# POPULATION MONITORING

In November 2002, the Legislative Audit Division of the State of Montana reported on a performance audit of the FWP big game inventory and survey process (Legislative Audit Division, 02P-05, 2002). Conclusions and recommendations in the report as summarized in the 2005 Elk Management Plan are as follows:

1) The department employs game management methods that compare to accepted standards, but could improve its process.
2) The current techniques used to assess game population status have evolved from compromise among needs for accuracy, financial restrictions, and personnel availability.
3) The department could refine its techniques for all species to better incorporate strategies that relate to more thorough and objective analyses.

More specifically, the legislative auditor recommended the department refine its survey and inventory techniques for all species to better incorporate the concepts of:

1) Repetitive surveys of representative management areas;
2) Standardized and documented protocol that is easily transferable;
3) Use of visibility bias adjustments and required sample sizes;
4) Tying survey results directly to management objectives and subsequent recommendations;
5) Understandable and concise presentation to the public based on objective analysis.

In a formal response to the legislative auditor, FWP recognized the validity of the recommendations but pointed out the difficulty and expense in attempting to estimate exact population numbers. Instead, for most big game species, FWP conducts trend surveys to determine relative change in population numbers across several years. Trend counts are the basis for monitoring populations in relation to objectives and for making hunting season permit/license level recommendations to meet objectives.

In most bighorn sheep hunting districts in Montana, annual surveys are conducted with an attempt at total coverage of bighorn sheep distribution within the district. Montana has not used any type of population estimation but has relied on the trend in actual number of bighorn sheep counted to make management decisions and hunting season recommendations.

Because bighorn sheep are hunted conservatively, FWP biologists believe the need for precise population estimates is outweighed by reliable trend data collected systematically over time. Surveys are conducted annually in 34 hunting districts and periodically for five smaller populations that currently are not hunted. Almost all surveys are conducted using helicopters, and surveys are flown, with few exceptions, in late winter to early spring, prior to animals moving from winter ranges.

Wildlife biologists and researchers generally recognize that some form of population estimation, if done correctly, can provide a more accurate assessment of actual bighorn numbers (Irby et al. 1988; George et al. 1996; Rabe et al. 2002). However, George et al. (1996) found that while sightability probabilities were similar between survey flights in alpine habitats, they varied widely in timbered habitats. A similar situation exists in northwestern Montana where habitats used by bighorn sheep, particularly rams, consist of dense coniferous forests making observability of rams difficult and results variable. While long-term population trend data in this area may be reliable, other data gathered in conjunction with aerial survey data, such as the average age of rams in the harvest, are used when making recommendations for the number of either-sex licenses to issue.

Differences in survey methods and results and differences in demographic responses of deer among five ecological/habitat management units (Northwest Montane, Mountain Foothills, Prairie/Mountain Foothills, Southern Mountains and Prairie/Breaks) were recognized in Montana's Adaptive Harvest Management for mule deer (Wildlife Division, FWP, 2001). Bighorn sheep are distributed within these same habitat units and also have somewhat different population dynamics as a result of the variations in habitat. To develop accurate sightability models for bighorn sheep across Montana, individual models would have to be developed for each management unit. Accomplishing this task would require marking an adequate number of animals in at least one population in each management unit and doing repetitive surveys to develop the sightability index.

FWP has accomplished this in some areas for elk and mule deer but not for bighorn sheep. Because of budget constraints, FWP annually prioritizes survey efforts for most big game species, and the cost of developing a sightability index for bighorn sheep on even one management unit is probably not realistic. One possibility, as suggested by Rabe et al. (2002), is to stratify a state by habitat type (in this case by management unit) and randomly select a sample of the hunting districts in each unit to develop sightability models, or survey the same selected districts annually to develop trend data. Presumably, the information collected would be applicable to other districts/populations in a particular unit.

Two concerns that confront any wildlife survey effort are: 1) what is the information going to be used for (objectives) and 2) is the quality of the information collected adequate to choose between alternative management actions in order to meet objectives.

In Montana, survey information is used to assess whether population objectives for individual hunting districts are being met. Season recommendations are made based on survey information that informs a basic population model in order to estimate allowable harvest (see Population Management section). Survey results also are used to evaluate the health of various herds locally and statewide. Specifically, biologists examine lamb production and recruitment to assess to some degree the health of individual populations on an annual basis (e.g., low recruitment may indicate poor herd health).

Survey methodologies in Montana have evolved over time and are for the most part specific to the individual population or region where habitats and bighorn sheep seasonal use of habitat is similar. Choice of methods considers the type of aircraft utilized, the best time of year to observe sheep in a particular habitat, conducting flights in the best observational conditions, flying with experienced pilots and observers, and consistent coverage of areas considering bighorn sheep distribution at the time of survey.

As is the case in any wildlife survey effort, variables encountered during surveys add uncertainty to survey results, so survey data should be interpreted by or in collaboration with the person doing the survey. Biologists in Montana believe the current survey efforts are adequate to answer questions about population objectives and herd health. Specifically, trend data has been sufficiently accurate to determine the number of ewe licenses to issue for population management in larger herds, to determine lamb production and recruitment rates in relation to herd health, and to recommend harvest rates that sustain the desired age structure in the ram segment.

The challenge for the future is to maintain the current level of survey efforts on bighorn sheep. With increasing costs of aircraft rental and potential loss of qualified pilots and observers, it is possible survey efforts will have to be scaled back and locations and frequency of survey efforts prioritized.

If resources to survey not only bighorn sheep, but also all big game species become more limited, we recommend the following prioritization criteria:

1) Hunting districts that are at population objective and are currently being managed either through harvest of ewes and/or translocation should be surveyed annually.
2) Hunting districts that typically issue more than three licenses for rams should be surveyed on an annual basis, if possible, to determine the number of licenses to issue.
3) Newly established populations should be surveyed annually to determine seasonal distribution and population status in relation to objectives.
4) Hunting districts that issue one to three licenses for rams or have quotas for that number of rams could be surveyed every other year.

## Information Collected

A difference in the method used to classify rams, which occurs in only a few hunting districts, is the primary inconsistency in statewide data collection. This is not a large problem, and to a degree is merely a matter of semantics, but we recommend that rams be classified by the degree of curl and not class of ram. A suggested form for data collection is contained in Appendix G.

When surveying bighorn sheep, most biologists record waypoint locations. This information is important for developing seasonal distribution maps, and actual location data is also being used as the primary input into a habitat evaluation model (see Translocation section).

FWP has been slowly implementing statewide databases for big game survey data. These databases are essential for timely assimilation of data for a regional, statewide, and range-wide analysis.

## Harvest Survey Information

Hunters are surveyed by telephone after the hunting season ends to determine their success. Although the success rate on ram (either-sex) licenses is generally at or near 100%, it does vary in some districts where ewes are hunted. Reported average success rates by district are important to help determine the number of ewe licenses to issue in a district to achieve a certain harvest level (see Population Management section).

Hunters harvesting a ram must personally present the complete head and intact cape within 48 hours to any FWP office, game warden, or designated employee in the administrative region where the bighorn ram was taken. At that time, FWP employees record biological and other data on a Bighorn Sheep Harvest Form.

In the past, there was no central repository for these forms and information was frequently lost. Beginning in 2007, FWP began entering data from harvest forms for a number of species directly into a Mandatory Reporting Response Entry System (MRRE) soon after the form was filled out. The MRRE is located on FWP's internal site and is available to employees. This system has greatly enhanced access to bighorn sheep harvest data and will be an asset in summarizing this data for hunting districts, as well as on a regional and statewide basis, in a timely and accurate manner.

# POPULATION MANAGEMENT

Although there are some statewide objectives for bighorn sheep management in this Conservation Strategy, it is the objectives for individual populations/hunting districts that define bighorn sheep management in Montana.

Chapter 2 of the Conservation Strategy presents the objectives, demographic criteria, and strategies, including harvest prescriptions, for individual populations/hunting districts. In this section, there is a brief description of the history of bighorn sheep management in Montana, how the "prescriptive process," which uses Adaptive Harvest Management (AHM) concepts, was developed, and how prescriptions work to achieve specific objectives.

Montana currently manages hunting of bighorn sheep through a number of different hunting regulations (see Hunting, Chapter 1). In 2008, there were 36 hunting districts open for hunting, with hunting of rams managed with either-sex licenses for 28 of those, a legal ram regulation for seven districts and an any-ram regulation for one district. Population levels of bighorn sheep are managed primarily through issuance of adult ewe licenses, translocation, a combination of the two, or are self-regulating (i.e., generally due to habitat constraints). In 2008, FWP issued a total of 245 ewe licenses in 16 hunting districts. Additionally, populations that have gone through a die-off are generally slow to recover to former status due to decreased lamb recruitment. Such populations may recover sufficiently to provide limited ram harvest, but in the case of significant mortality due to a pneumonic event, recovery may only reach what may be considered a minimum viable population (see Translocation section). Harvest of ewes would not be necessary or justified in such cases. Populations that have gone through a significant die-off generally should have objectives reduced, even if the population may have sustained significant ewe harvest prior to the die-off. This reduction reflects what the population could produce and sustain and not raise expectations to the public that may not be attainable. If populations do recover, this Conservation Strategy is intended to be flexible enough to allow revision of objectives to reflect recovery.

In the past, the process for recommending the number of licenses to be issued has not been consistent among biologists across the state. Because bighorn sheep populations are relatively small and management is often designed around producing "trophy" males, license/quota levels have been conservative. One of the primary objectives in the development of this Conservation Strategy is to tie the existing and proposed hunting season structure and license/quota levels to the monitoring program. As part of this effort, objectives for populations and ram characteristics within those populations that are currently hunted have been developed; likewise for populations where hunting may occur in the future and for populations that have gone through declines and are in a recovery stage. These objectives are presented in the individual hunting district/population management strategies in Chapter 2.

In small, self-regulating populations or populations that have gone through a recent die-off event, generally populations of less than 125, no ewe licenses are issued and the number of ram licenses issued is usually based on the number of legal rams (¾-curl) observed during annual or periodic surveys. In 2008, FWP offered one to three either-sex licenses in 11 hunting districts and one to three legal ram licenses in seven districts. In the case of the five unlimited districts, these were quotas, not licenses. Monitoring and management of these districts in relation to hunting is straightforward, and licenses/quota levels have changed little over time.

Monitoring and meeting objectives for individual populations becomes more complex in districts where FWP issues more licenses for the ram segment, ewe licenses are issued, and/or trapping and transplanting may occur. In recent years, Montana has implemented AHM concepts into the hunting regulation process for mule deer and elk (Wildlife Division, FWP, 2001, 2005). Comparable bighorn AHM consists of:

1) Objectives for numbers of bighorn sheep and counted sex/age ratios in the populations.
2) A strong monitoring program (post-season aerial surveys) to measure total numbers of bighorn sheep counted and sex/age ratios in the populations
3) Sets of hunting regulation alternatives to implement when bighorn sheep are at Standard Package, Liberal Package (above), or Restrictive Package (below) objectives.

FWP then monitors results of the implementation of regulation alternatives to determine if objectives are being achieved. If monitoring indicates that regulation packages are not achieving objectives, the AHM process will be flexible enough to permit design and implementation of new regulation packages. The AHM process also affords the opportunity to use multiple competing models of population dynamics, which can be used along with monitoring data to provide insight into the population dynamics of bighorn sheep, such that the prescriptive abilities improve over time as learning occurs. The Conservation Strategy will therefore evolve, and as objectives can change, learning from the AHM process occurs.

At this stage of implementation, the AHM process for bighorn sheep management assumes only a single additive mortality/density independent reproduction population model that is used to predict the effects of regulation alternatives on bighorn sheep populations relative to objectives. AHM is a dynamic, learn-as-you-go process. There will be a need to adjust population objectives, monitoring parameters and guidelines, population models, and hunting regulation packages as results of the initial efforts are determined through monitoring. Therefore, the public should realize that the Conservation Strategy is not set in stone, but will evolve as learning takes place through the AHM process. Further, although the Conservation Strategy will serve as a source of information and guidance to the FWP Commission, it does not preempt Commission authority to formulate annual rules, set hunting seasons and regulations, or implement emergency actions in response to unexpected events or circumstances.

## Population Management Through Ewe Harvest

Population objectives for individual populations have been developed by local biologists based on a number of factors including:

1) The ability of the habitat to support a given number of bighorn sheep (particularly winter range).
2) Amount, type, and distribution of other grazing animals (both native and domestic).
3) Public access to bighorn sheep and the habitat they use, which influences the ability to manage numbers through hunting and translocation.
4) Populations are managed below what is considered carrying capacity to keep densities down in an attempt to reduce the potential for disease outbreaks.

The ability to manage for these objectives varies depending on the current status of the overall population and thus the different season packages or prescriptions for some populations. In 1995, the U.S. Fish and Wildlife Service (USFWS) began using AHM concepts in managing waterfowl. Subsequently, in 1997, a specific strategy was developed using AHM for northern pintails (*Anas acuta*) and is still in use today. The goal of the strategy, which is pertinent to managing bighorn sheep, is to maintain harvest opportunity consistent with current population status while reducing acrimony about annual regulation setting by basing it on objective biological criteria (USFWS 2007).

FWP used some of the basic concepts in the pintail strategy to develop the basic population model for managing bighorn sheep populations, particularly the female segment. The model is described by the following equation, and its application is also explained below:

### Ewe Harvest Model

The predicted ewe population ($E_{t+1}$) in year t + 1 is calculated as:

$$E_{t+1} = \{[E_t + (L * 0.5)] * 0.95\} * (1 - HR)$$

where:
$E_t$ = number of ewes at time of survey
L = number of lambs at time of survey
L * 0.5 = number of female lambs at time of survey

0.95 = annual survival rate (Jorgenson et al. 1993, 1997) (In this model it is assumed to be equal for lambs and adult females)

HR = harvest rate (Harvest rate varies depending on population status)

In this model $\{[E_t + (L * 0.5)] * 0.95\}$ is the number of ewes entering the fall hunting season and $(1 – HR)$ is the survival rate during the hunting season. The utility of the model is to calculate the number of licenses to issue to achieve a desired ewe population level the following year. This is accomplished by varying the harvest rate based on the status of the other elements in the model.

HR is calculated by:

$$HR = \frac{TH}{\{[E_t + (L * 0.5)] * 0.95\}}$$

where:

TH is total harvest = number of licenses issued multiplied by the management success (MS). Management success varies depending on hunting district; a recent 5-year average specific to that district would be used in the model and is the number of animals harvested divided by the number of licenses issued.

therefore:

$$HR = \frac{Issued * MS}{\{[E_t + (L. * 0.5)] * 0.95\}}$$

and:

$$E_{t+1} = \{[E_t + (L * 0.5)] * 0.95\} * \left\{1 - \left\{\frac{Issued * MS}{[E_t + (L. * 0.5)] * 0.95}\right\}\right\} \quad (1)$$

For a stable population, where $E_t+1 = E_t$ and solving for the number of licenses to issue:

$$Issued = \frac{0.95(L * 0.5) – 0.05\ E_t}{MS}$$

For an increasing population where the number of ewes is greater than objective, the specific values for $E_t+1$ and $E_t$ are entered into equation (1) above and (Issued) is solved for, providing the number of licenses to issue to achieve the objective number of ewes.

This equation can be used to predict the number of ewe licenses to recommend depending on current status of the population. By knowing the number of ewes entering the fall hunting season, the number of ewes that need to be harvested can be calculated to achieve objectives of increasing, stabilizing, or reducing the size of the ewe segment in the population. The number of licenses issued is the variable that is adjusted to achieve that objective, which is tied to the number of ewes harvested via the management success rate.

An example of how this process is applied to a population is contained in Table 3.

Additionally, for some larger populations there can be a fourth prescription where ewe harvest and translocation are both utilized to meet objectives.

## Ram Harvest Characteristics

Other than for smaller populations of bighorn sheep, where a very limited number of licenses are issued, harvest of rams is based primarily on three criteria. Those criteria consist of where the population stands in relation to overall objectives, the ram: ewe ratio, and the number or percent of rams greater than or equal to ¾-curl in the ram segment, or in some populations, the average age of rams in the harvest (Table 4). Again, these parameters vary, primarily by habitat or ecological region. In the management plans for individual populations in Chapter 2, many of the populations where a significant number of rams are harvested annually have objectives for rams that include an overall ram: ewe ratio and an average age of harvested rams. Because bighorn rams in Montana are largely managed as a trophy animal, with an average age of 6 to 7 years old, the ram: ewe ratio is based, in part, on the total number of rams it takes to produce a given number of rams that are at least ¾-curl in the harvest. The average age of rams in the harvest is based on the ability of an area or population to produce and sustain that age criteria at a given harvest rate. To recruit a relatively large number of rams into the age class depicted in objectives, it takes 40 to 60 rams: 100 ewes, depending on the area. In more productive populations or in habitats where horn growth is more rapid, rams produce horns that most hunters would consider trophy status at a younger age. For example, rams in the Missouri River Breaks (Hunting Districts 482, 622, and 680) might achieve a ¾-curl by age 3½. In comparison, a ram from the Rocky Mountain Front might not reach ¾-curl status until 5½ years of age. To achieve a similar harvest level of mature rams, or rams that meet objectives, in the Breaks situation, a lower ram: ewe ratio would be required as well as a lower average age of rams in the harvest than in the Front example.

In larger, more productive populations, ram harvest can contribute to overall population management. In such populations, the number of rams harvested can be combined with ewe harvest to determine the status in relation to population demographics.

The number of licenses issued for rams is based, in part, on harvest rates established over

| MOUNTAIN-FOOTHILLS | No. Bighorns Counted on Survey Area | Recruitment Lambs: 100 Ewes | Regulation Types | Harvest Rates |
|---|---|---|---|---|
| Standard Regulation | ± 10% of 250 | Between 30-40 | Limited Entry Ewes | Up to 15% of Ewes |
| Restrictive Regulation | More than 10% below 250 | Less than 30 | Fewer than 5 ewe licenses | Less than 5% of ewes |
| Liberal Regulation | Greater than 10% above 250 | Greater than 40 | Limited Entry Ewes or translocation if > 25 sheep including rams are available | Up to 20% of Ewes |

Table 3. Summary of regulation types under different population criteria for ewe harvest and population management.

| MOUNTAIN-FOOTHILLS | Number of Either-Sex or Legal Ram Licenses Is | When the Herd Has | | |
|---|---|---|---|---|
| | | Population Size | Ram: 100 Ewe ratio | % of Rams with ≥ ¾-curl |
| Stanard Regulation | Up to 15% of the ¾-curl rams | ± 10% of 250 | 40-60:100 | ≥ 30 |
| Restrictive Regulation | Up to 10% of the ¾-curl rams | More than 10% below 250 | < 40:100 | < 30 |
| Liberal Regulation | Up to 20 % of the ¾-curl rams | Greater than 10% above 250 | > 60:100 | ≥ 30 |

Table 4. Summary of potential ram harvest under different population parameters and criteria.

time that achieve the objective of producing trophy status animals. In the Conservation Strategy, these harvest rates are reflected through the AHM process by different season packages specific to population objectives. In most ecological regions, the number of greater than ¾-curl rams can be determined during annual surveys. The number of greater than ¾-curl rams is one of the key variables used in recommending license levels for rams. However, in the Northwest Montane Ecological Zone, which is characterized by heavily timbered bighorn sheep habitat, it is difficult to observe rams and accurately classify them. In this case, the average age of rams and horn size in the harvest, monitored over time in conjunction with aerial survey data, is used in formulating recommendations for license levels on rams.

## Criteria for Reopening Hunting in Populations Having Gone Through Major Declines

Several bighorn sheep populations in Montana have gone through major declines as a result of die-offs. In 2009, there are currently four hunting districts that are closed to hunting as a result of die-offs or declines. Bighorn sheep populations are often slow to recover following die-offs but over time several populations in Montana have gone through these types of declines and recovered sufficiently to reopen hunting. The question arises, at what stage of recovery is hunting reinstituted? Criteria have been developed and are being used in two such populations (Hunting Districts 340 and 380) and a third (Hunting District 381), which is in a declining stage and may have to be closed. These criteria are included in the management plans for those districts in Chapter 2 and reflect a recovering population that can sustain a minimal harvest. Hunting of bighorn sheep in these hunting districts will be recommended when at least three of the following four criteria have been met for a minimum of three successive years:

1) The population is at least 75 observable sheep,
2) There are at least 30 rams: 100 ewes,

3) More than 30% of the rams are at least ¾-curl, and
4) There are at least 30 lambs: 100 ewes.

Monitoring of these sheep will continue at a level sufficient to determine if these criteria are being met. If so, license levels for rams will be based, in part, on the number of ¾-curl rams observed during surveys. While these criteria may not be appropriate in every situation, similar criteria should be developed for each population that has gone through a major decline resulting in closure of the district to hunting.

## Other Opportunities

Two additional harvest opportunities exist that could contribute to population management efforts. The first is the opportunity to harvest rams of ½-curl or less. Montana initiated a ½-curl or less regulation in 1984 but used it in only two hunting districts as a population control measure (McCarthy 1986). Typically, rams ½-curl or less are three years old or younger. McCarthy (1986) further stated that younger rams might be removed from a population without affecting the future number of larger animals, as long as removal rates are compensatory for, and not additive to, natural mortality. Jorgenson et al. (1997) found annual mortality rates for two- to three-year-old males at two study areas ranged around 8-13%. Some populations have almost an equal number of rams and ewes, and the number of ½-curl or less rams can make up a significant number of the total ram population. Therefore, harvest under this regulation could contribute moderately to population management. Additionally, younger rams tend to wander and have the greatest potential for mixing with domestic animals. Limited harvest of young rams may reduce the risk of the mixing of wild sheep and domestic livestock.

Another harvest opportunity, which would be a new concept and need FWP Commission approval, is to allow the holders of either-sex licenses for hunting districts that are over population objectives to purchase an additional license to allow them to harvest an ewe. The idea is that to many holders of an either-sex license, which for most people will be their only opportunity to harvest a bighorn in Montana, it would be of interest to them to harvest a ewe along with a ram. This would be another way to increase ewe harvest where needed.

The opportunity to combine aspects of the current unlimited season structure with aspects of a limited-entry structure in certain areas is a hunting season concept in need of consideration and discussion. Montana is the only state that currently offers unlimited hunting in some areas. Historically, districts that offered some unlimited hunting opportunities provided a tremendous amount of hunter opportunity and at times contributed significantly to statewide harvest. Most of Montana's bighorn sheep populations would not be able to sustain an unlimited season structure, primarily because of ease of access, which could result in excessive harvest of the ram segment. However, FWP needs to explore situations, innovative season structures, and other possibilities for improving hunter access to harvest bighorn sheep in Montana.

## Metapopulations – Positive and Negative Aspects

The concept of using a metapopulation approach to ensure the sustainability of bighorn sheep has in recent years become popular among conservation biologists and wildlife management agencies. A metapopulation is a set of populations distributed over a number of patches that are connected, to varying degrees, by dispersal (Hess 1996). A patch in relation to a bighorn sheep metapopulation would be a defined portion of the landscape that contains all the elements (food, cover, and water) that support a subpopulation of the metapopulation. The functionality of a metapopulation is determined by population dynamics and population movements. Corridors are the mechanism providing interchange among populations. The objectives of metapopulation management include:

1) Minimizing extinction rates of species threatened by habitat loss and fragmentation.
2) Distributing members of a species among several geographically disjointed areas of suitable habitat to provide protection against extinction caused by a single catastrophic event.
3) Providing movement to recolonize areas in which a population has gone extinct (Hess 1996).

Bailey (1992) points out the need for developing long-range plans to maintain or enhance bighorn sheep herds and metapopulations. Risenhoover et al. (1988) indicated that as a first step in maintaining or reestablishing traditional movement patterns of bighorn sheep, seasonal ranges and migration corridors should be identified.

Once identified, specific projects to maintain or create interconnections among populations can be implemented (Bailey 1992). In a review of studies on corridors, Beier and Noss (1998) cited several studies offering evidence that population viability is improved in habitats connected by corridors.

## Metapopulations – Positive Aspects

Some of the benefits of a viable metapopulation are maintaining or increasing genetic variation, which increases the fitness of the individual as well as the population (Lacy 1997). Further, lower genetic variation depresses individual fitness, resistance to disease and parasites, and flexibility in coping with environmental challenges. Fitzsimmons and Buskirk (1992) suggested that corridors providing for connectivity, dispersal, and gene flow among populations can offset habitat fragmentation and herd isolation, thereby providing for genetic variability and population viability. Generally, metapopulations have a larger population size than isolated populations of bighorn sheep, and metapopulations also have a larger patch size. Singer et al. (2001), in analyzing 24 translocated populations of bighorn sheep, found that population size and patch size played a significant role in the ability of a population to recover rapidly from an epizootic event.

In a program to restore bighorn sheep populations in and near several western national parks, Singer et al. (2000) attempted to establish metapopulations. This approach was thought to produce populations that would be less vulnerable to extirpation than small, isolated populations due to demographic or stochastic events or contact with domestic sheep. Also, metapopulations would be less susceptible to rapid losses of genetic heterozygosity, inbreeding depression, or genetic drift associated with small population sizes and insularity.

To simulate the process of genetic flow created by a metapopulation, wild sheep managers have augmented isolated populations with a few sheep from other populations. Hess (1996) stated that it is not clear that moving individuals among populations to increase genetic diversity will provide protection against exotic diseases introduced into naïve populations. However, Hogg et al. (2006) were able to demonstrate that, due to augmentation of an isolated bighorn sheep population with a few individuals from an outbred population, there was marked improvement in reproduction, survival, and other fitness-related traits.

## Metapopulations – Negative Aspects

While maintaining connectivity among subpopulations can have positive benefits, there is some evidence that increased contact increases the prevalence, incidence and rate of disease spread in the overall population, and increased contact can enable a disease to persist within the metapopulation (Hess 1996). Corridors connecting subpopulations can act as conduits for contagious diseases, domestic animals, and predators (Simberloff and Cox 1987). Cassirer and Sinclair (2006) described a situation in a Hell's Canyon bighorn sheep metapopulation where chronic although sporadic pneumonia-caused mortality was the primary factor limiting population growth during their six-year study. Similarly, a pneumonia epizootic in Colorado in a bighorn metapopulation beginning in 1997 reduced survival and recruitment, primarily of lambs, decreasing the population in the winter of 2006-07 to about half of that estimated prior to the epidemic (George et al. 2008).

Onderka and Wishart (1984) describe a pneumonia epizootic in bighorn sheep originating in southern British Columbia and caused by contact with domestic sheep. The epizootic began in December of 1981, by the fall of 1982, the epidemic had moved east across the Continental Divide into southern Alberta (Waterton Lakes National Park), and by early winter 1983 had moved into Glacier National Park. This same epizootic is suspected of moving farther south into populations in Montana along the Rocky Mountain Front and Sun River during the winter of 1983-84 (Andryk and Irby 1986). Through the analysis of mtDNA from bighorn sheep in several western states and provinces, including the aforementioned, Luikart and Allendorf (1996) demonstrated the likelihood of gene flow having occurred on a regional scale at some time in the past. This type of connectivity, as illustrated by disease transmission over long distances, may have been common prior to human-caused habitat fragmentation, which has made such movements more difficult. While this example of movement of animals among bighorn sheep populations probably represents an extreme in recent times, the end result is likely less potential for genetic exchange between populations but rather an increased risk of disease transmission.

## Metapopulations in Montana – Current Situation

Montana is fortunate to have large blocks of bighorn sheep habitat supporting approximately five separate metapopulations. Each of the five ecological regions (see Habitat Monitoring and Management) sustains at least one metapopulation. While there is known or in some cases suspected interchange between populations within these metapopulations, the degree of interchange and subsequent effect on genetic structure is largely unknown. These metapopulations generally consist of indigenous populations that persisted through the major declines that occurred around the turn of the 19th century. Perpetuation of these populations has been largely due to the separation of wild sheep and domestic sheep and goats and the reduction in potential for disease transmission associated with contact between these species. Some metapopulations in Montana occur in largely unfragmented habitats, and from that perspective are relatively easy to manage. Other metapopulations, however, are faced with increasingly fragmented habitats, and connectivity of subpopulations includes movements across major highway systems and increasing human development in movement corridors.

As part of this Conservation Strategy, a Translocation Program has been developed which includes a Habitat Evaluation Procedure (HEP) and criteria for selecting new transplant sites. Realizing the potential value of establishing metapopulations, preference would be given to sites with the potential for interchange with existing populations, provided that separation criteria with domestic animals is met. A facet of the HEP is to look at the proximity of potential transplant population distribution in relation to existing domestic sheep and goat distribution. As part of the HEP, a Geographic Information System (GIS) analysis identifying bighorn sheep habitat is being conducted. That analysis includes the mapping of the current distribution of domestic sheep grazing allotments on public lands (Figure 10). A preliminary examination of that distribution reveals that, although there is suitable unoccupied habitat, the proximity of domestic sheep to potential bighorn sheep habitat, and the potential for contact with domestic sheep based on minimum distance between the species, may preclude translocating wild sheep in some areas. This situation is compounded by the lack of knowledge of domestic sheep and goat distribution on private lands, which can further restrict the ability to establish bighorn sheep populations in some areas.

The HEP as described in the Translocation section of this document will be an ongoing analysis and will undoubtedly identify some potential transplant sites. While connecting existing populations with new populations established through translocation is desirable to improve genetic flow, this should not occur if the potential for disease transmission exists because contact with domestic animals is a possibility. We agree with Bleich et al. (1996) that the protection of the integrity and health of existing populations and metapopulations has to be the first priority in management of bighorn sheep as opposed to creating new metapopulations. Bleich et al. (1996) also concluded that demographic (recruitment and mortality) processes are more important than genetics in the long-term persistence of populations within metapopulations.

In isolated populations where metapopulations can't be established and genetic variation is suspected in affecting population viability, it may be desirable and less expensive to move individuals manually than to try to establish linkages among populations (Simberloff and Cox 1987). Hogg et al. (2006) demonstrated that augmentation can improve the fitness of a population in a relatively short time period. Ramey et al. (2000) listed five issues that need to be addressed when considering augmenting such populations, including whether a severe genetic bottleneck actually exists and how the sex and age of an augmentation should be structured.

There is a lack of knowledge regarding certain aspects of bighorn sheep metapopulations in Montana, and there is a need to focus research efforts to ensure their long-term maintenance. Movement studies were conducted in some metapopulations, which provided seasonal movement patterns including use of corridors, but largely this information is lacking. We need to know more regarding seasonal movements, dispersal patterns, habitat connectivity, and characteristics of corridors important to making and keeping existing metapopulations functional. Finally, as Hilty et al. (2006) suggested, we need to identify and protect corridors that provide connectivity among bighorn sheep populations before habitats are fragmented, rather than trying to restore corridors after fragmentation.