TEXAS J. SCI. 57(1):25-34 FEBRUARY, 2005

IDENTIFYING LANDSCAPES FOR DESERT BIGHORN SHEEP TRANSLOCATIONS IN TEXAS

Shawn L. Locke, Clay E. Brewer and Louis A. Harveson

Department of Wildlife and Fisheries Sciences
Texas A&M University, College Station, Texas 77843-2258
Texas Parks and Wildlife Department
P.O. Box 343, Fort Davis, Texas 79734 and
Department of Natural Resource Management
Sul Ross State University, Box C-16, Alpine, Texas 78932

Abstract.–This study used a GIS-based evaluation of escape terrain to identify landscapes for potential desert bighorn sheep (*Ovis canadensis*) translocations sites in west Texas. The quantity and heterogeneity of escape terrain (i.e., slopes $\geq 60\%$ with a contiguous 150-m buffer) were quantified for Big Bend National Park, Guadalupe Mountains National Park, Big Bend Ranch State Park, and Black Gap Wildlife Management Area using a 30-m digital elevation model. Big Bend National Park had the largest amount of escape terrain (501 km^2) of the four study areas but had the largest perimeter-to-area ratio (4.9). Guadalupe Mountains National Park had the smallest amount of escape terrain (112 km^2) but also had the smallest perimeter-to-area ratio (2.8). Although other factors (e.g., vegetation, water availability, predators, and interspecific competitors) should be considered prior to translocation, the GIS-based evaluation offers an efficient, preliminary, and quantitative method for evaluating desert bighorn sheep habitat. Based on the results of this study, biologists should further evaluate Big Bend National Park and Big Bend Ranch State Park for future desert bighorn sheep translocation sites in Texas.

Historically, desert bighorn sheep (*Ovis canadensis*) occupied the rugged, mountainous terrain of west Texas (Cook 1994). Approximately 1,500 desert bighorn sheep were estimated to inhabit the Trans-Pecos ecoregion (Gould 1962) in the mid 1880s (Cook 1994). However, Bailey (1905) estimated the number of sheep in Texas had declined to 500 individuals by the beginning of the 20^{th} century. Desert bighorn sheep continued to decline as a result of unregulated hunting, disease, interspecific competition (i.e., domestic sheep and goats), as well as predation, and by 1960, desert bighorn sheep were extirpated from Texas (Davis & Taylor 1939; Cook 1994).

Restoration efforts by the Texas Parks and Wildlife Department (TPWD) began in the mid 1950s, and although early efforts were of limited success due to disease and predation (Krausman et al. 1999), more recent efforts (last 20-25 years) have been more successful. Currently, desert bighorn sheep have been restored to seven mountain ranges in the Trans-Pecos region and with a total population size exceeding 500 individuals (Brewer, pers. comm.).

Translocation is the management tool used by TPWD to establish desert bighorn sheep populations on public lands within historic range sites. However, current evaluation of desert bighorn sheep habitat prior to translocation is conducted through field observations. This is an inefficient method for evaluating the suitability of large landscapes for desert bighorn sheep restoration.

McKinney et al. (2003) hypothesized the size of desert bighorn sheep populations in Arizona were correlated to amount and configuration of escape terrain, and recommended translocation sites contain ≥ 15 km^2 of escape terrain. Escape terrain provides bedding and lambing areas, and is important in predator avoidance, therefore escape terrain is often considered the most critical component of bighorn sheep habitat (Buechner 1960; Ferrier & Bradley 1970; Geist 1971; Wilson et al. 1980). The use of geographic information system (GIS) technology provides an efficient, preliminary, and quantitative technique for evaluating habitat quality prior to desert bighorn sheep translocations (McKinney et al. 2003).

The goal of this study was to identify potential future translocation sites for desert bighorn sheep in Texas. The primary objective was to conduct a GIS-based evaluation of the quantity and heterogeneity of escape terrain for landscapes in the Trans-Pecos ecoregion of Texas. A second objective was to identify large blocks of potential habitat to serve as future re-introduction sites.

MATERIALS AND METHODS

Areas evaluated in this study were located in the Trans-Pecos ecoregion of west Texas. Big Bend National Park (BBNP), Big Bend Ranch State Park (BBRSP), and Black Gap Wildlife Management Area (BGWMA) are located in the southern portion of the Trans-

Pecos along the Rio Grande, an area often referred to as the Big Bend Area (Figure 1). Guadalupe Mountains National Park (GMNP) is located in the northern portion of the Trans-Pecos along the Texas/ New Mexico border. All four study areas were evaluated for their potential as future desert bighorn sheep translocation sites. At the time of the study in 2004, BBNP, GMNP, and BBRSP did not contain desert bighorn sheep populations. Reintroduction efforts have occurred at BGWMA since the late 1950s with little success due to disease and predation (Cook 1994). Populations have since been established at BGWMA, and with the most recent translocation of 45 individuals (year 2000) current estimates range between 100-125 individuals (Foster, pers. comm.).

The Trans-Pecos is located within the Chihuahuan Desert. The study areas range in elevation from 475 m (above sea level) along the Rio Grande at BGWMA to 2,667 m at Guadalupe Peak in the Guadalupe Mountains (Powell 2000). Soils are of either igneous or limestone origin, and the climate is arid with an average annual rainfall of 30.5 cm with peak rainfall occurring between July and September (Powell 1998). The Trans-Pecos is biologically diverse and Powell (1998) categorized 5 broad vegetation types: Chihuahuan Desert scrub, desert grassland, oak/juniper/pinyon woodland, conifer forest, and riparian community.

Escape terrain area was calculated for all four study areas in a GIS using a 30-m resolution digital elevation model (Divine et al. 2000). Escape terrain was defined as slopes ≥ 60% (Holl 1982; Smith et al. 1991; McCarty & Bailey 1994) with a contiguous 150-m buffer (McKinney et al. 2003). Elevations ≥ 1,600 m and ≥ 2,200 m at BBNP and GMNP, respectively were excluded from analysis due to the dense conifer forests supported in the upper elevations (Powell 1998). Desert bighorn sheep would likely not use these areas due to reduced visibility (Risenhoover & Bailey 1985; Wakeling 1989; Smith et al. 1991; McCarty & Bailey 1992; 1994). A ratio of perimeter (km) to area (km^2) of escape terrain (perimeter-to-area ratio, McKinney et al. 2003) was calculated to indicate a measure of patchiness or "edge effect" in the habitat (Singer et al. 2001).

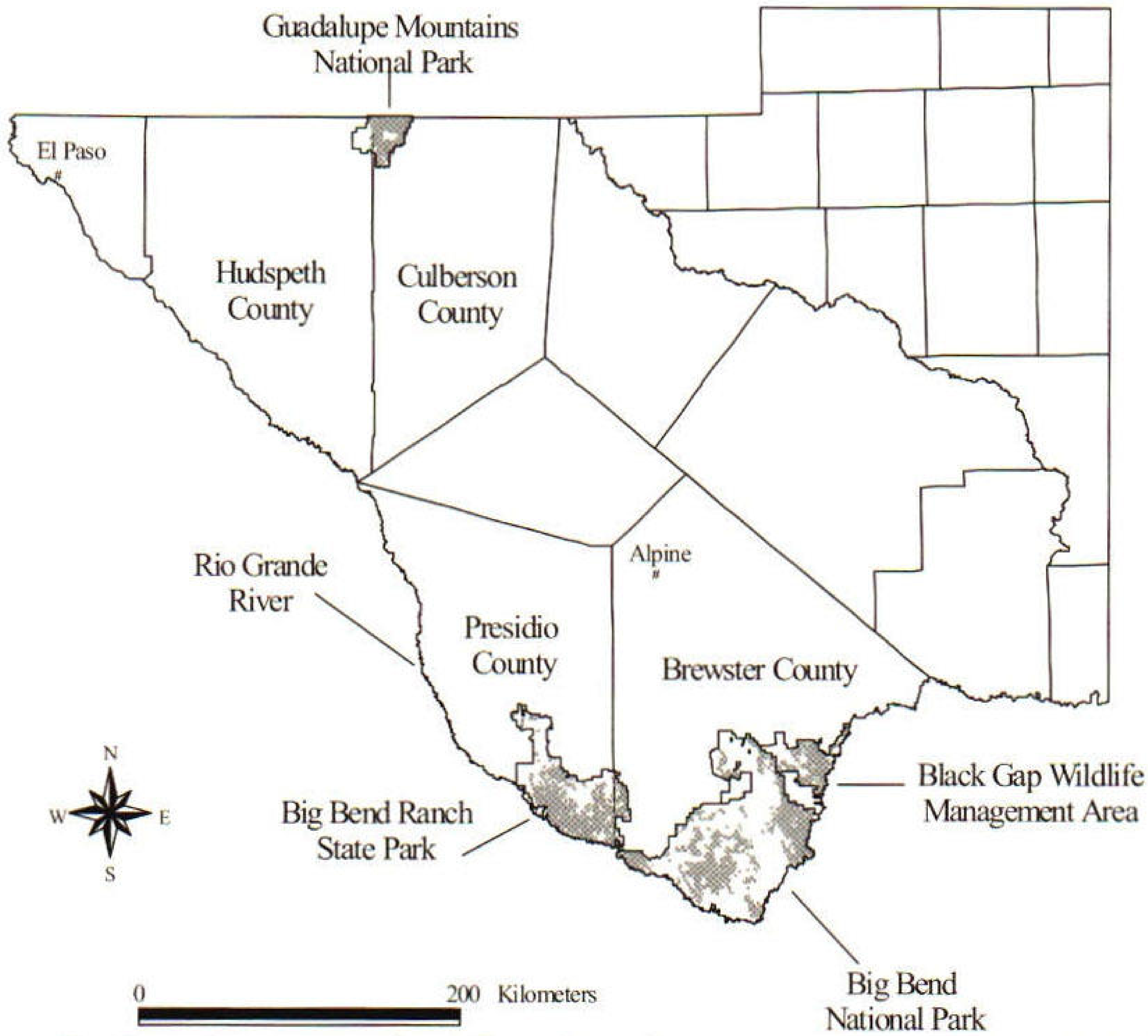

Figure 1. Location, area, and configuration of escape terrain (shaded gray) of four potential translocation sites for desert bighorn sheep in the Trans-Pecos ecoregion of Texas.

RESULTS AND DISCUSSION

Big Bend National Park had the largest amount of escape terrain (501 km^2) of the four study sites and the second largest perimeter-to-area ratio (4.9, Table 1, Figure 1). Big Bend Ranch State Park had the second largest amount of escape terrain (324 km^2) and the largest perimeter-to-area ratio (5.0). Black Gap Wildlife Management Area and GMNP had the third and fourth most escape terrain, respectively. Each of these study sites exceeded the minimum amount of escape terrain (15 km^2) recommended and the perimeter-to-area ratios were considerably smaller than those reported in Arizona (McKinney et al. 2003) suggesting escape terrain within the study areas was contiguous.

Table 1. Area and perimeter-to-area ratios of escape terrain located at Big Bend National Park (BBNP), Big Bend Ranch State Park (BBRSP), Black Gap Wildlife Management Area (BGWMA), and Guadalupe Mountains National Park (GMNP) in Texas.

StudyArea	Escape Terrain (km^2)	P:A*
BBNP	501	4.9
BBRSP	324	5.0
BGWMA	135	4.6
GMNP	112	2.8

*P:A = perimeter (km) to area (km^2) ratio of escape terrain.

Within numerous vertebrate species, population persistence has been positively correlated with habitat patch size (Fritz 1979; Schoerner & Spiller 1987; Thomas 1990; Fahrig & Merriman 1992; Kindvall & Ahlen 1992; Hanski 1994), and larger patches typically support larger populations (Gilpin & Soule 1986). Saunders et al. (1991) suggested larger patches contain more biological diversity and have lower perimeter-to-area ratios thus permitting greater genetic heterozygosity in wildlife populations. Singer et al. (2000a) recommended translocating bighorn sheep into large blocks of habitat with the potential for more than one subpopulation. Large blocks of habitat may allow ungulate populations to have larger ranges resulting in less overcrowding and improved body condition (Singer et al. 2001).

Theoretically, larger blocks of habitat may support larger bighorn sheep populations, and although there is some disagreement on the size of habitat needed for the persistence of desert bighorn sheep (Krausman & Leopold 1986; Krausman et al. 1993; Krausman et al. 1996), the goal in Texas is to establish large, self-sustaining desert bighorn sheep populations. Big Bend National Park, BBRSP, and BGWMA each have large amounts of escape terrain and relatively low perimeter-to-area ratios (≤ 5.0) suggesting these three study sites consisted of relatively large habitat patches rather than patchy. In addition these three study sites share borders (Figure 1) thus increasing the total amount escape terrain or patch size and the ability to support > one subpopulation. Guadalupe Mountains National Park had the lowest perimeter-to-area ratio (2.8) but also had the least amount of escape terrain (112 km^2). The GMNP is near the Sierra Diablo Mountains which contains established populations of desert bighorn sheep. However, barriers (e.g., highways, fencing) may preclude bighorn populations from interacting thereby isolating potential bighorn sheep populations in GMNP.

The GIS-based evaluation of escape terrain represents an efficient yet preliminary method for quantifying the amount of habitat prior to desert bighorn sheep translocations. However, translocations should not be based solely on the amount of escape terrain. Evaluations of other variables should be considered. For instance, permanent water sources should be mapped to determine availability. Adequate water sources should exist or be provided (e.g., man-made guzzlers) ≤ 8 km apart and within proximity to escape terrain (Douglas & Leslie 1999). Additionally, the composition and structure of vegetation communities is important to consider. Desert bighorn sheep are opportunistic and highly adaptable in regard to diet (Browning & Monson 1980; Brewer 2001), but prefer areas with high visibility (Risenhoover & Bailey 1985; Wakeling 1989; Krausman et al. 1999). Contact with domestic livestock and exotic sheep species (e.g., *Ammotragus lervia*) should be minimized or eliminated to prevent disease transmission, and interspecific competition (Douglas & Leslie 1999; Krausman et al. 1999; Singer et al. 2001). Predation can also be a limiting factor for translocated populations (Krausman et al. 1999), but predator management may allow populations time to be established. Finally, desert bighorn sheep contact with humans and human activities should be minimized especially during the rut and lambing seasons (Papouchis et al. 2001). Habitat should be free of natural (i.e., rivers, dense vegetation, and impassable canyons) and man-made barriers (i.e., fences, highways, and human constructions) to allow maximum mobility and genetic exchange among populations (Singer et al. 2000b).

Translocating desert bighorn sheep into historic range sites can be an effective management tool (Singer et al. 2000a), however translocations of large ungulates including desert bighorn sheep are expensive, time consuming, and politically challenging (Beck et al. 1994; Biggens & Thorne 1994; Wolf et al. 1996; Dunham 1997; Fritts et al. 1997). Furthermore, many transplanted herds of bighorn sheep have either remained small in numbers or subsequently failed (Risenhoover et al. 1988). Therefore, evaluating the area and configuration of escape terrain of potential re-introduction sites is a critical, yet preliminary step prior to translocation. McKinney et al. (2003) offers an efficient and quantitative GIS-based method for evaluating potential desert bighorn sheep re-introduction sites and may improve the potential for translocation success. Based on the results of this study TPWD biologists should further investigate BBNP and BBRSP as potential sites for future desert bighorn sheep translocations.

Acknowledgments

Funding for this project was provided by Texas Parks and Wildlife Department, Sul Ross State University, Texas Bighorn Society, West Texas Chapter of Safari Club International, and Houston Safari Club. We would like to thank C. E. Brewer and J. Foster, Texas Parks and Wildlife Department, for providing unpublished data and personal observations concerning desert bighorn sheep in Texas. The authors are grateful to R. R. Lopez for providing comments of early drafts of this manuscript and we thank Dr. D. Divine, and another anonymous reviewer for providing helpful comments and suggestions.

Literature Cited

Bailey, V. 1905. Biological survey of Texas. USDA Bureau. Biological Survey, North America. Fauna, 25:1-222.

Beck, B. B., L. G. Rapaport, M. R. Stanley Price & A. C. Wilson. 1994. Reintroduction of captive-born animals. Pp. 265-268, *in* Creative conservation: Interactive management of wild and captive animals (P. J. S. Olney, G. M. Mace, and A. T. C. Feistner, eds.), Chapman and Hall, London, United Kingdom, 1+517 pp.

Biggins, D. E. & E. T. Thorne. 1994. Management of an endangered species: the black-footed ferret. Pp. 368-374, *in* Principles of conservation biology (G. K. Meffe and C. R. Carroll, eds.), Sinauer Associates, Sunderland, 1+729 pp.

Brewer, C. E. 2001. Diets of desert bighorn sheep at Elephant Mountain Wildlife Management Area, Texas. Unpubl. M.S. thesis, Sul Ross State Univ., Alpine, 88 pp.

Browning, B. M. & G. Monson. 1980. Food. Pp. 80-99, *in* The desert bighorn: its life history, ecology, and management (G. Monson and L. Sumner, ed.), Univ. of Arizona Press, Tucson, 1+400 pp.

Buechner, H. K. 1960. The bighorn sheep in the United States: its past, present, and future. Wildlife Monographs, 4:11-74.

Cook, R. L. 1994. A historical review of reports, field notes and correspondence on the desert bighorn sheep in Texas. Special Report to the Desert Bighorn Sheep Advisory Committee. Contribution to Federal Aid Project Number W-127-R and W-123-D. Texas Parks and Wildlife Department, Austin, 68 pp.

Davis, W. B. & W. P. Taylor. 1939. The bighorn sheep of Texas. Journal of Mammalogy, 20:440-445.

Divine, D. D., D. W. Ebert & C. L. Douglas. 2000. Examining desert bighorn habitat using 30-m and 100-m elevation data. Wildlife Society Bulletin, 28:986-992.

Douglas, C. L. & D. M. Leslie, Jr. 1999. Management of bighorn sheep. Pp 238-262 *in,* Mountain sheep of North America (R. Valdez, and P. R. Krausman, eds.), The Univ. of Arizona Press, Tucson, 1+353 pp.

Dunham, K. M. 1997. Population growth of mountain gazelles, Gazella gazelle, reintroduced to central Arabia. Biological Conservation, 81:205-214.

Fahrig, L. & G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology, 8:50-59.

Ferrier, G. J. & W. G. Bradley. 1970. Bighorn habitat evaluation in the Highland Range of southern Nevada. Desert Bighorn Council Transactions, 14:66-93.

Fritz, R. S. 1979. Consequences of insular population structure: distribution and extirpation of Spruce Grouse populations. Oecologia, 42:57-65.

Fritts, S. H., E. E. Bangs, J. A. Fontaine, M. R. Johnson, M. K. Phillips, E. D. Koch & J. R. Gunson. 1997. Planning and implementing a reintroduction of wolves to Yellowstone National Park and central Idaho. Restoration Ecology, 5:7-27.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. of Chicago Press, Chicago, 1+383 pp.

Gilpin, M. E. & M. E. Soule. 1986. Minimum viable populations process of species extinction. Pp. 19-34 *in* Conservation Biology: the science of scarcity and diversity (M. E. Soule, ed.), Sinauer Associates, Sunderland, 1+584 pp.

Gould, F. W. 1962. Texas plants – a checklist and ecological summary. Texas Agricultural Experiment Station, MS-585, College Station, 1+62 pp.

Hanski, I. 1994. Patch-occupancy dynamics in fragmented landscapes. Trends in Ecology and Evolution, 9:131-135.

Holl, S. A. 1982. Evaluation of bighorn sheep habitat. Desert Bighorn Council Transactions, 26:47-49.

Kindvall, O. & I. Ahlen. 1992. Geometrical factors and metapopulation dynamics of the bush cricket, *Metrioptera bicolor* Philippi (Orthoptera: Tettigoniidae). Conservation Biology, 6:520-529.

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

Krausman, P. R., R. C. Etchberger & R. M. Lee. 1993. Persistence in mountain sheep. Conservation Biology, 7:219.

Krausman, P. R., R. C. Etchberger & R. M. Lee. 1996. Persistence of mountain sheep populations in Arizona. Southwestern Naturalist, 41:399-402.

Krausman, P. R., A. V. Sandoval & R. C. Etchberger. 1999. Natural history of desert bighorn sheep. Pp. 139-191 *in* Mountain sheep of North America (R. Valdez, and P. R. Krausman, ed.) The University of Arizona Press, Tucson, Arizona, 1+353 pp.

McCarty, C. W. & J. A. Bailey. 1992. Measuring visual obstruction caused by discrete objects in bighorn sheep habitats. Desert Bighorn Council Transactions, 36:1-3.

McCarty, C. W. & J. A. Bailey. 1994. Habitat requirements of desert bighorn sheep. Special Report 69. Colorado Division of Wildlife, Denver, 1+36 pp.

McKinney, T., A. R. Boe & J. C. deVos, Jr. 2003. GIS–based evaluation of escape terrain and desert bighorn sheep populations in Arizona. Wildlife Society Bulletin, 31:1229-1236.

Papouchis, C. M., F. J. Singer & W. B. Sloan. 2001. Responses of desert bighorn sheep to increased human recreation. Journal of Wildlife Management, 65:573-582.

Powell, A. M. 1998. Trees and shrubs of the Trans-Pecos and adjacent areas. University of Texas Press, Austin, 1+498 pp.

Powell, A. M. 2000. Grasses of the Trans-Pecos and adjacent areas. Iron Mountain Press, Marathon, Texas, 1+377 pp.

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

Risenhoover, K. L., J. A. Bailey & L. A. Wakelyn. 1988. Assessing the Rocky Mountain bighorn sheep management problem. Wildlife Society Bulletin, 16:346-352.

Saunders, D. A., R. J. Hobbs & C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology, 5:18-32.

Schoerner, T. W. & D. A. Spiller. 1987. High population persistence in a system with high turnover. Nature, 330:474-477.

Singer, F. J., C. M. Papouchis & K. K. Symonds. 2000a. Translocations as a tool to restoring populations of bighorn sheep. Restoration Ecology, 8:6-13.

Singer, F. J., E. S. Williams, M. W. Miller & L. C. Zeigenfuss. 2000b. Population growth, fecundity, survivorship, and dispersal in recovering populations of bighorn sheep. Restoration Ecology, 8:75-84.

Singer, F. J., L. C. Zeigenfuss & L. Spicer. 2001. Role of patch size, disease, and movement in rapid extinction of bighorn sheep. Conservation Biology, 15:1347-1354.

Smith, T. S., J. T. Flinders & D. S. Winn. 1991. A habitat evaluation procedure for Rocky Mountain bighorn sheep in the intermountain West. Great Basin Naturalist, 51:205-225.

Thomas, C. D. 1990. What do real population dynamics tell us about minimum viable population sizes? Conservation Biology, 4:324-327.

Wakeling, B. F. 1989. Habitat selection and use by desert bighorn sheep in the Superstition Mountains, Arizona. Unpubl. M.S. thesis, Arizona State Univ., Tucson, 1+54 pp.

Wilson, L. O., J. Blaisdell, G. Welsh, R. Weaver, R. Brigham, W. Kelly, J. Yoakum, M. Hinks, J. Turner & J. DeForge. 1980. Desert bighorn habitat requirements and management recommendations. Desert Bighorn Council Transactions, 24:1-7.

Wolf, G. M., B. Griffith, C. Reed & S. A. Temple. 1996. Avian and mammalian translocations: update and reanalysis of 1987 survey data. Conservation Biology, 10:1142-1154.

SLL at: sloc@neo.tamu.edu