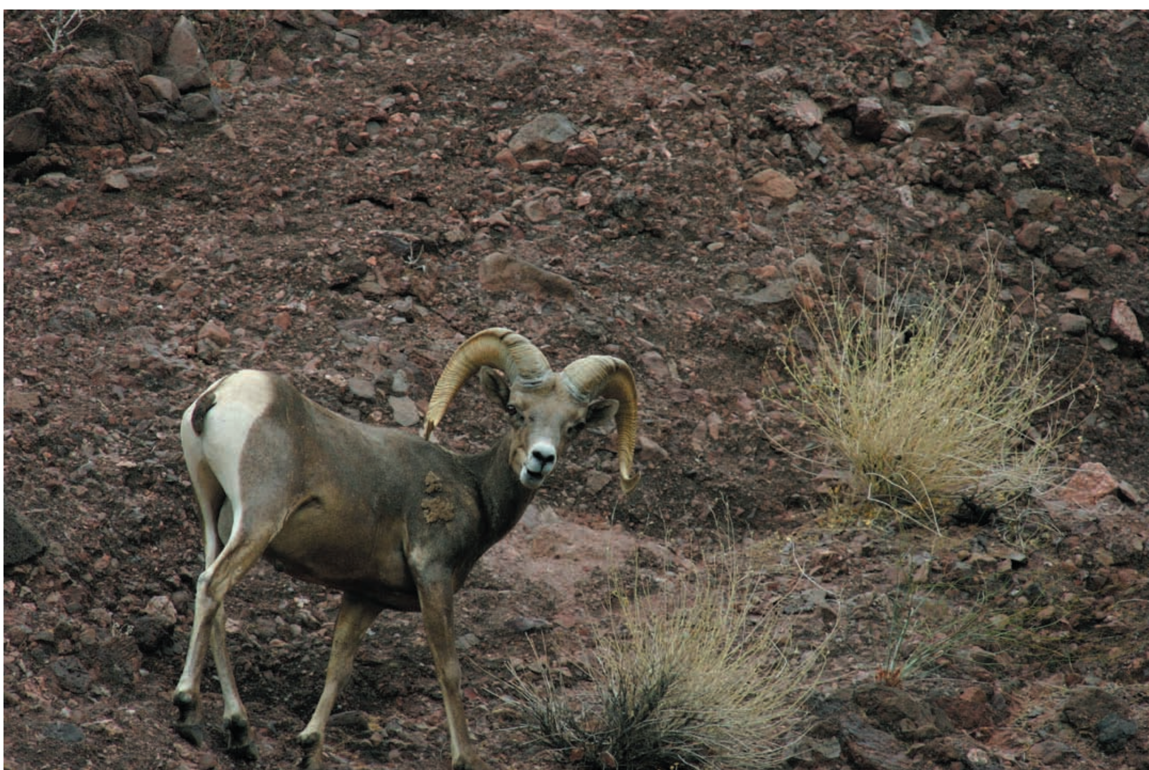
Wildlife Water Developments
and
Desert Bighorn Sheep
in the
Southwestern United States



A document prepared by the
Arizona Desert Bighorn Sheep Society
2004

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Foreword

Formed in 1967 by dedicated sportsmen, the Arizona Desert Bighorn Sheep Society promotes management of bighorn sheep (Ovis canadensis) to establish viable, self-sustaining bighorn sheep populations in Arizona. Although originally coined the Arizona *Desert* Bighorn Sheep Society, a successful introduction of Rocky Mountain Bighorn Sheep in eastern Arizona expanded the scope of the organization to include interests in Rocky Mountain bighorn sheep.

The organization established 8 goals to support its overall mission. The primary 2 objectives that have been the focus of the society since its creation include developing water resources and reintroducing bighorn sheep into suitable historic ranges. The remaining 6 supporting goals include preventing human encroachment into bighorn sheep habitat, assisting government agencies with bighorn sheep population surveys, supporting the reduction of feral burro populations in bighorn sheep habitat, informing the public about bighorn sheep and their survival needs, promoting research needed for better management of bighorn sheep, and supporting efforts to reduce competition with domestic livestock and predators, where necessary.

The purpose of this publication is to document several events involving desert bighorn sheep and other ungulates in and around wildlife water developments in Arizona to contribute to our understanding of the effects wildlife water developments may have on desert bighorn sheep individuals and populations. Continued research, evaluation, and discussion regarding the factors that contribute to the decline and well-being of bighorn sheep will better equip wildlife managers with the tools they need to meet the habitat requirements of these species, and will result in a public that can make well-informed, cost-effective decisions that ultimately support bighorn populations for the enjoyment of future generations.

Background

The Arizona Game and Fish Department (AGFD) began constructing artificial water developments in 1946. Initially designed to benefit game bird populations, water developments have been used to increase wildlife populations in areas where water is a limiting factor (Wright 1959), to mitigate loss of natural water sources (Wright 1959, deVos et al. 1983), and to enhance amphibian populations (AGFD 1997, Rosen and Schwalbe 1998, Sredl and Saylol 1998). It has only been in recent times that the value of human-made water structures to desert bighorn sheep has been questioned.

Controversy about water structures exists because desert bighorn sheep have been found in areas devoid of permanent free water (Seton 1929; O'Conner 1939; Brown 1984, 1997). Broyles (1995, 1997) and Broyles and Cutler (1999) challenged the benefit of creating artificial watering sources for desert bighorn sheep. Yet, some studies (Leslie and Douglas 1979; Krausman and Etchberger 1995; Krausman 2001) support the use of water developments to enhance bighorn sheep populations.

Some of the conflict in the scientific literature on the effects of water developments on desert bighorn sheep can be attributed to study design problems including studies that were primarily descriptive or anecdotal, short in duration, limited in design, restricted to a few species, and influenced by weather extremes (AGFD 1997). One study conducted in Nevada (Leslie and Douglas 1979) demonstrated an increase in desert bighorn sheep with an

Desert bighorn sheep at a water development.

increase in availability of water developments, yet another reported a decline in sheep populations in Death Valley because of erratic and inadequate natural water resources (Douglas 1988). Ballard et al. (1998) found desert bighorn sheep selected habitat near water sources, however, developments have not always resulted in increased sheep populations. Broyles and Cutler (1999) concluded desert bighorn sheep populations in areas with available surface water did not differ from populations in areas without surface water. An earlier study (Krausman and Etchberger 1996) demonstrated desert bighorn sheep were not attracted to new water catchments, and concluded water was not a limiting factor for desert bighorn sheep in that particular area. However, a more recent study (Turner et al. 2004) found that 97% of the observations in this study of critical habitat for Nelson's bighorn sheep in California were made within 2 miles of a perennial water source.

Bighorn sheep ram at a water development.

The AGFD conducted a review of all literature on water developments in desert environments and published a briefing document in 1997 titled, "Wildlife Water Developments in Arizona: A Technical Review." The review failed to document adverse effects from water developments and concluded the continued development of wildlife waters, concurrent with expanded planning processes, a strong monitoring and evaluation program, and research on ecological effects, was warranted. The 1997 paper was followed by a 2002 paper that summarized the results of recently published information on water developments, and offered continued support of water developments, again failing to document adverse effects from artificial water structures.

These potential adverse effects include concerns about predators (Bourliere 1963, Monson 1965, Cunningham and deVos 1992, Krausman and Etchberger 1993), drowning or starvation as a result of being trapped in the water development (Mensch 1969, AGFD, unpubl. data; Allen 1980, Baber 1983), disease transmission and poor water quality (Monson 1965, Witham et al. 1982, deVos and Clarkson 1990, Kubly 1990, Broyles 1995, Schmidt and DeStefano 1996, Swift et al. 2000), introduction and expansion of non-native species (Broyles 1995, Manseau et al. 1996), and soil compaction and overgrazing adjacent to water developments (Ayeni 1975, Tolsma et al. 1987).

Natural water sources can have drawbacks, as well. Bedrock tinajas are naturally occurring habitats that have smooth vertical walls that angle inward. After a recharge event, tinajas offer a source of water for many wildlife species, however, they can become death traps for wildlife as the water level recedes. Mensch (1969) described the loss of 34 desert bighorn sheep in one tinaja. One of the major efforts to improve water sources where entrapment has occurred is to modify tinajas to allow animals to escape should they slip into the water.

This publication documents several events involving desert bighorn sheep and other ungulates in and around wildlife water developments in Arizona to better understand the effects wildlife water developments may have on desert bighorn sheep individuals and populations.

Desert Bighorn Sheep Biology in Relation to Free-Standing Water

Animals that live in arid environments have developed physiological and behavioral adaptations that include lower metabolic and water turnover rates, and an ability to live without water for extended periods of time. Desert bighorn sheep can live for up to 10 days without drinking water (Krausman et al. 1985), although they readily use free-standing water when it is available (AGFD 1997). Water intake varies depending on how long it has been since the animal last drank (Turner 1970). An animal that has had water in the previous 24 hours will consume 11% to 16% of its weight in water, while an animal that has not had water in 5 days will consume 14.7% to 18.7% of its weight in water. Dehydration that exceeds 20% of body weight will result in death (Turner 1970). Desert bighorn sheep can rehydrate and replace 50% of their blood plasma volume in 4 hours (Turner 1979).

The need for water in mammals varies with age (Davis et al. 1978), reproductive status (Bradford 1975, Short 1981, Baharav 1983, Chevalier 1984, Farrell and Christian 1987), and ambient temperature (MacFarlane 1969, Chevalier 1984). Hailey (1967) correlated availability of water with lamb production and recruitment of a desert bighorn sheep herd.

Distribution of desert bighorn sheep relative to water

Although all ungulates are capable of obtaining water from forage (Short 1981), the distribution of desert bighorn sheep has been correlated with proximity to water (AGFD 1997). Leslie and Douglas (1979) documented 84% of desert bighorn sheep are found within 1.2 miles of water sources during summer months. Cunningham (1982), Olech (1979), and Bristow et al. (1996) documented similar summer aggregations of desert bighorn sheep around natural and human-made water sources. A more recent study by Turner et al. (2004) that examined habitat for Nelson's bighorn sheep in California determined that 97% of their observations (n = 12,411) were made within 1.86 miles of perennial water.

Desert bighorn sheep ewe and lamb in typical rocky, arid habitat.

McQuivey (1978) reported the effect of adding water resources on the summer range of desert bighorn. He noted that the addition of water allowed desert bighorn sheep to remain in the Desert Range during the summer. Prior to the water developments, the herd would move to the Sheep Range during the summer. He also reported that 82% of 488 desert bighorn sheep were found within a 2-mile radius of known water sources in the summer, reducing the amount of possible habitat for desert bighorn sheep to 15–20% of all habitats. Desert bighorn sheep are widely distributed in areas such as the Central Nevada ranges, where water is not a limiting factor. McQuivey identified several dry ranges in Nevada that supported desert bighorn sheep during cooler months, but not during summer.

Monson (1965) documented 4 events involving mortalities of 20 or more desert bighorn sheep near bodies of water during summer months. Today, each of the water sources documented by Monson would be considered critical waters for desert bighorn sheep (i.e., waters used by desert bighorn sheep that are isolated or part of a local cluster of water sources, greater than 3.1 miles from the nearest alternative water source).

Timing and location of desert bighorn sheep releases may affect survivability—lack of reliable water sources at or near desert bighorn sheep release sites may contribute to mortality. The AGFD captured desert bighorn sheep and released them in July in western Arizona and southwest Colorado. There were no mortalities among the desert bighorn sheep released in Colorado at higher elevations, whereas 40% of the sheep released in western Arizona died. The transplanted desert bighorn sheep that survived in western Arizona remained near water development sites, while those that perished left the release area.

Desert Bighorn Sheep/Water Interactions

Desert bighorn sheep and mule deer have perished at a number of natural and human-made water developments that have gone dry (Tables 1 and 2). Swift et al. (2000) documented the largest loss of desert bighorn sheep in 1995 at 2 wildlife water developments in California. In that incident, a total of at least 45 bighorn sheep died at the Old Dad and Vermin guzzlers after the guzzlers went dry.

Table 1. Losses of bighorn sheep at dry water sources.

Location	Date	Observer	Loss	Comments
Mojave Tanks Trigo Mts. AZ	1934	H. Morrow	23 bighorn sheep	Kofa 2004 NWR Annual Report
Little White Tanks Kofa NWR, AZ	1943	Lt. Hatfield	1 ram, 5 mule deer	
Stubbe Spring Joshua Tree NM, CA	~1968	L. Lutz	2 rams	Guzzler constructed
Butterfly Tank Estrella Mts, AZ	July 1987	J. Gunn, AGFD	1 ram, 1 ewe	Facility renovated in 1990
Lazarus Tank Plomosa Mts, AZ	July 1983	J. Witham	2 bighorn sheep	5 live dehydrated sheep observed
Little Bones Cave Plomosa Mts, AZ	July 1983	J. Witham	5 bighorn sheep	
Muddy Mts guzzler #5 Muddy Mts, NV	July 1994	P. Cummings, NDOW	2 ewes	Dry ephemeral seep & water development
Trigo Tinajas Trigo Mts, AZ	~1994	G. Searles	Several bighorn sheep	
Vermin tank guzzler Old Dad Mts, CA	August 1995	A. Pauli, CDFG	3 bighorn sheep	See Swift et al. 2000
Old Dad Pk. Guzzler Old Dad Mts, CA	August 1995	A. Pauli, CDFG	42 bighorn sheep	See Swift et al. 2000
Suds Hole guzzler Sheep Hole Mts, CA	July 2000	CDFG	6 bighorn sheep	
Bear Claw guzzler Sheep Hole Mts, CA	July 2000	CDFG	Several bighorn sheep	
Catchment #933 Plomosa Mts, AZ	August 2000	D. Pfleger, AGFD	1 ram, 1 ewe, 3 mule deer, and 1 coyote	
North Pinta Tank Cabeza Prieta NWR	August 2004	Jim Cain, UA	1 ewe	Waters were turned off in January 2004

Table 2. Bighorn sheep losses in death traps.

Location	Date	Observer	Loss	Comments
White Tanks Tank Mts, AZ	~1954	J. Russo, AGFD	Undetermined	Steps added
Dead Deer Tank Eagletail Mts, AZ	~1956	J. Russo, AGFD	Several bighorn sheep and mule deer	
Pintwater Range, NV	Post 1962	Unknown	1 ram	McQuivey 1978
N. Eldorado Tinaja, NV	Post 1962	Unknown	1 ram	McQuivey 1978
Julian Wash Chocolate Mts, CA	Fall 1968	J. Mensch, CDFG	34 bighorn sheep of various ages/sexes	Steps added
Golden Door cistern Black Mts, AZ	~1984, AGFD	A. Fuller	11 bighorn sheep of various ages/sexes	Metal grate cover installed
Hidden Valley pothole Trigo Mts, AZ	~1984, AGFD	R. Remington, AGFD	Undetermined; bighorn sheep and burro	Spiral ramp constructed
Marble quarry, Carrara canyon, Bare Mts, NV	Summer 1992	B. Adkins, NDOW	4 bighorn sheep (2 ewes and 2 lambs)	
Muerto Tank Sand Tank Mts, AZ	~1994	J. Gunn, AGFD	Undetermined	
Red Tank Kofa NWR, AZ	Summer 1996	R. Henry, AGFD	6 bighorn sheep and 2-3 unknown ungulates	Steps added
Old Moonshine Tank Kofa NWR, AZ	Summer 1996	R. Henry, AGFD	3 bighorn sheep and 3 mule deer	Steps added
Maggot Tank Kofa NWR, AZ	Summer 1996	R. Henry, AGFD	9 bighorn sheep and 2 mule deer	Steps added

Case Studies of Desert Bighorn Sheep Mortality and Survival near Water Sources

Understanding the value of water to bighorn sheep can be aided by reviewing the wealth of observational information available from wildlife management agencies. The following case studies document direct mortality events at dry waters, and population increases when dependable water is added to the dry areas. Taken as a whole, these case studies support the value of developing wildlife waters, particularly in areas where habitat fragmentation has occurred, resulting in loss of traditional waters to bighorn sheep.

Arizona

Catchment #933

During a routine inspection in June of 2000, 12 inches of water was found in catchment #933, a 15-year old water structure in western Arizona. In August of 2000, AGFD officials inspected that same water catchment and found it was dry. They observed a class II desert bighorn sheep ram in poor physical condition bedded near the storage tank, a dead class IV ram, a dead mature mule deer buck, and a dead coyote lying near the tank. In addition, 3 class I rams, 1 class III ram, 4 ewes, a male and female yearling, 1 lamb, and 1 mule deer were alive inside the tank. There were also 2 dead mule deer inside the tank. The fish and wildlife officials provided 4 gallons of water to the animals inside the tank, which was immediately consumed by the bighorn sheep. The officials radioed headquarters for water hauling, and dismantled a portion of the tank to allow the animals to escape. They noted that the wildlife found dead in and around the tank appeared to have died from dehyhdration.

Desert bighorn sheep drinking from a water cooler in catchment #933.

Dead bighorn sheep ram found August 6, 2000 at AGFD Unit #933.

They also suspected that the wildlife had jumped into the tank to consume the remaining 2 inches of water left in the tank after the float-regulated drinker went dry. The ungulates were able to jump into the tank from higher elevations, but would not or could not leave the tank after entering. The size of the antlers on the mule deer and horns of the desert bighorn ram found outside the tank likely prevented them from entering the narrow opening into the tank.

The site was revisited 56 days later in October of 2000 when temperatures were still reaching the low 100s. There was 2 feet of water in the tank. A dead adult bighorn ewe was observed 0.5 miles northeast of the tank, and was estimated to have died that summer. Numerous deer pellets representing deer of all age classes were observed on trails around the catchment. There was no evidence of recent browse on cacti near or within 0.5 miles of the catchment.

Catchment #933 met its objective to provide a permanent water source for a new herd introduced to the northern portion of the Plomosa Mountains. The nearest water source from the catchment is about 7.5 miles to the southeast through mostly contiguous habitat. Additional long-term monitoring of the catchment will provide further insight regarding its dependency to desert bighorn sheep.

Lazarus Tank

In July of 1979, Witham (1982) found a dead 9-year old ram and 5 visibly dehydrated live desert bighorn sheep near Lazarus Tank in the Plomosa Mountains. A necropsy indicated that the ram was in fairly good physical condition with substantial body fat in the abdominal cavity. However, the light weight of the ram suggests it was suffering from dehydration. Five days later, a hiker found a dead 3-year old ram at the same dry water source.

On July 21, 5 mature rams were found dead in a cave 1.75 miles northwest of the site. The rams showed signs of recent rutting activity, and appeared to have died at about the same time as the 9-year old ram found near the watering hole. A nearby tinaja had also gone dry. The nearest permanent water source is 41 years old and located about 4 miles north/northeast through contiguous habitat. Numerous succulent cacti were available in the area.

Cabeza Prieta National Wildlife Refuge

The 860,010 acre Cabeza Prieta National Wildlife Refuge in southwest Arizona was established in 1939 in part to protect a sizable portion of desert bighorn sheep habitat. Eight large mountain ranges are located within the refuge, and the refuge as a whole is divided roughly in half into two management units: 46A and 46B. The eastern half, unit 46A, includes the Growler, Granite, and Aqua Dulce mountain ranges. The western portion, unit 46B, includes the Mohawk/Bryan, Sierra Pinta, Sierra Arida, Tule, and Cabeza Prieta mountain ranges. Much of the refuge (803,418 acres) was designated as wilderness in 1990.

State and federal wildlife officials conduct standardized aerial desert bighorn sheep surveys every 3 years. From 1993 to 2002, there were periods of atypical summer and winter drought in many Arizona deserts including the Cabeza Prieta. Sheep surveys during this period indicated a 49% decrease in the estimated bighorn sheep population in unit 46A where its three mountain ranges are believed to be devoid of perennial bighorn water. The Granite, Aqua Dulce, and Growler Ranges experienced reductions of 73%, 45%, and 35%, respectively, compared to decreases in sheep population estimates of 29% in unit 46B where many of the ranges contain more reliable and permanent water. During this same period, there was less than a 13% population decrease in the Cabeza Prieta range, and a 27% reduction noted in the Sierra Pintas (AGFD survey data, 1993-2002, AGFD-Bob Henry, Pers. Comm.).

Other bighorn populations in southwest Arizona demonstrated similar responses to those experienced in the western 46B portion of the Cabeza Prieta. The more reliably watered Kofa National Wildlife Refuge, located 40 miles to the north, experienced a 23% reduction in its bighorn sheep population during this same period, and is in stark contrast to the reductions noted above in the eastern 46A portion of the Cabeza Prieta.

Kofa National Wildlife Refuge

The Kofa National Wildlife Refuge (KNWR) in Yuma, Arizona is an example of a desert bighorn sheep population that has remained relatively stable over time, despite a decline observed from surveys conducted in 2003. At the landscape level, the Sonoran Desert contains substantial natural watering sources. Within 746 square miles, there are 11 springs, 7 natural tinajas, and 25 ephemeral sites that have been improved to various degrees (Sanchez and Haderlie 1988). From 1987 through 1994, 350 desert bighorn sheep were removed for transplants, and about 110 rams were harvested by sport hunters. Population estimates for this time period ranged from 638 to 929 (USDI 1996), and the current population is estimated at 623 (AGFD survey data, 2003, AGFD-Bob Henry, Pers. Comm.). Although water sources alone cannot account for the robustness and stability of desert bighorn sheep in KNWR, they must certainly be a significant contributing factor.

Gila Bend Mountains

The Gila Bend Mountains herd of desert bighorn sheep was extirpated, and the only natural spring in the area was exploited by miners and used by livestock. Access to the Gila River had been halted by water diversion and tamarack invasion.

The southern portion of this range is about 155 square miles and contains 3 fairly reliable water sources. Between 1987 and 1993, 3 strategically placed water structures were installed on Signal Peak, Woolsey Peak, and Bunyan Peak, and 50 desert bighorn sheep were released during 4 releases. Surveys conducted in 1997 and 1999 found 94 and 86 bighorn sheep, respectively, and there is substantial use of the water structures.

Desert bighorn sheep drinking at the Dripping Springs watering hole in the Gila Mountains.

Eagletail Mountains

The desert bighorn sheep population in the Eagletail Mountains was extant, but static, with a very low density of 35 individuals. The desert bighorn sheep had access to natural water, a known death trap, and a quasi-perennial spring that was also used by livestock. One water source was renovated in 1989, 1 was constructed in 1990, and another was enlarged and renovated in 1996. In 1984, biologists released a total of 16 desert bighorn sheep into this area. A survey in 1994 revealed 35 bighorn sheep. A total of 75 were found in 1997—the same year that 10 were removed for translocation. In October of 2000, 160 desert bighorn sheep were found in this area and an additional translocation of 25 animals occurred. The most current survey conducted in 2003 revealed 99 observations of bighorn sheep.

Saddle Mountain

Saddle Mountain is a small isolated mountain complex located adjacent to Interstate 10 and more than 20 miles from both the Eagletail and Gila Bend ranges. A lone water source was constructed in 1995. The population of bighorn sheep increased and stabilized, and a survey conducted in 2003 supported the expansion of hunting opportunities in management unit 41W to include Saddle Mountain.

Sierra Estrella Mountains

The Sierra Estrella Mountains are located in central Arizona near Phoenix, and contain about 140 square miles of good to excellent desert bighorn sheep habitat. They contain limited natural water that includes 2 ephemeral tinajas and a quasi-perennial spring. Prior to human settlement, desert bighorn sheep may have been able to access the Gila and Santa Cruz rivers, and there are extensive rock murals depicting desert bighorns and hunting along the base of the mountains.

Surveys of desert bighorn sheep in these mountains ranged from 11 to 18 individuals over a period of 20 years. The AGFD, Arizona Desert Bighorn Sheep Society, and Bureau of Land Management renovated the 2 ephemeral tinajas in 1990, resulting in large tinajas over 9 feet deep. The sites have not been dry since 1990. Pellet groups, bed sites, and browse use indicate the area is increasingly frequented by desert bighorn sheep (John Gunn, Pers. Comm.). Prior to the tinaja renovations, a total of 4 desert bighorn sheep were observed per hour, while counts after the renovations noted 10.1 sheep per hour and a total of 38 individuals.

Table Top Mountain

The Table Top Mountains in central Arizona are an isolated mountain range that has no high elevation permanent water sources, but has habitat similar in size and quality to the Silver Bell Mountains and Saddle Mountain, both of which maintain resident bighorn sheep populations. No bighorn sheep were observed during a survey in 1981, despite historical accounts of their presence and documented populations in the adjacent and isolated Sand Tank and Saw Tooth mountains. A total of 34 desert bighorn sheep were observed during the abnormally wet spring of 1993. In the fall of 1993, 13 desert bighorn sheep were observed, and a 1995 survey produced 18 observations. In 1998, only 5 sheep were observed.

A number of factors could be limiting the ability of this population to expand or sustain itself. These include lack of a strategically placed high elevation water structure, increased visitation by the public as a result of wilderness designation, and the small size of the bighorn sheep population (see Discussion section).

Bighorn sheep ram drinking at a watering hole.

Maricopa Mountains

A healthy population of bighorn sheep in the Maricopa Mountains once provided a source for translocation. However, absence of high elevation water, degradation of habitat, and climate factors have made it difficult to sustain a population of desert bighorns in this area. A survey in 1996 noted 90 bighorn sheep. In 1999, 50 bighorn sheep were observed, and in 2002, only 15 bighorn sheep were sighted, indicating a dramatic 83% decrease in the population. These survey results are in stark contrast to the more robust and stable population located 30 miles away across highway 85 in the well-watered Gila Bend Mountains (see above). During this same time frame, survey results in the Gila Bend Mountains indicated a reduction in bighorn sheep, about half of what was experienced in the Maricopa Mountains (AGFD survey data, 1996–2002).

Tinajas Altas Mountains

Located in the extreme southwest corner of Arizona, the Tinajas Altas Mountains lie in the most arid part of the state and contain the famed tiered natural potholes (tinajas) for which the mountain range is named. These tinajas were well known as the last source of reliable water for early travelers on the Camino del Diablo before their final passage to the Colorado River. In more recent times, the AGFD has hauled water to the largest lower tank to keep it from going dry during the summer months.

Desert bighorn sheep have historically occupied the habitat in the Tinajas Altas Mountains. During the wet cycle of the 1980s, a survey (1986) resulted in an estimated population of 43 bighorn sheep. After the subsequent construction of 3 permanent perennial water developments strategically placed throughout the range, a 2000 survey revealed an estimated population of 93 sheep—a doubling of the desert bighorn population (AGFD-John Hervert, Pers. Comm.). This increase is particularly notable as the region was experiencing an extreme drought and other populations in the region had declined.

Desert bighorn sheep near a water structure in the Tinaja Altas Mountains.

California

Suds Hole Guzzler

In July of 2000, the Suds Hole Guzzler, a big game water development in the Mojave Desert, was inspected by a volunteer who observed a dry drinker and both dead and alive desert bighorn sheep. Carcasses showed signs of dehydration as the cause of death. The volunteer observed a coyote kill a ewe that was in poor physical condition.

California Game and Fish officials conducted helicopter surveys of the area that same week and observed another dry guzzler (Bear Claw) south of Suds Hole Guzzler. They observed dead ungulates, and concluded there was a 75% reduction in the desert bighorn sheep population compared to previous years.

Nevada

River Mountains

Leslie and Douglas (1979) studied the ecology of a desert bighorn sheep herd in the River Mountains in southwest Nevada. These mountains were seasonally occupied by desert bighorn sheep during periods of better than average rainfall. Movement patterns included annual summer exodus to the Colorado River. In 1940, a human-made water source became available and the River Mountain population became largely isolated by a highway. The population was estimated at 37–60 animals in 1964–65.

By 1969, the population was estimated at 88 animals. Forty-four desert bighorn sheep were captured from the River Mountain population from 1969 to 1977. In 1973, a second human-made watering source was constructed and became available to the sheep, and a large percentage of the population began watering there. In October of 1973, the population was estimated at 205 animals.

In the summer of 1975, a third water source became available, and the population that fall was estimated at 278 animals. Despite human-related encroachment on all sides, the River Mountains have continued to support a stable and productive desert bighorn sheep population numbering about 300 animals. Both sport harvest and translocation of sheep are possible as a result of the size of this population.

Specter Mountains

The Specter Mountains consist of about 106 square miles in the Mojave Desert north of Las Vegas, Nevada. The range is thought to be without permanent water and was, at one time, without a resident population of desert bighorn sheep. Between 1989 and 1991, 6 water developments were constructed. In 1990, 19 desert bighorn sheep were released, followed by 20 in 1993, and 5 in 1995. In 1998, a total of 119 desert bighorn sheep were surveyed, and 15 were captured for translocation to another range (Nevada Department of Wildlife, Unpublished data).

Discussion

The effects of an ever expanding human population on wildlife habitat are the greatest challenges that wildlife management agencies face, particularly in the southwestern United States. Some human-related effects are obvious, such as the development of travel corridors or the direct loss of habitat to urbanization. However, wildlife populations could potentially be influenced by the role of human activities in global climate change or changes in precipitation patterns. Criticism of artificial water developments has focused on studies that failed to consider critical changes in climate, extensive fragmentation of bighorn sheep habitat, the small size of extant bighorn sheep populations, and the implications of small population size to instability of these small populations. Recent studies have demonstrated the importance of these factors to bighorn sheep and the habitat in which they depend. We have summarized some of the recent literature on these factors in an effort to better understand the need for active management of wildlife habitat; in this case, the development of free-standing water for bighorn sheep where this habitat component is unavailable to bighorn sheep, or to mitigate other negative influences.

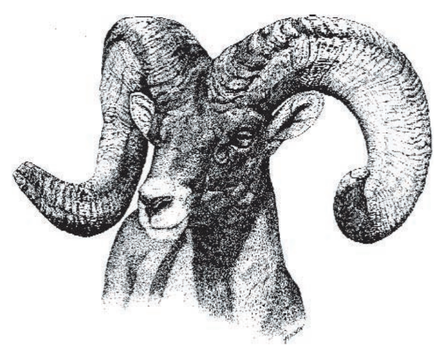
Climate and Habitat Change

Most studies on water use by desert bighorn sheep have been designed to address other questions and have failed to assess the role of climate during these studies (deVos et al. 1998). Temperature and precipitation changes can affect both the plants and animals in a region. Global warming has drawn considerable attention as a major influence on the environment. Walther et al. (2002) documented changes in plant phenology, species composition, and abundance of many species as a result of recent warming trends. Hanski (1999) suggested that climate change can decrease habitat quality and lead to extirpation of populations when small, interconnected populations exist, as is the case with bighorn sheep.

Although the southwestern United States has been undergoing changes in flora and fauna as the region has become warmer and drier in the last 12,000 years (Lowe and Brown 1994), the greatest rate of change has occurred in the last 150 years (Fredrickson et al. 1998). Burning of fossil fuels increases carbon dioxide (Fredrickson et al. 1998, Turner et al. 2003), a possible cause of accelerated desertification in the Southwest.

Turner et al. (2003) suggest that the climate of the Southwest is affected by the global climate system as a whole, and indicate that wind patterns in the northern hemisphere play an important role in precipitation in the region. Since the 1960s, wind patterns have been classified as meridional, which results in great variability in precipitation in a region (Turner et al. 2003). As a measure of the great interannual variation in precipitation that occurs in the Sonoran desert, these authors calculated coefficients of variation for several weather stations in the Sonoran desert and found that the western portion of the Sonoran desert was highly variable—both extremely wet and dry periods occur. Yuma Arizona, on the western edge of the Sonoran desert, demonstrates this extreme—only 0.25 inches of rainfall fell in 1956, yet 11.41 inches fell in 1905. Undoubtedly, these extremes would result in different requirements for wildlife related to free-standing water.

Much of the attention on the cause of extirpation of bighorn sheep populations has focused on patch size (Berger 1990, Krausman et al. 1996a, Wehausen 1999), however, Epps et al. (2004) investigated the role of climate change on bighorn sheep and concluded that increased temperature and decreased precipitation in the late 1900s was an important factor in bighorn sheep population extirpations in California. Although bighorn sheep are well adapted to hot, dry regions (Hansen 1982), the increase in aridity (Turner et al. 2003) and temperatures (Lane et al. 1994, Turner et al. 2003) have been particularly severe. These factors in concert present great challenges to bighorn sheep survival, particularly in lower elevation ranges (<4,900 feet; Epps et al. 2004), which includes most of the occupied desert bighorn sheep range in the Southwest.



Management of small, isolated populations

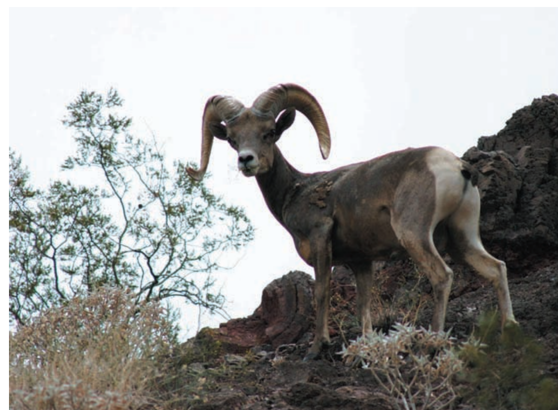
Management of small wildlife populations is a growing concern to wildlife managers globally as human-related infrastructure such as highways, powerlines, dams and aqueducts, and urban expansions fragment habitats and wildlife populations into smaller, discreet units, which in turn increases the risk of a species' extinction (Gilpin and Soulé 1986, Shaffer 1987, Soulé 1987, Pimm et al. 1988, Belovsky et al. 1994). Lynch et al. (1995) attributes the increased risk of extinction to 3 risk factors related to small populations—random changes in birth or mortality rates, random extremes in critical environmental factors such as extreme droughts or hurricanes, or genetic problems such as accumulation of deleterious mutations or inbreeding depression.

There has been a relentless decline in the distribution and numbers of bighorn sheep throughout their range. Many extant populations are isolated from occupied ranges that were once connected (Buechner 1960). Cooperrider (1985) estimated that about 1 million bighorn sheep occupied North America prior to European settlement. Fewer than 12,000 persisted after more than a century of human-caused declines (Monson and Sumner 1980).

Russo (1956) summarized historic records for bighorn sheep and reported this species occurred in most mountainous regions of Arizona, but by the mid 1950s were absent from the San Francisco Peaks and Bill Williams Mountains (northern Arizona), most of the Verde River drainage (central Arizona), and many isolated mountains in southern Arizona. Through aggressive conservation activities and translocations over the past forty years, the trend in bighorn numbers and distribution have experienced a dramatic reversal. The threat, however, to introduced and native bighorn sheep populations continues to exist as evidenced by the extirpation occurring in the Santa Catalina Mountains as recently as the mid-1990s.

As a result of these declines and a rapidly expanding human population in Arizona, most bighorn sheep populations are small (<100; AGFD, unpublished data; Table 1), isolated from other contiguous populations, and at risk of extirpation due to small size. There are 42 herd units identified by the AGFD—only 4 of these have total populations greater than 300 animals. The effective population size for these populations is small and should be considered as populations at risk.

Can small desert bighorn sheep populations persist? After evaluating 122 bighorn sheep populations, Berger (1990) concluded that 100% of populations with <50 individuals went extinct within 50 years and that populations with >100 individuals persisted for up to 70 years. Krausman et al. (1996a) followed methods of Berger (1990) and conducted an assessment of the importance of population size on persistence of Arizona bighorn sheep populations. They found no significant difference in persistence times between populations >100 and those <50. Wehausen (1999) followed similar methods to re-evaluate California bighorn sheep populations (as did Krausman and Etchberger (1993)). He could not support the hypothesis posed by Berger (1990) regarding the disproportionate extinction rate for populations <50 animals.



A desert bighorn ram in typical rocky, arid habitat.

Although there was disagreement between the above studies regarding the actual number of bighorn sheep required to ensure survival, it is important to point out that all of these studies documented extinctions occurring in small, isolated, bighorn sheep populations. Belovsky et al. (1994) point out that the debate on the actual population size is moot because the dynamics of small populations is well documented and there is no guarantee of persistence. Further, Diamond (1972) suggested that patch size alone was the most important variable in determining the rate of population collapse. Bighorn sheep are at risk because of small population size and the small, isolated habitat patch sizes they occupy (Epps et al. 2004).

Although the focus of concern over management of small populations has been on decreased genetic diversity (Frankham 1996), undesirable mutations can build up over many generations when effective population size is less than 100 individuals (Lynch et al. 1995). Singer et al. (2001) and McKinney et al. (2004) noted that patch size is also an important factor for population persistence.

Undoubtedly, decreased genetic diversity, reduced patch size caused by habitat fragmentation, and inability of animals to move between isolated populations increase pressures on typically small, isolated bighorn sheep populations. As many studies suggest, increased management efforts are required to avoid population extinctions (Berger 1990, Belovsky et al. 1994, Krausman et al. 1996b).

Soulé et al. (1979) reported that benign neglect (lack of active management) will lead to faunal collapse. Given the changes that have occurred in the Southwest including increasing desertification, increasing habitat fragmentation, and the resulting decreasing net effective size of most bighorn sheep populations, benign neglect (as it relates to development and maintenance of artificial waters) is a management approach that will undoubtedly result in continued extirpations of local bighorn populations. We agree with one of the conclusions from Soulé et al. (1979:269): "The loss of this living heritage would be a tragedy and a human disgrace."

Conclusion

The purported adverse effects from water developments in the Southwest are poorly supported in the scientific literature (AGFD 1997). Rather, there are many studies that support use of and benefits from artificial water sources by many wildlife species, including bighorn sheep. Additionally, there are many observational reports of use and benefits from provision of free-standing water to bighorn sheep. Although these reports are not peer-reviewed and published, they should not be ignored in deciding an appropriate management approach to developing artificial waters. A hands-off, preservationist approach to maintenance of biological diversity (Belovsky et al. 1994) is no longer a feasible option for wildlife managers, particularly when the focus of management is a species such as desert bighorn sheep, where human-related impacts have resulted in generally small population sizes. When water is recognized as a limiting factor for the health of a desert bighorn sheep population, and in the absence of documented adverse impacts of water developments, we believe water developments should be a component of effective bighorn sheep management. To do otherwise will continue to place bighorn sheep populations at risk for extirpation.

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