California Fish and Game 95(4):153-159; 2009

FACTORS TO CONSIDER WHEN REPROVISIONING WATER DEVELOPMENTS USED BY MOUNTAIN SHEEP

VERNON C. BLEICH
Department of Biological Sciences
Idaho State University
Pocatello, ID 83209
vbleich@ndsupernet.com

ABSTRACT

Mountain sheep, *Ovis canadensis*, occur in a naturally fragmented population structure, but have been extirpated from much of their historical distribution. Further, extant populations are subject to disruption of movement corridors, which exacerbates fragmentation. Water developments have been established to enhance the probability of persistence of the subpopulations that comprise metapopulations of those large herbivores, but such developments sometimes become dry. Suggestions are presented to help managers prioritize the order in which to reprovision water in the event that multiple developments become dry simultaneously. Given that a metapopulation contains habitat patches of differing quality, and that large subpopulations usually exhibit greater genetic diversity than small populations, reprovisioning is best prioritized in terms of benefits to (1) small, isolated subpopulations that are most subject to stochastic events and least likely to receive immigrants; (2) large, well-connected subpopulations in which intervention might be expected to benefit many individuals and, thereby, provide more potential colonists than would smaller, isolated subpopulations; and (3) small, well-connected subpopulations that are most apt to receive immigrants from nearby subpopulations.

Elevation, rainfall, and availability of water influence the persistence of mountain sheep, *Ovis canadensis*, in desert ecosystems (Epps et al. 2004), and no large populations are known to exist in the absence of reliable sources of surface water (Wehausen 2007[1]). Because some movement corridors have been disrupted, and habitats occupied by mountain sheep are being increasingly fragmented, potential benefits of developing water sources to mitigate impacts of anthropogenic activities are receiving increased attention (Dolan 2006). Broyles (1995) questioned the value of wildlife water developments; nevertheless, they are used extensively to enhance habitat for mountain sheep (Bleich et al. 2005, Krausman et al. 2006). Despite being largely reliable, wildlife water developments occasionally become dry as a result of insufficient precipitation or mechanical failure (Bleich and Pauli 1990); if that occurs., management goals cannot be met and conservation objectives become more difficult to achieve. Further, if >1 development is dry, managers either must determine which to reprovision (i.e., refill with water), or prioritize the order in which they are to be reprovisioned.

[1] Wehausen, J. D. 2007. Wilderness and guzzlers for desert bighorn sheep. Desert Report, December 2007:49.

In this note, I summarize recommendations (Bleich 2008[2]) that will be useful to managers when ≥2 water developments are dry simultaneously. It is my hope that these suggestions will help ensure that fiscal and logistical resources are expended most effectively, and with the greatest benefit to the conservation of mountain sheep.

Traditionally, mountain sheep populations were defined by the isolated mountain ranges they inhabited (e.g., Buechner 1960, Weaver 1973). It has become increasingly evident, however, that those large herbivores occur as metapopulations that are comprised of individual populations occupying disjunct geographic areas (Schwartz et al. 1986; Bleich et al. 1990, 1996; Bailey 1992; Krausman 1997; Epps et al. 2007). Moreover, the importance of small, seemingly isolated populations to the conservation of mountain sheep has been increasingly realized (Krausman and Leopold 1986; Schwartz et al. 1986; Bleich et al. 1990, 1996; Krausman 1997).

In the western United States, management and conservation of mountain sheep are based largely on the concept of a metapopulation structure (Torres et al. 1994, 1996; Singer et al. 2000; Epps et al. 2003). Extirpation of any population has serious implications for metapopulation persistence, particularly given the philopatric behavior and conservative colonization rates of mountain sheep (Geist 1971, Festa-Bianchet 1991, Bleich et al. 1996). Thus, loss of >30% of historical populations from California (Epps et al. 2003) is disconcerting; similar trends exist among other states inhabited by those specialized ungulates (Trefethen 1975).

Despite blockage of intermountain movement corridors and disruptions of connectivity by anthropogenic barriers (Epps et al. 2005a), available evidence indicates that opportunities for colonization still exist (Epps et al. 2005b). Wildlife water developments play a potentially important role in maintenance of connectivity among populations because they (1) allow mountain sheep to make use of otherwise suitable habitat that lacks reliable sources of surface water; (2) increase the probability of pioneering individuals encountering surface water in areas that otherwise provide suitable habitat; (3) enhance the likelihood of immigrants encountering conspecifics; or, (4) increase survival rates during periods of thermal stress or drought. Thus, wildlife water developments have the potential to increase population size, enhance survival, and facilitate genetic exchange; resultant increases in fitness have implications for gene flow and rates of colonization (Bleich 2008[2]). Indeed, the positive influences of wildlife water developments on the number, size, and stability of mountain sheep populations (Wehausen 2007[1]) have implications for metapopulation function and, hence, for persistence of the species.

There is agreement that small populations of mountain sheep are more vulnerable to extirpation when compared to large populations (Berger 1999, Wehausen 1999), and that demographic consequences of declines can be severe (Lande 1988). As a result, persistence of small populations can be impacted to a greater extent by a numerically equivalent loss of individuals when compared to large populations. Under some circumstances the loss of a large population could, nevertheless, be more damaging to metapopulation function than the loss of a small one. Large populations likely possess greater genetic diversity (Frankham 1996) and potentially produce more emigrants (Bailey 1992), both of which are essential to metapopulation function. Some populations occupy areas of better quality habitat and

[2] Bleich, V. C. 2008. Reprovisioning wildlife water developments: considerations for determining priorities to transport water. Society for the Conservation of Bighorn Sheep, Pasadena, California, USA.

thereby have access to more abundant resources than mountain sheep inhabiting small, isolated mountain ranges (Bailey 1992); as a result, those populations generally are larger and better able to withstand environmental stressors. In contrast, small populations that occupy marginal habitat are more vulnerable yet they, along with habitat that is occupied occasionally by transient individuals, can play important roles in maintaining connectivity (Schwartz et al. 1986; Bleich et al. 1990, 1996). Hence, when it is necessary to reprovision >1 dry water development, I recommend managers consider the tradeoffs associated with the potential extirpation of a small population in the context of the partial loss of a larger population, and that degree of isolation of each population receives serious consideration by managers faced with any such decision.

Two factors, distance to the nearest population and the number of proximate populations, have important implications for metapopulation function. Both play roles in connectivity (Epps et al. 2006), and thereby influence the probability of a geographic area being colonized by mountain sheep following an extirpation. As a result distances to, and the number of, proximate populations, influence the probability of dispersing individuals encountering resources necessary to survive, or of encountering conspecifics in a new area. Other factors being equal, the more isolated a population is, the more vulnerable it is. Persistence of small, isolated populations is more apt to be impacted by water shortages than is the persistence of populations having greater potential for connectivity to other areas inhabited by mountain sheep. Thus, when >1 development is dry, I suggest that the potential for connectivity with other areas inhabited by mountain sheep be considered in the context of benefits to the metapopulation as a whole, and how metapopulation function will best be served by ensuring availability of water.

Although the density of mountain sheep might be quite low (e.g., <1 individual/km^2) in a given area, total numbers of animals still can be greater than where mountain sheep occur at higher densities (Bleich 2008[2]). Thus, population density could present a misleading indicator of need to reprovision a water development, and thereby result in transport of water to a lower-priority area than would consideration of absolute numbers alone. Hence, population density in a given geographic area is a less important indicator of need to reprovision water than is population size. Among subpopulations occupying a single mountain range, however, the simultaneous presence of $\geq$2 dry developments will necessitate a decision regarding which to refill. In such situations, the relative abundance of animals in the vicinity of each dry development becomes a meaningful consideration, and transport of water to the development likely to benefit the greatest number of sheep is recommended. Such fine-scale information on relative abundance of mountain sheep within mountain ranges is, unfortunately, largely unavailable.

Despite the importance of population size to conservation objectives, I encourage managers to ensure that water is available to the greatest number of populations in need of that resource during the hot season. Using Weaver's (1973) suggestions or Turner's (1973[3]) estimates of water demands, managers can calculate the amount needed by a population during thermally stressful periods. For example, 25 mountain sheep would "require" approximately 10,000 L of water over the summer according to Weaver's (1973) criteria, and I suggest that transporting excess water to a single development while neglecting to

[3] Turner, J. C. 1973. Water, energy and electrolyte balance in the desert bighorn sheep, *Ovis canadensis*. Ph.D. dissertation, University of California, Riverside, USA.

reprovision another would be neither prudent nor of benefit to overall conservation objectives.

The length of time that a water development has been dry should play an important role in the decision making process. Lack of surface water during summer over multiple years has potentially greater impacts on a population than an absence of water over a shorter period of time, because annual impacts likely are cumulative. Alternatively, if a development has been dry for several years, it could be argued that any impacts to the population that used that development already have occurred, and that if a development upon which sheep currently are dependent is not reprovisioned, the impacts would be disproportionately greater. If managers adhere to the recommendations presented herein, such situations are unlikely to occur; nevertheless, when setting priorities to reprovision dry water developments, I suggest managers assess impacts already incurred by the respective population(s).

Clearly, availability of alternative water sources is an important consideration when prioritizing areas to reprovision. It seems intuitive that the need to reprovision dry water development(s) in areas having alternative water sources is less than in those areas without alternative sources. The potential value of an alternative source is diminished, however, if it has not previously received regular use by members of the population. Hence, when deciding which of several developments to reprovision, I suggest managers give serious consideration to the amount of use alternative water sources previously have received.

Male and female mountain sheep segregate for much of the year (Bleich et al. 1997), and different parts of a mountain range can be used primarily by one sex or the other and with the result that males and females sometimes use separate water sources (Whiting 2008[4]). In desert ecosystems, sexual segregation generally peaks during spring and early summer, but males and females aggregate for breeding during late summer and early fall (Bleich et al. 1997, Rubin et al. 2000). During thermally stressful periods, females and young are most closely tied to surface water and visitation rates are high (Bleich et al. 1997). I suggest that dry developments in areas used predominately by females and young receive a higher priority for reprovisioning than areas used predominately by males. By providing water at those developments, physiological needs of males likely will be met because they join females during the hottest time of the year (Bleich et al. 1997). Thus, sex and age structure of the population, combined with the seasonal distributions of males and females, are important considerations when prioritizing efforts to reprovision dry developments.

Decisions to reprovision a dry development will be influenced by the methods available to implement that task. If water can be provided without undue fiscal or logistical commitments, as when it can be transported by motor vehicle, those situations are best resolved as they arise. If >1 development is dry, I suggest that managers distribute their effort to ensure that anticipated needs of the greatest number of populations are met. It would not be a sound strategy to provide more water than necessary at one development at the expense of another if the anticipated needs of both (or several) can be met. The same strategy will be applicable even when aerial transport of water is the only means by which developments can be reprovisioned. I suggest that neither level of difficulty nor cost are important factors when determining which development(s) to reprovision, or the amount of water to be transported.

---

[4] Whiting, J. C. 2008. Behavior and ecology of reintroduced Rocky Mountain bighorn sheep. Ph.D. dissertation, Idaho State University, Pocatello, USA.

Management prescription (i.e., whether the population is harvested or not) is of less importance than most other factors. Harvest strategies include removal of animals for translocation or by hunting; in one setting, females will be disproportionately selected for removal and, in the latter, mature males will be disproportionately targeted. In both situations, the population likely is large and healthy, or it would not be managed under either of those strategies (Bleich 2008[2]). Thus, management prescription alone is unimportant relative to most other factors when prioritizing actions to be undertaken.

The observations, experiences, and resulting opinions of individuals familiar with specific geographic areas warrant some consideration, particularly if they have been compiled over extended periods of time and under a variety of environmental conditions. Nevertheless, when prioritizing efforts to reprovision dry water developments, I suggest the vulnerability of a population as perceived subjectively is much less meaningful than are other factors.

In summary, managers are encouraged to reprovision developments as they become dry, rather than waiting until >1 development no longer provides water. If, however, managers are faced with multiple dry developments, I recommend they do so with the objective of ensuring water is available to the greatest number of populations, but without compromising the persistence of those that are large. Given that a metapopulation of mountain sheep consists of occupied (and potentially unoccupied) habitat patches of differing quality, and that large populations likely exhibit greater genetic diversity than small ones, I suggest actions to reprovision dry water developments are best implemented in the context of benefits to (1) small, isolated populations that are most subject to stochastic events and least likely to receive immigrants; (2) large, well-connected populations in which intervention would be expected to benefit many individuals and, thereby, provide more potential emigrants than smaller, isolated populations; and (3) small, well-connected populations that are most likely to receive immigrants from nearby areas.

ACKNOWLEDGMENTS

I thank B. Broyles, C. W. Epps, J. J. Hervert, J. Hybarger, M. C. Jorgensen, G. C. Kerr, S. Marschke, S. S. Rosenstock, G. W. Sudmeier, G. Thomas, and J. D. Wehausen for providing critical reviews of the original report (Bleich 2008[2]) on which this note is based, and B. F. Wakeling and an anonymous reviewer for suggestions that resulted in a markedly improved manuscript. Support for preparation of the manuscript was provided by the Society for the Conservation of Bighorn Sheep; this is Professional Paper 070 from the Eastern Sierra Center for Applied Population Ecology.

LITERATURE CITED

Bailey, J. A. 1992. Managing bighorn habitat from a landscape perspective. Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council 8:49-57.

Berger, J. 1999. Intervention and persistence in small populations of bighorn sheep. Conservation Biology 13:432-435.

Bleich, V. C., and A. M. Pauli. 1990. Mechanical evaluation of artificial watering devices built for mountain sheep in California. Pages 65-72 *in* G. K. Tsukamoto and S. J. Stiver, editors. Wildlife water development. Nevada Department of Wildlife, Reno, USA.

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

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353-373 *in* D. R. McCullough, editor. Metapopulations and wildlife conservation. Island Press, Covelo, California, USA.

Bleich, V. C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs 134:1-50.

Bleich, V. C., J. G. Kie, E. R. Loft, T. R. Stephenson, M. W. Oehler, Sr., and A. L. Medina. 2005. Managing rangelands for wildlife. Pages 873-897 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Broyles, B. 1995. Desert wildlife water developments: questioning use in the southwest. Wildlife Society Bulletin 23:663-675.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs 4:1-174.

Dolan, B. F. 2006. Water developments and desert bighorn sheep: implications for conservation. Wildlife Society Bulletin 34:642-646.

Epps, C. W., V. C. Bleich, J. D. Wehausen, and S. G. Torres. 2003. Status of bighorn sheep in California. Desert Bighorn Council Transactions 47:20-35.

Epps, C. W., D. R. McCullough, J. D. Wehausen, V. C. Bleich, and J. L. Rechel. 2004. Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology 18:102-113.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, R. R. Ramey II, and D. R. McCullough. 2005a. Highways block gene flow and cause rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8:1029-1038.

Epps, C. W., J. D. Wehausen, P. J. Palsbøll, and D. R. McCullough 2005b. Using genetic analyses to describe and infer recent colonizations by desert bighorn sheep. Pages 51-62 *in* J. Goerrissen and J. M. André, editors. Sweeney Granite Mountains Desert Research Center 1978-2003: a quarter century of research and teaching. University of California Natural Reserve Program, Riverside, USA.

Epps, C. W., P. J. Palsbøll, J. D. Wehausen, G. K. Roderick, and D. R. McCullough. 2006. Elevation and connectivity define genetic refugia for mountain sheep as climate warms. Molecular Ecology 15:4295-4302.

Epps, C. W., J. D. Wehausen, V. C. Bleich, S. G. Torres, and J. S. Brashares. 2007. Optimizing dispersal and corridor models using landscape genetics. Journal of Applied Ecology 44:714-724.

Festa-Bianchet, M. 1991. The social system of bighorn sheep: grouping patterns, kinship, and dominance rank. Animal Behavior 42:71-82.

Frankham, R. 1996. Relationship of genetic variation to population size in wildlife. Conservation Biology 10:1500-1508.

Geist, V. 1971. Mountain sheep. A study in behavior and evolution. University of Chicago Press, Chicago, Illinois, USA.

Krausman, P. R. 1997. The influence of landscape scale on the management of desert bighorn sheep. Pages 349-367 *in* J. A. Bissonette, editor. Wildlife and landscape ecology: effects of pattern and scale. Springer-Verlag, New York, New York, USA.

Krausman, P. R., and B. D. Leopold. 1986. The importance of small populations of desert bighorn sheep. Transactions of the North American Wildlife and Natural Resources Conference 51:52-61.

Krausman, P. R., S. S. Rosenstock, and J. W. Cain III. 2006. Developed waters for wildlife: science, perception, values, and controversy. Wildlife Society Bulletin 34:563-569.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Rubin, E. S., W. M. Boyce, and V. C. Bleich. 2000. Reproductive strategies of desert bighorn sheep. Journal of Mammalogy 81:769-786.

Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. Biological Conservation 37:179-190.

Singer, F. J., V. C. Bleich, and M. A. Gudorf. 2000. Restoration of bighorn sheep metapopulations in and near western national parks. Restoration Ecology 8(4s):14–24.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1994. Status of bighorn sheep in California, 1993. Desert Bighorn Council Transactions 38:17-28.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1996. Status of bighorn sheep in California, 1995. Desert Bighorn Council Transactions 40:27-34.

Trefethen, J. B. (editor). 1975. The wild sheep in modern North America. Winchester Press, New York, New York, USA.

Weaver, R. A. 1973. California's bighorn management plan. Desert Bighorn Council Transactions 17:22-42.

Wehausen, J. D. 1999. Rapid extinction of mountain sheep populations revisited. Conservation Biology 13:378–384.

Received: 22 January 2009
Accepted: 6 April 2009