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2003

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Dedications

Lives are precious things, and what we choose to spend them on speaks to our values and the things we most hold dear. In our lives, we are fortunate to encounter special people that make a difference in our lives professionally and personally. There have been several special people that made a difference in bighorn sheep management that have ended their mortal careers since the last *Desert Bighorn Council Transactions* went to press. We would like to dedicate this volume to their memories.

Florence "Buddy" Welles
August 21, 1907 – January 23, 2004

Most of us knew her as "Buddy," the first Ewe of the Desert Bighorn Council. In the drawing I made for the title page of the Desert Bighorn book, Buddy is the only ewe, centered, as she was the only female bighorn researcher in the early years. The rams arranged along the skyline represented the male contributors to the book. The drawing was never used in the final printing and I had it framed as a gift to Gale Monson, who along with Lowell Sumner, edited the final draft of the book. Buddy and I were wives and partners of sheep biologists and first became friends in 1960. Chuck and I with our two children were stationed at Corn Creek Field Station, part of the Desert National Wildlife Refuge. Ralph and Buddy were deep into their research of the Desert Bighorn of Death Valley. Buddy and Ralph were original members of the Desert Bighorn Council, actively involved in all its activities.

When Chuck was killed in 1973 while on an aerial survey to locate a site to transplant bighorn to ranges in Utah, a memorial fund was set up to aid young biologists who shared an interest in the survival and study of the sheep. Later, when Ralph passed away we renamed the fund the Hansen-Welles Memorial Fund.

I spent long weekends with Buddy just before she passed away and her memory of their field days studying the Death Valley Sheep was remarkable. In Ralph's early days as a teenage cowboy he learned to name the various cattle in the herds and gave them distinctive names. This he did with the sheep and they individually identified many of them with special names.

Buddy's stories of their adventures were vivid. One in particular was special. At one of the springs in the mountains of Death Valley she got into the water and sat with only her head (with hat) above the surface. After several hours her patience was rewarded when sheep came in to drink right in front of her.

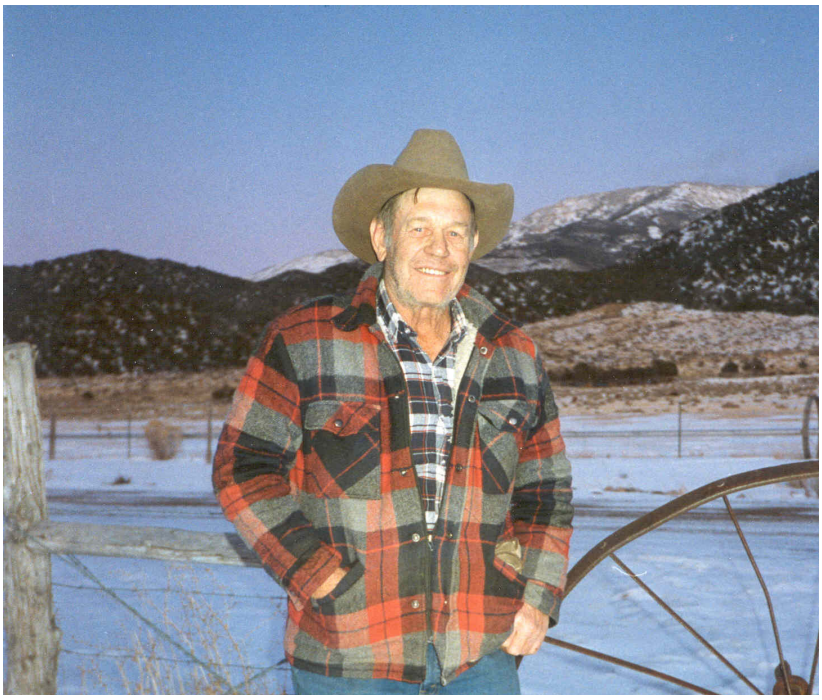
Buddy was a special helpmate in their 61 years of marriage. She was with Ralph during all his research, carrying cameras, taking notes, and finally typing the drafts of 'The Bighorn of Death Valley' on a tiny portable typewriter in their small camping trailer. This doesn't count the usual camp chores.

In her 96 years she successfully mastered four separate goals. First, receptionist for the Actors Equity Association, a precursor of today's Screen Actors Guild. Second, 18 years at the Palo Alto Community Theatre, where she acted, danced, designed and directed choreography for the shows and played the accompaniment of their many musical productions. Third, her 17 years with the National Park Service, and fourth, 31 years as a volunteer in a Hospital Auxiliary.

Throughout all her years she continued her musical career. I shall never forget awakening to special music when visiting, for she played her special 105-year-old Steinway regularly till the end of her life. Most of what she worked at during her lifetime was done on a volunteer basis. A wonderful woman! I am proud to call her one of my best friends.

Pat Hansen – May 2004

A Tribute to Carl Mahon



In May 1965, the first formal research of the desert bighorn sheep in southeast Utah was undertaken. But the first real research of the desert bighorn sheep in southeastern Utah began prior to May 1965, by Carl Mahon. He repeatedly sighted wild sheep while working for the Bureau of Land Management and from trips he made on his own time and funds on weekends and holidays. During these times he searched the nooks and crevices of the canyon lands of southern Utah to determine desert bighorn distributions and gather other data.

After recording numerous sightings and other information on the Utah desert bighorn, Carl was successful in enlisting the support of the local sportsmen club to petition State Legislators and the Director of the Division of Wildlife Resources to study the desert bighorn in the area. Carl knew that once formal studies of the Utah desert bighorn were undertaken, intensive management and protection would follow.

When formal research was initiated, interviews of many local residents who worked in the canyonlands country revealed few had not seen any desert bighorn but many recalled seeing "those little red goats" (desert bighorn ewes and lambs). Sightings of mature rams were rare during this period. Carl never commented on the razzing he took when trying to gain support for formal studies of the desert bighorn. I am sure many local residents, including some personnel of the Utah Division of Wildlife Resources, made comments something to the effect of: "Sure is bad when an old cowboy cannot tell the difference between 'little red goats' and wild sheep."

Carl knew what he was studying and never gave up the cause to have formal wild sheep studies. Beginning in May 1965 and for each formal bighorn study to follow, Carl took the new (graduate student) researchers under his wing and guided them as an advisor to successful studies.

Carl's persistence and untiring dedication to the desert bighorn sheep never faltered for those years before 1965 and until his death on November 11, 2004. Over the years he became a nationally recognized desert bighorn sheep expert. He published several papers in the *Desert Bighorn Council Transactions* and received an Achievement Award from the Desert Bighorn Council. He was the recipient of the Conservation Award given by the Foundation for North American Wild Sheep (FNAWS) and received Utah's highest award from the Utah Chapter of FNAWS.

Carl's easy-going manner and wit endeared him to all who knew him. He was also extremely knowledgeable on the archeology of the Indians that historically inhabited the canyon lands country.

After most of the formal bighorn sheep studies were completed, Carl continued to monitor the sheep herds and support the management of the Utah desert bighorn sheep. He guided many a desert bighorn sheep hunter between 1967 and 2001. On many of these hunting trips, Carl donated his services and no doubt related the desert bighorn sheep life history.

The desert bighorn sheep and wild sheep communities have lost a true champion in Carl Mahon, but his legacy will live on. In the late 1960s, in the heart of Utah desert bighorn sheep habitat, Mahon Canyon was named after Carl. It will forever appear on all U.S.G.S. maps.

Lanny Wilson – 2004

A Tribute to James Blaisdell

The Desert Bighorn Council members and, indeed, bighorn sheep lost a good friend in December 2004 with the passing of James Blaisdell.

Jim was a World War II veteran, then loyally attended the reunions of his U. S. Army Air Corps unit of which he was a bombardier while serving in the European Theater. Taking advantage of the GI Bill, Jim obtained a degree in wildlife management and began his career with the California Department of Fish and Game. He later gained employment with the Federal government.

While assigned to work at Grand Canyon National Park, Jim developed a life-long concern for bighorn sheep. He became a participant in the Desert Bighorn Council during its earliest formative years. Jim served the Council on numerous committees and as Chairman when the National Park Service hosted the meeting at Grand Canyon in 1962.

It was at the 1962 meeting when the Council made the decision and began planning for production of the book *The Desert Bighorn*. Jim was elected to chair the Technical Staff with duties that included "whipping up" the contributing authors to meet their commitments and deadlines, eliminating redundancy, and generally helping the editors. For this and other services, the Council awarded Jim the honor plaque in 1979.

Until his retirement, Jim continued to work for reductions in feral burro populations, reintroduction of bighorn sheep, and the separation of domestic and wild sheep. Although small in stature, Jim Blaisdell stood tall in the world of wildlife conservation. We will all miss him.

Dick Weaver

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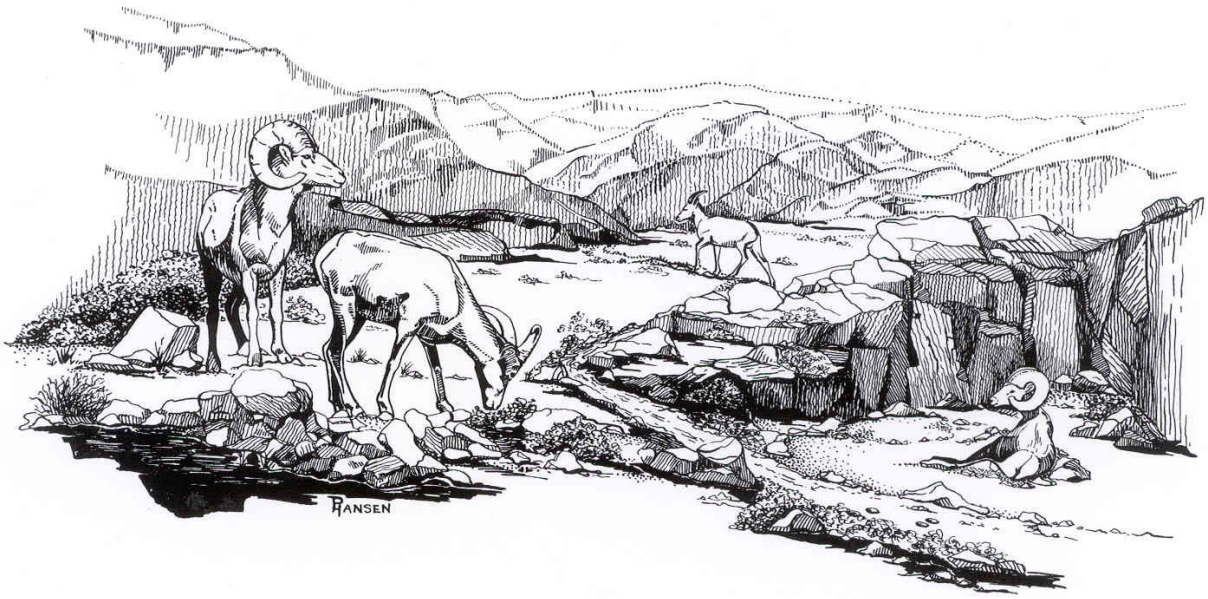
Technical Reports



The potential for botulism in desert-dwelling mountain sheep

Vernon C. Bleich

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Abstract Mountain sheep (*Ovis canadensis*) inhabit arid portions of southwestern North America and use a variety of water sources. Recently, botulism was implicated in the deaths of numerous mountain sheep that drank contaminated water from an artificial catchment in the Mojave Desert, California. That incident has been referenced repeatedly as evidence that such watering devices are a hindrance to conservation. Personal observations accumulated over >30 years, when combined with the results of a brief literature review, suggest conditions suitable for the production of botulinum toxin at *natural* water sources used by mountain sheep occur more frequently than previously recognized. This possibility has important implications for population dynamics of mountain sheep. Managers should take actions necessary to decrease the likelihood of mountain sheep being exposed to conditions suitable for production of botulinum toxin.

Key Words botulinum toxin, California, *Clostridium botulinum*, disease, mountain sheep, mortality, *Ovis canadensis*, Sonoran Desert, tinaja, water quality, wildlife water developments

Desert Bighorn Council Transaction 47:2–8

Botulinum toxin is produced by an anaerobic bacterium (*Clostridium botulinum*) that is frequently associated with carrion and moist environments (Kriek and Odendaal 1994). This powerful neurotoxin results in muscle paralysis (Simpson 1981) and is commonly involved in botulism outbreaks among waterfowl in western North America (Duncan and Jensen 1976). Botulism has been described in mountain sheep (*Ovis canadensis*) only recently (Swift et al. 2000), and evidence of its impacts to mountain sheep is limited (Rosenstock et al. 1999). In this note I summarize observations (n = 19; Table 1) that indicate conditions suitable for production of botulinum toxin are more common at natural water sources in Mojave and Sonoran desert environments than previously recognized.

Personal observations over more than 30 years, when combined with incidents described in the literature (Miller 1927, Monson 1965, Mensch 1969, Weaver and Mensch 1970, McQuivey 1978, Bleich 1993) indicate that the presence of a natural rock tank and carrion were nearly ubiquitous (Table 1). Warm water, low dissolved oxygen, and abundant organic matter are conducive to the production of botulinum toxin, especially when carrion is present (Kriek and Odendaal 1994). During summer, water in tinajas is warm (deVos

and Clarkson 1990; Baron et al. 1998) and levels of dissolved oxygen are low (deVos and Clarkson 1990), seldom exceeding 10% saturation during July and August in pools not flushed by rainwater (Kubly 1990). Further, water in tinajas supports a rich aquatic invertebrate fauna (Baron et al. 1998), and honeybees (*Apis mellifera*), which are physiologically dependent on the availability of free water (Atmowidjojo et al. 1997), can be abundant at water sources used by mountain sheep (Boyce et al. 2003). As aquatic invertebrates and insects die and decay in water, they contribute substantially to anoxic conditions (Kubly 1990) that can persist for extended periods.

Tinajas (Figure 1) are the only natural sources of water in the East Chocolate Mountains (Weaver and Mensch 1969), the Nopah Range (Weaver and Hall 1972), and at Old Dad Peak (Weaver et al. 1969), and they are extremely important sources in the Kingston Range (Weaver and Hall 1972). Further, Spring Tank (a tinaja) is the most important natural water source for mountain sheep in the Chuckwalla Mountains (Weaver and Vernoy 1970), and adits mimic tinajas. Moreover, tinajas are abundant in southwestern Arizona (Broyles 1996), represent important sources of water for mountain sheep during summer (Halloran 1949; Halloran and Deming 1958), and their potential to entrap sheep (that decay and become carrion; Figure 2) is well known (Monson 1957).

Botulism has been confirmed in only 1 case involving mountain sheep (Swift et al. 2000), but conditions potentially suitable for the production of botulinum toxin and dead mountain sheep were found at each of the sources described in Table 1. Other factors, including epizootic hemorrhagic disease (EHD) and bluetongue (BT) (Jessup 1985) or toxins from cyanobacteria (Schwimmer and Schwimmer 1968, Bartram and Chorus 1999) could explain the presence of dead sheep at the water sources described herein. Neither EHD nor BT would, however, be expected to produce sudden group mortalities at a water source, and no evidence of cyanobacterial toxins have been detected in hundreds of samples from wildlife water developments in Arizona that have been analyzed (S. S.

Figure 1. Tinajas represent important sources of water for mountain sheep inhabiting desert environments. This tinaja, located in the Kingston Range, San Bernardino County, California, is used heavily by male and female mountain sheep during summer. Photo courtesy of T. W. Glenner.

Figure 2. Tinajas can be death-traps for mountain sheep, which decay and contribute to anaerobic conditions suitable for the production of botulinum toxin. This tinaja is located in the Sheephole Mountains, San Bernardino County, California, and is one of the few natural sources of water in that range. Photograph courtesy of T. W. Glenner.

Rosenstock, Arizona Game and Fish Department, personal communication).

Observations reported herein suggest that conditions suitable for the production of botulinum toxin occur more frequently in desert environments than previously recognized; moreover, such conditions clearly are not restricted to wildlife water developments. As a result, botulism could be a more important factor in the dynamics of mountain sheep populations inhabiting desert areas than previously realized. Most populations of that species are characterized by a fragmented distribution and are quite small (Bleich et al. 1990); small populations of mountain sheep are predisposed to greater overall risks of extinction (Berger 1999).

The conservation of mountain sheep may be enhanced if managers better document water source conditions, strive to identify causes of deaths among mountain sheep and, where needed, take action to minimize the potential for future losses. Indeed, managers should strive to prevent "...contamination [of water sources] by animals, including bighorn sheep, that fall into such tanks and drown" (Graf 1980). Actions, such as constructing escape ramps (Mensch 1969, Bleich 1979, Kubly 1990), to correct environmental conditions that might lead to production of botulinum toxin should be pursued as locations likely to entrap animals are discovered. Prevention of drowning, rather than consideration of the potential for more widespread losses associated with botulism, however, has been the historical motivation for such actions.

Evidence presented herein indicates that conditions potentially suitable for production of botulinum toxin occur more frequently than heretofore reported and are not uncommon at natural water sources. Moreover, other observations of entrapment of mountain sheep in tinajas located in Nevada and Arizona (Arizona Desert Bighorn Sheep Society 2004) are consistent with the hypothesis that conditions suitable for the production of botulinum toxin occur more frequently than previously recognized. Correcting situations conducive to the production of botulinum toxin necessarily involves use of mechanized equipment, but is compatible with wildlife conservation both within and outside of wilderness administered by the Bureau of Land Management (Bleich 2001) or Fish and Wildlife Service (Bleich 1999). Actions to decrease the potential for such conditions to develop at water sources in wilderness administered by the National Park Service would, however, be difficult to undertake (Bleich 1999, 2001). Nonetheless, those actions clearly are in the best interest of minimizing mortalities of mountain sheep in the deserts of North America.

Acknowledgments: I thank F. L. Botti, R. Campbell, R. R. Celentano, L. J. Coombes, W. Dressel, T. E. Evans, T. M. Glenner, J. R. Jaeger, G. P. Mulcahy, A. M. Pauli, G. W. Sudmeier, B. Tuck, and R. A. Weaver for assistance in the field or for providing useful information. I thank H. B. Ernest, D. A. Jessup, P. K. Swift, and an anonymous reviewer for helpful comments on the manuscript. Field work upon which these observations are based has been supported by CDFG for more than 3 decades. This is a contribution from the CDFG Mountain Sheep Conservation Program and is Professional Paper 039 from the Eastern Sierra Center for Applied Population Ecology (ESCAPE).

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Vernon C. Bleich *has been employed by the California Department of Fish and Game (CDFG) for >30 years, where he has worked extensively with mountain sheep in the Mojave, Sonoran, and Great Basin deserts of southeastern California. In 2001, Vern received the Desert Bighorn Council's Ram Award in recognition of his contributions toward the conservation of mountain sheep. Currently, Vern directs the CDFG Sierra Nevada Bighorn Sheep Recovery Program.*

Table 1. Observations suggesting conditions suitable for production of botulinum toxin, and evidence of botulism poisoning of mountain sheep in the Sonoran and Mojave deserts. At least 1 mountain sheep was dead at each location.

Water Source	Water Present?	Desert Ecosystem	Carrion Present?	Location	Source of Information
Tinaja	Yes	Mojave	Yes	Kingston Range, CA	G. Sudmeier[1]
Spring	Yes	Mojave	Yes	Sacramento Mtns., CA	V. Bleich[2]
Tinaja	Yes	Sonoran	Yes	East Chocolate Mtns., CA	V. Bleich[3]
Tinaja	No	Mojave	No[4]	Nopah Range, CA	V. Bleich[5]
Tinaja	Yes	Mojave	Yes	Old Dad Peak, CA	R. Weaver[6]
Tinaja	Yes	Mojave	Yes	Old Dad Peak, CA	G. Sudmeier[7]
Tinaja	Yes	Mojave	Yes	Sheephole Mtns., CA	T. Glenner[8]
Adit	Yes	Mojave	Yes	Dead Mtns., CA	W. Dressel[9]
Adit	No[11]	Mojave	Yes	Coxcomb Mtns CA	G Sudmeier[1]
Tinaja	Yes	Sonoran	Yes	Chuckwalla Mtns., CA	B. Tuck[12]
Tinaja	Yes	Sonoran	Yes	Fish Creek Mtns., CA	Miller 1927
Tinaja	Unknown	Sonoran	Unknown	Trigo Mtns., AZ	Monson 1965
Tinaja	Unknown	Sonoran	Unknown	Tinajas Altas Mtns AZ	Monson 1965
Tinaja	Unknown	Sonoran	Unknown	Tank Mtns., AZ	Monson 1965
Tinaja	Yes	Sonoran	Yes	East Chocolate Mtns., CA	Mensch 1969
Tinaja	Yes	Sonoran	Yes	Chuckwalla Mtns., CA	Weaver and Mensch 1970

Tinaja	Unknown	Mojave	Unknown	North Pintwater Range, NV	McQuivey 1978
Tinaja	Unknown	Mojave	Unknown	Eldorado Range, NV	McQuivey 1978
Tinaja	Yes	Mojave	Yes	Old Dad Peak, CA	Bleich 1993

[1] G. Sudmeier, Society for the Conservation of Bighorn Sheep, personal communication 1976.

[2] V. Bleich, California Department of Fish and Game, personal observation 1976.

[3] V. Bleich, California Department of Fish and Game, personal observation 1978.

[4] Articulated skeletons of 3 mature males were found in a shaded area approximately 20 m from the tinaja.

[5] V. Bleich, California Department of Fish and Game, personal observation 1982.

[6] R. Weaver, California Department of Fish and Game, personal communication 1984.

[7] G. Sudmeier, Society for the Conservation of Bighorn Sheep, personal communication 1995.

[8] T. Glenner, Society for the Conservation of Bighorn Sheep, personal communication 1998.

[9] W. Dressel, Bureau of Land Management, Needles Field Office, personal communication 2002.

[10] Remains of 1 female in the adit below the waterline clearly had been submerged before the adit dried.

[11] G. Sudmeier, Society for the Conservation of Bighorn Sheep, personal communication 2002.

[12] B. Tuck, Society for the Conservation of Bighorn Sheep, personal communication 2004.

The history of desert bighorn sheep management in Utah

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Abstract Historical evidence documents that desert bighorn sheep (*Ovis canadensis nelsoni*) are native to Utah. Although bighorn sheep were protected from hunting by state law in 1899, desert bighorn sheep populations declined precipitously. The Utah Department of Fish and Game (UFGD) conducted a fixed-wing airplane survey in 1964 to determine if bighorn sheep still existed in the state. A small population was found in San Juan County and research projects were initiated in 1965. Researchers found a population of about 250 bighorn sheep, and limited hunting was allowed in 1967. Ten hunters harvested 9 rams that year.

After finding a viable population in southeastern Utah in 1967, UFGD, which became the Utah Division of Wildlife Resources (UDWR) in 1972, established a goal to reintroduce desert bighorn sheep into suitable habitat throughout the state. Since 1973, over 600 desert bighorn sheep have been transplanted into 9 different areas. The purpose of this paper is to document the results of those efforts, other management activities, and research conducted on desert bighorn sheep in the state.

Key Words history, hunting, management, mountain sheep, *Ovis canadensis*, translocation, Utah

Desert Bighorn Council Transactions 47:9–15

Historical Information

Historical evidence documents that bighorn sheep (*Ovis canadensis*) are native to the state of Utah. Fossils, skeletal remains, and depictions in pictographs and petroglyphs document that bighorn sheep were found in the area and used by ancient inhabitants (Dalton and Spillett 1971). The first written record of bighorn sheep in Utah was made by Father Escalante (Briggs 1976), who reported "wild sheep lived in such abundance that their tracks are like those of great herds of domestic sheep." Other early explorers and trappers also reported observations of bighorn sheep throughout the state (Rawley 1985).

Skeletal remains of bighorn sheep found in the state suggest that those that lived along the Green and Colorado Rivers were desert bighorn sheep (*O. c. nelsoni*), and those in northern Utah were the Rocky Mountain subspecies (*O. c. canadensis*) (Wilson 1966). Buchner (1960) reported

that bighorn sheep were widespread prior to 1920, but with the advance of western civilization bighorn sheep numbers began to decline. Possible causes of decline included competition with vast numbers of domestic livestock introduced to the area and exposure to their associated diseases. Over-hunting by uranium miners and others in the 1940s and 1950s may have also contributed to the decline (Bates 1983, Follows 1969).

State Management

The first law in Utah protecting bighorn sheep was passed in 1876. The Utah Territorial Legislature prohibited hunting of bighorn sheep and other big game species between 1 January and 1 July each year. In 1899, another law was passed that prohibited bighorn sheep hunting altogether (Rawley 1985). In spite of this protection, bighorn sheep populations continued to struggle. Several outbreaks of scabies mite were documented, as was poaching by uranium miners (Follows 1969).

In 1964, the UFGD received reports of a remnant population of desert bighorn sheep (Heggan, personal communication). UFGD conducted a fixed-wing airplane survey of the Red and White Canyon areas and found a few desert bighorn sheep. Negotiations with Utah State University began at that time, resulting in 2 major research studies conducted east of Lake Powell in southeastern Utah (Wilson 1966, Irvine 1969). These early studies focused on numbers, distribution, and forage selection.

A fixed-wing survey was conducted again in 1966 of known desert bighorn sheep populations in the White Canyon area. Fifty-three bighorn sheep were observed during this survey. This count, coupled with ground counts, yielded an estimated population of about 135 bighorn sheep (Wilson 1966).

As a result of the information derived through these studies, Utah held its first desert bighorn sheep hunt in 1967. Ten permits were issued, valid only in San Juan County, and 9 rams were harvested (John 1968). Season dates were from 11 November through 19 November 1967.

Research

After a brief intermission, Utah again became active in desert bighorn sheep research in the 1970s. Dean (1977) documented distribution of desert bighorn sheep in Canyonlands National Park, including changes in distribution after the Park was established in 1966. Later research sponsored by the National Park Service described habitat use (Bates 1983), nutritional requirements (Hull 1984), and ecology of transplanted bighorn sheep (Steele and Workman 1987, Haas 1990, Alston et al. 2003).

Desert bighorn sheep research on lands administered by the Bureau of Land Management (BLM) also occurred, beginning in 1981. Much of this research focused on impacts of human disturbance on desert bighorn sheep populations (King 1985). A similar project is currently underway, using GPS technology to look at effects of increasing recreational activities on desert bighorn sheep in the Moab area (Martinez and Flinders 2002).

Transplants

The National Park Service conducted the first desert bighorn sheep transplant in Utah. Bighorn sheep had once been abundant in the area in and around Zion National Park, but their numbers declined and bighorn sheep were eventually extripated from the area (McCutchen 1977). In 1972, 12 desert bighorn sheep from Nevada were released into a 36 ha enclosure

at Zion National Park. By 1977, the population had increased to 22 animals and 13 were captured and released into a 5 ha enclosure and eventually released into the wild. However, problems were encountered with using enclosures. The bighorn sheep population increased at an unacceptably slow rate, and animals in the enclosure contracted diseases, such as sinusitis (Bunch et al. 1978). Future releases did not use the enclosure method.

From 1967 to 1975, bighorn sheep populations increased and expanded in other parts of the state and the UDWR, formerly UFGD, established a goal to reintroduce desert bighorn sheep into all suitable historical habitat. The first transplant occurred in 1975. Four bighorn sheep were moved from the Colorado River corridor upstream of Lake Powell to Moody Canyon that year, and supplemented with 13 in 1976. Seven bighorn sheep from Nevada were released in Westwater Canyon in 1979. Twelve bighorn sheep from Red Canyon were released in the North San Rafael Desert in 1979.

Research conducted in Canyonlands National Park in the early 1980s discovered a rapidly increasing population (Bates 1983). The UDWR and the National Park Service entered into a cooperative agreement at that time to use the Island in the Sky District of Canyonlands National Park as a source for future transplants. UDWR agreed to pay all transplants costs, and release an equal number of bighorn sheep on National Park Service lands as released on BLM or state lands.

One hundred eighty-four desert bighorn sheep were moved between 1982 and 1986 from the Island in the Sky District to a number of units, including the North San Rafael, South San Rafael, Little Rockies, and Kaiparowitz on BLM lands, and National Park Service units including Arches, Capitol Reef, and the Maze (UDWR 1999).

Populations in some areas, most notably the North and South San Rafael, Potash, and Escalante, increased rapidly and became source populations for future transplants. Transplant sites using bighorn sheep from these herds include the South San Rafael, Dirty Devil River, North Wash, Professor Valley, Rogers Canyon, Coyote Canyon, and Paria River. One hundred and fifty-eight desert bighorn sheep were transplanted from these units from 1990 to 2003.

Utah has been active in working with other states on desert bighorn sheep reintroductions. In addition to the Zion release, Nevada has donated 85 bighorn sheep to Utah for release along the Dolores River, Grand Staircase National Monument, Paria River, and North San Juan. Although once supporting a viable herd, bighorn sheep in the North San Juan Unit were extirpated following exposure to a band of domestic sheep. Bighorn sheep released in Utah have also come from Arizona. Sixty-seven bighorn sheep from Arizona were released in Coyote Canyon, the Smokey Mountains, and the Beaver Dam Slope. Utah has also donated desert bighorn sheep to other states. Twenty-six bighorn sheep from the San Rafael units were released in Colorado along the Dolores River in 2001. Several others were donated to Texas in 1982 and 1985.

More than 600 desert bighorn sheep have been transplanted in Utah from 1973 to 2003.

Capture Methods

Capture of desert bighorn sheep was necessary to conduct research and transplants. Chemical immobilization, using the narcotic M-99, occurred from 1972 through 1979. Bighorn sheep were shot with a tranquilizer dart from a helicopter.

As soon as practical after the sheep was immobilized, effects of the tranquilizer were reversed using M 50-50 (Bates 1983).

Capture-related mortality was high using chemical immobilization. Twenty-three percent of 147 bighorn sheep died as a result of being captured using this method (Bates et al. 1985). In addition, some personnel were exposed to dangerous drugs. Fortunately, none were seriously injured.

A decision was made in 1981 to try a different method. Jessup et al. (1982) had success using tangle nets to capture desert bighorn sheep in California. Bighorn sheep were captured in 1981 in Utah using stationary tangle nets, where sheep were chased to the capture location. In 1982, a mobile method was employed where a team of 2 biologists was flown in a helicopter until a band of sheep was located. The team was then dropped off at a suitable capture location, and 1 section of net was set up. The helicopter pilot then herded the bighorn sheep to the net. Using this method, 136 bighorn sheep were caught from 1981 to 1984, with only 1 mortality (Bates et al. 1985).

Use of net guns developed by Coda Industries to capture bighorn sheep began about 1983, and UDWR began to use this method in 1985. This has resulted in a reduction in capture time per animal from 2.0 hours flight time for chemical immobilization, and 0.8 hours for tangle net capture, to about 0.5 hours of flight time for capture by net guns. From 2001 to 2003, 87 desert bighorn sheep were captured in Utah using net guns, with 2 mortalities (2.2%).

Aerial Surveys

A fixed-wing airplane was used to survey desert bighorn sheep in Utah from 1966 to 1970. Information from desert bighorn sheep research was used to supplement the population estimate in 1967 (Wilson 1968). Helicopters were first used in 1971 and have been used to survey desert bighorn sheep in the state since that time. Several efforts were made from 1983 through 1985 to do a double survey procedure in Canyonlands National Park to attempt to estimate bighorn sheep numbers. A group of observers on the ground documented the number of rams, ewes and lambs in the survey area at the same time the helicopter survey was conducted. A comparison was made between bighorn sheep observed by both methods, versus those seen by just one. The National Park Service has also been using a sightability model for the past 10 years in Canyonlands National Park.

Fixed-wing flights from 1966 to 1970 averaged 56 bighorn sheep counted per year, whereas the number counted using a helicopter from 1971 through 2001 averaged 440 (Figure 1). The current population estimate for Utah is about 2,700 desert bighorn sheep. While the trend is up statewide, largely due to increasing populations in transplanted areas, population declines have been observed in some areas. Bighorn sheep in the North San Juan Unit came in contact with a domestic sheep herd in 1987. The population in that unit was extirpated, possibly a result of being exposed to diseases for which they had no

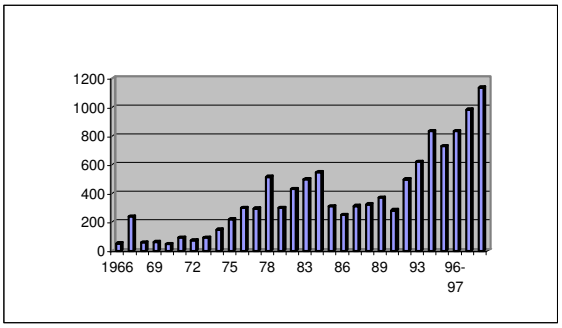

Figure 1. Desert bighorn sheep observed during aerial surveys in Utah, 1966–2002.

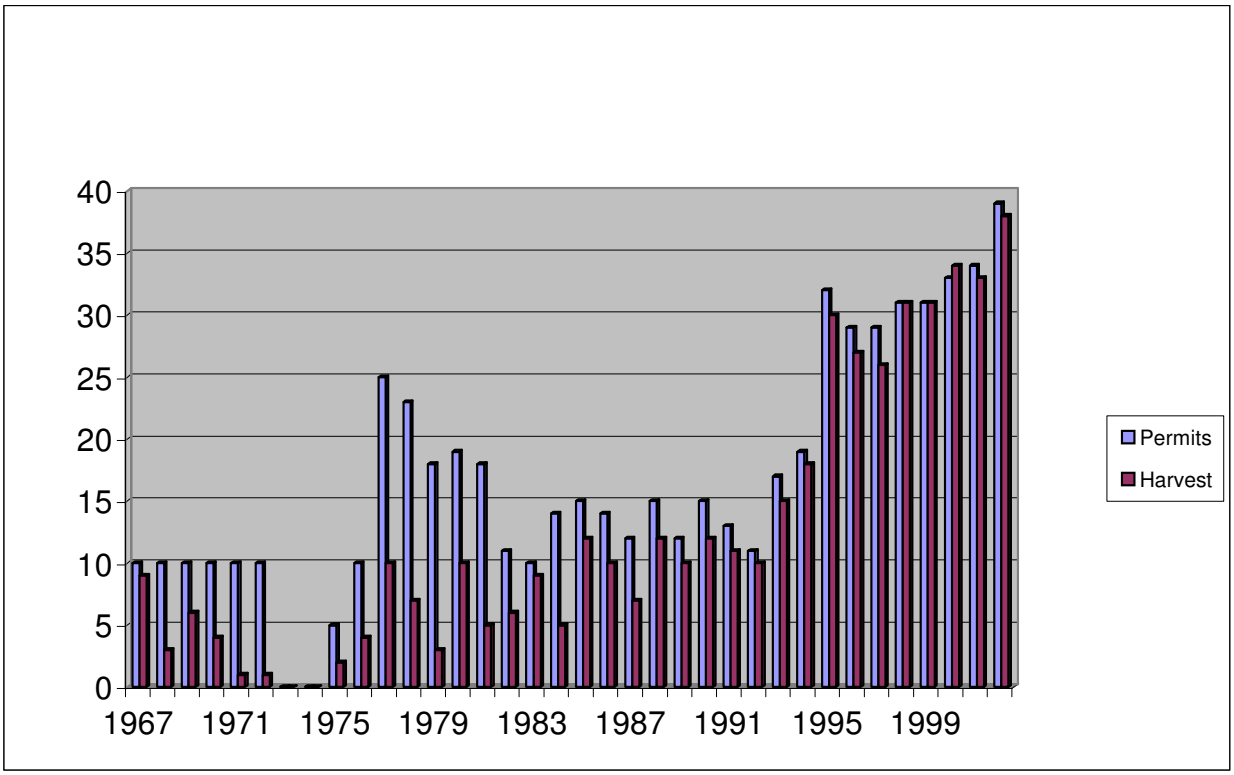

Figure 2. Annual permits for and harvest of desert bighorn sheep in Utah, 1967–2002.

resistance. Two desert bighorn sheep releases occurred in 1998 and 2000 within the area, but a self-sustaining herd has not been established. Populations have also declined in the South San Juan Unit and in Canyonlands National Park.

Habitat Improvement

Desert bighorn sheep habitat improvement projects have focused on 2 areas: water development and reducing conflicts with domestic livestock. Guzzlers have been installed in 45 different locations throughout southern Utah for desert bighorn sheep, and temporary water sources, such as a drinker attached to a water tank, have been used in about 10 locations during periods of extreme drought.

Using conservation permit funds, the UDWR has worked closely with the Foundation for North American Wild Sheep to purchase grazing permits from willing sellers to convert domestic sheep allotments to cattle, or retire permits if appropriate. So far, grazing permit conversions or purchases to benefit desert bighorn sheep have occurred in the North and South San Rafael, LaSal, Henry Mountain, and Virgin River units.

Hunting

With the exceptions of 1973 and 1974, hunting of desert bighorn sheep has been allowed in Utah from 1967 to the present. Six hundred fourteen permits were issued during that period (Figure 2), with typically just under 90% being issued to resident hunters. An average of 14 permits per year were issued from 1967 to 1992. The average annual harvest per year during

this period was 6.9, or about 50% hunt success. From 1993 through 2002, an average of 29 permits was issued per year, with a high of 38 in 2002. Hunters took an average of 28.3 rams annually, for a 96% success rate. The highest harvest was 38 rams taken in 2002.

Through the Conservation Permit program, desert bighorn sheep management has been funded through hunting. Utah issued its first Statewide Desert Bighorn Permit at auction in 1980. It sold for $20,000 at the Foundation for North American Wild Sheep banquet. This program has been expanded since that time, and currently Utah offers the following desert bighorn sheep permits to Conservation Groups to assist them in raising funds for bighorn sheep management: statewide desert and Rocky Mountain bighorn sheep permits, 1 each; 2 Rocky Mountain bighorn sheep area conservation permits; and 4 desert bighorn sheep area conservation permits. In 2002, the statewide desert bighorn permit sold for $68,500. The total raised through the sale of all permits was $305,000. These funds have been used to pay for transplants, research, grazing permit purchases, and habitat improvement projects.

Future Management

Management of desert bighorn sheep in the future will be guided by the Utah Bighorn Sheep Statewide Management Plan, which was completed by UDWR in 1999. This plan will be reviewed in 2005. The goal of the plan is to establish optimum populations of bighorn sheep in all suitable habitat within the state. The plan sets as an objective increasing the number of desert bighorn sheep statewide from 2,600 to 3,800 through transplants, habitat improvements, predator control, and disease monitoring. It also sets an objective of managing for a diversity of ram age classes, with at least 30% of rams 6.5 years of age or older. Other objectives call for a 50% increase in hunting opportunity, and increased public awareness, and expanded viewing opportunities of bighorn sheep. Finally, the plan sets priorities for future transplants.

Conclusion

Through aggressive management, desert bighorn sheep, a species once abundant but almost lost through human-related activities, have been reestablished throughout much of their former habitat in Utah. Population increases have been documented, and animals have been transplanted from areas of increase. Some of the native populations have again declined due to diseases. However, the statewide population has continued to grow, most notably in transplanted populations. Some of these translocated populations are now being used to restock native populations.

Hunting has provided a valuable recreational opportunity to both residents and non-residents of Utah. Through the Conservation Permit Program, hunting has also provided funding for desert bighorn sheep management. Continued growth is guided by the Utah Bighorn Sheep Statewide Management Plan.

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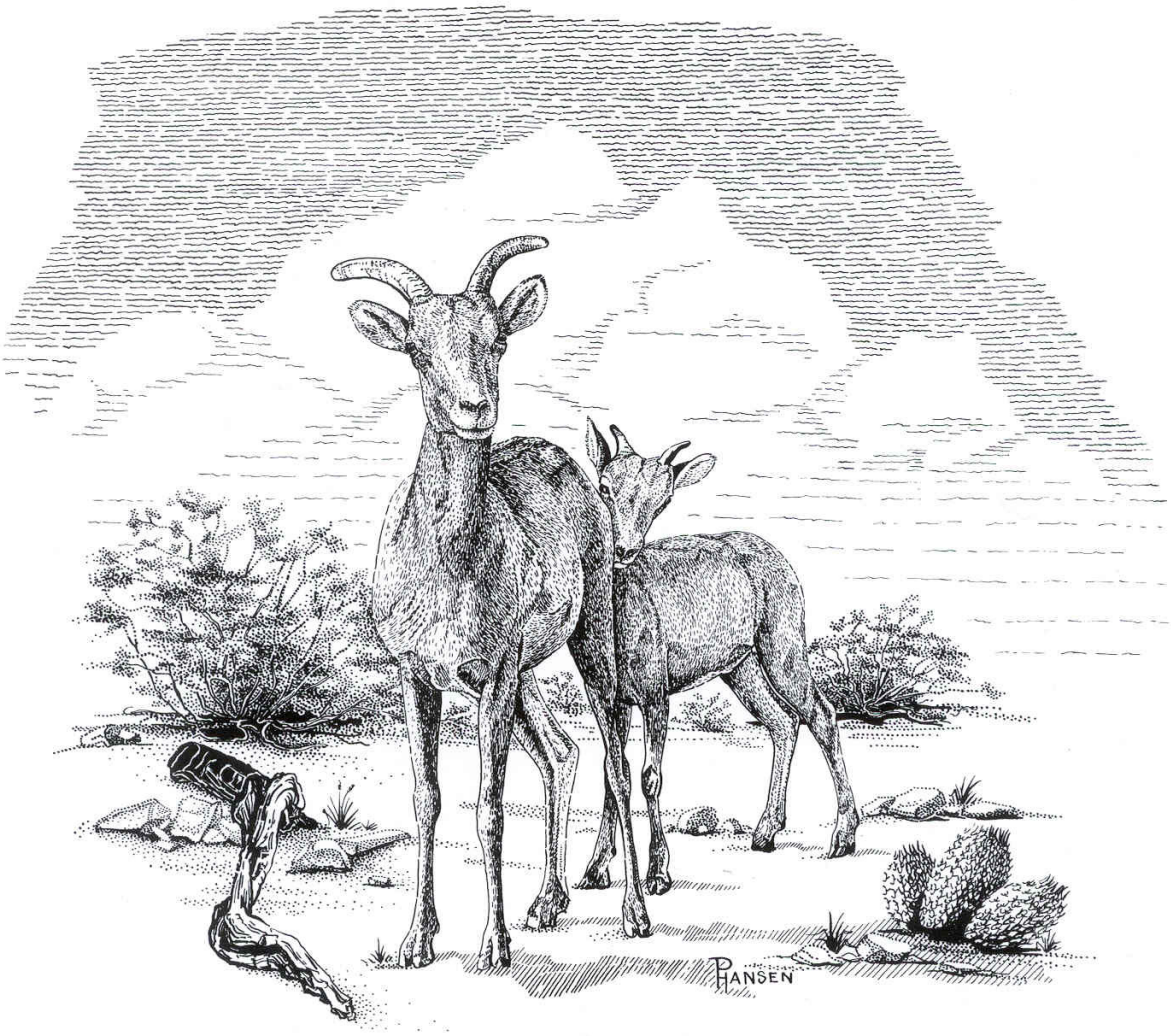
P HANSEN

Status of bighorn sheep in Arizona, 2002–2003

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Desert Bighorn Council Transactions 47:18–19

Populations

Estimates of Arizona's desert bighorn sheep (*Ovis canadensis mexicana and O. c. nelsoni*) populations have declined over the past 2 years. Desert sheep are estimated to number about 5,500. Ram:100 ewes:lamb ratios averaged 56:100:23 in 2002 and 39:100:30 in 2003. Declines in populations are largely tied to drought.

In 2003, a notable disease outbreak occurred within Unit 37A in a herd of about 100 desert bighorn sheep (*O. c. mexicana*) that occupied the Silver Bell Mountains. These sheep contracted keratoconjunctivitis and contagious echthyma after exposure to domestic goats that were released without permission during fall 2003. Several lawsuits are pending in this arena.

Rocky Mountain bighorn sheep (*O. c. candensis*) continue to do well in Arizona, and seem less impacted by the drought than were Arizona's desert sheep. This population is estimated at about 800 animals. Ram:100 ewes:lamb ratios averaged 46:100:33 in 2002 and 44:100:20 in 2003.

Research

The Department is currently involved in a research study of bighorn sheep in northwestern Arizona. Objectives of this study include disease monitoring, survival, and impacts of highway development.

Habitat

The Department works with private organizations (primarily the Arizona Desert Bighorn Sheep Society [ADBSS]) and federal agencies to achieve habitat improvements. Many of these projects are solicited each year through the Department's Habitat Partnership Committees and are funded with Special Big Game Tag funds generated through the sale of Arizona's 2 sheep tags.

In 2002, the Department and ADBSS coordinated on 17 individual projects for $333,854, and in 2003 we coordinated on 20 projects for $376,720. Most projects involved building or maintaining water sources, but also included prescribed fire, sheep survey, and transplants.

Transplants

In 2002, the Department conducted 2 captures and translocations. The first was a transplant of 26 Rocky Mountain bighorn sheep from Eagle Creek near Clifton-Morenci to the Bear Canyon area in east-central Arizona. While the capture and release of these animals was largely uneventful, most radiocollared bighorn sheep were able to relocate from the release site to the capture site (about 50 km as the *Corvus* flies) before the first post-release monitoring flight.

During 2002, the Department also captured 21 desert bighorn sheep (*O. c. mexicana*) in the Kofa Mountains; 1 died as a result of the capture effort. These 20 sheep were provided to the New Mexico Game and Fish Department for release in the San Andres Mountains in New Mexico.

In 2003, the Department captured 30 desert bighorn sheep (*O. c. mexicana*) from the Trigo, Chocolate, New Water, and Plomosa Mountains and moved them to the Mineral Mountains in central Arizona. No mortalities were detected for over 9 months following this release, and mountain lions (*Puma concolor*) have yet to kill any bighorn sheep since the release.

Additionally in 2003, 27 Rocky Mountain bighorn sheep were moved from Wheeler and Pecos Peaks in New Mexico to Bear Canyon in Arizona to supplement a small herd.

The Department continues to plan for additional transplant opportunities, especially for Rocky Mountain bighorn sheep. The Chevelon Canyon area has remained a high priority for future releases, although a domestic sheep allotment in close proximity kept this transplant from becoming a reality. Other areas of consideration are West Clear Creek and a supplemental release in Bear Canyon to expand the existing distribution of sheep.

Harvest

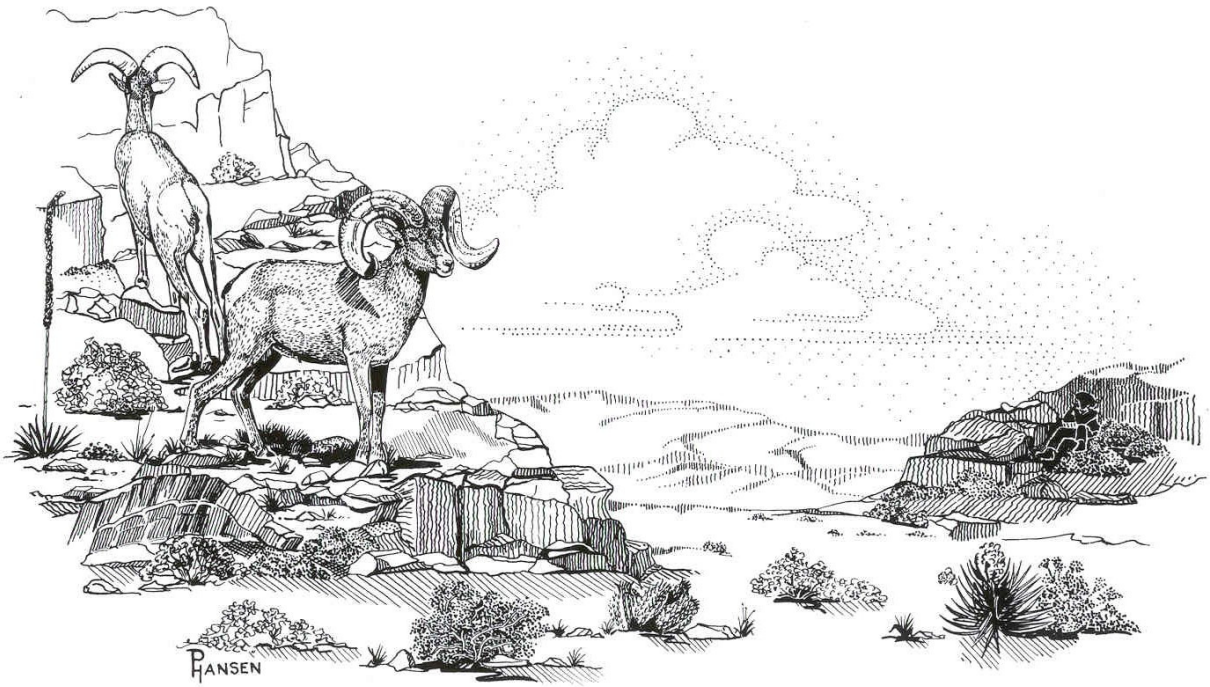
Bighorn sheep permits remain the most sought after hunting permits in Arizona. In 2002, 13,013 individuals applied for the 104 available permits, whereas in 2003, 16,049 individuals applied for the 99 available permits.

During the 2002 season, 101 hunters participated, harvesting 92 rams in 674 days of hunting. Hunt success averaged 91.1%. In 2003, 95 hunters participated, harvesting 87 rams in 764 days of hunting. Hunt success averaged 91.6% in 2003.

In 2002, age of harvested rams ranged from 1.5 to 10.5, and horns green scored from 122 3/8 to 180 1/8. In 2003, age ranged from 3.5 to 11.5 on harvested rams, and green scores on horns ranged from 113 5/8 to 181 4/8.

Continuing a long history, the Arizona Game and Fish Commission awarded the Special Big Game License Tags for bighorn sheep (2 tags per year) to ADBSS in 2002 and 2003. Each year, ADBSS has traditionally auctioned 1 tag at the Foundation for North American Wild Sheep Annual Convention and raffles the second tag. In 2002 and 2003, ADBSS raised $209,900 and $233,750 by marketing these tags.

State Status Reports



Status of bighorn sheep in California

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Desert Bighorn Council Transactions 47:20–35

Successful management of bighorn sheep requires detailed and timely knowledge of the status and distribution of populations of those unique ungulates. This inventory of bighorn sheep in California is intended to update previous population inventories published by Wehausen et al. (1987), Weaver (1989), and Torres et al. (1994; 1996). For the 1994 population inventory, the California Department of Fish and Game (CDFG) established a Geographic Information System database showing the historical and then-current distribution of bighorn sheep populations in the state. The 1996 inventory summarized changes known to have occurred during the preceding two years. Here, we present updates to the sizes, distributions, and identities of these populations (Table 1), organized by "metapopulation" management units (Figure 1) as defined by Torres et al. (1994). These updates reflect demographic changes in bighorn sheep populations over nine years, including extirpations and reestablishments through translocation or natural recolonization, as well as new data on the distribution and size of those populations. Because of the varying precision of the population estimates, we again present them categorically as size classes. The estimates are derived from helicopter surveys by CDFG, counts and camera monitoring at waterholes, minimum counts derived from non-invasive genetic sampling (Epps 2004, 2005), mark-resight estimates, and minimum ground counts. Because some estimates are based on few data and may not have been updated since previous inventories, we also present information on the source of each estimate, and indicate those areas where new information is needed. This approach will help establish priorities for future efforts and provide opportunities to better assess data uncertainties.

During 1995–2004, a number of legislative and taxonomic revisions concerning bighorn sheep in California occurred. Although the Peninsular bighorn sheep (*Ovis canadensis cremnobates*) is no longer considered a valid subspecies (Ramey II 1995; Wehausen and Ramey II 1993), the populations in the Peninsular Ranges were listed as endangered under the distinct vertebrate population provision of

Table 1. Extant and extirpated populations of bighorn sheep in California as of the end of 2004. Population size class estimates typically include all sex and age classes. Size class estimates of 0 do not necessarily indicate lack of use by bighorn sheep, as some of these areas are known to be used by transient rams. "Population Status" indicate which populations have changed status due to extinction or recolonization, or redefinition since 1993 (Torres et al. 1994) and 1995 (Torres et al. 1996). "Data Source" indicates the most recent year of data collection, as well as the source and type of data.

Metapopulation	Population	[1]Population Status	Population Size Class	Data Source-Year of Most Recent Data
Peninsular Ranges	Carrizo Canyon	N[3]	101–150	CDFG 2004[5,6]
	Vallecito	N	101–150	CDFG 2004[5,6]
	South San Ysidro	N[3]	25–50	CDFG 2004[5,6]
	North San Ysidro	N[3]	25–50	CDFG 2004[5,6]
	Coyote Cyn.	N[3]	25–50	CDFG 2004[5,6]
	Santa Rosa, E. of Hwy 74	N[3]	201–300	CDFG 2004[5,6]
	Santa Rosa, W. of Hwy 74	N[3]	51–100	J. DeForge[7]
	San Jacinto	N	25–50	S. Ostermann[7]
San Gabriel	San Gabriel	N	201–300	CDFG 2004[5]
Western Transverse Range	San Rafael	R	25–50	CDFG 2002[5]
	Caliente Peak	E	0	No new data
Sonoran	W. Chocolate (Gunnery)	N	101–150	CDFG 2004[5]
	E. Chocolate (Colorado R.)	N	51–100	CDFG 2004[5]
	Orocopia-Mecca Hills	N	51–100	CDFG 2004[5]
	Chuckwalla	A	25–50	No new data
	Cargo Muchacho	E	0	No new data
	Palo Verde	E	0	No new data
South Mojave	Newberry-Ord	N[3]	25–50	C. Epps 2001–2003[8,9]
	Rodman	E	0	C. Gallinger 2003[9]
	Bullion	R	<25	No new data
	Sheephole	A	51–100	CDFG 2004[5]
	San Gorgonio	N	51–100	CDFG 2004[5]; T. Anderson[9]
	N. San Bernardino (Cushenbury)	N	25–50	CDFG 2002[5,6]
	Little San Bernardino	N	151–200	CDFG 2001[5]
	Queen	N	51–100	CDFG 2003[5]; C. Epps 2002[8,9]
	Pinto	E	0	No new data
	Eagle	N	51–100	C. Epps 2002–2003[8,9]
	Coxcomb	N	<25	C. Epps 2002–2003[8,9]
	Granite-Palen	N	<25	C. Epps 2002–2003[8,9]
	McCoy	E	0	No new data
	Little Maria	E	0	No new data
	Big Maria	E	0	No new data
	Riverside	E	0	No new data
	Iron	N[2]	<25	C. Epps 2001–2003[8,9]
	Turtle	N	51–100	C. Epps 2001–2003[8,9]; CDFG 2000[5]

Table 1 (continued).

Metapopulation	Population	[1]Population Status	Population Size Class	Data Source-Year of Most Recent Data
South Mojave (cont)	Whipple	R	25–50	CDFG 1999[5]
	Old Woman	N	51–100	C. Epps 2001–2003[8,9]
	Chemehuevi	N	25–50	C. Epps 2002–2003[8,9]
	Sacramento	E[2]	0	C. Epps 2001–2003[8,9]
	Clipper	N	25–50	C. Epps 2001–2003[8,9]; CDFG 2004[5]
	South Bristol	N[2]	51–100	CDFG 2004[5]
	Marble	N	101–150	CDFG 2004[5,6]
Central Mojave	Cady	N	25–50	C. Epps 2001–2003[8,9]
	North Bristol	E[2]	0	C. Epps 2003[8,9]
	Old Dad- Kelso-Marl	N	201–300	CDFG 2004[5,6]
	Club Peak	N[3]	25–50	C. Epps 2002[8,9]
	Granite	N	25–50	C. Epps 2001–2003[8,9]
	Providence	N	51–100	C. Epps 2001–2003[8,9]
	Wood-Hackberry	N	25–50	C. Epps 2001–2003[8,9]
	Castle-Hart-Piute	N	51–100	C. Epps 2001–2003[8,9]; Viceroy Mine 2003[7]
	Dead	N	25–50	No new data
Central North Mojave	Clark	N	25–50	CDFG 2004[5]
	Kingston-Mesquite	N	51–100	CDFG 2004[5]
	Nopah	N	51–100	CDFG 1999[5]
	Soda	E	0	G. Sudmeier 2004[9]
	Avawatz	A	51–100	CDFG 1995[5]
North Mojave	Granite-Quail	E	0	No new data
	Owlshead	N[2]	<25	G. Sudmeier 2004[9]
	Eagle Crags	R	<25	CDFG 2002[5]
	Argus-Slate	R	51–100	R. Osgood 2003[9]; CDFG 1993[5]
	Coso	E	0	No new data
	South Panamint	N	51–100	CDFG 1996[5]; (Oehler 1999)
	Tucki	N	25–50	No new data
	Panamint Butte-Hunter	N	51–100	No new data
	Tin	N	51–100	No new data
	Dry Mtn-Last Chance	N	51–100	J. Wehausen 2003[8,9]
	Inyo	N	101–150	J. Wehausen 2003[8,9]
	Deep Springs	N[2]	<25	S. Hetzler 2000[9]
	North White	N	201–300	CDFG 2004[7]
	South White	R	25–50	CDFG 2004[7]
Very Southern Sierra Nevada	Cache Peak	E	0	No new data
	Chimney Peak	E	0	No new data
Southern Sierra Nevada	Great Western Divide	E	0	No new data
	Olancha Peak	E	0	No new data
	Mt. Langley	R	51–100	CDFG 2004[7]
	Mt. Williamson	N	25–50	CDFG 2004[7]
	Bubbs Creek	N[4]	<25	CDFG 2004[7]
	Mt. Baxter	N	51–100	CDFG 2004[7]
	Sawmill Cyn.	N[3]	<25	CDFG 2004[7]
	Taboose	E	0	No new data
	Mt. Tom	E	0	No new data

Table 1 (continued).

Metapopulation	Population	[1]Population Status	Population Size Class	Data Source-Year of Most Recent Data
Southern Sierra Nevada (continued)	Wheeler Ridge	R	51–100	CDFG 2004[7]
Central Sierra Nevada	Convict-McGee Cr.	E	0	No new data
	Lee Vining-Bloody-Lundy Cyn.	R	25–50	CDFG 2004[7]
	Sonora Pass	E	0	No new data
	Sweetwater	E	0	No new data
Northeastern California	Truckee River	E	0	No new data
	Skedaddle-Smoke Cr.	E	0	No new data
	Warner	E	0	No new data
	Lava Beds/ Mt. Dome	E	0	No new data
	Mt. Shasta	E	0	No new data
	Goosenest	E	0	No new data
	Bogus Mt.	E	0	No new data

[1] N = native; A = augmented; R = reintroduced; E = extirpated
[2] Population status has changed since 1995 (Torres et al. 1994, 1996)
[3] Population has been redefined since 1995 (Torres et al. 1994, 1996)
[4] Newly-discovered population
[5] Helicopter survey-capture
[6] Mark-resight population estimates
[7] Direct counts from ground observations
[8] Partially based on minimum genotypic counts from non-invasive genetic data
[9] Field observations of animals or sign

Table 2. Bighorn sheep population size class profile and summary by metapopulation for the 2004 population inventory, with comparison to total population numbers from the 1995 inventory (Torres et al. 1996).

Metapopulation	0	<25	25–50	51–100	101–150	151–200	201–300	>300
Peninsular Ranges	0	0	4	1	2	0	1	0
San Gabriel	0	0	0	0	0	0	1	0
Western Transverse Range	1	0	1	0	0	0	0	0
Sonoran	2	0	1	2	1	0	0	0
South Mojave	7	4	5	7	1	1	0	0
Central Mojave	1	0	5	2	0	0	1	0
Central North Mojave	1	0	1	3	0	0	0	0
North Mojave	2	3	2	5	1	0	1	0
Very Southern Sierra	2	0	0	0	0	0	0	0
Southern Sierra Nevada	3	2	1	3	0	0	0	0
Central Sierra Nevada	4	0	1	0	0	0	0	0
Northeastern California	7	0	0	0	0	0	0	0
Total	30	9	21	23	5	1	4	0
1995 Total	36	13	20	17	10	10	0	0
Net Change Since 1995	-6	-4	+1	+6	-5	-9	+4	0

the Endangered Species Act in 1998. Meanwhile, the uniqueness of Sierra Nevada bighorn sheep was established on the basis of genetic and morphometric evaluations (Ramey II 1995; Wehausen and Ramey II 2000). Formerly *O. c. californiana*, now classified as *O. c. sierrae* (Wehausen et al. 2005), Sierra Nevada bighorn sheep also were listed as endangered by the federal government in 2000.

Populations

Five apparent natural recolonizations and 2 apparent population extirpations are suspected to have occurred since the 1993 population inventory (Table 1); 2 of those recolonizations (Deep Springs Range and South Bristol Mountains) were noted but not described in the 1995 inventory. In the Mojave Desert, radiocollared ewes were first documented traveling to the nearby South Bristol Mountains in 1993 and subsequently were found to bear lambs. At least 2 ewes permanently emigrated to that range, and that small founding population has since increased considerably. Similarly, in 2000, fresh sheep sign was observed in the Iron Mountains, and during subsequent field investigations a small, reproducing population was found to be resident, with occasional movement of radiocollared rams to and from the nearby Old Woman Mountains. Bighorn sheep were also reported again in the Deep Springs region where they likely had been extirpated. Recent evidence of recolonization of the Owlshead Mountains by bighorn sheep has also been reported. Investigations at all known water sources in the Sacramento Mountains, formerly the site of a viable population of bighorn, suggested that no population remains in that area. Only 6 fecal samples were recovered at one location in 3 trips during 2001–2002, and genetic analyses indicated that they all were derived from 2 rams (C. Epps, unpublished data). Finally, anecdotal evidence suggests that the Resting Spring Range near Death Valley and the Calumet Mountains in the South Mojave may support populations of bighorn sheep, but further investigation is needed before they can be added to the population inventory.

More information has been obtained on several of the populations where reestablishment by translocation previously had been attempted. The reintroduced San Rafael population, thought to be non-viable (Torres et al. 1994), is now known to be extant. Recent surveys of the Eagle Crags during 2002 detected few ewes and numerous rams, and additional research is needed to determine if that population remains viable. In the North Bristol Mountains, genetic analyses of fecal samples obtained during summer at known water sources demonstrated that all samples were from rams (C. Epps, unpublished data), suggesting that a viable population no longer exists.

Recent research resulted in the redefinition of several populations. In the Peninsular Ranges Metapopulation; the Pinto-Inkopah, Jacumba-Inkopah, Laguna, and Tierra Blanca populations (Torres et al. 1994) are now combined under the Carrizo Canyon population. The population in the Fish Creek Mountains has been included with the Vallecito Mountain population. Further, the North Anza Borrego population has been subdivided into 3 populations (South San Ysidro Mountains, North San Ysidro Mountains, and Coyote Canyon). Finally, the Santa Rosa Mountains

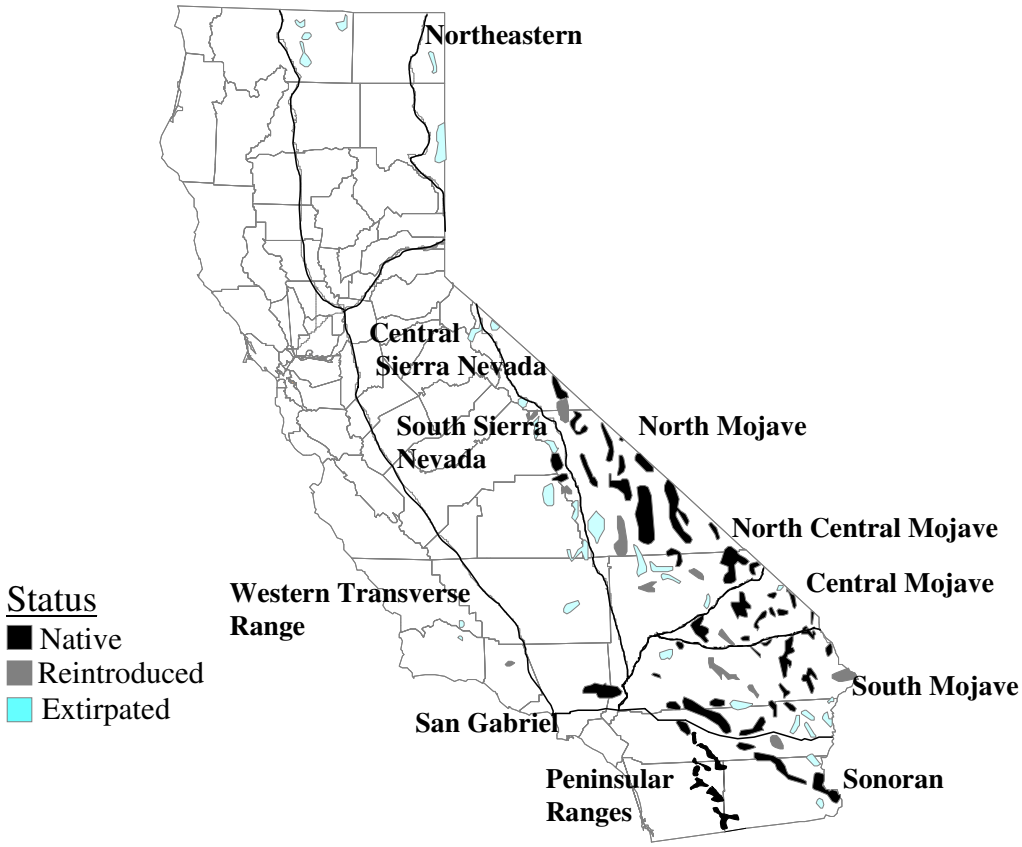

Figure 1. Metapopulations of bighorn sheep, with updated population polygons. Redefined Peninsular population polygons are loosely depicted; an updated GIS map is under preparation.

population has been split into 2 populations occurring on the east and west sides of Highway 74.

In the South Mojave Metapopulation, we have combined the Newberry and Ord populations into a single population. In the Central Mojave Metapopulation, the New York Mountains have been removed from the inventory; although important as a transitional range, the New York Mountains are poor habitat and may never have supported a viable population. We have also designated Club Peak as a population separate from Old Dad Peak; although movement by males and females with resultant gene flow occurs between these 2 areas, enough geographic and genetic separation exists (Epps 2005) that they probably have independent demographic trajectories.

In the Sierra Nevada, a small population of bighorn sheep recently was discovered at Bubbs Creek on the west side of the range (SNBSRP 2004), and may be a recent recolonization. We have also reclassified the Sawmill Canyon population as distinct from the Mount Baxter population, a demographic separation known since the 1970s (Wehausen 1979, 1996). Anecdotal accounts have suggested that bighorn sheep may be appearing again in northeastern California, although this population is not yet regarded as reestablished; at least 1 young male was

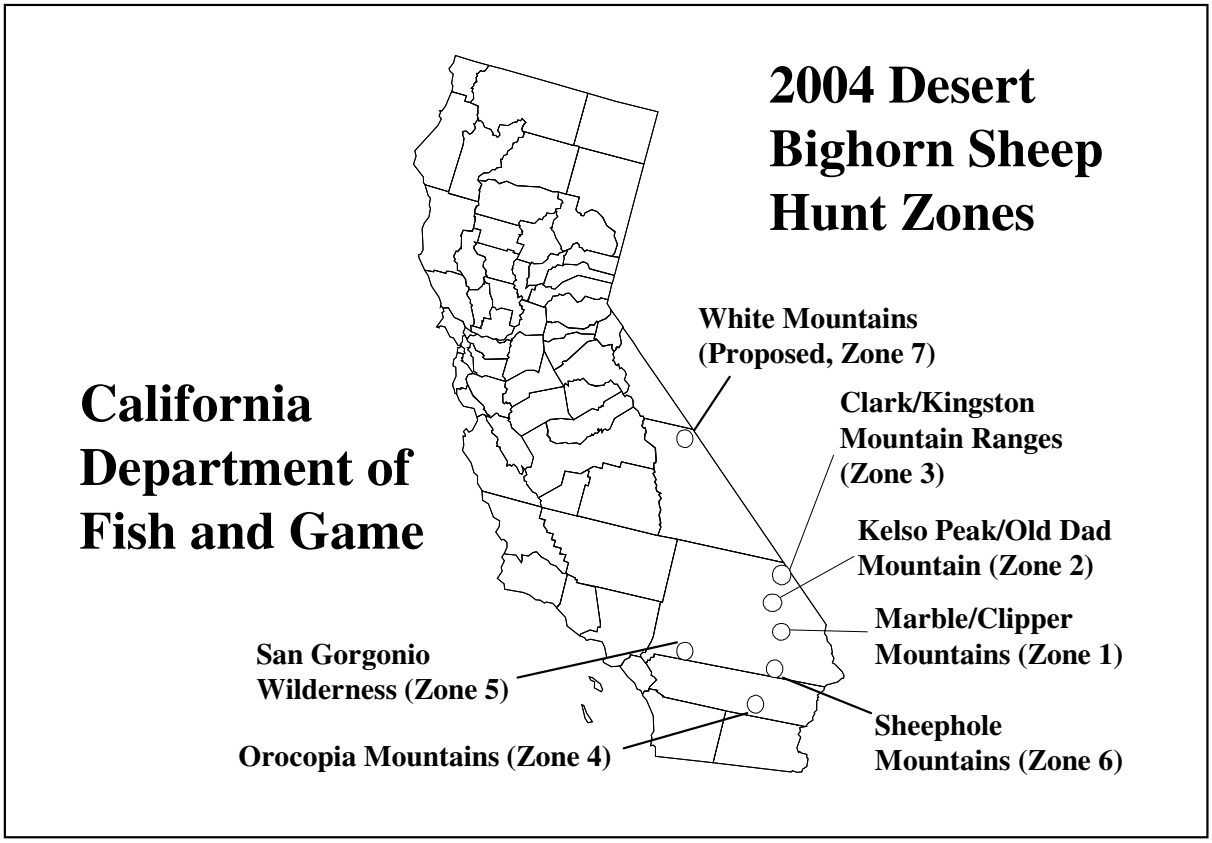

Figure 2. Locations of 2004 desert bighorn sheep hunt zones in California.

removed from the Warner Mountains after it was observed with a band of domestic sheep.

We used this population inventory to examine major population trends since 1995. Although the range of population estimates between 1995 and 2004 overlap in all categories and make definitive conclusions difficult, bighorn sheep numbers in California appear to show an upward trend. The distribution of populations by metapopulation and size class (Table 2) showed an increase in the number of populations in the 25–50 and 51–100 size classes, as well as a strong increase in the number of large populations of 201–300; all other size categories declined in number. As a result, the median total population estimate has increased by 844 animals since 1995 (Table 3).

Regional totals (Table 4) suggest a strong upward trend for bighorn sheep in the Peninsular Ranges. Estimated numbers of bighorn sheep in the Sierra Nevada (SNBSRP 2004) also suggest a strong increase since 1995; this reflects the recovery of Sierra Nevada bighorn from a low of about 100 individuals that occurred in 1995 (Wehausen 1996). Overall numbers of desert bighorn sheep (excluding Peninsular populations) likewise appear to have increased slightly, and the total number of viable populations (excluding reclassifications) has increased during this

time period. Many areas of current or former use by populations of bighorn sheep have not been investigated in more than a decade (Table 1). Those areas should be re-visited to determine whether changes in status have occurred.

Table 3. Bighorn sheep population estimates by metapopulation (2004). Low, median, and high totals result from summing the low, mid, and high values of each size class.

Metapopulation	Low	Median	High
Peninsular Ranges	554	731	900
San Gabriel	201	251	300
Western Transverse Range	25	38	50
Sonoran	228	316	400
South Mojave	738	1076	1396
Central Mojave	428	593	750
Central North Mojave	178	266	350
North Mojave	610	872	1122
Very Southern Sierra	0	0	0
Southern Sierra Nevada	180	292	398
Central Sierra Nevada	25	38	50
Northeastern California	0	0	0
Total	3167	4473	5716
1995 Total (Torres et al. 1996)	2541	3629	4712
Net Change Since 1995	+626	+844	+1004

Table 4. Bighorn sheep population estimates by geographical region (2004). 1995 estimates (calculated from or reported in Torres et al. 1996) are indicated in parentheses.

Region	Low	Median	High
Peninsula	554 (303)	731 (404)	900 (500)
Sierra	205 (101)	330 (163)	448 (224)
Other	2408 (2137)	3412 (3061)	4368 (3988)
Total	3167 (2541)	4473 (3628)	5716 (4712)

Research

The past 10 years have been marked by numerous and extensive research projects by CDFG, universities, and other agencies that have further advanced our understanding of bighorn sheep taxonomy, demography, distribution, ecology, behavior, and metapopulation dynamics in California. CDFG has continued to conduct annual surveys in the hunt zones (Figure 2) and occasionally other populations, and has captured and radiocollared bighorn in the Cushenbury, Old Dad Peak, Old Woman Mountains, Iron Mountains, Queen Mountains, East Chocolate Mountains, Orocopia Mountains, South Bristol Mountains, Marble Mountains, Panamint Mountains, Eagle Crags, White Mountains, San Gabriel Mountains, Vallecito Mountains, Carrizo Mountains, South San Ysidro Mountains, North San Ysidro Mountains, Coyote Canyon, East Santa Rosa Mountains, West Santa Rosa Mountains, San Jacinto Mountains, Lee Vining, Wheeler Ridge, Sawmill Canyon, Mount Baxter, and Mount Langley populations during 1995–2004.

A substantial number of publications concerning bighorn sheep in California was produced during 1995–2005. While not an

exhaustive list, we present here a brief bibliography, organized loosely by topic (some papers are included in more than one topic area); we include material in the professional literature in this list, as well as unpublished theses and dissertations. Papers on habitat management, use or selection for bighorn sheep in California include Andrew et al. (1997*a*; 1999; 2001), Bleich et al. (1997), Divine (1998), Divine et al. (2000), Lesicka and Hervert (1995), Longshore and Douglas (1995), Oehler (1999), Oehler et al. (2003), Rubin et al. (2002*b*), Turner et al. (2004), and Rechel (2003). Contributions relevant to metapopulation processes include Bleich et al. (1996), Epps (2004; 2005), Epps et al. (2004), and Wehausen (1999). The topic of predation and bighorn sheep was examined by Bleich (1996; 1999*a*), Bleich et al. (2004), Boyce et al. (1996*b*), Ernest et al. (2002), Hayes et al. (2000), Schaefer et al. (2000), and Wehausen (1996). Bighorn sheep demography was also an important area of research (Andrew et al. 1997*b*; Coonan 1995; DeForge et al. 1995; DeForge et al. 1997; Douglas and Longshore 1995; Holl et al. 2004; Ostermann et al. 2001; Rubin et al. 1998; Rubin et al. 2002*a*; Schaefer et al. 2000; Wehausen 2005). Considerable research was published on morphometrics, taxonomy, and the rapidly-growing field of genetics (Boyce et al. 1996a; Boyce et al. 1999; Epps 2004, 2005; Gutierrez-Espeleta et al. 1998; Jessup and Ramey II 1995; Ramey II 1995, 1999; Wehausen and Ramey II 2000; Wehausen et al. 2004; Wehausen et al. 2005). Research on life history and behavior (Rubin 2000; Rubin et al. 2000; Wehausen 2005) as well as disease and physiology (Drew et al. 2001; Jessup et al. 1995; Singer et al. 1997; Swift et al. 2000) also was published, as was information evaluating translocation techniques (Thompson et al. 2001) and evaluations (Ostermann et al. 2001).

Habitat Improvements

Water development and maintenance projects long have been part of the CDFG strategy for maintaining and enhancing populations of bighorn sheep (Bleich et al. 2005). During the last decade, however, the pace of development projects slowed considerably, largely as a result of passage of the California Desert Protection Act. This act created numerous wilderness areas and established the Mojave National Preserve and, thereby, complicated efforts to continue water development projects (Bleich 1999*b*). Despite the near absence of habitat improvement projects during the last decade, maintenance of existing development has continued, largely by volunteer organizations such as the Society for the Conservation of Bighorn Sheep and Desert Wildlife Unlimited. Over the past decade, an average of about five major volunteer projects have occurred each year, and have included activities such as replacement of water storage tanks, tamarisk removal, and otherwise routine maintenance including replacement of damaged or corroded fittings. Additionally, volunteers have established seven stations that monitor availability of water at anthropogenic catchments and transmit information via satellite link (Hill and Bleich 1999); those stations have provided invaluable information that has been useful in scheduling inspections or needed repairs.

Harvest (1996–2004)

Hunting of bighorn sheep in California began in 1987; hence, it is a

relatively new phenomenon after >100 years of total protection (Wehausen et al. 1987). Since the onset of the hunting program, 7 hunt zones have been established and, pending final approval by the California Fish and Game Commission, an eighth zone is proposed to open in 2005 (Figure 2). Since 1996, several changes have affected hunting of bighorn sheep in California. Because of severe drought, numbers of sheep in the Orocopia Mountains have declined substantially, necessitating that harvests in that area be restricted severely. A similar downward trend in the East Chocolate Mountains resulted in the closure of that zone, and harvest proposals for the Clark and Kingston mountains have been modified downward during recent seasons. Regulations in California restrict the harvest of bighorn sheep to adult males having approximately a ¾ horn curl.

Since 1996, hunter opportunity has been approximately constant, and hunter success in California remains in excess of 90% (Table 5); slight changes in hunter opportunity on an annual basis reflect the conservative nature of the harvest program, as well as annual adjustments based on current survey results. In general, revenue from fund-raising auction tags has fallen off slightly since 1996 (Table 5).

Problems-Opportunities

Listing of bighorn sheep in the Sierra Nevada and in the Peninsular Ranges as endangered by the federal government resulted in some unanticipated opportunities. In the Sierra Nevada, the California Legislature made funding available to support a substantial recovery program that includes 3 full-time CDFG personnel and 3 full-time contract personnel; the U. S. Fish and Wildlife Service (USFWS) delegated responsibility for implementing the recovery program to CDFG (Bleich 2001*a*). To date, results have been encouraging, and the population of bighorn sheep in that range has increased from about 100 individuals to about 300 animals since 1999 (Table 4, SNBSRP 2004). Currently, the biggest obstacle with which the recovery effort is faced is the potential for disease transmission from domestic sheep, which are grazed on allotments proximate to ranges occupied by Sierra Nevada bighorn sheep. A draft recovery plan was circulated for public review during 2003; efforts to update the plan with new information and to finalize it are continuing. In the Peninsular Ranges, recent population surveys indicate a continuing upward population trend (Table 4). New information from ongoing telemetry investigations has resulted in the redefinition of subpopulations of bighorn sheep inhabiting the Peninsular Ranges. Recovery efforts are being carried out cooperatively by the USFWS, CDFG, University of California, and several nongovernmental organizations.

Bighorn sheep inhabiting the San Gabriel Mountains once represented the largest population of that species in California (Torres et al. 1994). A substantial population decline, attributed in part to changes in habitat associated with fire suppression and predation by mountain lions (Holl et al. 2004) continued during the late 1990s. As a result of that continuing decline, CDFG, the United States Forest Service, and Los Angeles County Fish and Game Commission initiated a cooperative effort to halt the decline and, eventually, restore bighorn sheep to higher population levels in the San Gabriel Mountains. Lack of funds

continues to plague the project, but federal monies made available as the result of the devastating fires that burned throughout that range in 2003 offer some promise that the restoration effort will be successful.

During 2003, CDFG initiated an effort to complete plans for bighorn sheep conservation that were based on the premise that bighorn sheep existed in a metapopulation structure. Recent research (Epps 2004, 2005) has evaluated metapopulation structure and dynamics for bighorn sheep in California, and a CDFG project is underway to update the GIS map of bighorn sheep habitat in California. A draft plan for the Sonoran Desert Metapopulation was completed on schedule, but has not yet been finalized. The budgetary crisis with which the State of California has been faced for the last several years has resulted in the loss of numerous

Table 5. Summary of Nelson (desert bighorn) sheep tag allocations, harvest, applications, and revenue from 1987–2004 in California.

Year	Tags Allocated	Tags Filled	Total Applicants	Fundraising Tag Revenue	Drawing Tag License Fees	Totals
1987	9	9	4,066	$70,000.00	$21,930.00	$91,930.00
1988	9	7	3,385	$59,000.00	$18,525.00	$77,525.00
1989	9	9	3,185	$40,000.00	$17,525.00	$57,525.00
1990	6	6	2,591	$37,000.00	$13,955.00	$50,955.00
1991	8	7	2,834	$42,000.00	$15,570.00	$57,570.00
1992	12	12	3,798	$61,000.00	$22,464.50	$83,464.50
1993	11	9	4,318	$100,000.00	$25,082.00	$125,082.00
1994	14	10	4,692	$162,000.00	$28,422.00	$190,422.00
1995	16	14	4,217	$187,000.00	$26,312.00	$213,312.00
1996	14	10	4,493	$193,500.00	$28,702.75	$222,202.75
1997	11	11	3,925	$84,000.00	$26,836.25	$110,836.25
1998	10	9	4,853	$150,000.00	$32,588.00	$182,588.00
1999	11	11	5,058	$95,000.00	$34,120.00	$129,120.00
2000	10	10	5,445	$76,000.00	$36,288.00	$112,288.00
2001	14	12	5,754	$148,000.00	$40,539.00	$188,539.00
2002	14	12	7,147	$138,000.00	$51,485.25	$189,485.25
2003	10	10	7,697	$51,691.00	$54,679.75	$106,370.50
2004	13	12[2]	7,285	$58,884.50[1]	$40,536.00[1]	$99,420.50[1]
Total[1]	201	180	84,743	$1,753,075.50	$535,550.50	$2,288,635.75

[1] 2004 totals have not been finalized
[2] As of January 31, 2004; 2004–2005 season has not ended

personnel in CDFG, and the reassignment of others to unanticipated tasks. Although the long-term benefits of conservation planning on a metapopulation basis are clear (Bleich et al. 1996), timely completion of that effort will be a function of the priority in which it is viewed by the CDFG administration.

In 1994, Congress passed the California Desert Protection Act (CDPA), which established numerous wilderness areas throughout the deserts of California, and transferred management authority for much of the eastern Mojave Desert from the Bureau of Land Management (BLM) to the National Park Service (NPS, Bleich and Pauli 1999). That legislation has been especially problematic for issues of bighorn sheep conservation because the majority of ranges occupied by bighorn sheep were designated as wilderness; further, differing agency management policies and philosophical differences have complicated conservation activities within areas recently transferred to NPS (Bleich 1999*b*). A Memorandum of Agreement between CDFG and BLM has facilitated access to wilderness areas by CDFG for conservation activities; such an agreement has not yet been achieved with NPS despite the specific acknowledgment of CDFG management authority in the newly designated Mojave National Preserve (MNP, Bleich 2001*b*). As a result, wildlife conservation activities proposed by CDFG to occur in the MNP remain contentious.

During 1999, the California Legislature passed a bill that provided CDFG the authority to remove mountain lions if it was determined that those predators were "…an imminent threat to the survival of any threatened, endangered, candidate, or fully protected sheep species." That legislation provided CDFG with management options that had been usurped with the passage of a ballot initiative in 1990, which designated mountain lions as a specially protected mammal. With the exception of individual animals subject to hunter harvest, all bighorn sheep in California are fully protected and, thereby, subject to the initiative passed in 1999.

As noted previously, passage of the CDPA complicated many conservation activities proposed by CDFG throughout the majority of the range of bighorn sheep in California. Further, large-scale plans, such as those prepared by BLM for the Northern and Eastern Colorado Desert that provided authority for implementation of habitat improvement and maintenance projects, have been successfully challenged in court. In the absence of regular maintenance activities, past efforts to enhance conditions for bighorn sheep will be negated. Efforts to enhance habitat and to translocate bighorn sheep have been compromised by court challenges, thereby affecting well-intended proposals to benefit that species. Without recognition that well-intentioned but conflicting legislation is problematic for wildlife conservation, management on behalf of bighorn sheep and wildlife in general will become even more difficult (Bleich 1999*b*, 2005).

Several apparent outbreaks of disease occurred in California in the past decade. Those events occurred in the Old Woman Mountains (San Bernardino County) and in the northern Panamint Range (Inyo County), and subsequently were investigated by CDFG. Mortality rates, as determined from animals that were captured for sampling and then telemetered, were not remarkable; hence, the demographic consequences of those events appeared to be minimal, but warrant further investigation.

In 1995, in excess of 40 bighorn sheep died as a result of probable botulism poisoning at Old Dad Peak (San Bernardino County) (Swift et al. 2000). The immediate demographic consequences of that event were substantial, but the population has since compensated for those losses and remains among the largest in California (Table 1).

The majority of funding for conservation activities affecting bighorn sheep in California originates with the sale of fund-raising auction tags. Individual tags have brought as much as $150,000 during previous years (Table 5, Pauli 2002) but, in general, revenues from the sale of fund-raising tags have been declining. This may be a function, in part, of poor economic times over the past several years, but it also reflects the availability of only a single fund-raising tag since 2002. In the absence of additional financial support, CDFG bighorn sheep management activities likely will remain constrained by funds generated through the sale of bighorn sheep hunting permits. During 2005, a new hunt has been proposed for the White Mountains; if that proposal is approved by the California Fish and Game Commission, a second fund-raising tag may yield a substantial increase in funds available for bighorn sheep management in the coming year.

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Status of desert bighorn sheep in New Mexico, 2002 and 2003

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In autumn 2002, there were an estimated 237 free-ranging desert bighorn sheep in New Mexico. This is a 43% increase over the 166 bighorn sheep present in 2001. The increase was primarily due to a transplant of 51 bighorn sheep to the San Andres Mountains. Excluding this transplant, statewide numbers were up 9% from 2001, with all populations stable, except for the increasing Fra Cristobal herd. There were 41 functional radiocollars in the beginning of 2002, which is fewer than we have had historically. This was due to radiocollar failure.

In autumn 2003, there were an estimated 238 free-ranging desert bighorn sheep in New Mexico, which is essentially the same as 2002 population estimates. During autumn 2003 there was a transplant of 51 bighorn to the Peloncillos Mountains. The San Andres, Little Hatchets, and Ladron populations were stable, but the Big Hatchet and Fra Cristobal populations decreased. As a result of transplanting radiocollared bighorn sheep to the Peloncillos Mountains (n = 30), and a remarking effort in the Fra Cristobal Mountains (n = 15), the total number of functional radiocollars increased to 88.

Mountain lion predation remains the primary cause of mortality, and has been responsible for approximately 85% of all known-cause mortality of radiocollared bighorn sheep since 1992. In 1999, a program was implemented for contractors to remove mountain lions in desert bighorn sheep ranges. The program was ineffective in both 1999 and 2000 because of the inability to remove lions. The contracts were modified during 2001–2003, and 44 mountain lions were harvested in 4 desert bighorn sheep ranges under this program.

Population Status

Peloncillos

In the Peloncillos Mountains, the population increased from an estimated 25 individuals with <10 ewes in 2001, to approximately 55 individuals. The increase was due to an augmentation of 33 bighorn (13 rams, 20 ewes) from the captive Red Rock population. Nine mountain lions have been removed by the hound hunters under contract between 2001 and the end of 2003. In 2002, this became the first range in which we believe we substantially reduced mountain lion density.

Hatchets

The Hatchet Mountains herd is composed of 2 subherds located in Little Hatchet and Big Hatchet Mountains. The population estimate for the Little Hatchets

increased from 20 in 2001 to 24 in both 2002 and 2003. The ewe population in the Big Hatchet Mountains has apparently declined to a single radiocollared ewe. Contract houndsmen have removed 5 mountain lions from 2001–2003. Two of the best dryland houndsman were employed to hunt mountain lions, but the rocky, dry, steep terrain makes it very difficult to be successful. The last estimate was a minimum of 6 mountain lions left in the area. It is likely that the only way to effectively treat the area is with snares, which is currently not an option because the potential presence of jaguars and wolves requires certain issues be addressed, which has not yet occurred.

No more than 30 individuals have ever been documented in the Alamo Hueco Mountains, and since 1996 no more than 7 have been observed. In 2001, only 1 ram was observed, therefore we believe the population is extinct. The Animas Mountains population is the only documented self-starting herd in the state. However, in 1996, only 13 bighorn sheep were observed, and no bighorn sheep were observed in 2001 or 2002. Therefore, we believe the population is extinct.

Ladron Mountains

Between 1992 and 1999, 42 bighorn were released in the Sierra Ladron. The population declined to a low of 20 individuals in 2000 and started increasing after that. The spring 2003 estimate was 30 individuals, of which 8 were lambs. Given the large size of the range and low numbers of bighorn sheep, this is the most difficult mountain range to survey. A contract snareman has removed 11 mountain lions since 2001 and we believe we have substantially reduced the mountain lion population in this range.

Fra Cristobal Mountains

In November 1995, 37 bighorn sheep were transplanted to the privately owned Armendaris Ranch to establish a population. Some cougar removal and good habitat helped this population to increase to an estimated 75 individuals by the end of 2001, however there was a subsequent decline resulting in a population of 58 individuals by 2003. The decline was due to the disappearance of 9 female yearlings and 17 rams during autumn 2002 or winter 2002–2003. These bighorn sheep have not been sighted elsewhere, and we do not know what happened to them. Two Master's students researched habitat use and lamb mortality in this herd from 1999–2001. Fifteen bighorn were captured, fitted with radiocollars, and released during October 2003. A full time technician is monitoring the bighorn sheep herd, and a second technician is snaring mountain lions. Female mountain lions are removed, and male mountain lions are radiocollared and monitored. The males are removed if they kill a bighorn sheep or remain in bighorn sheep country. Fourteen radiocollared lions have been removed or died since 1999.

San Andres Mountains

Following a 36 month sentinel ram study, it was decided that the risk of a scabies outbreak was minimal, and NMDGF transplanted 18 ewes and 2 rams from the Kofa National Wildlife Refuge in Arizona, and 13 ewes and 18 rams from Red Rock, to the San Andres National Wildlife Refuge during November 2001. In combination with the 9 extant bighorn sheep already on the mountain, these 60 bighorn sheep

represent the largest desert bighorn sheep transplant in New Mexico to date. Mountain lion control was done for 5 weeks prior to the release, resulting in the removal of 3 mountain lions. Another 3 mountain lions were removed between the release and the end of 2001, and 12 mountain lions were removed in 2002. A full-time monitor is tracking the bighorn sheep to determine causes of mortality, to enable us to snare off of fresh carcasses when mountain lions are the cause of death, and to monitor lambing and recruitment. To date, 8 bighorn sheep have been killed by mountain lions, 1 died from falling, 6 have died from unknown causes, and 1 died from pneumonia.

Red Rock

Negative impacts over the past few years from a skewed sex ratio and increased predation rates resulted in a stable population resulting in no ewes transplanted since 1997. The supplemental feeding program that was reinstated in 1999 has resulted in yearling male:female ratios of 267:100, 142:100, 108:100, and 120:100 from 2000–2003, respectively. Increased predation has also been a problem, and since 2001, 13 mountain lions have been killed in or near the facility. Additional efforts have also been put into fence repair and predator control, resulting in declining predation. In November 2001, 11 bighorn were radiocollared to help ascertain causes of mortality for bighorn inside the pen. No mortalities occurred during 2002, but three occurred during 2003. One mortality was caused from an injury sustained during the 2003 capture, and the other two causes of death are unknown though they are not believed to have been caused by predators. During the 2002 spring census, the population was estimated at 100 individuals. Following the transplant of 31 (18 rams, 13 ewes) to the San Andres Mountains, there were an estimated 66 bighorn sheep in the pastures. During the 2003 spring census, the population was estimated at 91 individuals, and subsequent to the transplant of 33 bighorn sheep (13 rams, 20 ewes) to the Peloncillos Mountains, the population was estimated at 59 bighorn sheep.

Management Activities

Recovery Plan

In 2002, New Mexico's Long-range Plan for Desert Bighorn Sheep Management 1995–2002, expired. This plan was rewritten as a recovery plan as specified in the NM Wildlife Conservation Act (WCA). In accordance with the WCA, an Advisory Committee meeting was held in multiple towns in New Mexico, and an Advisory Committee was established. With their assistance, the Plan for the Recovery of Desert Bighorn Sheep in New Mexico 2003–2013 was written and subsequently approved by the State Game Commission.

Fire

Decreased fire frequency has lead to increased woody vegetation density in most bighorn sheep ranges in the west. Livestock grazing has reduced the quantity of fine fuels available to carry a fire, making it nearly impossible for natural or prescribed fires to reduce woody vegetation density. Several prescribed burns have been implemented in desert bighorn range in the past ten years. The majority of these fires were not very successful because of insufficient fine fuels, and weather conditions were often either too cool or too humid. Fires scheduled during 2002 were cancelled because of political issues.

However, fires in the Ladrons, San Andres, and Big Hatchets were carried out during spring 2003, though none of them burned as widely as hoped.

Status of Desert Bighorn Sheep in Texas, 2002–2003

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Desert Bighorn Council Transactions 47:40–42

Populations

For the past several years, Texas has reported 7 free ranging populations of desert bighorn sheep. These occur within the Trans Pecos region of the state including the Baylor, Beach, Sierra Diablo, Sierra Vieja, and Van Horn Mountains, and the Texas Parks and Wildlife Department's (TPWD) Black Gap and Elephant Mountain Wildlife Management Areas (WMA). A transplant conducted December 2000 of 45 bighorns (22 M, 23 F) from Elephant Mountain WMA to Black Gap WMA resulted in a substantial increase in movement. Desert bighorn sheep currently occupy suitable habitat between management areas on both private and public land including Big Bend National Park. Limited production is occurring within these areas.

Restoration efforts in Texas have resulted in re-establishing desert bighorn sheep numbers to the population levels of the early 1900s. Numbers are currently estimated at over 600 animals. Helicopter surveys conducted August-September of 2002 and 2003, indicated an increasing bighorn sheep population. The most substantial increase has consistently been reflected in the Sierra Diablo Mountains (36% in 2002 and 18% in 2003). In 2002, 352 total bighorn sheep were observed during 61.1 hours of flight time (5.8 sheep/hour). Ratios of 71 rams:100 ewes:48 lambs were reflected. Not all areas were flown in 2002 because of time and funding shortages. The 2003 surveys produced a record 477 classifications in 51.9 hours of flight time (9.2 sheep/hour). Survey results yielded ratios of 58 rams:100 ewes: 59 lambs.

Research

A study concerning home ranges, movements, and mortalities of desert bighorns at Elephant Mountain WMA was completed during the reporting period.

Habitat Improvements

In March 2002, 8 water catchments were refurbished in the Sierra Diablo Mountains including replacement and burying of tanks, drinkers and waterlines, and construction of helicopter pads. A similar project was conducted at Black Gap WMA in 2003. Thirteen water catchments were refurbished during the project. These projects were accomplished through the cooperative efforts of the Texas Bighorn

Society (TBS), private landowners, and TPWD.

Harvest

Bighorn sheep restoration and management in Texas continues to be funded by hunters through the Federal Aid in Wildlife Restoration Program, Foundation for North American Wild Sheep (FNAWS) auction permits, and the Texas Grand Slam Hunt Program. Forty-five desert bighorn sheep hunting permits have been issued since the Texas Legislature reinstated hunting in 1988. These include: 24 private landowner permits, 13 public hunting permits, 7 FNAWS permits, and 1 TBS permit. Since 1989, $481,000 has been generated from 7 FNAWS permits. Additional funding for research and management has been generated from 7 Texas Grand Slam permits. Overall success for desert bighorn sheep hunting in Texas is 84%.

Six desert bighorn sheep hunting permits were issued for the 2002–2003 hunting season including: 1 FNAWS permit (Elephant Mountain WMA), 1 Texas Grand Slam Hunt permit (Elephant Mountain WMA), 2 general public hunter permits (1 Beach Mountain and 1 Sierra Diablo WMA), and 2 private landowner permits in the Sierra Diablo Mountains. A 100% hunter success rate was achieved during the season. Among the successful hunters was long-time supporter, Mr. Bernie Fiedeldey, who purchased the 2003 FNAWS auction permit for $62,000. Mr. Fiedeldey's second Texas Ram scored 170 2/8 (green) and was harvested at Elephant Mountain WMA. Also among the successful hunters was 11-year old Tolman Moore, who harvested a 169 2/8 (green) ram at Elephant Mountain WMA.

The 2003–2004 hunting season proved to be another record year for Texas in several categories. Seven total bighorn sheep hunting permits were issued for the season, which tops the previous record of 6 issued during the 2000–2001 and 2002–2003 seasons. The very first permit for the Black Gap WMA population was among these. In addition, the first TBS permit was issued to assist in generating revenue for bighorn restoration efforts. The hunting opportunity was purchased by Mr. Glen Thurman at the annual fundraiser auction for a record $102,000. On March 2, 2004, Mr. Thurman successfully harvested a new state record at Elephant Mountain WMA. Scoring 177 1/8 (green), the ram surpasses the previous 1997 record of 176 1/8 harvested in the Baylor Mountains. Permits issued for the 2003–2004 hunting season included: 5 private landowner (1 Black Gap WMA, 2 Sierra Diablo Mountains, 1 Baylor Mountain, and 1 Beach Mountain), 1 Grand Slam Permit (Elephant Mountain WMA) and 1 TBS permit (Elephant Mountain WMA).

Problems-Opportunities

Survey efforts must be expanded to properly evaluate the status and condition of desert bighorn populations in new areas.

The future of desert bighorn sheep management in Texas must be addressed through appropriate planning strategies. Evaluation of existing management efforts, establishment of long-term goals, and long-term planning are critical for proper management.

Planning efforts are currently in progress for establishing the eighth free-ranging desert bighorn population in Texas. Big Bend Ranch State Park is considered as the top priority. However, success will require overcoming many obstacles including: human disturbances, predator issues, and exotics.

A meeting was recently conducted to discuss the potential for bighorn sheep restoration in Guadalupe Mountains National Park (GMNP). Personnel from New Mexico Game and Fish (NMGF), National Park Service, Bureau of Land Management, U. S. Forest Service, National Fish and Wildlife Foundation, and TPWD attended. The first step will involve completion of a feasibility study. Bighorn sheep restoration within GMNP is not the top priority for TPWD or NMGF.

Elephant Mountain will continue to serve as the primary source of brood stock for re-introduction efforts. However, additional out of state brood stock may be needed to facilitate restoration of desert bighorn sheep in areas of suitable habitat.

The private landowner remains the single most important factor in restoring and maintaining viable desert bighorn sheep populations in Texas. Efforts to educate landowners regarding proper management of desert bighorn sheep must continue to be expanded.

Aoudad sheep continue to be observed mixing with desert sheep in Texas. TPWD has the authority, coupled with landowner consent, to eliminate aoudads by lethal means for controlling encroachment in habitat used by desert sheep.

Mountain lion predation continues to be one of the limiting factors of desert bighorn sheep populations in Texas. Predator control efforts must be continued in sheep restoration areas to minimize losses to desert bighorn sheep brood stock.

Construction of wind generators within critical desert bighorn sheep habitat areas has recently been proposed on state owned General Land Office properties. The noise and motion produced by the structures themselves, and increased human disturbances resulting from road construction and other maintenance activities are among the concerns. Efforts to prevent wind-power development within bighorn sheep habitat are currently in progress.

Table 1. Summary of desert bighorn sheep numbers and locations in Texas, 2002 and 2003

	Rams		Ewes		Lambs		Unknown		Totals	
Location	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Black Gap WMA	11	15	13	34	5	22	1	-	30	71
Chilicote Ranch[a]	a	a	a	a	a	a	a	a	a	a
Elephant Mt. WMA	31	24	15	32	2	20	-	-	48	76
Metapopulation										
Baylor Mt.	7	14	19	26	16	9	-	-	42	49
Beach Mt.	19	36	37	31	16	20	-	-	72	87
Sierra Diablo Mts.	46	47	76	87	38	54	-	-	160	188
Van Horn Mts	a	4	a	2	a	0	a	-	a	6
Totals	114	140	160	212	77	125	1	0	352	477

[a] Survey not conducted

A review of recent wild sheep surveys in Baja California Sur, Mexico

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Introduction

Standardized helicopter surveys are widely used to determine wild sheep population trends (Remington and Welsh 1989). To determine population density and distribution of wild sheep in Baja California Sur, Mexico, standardized helicopter surveys were flown beginning in 1996. Surveys are standardized by flying at the same time of year, same time of day, same speed, same elevation, and with the same observers. The results from these and subsequent surveys were used to initiate a sport harvest program to take advantage of the available wildlife resource and to produce revenue to help fund a wild sheep conservation program.

To determine current population trends and to ensure that the sport harvest program was having no adverse impacts on the wild sheep population in Baja California Sur, standardized helicopter surveys were again conducted in 2003. In this report, the results of these current surveys are compared to those of surveys conducted in 1996, 1997, and 1999 to provide a view of the population trends of wild sheep in Baja California Sur, Mexico. The determination of these trends is particularly important as the number of harvest permits for wild sheep has increased substantially during this period. This data is essential for the Wildlife Department of Mexico to properly manage their wild sheep populations.

Early estimates of the number of wild sheep in Baja California Sur, Mexico, have previously been discussed by Jaramillo-Monroy et al. (1991) and Jaramillo-Monroy and Castellanos-Vera (1992). These estimates were based upon ground surveys and observations made during hunts conducted between 1976 and 1987. Population estimates were given as 110–160 animals in Las Virgenes-La Reforma, 300–350 animals in La Giganta, and 30–50 animals in El Mechudo. Subsequent helicopter surveys during 1996–1999 produced population estimates of 250–300 animals in Las Virgenes-La Reforma and 150–200 animals in the El Mechudo-Tarabillas area (Lee 1999).

Methods

The methodology of helicopter surveys has been described in Lee and Lopez-Saavedra (1993, 1994). The surveys conducted in 2003 were flown in the same fashion, and with many of the same observers, as those in 1996, 1997, and 1999. The 1996, 1997, and the 1999 surveys were conducted in mid to late October; the 2003 survey was conducted in early November. During the surveys, the helicopter is flown at approximately 80 km/hr and the observers

view approximately 200 m per side for a total coverage of about 30 km^2 per hour. Considering the time spent maneuvering to classify animals, the actual area covered is about 25 km^2 per survey hour.

Results

Various mountainous areas in Baja California Sur were flown during November 2003 (Tables 1 and 2).

An additional survey was conducted with CIBNOR 27–28 March 1999, that produced 49 observations in 3.0 hours in the El Mechudo-Tarabillas area. Classifications for that survey were 2 Class I, 0 Class II, 1 Class III, 2 Class IV, 33 adult ewes, 6 lambs, 1 male yearling, and 4 female yearlings.

Discussion

The wild sheep population in Baja California Sur, Mexico appears to be increasing. Using the Biosphere as an example, the 4 consecutive surveys produced increases in total population (99, 103, 131, and 137), and in total number of rams (27, 32, 34, and 34). The number of Class 3 and 4 rams observed during the 4 surveys was quite consistent (21, 25, 26, and 23). These survey data produce ram:100

Table 1. Sheep observed and the number of sheep observed per survey hour for each of the areas flown during the 4 surveys periods in Baja California Sur, Mexico.

	1996 observed	1996 no./hr	1997 observed	1997 no./hr	1999 observed	1999 no./hr	2003 observed	2003 no./hr
Virgenes	21	35.0	24	26.7	29	32.2	87	79.1
Aguajitos	51	28.3	41	12.8	33	15.7	19	11.9
Reforma	27	20.8	38	22.4	69	49.3	22	22.0
Mechudo			25	14.7	28	15.6	15	30.0
Tarabillas					49	13.6	43	43.0
Giganta			36	9.7	4	2.0	34	17.9

Table 2. The age and sex classifications (data are listed as Class I rams, Class II rams, Class III rams, Class IV rams, adult ewes, lambs, male yearlings, female yearlings), total number of wild sheep classified, the number of hours flown, and the number of observations per hour for each of the surveys flown in the combined area of the El Vizcaino Biosphere Reserve, Baja California Sur, Mexico.

Year	Classifications	Total	Hours	Observations/Hr
1996	2-4-9-12-46-16-3-5	99	3.7	26.8
1997	3-4-13-12-55-13-2-1	103	5.8	17.8
1999	4-4-15-11-64-19-8-7	131	4.4	29.8
2003	4-7-12-11-67-20-8-8	137	4.2	32.6

ewes:young ratios of 59:100:52; 58:100:29; 53:100:53, and 49:100:54 for the 4 surveys, respectively.

An important consideration during this period is the possible over harvest of rams through the sport harvest program. The evidence of over harvest would appear first in a reduction in the ratio of Class 3 and 4 rams (those chosen by hunters) and second in a reduction in the ram to ewe ratios. In the Biosphere, the ratios of Class 3 and 4 rams to 100 ewes for the 4 surveys are 46, 46, 41, and 34; and the percentage of Class 3 and 4 rams to total rams is 78, 78, 77, and 68. This reduction in male percentages is due to the 50% increase in the number of females from 46 to 67, not due to a reduction in the number of males (which actually increased as shown above). This is in comparison with the 2003 survey data from Sonora where the ram to ewe ratio was 37:100; the ratio of Class 3 and 4 rams to 100 ewes was 19:100; and the percentage of Class 3 and 4 rams to total rams was 52% in 2003.

Average group size has a substantial effect on sightability rates. The average group size has increased from 3.7 in 1996 to 6.2 in 2003. This compares to an average group size of 3.3 in Sonora.

The population estimate for the Biosphere remains at 250–300. The consistency of the survey data shows the accuracy of these standardized surveys, as well as the stability of the population. Recruitment is relatively stable and at a productive level with 100 ewe to lamb/yearling ratios of 52, 29, 53, 54 for the 4 surveys.

In addition to survey data, harvest data is extremely important for a successful management program. It is essential to monitor the average age of the harvest, days per kill, and average horn size to ensure that the level of sport harvest has no adverse impact upon the population. The survey data indicates that the current harvest level appears appropriate for the wild sheep population in the Biosphere.

Further south in Baja California Sur during the 2003 survey, areas that had produced either no or few observations before, such as Sierra San Alberto and Sierra Agua Verde near Mulege, produced 9 and 18 observations, respectively. Those areas that did not fare well during the survey, such as northern La Giganta, were plagued by large numbers of domestic goats (Table 3).

Table 3. Areas surveyed, survey hours, and total observations in the La Giganta south of Loreto, Baja California Sur, Mexico.

Area Flown	Survey Hrs	Total
Santo Domingo	2.4	45
San Jose	0.5	20
Carmen Island	0.5	19
El Mechudo	0.5	15
Ley Federal #2	0.6	10
Tepentu	1.6	4
La Purisima	0.6	1
Ley Federal #1	0.3	0

These observations indicate that the wild sheep populations in a number of the areas are relatively substantial, producing observation rates up to 40 animals per hour. Other areas, however, currently support very small populations. La Purisima, for example, was also flown for 2.0 hours in 1999 and only 4 animals were observed. In some areas surveyed no wild sheep were observed, but hundreds of goats, burros, and cows were seen in what would have been good wild sheep habitat.

Recommendations

Due to the costs of helicopter surveys, safety concerns, and potential disturbance of the wild sheep, unless there has been some substantial change in climate

or harvest standardized surveys should be conducted no more than every 3 years.

The number of permits issued is not as important as the number of animals that are actually harvested. The standardized collection of harvest data is strongly encouraged; as is the use of horn plugs to facilitate the enforcement of harvest quotas.

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A 10-year view of wild sheep management in Sonora, Mexico

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Introduction

Helicopter surveys are widely used to determine wild sheep population trends (Remington and Welsh 1989). To determine population density and distribution of wild sheep in Sonora, Mexico, standardized helicopter surveys were flown beginning in 1992 (Lee and Lopez-Saavedra 1993 and 1994). Surveys are standardized by flying at the same time of year, same time of day, same speed, same elevation, and with the same observers. The results from these and subsequent surveys were used to initiate a sport harvest program to take advantage of the available wildlife resource and to produce revenue to fund a wild sheep conservation program, including habitat and movement studies, disease research, and transplants.

To determine current population trends and to ensure that the sport harvest program was having no adverse impacts on the wild sheep population in Sonora, standardized helicopter surveys were again conducted in 2003. In this report, the results of these current surveys are compared to those surveys conducted in 1992–1993 to provide a 10-year view of the population trends of wild sheep in Sonora, Mexico. The determination of these trends is particularly important, as the number of harvest permits for wild sheep has increased substantially during this period; and a large number of wild sheep have been taken from the wild and placed within enclosures. This data is essential for the Wildlife Department of Mexico to properly manage their wild sheep populations.

Early estimates of the number of wild sheep in Sonora, Mexico, have previously been discussed by Lee and Lopez-Saavedra (1993, 1994). Combining the results of the 2 surveys conducted in 1992 and 1993 produces a total of 893 individual sheep observed in 32 of the 42 mountainous areas surveyed on the mainland. The combined age and sex ratios for the mainland portion of Sonora (separating the Tiburon Island data) were 41 males:100 females. Of the males, 52% were classified as Class 3 or 4.

Methods

The methodology of helicopter surveys has been described in Lee and Lopez-Saavedra (1993, 1994). The surveys conducted in 2003 were flown in the same fashion, and with many of the same observers, as those in 1992–1993. The 1992, 1993, and 2003 surveys were conducted during November. During the surveys, the helicopter is flown at approximately 80 km/h and the observers view about 200 m per side for a total coverage of approximately 30 km^2 per hour. Considering the time spent maneuvering to classify animals, the actual area covered is about 25 km^2 per survey hour.

Results

The Wildlife Department of Mexico divided the various mountain ranges in Sonora into 11 regions. These divisions were based on proximity of suitable habitat, similarity of habitat, and containing no barriers to wild sheep movement within the region (Table 1). The age and sex classifications and the number of hours flown in each of the regions were recorded (Table 2).

Table 1. Wild sheep observed and the number of wild sheep observed per survey hour for each mountain range within the 7 regions surveyed during both 1992–1993 and 2003.

Range	1992–1993 observed	1992–1993 obs/hour	2003 observed	2003 obs/hour
Pinacate	25	16.7	22	27.5
Blanca	6	6.7	2	2.9
Pinta	6	3.5	11	15.7
San Francisco*	23	12.8	42	46.7
Cubabi	8	6.2	1	1.0
Silla	14	17.5	7	23.3
San Antonio	4	6.7	10	12.5
Coloraditos	0	0.0	1	5.0
Alamo*	19	14.6	0	0.0
Viejo	126	43.4	17	8.9
Verruga	15	21.4	11	27.5
Picu	8	8.0	9	9.0
Aguirre	29	41.4	16	17.8
Santa Maria	10	50.0	24	48.0
Julio	15	37.5	0	0.0
Vibora	0	0.0	10	14.3
Rajon	1	3.3	0	0.0
Los Mochos*	24	36.9	18	30.0
Tinajas	7	23.3	30	60.0
Tepopa	19	47.5	3	7.5
Seri	66	44.0	83	69.2
Cirios	77	48.1	18	16.4
Tordilla	30	75.0	15	18.8
TOTALS	532	24.9	350	22.4

*Surveyed both in 1992 and 1993; data presented are the averages of the 2 surveys

Table 2. Class I rams, Class II rams, Class III rams, Class IV rams, adult ewes, lambs, male yearlings, female yearlings) for each of the 7 regions surveyed during both 1992–1993 and 2003.

Area	1992–1993 Classifications	1992–1993 Hrs	2003 Classifications	2003 Hrs
Region 2	2-5-4-1-12-4-0	2.4	0-0-2-2-14-5-1-0	1.5
Region 3	2- 3- 4-0-13-5-1-1	3.5	1-2-3-0-32-11-0-4	1.6
Region 4	1-1-2-1-17-3-0-1	2.9	1-2-4-0-9-2-0-1	2.1
Region 7	5-20-21-3-110-17-25-22	7.2	5-5-7-1-42-13-2-2	5.8
Region 8	0-0-0-0-1-0-0-0	0.6	1-1-0-0-5-3-0-0	1.1
Region 10	0-1-3-1-12-5-1-1	0.6	1-2-2-0-11-2-0-0	0.6
Region 11	8-7-10-6-111-16-23-18	4.2	5-9-13-4-83-23-5-7	4.0
Totals	18-37-44-12-276-50-52-43	21.4	14-21-31-7-196-59-8-14	15.6

Discussion

The wild sheep population in Sonora appears to be quite stable. There appears to have been no adverse impact from the current management actions upon recruitment as the ewe to lamb ratio increased from 18.1 in 1992–1993 to 30.1 in 2003. The good lamb recruitment (30.1) reflects the favorable climatic conditions of the past year. Wild sheep, however, because they have a single offspring at a time, are not particularly well suited to take advantage of favorable conditions. During the 2003 survey, areas which had produced either no or few observations before showed increases, such as Noche Buena, El Tullido, Loma Bonita, Coloraditos, La Vibora, and La Pinta. The wild sheep in Sierra San Francisco and Sierra Seri have both shown considerable increases in number.

However, other areas did not fare as well. In particular, Sierra Viejo and El Alamo saw precipitous population declines. Feral goats were seen in both of these ranges. While the total observation rates for the 2 survey periods would indicate a very slight population decrease from 24.9 animals per hour to 22.4 animals per hour, if these 2 ranges (Sierra Viejo and El Alamo) are removed from the survey data, the observation rates per hour would decline to 18.1 in 1992–1993 and increase to 25.8 in 2003.

Average group size has a substantial effect on sightability rates. The average group size remained very similar between the surveys at 3.4 for 1992–1993 and 3.2 for 2003.

An important consideration during this period is the possible over harvest of rams through the sport harvest program. The evidence of over harvest would appear first in a reduction in the percentage of Class 3 and 4 rams (those chosen by hunters) and second in a reduction in the ram to ewe ratios.

The percentage of Class 3 and 4 rams to total rams actually increased from 50% in 1992–1993 to 52% in 2003. The ram to ewe ratio in 1992–1993 was 40.9 versus 37.2 in 2003. The ratio of Class 3 and 4 rams to ewes was 20.3 in 1992–1993 versus 19.4 in 2003.

As previously mentioned, it is apparent that the wild sheep in El Alamo and Sierra Viejo have experienced a considerable population decline during this period. Removing the survey totals from these 2 ranges provides total survey numbers of 387 in 1992–1993 and 333 in 2003. The removal of these data from both surveys

1992–1993 (4-17-16-3-70-9-17-10) and 2003 (1-2-3-0-9-2-0-0) results in all ram to ewe ratios of 34.5 versus 35.8, and Class 3 and 4 ram to ewe ratios of 18.0 versus 18.7, for the 2 survey periods respectively. The percentage of Class 3 and 4 rams to total rams becomes (14-20-28-9 versus 13-19-28-7) or 52% and 52%. The consistency of these data shows the accuracy of the standardized surveys, as well as the stability of the populations. It is also indicative of the appropriateness of the current harvest level.

Numerous additional surveys have also been conducted in 1995, 1996, 1997, 1999, and 2000, by the same observers, using the same methodology, and at the same time of year. Another survey was conducted in 2002 (though with different observers and at a different time of the year, so there is difficulty in comparing this data). These survey data support the above findings. In addition to survey data, harvest data is extremely important for a successful management program. For example, an increase in the number of days per kill, a reduction in the average age of harvest, and a reduction in average score would be indicative of an over harvest. Such harvest data, however, are beyond the scope of this survey report.

There has been no decline in either the ram to ewe ratios or the percentage of Class 3 and 4 rams. Therefore, the current harvest level, based only upon the survey data, appears appropriate for the wild sheep population in Sonora. However, it is essential to continue to monitor the average age of the harvest, days per kill, and average horn size to ensure that sport harvest has no adverse impact upon the population.

Tiburon Island

Another portion of Sonora of extreme importance to wild sheep is Tiburon Island. Following the 1975 transplant of 20 wild sheep from the adjacent mainland to the island, the wild sheep population flourished. The first substantial helicopter survey was conducted in 1993.

In 1993 in 4.7 hours a total of 293 animals were classified as 10-22-40-16-151-43-7-4. In 2003 in 5.1 hours a total of 306 animals were classified as 10-18-24-11-162-55-11-15. Age and sex ratios were 58:100:28 versus 39:100:34. Production of young animals on the island is quite good. However, while Class 3 and 4 males made up 64% of the rams in 1993, this had declined to 56% in 2003 (a survey conducted in 1999 produced an intermediate value for the Class 3 and 4 percentage of 59%).

Since 1998, over 200 animals have been removed from the island, about ¾ of these being females. With the effect of these removals, and considering the very restricted legal harvest (4 males per year); male animals are apparently being removed from the population by other means (perhaps poaching). While the legal sport harvest program appears to have no adverse impact upon the population, it may be necessary to better police the illegal activities that appear to be occurring.

Recommendations

Due to the costs of helicopter surveys, safety concerns, and potential disturbance of the wild sheep, unless there has been some substantial change in climate or harvest, standardized surveys should be conducted no more than every 3 years.

The number of permits issued is not as important as the number of animals that are actually harvested. The standardized collection of harvest data is strongly encouraged; as is the use of horn plugs to facilitate the enforcement of harvest quotas.

Acknowledgements: Thanks to all of the observers who participated in the survey: Armando Aparico, Crispin Ballesteros, Israel Barba, Enrique Grajeda, Rebeca Kobelkowsky, Eugenio Larios, Martin Leon, Franciso Navarro, Roberto Noriega, Juan Manuel Segundo, Ignacio Rivera, Felipe Rodriguez, Francisco Villa, and Ismael Wadarrama.

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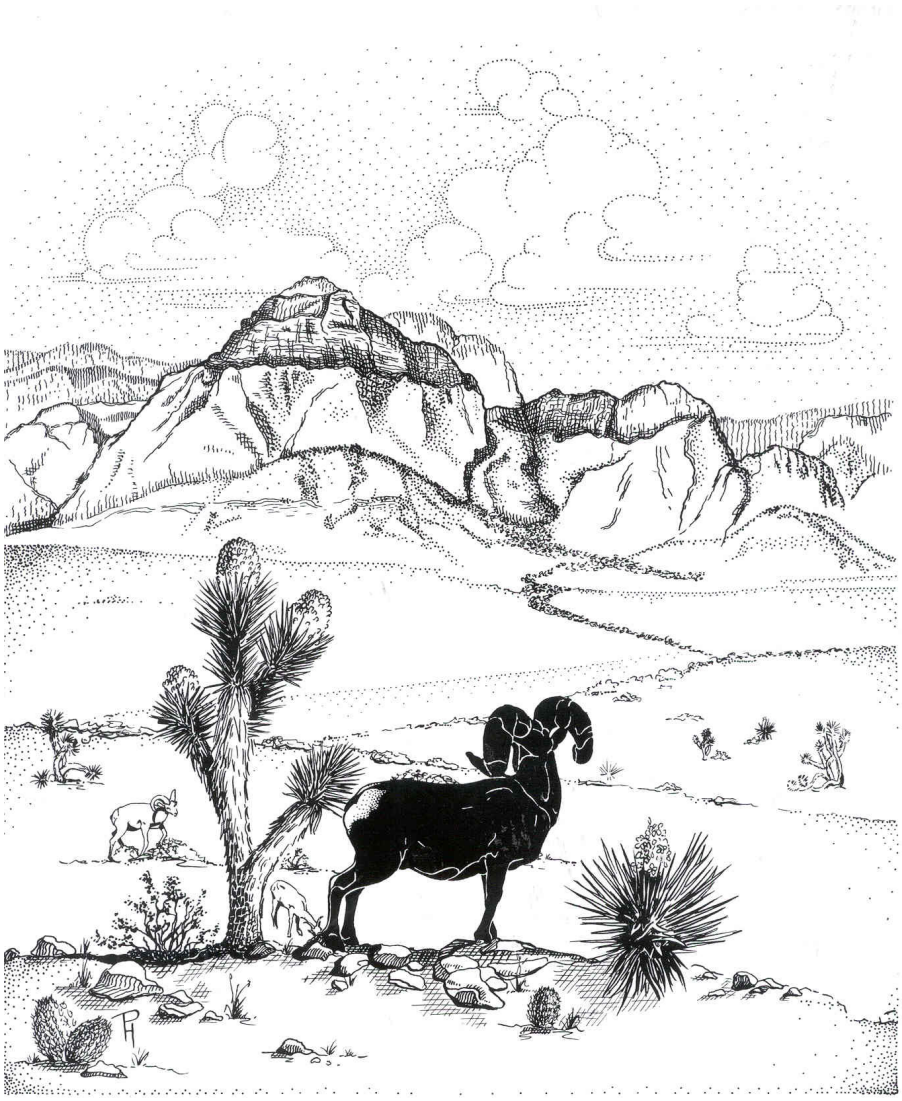
Abstracts of Presented Papers



Preliminary report on the effects of human recreation on desert bighorn sheep in southeastern Utah.

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Abstract: Human recreation is considered a major cause of stress in desert bighorn sheep (*Ovis canadensis nelsoni*) populations. Recreational use in southeastern Utah has increased 325% from 1979 to 1994 (Canyonlands National Park). On 19 and 20 February 2002, 18 radiocollars were placed on bighorn sheep near Moab, Utah. Nine of these radiocollars are Telonics GPS units, which will collect 5 data points per day for a 2-year period. Areas in which the sheep were radiocollared were rated according to their seasonal use. We will examine behavioral differences using 30-minute focal samples combined with scan samples every 10 minutes. We will also compare habitat preferences using 10-meter line transects combined with 1 m^2 circular plots. We expect to find that bighorn sheep in high use areas spend more time scanning and less time foraging than sheep in low use areas. We also expect sheep in high use areas to select poorer quality habitat to avoid conflicts with humans.

Land use planning and recovery of an endangered population of desert bighorn sheep in California.

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Abstract: In December 2002, the Bureau of Land Management (BLM) signed a Record of Decision amending the California Desert Conservation Area Plan. This plan amendment describes a Recovery Strategy for Peninsular bighorn sheep on BLM-managed public lands in the Santa Rosa and San Jacinto Mountains. There are 3 primary objectives of this strategy: (1) to restore and manage habitat to promote recovery of bighorn sheep; (2) to manage land uses to avoid, reduce, or mitigate disturbance; and (3) to manage bighorn sheep populations to promote recovery. We describe recovery objectives in the context of regional land use planning, implementation of these objectives, and the link between research and management decisions. In addition, we describe the development of a multiple jurisdiction trails management plan, intended to promote recovery of bighorn sheep while providing recreational opportunities on BLM-managed public lands. We monitored use of 7 trails under a voluntary trail avoidance program during spring 2001–2003. Results from the trail-monitoring program indicate that overall compliance with the voluntary trail avoidance program is high and that trail use has declined during the past 2 seasons.

Restoring California bighorn sheep populations in Idaho.

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Abstract: California bighorn sheep (*Ovis canadensis californiana*), believed to be widespread throughout northern Great Basin habitats ca. 1850, were extirpated from Idaho some time between 1920 and 1940. Stock from Williams Lake, British Columbia were reintroduced into southern Idaho in 1963 and subsequent years. Hunting was initiated in Idaho in 1969. Herd growth was rapid; the population increased from an estimated 90 bighorn sheep in 1970 to 570 in 1985. Rapid growth allowed personnel of the Idaho Department of Fish and Game to translocate over 400 bighorn sheep in Idaho and to other states between 1980 and 1993. In 1997, 8 southern Idaho herds numbered ca. 1,460 animals.

However, bighorn sheep herds began to decline in the mid to late 1990s. Between 1994 and 2002, the Little Jack Creek herd declined at a rate of 11%/year, based on helicopter surveys of the herd area. The number of sheep observed during June surveys of this herd declined from over 250 to less than 100; the number of lambs observed/100 ewes declined from 40–60 during 1985–1991 to 20–40 during 1993–2002. Cause of this decline is not known. Disease does not appear to be a factor. A study was initiated in 2002 with 38 radiocollared adult bighorn sheep; in the first year, 9 (24%) died. Of those, 5 were killed by mountain lions, and 2 more were probably killed by mountain lions but may have been predisposed to predators by capture and handling. Although data are limited, mountain lion populations appear to be growing throughout Idaho. Despite the declines in established herds, Idaho Fish and Game is continuing translocation efforts, with new herds established in south-central Idaho's Jim Sage Mountain in 2000 and Independence Peak in 2003.

Effects of spring cattle grazing on bighorn sheep habitat use.

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Abstract: Cattle grazing is a common land use in bighorn sheep (*Ovis canadensis*) habitats in the western United States; however, literature describing the compatibility of cattle and bighorn sheep is equivocal. We compared distributions of bighorn sheep and cattle for 3 consecutive years including the 1996–1998 cattle grazing seasons in Owyhee County, Idaho. Most cattle were present from mid-April through June coinciding with lamb rearing by bighorn sheep. Ewes moved into canyons for lambing in May and returned to rangelands in July after cattle left. We could detect no significant change in bighorn sheep distribution when cattle were present in sheep home ranges. Habitat used by both bighorn sheep and cattle included a strip of rangeland adjacent to the canyon rims as well as areas within the canyons that were accessible to cattle. We recommend that no management action should be taken that would concentrate cattle in bighorn sheep home ranges (e.g., water development, salt placement, fences, corrals) without identifying the location of bighorn sheep home ranges and the availability of adequate yearlong forage. The safest policy is to avoid management actions that would attract or hold cattle near canyons inhabited by bighorn sheep. The buffer distances within which concentrations of cattle are of concern is about 400 m for ewes and 700 m for rams.

Visual obscurity in a low-elevation population of Rocky Mountain bighorn sheep in southwestern New Mexico.

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Abstract: Bighorn sheep (*Ovis canadensis*) rely on keen vision and open habitat to detect and evade predators. We hypothesized that (1) dense vegetation in the Turkey Creek Study Area decreased visibility for bighorn sheep, resulting in greater habitat use of areas with less dense vegetation and (2) that aerial photo analysis of canopy cover in bighorn sheep habitat is not correlated with visual obscurity measured on the ground. We measured visual obscurity caused by vegetation and topography at bighorn sheep bedding and foraging sites (n = 123) in southwestern New Mexico and compared them with random sites (n = 120). We measured percent canopy cover from 1999 aerial photos using GIS to assess the relationship between canopy cover and visual obscurity. We found no difference in visual obscurity among social groups (ewes, rams, mixed) at bighorn sheep bed and forage sites (χ^2 = 2.79, df = 3, P = 0.426; χ^2 = 4.40, df = 3, P = 0.222; respectively). When social groups were lumped, we found a significant difference in visual obscurity at bedding and foraging sites (Z = -4.99, df = 1, P < 0.001) and no correlation between canopy cover measured from aerial photos and visual obscurity measured on the ground (r = 0.041, P = 0.619). Our results indicate that aerial photo interpretation may not be a reliable measure of visibility in some bighorn sheep habitats and should be applied cautiously if used.

Ecological assessment of the reintroduced Rocky Mountain bighorn sheep along the Wasatch Front Mountains in central Utah.

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Abstract: In the past 3 years, herds of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) have been reintroduced along the mountain ranges adjacent to the heavily populated Wasatch front in central Utah. This is a preliminary presentation of data gathered since the bighorn sheep reintroduction. The data collected includes range and habitat use, foraging selection and preference, population status (i.e., parturition timing, lamb survival, and recruitment), and causes of mortality. Also, prior to and during the study, mountain lion (*Puma concolor*) harvest permits were doubled to assist the re-establishment of these bighorn sheep herds. Hunter harvest sheets have been examined to show population demographics of the mountain lions removed from the study area.

Desert bighorn sheep and mountain lions: confronting the challenges.

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Abstract: Mountain lions (*Puma concolor*) and bighorn sheep (*Ovis canadensis*) have co-evolved as a predator and prey. Bighorn sheep populations have declined over the past several centuries across their range due to a variety of anthropogenic causes and have been the subject of extensive translocation efforts in recent years in an effort to reestablish populations in historic habitat. In the past several decades mountain lion predation has also been implicated in the decline of several populations of endangered bighorn sheep, including the federally listed Peninsular (*O. c. cremnobates*) and Sierra Nevada populations in California and state listed desert bighorn sheep (*O. c. mexicana*) populations in New Mexico. We hypothesize that this recent phenomenon has resulted from land and wildlife management practices that have affected both species. Restoring the natural relationship between mountain lions and bighorn sheep presents both biological and ethical challenges. We discuss the current status of management efforts, review several hypothesis of why predation has become a limiting factor for bighorn sheep recovery, and discuss current and potential management options.

Synopsis of desert bighorn sheep-mountain lion management issues in New Mexico.

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Abstract: Despite translocating 305 desert bighorn sheep into New Mexico since 1979, the current population estimate is only 235. Monitoring of 224 radiocollared desert bighorn sheep between 1992 and 2002 determined that this species is primarily top-down regulated by mountain lion predation throughout its range in New Mexico. Since 1992, 85% of known-cause mortality of radiocollared desert bighorn sheep has been mountain lion predation. Because all desert bighorn sheep populations are considered to be below carrying capacity, this mortality is primarily additive. Empirical data suggests that and distribution have increased since the legal designation as a game animal in 1971. Hypothesized changes in mountain lion numbers may have resulted in the decline of other native species in addition to desert bighorn sheep. The role of exotic ungulates in "subsidizing" mountain lions and potentially maintaining high mountain lion numbers despite a mountain lion management action designed to reduce high lion predation on desert bighorn sheep are also discussed.

Long term fecal nitrogen data sets from California.

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Abstract: Since the mid-1970s, I have used fecal nitrogen (FN) to track diet quality of bighorn sheep populations in a wide variety of habitats in California. From the eastern Mojave Desert I now have continual (monthly) FN data from 3 different populations that exceed 15 years in length. These allow analyses of resource predictability. I will discuss this methodology and some of what I have learned from it over the past quarter century.

Functional factors of habitat selection and the population dynamics of desert bighorn sheep in the Grand Staircase-Escalante National Monument.

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Abstract: In 1999 and 2000, 2 translocations of desert bighorn sheep (*Ovis canadensis nelsoni*) were released on the southern end of the Grand Staircase-Escalante National Monument. This effort was to supplement past efforts to recover bighorn sheep into former habitat. Twenty individuals were released in 1999 and 21 in 2000 with radiocollars for telemetry monitoring. With the absence of mountain lion and low occurrence of disease, mortality was low (0–22%) and recruitment high (50–75%). Total population size by 2001 was 54 individuals. With the reoccupation of mountain lion into the area in 2002 and 2003, only 4 of 19 radiocollared sheep were reported alive. Present population numbers (2002 and 2003) are only estimates from aerial surveys by the Utah Division of Wildlife Resources. Radiocollared sheep were invaluable in assessing habitat use, herd interactions, and assisted in understanding bighorn sheep settling patterns. Data were collected on individual identification, sex, age class, and vigor class for each bighorn sheep monitored in 1999–2001. Macrohabitat data were also collected at the same time by measuring the nearest distances of bighorn sheep to humans, water, riparian area, escape terrain, nearest cohorts, other animals, vertical cliff face, roads, trail, tree, cougar cover, and horizontal cover. Five of these 12 factors proved to be most important to sheep habitat selection. These factors were proximity to surface water, escape terrain, cougar cover, vertical cliff, and horizontal cover. Of all, water proximity is the most important factor in sheep use in summer months, yet differed in significance between years. Our data prove congruent and supplemental to a previously developed habitat model.

A business approach to wildlife management.

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Abstract: During the past 13 years, through cooperation with the Bureau of Land Management, the U. S. Forest Service, the Utah Division of Wildlife Resources, and Utah public and private land ranchers, 23 new bighorn sheep herds have been established in Utah. Wild sheep populations have increased from less than 300 to nearly 4, 500. Hunter permits have increased from 9 to 56. By working with other states and Canada, transplant stock has come into Utah from Alberta, Arizona, British Columbia, Colorado, Montana, Nevada, and Wyoming. Utah now has large enough herds to provide for in-state transplants of Rocky Mountain and California bighorn sheep and has provided Colorado with desert bighorn sheep.

The Foundation for North American Wild Sheep (FNAWS), based in Cody, WY and its chapters in Utah, Minnesota-Wisconsin, Iowa, and Eastern have provided almost all of the funding for this remarkable effort. Jim Karpowitz has done a phenomenal job as the Bighorn Sheep Coordinator in Utah. The Utah Wildlife Board has adopted aggressive predator management policies that have removed nearly 200 mountain lions in the past few years to help protect this $4 million investment.

Utah FNAWS has developed a series of 5-year strategic plans for each existing sheep herd and for future sheep herds, identifying specific actions for habitat, water development, predators, grazing issues, and transplant actions. These strategic plans help guide financial expenditures of over $300,000 a year.

Following are the bighorn sheep herds that Utah FNWAS has been involved with over the past 13 years:

Desert Bighorn Sheep	Rocky Mountain Bighorn Sheep	California Bighorn Sheep
North San Juan	North Slope Uintas	Antelope Island
South San Juan	Flaming Gorge	Newfoundland Mountains
Professor Valley	South Slope Uintas	Silver Island Mountains
Potash	Rattlesnake	
Dirty Devil	Range Creek	
Little Rockeis	Rock Canyon	
Escalante	Timpanogas	
Kaiporowitz	Nebo	
Paria River		
Beaver Dam Mountains		
North San Rafael		
South San Rafael		

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GENERAL POLICY: Original papers relating to desert bighorn sheep ecology and management are published in the *Desert Bighorn Council Transactions*. All papers presented at the Council's annual meetings are eligible for publication. There are 3 types of papers published in the *Transactions*: technical papers; state reports; and opinions, comments, and case histories or notes. Technical papers are peer reviewed. State reports are edited for syntax and style. Opinions, comments, and case histories and notes provide for philosophical presentations and the presentation of ideas and concepts. These papers are also peer reviewed. Additional papers may be published when reviewed and approved by the Editorial Board. Papers must be submitted to the Editor within 1 year of the Council's annual meeting to be considered for the current edition of the *Transactions*.

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DESERT BIGHORN COUNCIL MEETINGS 1957 - 2003

Year	Location	Chairperson	Secretary	Treasurer	Transactions Editor
1957	Las Vegas, NV	M. Clair Albous			
1958	Yuma, AZ	Gale Monson & Warren Kelly			
1959	Death Valley, CA	M. Clair Albous	Fred Jones	Fred Jones	
1960	Las Cruces, NM	Warren Kelly	Fred Jones	Fred Jones	
1961	Hermosillo, MX	Jon Akker	Ralph Welles	Ralph Welles	
1962	Grand Canyon, AZ	James Blaisdell	Charles Hansen	Charles Hansen	Charles Hansen & L. Fountein
1963	Las Vegas, NV	Al Jonez	Charles Hansen	Charles Hansen	Jim Yoakum
1964	Mexicali, MX	Rudulfo Corzo	Charles Hansen	Charles Hansen	Charles Hansen & D. Smith
1965	Redlands, CA	John Goodman	John Russo	John Russo	Jim Yoakum
1966	Silver City, NM	Cecil Kennedy	John Russo	John Russo	Jim Yoakum
1967	Kingman, AZ	Claude Lard	John Russo	John Russo	Jim Yoakum
1968	Las Vegas, NV	Ray Brechbill	John Russo	John Russo	Jim Yoakum
1969	Monticello, UT	R. & B. Welles	W. G. Bradley	W. G. Bradley	Jim Yoakum
1970	Bighop, CA	William Graf	W. G. Bradley	W. G. Bradley	Jim Yoakum
1971	Santa Fe, NM	Richard Weaver	Tillie Barling	Tillie Barling	Jim Yoakum
1972	Tucson, AZ	George Welsh	Doris Weaver	Doris Weaver	Charles Hansen
1973	Hawthorne, NV	Warren Kelly	Doris Weaver	Doris Weaver	Juan Spillet
1974	Moab, UT	Carl Mahon	Lanny Wilson	Lanny Wilson	Juan Spillet
1975	Indio, CA	Bonnar Blong	Lanny Wilson	Lanny Wilson	Charles Hansen
1976	Bahia Kino, MX	Mario Luis Cossio	Peter Sanchez	Peter Sanchez	Charles Hansen
1977	Las Cruces, NM	Jerry Gates	Peter Sanchez	Peter Sanchez	Charles Hansen
1978	Kingman, AZ	Kelly Neal	Peter Sanchez	Peter Sanchez	Charles Hansen
1979	Boulder City, NV	Bob McQuivey	Peter Sanchez	Peter Sanchez	Charles Hansen
1980	St. George, UT	Carl Mahon	Peter Sanchez	Peter Sanchez	Charles Hansen
1981	Kerrville, TX	Jack Kilpatric	Peter Sanchez	Peter Sanchez	Charles Hansen
1982	Borrego Sprs., CA	Mark Jorgensen	Rick Brigham	Rick Brigham	Charles Hansen
1983	Silver City, NM	Andrew Sandoval	Rick Brigham	Rick Brigham	Charles Hansen
1984	Bullhead City, AZ	Jim deVos, Jr.	Rick Brigham	Rick Brigham	Charles Hansen
1985	Las Vegas, NV	David Pullman, Jr.	Rick Brigham	Rick Brigham	Charles Hansen
1986	Page, AZ	Jim Guymon	Bill Dunn	Bill Dunn	Paul Krausman
1987	Van Horn, TX	Jack Kilpatric	Bill Dunn	Bill Dunn	Paul Krausman
1988	Needles, CA	Vernon Bleich	Don Armentrout	Don Armentrout	Paul Krausman
1989	Grand Junction, CO	Jerry Wolfe	Don Armentrout	Don Armentrout	Paul Krausman
1990	Hermosillo, MX	Raul Valdez	Don Armentrout	Don Armentrout	Paul Krausman
1991	Las Cruces, NM	Bill Montoya	Don Armentrout	Don Armentrout	Paul Krausman
1992	Bullhead City, AZ	Jim deVos, Jr.	Stan Cunningham	Stan Cunningham	Paul Krausman
1993	Mesquite, NV	Kathy Longshore	Charles Douglas	Charles Douglas	Walter Boyce
1994	Moab, UT	Jim Guymon	Charles Douglas	Charles Douglas	Walter Boyce
1995	Alpine, TX	Doug Humphries	Charles Douglas	Charles Douglas	Ray Boyd
1996	Holtville, CA	Andy Pauli	Charles Douglas	Charles Douglas	Ray Boyd
1997	Grand Junction, CO	Dale Reed & Van Graham	Steve Torres	Charles Douglas	Raymond Lee
1998	Las Cruces, NM	Eric Rominger & Dave Holdermann	Darren Divine	Charles Douglas	Raymond Lee
1999	Reno, NV	Rick Brigham & Kevin Hurley	Darren Divine	Charles Douglas	Allan Thomas & Harriet Thomas
2000	Bullhead City, AZ	Ray Lee & Jim deVos	Darren Divine	Charles Douglas	Jon Hanna
2001	Hermosillo, Sonora, Mexico	Carlos Castillo & Jim deVos	Darren Divine	Charles Douglas	Jon Hanna
2002	Palm Springs, CA	Mark Jorgenson	Darren Divine	Charles Douglas	Jon Hanna
2003	St. George, UT	Jim Karpowitz	Darren Divine	Darren Divine	Brian Wakeling