Bienn. Symp. North. Wild Sheep
and Goat Counc. 9:149-158.

CONSEQUENCES OF HABITAT FRAGMENTATION ON WILD SHEEP METAPOPULATION MANAGEMENT WITHIN USA

DONALD J. ARMENTROUT, Bureau of Land Management, Eagle Lake Resource Area, 705 Hall Street, Susanville, CA 96130
RAYMOND J. BOYD, Bureau of Land Management, Service Center, Denver Federal Center, Building 50, Denver, CO 80225

Abstract: Comparisons of current and historical wild sheep habitat information with wild sheep distribution data gathered for the Bureau of Land Management's Bureauwide Mountain Sheep Ecosystem Strategy Plan indicate continuing fragmentation of metapopulation habitat. Implications of this fragmentation include a potential permanent loss of viable wild sheep habitat with a subsequent loss of metapopulation viability. The data illustrate that actual and potential habitat fragmentation occurs throughout the western United States rather than being confined to just a few locations. Habitat that links populations can be overlooked because it is not viewed as typical wild sheep habitat. The paper discusses how fragmentation has impacted some metapopulations and provides recommendations for achieving metapopulation management.

Prior to settlement, wild sheep were widely distributed in most mountain ranges and badlands of western North America. Since that time apparent large scale habitat fragmentation has taken place (Wishart 1978) (Fig. 1). Fragmentation occurs when a large expanse of habitat is transformed into a number of smaller patches which are isolated from each other thus forming a matrix of habitats unlike the original. Using Hanski and Gilpin's (1991) definition of fragmentation, we believe wild sheep, as one of many species with formerly continuous spatial distributions, are experiencing habitat fragmentation. Fragmentation of habitat remains the principal threat to most species in the temperate zone (Wilcove et al. 1986).

The key to management of all races of wild sheep is habitat protection, maintenance, and enhancement (Nichols 1978, Wishart 1978). Until recently the predominate approach to habitat management has been at the local scale (Bleich et al. 1990). Local scale is defined as the scale at which individuals move and interact with each other in the course of their routine feeding and breeding activities (Hanski and Gilpin 1991). A metapopulation is defined as a set of local populations which interact via individuals moving among local populations. A species restricted to a newly fragmented habitat does not necessarily function as a metapopulation. It may have such a restricted ability to disperse that a local population, once extinct, will remain extinct. We must understand the dynamics of these fragmented populations so that proper management remedies can be attempted to prevent total extinction (Hanski and Gilpin 1991). Metapopulation scale in relation to local scale has been defined by Hanski and Gilpin (1991) as the scale at which individuals infrequently move from one place (population) to another, typically across habitat types which are not suitable for their feeding and breeding activities, and often with substantial risk of failing to locate another suitable habitat patch in which to settle. The importance of metapopulations to bighorn sheep (*Ovis canadensis*) and the adverse impacts of fragmentation have been addressed (Schwartz et al. 1986, Bleich et al. 1990, Berger and Wehausen 1991, Ramey 1991).

The Bureau of Land Management (BLM), as well as other habitat management agencies has begun managing for biodiversity over broad ecosystems, resulting in a focus on landscape ecology and metapopulation management. Forman and Godron (1986), in defining landscape ecology, pointed out that landscape ecology has many similarities with metapopulation studies, including survival of species, communities, and ecosystems in fragmented habitats; how to distinguish the matrix, or the distinction between habitat patches and their surroundings; origin, size and shape of habitat patches; and the role of habitat corridors in

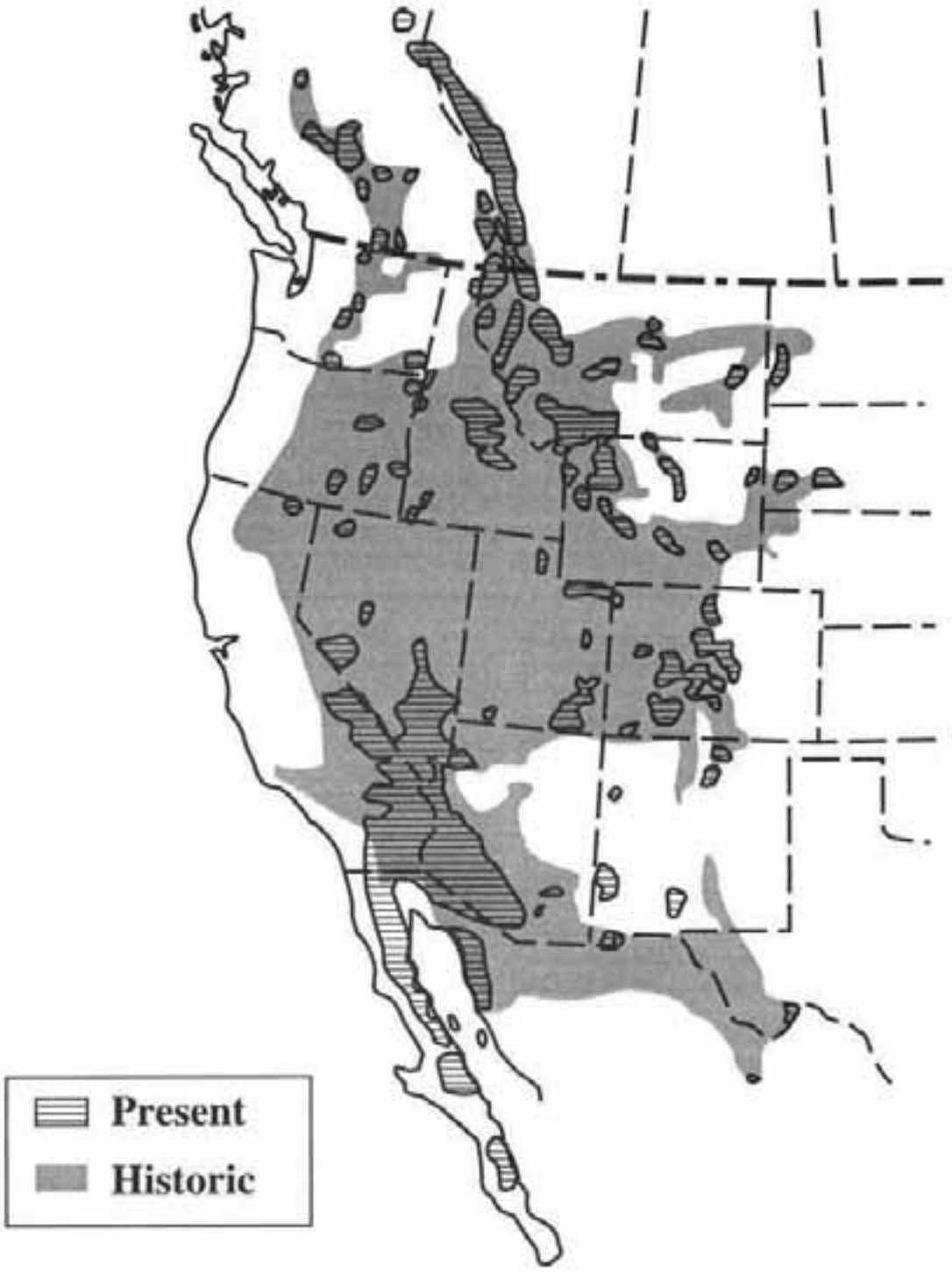

Fig. 1 - Present and Historic Distribution of Mountain Sheep in the Western United States (after Wishart 1978).

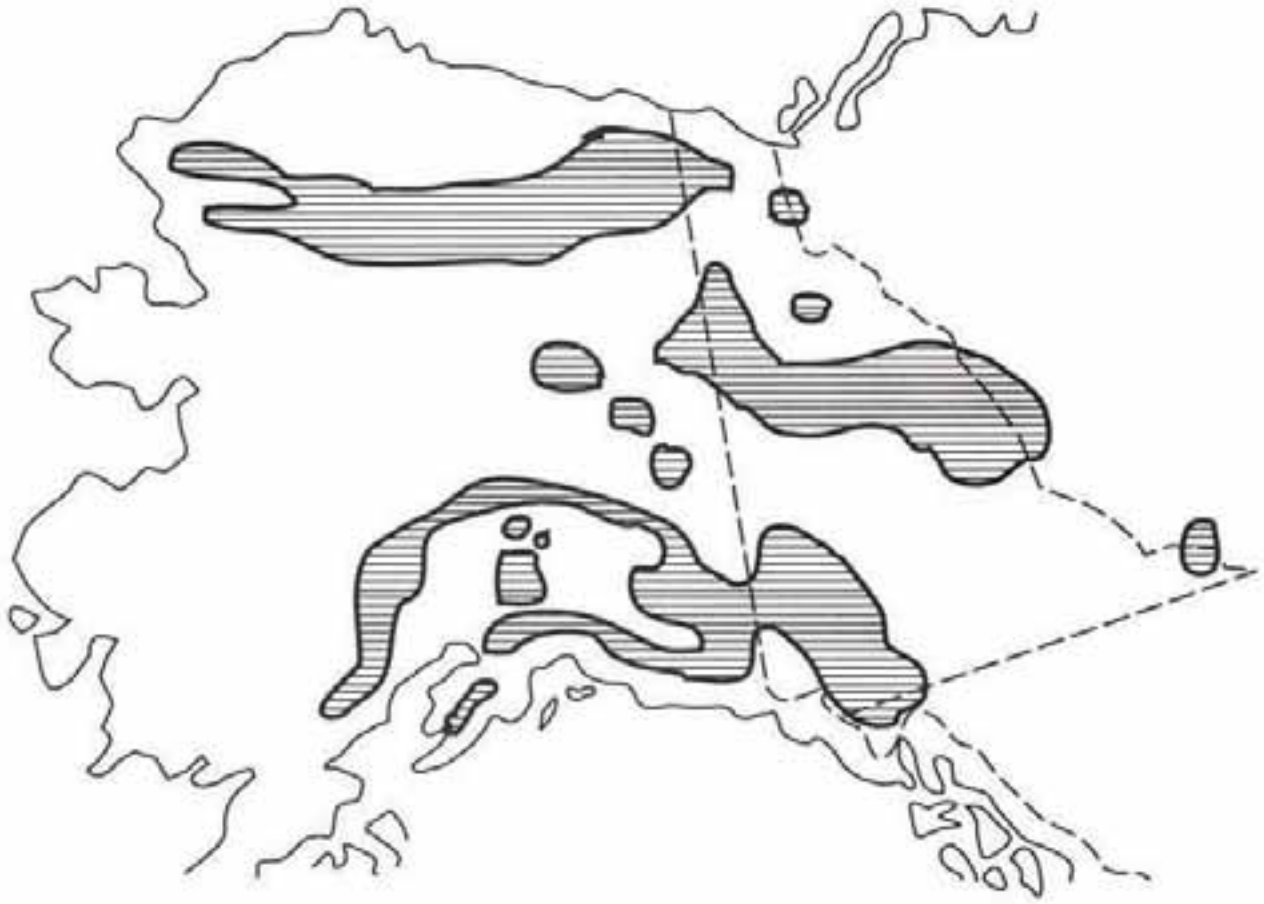

Fig. 2 - Present Distribution of Dall Sheep in Alaska and Canada (after Nichols 1978).

Fig. 3 - Present and Historic Distribution of Desert Bighorn Sheep in the Western United States.

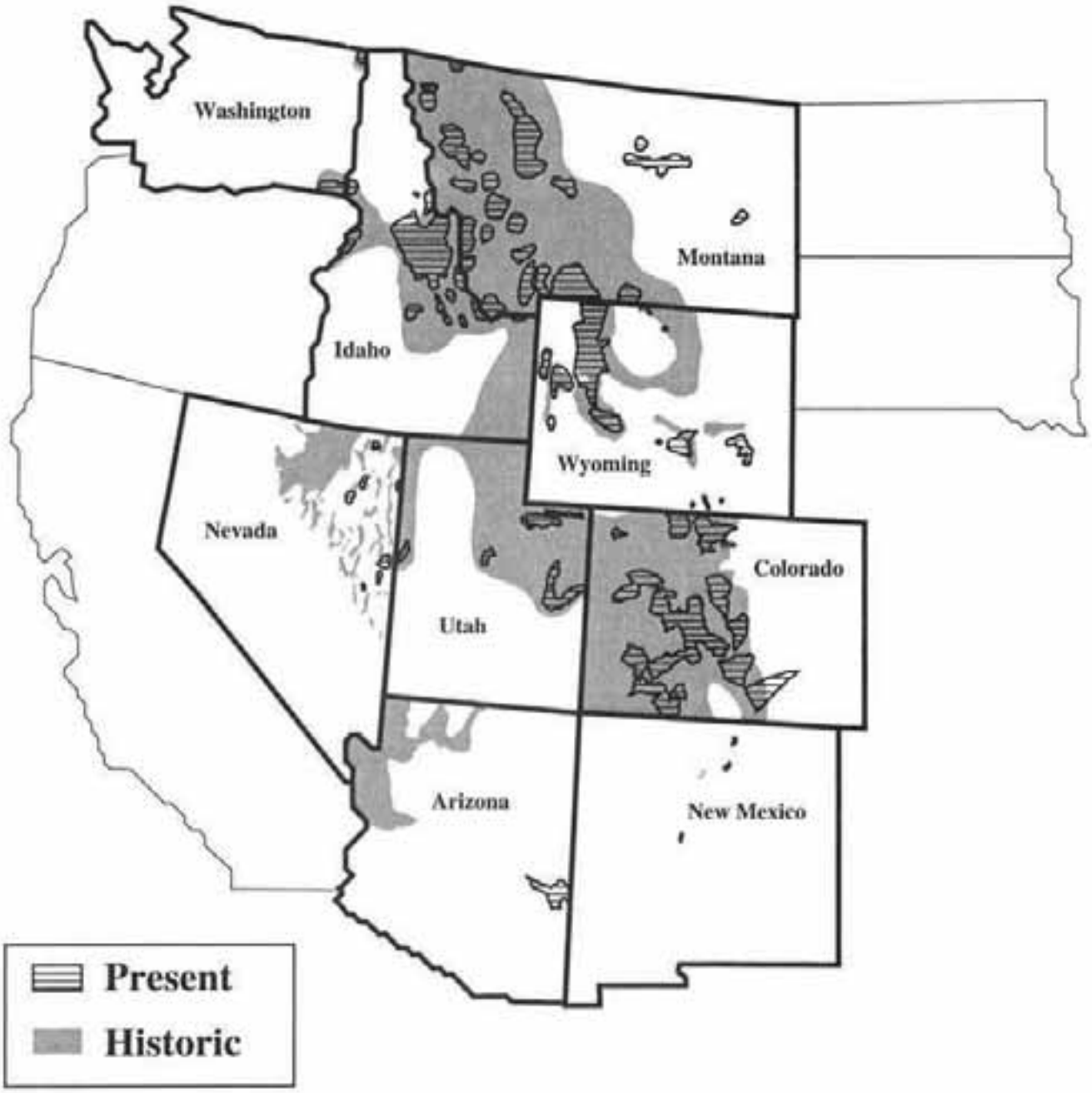

Fig. 4 - Present and Historic Distribution of Rocky Mountain Bighorn Sheep in the Western United States.

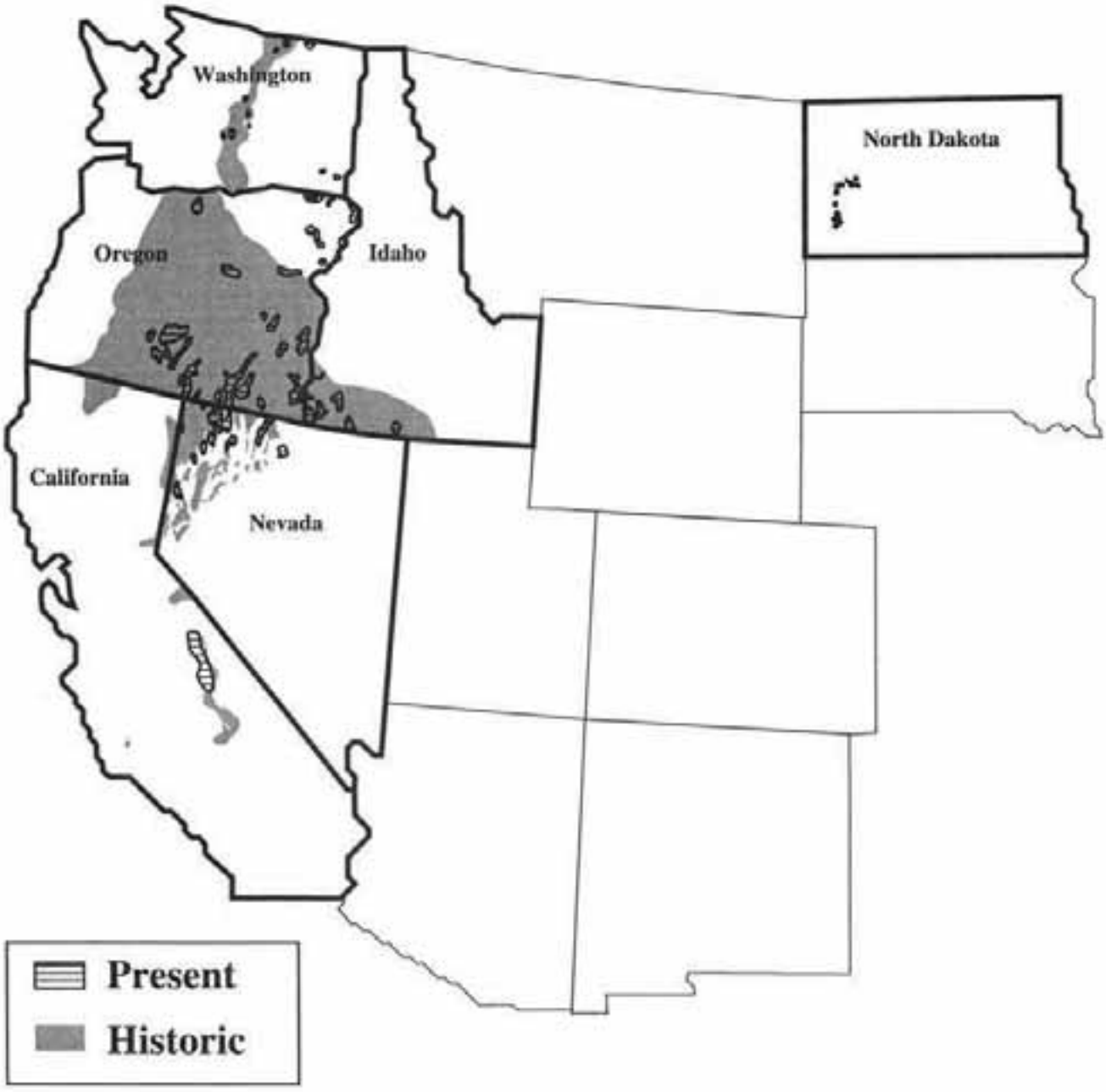

Fig. 5 - Present and Historic Distribution of California Bighorn Sheep in the Western United States

facilitating dispersal and hence maintaining viable populations. Metapopulation studies developed deductively, with extensive use of mathematical models and, with extensive testing of any advances against observational data and experimental systems. On the other hand, landscape ecology is holistic in its approach and focuses on the entire landscape. Merging of the 2 disciplines should make for exciting scientific synthesis.

One of the first strategy plans based on landscape ecology being prepared by the BLM through interagency cooperation is entitled, *Mountain Sheep Ecosystem Management on Public Lands*. This planning effort will establish Bureau-wide goals for managing the thinhorn sheep and 3 bighorn sheep subspecies which occur on public land. These wild sheep are Dall sheep (*Ovis dalli dalli*) (Fig. 2), desert bighorn sheep (*O. c. nelsoni*) (Fig. 3), Rocky Mountain bighorn (*O. c. canadensis*) (Fig. 4), and California bighorn (*O. c. californiana*) (Fig. 5). In order to prepare such a plan we need to understand as much as possible about current management practices, wild sheep distribution, population numbers, population and habitat limiting factors, and several management support items including habitat manipulation projects, land acquisition exchange needs, and right-of-way acquisition. One of our first steps was to quantify and document these items. We will limit the discussion in this paper to those responses pertinent to metapopulation management.

We thank all the state wildlife agencies, BLM, USDA Forest Service, and private members of the interagency team who developed the questionnaire used to gather the needed information and who will continue to be involved in the task of completing the plan.

METHODS

A compiled dBASE IV data base in the form of a questionnaire was sent to all 138 BLM field offices. Although the BLM biologists were to respond directly to the questionnaire, all responses were to be coordinated with state wildlife agencies and other federal agencies. To date, 134 (97%) of those contacted have responded. Questions tied directly to analyzing the state of metapopulation management included total number of habitat acres currently occupied, total number of acres that are suitable habitat but unoccupied, total acres of historic habitat which are no longer suitable for habitation, and factors which limit habitat use. Suitability is determined from habitat inventory results. The questions were to be applied to a biological unit or bioregion by species or sub-species. A biological unit/bioregion is defined as a territory having a combination of biological, social, and geographic criteria, rather than geopolitical considerations; generally, a system of related, interconnected ecosystems. In most cases, this formerly was called a herd unit. Because Canada is not presently included in this planning effort, we are reporting only on sheep populations within USA.

RESULTS

The 134 respondents provided information for 252 biological units/bioregions. From a total of 57,743,704, acres, 81% (46,576,169 acres) are occupied habitat, 6% (3,611,274 acres) are unoccupied suitable habitat and 13% (7,556,261 acres) are historic unsuitable habitat. Within the 252 total biological units/bioregions, 24% are unoccupied, 24% have a population of 50 or less individuals, 25% have a population between 51 and 100, and 27% support populations of >100 individuals. Analysis of the habitat information was completed for individual species and sub-species.

Dall Sheep

Dall sheep in Alaska. Alaska contains 29,475,300 acres of Dall sheep habitat (Fig.2). Dall sheep currently occupy 96% (28,339,300 acres) of the total with unoccupied suitable and historic unsuitable each being 2% or 468,000 acres and 668,000 acres respectively.

Desert Bighorn Sheep

Six of the 11 western states provide a total of 17,501,022 acres of habitat (Fig. 3). Desert bighorn sheep occupy 75% (13,143,340 acres) of this area with 9% (1,531,672 acres) suitable but unoccupied and 16% (2,826,010 acres) unsuitable historic habitat.

Rocky Mountain Bighorn Sheep

Ten of the 11 western states provide a total of 7,430,439 acres of habitat (Fig. 4). Rocky Mountain bighorn sheep occupy 52% (3,842,056 acres) of this area while 13% (951,964 acres) is unoccupied but suitable and 35% (2,636,419 acres) is unsuitable historic habitat.

California Bighorn Sheep

Five of the 11 western states provide a total of 3,336,943 acres of habitat (Fig.5). California bighorn sheep occupy 37% (1,251.473 acres) with 20% (659,638 acres) unoccupied but suitable and 43% (1,425,832 acres) unsuitable historic habitat.

DISCUSSION

With 134 respondents listing a total of 252 biological units, it is not clear if the metapopulation management approach has become a working concept. A review of Figures 2 through 5 indicates the application of metapopulation management principles are being applied unequally throughout the 11 western states and Alaska. Several of the respondents have mapped and reported on individual local populations rather than displaying and discussing existing metapopulations.

With a 1993 total estimated population of 72,396 wild sheep in the western United States and Alaska we have made some progress in increasing sheep numbers from the estimated population of 65,725 in 1974 (Trefethen 1975). Of the 252 biological units reported, 60 (24%) have a "0" population. Eighteen of the 60 biological units with "0" populations are predicted to be populated by the year 2000 through transplants and dispersal. We presume these 18 represent the suitable unoccupied habitat. The remaining 42 "0" population biological units should represent the 7,556,261 acres of unsuitable historic habitat which indicates continued fragmentation of habitat. Discarding the 60 "0" populations we are left with 192 occupied biological units. Taking the conservative approach and following Berger (1990) we conclude that sheep in 32% (61) of the remaining 192 biological units will likely go extinct within 50 years. Wehausen (1995) reviewed Berger's work and has raised doubt concerning the likelihood of these populations actually going extinct. Careful population monitoring will be necessary to determine which view is correct. This amount of time, taken in the context of biodiversity and ecosystem management, is not adequate to state there would be a viable population or metapopulation in those biological units. A worst case scenario for the 61 populations which could go extinct within 50 years is that an additional 3,705,263 acres of presently occupied habitat would be lost.

The majority of occupied habitat is found in those areas where the human influence is least felt. Fifty one percent of occupied wild sheep habitat occurs in Alaska with the remaining 49% spread through the 11 western states. At the other end of the spectrum, 50% of the unsuitable historic habitat is found in 4 states, including California (18%), Nevada (13%), and Wyoming and Idaho (10% each). This finding is consistent with the thrust of landscape ecology which is particularly concerned with the human role in landscape development (Hanski and Gilpin 1991). California has not only undergone tremendous urbanization during the 20th century, it joins the other 3 states in having widespread, intensive livestock grazing. Livestock grazing was the primary habitat limiting factor cited by the majority of those responding. Other habitat limiting factors included habitat fragmentation and timber management. Habitat fragmentation can be a cause for population decline or extinction as a result of land use practices. Aggressive reintroduction programs, where appropriate, could raise the total occupied habitat by 6%.

Review of the questionnaire results on a species and subspecies basis supports the general consensus that increased habitat fragmentation leads to populations and habitats that are in jeopardy.

Dall Sheep

Dall sheep habitat is the least fragmented of all the species and subspecies addressed in this paper. Its 7 biological units range in size from over 21,000,000 acres to 690,400 acres. Population figures for Dall sheep appear to have remained basically stable over the last 20 years. Alaska is extremely low in human population for its size, with limited access to many parts of the state. Livestock grazing is not an issue in Alaska at this time. Once the land selection issues associated with the Native Claims Act have been resolved, the metapopulation situation may change.

Desert Bighorn Sheep

Three of the 20 biological units identified with "0" population are suitable unoccupied habitat. The remaining 17 represent the 2,636,419 acres of unsuitable historic habitat. A review of Figure 7 illustrates the habitat fragmentation that has taken place to date. Fifteen of the remaining 70 biological units support population levels of less than 50 individuals, potentially predisposing desert bighorn habitat to a loss of approximately 1,701,056 acres (a 10% increase in habitat loss in the next 50 years). A continued aggressive reintroduction and augmentation program into appropriate locations could perhaps recover 9% of the habitat available.

decrease the potential for extinction of low population habitats, and increase metapopulation potential by lowering habitat fragmentation. Livestock grazing, habitat loss and habitat fragmentation are identified as habitat limiting factors. In states where livestock grazing has been identified as a major habitat limiting factor, disease could be carried from population to population by individuals who have had nose to nose contact with domestic sheep. Livestock grazing in this context is in itself a habitat fragmenting activity. In California, what should be one extraordinarily large metapopulation is fragmented into 5 smaller metapopulations by fenced, multiple-lane highways and, two open aqueducts.

Desert bighorn sheep populations appear to have increased over the past 20 years from approximately 11,115 individuals in 1974 (Trefethen 1975) to 15,858 in 1993. Livestock grazing and disease are the top 2 population limiting factors.

Rocky Mountain Bighorn Sheep

Three of the 16 biological units identified with "0" population are suitable unoccupied. The remaining 13 biological units represent unsuitable historic habitat areas which indicates a loss of 35% of the total habitat for these sheep. A review of Figure 4 illustrates the habitat fragmentation that has taken place to date. Fifteen of the remaining 55 biological units support population levels of less than 50 individuals, predisposing Rocky Mountain sheep habitat to a loss of approximately 1,433,161 acres of habitat (a 19% increase in habitat loss in the next 50 years). An aggressive reintroduction program into appropriate locations could perhaps recover 13% of the habitat available and increase metapopulation potential by lowering fragmentation. Livestock grazing, timber management practices and habitat fragmentation are identified as habitat limiting factors. Rocky Mountain bighorn sheep populations appear to have decreased over the past 20 years from approximately 13,110 individuals in 1974 (Trefethen 1975) to 9,163 in 1993. Livestock grazing and disease are the top 2 population limiting factors.

California Bighorn Sheep

Eleven of the 24 biological units with "0" population are suitable unoccupied. The remaining 13 biological units represent unsuitable historic habitat areas which account for the 43% loss of total California bighorn sheep habitat. Thirty of the remaining 60 biological units support populations of less than 50 individuals, which raises the potential for the loss of 727,126 acres or 22% more habitat. An aggressive appropriately designed reintroduction program could increase the occupied portion of total habitat by 20% which may lower the high level of habitat fragmentation which is evident (Fig. 9). Livestock grazing, and habitat fragmentation are 2 of the top habitat limiting factors.

California bighorn sheep populations have increased over the last 20 years from approximately 1,500 in 1974 (Trefethen 1975) to an estimated 4,995 individuals. This apparent paradox demonstrates a "semi-feast or famine" population situation. Sixty percent of the occupied biological units with populations greater than 50 individuals contain populations in excess of 100 individuals. Most of the remaining populations are close to a 100 individuals per area level. A review of the amount of acres contained within the occupied areas results in a determination of high density populations. If, as reported, livestock grazing and disease are the primary population limiting factors, these high density fragmented populations could quite easily become endangered. This has been demonstrated in 4 populations in California.

RECOMMENDATIONS

The largest single road block to adequate ecosystem management is the ability to change attitudes and agency thought processes. For a highly vagile species such as bighorn sheep, large areas must be managed for wide-ranging metapopulations. With these points in mind, we offer recommendations for implementing and maintaining the metapopulation/landscape ecology approach needed to insure the continuation of viable bighorn sheep populations.

1. All agencies involved in management of bighorn sheep must move from territorialism to mutualism. We are all working to perpetuate a species which is wide ranging and has no ability to recognize jurisdictional boundaries. We, therefore, are acting imprudently if we ignore natural laws in favor of "territorial imperative."
2. Using the interagency plan being prepared for BLM as a starting point, bighorn sheep biologists and managers should form interagency advisory groups. There should be a group for each separate species and subspecies. Each interagency group should undertake the following tasks.

a. Determine the current geographical distribution of the target wild sheep.

b. Determine where the geographical distribution has been fragmented into metapopulations and local scale populations.

c. Establish the functionality of these metapopulations and local populations in terms of their viability through population demographic studies and habitat trends.

d. Establish where within the geographical distribution there is potential for recovery of "lost" habitat and put a strategy in place to accomplish the recovery.

e. Implement a strategy which will maintain viable metapopulations far into the future.

3. Develop ecosystem based guidelines for continual successful management of wild sheep on a metapopulation basis and provide to all agencies and private organizations involved with bighorn sheep management

The Northern Wild Sheep and Goat Council and the Desert Bighorn Council may be the appropriate organizations to work with agencies and other organizations in forming the interagency groups.

LITERATURE CITED

BERGER, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conserv. Biol. 4:91-98.

____, AND J. D. WEHAUSEN. 1991. Consequences of a mammalian predator-prey disequilibrium in the Great Basin Desert. Conserv. Biol. 5:244-248.

BLEICH, V. C., J. D. WEHAUSEN, AND S. A. HOLL. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conserv. Biol. 4:383-390.

FORMAN, R. T. T., AND M. GODRON . 1986. Landscape ecology. John Wiley & Sons., New York, NY.

HANSKI, I., AND M. GILPIN. 1991. Metapopulation dynamics: brief history and conceptual domain. Pages 3-16 in M. Gilpin and I. Hanski (eds.), Metapopulation dynamics: empirical and theoretical investigations. Academic Press, San Diego, CA. 336 pp.

NICHOLS, L. JR. 1978. Dall's sheep. Pages 173-189 in J. L. Schmidt and D. L. Gilbert (eds.), Big game of North America. Stackpole Books, Harrisburg, PA. 494 pp.

RAMEY, R. R. II. 1991. Genetics and conservation of North American mountain sheep: implications for management on BLM lands. Rpt. to the Bureau of Land Manage. Denver, CO. 25 pp.

SCHWARTZ, O. A., V. C. BLEICH, AND S. A. HOLL. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. Biol. Conserv. 37:179-190.

TREFETHEN, J. B., (ed.). 1975. The wild sheep in modern North America. Boone and Crockett Club. The Winchester Press, New York, NY. 302 pp.

WEHAUSEN, J. D. 1995. Rapid extinction of mountain sheep populations revisited. Presented at the 39th Annual Meeting of the Desert Bighorn Counc., Alpine, TX. (In Press).

WILCOVE, D. S., C. H. MCLELLAN, AND A. P. DOBSON. 1986. Habitat fragmentation in the temperate zone. Page 237-256 in M. E. Soule (ed.), Conservation Biology. Sinauer Assoc., Inc., Sunderland, MA. 584 pp.

WISHART, W. D. 1978. Bighorn sheep. Pages 161-171 in J. L. Schmidt and D. L. Gilbert (eds.), Big game of North America. Stackpole Books, Harrisburg, PA. 494 pp.