally sedentary, and may disappear from the smaller wilderness areas. The irony is that some intervention will be necessary to provide the highest possible degree of naturalness in many wilderness bighorn herds.

STATUS OF WILDERNESS MANAGEMENT RELATING TO BIGHORN SHEEP

The Forest Service and BLM administer 287 wilderness areas in 11 western states, excluding Alaska (U.S. For. Serv. 1990, Bur. of Land Manage. 1991). Many of these areas contain both BLM and Forest Service lands; 7 wilderness areas overlap state boundaries. (Additional wilderness areas administered by the U. S. Fish and Wildlife Service and the Park Service are not included here.) Bighorn sheep occur in 106 of these wilderness areas, according to a survey of state biologists. Additional wilderness areas contain historic range from which bighorns have been extirpated.

Sixty-three percent of these 287 wilderness areas are <20,250 ha (50,000 acres, Table 1) and 40 of these smaller wilderness areas currently have bighorn sheep. Arizona added 39 BLM wilderness areas in 1990; 33 of these were <20,250 ha. Consequently, Arizona has the largest number of small wilderness areas among the western states

(Table 1). The preponderance of small wilderness areas may increase similarly in other states when more BLM study areas are designated as wilderness. Small wilderness areas are not likely to include the entire annual ranges of bighorn herds. A survey of 18 bighorn herds in Colorado (Wakelyn 1984:55) suggests that a herd of 150 sheep will range over about 16,000 ha (40,000 acres). While many wilderness areas exceed this area, some proportion of each wilderness area is not suitable bighorn habitat.

Table 1. Characteristics of Forest Service and Bureau of Land Management wilderness areas in 11 western states.

Size	Number of wilderness areas[a]											
(10^3 acres)	AZ	CA	CO	ID	MT	NM	NV	OR	UT	WA	WY	Total
<10	18	4	3	0	1	2	0	7	1	4	0	40
10-50	48	24	4	0	3	13	7	16	10	11	5	141
50-100	9	6	7	0	2	2	4	4	1	1	0	36
100-150	4	3	6	0	0	0	2	3	0	3	2	23
150-200	1	4	3	0	1	0	0	2	0	3	2	16
200-250	0	2	1	2	2	2	0	0	0	0	0	9
>250	1	3	1	2	3	1	0	2	1	3	5	22
Total	81	46	25	4	12	20	13	34	13	25	14	287
Ave. size (10^3 acres)	34	86	103	1031	262	76	61	62	60	104	219	96
% <50,000 acres	81	61	28	0	33	75	54	68	85	60	36	63
No. with bighorn	32	7	19	4	8	6	10	3	3	3	11	106

[a]Seven wilderness areas occurring in 2 states are listed in the states having the largest portions of the areas. This "diminishes" the number of wilderness areas in Idaho, Montana and Wyoming by 1 area each, and in Oregon and Utah by 2 areas each.

Not only are many wilderness areas small in relation to the ranges of bighorn sheep, they are often narrow in width. The average width across 25 wilderness areas in Colorado is about 9.7 km (6 miles, S = 4.8 km or 3 miles); the average width across 81 wildernesses in Arizona is about 5.6 km (3.5 miles, S = 3.2 km or 2 miles). In contrast to these dimensions, many bighorn herds once migrated annually over longer distances, and some still do. For example, Smith (1954) noted that Idaho bighorns commonly migrated 16-32 km (10-20 miles), and 1 herd migrated 64 km (40 miles), each year. Maintaining or reestablishing such migrations, often across wilderness boundaries, would enhance the naturalness, and therefore wilderness value, of bighorn herds.

We surveyed the status of wilderness management in 6 western regions of the Forest Service and the Arizona BLM. Our survey emphasized practices and policies related to prescribed natural fires, prescribed ignitions of fire, development and maintenance of wildlife water sources, and use of aircraft for wildlife census, reintroduction of native species, and capture of animals. Responses were obtained from

the BLM, from 4 Forest Service regional offices, from 4 of 11 Forest offices in the Southwest Region, and from 5 of 17 Forest offices in the California Region of the Forest Service. These responses related to 226 wilderness areas.

We found only 14 wilderness areas (7 FS, 7 BLM) with approved wilderness management plans, or wilderness fire management plans. Another 41 plans (20 FS, 21 BLM) were reported as currently being developed or scheduled before 1995. Without such plans, almost all natural fires must be suppressed in wilderness. (In 1 Forest Service region, respondents from 3 Forests indicated that their Forest plans authorized letting some natural fires burn in some wilderness.) We found evidence that some natural fires had been allowed to burn in 21 Forest Service wilderness areas since 1980. Apparently, all fires have been suppressed in more than 200 wilderness areas in the West.

Respondents identified 30 wilderness areas that are, or are expected to be, managed under a policy allowing some natural fires to burn. Twelve of these areas are >81,000 ha (200,000 acres). Ten are <20,250 ha (50,000 acres), 1 in California and 9 in Arizona. Respondents from the heavily forested Rocky Mountains believed that natural fires could not be allowed to burn in "small" wilderness areas because the risk of fire leaving the area would be unacceptable.

Respondents were asked if prescribed ignitions of fire might be used in wilderness to allow fire to play its natural ecological role, or to correct unnatural vegetative conditions resulting from human influence. Results were highly variable. For 2 Forest Service regions, respondents quoted the agency manual (2324) to claim that prescribed ignitions were not authorized for these purposes. In another region, the respondent believed that prescribed ignitions were authorized, but would not be approved. In 3 regions of the Forest Service, prescribed ignitions of fire to maintain natural vegetation in wilderness is authorized, at least on some Forests. We found only 1 instance of prescribed ignition having been used in wilderness to restore fire to its natural role in the ecosystem. (It was also noted that bighorn sheep were a significant wilderness value that would be sustained by this fire.) The Arizona BLM is allowed to consider using prescribed ignition of fire to maintain natural vegetation under the guidelines of 7 completed wilderness fire plans.

We found water developments for bighorn sheep in 18 wilderness areas in Arizona (16 BLM, 2 FS) and 1 wilderness in California (FS). There was complete agreement among respondents that maintenance of these structures must be by primitive means and with the minimum equipment needed - to minimize disruption of wilderness conditions. We found no evidence that proposals to construct water developments for bighorn had been denied; although the Arizona BLM policy is to defer such proposals until the appropriate wilderness management plans are done.

The Arizona BLM responded that aircraft may be used in wilderness areas for wildlife census, for capture of animals, and for reintroduction of native species. However, responses varied greatly among units of the Forest Service. Use of aircraft for census is not

allowed on 1 Forest; it requires a special decision on 2 Forests and throughout 2 Regions; it is allowed on 1 Forest and throughout 2 Regions. (These 4 Forests with different policies are in 1 Region.) Use of aircraft for capture of animals is not allowed on 1 Forest and throughout 1 Region; requires a special decision on 2 Forests and throughout 3 Regions; is allowed on 1 Forest and throughout 1 Region. (Again, the Forests are in 1 Region.) Use of aircraft for reintroducing native species requires a special decision on 3 Forests and throughout 4 Regions; is allowed on 1 Forest and throughout 1 Region. (The Forests are in 1 Region.)

The status of wilderness planning and the interpretation of wilderness regulations in the manual vary greatly among Forests and Regions of the Forest Service. At an extreme, 1 Region has no wilderness management plans completed or being developed, suppresses all natural fires in wilderness, responded that prescribed ignition of fire is not authorized in wilderness, and would not allow use of aircraft for capture of animals in wilderness. In another Region, there is an emphasis on developing wilderness management plans, natural fires may burn in several wildernesses - even relatively small ones, and a prescribed ignition of fire has been approved to enhance wilderness value. In our survey, several state biologists complained that wilderness management policies also varied when supervisors changed within BLM or Forest Service units. We believe some of this variation is due to lack of clear direction in the Forest Service manual.

RECOMMENDATIONS

Although the wilderness act emphasizes preservation of natural processes as a goal of wilderness management, the Forest Service manual provides limited and inconsistent directions for achieving naturalness in wilderness. A Forest Service workshop, with experts in ecology and the dynamics of ecosystems, should be convened to revise at least those portions of the manual dealing with wildlife, habitat management, and fire. Until revisions are done, wilderness plans should be based upon interpretations of the entire wordings of the manual, and not upon strict interpretations of isolated sections.

Each wilderness area is unique and offers original opportunities and challenges for maintaining - to the extent possible and practical - a natural ecosystem. Small wilderness size and abundant interactions across boundaries characterize most wilderness areas. These problems should be addressed for each wilderness area by convening representatives of agencies and publics affected by each wilderness management plan, including state fish and wildlife agencies that manage animals migrating across wilderness boundaries (FSM 2323.32, BLMM 8560.34.A.2). Joint understanding of specific wilderness goals, and joint determination of the extent to which these goals may be achieved, should reduce conflicts between optimization management and wilderness management; and may eliminate conflicting and inefficient management activities.

In desert areas, development and care of bighorn water sources can maintain both optimization and wilderness values of the animals. Water

sources are often funded by agencies and/or foundations primarily interested in optimization values; while costs for development and care are often increased by requiring primitive methods that will preserve wilderness values. In these cases, financial support of bighorn water sources from federal agencies or from wilderness foundations is justified.

The western states need almost 300 wilderness management plans. All these plans will not be completed quickly. Until plans for wilderness bighorn sheep are developed, management should maintain options for maximizing wilderness values of bighorn herds. Interim goals should be to maintain existing populations and their genetic diversities, and to maintain existing traditionally-used seasonal ranges and migration corridors. (This may require some of the management strategies suggested below.) In wilderness areas where bighorns have been extirpated, and it is clear that reestablishing bighorns is possible and will contribute to the wilderness area's natural biodiversity, transplanting sheep need not be delayed until detailed wilderness management plans are done.

In summarizing the results of a workshop on ecosystem management for parks and wilderness areas, Johnson and Agee (1988:11-12) suggest that planners (1) identify primary components of wilderness systems; (2) define ecosystem boundaries, perhaps going beyond wilderness boundaries, for these components; (3) adopt goals and management strategies for primary components; and (4) develop monitoring systems to assess goal achievement for each component. (The concept of identifying "primary values" of wilderness areas is introduced in FSM 2323.35a.) In most, if not all, wilderness areas containing bighorn sheep, they should be designated as primary components for many of the following reasons:

(1) Most wilderness bighorn herds have exceptional recreational and esthetic values.

(2) Some herds have locally important economic value. Congress has recognized economic values of other wilderness resources by allowing grazing and mining to be "grandfathered in".

(3) Most bighorn herds should have large home ranges. Maintaining their habitats may protect smaller species having similar habitat needs and may stimulate coordination of management across wilderness boundaries. Thus, bighorn sheep qualify as an indicator species (Salwasser 1988:95).

(4) Bighorn sheep are far below their pristine abundance and distribution (Buechner 1960). Only a few other large western mammals have been reduced as much (or more) as bighorns. Bighorns are listed as "threatened" in California.

(5) Dispersed, relatively small bighorn herds must be managed as metapopulations in order to preserve the genetic resources of the species (Bleich et al. 1990, Bailey 1992), and these resources contribute to wilderness value. Some metapopulations will include herds in wilderness areas.

Wilderness plans should not be vague in defining goals for bighorn sheep. The "complete naturalness" goal and "let it be" strategy can result from indolent disregard of the diversity and dynamics of natural processes and of the real constraints for achieving naturalness in wilderness. Indolence may be fostered by the slow rates at which herds decline and become sedentary, in relation to the rates at which government employees transfer among jobs.

Goals for wilderness bighorn sheep should be developed according to local opportunities and constraints. They should include reintroduction of sheep into historic ranges, participation in regional bighorn metapopulations, minimum acceptable levels for herd sizes and movements, and the elimination of contact with domestic sheep.

Bighorn sheep should be reintroduced onto historic ranges within wilderness (BLMM 8560.34.D.1, FSM 2323.33a). Goals for reintroduced herds should include reestablishing historic movement patterns.

Each wilderness plan for bighorn sheep should address the potential contribution of the wilderness herd and habitat to a larger metapopulation that will conserve genetic variation of the species. This mandate is implied in many sections of the BLM and FS manuals that emphasize the preservation of natural resources and processes - in this case, genetic resources and evolution. Metapopulations should be recognized in management plans of all agencies responsible for the metapopulations' herd-components and their habitats. Ideally, contacts between herds would involve natural movements. However, some wilderness bighorn herds surrounded by unsuitable habitat should be augmented genetically by occasional transport of sheep from other herds.

Herd sizes and movements should be allowed to fluctuate, without human interference, above threshold levels. These thresholds should be selected to reduce to acceptable levels, the threats of herd extinction, and of long-term loss of migratory habits and genetic resources. When bighorn herds or their movements decline to threshold levels, human intervention is warranted. This may include prescribed ignition of fire, simulating a natural fire regime (BLMM8560.35.A.3, FSM 2323.35A); providing artificial water sources to replace waters that have been depleted inside or out of wilderness by human activities (BLMM 8560.34.C.6, FSM 2323.35A); and transplanting sheep to provide "artificial immigration" and augment genetic diversity. Such intervention may be necessary to maintain a herd in as natural a state as possible.

Selecting a minimum population threshold for a wilderness bighorn herd will be somewhat subjective and arbitrary. Small herd size fosters inbreeding, but acceptable rates of inbreeding are unclear. The risks of stochastic fadeouts due to small herd sizes are also uncertain, and will be greater in wilderness areas with more variable physical environments and less diverse habitat resources. These risks must be weighed against the amount of human intervention, and compromise of other wilderness values, necessary to maintain a larger, less threatened, herd.

In reviewing the historic record, Berger (1990) concluded that populations of <50 bighorns are not viable, and that long-term persistence of herds <100 is questionable. Soule' (1980) suggested that vertebrate populations equivalent to <50 "effective breeders" will exceed an (arbitrarily selected) unacceptable rate of inbreeding. In bighorn sheep, having the equivalence of 50 effective breeders will require a herd of about 150 animals (Fitzsimmons 1992), depending upon sex-age structure and other factors. Even with 150 bighorns, genetic variation and adaptability will gradually be lost through random selection (drift). Maintaining genetic variation in large mammals will require ≥1000 animals (Franklin 1980). These animals may exist in a metapopulation of several herds connected, genetically, by occasional movements of individuals.

Given the scientific uncertainty, we suggest that wilderness planners select ≥150 bighorn sheep as a minimum threshold for herds proposed as core populations (Bailey 1992) of recognized metapopulations. Selecting a threshold of <150 sheep may be appropriate for 1) small wilderness areas incapable of supporting many sheep, for which herds are designated interdependent components of patchy metapopulations; and 2) wilderness bighorn ranges for which occasional extirpation and refoundering are considered natural processes in satellite populations. Most often the metapopulation will include herds outside wilderness boundaries. We encourage abundant critique and discussion of these suggestions (cf. Geist 1975:105, Thomas 1990). However, 2 recent surveys (Thorne et al. 1985; Bur. of Land Management, n.d.) indicate that >60% of bighorn herds in the United States contain <100 sheep. Achieving 150 bighorn would improve the security of many wilderness bighorn herds, and goals may be revised as new information may dictate. We believe many wilderness bighorn herds are now isolated and <150 animals. For these herds, human intervention is already warranted and should be considered in developing wilderness plans and in interim management of areas without completed plans.

We suggest that wilderness planners establish goals to maintain at least 1 migration corridor between each pair of seasonal bighorn ranges within a wilderness, and to maintain suitable corridors between some wilderness herds and nearby herds outside the wilderness. A common threat to these corridors will be biotic succession, a consequence of lack of fire. We believe many wilderness bighorn herds are now unnaturally sedentary, warranting timely human intervention (Risenhoover et al. 1988).

A wilderness goal for bighorns should be to eliminate contact with domestic sheep (Desert Bighorn Counc. Tech. Staff 1990). Options are to vacate existing allotments, or convert them to cattle, perhaps through exchange of use with areas away from bighorns. Other options are to stringently control the distribution of domestic sheep, and to encourage and maintain dense forests as barriers to discourage movements of wild sheep toward domestic sheep.

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