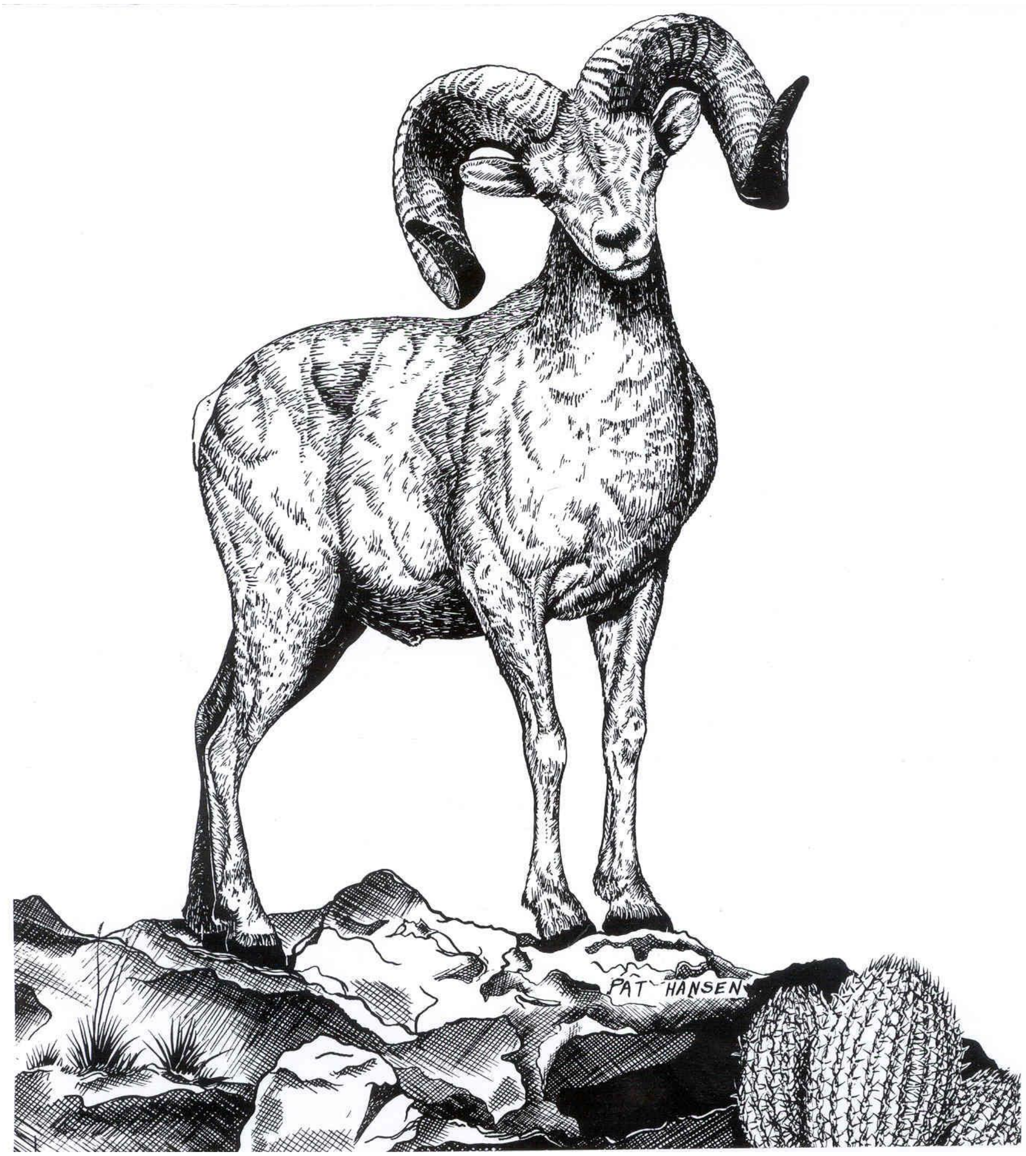
DESERT BIGHORN COUNCIL TRANSACTIONS



VOLUME 52 2013

Editor's Note – Ain't Nuthin' But a Paper Cut

On September 25, 2013 at 1:45p MST, my son Seth, while on a dismounted patrol in Wardak Province in Afghanistan, stepped on an improvised explosive device. It was 2:15a on September 26 in Afghanistan. He was medevaced to Bagram Airbase, shipped to Landstuhl Regional Medical Center in Germany, and then flown to Walter Reed National Military Medical Center (WRNMMC) in Bethesda, MD. He arrived on October 1. My wife, younger son, and I arrived on October 2. He has recovered from his physical wounds, but he lost his left leg below the knee.

During my first visit, and before I returned to Arizona, we began touring the hospital and military advanced training center (MATC) with Seth, his doctors, and medical care professionals. On the first visit to the MATC, I was amazed to see over 50 soldiers in various physical exercises, many that had lost far more than just a leg, working to recover their fitness and mobility. An individual that had lost parts of all his limbs was running around a track with his prosthetics, another that had lost both legs at the hip was bouncing a ball on an adjacent wall to practice his balance. I was overcome by the power I felt in this room of wounded warriors in recovery.

About that time, the physical therapist introduced us to Will, a physically-fit individual that had just walked up to us. Will took one look at Seth in his wheel chair and said "Hello Paper Cut." I contemplated making an effort to whoop his rude ass, but then remembered how physically fit he appeared. Then I noticed Will was wearing a prosthetic where his lower right leg should have been. Seth didn't immediately respond, but Will followed up. "I'm in the same boat as you, but take a look at this place. Around here if you're simply missing a leg below the knee, it ain't nuthin' but a paper cut."

On December 2, Seth took his first steps with his prosthetic leg. In the months that followed, he has progressed to dove hunts, turkey hunts, mini-marathons, mini-triathlons, and scuba dive trips. During fall 2014, he will participate in an elk hunt. Physically and mentally, he is progressing quite well. His life is not perfect, his recovery is not fully complete, but I am so pleased that I have my son and he has had the care he received. But I'll never forget the first moment of perspective that Will shared with us, probably never knowing what an effect it would have on me. "Ain't nuthin' but a paper cut!"

I believe there is much in our lives that can destroy us if we allow it. Our personal financial situation may become compromised, our careers may not follow the trajectory we desire, and many of our professional work plans may not get accomplished. Bighorn sheep translocations may be postponed, disease outbreaks may reduce vital herds, and land management planning may frustrate us. While dealing with the daily frustrations, we sometimes don't stop to look at the progress we have achieved. The important thing is that we remain in the ring and keep swinging. President Theodore Roosevelt described this important concept in his "Man in the Arena" speech. We have to learn from our failures and adopt new strategies, but we cannot quit trying. And we need to keep building the teams to get work done. Teamwork gets far more done than the same number of individuals working alone.

I am pleased with what Seth has accomplished. I am also pleased to have seen the support that my wife and my younger son, Micah, provided to Seth by moving to Bethesda as his non-medical attendants for the 9 months following his arrival at WRNMMC. As an inspirational speaker named Greg Stube pointed out (after he had suffered traumatic injuries in Afghanistan and experienced a protracted recovery), soldiers volunteer in the USA, but wives, mothers, and siblings are conscripted without choice. This experience reinforced what I already knew, but often forget – if we take the time to look beyond the immediate challenge, we can envision and realize success.

How much in our profession is similar. The restoration of wildlife under the North American Model of Wildlife Conservation is a success many may never have dreamed possible in 1900. How many successes have been documented in the volumes of the *Desert Bighorn Council Transactions*? Let's keep in mind that setbacks, no matter how insurmountable they may appear when they occur, may simply be "nuthin' but a paper cut" in retrospect.

-- Brian Wakeling

Desert Bighorn Council Transactions 2013

A Compilation of Papers Presented at the 52nd Meeting

Las Cruces, New Mexico April 17–20, 2013

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2013

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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 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 dedicate this volume to their memories.

James Donovan Yoakum (1926–2012)

Many of you reading this may not know who Jim Yoakum was, but read on. He was born in Templeton, California on June 14, 1926. He served in the U.S. Navy from 1944–1947, seeing many tough battles including Iwo Jima. His time in service was a small part of his life, but the G.I. Bill gave him an education, a career, and a place to call home. After seeing the devastation of war, he sought wilderness and wildlife. His first purchase after World War II was a saddle, while taking a job as a forest lookout near Big Sur on the California coast. After that summer he attended Humboldt State College in the redwoods of California, graduating in 1953. He went on to Oregon State University where he earned a Masters degree in 1957. Jim was hired by the Bureau of Land Management as its first wildlife biologist and spent most of his 28-year career in the BLM Nevada State Office in Reno. He did take time out to study alpacas and vicunas in South America in the mid-1960s, and did a stint teaching at both Humboldt State and University of Nevada Reno. Jim was a strong advocate for wildlife and for professionalism among wildlife biologists. He was a mainstay in the Nevada chapter of The Wildlife Society (TWS) as well as the Western Section of TWS, where he held several positions and was honored with several awards. Jim continually pushed biologists around him to do better for wildlife and wildlife management.

He earned his Masters degree on pronghorn ecology. While conducting his field work, Jim used a black Labrador retriever to help him locate antelope fawns. The dog would hold the fawns down with his paws until Jim got to them. He had a succession of Labs, mostly black (the second to last, Teena, was a yellow Lab), throughout the rest of his life, and they accompanied him anywhere he drove. "Teena" is an American Indian name for pronghorn. Those speedsters were the wildlife love of his life. He coauthored "Pronghorn Ecology and Management" with Bart O'Gara, a comprehensive 900+ page book to which he made last-minute changes up until the moment it went to the printer. The book represents a monumental bookend to his love of wildlife and wild places, and a solid foundation for those who follow.

Along the way, Jim found time for desert bighorn sheep. He attended many Desert Bighorn Council annual meetings in the 1960s and early 1970s. Jim served one year as a member of the DBC Technical Staff and presented several papers, but is most remembered for being *Desert Bighorn Council Transactions* editor from 1965 through 1971.

For those of you who attended the fiftieth year of the Desert Bighorn Council in Las Vegas in 2007, Jim was there, older and slower but still the hard-core wildlife advocate he always was.

Jim passed over on November 20, 2012.

-- Rick Brigham, Don Armentrout, and Dick Weaver

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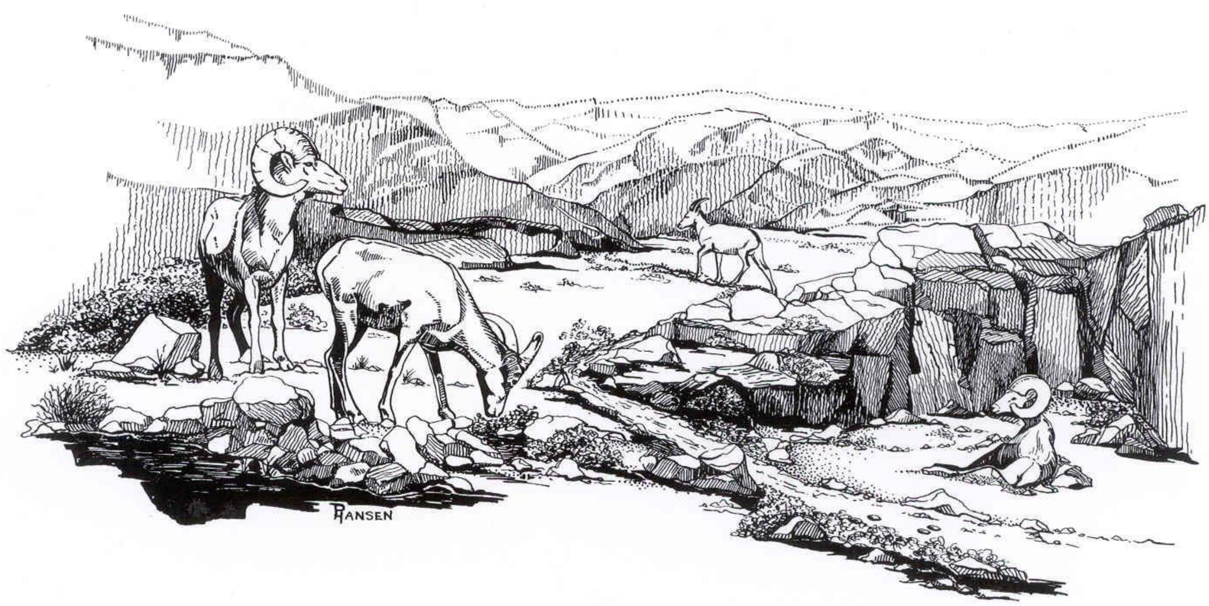

Invited Paper: Strategies for managing mountain lion and desert bighorn sheep interactions

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Abstract This paper is a compilation of comments made by an invited panel of experts at the Desert Bighorn Council meetings in Las Cruces, NM on Thursday, April 18, 2013. The experts were asked to speak on the topic of bighorn sheep (*Ovis canadensis*) and mountain lion (*Puma concolor*) interactions and effects of management actions. The panel included Clay Brewer (Texas Parks and Wildlife), Bob Henry (Arizona Game and Fish Department), Elise Goldstein (New Mexico Department of Game and Fish), and John Wehausen (University of California, White Mountain Research Station); the discussion was facilitated by Eric Rominger (New Mexico Department of Game and Fish). These experts agreed to collaborate on response to 8 questions: 1) are there examples of high cause-specific mortality of bighorn sheep attributed to mountain lions, 2) are there herds in your state that are producing surplus bighorn sheep in the presence of mountain lion predation, 3) if you are employing mountain lion control within any bighorn sheep herd within your state, do you envision a point at which that control may cease without detrimental effects to the bighorn sheep herd, 4) what rate of removal on mountain lions have been necessary to allow for bighorn sheep to grow, 5) what abundance estimates do you have for mule deer (*Odocoileus hemionus*) in areas where bighorn sheep populations are experiencing high predation by mountain lions, 6) do any other predators in your state have population level effects on bighorn sheep, 7) do you believe that mountain lion predation on bighorn sheep is influenced by mule deer abundance by prey switching or buffering, and 8) have the dynamics of mountain lion predation on bighorn sheep changed over time?

Desert Bighorn Council Transactions 52:1–15

Key words Arizona, California, New Mexico, predator-prey relationships, Texas

Clay Brewer.—Bighorn sheep numbers in Texas during the late 1800s were estimated to be as high as 1,500 animals. By the early 1900s, Texas bighorn sheep populations had declined or were extirpated from much of the historically occupied ranges, and it is believed that the last native bighorn sheep were gone by the early 1960s. Restoration efforts were initiated in 1954 with the development of a cooperative agreement between the Texas Game, Fish, and Oyster Commission of Texas, U.S. Fish and Wildlife Service, Boone and Crockett Club, Wildlife Management Institute, and Arizona Game and Fish Department. Initial efforts focused on propagation of desert bighorn sheep in captivity to provide source stock for transplanting into suitable habitat. The first propagation facility was constructed on Black Gap Wildlife Management Area (WMA) and was operational by 1959. Additional facilities were constructed on Sierra Diablo WMA (1970), Sierra Vieja Mountains (1977), and Sierra Diablo WMA (1983).

At the same time restoration was occurring, there were some interesting things occurring in the livestock world. In the early years, predator control efforts were conducted by both landowners and the federal government not only with mountain lions but coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and eagles (*Haliaeetus leucocephalus* and *Aquila chrysaetos*). The literature indicates that mountain lion numbers remained fairly low in Texas through the 1930s and 1940s. Significant changes occurred in the 1950s as a result of severe drought throughout the state. In the Trans-Pecos region, the domestic sheep and goat industry completely vanished because of the drought and predator control went with it. However, permanent waters along with artificially high prey numbers such as mule deer and javelina (*Pecari tajicu*) remained in place. Over the next 30 years, the west Texas mountain lion population may have reached record numbers and expanded into areas that had been vacant for decades. This was occurring at the very same time as bighorn sheep restoration.

Since the mid-1950s, mountain lion predation-related mortalities in desert bighorn sheep have averaged about 50%. A 173-ha brood pasture was constructed on Black Gap WMA and stocked with 16 bighorn sheep from Arizona in 1957–1959. By about 1970, the herd increased to about 68 animals. In 1971, the Texas Parks and Wildlife Department (TPWD) began releasing bighorn sheep onto Black Gap WMA. These free-ranging sheep remained in the vicinity of the brood pasture and experienced good lamb production and survival for 2 years following their release and declined after that as a result of a significant increase in predator populations. In fall 1971, the brood herd within the 173-ha enclosure was decimated by disease (bluetongue and pneumonia) and poor range conditions, with about half of the sheep lost in the die off. Shortly after this event, there was a commission-directed reduction in the predator control program that had been conducted since the construction of the Black Gap brood pasture. In 1975, the predator control program was discontinued altogether for about 1 year. Losses of bighorn sheep to mountain lions and bobcats within the enclosure became common occurrences. Subsequently, the moratorium on predator control was modified to permit limited trapping within a 6.5-km radius of the pasture. However, mountain lion and bobcat predation continued to plague the Black Gap pasture through the late 1970s and as a result, propagation efforts were abandoned at that location.

In 1987, bighorn restoration efforts were initiated at Elephant Mountain WMA with the release of 20 bighorn sheep from the Sierra Diablo WMA propagation facility.

Despite intensive predator management activities, predation restricted numbers for several years. Bighorn sheep numbers remained between 35–50 for years, with practically no lamb production in some years. Persistent predator management along with protection and other management strategies resulted in an expanded population with numbers exceeding 160 several times over the last decade. The area currently serves as the primary source of broodstock for reintroductions (3 transplants in last 10 years).

A similar experience occurred in the Baylor Beach Sierra Diablo metapopulation. Bighorn sheep numbers climbed to about 100 animals and remained stable for a number of years. Cooperative predator management was implemented in the late 1990s between landowners and TPWD. These efforts resulted in numbers reaching 800 animals with lamb:ewe ratios of 56:100 reported. This is currently the largest population in the state.

Big Bend State Park is currently the top priority for restoration efforts. Over the last 3 years, about 150 sheep have been released on the area. A number of bighorn sheep were radiocollared during the transplant and the predation rate has averaged 39%.

All bighorn sheep populations in Texas are subject to mountain lion predation. Both Elephant Mountain and the Baylor, Beach, and Sierra Diablo metapopulation are currently producing surplus animals in the presence of mountain lions. We have practiced predator control within both areas but not at consistent levels or intensities.

Predator management is not the answer to all of life's problems. It is labor intensive and often hit or miss at best. While I believe we have to be realistic, some form of adaptive management has to be our ultimate goal. Implementation of properly planned, science-based, and site-specific predator management must include:

- Measurable bighorn sheep and predator management goals and objectives,
- Specified scale, frequency, intensity, duration and monitoring to determine whether the desired results are achieved, and
- Public outreach and education.

Historically, we've managed mountain lions intensively and persistently and it has served us well. We've restored desert bighorn sheep to late 1800 population levels, and I'm not ashamed of how we've accomplished it. Having said that, mountain lion management in Texas is not as aggressive as it once was for a number of reasons: increased bighorn sheep numbers, absentee landowners; staffing shortages; loss of experience; and other factors including the need for better science and accountability. The April 2012 Texas Monthly article, "*The case of the Big Bend burro killings*," particularly the part about "who gets to play God in west TX," is a good example of why accountability is important. Implementing adaptive management strategies in our predator management program is an important goal.

Decisions concerning predator management have significant consequences for managers, both biologically and politically. Bighorn sheep were completely gone from Texas and until recently, we haven't had the luxury of deciding whether or not predator management was a good or bad thing. Loss of a single animal was devastating. The bottom line, restoring bighorn sheep in Texas required aggressive predator control and we have been successful because our efforts. Today's managers work in different times and have to decide what works best for them. Rest assured, they will deal with the consequences resulting from their decisions.

Mountain lions in Texas are currently classified as a non-game animal with no closed season and no bag limit. Texas comprises 97% privately-owned land and our biologists work closely with landowners to achieve specific management goals on their properties. Confidentiality laws are in place to protect landowners. As result, much of what occurs on private land isn't reported. State predator management occurs on state-owned land only, which is a small percentage of the landscape. Most predator management occurs during cooler seasons.

Overall, predator management has been inconsistent through the years and within seasons. We have no sound population estimate for mountain lions.

Deer abundance in Texas ranges from 49.4–123.5/100 km^2 within high mountain lion predation areas of Texas. Within the Big Bend region, deer abundance averages 49.4 deer/100 km^2 with mean observation rates of 9.56 deer/hr.

Mountain lions have never been considered trivial predators of desert bighorn sheep in Texas. DBC Transactions after 1959 indicate that staff members Tommy Hailey, Jack Kilpatrick, and others were reporting on the effects of mountain lions when most other western states believed that the effects of mountain lions were minimal. Some of the early reports document predation by bobcats and eagles. I believe predators other than mountain lions can cause problems, particularly during the early stages of restoration and lambing seasons. However, I really don't have any data indicating specific population level effects.

I believe mountain lions are opportunistic and prey on whatever is available. Natural communities and the processes that maintain them are drastically different than what they once were. Examples include artificially high deer numbers resulting from an increased and a well-distributed permanent water supply, supplemental feeding, and other factors. I also think climatic conditions are important. In Texas, mountain lions prey primarily on deer. When it rains, other prey species become more abundant and available such as javelina, porcupines (*Erethizon dorsatum*), skunks (*Mephitis* spp.), rabbits (*Sylvilagus* spp.), and other prey species. Average kill rates are: 1 kill/3–5 days for a female raising cubs and 1kill/5–14 days for adult males. More prey is required in hot weather because the kill spoils quickly, making it necessary for a mountain lion to kill more often to obtain fresh meat. In cooler weather, the kill lasts longer, which decreases the frequency of killing.

While I believe that mountain lions have always been a major factor in the population dynamics of desert bighorn sheep, the environment in which they live is different than it once was. As previously indicated, natural communities and the processes that maintain them are drastically different than they once were. Changes include restricted movements from fences, highways and other barriers, and artificially high prey numbers resulting from an increased and a well-distributed permanent water supply, supplemental feeding, and other factors.

Robert S. Henry.—For the past 6 years, my colleagues and I in the Arizona Game and Fish Department and U.S. Fish and Wildlife Service, along with the University of Arizona, have been studying the relationship of bighorn sheep and mountain lion in southwestern Arizona, primarily on the Kofa National Wildlife Refuge (KNWR) and surrounding areas. This work was initiated in response to a large decline in the Kofa bighorn sheep herd and coincidental arrival and increase of mountain lions into an area that had few records of mountain lions in the previous 50 years. As part of this study we've radiocollared both bighorn sheep and mountain lions, surveyed bighorn sheep annually, carefully monitored mountain lion kills, and determined genetic relationships of mountain lions. Most of my examples for this paper will derive from this study and this area.

On the KNWR, mortality rates of radiocollared female bighorn sheep during 2008–2012 ranged from 0.05–0.17. Sixteen of 23 mortalities (70%) were attributed to mountain lion predation. However, this rate declined from 100% of mortalities due to lions in 2008 to 50% by 2012. In several translocations, mountain lion predation varied: in the Harquahala Mountains, 7 of 8 mortalities (88%); in the Harcuvar-Granite Wash area, 23 of 47 mortalities (49%); and in the Big Horn Mountains 12 of 22 mortalities (55%) were attributed to mountain lions. I know of no extirpations of bighorn sheep populations that were caused by mountain lion predation but large declines to near zero in the Eagletail Mountains and the Sand Tank-Sauceda Mountains have been attributed at least in part to mountain lion predation.

In Arizona, not all bighorn sheep populations may be regulated by mountain lion predation. A research project in Unit 22 east of Phoenix conducted by Ted McKinney demonstrated substantial predation by mountain lions and yet the bighorn sheep population is still thriving. This is an exploited mountain lion population, and reported harvest of mountain lions in this unit averages 10–20 year. The bighorn sheep are either out-producing losses to predation or they're avoiding predation, either by avoidance behaviors or by alternate prey absorbing the bulk of the predation pressure.

In Arizona, by commission policy, we have to write a predation management plan before doing any predator control, and part of that plan has to be a description of the situation that will allow cessation of the control. On Kofa NWR, we set decision points at a bighorn sheep population of 600 and 800. The higher number represents the long-term mean bighorn sheep population. When the bighorn sheep population is below 600, we implement predator control. When the population is greater than 800, we will cease predator control. When the population is between 600 and 800, we may implement control, depending on several factors such as the trend direction. We are currently below the 600-bighorn sheep mark with active mountain lion control. I believe you have to look at population and mortality trends and not just at the cutoff number to make predator control decisions.

The KNWR herd is currently the only bighorn sheep herd in Arizona with an active mountain lion control program in place specifically to protect bighorn sheep. The KNWR covers 2,700 km^2. Seven mountain lions were removed from it in 2011 and 2012. Using the mountain lion density estimate, I would expect 11 lions to inhabit the area. Therefore, removing 7 lions out of an expected 11 would represent a 64% cull rate.

Another way to look at it is from 2011 through 2013, we've been removing 3 to 4 mountain lions per year. Based on estimates from sign, cameras, and trapping, there have typically been about 5 mountain lions in the area. Using this population estimate, the cull rate would be 60–80%.

It is difficult to define a mountain lion population much less put a number to it. As large as the KNWR is, most desert mountain lions have a much larger home range, so therefore individual mountain lions move on and off the study area. Consequently, it is difficult to know how many are there at any given time.

Many of our small desert bighorn sheep herds inhabit arid mountains with no deer present. However, most of the ranges are small and are surrounded by valleys inhabited by mule deer. Mountain lion home ranges in all cases would overlap both bighorn sheep and deer habitat. Mule deer densities throughout southwestern Arizona are typically sparse and fairly consistent, though some areas of higher densities do occur. Typical mule deer densities range from about 30–40/100 km^2. On KNWR, mule deer average about 36/100 km^2. In most areas there are few other ungulates present, other than a few javelina, burros, and livestock.

I don't have any data to suggest any other predator would regulate bighorn sheep populations. Bobcat is probably the most likely secondary predator, especially on lambs. There may be some golden eagle predation, but we have no evidence of it.

In southwestern Arizona over the past 20 years there has been an apparent change from mountain lions having little effect on bighorn sheep to being a major limiting factor. This change has coincided with an overall decline in mule deer numbers, from averaging about 75/100 km^2 to the current 35/100 km^2. For this situation to occur, prey buffering is more likely than prey switching to explain the change I have observed.

Mountain lions have probably always played a role in desert bighorn sheep population dynamics where their ranges overlapped. We can only speculate how the changes from pre-Columbian contact to the present time have affected bighorn sheep and mountain lion population distribution, abundance and behavior. One of the major changes has been the introduction of domestic ungulates. In desert environments this led to a better distribution of water, the introduction of foreign disease organisms, and greater numbers of non-bighorn sheep ungulate prey for lions. The potential interaction of all these changing variables has made the system too complex for us to understand, but if any of these changes has led to a lessening of reproductive success of bighorn sheep, then they become more vulnerable to predation at a population level.

Elise Goldstein.—Mountain lion predation accounted for a substantial proportion of the mean annual mortality for most bighorn sheep populations monitored in New Mexico during the period when no mountain lion removal was undertaken (Table 1). A single year of particularly high mountain lion predation can reduce herd size such that it is nearly impossible to recover,

Table 1. Average annual mortality rates and average mortality rates attributable to mountain lion predation (maximum single year rate in parenthesis) in 5 bighorn sheep herds in New Mexico and statewide during a period when no mountain lion removal was undertaken.

	Average annual mortality rate	
Category	All causes	Mountain lion predation
Statewide	0.21	0.16
Ladrones	0.21	0.14 (0.45)
Hatchets	0.20	0.14 (0.20)
Peloncillos	0.25	0.22 (0.27)
San Andres	0.26	0.15 (0.77)
Fra Cristobals	0.18	0.18 (0.27)

even if mountain lion predation rates are lower in subsequent years

The San Andres population was reduced to about 30 bighorn sheep following the scabies epidemic of 1978–1979. This number persisted for about 15 years. The annual mortality rate from mountain lion predation went from 0.50 in 1996 to 0.77 in 1997, and the population was reduced to 1 animal before it was augmented in 2002.

The Animas herd was extirpated in 2001 when the only 2 radiomarked ewes were killed by mountain lions; the Alamo Hueco herd was extirpated during this same time period, although there were no radiomarked bighorn sheep by which to determine cause. Following a period of very high lion predation in the Bootheel metapopulation, the Big Hatchet herd declined to just 2 known ewes in 2005 and the Peloncillo herd declined to just 2 known ewes in 2003. Both of these herds were almost certain to have been extirpated if they had not been augmented. During the 1990s and early 2000s, statewide desert bighorn sheep populations were decreasing an average of 10% annually when augmentations were not included with about 85% of known-cause mortality attributable to mountain lion predation. Currently, there are no desert bighorn sheep populations in New Mexico that suffer from mountain lion predation that are producing surplus bighorn sheep that may be used for translocations.

No bighorn sheep herds have grown large enough to allow New Mexico to decrease pressure on mountain lions, with the exception of the Fra Cristobal herd. However, this herd is being used as a source herd for transplants therefore we have not decreased the intensity of removal. Even with reducing the number of mountain lions, there is still a statewide average annual mortality rate of 0.06 from mountain lion predation and most of the New Mexico herds are stable or slowly increasing during years when an augmentation does not occur. However, there is a written management strategy documenting how the level of mountain lion removal will decrease as the bighorn populations become larger and the herd is not to be used as a source for translocation. The strategy is:

- When there are ≤75 ewes in the population, all mountain lions entering desert bighorn range may be euthanized,
- When there are 76–99 ewes in the population no mountain lion control will be implemented unless:
  - An offending mountain lion is documented, mountain lion control may be implemented for 2 months, or
  - An average mortality rate of 0.05 or greater from mountain lion predation is observed in any 12 consecutive month period, mountain lion control can be reinstated for 6 months,
- ≥100 ewes in the population
  No mountain lion control will be implemented unless:
  - An offending mountain lion is documented, attempts may be made to kill that mountain lion, or
  - An average annual mortality rate of 0.10 or greater from mountain lion predation is observed in any 12 consecutive month period, mountain lion control can be reinstated for 6 months.

Although it is unknown if this strategy will be effective, it provides an opportunity to reduce the intensity of mountain lion control and to reinitiate it if predation has a negative effect on a bighorn sheep herd. Once bighorn sheep herds become large enough to implement this strategy, adjustments can be made if necessary.

Table 2. Number of mountain lions removed by year and mountain range in New Mexico, 2001–2012.

Year	Peloncillos	Sierra Ladrones	Hatchets	San Andres	Fra Cristobals	Caballos
2001–2002	4	4	1	-	1	-
2002–2003	5	7	4	16	5	-
2003–2004	5	0	0	3	3	-
2004–2005	0	4	1	3	4	-
2005–2006	0	2	6	3	2	-
2006–2007	3	4	1	4	3	-
2007–2008	0	10	1	0	2	-
2008–2009	1	2	0	1	4	1
2009–2010	5	7	1	0	1	0
2010–2011	0	8	1	0	3	1
2011–2012	3	3	0	0	5	2
Mean/100 km^2	0.6	1.3	0.4	0.9[a]	2.9	0.3

[a] The first year of control, 4.8 mountain lions/100 km^2 were removed using the entire area available for control. This declined to 0.95 mountain lions/100 km^2 in the next 2 years.

Currently, an average of 2.5 mountain lions is removed per mountain range per year, although the actual number of mountain lions removed per year ranged from 0 to 16 (Table 2). About 1.1 mountain lions/100 km^2 are removed per year in desert bighorn sheep ranges. This average ranges from 0.3 to 2.9 lions removed per 100 km^2 depending on the mountain range.

The mean number of mountain lions removed per 100 km^2 in the Fra Cristobals (2.9/100 km^2) is higher than most other mountain ranges. However a full-time mountain lion snareman has worked in the Fra Cristobals. In the other ranges, snaremen and houndsmen work about 25% of the time or less. The additional snaring effort has likely contributed to increased removal rates. The first year that mountain lions were removed in the San Andres Mountains, there were 4.8 mountain lions/100 km^2 culled.

The San Andres, Big Hatchets, and Little Hatchet mountains have had low levels of mountain lions removed. Based on helicopter survey data, these mountain ranges have deer abundance of about 8–20 deer/100 km^2, 8 deer/100 km^2, and 14 deer/100 km^2, respectively. In the Fra Cristobal Mountains, where mountain lion removal has been high, the deer abundance is estimated at about 65 deer/100 km^2.

In more than 90 helicopter surveys conducted in desert bighorn sheep habitat since 1996, only 4 surveys have recorded >20 deer/hour (1998 Animas and 1999, 2008, and 2009 Fra Cristobal surveys). More than 100 deer were only seen in 1 survey (2009 Sierra Ladron). Deer abundance in New Mexico desert bighorn sheep ranges have been extremely low since at least 1996.

In New Mexico, all documented predator-killed adult bighorn sheep have been killed by mountain lions, with the exception of 1 golden-eagle kill in the Fra Cristobals. Therefore, the data suggest that mountain lions are the only predator having population effects on adult desert bighorn sheep. However, data from 2 studies exploring causes of bighorn sheep lamb mortality have shown that both coyotes and golden eagles prey on bighorn sheep lambs. In the Fra Cristobals, 14% of radiocollared lambs were killed by golden eagles in 2001 and 0% were killed in 2002. No coyote kills were documented. In the Peloncillo Mountains, a single radiocollared lamb was killed by a gray fox in 2012. As of the end of May 2013, 29% of radiocollared lambs have been killed by coyotes. Although it is difficult to draw statewide conclusions based on a small data set, coyotes and golden eagles appear to have the ability to negatively affect lamb cohorts in some years.

Mountain lions are unlikely to decline, even at very low prey densities, especially with the ability to prey-switch to domestic livestock. Therefore, we hypothesize that higher numbers of alternate prey may reduce effects on desert bighorn sheep. Managers should be aware that large declines in alternate prey such as deer may result in increased risk of predation for desert bighorn sheep. Currently deer abundance in occupied desert bighorn sheep ranges are very low and do not come close to approaching a level where they might provide a buffer.

It is our opinion based on reading of the historical literature of C. Sheldon and W. Hornaday that abundance of desert deer and desert bighorn sheep were very low historically, rather than the "deer behind every bush" scenario described by some. When mountain lion sign was reported to be numerous in the Pinacate Mountains in Mexico, desert bighorn sheep numbers were reported to be low. Based on the evidence that mountain lions limit deer and desert bighorn sheep today, there is no reason to think they did not limit them historically.

Mountain lion:ungulate ratios seem to be positively correlated with the level of mountain lion removal conducted in the mountain range. In the northern San Andres Mountains where no lion control has been conducted, the mountain lion:deer ratio may be as high as 1:4.5. In areas where a low level of mountain lion removal has occurred (Big Hatchet and Little Hatchet mountains), the ratios are about 1:22 and 1:34, respectively. In the Fra Cristobal Mountains where the level of mountain lion removal has been the greatest, the ratio is about 1:352. All of these are substantially higher than the mountain lion:deer and bighorn sheep ratios estimated for the Sierra Diablo WMA in Texas that may be as low as 1:3,200.

John Wehausen.—California includes a large desert region in its southeastern corner and bighorn sheep habitat there encompasses great variation in habitats, ranging from low elevation hot Sonoran Desert at the south end to high elevation cold alpine desert in the White Mountains and Sierra Nevada. These habitats vary greatly in their ability to support sympatric or adjacent deer populations. Mountain lions in California prey on bighorn sheep only in regions that support sufficient abundance of deer in close proximity, except for the occasional mountain lion that wanders briefly into more distant bighorn sheep habitat lacking nearby deer. At the southern end of bighorn sheep habitat east of the Coachella Valley, desert mule deer inhabit ironwood (*Olneya tesota*) washes in Sonoran Desert habitat, but the deer abundance is too low to support resident mountain lions. Deer abundance is high enough to support mountain lion populations in California only where there is higher rainfall.

There are multiple such regions of higher rainfall. One is along the western edge of bighorn sheep distribution from the Mexican border in the Peninsular Ranges to the Sierra Nevada. The steep rain shadow effect along this western border of the desert region generates dry desert habitat suitable for bighorn sheep to the east, but also adjacent and sometimes overlapping wetter habitat to the immediate west that is suitable for deer populations of sufficient size to support resident mountain lions. In some regions along this western margin (e.g., San Gabriel and San Bernardino Mountains), bighorn sheep live in chaparral habitat that is basically unsuitable due to tall climax vegetation resulting from excessive rainfall, and is dependent on regular fires to create openings for bighorn sheep.

The more northern desert mountain ranges of California in the immediate rain shadow of the Sierra Nevada also pick up higher critical winter rainfall for 2 reasons. First, they are higher and cooler ranges that catch the moisture from storms. Second, because most cool season storms track south to California from the far north before angling east, the northern desert receives more rainfall. The entire northern desert region from the Coso, Argus, Panamint, and Funeral Mountains north supports deer and resident mountain lions.

Finally, a series of mountain ranges on the eastern edge of the Mojave Desert also receive higher rainfall and support a finger of great basin habitat that extend from Nevada into California as far as the Granite Mountains just north of Interstate Highway 40. While some of this Great Basin habitat that lies north of Interstate Highway 15 supports native deer and mountain lions, the deer south of that highway are derived from an introduction by the California Department of Fish and Game in 1948. Numerous years later mountain lions expanded into this region south of I-15 and established a sustaining population that was well documented to prey on bighorn sheep in the Granite Mountains (Wehausen 1996).

Deer and mountain lions overlap many bighorn sheep populations in California, but there has been no study of the predator-prey relationships for many of those bighorn sheep populations, and many deer populations are similarly not well studied. What can be stated is that the largest deer populations occur along the western edge of the desert, especially the Sierra Nevada, where migratory behavior greatly increases forage resource availability and annual nutrient intake, and where detailed studies have taken place. I have drawn on those data to answer some of the panel questions below.

Johnson et al. (2013) presented figures for the Mount Baxter and Wheeler Ridge populations in the Sierra Nevada that depicted negative sloped relationships between annual bighorn sheep survival (Y axis) annual lion-caused mortality (X axis), indicating that lion predation was the primary driver of adult survivorship. In those graphs, annual lion-caused mortality reached a high of 25% for the Mt. Baxter herd, but only barely exceeded 10% for the Wheeler Ridge herd. However, between successive radiomarking efforts a year apart (October 2008 to October 2009), 5 of 12 radiocollared ewes in the Mt. Baxter herd were killed by mountain lions, which is a 42% mortality rate.

For bighorn sheep in the Granite Mountains in the Mojave Desert, Wehausen (1996) measured a peak mountain lion-caused mortality rate of 37.5% over a 3-year period during 1988–1990. For the 1992–1998 study period in the Peninsular Ranges of southern California, Hayes et al. (2000) reported average annual mountain lion-caused mortality rates for each of 6 subpopulations that ranged from 9–25% and averaged 14% across all subpopulations. On an annual basis across all populations, that mortality ranged from 9–21%.

Mountain lion predation is not known to have directly extirpated any population in California. However, mountain lion predation seems to account for the current absence of bighorn sheep in Lee Vining Canyon in the Sierra Nevada. Following some post-release mortality and the emigration of 3 ewes, the trend over the first 2 years of the herd reintroduced in 1986 to Lee Vining Canyon in the Sierra Nevada was a continuing population decline. Cause-specific mortality suggested a trajectory leading toward extirpation that would be ultimately driven by mountain lion predation in winter had intervention not taken place beginning in 1988. Three consecutive years of winter mountain lion control beginning in 1988 and a small augmentation (8 ewes and 3 rams) the same year transformed a small declining population into a population growing at 24%/year during drought years. In 1990, the people of California passed an initiative that made mountain lions a specially protected mammal and ended mountain lion control in Lee Vining Canyon. What followed was a behavioral change in that bighorn sheep population. Use of Lee Vining Canyon in winter largely ceased, with bighorn sheep descending from higher elevations instead during spring. This new behavioral pattern worked until the heavy winter of 1994–1995 resulted in the loss of more than half of the population. In spring 1998, a mountain lion was documented killing bighorn sheep in Lee Vining Canyon, after which the small number of surviving females abandoned that winter range entirely and moved north, eventually developing new habitat use patterns centered in Lundy Canyon. There has not been a female documented to use the Lee Vining Canyon winter range since 1998. If a population is defined geographically, the Lee Vining Canyon herd can be classified as having been extirpated, and mountain lions seem to have caused that extirpation, even though a small population of that lineage persists in Lundy Canyon.

Surplus is a term that has been defined in multiple ways over time. I will interpret it to simply refer to situations in which there is confidence that the population in question can replace animals removed and that the post-removal population is large enough to provide a buffer against future uncertainties.

In the Sierra Nevada, mountain lion predation is largely an issue on winter ranges along the eastern base of the mountains where bighorn sheep overlap wintering deer (Wehausen 1996). There are 3 such populations with mountain lion predation that have been tapped for translocation stock: Mount Langley, Sawmill Canyon, and Wheeler Ridge; and a fourth, Mt. Baxter, is expected to be used for this purpose in the near future. This is possible for multiple reasons. First, at Wheeler Ridge, mountain lion predation appears to have been focused more on rams, while ewes are the primary focus for translocations. Second, there is variation among populations in abundance of nearby wintering deer and, thus, also the amount of mountain lion activity. In particular, the Mount Langley herd has notably lower deer abundance, less mountain lion activity, and lower predation on bighorn sheep (Davis et al. 2012). Third, bighorn sheep in the Sierra Nevada can avoid predation by staying high in the mountains in winter and have shown considerable variation among years and individual sheep in their use of low elevation winter ranges. Of note is the Sawmill Canyon population that has shown considerable winter range avoidance in many years, yet has grown to a size suitable for removals. Fourth, mountain lion predation on these sheep has been controlled to varying degrees through selective removal of mountain lions that kill bighorn sheep (Davis et al. 2012).

The recovery plans for bighorn sheep listed federally as endangered in the Peninsular Ranges (U. S. Fish and Wildlife Service 2000) and the Sierra Nevada (U. S. Fish and Wildlife Service 2007) both include such action in recovery goals. Those goals call for reaching both a specified geographic distribution and numbers of sheep by region that together allow downlisting to threatened. Once that is achieved, each plan calls for cessation of all management actions while continuing close monitoring of populations for 2 generations (12 years) in the Peninsular Ranges and 1 generation (7 years) in the Sierra Nevada, after which delisting might be considered depending on the outcome.

In the Peninsular Ranges there have been no mountain lions removed to protect bighorn sheep, but most herds grew regardless. In the Sierra Nevada, on average 1.8 mountain lions were removed per year during 1999–2011 when Wildlife Services was contracted to monitor and manage this predation (Davis et al. 2012). As a percent of mountain lions present each year, these removals have varied from 0% to 75%. In the southern recovery unit over a 12-year period, 12 of 60 lions (20%) known to be present on an annual basis were removed. In the central recovery unit over those same 12 years, 9 of 72 lions (12.5%) known to be present on an annual basis were removed. Combined these come to about 16% removed. For the average of 1.75 mountain lions removed per year in those 2 recovery units, there were 11 that were not removed. However, it should be noted that this rate of culling was not sufficient to protect all bighorn sheep populations from significant demographic effects of mountain lion predation in all years (Davis et al. 2012).

Data were available only for deer winter ranges in the eastern Sierra Nevada that overlap bighorn sheep winter ranges. For the bighorn sheep central recovery unit, the Round Valley deer herd uses about 250 km^2 and has ranged in size from 939 to 5,978 deer. This translates to about 375–2,400 deer/100 km^2. For the Goodale deer herd that overlaps the bighorn sheep southern recovery unit the range was about 94–244 deer/km^2.

Mountain lions are the only predator shown to have population level effects on bighorn sheep, but bobcats have been documented to kill bighorn sheep in a variety of habitats. In California, mountain lions have been documented to have significant demographic effects on bighorn sheep in situations ranging from very low deer densities to high deer densities.

Predator-prey dynamics seem to be far more complex than common, simplistic alternatives. There seems to be a false perceived dichotomy between predators that prey switch or prey that serves as a buffer to others, and an assumption of a tipping point that would put the system in one realm or the other. I approach this problem from a different perspective based on a few premises presented here. First, bighorn sheep populations are small in general, which is why a small number of lions preying on them can have a large demographic effect, and why bighorn sheep alone cannot support resident mountain lions for very long. Second, mountain lion numbers reflect prey availability (e.g., deer abundance). Third, mountain lions are opportunists that do no pass up meals. As such, they readily expand the prey base that they exploit when opportunity presents itself. For mountain lions feeding largely on deer, bighorn sheep would be such a prey base expansion. I do not accept the concept of prey switching as a generalized behavior, which implies feeding on 1 or the other prey species. This might be a reasonable model where the 2 prey sources are geographically isolated by distance, but where deer and bighorn sheep overlap or are contiguous in distribution, data appear to show that mountain lions feed on varying mixtures of deer and bighorn sheep once they discover bighorn sheep as a potential prey base. What leads to mountain lions discovering bighorn sheep as a prey source? I approach this from a probability standpoint. My fourth premise is that the probability that 1 or more lions will discover bighorn sheep and add them to their prey base is a function of both the size of the local mountain lion population and the size of the bighorn sheep population. The more mountain lions there are, the higher the probability that they will discover bighorn sheep; and the more sheep there are the higher the probability that a mountain lion will encounter and kill it, thereby discovering this different prey species. Where female mountain lions discover and prey on bighorn sheep, their offspring will learn to do so also, and this will become a cultural trait. Finally, there will be situations like the southern recovery unit of Sierra Nevada bighorn sheep, where the geographic nature of the limited distribution of wintering deer and bighorn sheep, coupled with the natural attraction to mountain lions of physical features in bighorn sheep habitat, will cause essentially every mountain lion to discover bighorn sheep except when the bighorn sheep population is low.

I would not expect a large deer population to buffer bighorn sheep. More deer means more mountain lions and more mountain lions will mean higher probabilities of some mountain lions discovering bighorn sheep and adding them to their prey base. Again, it does not take many mountain lions preying on bighorn sheep to have a demographic effect.

It appears that bighorn sheep populations alone are not large enough to support lion populations except on a short term basis; thus, changes in relationships among predator and prey must look at the history of abundance of deer and other primary prey of mountain lions, including livestock. Have there been major ecosystem changes that have favored deer and mountain lions that have led to the mountain lion influences on bighorn sheep documented in recent decades? Berger and Wehausen (1991) addressed this question relative to the Great Basin using 3 sources of information: journals of early explorers who were living off the land; data from archeological site excavations; and documented use of deer products (e.g., clothes) by Native Americans at the time of contact. All 3 sources of information indicated that deer were rare to absent across most of the Great Basin at the time of contact; bighorn sheep and pronghorn were the ungulates clearly present and used, but early explorers sometimes had a hard time finding game. At the western edge of the Great Basin east of the southern Sierra Nevada, an unpublished compilation of data from Native American midden site studies found that deer were well represented about 10,000 years ago in the earliest midden sites; but after that time bighorn sheep were the most abundant identifiable ungulate, with pronghorn a close second, and deer a distant third. These apparent ecosystem differences would have greatly influenced mountain lion densities; the absence of deer would likely have translated to a very low density of mountain lions.

The larger question is what has driven these ecosystem changes. For the Great Basin the traditional explanation has been that overgrazing by cattle converted grassland habitat to brush that favored deer (Gruell 1986). An alternative explanation concerns effects of hunting by Native Americans. Native Americans are now recognized to have been much more effective hunters than once thought and capable of significantly depleting preferred game species (see chapters in Kay and Simmons 2002). The potential major ecosystem influences of Native Americans should not be ignored relative to this question. The removal of the Native American as a major predator in these ecosystems is an obvious major change that has been ignored relative to this question.

Finally, in understanding how we got to our current situation relative to bighorn sheep and mountain lions, we need to be cognizant of history in the twentieth century. In California, mountain lion bounties ended in 1963, and in addition to the bounty system, the state employed mountain lion trappers for many years. Then, in 1972 there was a legislative moratorium on mountain lion sport hunting that also mandated careful record keeping relative to issuance of depredation permits and mountain lions killed under those permits. The resulting data show a strong and steady rise in depredation permits and mountain lions killed through the 1980s, a peaking in the final decade of that century, and then some decline. It appears that the state mountain lion population was depressed by human persecution during the first half of the twentieth century and then released in the second half of that century when there was an abundance of deer, with a likely result that the mountain lion population overshot its carrying capacity in the 1990s. Some years ago Steve Torres presented a (still unpublished) paper at a Desert Bighorn Council meeting regarding a compilation of data on numbers of mountain lions killed in western states under bounties in the first half of the twentieth century and numbers killed today by sport hunting and depredation permits. His unexpected discovery was that more mountain lions were being killed annually in recent years than under the bounty system. This may reflect higher mountain lion populations in recent decades, and that may be due to the early success in depressing mountain lion populations in the first half of the twentieth century.

I calculated mountain lion:ungulate ratios only for the Round Valley deer herd that overlaps the bighorn sheep central recovery unit in the Sierra Nevada; it was limited to the years 2000–2011 when deer numbers were based on mark-resight estimates and mountain lion numbers were carefully monitored in this zone. Mountain lion data were taken from Davis et al. (2012) corrected for mountain lions not recorded in some years but found still alive in subsequent years. Mountain lion numbers varied from 4 to 9 and deer from 1,703 to 3,100. On average there were 365 deer per lion with a range of 207–555. The adjacent Wheeler Ridge bighorn sheep population was not included as potential prey because of its small size relative to deer. The addition of these bighorn sheep as available prey would increase this ratio by <5%.

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Human dimensions of reintroduced bighorn sheep and an associated increased mountain lion harvest along an urban interface

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Abstract Wildlife agencies have reintroduced bighorn sheep (*Ovis canadensis)* to many of their formerly occupied areas in the latter half of the twentieth century, however many former occupied areas are now on the urban interface due to urban expansion. Preliminary findings in the biological literature suggest bighorn sheep can thrive adjacent to human activity; however, within the sociological literature, little information exists regarding public opinion of reintroductions and translocations. To fill this gap in the literature, survey research was conducted regarding a bighorn sheep reintroduction and an associated increase in mountain lion (*Puma concolor*) harvests along an urban interface. Consistent with other research, we found the majority of residents viewed bighorn sheep, and the reintroductions thereof, positively. Among older respondents and respondents living closer to the urban fringe, attitudes regarding bighorn sheep were more polarized. Despite a significant public relations effort, residents remained largely uninformed of management actions pertaining to bighorn sheep or the associated harvest of mountain lion near the release sites. Only 14% of respondents had knowledge of the increased mountain lion permits issued, and <1% knew about how many mountain lions were harvested. Although some individuals disagreed with mountain lion control, the significant indifference and unawareness by respondents indicates that, from a social perspective, preemptive predator control may remain a viable management option for wildlife agencies. We conclude that sociological aspects are not likely to impede future reintroductions adjacent to neighborhoods with similar demographics, however comparative studies with different demographics are warranted.

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Key words attitudes, bighorn sheep, human dimensions, mountain lion, *Ovis canadensis*, public, *Puma concolor*, wildlife

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) thrived in Utah's north-central mountain ranges until the 1930s when populations began to decline until only scattered sightings were reported during the 1960s (Smith et al. 1988). Reasons for the decline may include competition with livestock, disease from domestic sheep, unregulated hunting, and habitat degradation (Smith et al. 1988, Karpowitz and Stewart 2000). To combat population declines, wildlife agencies regularly use reintroduction and translocation efforts to re-establish populations (Risenhoover et al. 1988, Roy and Irby 1994). The success of these translocations varies depending on factors such as predation, disease, lamb survival, interspecific competition, and available water (Smith and Flinders 1991).

In 2000, the Utah Division of Wildlife Resources (UDWR) increased mountain lion harvest opportunities in anticipation of future bighorn sheep reintroductions. Later that year, UDWR reintroduced 25 bighorn sheep to Mount Timpanogos near Alpine, Utah. In 2001, the UDWR bolstered the Mount Timpanogos herd with 10 additional bighorn sheep and translocated 22 bighorn sheep to Rock Canyon, near Provo, Utah. In February 2002, 9 additional bighorn sheep were released on Mount Timpanogos. Because of the proximity to the urban interface and the potentially contentious increase in mountain lion harvest, UDWR held several public meetings to discuss their plan to reintroduce Rocky Mountain bighorn sheep to Utah. These reintroduction sites were closer to human activities and development than recommended in an earlier comprehensive habitat evaluation procedure used by UDWR (Smith et al. 1991). Because of the close proximity of bighorn sheep and humans, human-wildlife conflict was anticipated.

Biological literature suggests bighorn sheep can thrive adjacent to urban areas, however not without some adverse effects to the population. For example, bighorn sheep using habitat next to Californian metropolitan areas had increased parasite loads and alterations of behavior (Rubin et al. 2002). Furthermore, Dunn (1999) documented that human disturbance contributed to a decline in a population of desert bighorn sheep (*O. c. nelsoni*). In Canyonlands National Park, Utah, some bighorn sheep habituated to light human activity (Papouchis et al. 2001); yet, intense human activity such as interstate highway construction caused strongly negative behavioral reactions in bighorn sheep on River Mountain, Nevada (Leslie and Douglas 1980). Human disturbance on the Sierra Nevada Mountains did not adversely affect populations of bighorn sheep; although the bighorn sheep were somewhat spatially separated from humans (Hicks and Elder 1979). Nonetheless, the effects of human activity on bighorn sheep may not be immediately apparent as in some instances bighorn sheep selected lower quality habitat to avoid humans (Martinez et al. 2003). Additionally, physiological responses in bighorn sheep last longer than overt behavioral responses; therefore, human disturbance may be more injurious than observation may indicate (MacArthur et al. 1982).

Despite a relatively robust literature set regarding how bighorn sheep react to human disturbance, studies investigating the effects of bighorn sheep on humans are sparse. A notable exception is a study of human-bighorn sheep conflict in the Pusch Ridge Wilderness, Arizona (Harris et al. 1995) wherein the authors quantified opinions of people recreating in federally designated Wilderness areas that contained resident bighorn sheep. Limited human dimensions studies exist wherein bighorn sheep become a part of the urban landscape. While there are several attitudinal studies examining residents' beliefs toward predator control, they do not focus on the acceptability of increasing sport hunting of mountain lions for the purpose of increasing populations of huntable prey species, nor is spatially-explicit attitudinal information available.

Some studies suggest that reducing mountain lion populations prior to and during reintroductions of bighorn sheep benefits both species in the long-term (Hayes et al. 2000, Ernest et al. 2002, Kamler et al. 2002). By temporarily reducing the mountain lion population, bighorn sheep can establish a sustainable herd that will eventually contribute to the mountain lions' food base (Rominger et al. 2004). In accordance with this reasoning, the UDWR doubled mountain lion hunting opportunities by issuing 12 hunt permits each in management units 17a1 and 17a2 from 1999 to 2007 (Utah Division of Wildlife Resources 1999). As a result, hunters harvested about 118 mountain lions in management areas 17a1 and 17a2 from 1999 through 2006 (Hill and Bunnell 2006). Initially, the number of mountain lions killed increased proportionally to the number of permits issued. However, after 3 years the number of mountain lions harvested returned to pre-1999 levels, though the number of permits issued remained constant (Figure 1).

Although temporarily reducing predators to allow prey species to establish may be preferred biologically, the concept may be controversial from a sociological perspective. People who that value game animals for the products and the recreational opportunities they provide are likely to favor this management action. However, residents that appreciate wildlife for their intrinsic or ecological value may not favor a prey species over a predator species (*en sensu* Manfredo 2008). These value-laden

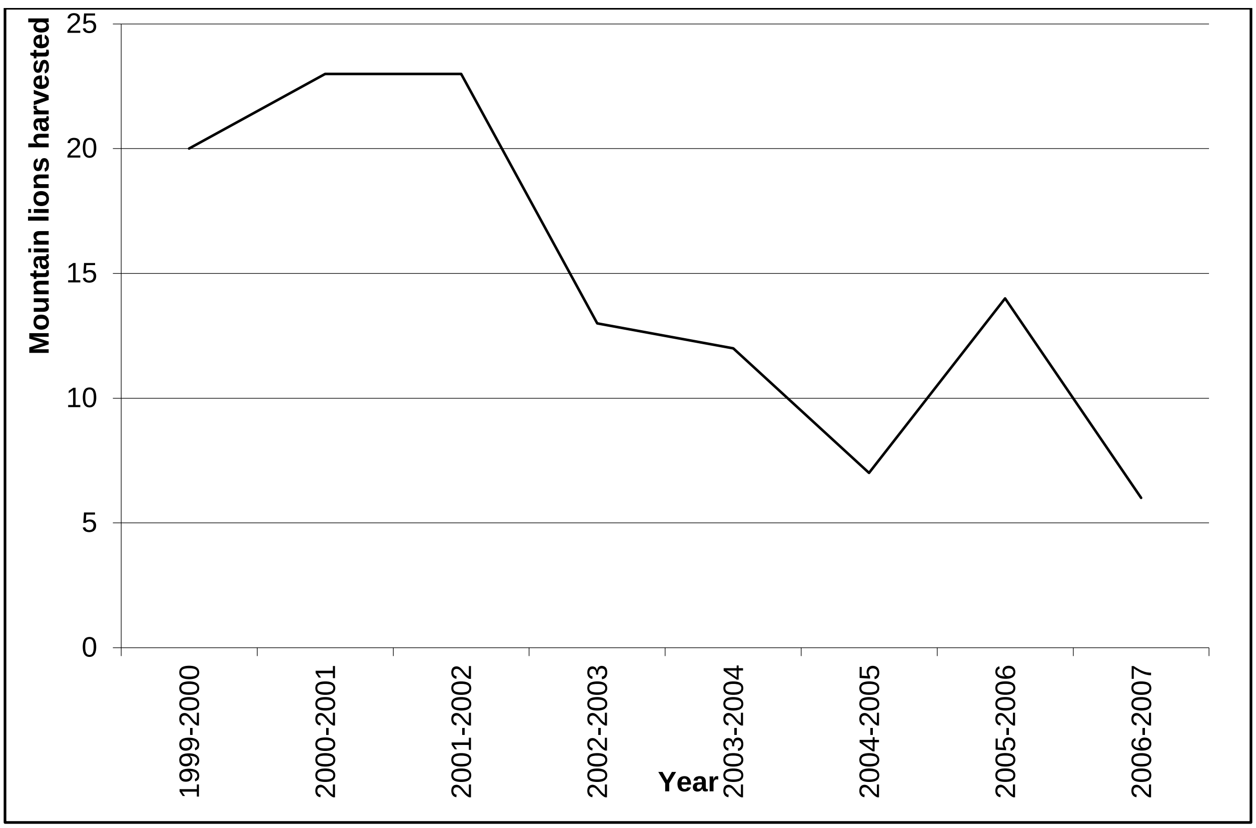


Figure 1. The quantity of mountain lions harvested in management units 17a1 and 17a2 in north-central Utah shows an initial increase and a subsequent decrease in harvest numbers after several years.

conflicts of opinion about wildlife are controversial in this and other scenarios (Madden 2004). Therefore, the statewide bighorn sheep management plan (UDWR 1999), including the mountain lion harvest component, was extensively discussed at the Regional Advisory Committee meetings prior to implementation of the increase in mountain lion harvests. While the practice of predator control to benefit a prey species is widely accepted within the realm of wildlife management, little is known regarding the public's perception of extensively harvesting mountain lions to reduce bighorn sheep predation. Interestingly, only 7% of people residing next to Saguaro National Park, Arizona, found it acceptable to kill a mountain lion to protect their prey species (Casey et al. 2005). However, if a prey species is threatened or endangered, it was more acceptable to harvest the responsible predator (Reiter et al. 1999). Scott and Parsons (2005) noticed that many respondents believed humans should not attempt to influence nature, contradicting the findings of Reiter et al. (1999). These contradictory results highlight the reality that human-wildlife conflicts are not only about conflicts between humans and wildlife "but also *between* humans *about* wildlife" (Madden 2004). As a result of these decisions being more visible, stakeholders are beginning to demand a seat at the decision-making table (Chase et al. 2002), and wildlife stewards are becoming more accepting of public input regarding managerial decisions (Chase et al. 2004, Mortenson and Krannich 2001). Since this co-managerial trend is likely to continue (Manfredo et al. 2003), it behooves natural resource agencies to account for sociological effects of managerial actions.

STUDY PURPOSE

Understanding public opinion is important as foothills are often desirable locations for residences, and homes increasingly occupy ideal bighorn sheep winter range. As reintroductions continue, they are likely to take place adjacent to urban, suburban, or exurban locations. For wildlife professionals to continue to use areas adjacent to urban development as potential reintroduction sites, biological research must continue to ensure bighorn sheep can tolerate anthropogenic disturbance. Additionally, human dimension research must document that humans tolerate bighorn sheep interactions and associated active management of mountain lion populations.

To achieve this goal, my purpose of was to investigate residents' attitudes toward bighorn sheep and the harvest of mountain lions. Specific objectives were to explore: 1) how proximity to the wildland interface affected residents' attitude toward bighorn sheep; 2) how demographics associate with attitudes toward wildlife management actions; 3) how human behaviors are related to acceptability of wildlife management actions; and 4) how acceptable it is to reduce predator populations for the benefit of the prey species. The first objective was based upon the presumption that nearby residents have more interactions with bighorn sheep and those interactions affect the respondent's attitudes toward bighorn sheep. The second objective was based on prior research that found sociodemographic characteristics of respondents influence opinions regarding wildlife (Scott and Parsons 2005). These differences in opinion may apply to ungulates other than bighorn sheep (Decker and Gavin 1987) and to bighorn sheep specifically (Harris et al. 1995). Therefore, we expected to observe differences regarding attitudes towards bighorn sheep, hunting bighorn sheep, and sport hunting generally along sociodemographic categories. The third objective was prompted by prior literature indicating correlations between attitudes and behaviors (Fishbein and Ajzen 1980, Homer and Kahle 1988). Because hunters have a vested interest in augmenting prey species (Stedman et al. 2004), we expected that residents who were hunters would favor bighorn sheep hunts, in addition, hunters would likely be better informed regarding the reintroduction effort and would observe more bighorn sheep. Further, because political affiliation has been associated with beliefs regarding hunting in other studies (Enck et al. 2000, Peterson 2004); we expected similar trends in our survey regarding approval of bighorn sheep hunts and sport hunting in general. As preemptively reducing the predator population is a prevalent technique used by wildlife agencies, it is important to determine whether stakeholders are supportive of this technique.

STUDY AREA

In 2005, the population along the Wasatch Front in Utah County was 356,545 people (United States Census Bureau 2005). Our study areas focused on neighborhoods in the cities of Provo and Alpine, located within 1.25 km of the Uinta National Forest boundary where bighorn sheep presently reside. Management unit 17a1 lies east of Alpine, and has a total area of 168 km^2. Management unit 17a2 lies east of Provo and has a total area of 352 km^2 (Figure 2). Although the 2 cities are separated by 18 km, urban development extends continuously north and south along the Uinta National Forest to the east (United States Geological Survey 2004). Both cities extend east into the foothills at an elevation of about 1,200 m (United States Geological Survey 2004). The associated Wilderness (National Wilderness Preservation System) contains Mount Timpanogos and is bordered by American Fork Canyon to the north and Provo Canyon to the south (Gazetteer of Utah Localities 1952). Alpine has 7,896 residents and Provo has 113,459 residents (United States Census Bureau 2005), though housing density was similar in each study area.

METHODS

Arcmap 9.1 (ESRI 2004) was used to subdivide Alpine and Provo neighborhoods into north and south sections in relationship to home ranges determined for bighorn sheep to establish a stratified-block sampling design (Ramsey and Schafer 2002). Each section was further divided into 3 strata according to the distance from the wildland-urban boundary (0–0.33 km, 0.34–0.66 km, and 0.67–1.25 km), yielding 6 sample blocks for each study area. If block stratification split a street, it was assigned to the sample block that contained the larger proportion of the street. Researchers randomly chose 5 streets within each sample block and distributed the survey to 5 households. At each home, data collection technicians briefly explained the survey's purpose and asked them to leave the completed questionnaire on the doorstep for collection. If necessary, technicians showed photos of bighorn sheep and mountain lions to participants to clarify the species involved in the survey and then recorded geospatial coordinates of the home on the completed questionnaire. For persons who expressed a desire to participate but could not at the time, technicians left instructions, a survey, and a self-addressed stamped envelope. Data collection occurred from 27 October 2005 through 19 November 2005.

Several resources were consulted to reduce bias in the survey instrument (Marsh

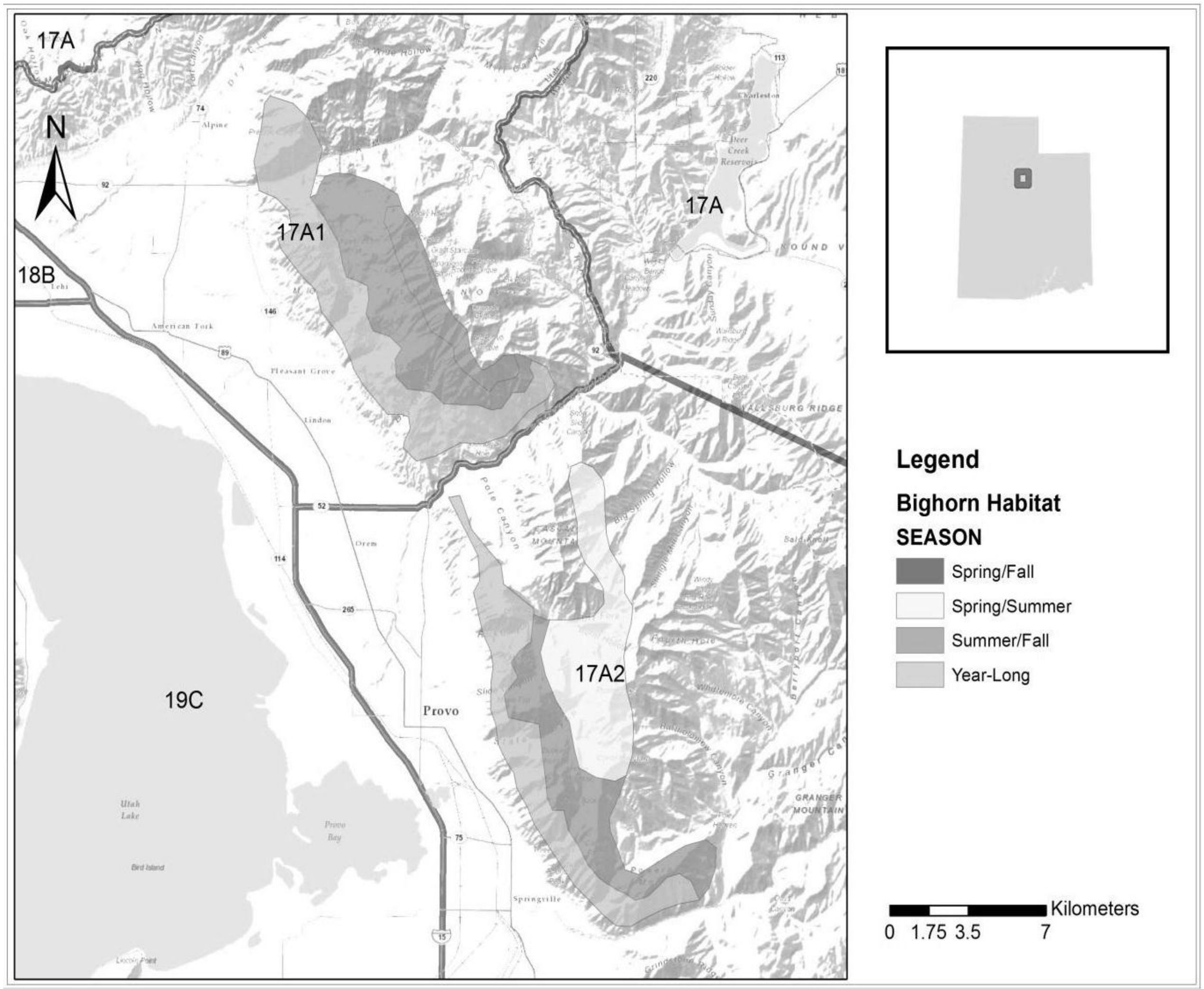
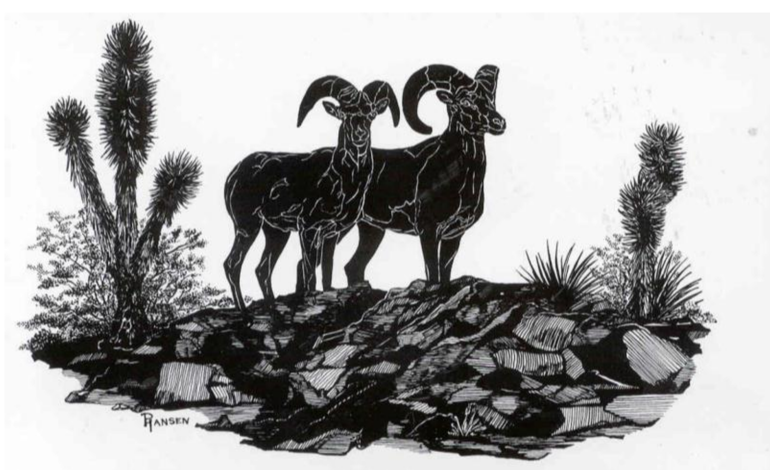


Figure 2. Location of Provo and Alpine in relation to hunting units 17a1 and 17a2. Provo and the city of Alpine are separated by 18 km. Both hunting units lie directly east of Provo and Alpine, respectively.



1982, Converse and Presser 1986, Fowler 1995). A panel of 8 individuals reviewed the survey for clarity, brevity, and bias (Casey et al. 2005). The survey was comprised of 26 questions relating to human-bighorn sheep interactions, mountain lion-human interactions, knowledge of management actions, wildlife attitudes, and demographics of the respondent. There was no method for estimating non-response bias, however the extremely high response rate (89.6%) precluded any need. Linear regression was used to illustrate the association of continuous variables, Chi-square was used for categorical data, and ANOVA was used to describe relationships between categorical and continuous data. Unless otherwise stated, α was set at 0.05 for statistical significance (SAS 2003). Measures of practical significance include eta (η) for continuous data and Cramer's V (φ_c; the generalized form for Phi) for categorical data. Strengths of association are congruent with those established in Vaske (2008).

RESULTS

We received 172 completed questionnaires from Provo residents and 165 from Alpine residents (n = 337). The average age of respondent was 53.5 ± 12.1 years old, had lived in the area 10.1 ± 10.5 years, and had 4.2 ± 2.0 members in their family. This sample has more males (57%) than females and 72.6% identified themselves as politically conservative. Seventeen percent self-identified as hunters, 95% of which were male. This sample was more educated than the average population with 67% having obtained a baccalaureate degree, and 32% had advanced degrees. Alpine and Provo respondents did not vary significantly by gender (χ^2_1 = 0.20, P = 0.21), hunter status (χ^2_1 = 0.35, P = 0.35), or political orientation (χ^2_9 = 7.28, P = 0.61).

Bighorn sheep.—A majority of the population (65%) held a positive opinion regarding bighorn sheep, 32% were neutral, and 3% of respondents indicated a negative opinion. Men ($F_{1, 298}$ = 6.08, P = 0.01, η = 0.14) and more-educated respondents (r = 0.17 P = 0.003) held more positive opinions of bighorn sheep as compared to their counterparts. Men were more approving of active manipulation of bighorn sheep populations ($F_{1, 323}$ = 26.08, P < 0.001, η = 0.27), saw more bighorn sheep ($F_{1, 323}$ = 11.02, P = 0.001, η = 0.18), were more approving of a bighorn sheep hunt ($F_{1, 317}$ = 17.22, P < 0.001, η = 0.23), and were more accepting of sport hunting ($F_{1, 322}$ = 12.34, P = 0.001, η = 0.19). Hunters knew more about aspects of the reintroductions (χ^2_1 = 3.92, P = 0.048, φ_c = 0.11), were more positive toward them ($F_{1, 302}$ = 6.97, P < 0.001, η = 0.15), saw more bighorn sheep ($F_{1, 329}$ = 13.31, P < 0.001, η = 0.20), and were more approving of a bighorn sheep hunt ($F_{1, 323}$ = 27.81, P < 0.001, η = 0.28) and hunting in general ($F_{1, 328}$ = 42.98, P < 0.001, η = 0.34). Politically conservative respondents were more approving of sport hunting ($F_{2, 208}$ = 5.26, P = 0.006, η = 0.22) as well as hunting bighorn sheep ($F_{2, 211}$ = 8.44, P < 0.001, η = 0.27). Older respondents tended to be more positive toward bighorn sheep (r = 0.12, P < 0.04) and more amenable to their population increasing (r = 0.18, P = 0.002).

As expected, closer residents had bighorn sheep on their property more frequently (r = 0.21, P = 0.02). Few residents (7%) experienced property damage, most in the form of damaged landscaping. Five percent viewed other aspects of bighorn sheep activity (e.g., fecal droppings or automobile hazards) as an annoyance. Yet, despite these damages and annoyances, respondents' opinion of bighorn sheep generally were similar or more positive since the time of the reintroductions ($\bar{x}$ = 3.37; *SE* = 0.73). Respondents living closer to the urban-wildland interface generally held less positive opinions of bighorn sheep ($r = 0.18$, $P = 0.002$). Paradoxically, residents living closer to the urban- wildland interface saw fewer bighorn sheep ($r = -0.27$, $P < 0.001$). More Provo residents (7.2%) reported bighorn sheep on their property than did Alpine residents (0.7%; [$\chi^2_1 = 8.74$, $P = 0.003$, $\varphi_c = 0.17$]). Not surprisingly, people more active in outdoor recreation saw more bighorn sheep ($r = 0.21$, $P < 0.001$) and had a more favorable opinion of them ($r = 0.20$, $P = 0.001$).

Mountain lion.—Nearly half of residents (48%) were neutral to the concept of hunting mountain lions to create higher ungulate populations, while 17% approved and 35% disapproved. On the 5-point Likert scale, the mean response was below the midpoint of the scale ($\bar{x}$ = 2.72; *SE* = 0.73), but the variance in the data suggests there was not strong consensus in this regard. In general, men were more accepting of mountain lion control than women were ($\chi^2_4 = 16.02$, $p = 0.003$, $\varphi_c = 0.23$) and had seen more mountain lions ($F_{1, 323} = 16.80$, $P = 0.001$, $\eta = 0.18$). Hunters saw more mountain lion ($F_{1, 324} = 17.43$, $P < 0.001$, $\eta = 0.23$), approved of mountain lion control ($F_{1, 314} = 5.27$, $P = 0.02$, $\eta = 0.13$), and indicated they had a better understanding of the utility of using hunting as a management tool ($F_{1, 329} = 61.83$, $P < 0.001$, $\eta = 0.40$) than their non-hunting counterparts. Respondents who participated in more outdoor recreation had observed more mountain lions ($r = 0.22$, $P < 0.001$).

As expected, respondents who desired more mountain lions in the area disagreed with hunting them to bolster bighorn sheep populations ($r = -0.30$, $P = 0.001$). Although 13% of total respondents wanted fewer mountain lions in the vicinity, yet 56% of those who indicates such would not support lethal removal as a method to achieve that end. Despite some strongly positive and negative attitudes regarding predator control, the majority of respondents were unaware of the increased mountain lion permits issued prior to the bighorn sheep reintroductions. Fewer than 15% of respondents indicated they were aware of the increase in mountain lion harvest, 3% claimed to know how many were harvested, but less than 1% could provide a quantity within 1 order of magnitude of the true number killed. There were correlative relationships between main constructs pertaining to bighorn sheep translocations and preemptive mountain lion control (Figure 3).

DISCUSSION

Utah is the only state that totally extirpated native bighorn sheep in the United States (Smith et al. 1988). The reintroductions east of Provo and Alpine are a continuation of an extensive plan to re-establish bighorn sheep to their former historical range in Utah. This research suggests that from a sociological perspective, these areas may continue to be used as bighorn sheep habitat, despite failed historical reintroduction attempts near human activity centers (UDWR 1999, Smith et al. 1991).

Although predominantly positive, Provo and Alpine respondents had a wide range of attitudes regarding bighorn sheep. A few respondents felt imposed upon by the reintroductions because bighorn sheep were not present when they built their homes. These individuals expressed resentment for having been subjected to effects associated with bighorn sheep (e.g., damage to landscaping, fecal material on property, automobile hazards). The majority of residents, however, recognized that bighorn sheep formerly occupied these areas and

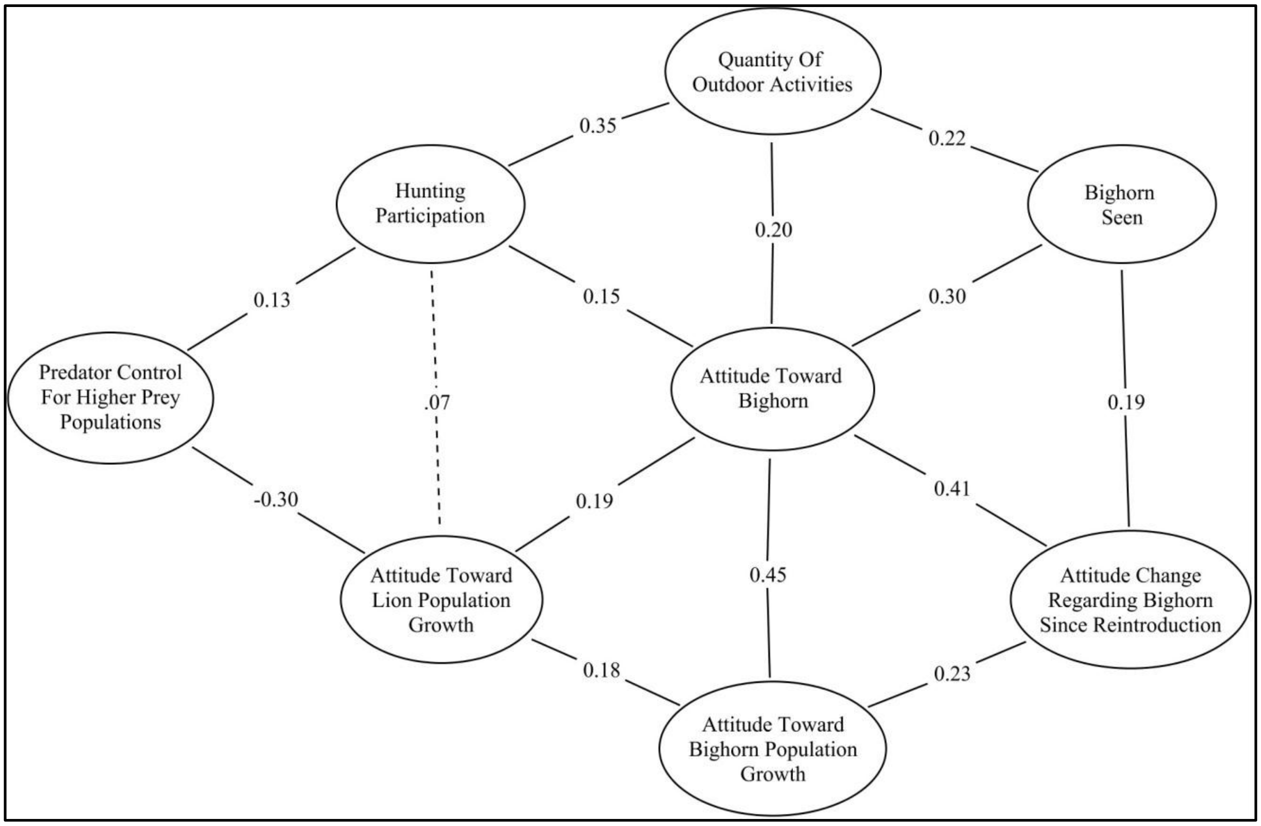


Figure 3. Path analysis of how constructs associated with bighorn sheep and mountain lion management relate to one another.

were willing to tolerate minor nuisances associated with them. Most human-bighorn sheep interactions generated positive experiences including feelings of intimacy with nature, satisfaction from teaching opportunities with children, and sharing the novelty of wildlife with family.

The diversity of attitudes regarding bighorn sheep may be derived from the variety of contexts under which humans interact with bighorn sheep. One interesting context is how the respondent perceives their connection to nature. Respondents who view themselves as separate from nature likely view bighorn sheep in their yard as intrusive. Several comments on the qualitative portion of the survey and directly to data collection technicians reflected those sentiments, taking the form of: "… if you leave them alone, they will leave you alone" or "I should not have to clean up after them." Conversely, respondents who view coupled human-ecological systems may react to the bighorn sheep more positively. Comments from respondents who may hold this perspective are embodied by phrases such as "they were here before I was" or "it's part of living this close to nature." The perceived relationship between built and natural systems (i.e., Coupled versus Segregated Human-Nature systems) as it relates to human-wildlife conflict is an area of inquiry in need of further research.

Conservation agencies need to find ways to continue improving communication with their stakeholders. The UDWR advertised these bighorn sheep reintroductions through print, television, and electronic media. The releases of bighorn sheep were attended by stakeholder groups, local celebrities, and nearby residents as well as representatives from the print and broadcast media. Yet despite large public outreach campaigns, people living near areas of bighorn sheep reintroductions were largely uninformed, or misinformed, regarding these management actions. Several residents were surprised there were bighorn sheep and mountain lion populations within 2 kms of their home. The surprisingly high level of respondent unfamiliarity to the increase in mountain lion harvests is further illustration of the unawareness toward wildlife conservation efforts.

Regardless of the opposition to predator control by some respondents, mountain lions limit population growth of bighorn sheep (Hayes et al. 2000, Holl et al. 2004), particularly with smaller bighorn sheep herds (Ernest et al. 2002), or when other prey is sparse (Kamler et al. 2002). Even if the quantity of bighorn sheep killed by mountain lions is acceptable, the adjustment of habitat use due to the threat of predation may affect the health of the herd (Wehausen 1996). Despite mounting evidence regarding the long-term benefits of predator control as part of reintroduction efforts to both mountain lions and bighorn sheep, some people remain opposed to this management technique. Researchers anecdotally noticed that this opposition stems from a fundamental lack of understanding of the resiliency of mountain lion populations and the general belief that because mountain lions are secretive that they are an imperiled species. However, in light of recent societal trends (Teel et al. 2010), the proportion of people who oppose predator control is likely to increase as the North American society continues to separate from nature (Manfredo et al. 1998).

Because urban development continues to use foothills, and therefore bighorn sheep winter range, our results will be instructive to other agencies that intend to translocate bighorn sheep. When reintroducing bighorn sheep, mitigation techniques may be useful in reducing human-wildlife conflict. Specific to this location, the main reason for bighorn sheep being present in neighborhoods was to access water and lush vegetation, so construction of water catchment devices at higher elevations and taking advantage of prescribed burns may reduce landowner conflict. If these options are not available or in locations where bighorn sheep frequently enter neighborhoods, hazing techniques (e.g., propane cannons, rubber bullets, repellants) may be helpful in reducing human-wildlife conflict, however these techniques are likely to spark their own controversies among some residents.

At the time of this study, people in adjacent neighborhoods remain generally positive toward bighorn sheep. Our study found minimal evidence that human-wildlife conflict or opposition to predator control would impede future translocations that include heavier harvest of predators. Therefore, if biological factors merit its use, agencies should continue to use mountain lion control as a management option to assist in the establishment of translocated bighorn sheep in habitats where mountain lions are common. Agencies may anticipate some opposition to predator control, however sociological and political ramifications may be addressed through appropriate outreach venues. Via stakeholder outreach, the public may learn that temporary reduction of mountain lions allows both predator and prey populations to grow in proportion to each other. Within the stakeholder outreach effort, if a portion is focused on the plasticity and resilience of mountain lion populations, it will likely produce more public support for this approach.

In this case study within Utah, both sociological and biological factors indicate that coexistence of humans and bighorn sheep in such proximity is likely to continue. Constituents in these study areas are generally politically conservative, hunter-friendly, trusting of state wildlife agencies, and tend to approach wildlife in a utilitarian way (Teel et al. 2005). However, housing developments in the foothills or peripheries of development tend to attract wealthier, more educated people who hold more postmodern values (Inglehart, 1997), and therefore will tend to approach wildlife in a more mutualistic way (Manfredo, 2008). As a result, these neighborhoods adjacent to potential bighorn sheep habitats may not be as approving of predator control. However, our findings may be cautiously applied to future bighorn sheep reintroduction sites with analogous sociodemographics.

ACKNOWLEDGEMENTS

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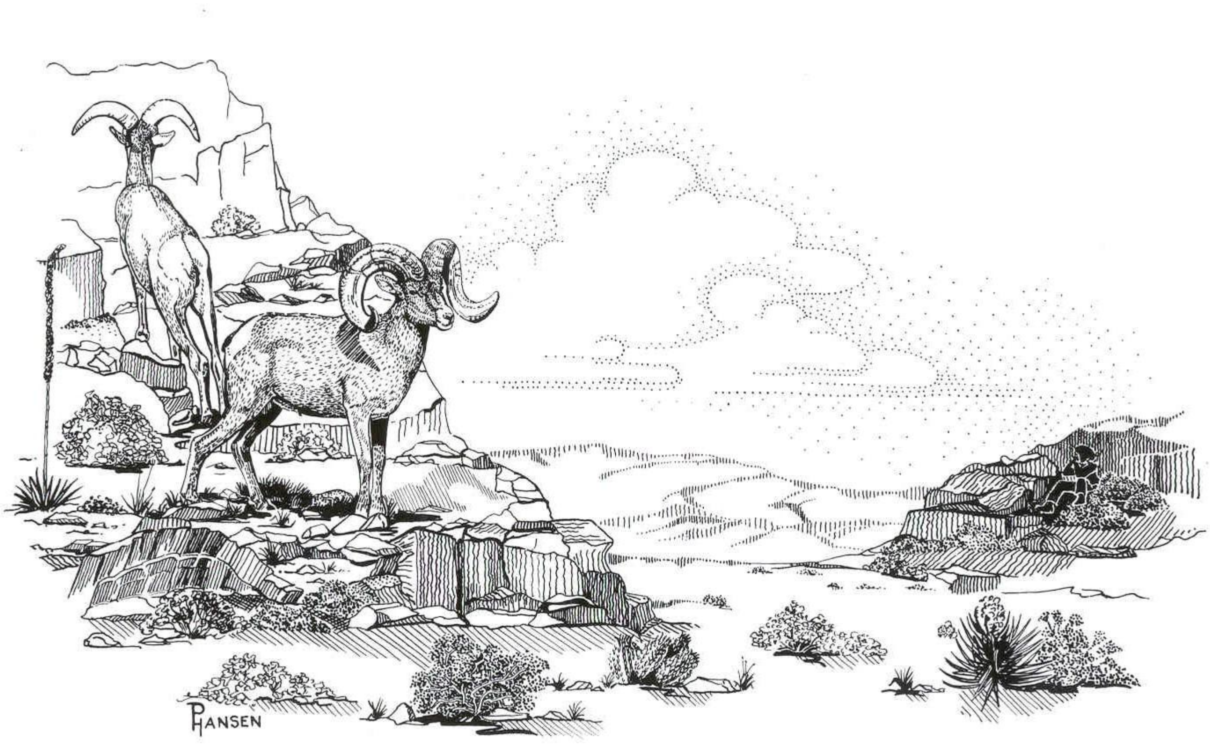
State Status Reports



Status of bighorn sheep in Arizona, 2012–2013

Brian F. Wakeling

Arizona Game and Fish Department, Game Branch,
5000 West Carefree Highway, Phoenix, AZ 85086, USA

Desert Bighorn Council Transactions 52:30–31

Populations

Estimates of Arizona's desert bighorn sheep (*Ovis canadensis mexicana* and *O. c. nelsoni*) populations have remained relatively stable over the past 2 years statewide. Ram:100 ewes:lamb ratios averaged 54:100:28 in 2012 (n = 2,543) and 50:100:26 in 2013 (n = 1,722). Based on survey data, Arizona currently has an estimated population of 4,500–5,000 desert bighorn sheep

The desert bighorn sheep population in the Kofa Mountains (Units 45A, 45B, and 45C) in southwestern Arizona has stabilized at about 400 animals (the population had been at about 800 in 2000). Good increases have been observed in portions of the Black Mountains (Units 15C and 15D) of northwestern Arizona. This area has served as a source for multiple translocations recently.

Rocky Mountain bighorn sheep (*O. c. candensis*) continue to prosper in Arizona. This population is estimated at about 1,000 animals. Ram:100 ewes:lamb ratios averaged 65:100:37 in 2012 (n = 522) and 91:100:26 in 2013 (n = 102). For both Rocky Mountain and desert bighorn sheep, Arizona surveys about one third of the population annually, although some areas of specific concern or recent translocations have been surveyed annually.

Research

Some ongoing monitoring of roadways and mitigating features on permeability for desert bighorn sheep continues, but most research has been published previously.

Habitat

The Department works with private organizations (primarily ADBSS and the Wild Sheep Foundation) and federal agencies to achieve habitat improvements for bighorn sheep. Many of these projects are solicited each year through the Department's Habitat Partnership Committees and are funded with Special Big Game License-Tag funds generated through the sale of 3 bighorn sheep tags.

In 2012, the Department and ADBSS coordinated on 14 individual projects for \$357,911 USD, and in 2013 we coordinated on 16 projects for \$380,520 USD. Projects involved building or maintaining water sources, habitat, sheep survey, and translocations.

Translocations

Arizona relocated 146 bighorn sheep through 5 translocations during the past 2 years. In 2012, 35 desert bighorn sheep (8

M, 26 F, 1 M lamb; another 16 [1 with clinical signs of contagious echthyma] were captured, marked, and released in Unit 15D) were captured on 1–3 November in the Black Mountains Unit 15D and relocated to Mount Wilson in Unit 15B West. During 13–14 November, 30 desert bighorn sheep (4 M, 22 F, 2 M lambs, 2 F lambs) were captured in Units 22 and 24B (Superstition Mountains) and released in the Mineral Mountains in Unit 37B. Finally, on 16 November 2014, 10 desert bighorn sheep (3 M, 6 F, 1 F lamb) were captured in the Plomosa Mountains in Unit 44B and released in the Buckeye Hills in Unit 39.

In 2013, 40 more desert bighorn sheep (7 M, 33 F) were captured on 14–16 November in the Black Mountains of Unit 15D and released in Peoples Canyon in Unit 16A. During 16–17 November, 31 desert bighorn sheep (6 M, 24 F, 1 M lamb) were captured in the Trigo and Plomosa Mountains of Units 43B and 44B and released within the Catalina Mountains in Unit 33. This brings the total of bighorn sheep moved in Arizona to 2,087.

The release into the Catalina Mountains was highly controversial due to the highly visible release and subsequent mountain lion (*Puma concolor*) management activities. An advisory committee had been established to work through the planning and implementation, to include the ADBSS, Sky Island Alliance, Center for Biological Diversity, Arizona Wilderness Coalition, the Wilderness Society, the U. S. Forest Service, and the Arizona Game and Fish Department participated on this project. Sixteen bighorn sheep were known to have died (14 to mountain lion predation) during the first 6 months, and 3 mountain lions were lethally removed. At this time, no further mortalities have occurred and a supplemental release is planned in November 2014.

Harvest

Bighorn sheep permits remain the most sought after hunting permits in Arizona. In 2012, 12,233 individuals applied for the 95 available permits, and in 2013, 13,488 individuals applied for the 106 available permits.

During the 2012 season, 93 hunters participated, harvesting 93 rams in 556 days of hunting. Hunt success was 100%. In 2013, 104 hunters participated, harvesting 99 rams in 652 days of hunting. Hunt success averaged 96% in 2013.

In 2012, age of harvested rams ranged from 3 to 12 ($\bar{x}$ = 8), and horns green scored from 96 1/8 to 186 7/8 ($\bar{x}$ = 159 4/8 B&C). In 2013, age ranged from 5 to 11 ($\bar{x}$ = 7.6) on harvested rams, and green scores on horns ranged from 131 1/8 to 186 1/8 ($\bar{x}$ = 163 2/8 B&C).

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 2012 and 2013, with a third tag in each year to the Arizona Big Game Super Raffle (AZBGSR). Each year, ADBSS has traditionally auctioned 1 tag at the Wild Sheep Foundation Annual Convention and auctions the second at their fundraising banquet. The third is raffled through AZBGSR. In 2012 and 2013, $356,450 USD and $389,750 USD were raised with these permits, respectively.

Status of desert bighorn sheep in New Mexico, 2011–2012

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Desert Bighorn Council Transaction 52:32–34

SYNOPSIS

Desert bighorn sheep (*Ovis canadensis*) were delisted from the New Mexico state endangered species list in November 2011. The statewide population continued to increase to an autumn 2012 estimate of 770 bighorn sheep (range = 715–825). Average annual adult mortality rates declined from 0.21 during years prior to mountain lion (*Puma concolor*) removal, to 0.11 once mountain lion removal was implemented. A combination of mountain lion removal and translocations has allowed desert bighorn sheep populations to increase.

DESERT BIGHORN SHEEP DELISTED FROM THE NEW MEXICO STATE ENDANGERED SPECIES LIST

After 31 years on the New Mexico state-endangered species list, desert bighorn sheep exceeded population requirements specified in the *Plan for the Recovery of Desert Bighorn Sheep in New Mexico* (Recovery Plan) and were removed from the state endangered species list. Desert bighorn sheep were down-listed to threatened status in autumn 2008 when the statewide population estimate was 455. At the time of delisting in autumn 2012, the population estimate was 658. This exceeded delisting requirements in the Recovery Plan of a statewide population ≥500 (Figure 1), with 3 populations or metapopulations ≥100 animals each. The metapopulations ≥100 animals were the Fra Cristobal-Caballo metapopulation (n = 250), the Bootheel metapopulation (n = 257), and the San Andres population (n = 125).

MOUNTAIN LION REMOVAL

A preventative mountain lion removal program was effectively implemented in desert bighorn sheep ranges in 2001, and is currently conducted in 6 desert bighorn sheep populations. Data from monitoring radiocollared desert bighorn sheep from 1992–2012 were used to calculate average annual mortality rates statewide and for individual herds using program MARK. The average annual mortality rate was 0.21 from all causes and 0.16 from mountain lion predation before mountain lion removal was implemented. These rates dropped to 0.11 and 0.06, respectively, once mountain lion removal was implemented. An average of 2.5 mountain lions is removed from each mountain range annually.

GRADUATE RESEARCH PROJECTS

Two graduate students are conducting research on desert bighorn sheep in New Mexico. One student fitted bighorn sheep ewes in the Peloncillo Mountains with vaginal implant transmitters that were ejected from the body during lambing. This notified the student that a lamb was born, enabling the student to hand-capture the lamb and fit it with a radiocollar. Lambs are monitored to ascertain mortality rates and causes of mortality. The second graduate student is comparing bighorn sheep foraging efficiency rates in the presence of cattle grazing (Caballo Mountains) with rates in the absence of cattle grazing (San Andres Mountains).

FRA CRISTOBAL-CABALLO MOUNTAINS METAPOPULATION

There are about 300–335 desert bighorn sheep in the increasing Fra Cristobal-Caballo mountains meta-population. The Caballo herd (n = 95–100) is assumed to have self-started from the Fra Cristobals in 2002, and a ram radiocollared in the Caballo Mountains was documented moving to the Fra Cristobals and back again. In 2009, 18 bighorn sheep were transplanted to augment the Caballos herd. A mountain lion snareman and a desert bighorn sheep graduate student work in the mountain range.

The Fra Cristobals population (n = 205–235) has been steadily increasing since 2006, which coincides with implementation of a more aggressive mountain lion removal program. There continues to be a full-time desert bighorn sheep and mountain lion monitor in the Fra Cristobals. Population growth has enabled the Fra Cristobals to serve as source stock for a transplant of 16 ewes to the Bootheel in 2011. This is the first time a transplant has been conducted from a wild herd to a wild herd in New Mexico. New Mexico Ranch Properties, Inc. remains an important partner in this herd's recovery.

BOOTHEEL METAPOPULATION

The Bootheel metapopulation estimate is currently 250–295 bighorn sheep. These herds were augmented in 2011 with 41 animals. The Peloncillo population experienced high lamb survival in 2012 leading to increasing numbers; the Hatchets population had a high mountain lion predation rate (0.12) which contributed to declining numbers. A houndsman works in each of the Hatchet and Peloncillo mountains and a graduate student monitors both populations.

SAN ANDRES MOUNTAINS

This population has slowly increased from 80–90 animals in 2006 to the current estimate of 115–135. A mountain lion snareman is available to work in the mountain range, and a graduate student monitors the herd.

RED ROCK CAPTIVE FACILITY

Twenty-five bighorn sheep were transplanted out of Red Rock in 2011. Nine ewes and 6 rams augmented the Peloncillos population, and 8 ewes and 2 rams augmented the Hatchet population. A half-time contractor maintains the fence, supplies supplemental feed and water, and removes mountain lions in and near the facility.

HUNTING

New hunts were established in 5 desert bighorns sheep ranges in the 2012 season. Public licenses increased from 1 in the Peloncillo Mountains to 16 distributed in 6 bighorn sheep herds. In addition, 3 private land licenses were issued in return for access for 3 public hunters in the Fra Cristobal Mountains. The new state record desert ram of 191 3/8 was harvested in the Ladron Mountains, and the new Pope and Young world record desert ram of 184 6/8 was also harvested in the Ladrones. The auction tag sold $145,000 in 2011 and $160,000 in 2012 (Table 1). Each year, 1 auction tag is sold at the Wild Sheep Foundation (WSF) convention to hunt either Rocky Mountain or desert bighorn sheep, and 1 permit is drawn in a raffle conducted by the New Mexico Chapter of WSF.

Table 1. Bighorn sheep auction license prices, and the scores of desert bighorn rams taken by the auction, raffle, and public hunters (top score only) from 2009-2012 in New Mexico.

	2009	2010	2011	2012
Auction Price	$90,000	$107,500	$145,000	$160,000
Auction Score	N/A	N/A	N/A	187 0/8
Raffle Score	169 6/9	170 4/8	160 0/8	184 6/8
Top Public Score	172 0/8	181 2/8	170 0/8	191 3/8

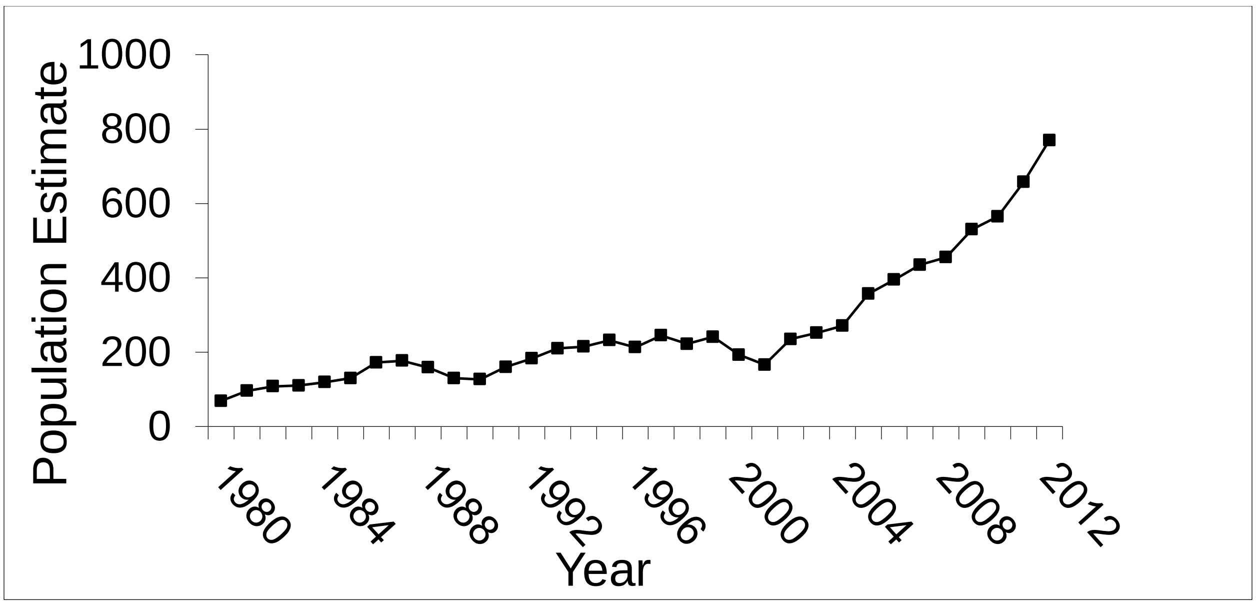

Figure 1. Desert bighorn sheep population estimates in New Mexico, 1980–2012.

Desert bighorn sheep state status report – Texas, 2011–2012

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Desert Bighorn Council Transactions 52:35–39

POPULATIONS

Extirpated by the early 1960s, desert bighorn sheep (*Ovis canadensis*) in Texas have been successfully restored to the late 1800 population levels and continue to expand. All desert bighorn sheep populations in Texas occur in the Trans-Pecos region of the state with the following areas supporting known desert bighorn sheep herds: 9 Point Mesa Mountain, Baylor, Beach, Eagle, Sierra Diablo, and Van Horn Mountains, and the Texas Parks and Wildlife Department's Big Bend Ranch State Park (SP), Black Gap Wildlife Management Area (WMA) and Elephant Mountain WMA.

Smaller populations are observed periodically within the travel corridor between Black Gap and Elephant Mountain that includes Dove Mountain, Little Dove Mountain, The Black Hills, and Three Mile Hill. Desert bighorn sheep are also sighted on various mountains along the lower canyons of the Rio Grande River as well as Big Bend National Park (BBNP; Persimmon Gap). Limited production is likely occurring in these smaller populations.

Desert bighorn sheep counts for the reporting period decreased slightly in comparison to 2009–2010. This slight decline is possibly the result of prolonged extreme drought conditions. Total bighorn sheep observed and sex and age ratios remained fairly consistent during 2011 and 2012 (Table 1).

TRANSLOCATIONS

Two transplants occurred during the reporting period. The first was conducted in December 2011. Ninety-five bighorn sheep (19 M, 76 F) were captured from the Beach, Baylor, and Sierra Diablo Mountains and released into the Bofecillo Mountains of Big Bend Ranch SP to augment the 2010 restoration effort. Forty-three bighorns were fitted with either store-onboard or satellite GPS radiocollars.

The second capture was conducted in December 2012. Forty-four bighorn sheep (22 M, 22 F) were captured from Elephant Mountain WMA and transplanted to 9 Point Mesa Mountain. Forty of 44 bighorn sheep were fitted with store-onboard or satellite GPS radiocollars. This not only marks the first transplant to mountain ranges within private property in over 15 years, but also the beginning of a new phase for bighorn sheep restoration in Texas.

Table 1. Total bighorn sheep observed, sex (M = male, F = female) and age (L = lamb) ratios, and corresponding survey hours in Texas during 2011–2012.

Year	Total observed	M :100 F:L	Flight hours	Bighorn sheep observed/hour
2011	1,026	55 100 24	86.18	11.89
2012	1,009	66 100 29	67.76	14.89

Table 2. Bighorn sheep permits authorized for 2011–2012 on state-public land and for private landowners in Texas.

Land ownership	2011 permits	2012 permits
State-public		
Big Bend National Park	0	0
Big Bend Ranch State Park	0	0
Black Gap Wildlife Management Area	0	0
Elephant Mountain Wildlife Management Area	2	2
Sierra Diablo Wildlife Management Area	1	1
Total	3	3
Private		
Baylor	1	1
Beach	2	3
Eagle	0	0
Sierra Diablo	5	7
South Brewster County	2	2
Van Horn	1	1
Total	11	14
Grand total	14	17

Table 3. Classification of desert bighorn sheep surveyed by location in Texas during 2011–2012.

	Rams		Ewes		Lambs		Total	
Location	2011	2012	2011	2012	2011	2012	2011	2012
Baylor Mountains	48	29	78	59	13	11	139	99
Beach Mountains	46	49	100	50	9	11	155	110
Brewster County	25	26	12	45	6	10	43	81
Big Bend Ranch SP	9	12	21	31	0	1	30	44
Elephant Mountain WMA	67	69	64	74	13	13	144	156
Eagle Mountains	5	0	5	0	0	0	10	0
Sierra Diablo Mountains	109	143	266	223	83	90	458	456
Van Horn Mountains	5	12	30	36	12	15	47	63
Total	314	340	576	518	136	151	1026	1009

Though there have been other releases into mountains within private property, this particular restocking of bighorn sheep habitat within private property is especially important because it will hopefully help pave the way for future restocking of mountains that occur within private property.

RESEARCH

The 2 sites with radiocollared bighorn sheep are Big Bend Ranch SP and 9 Point Mesa Mountain. The Big Bend Ranch SP bighorn sheep have 1 more year of a 3-year study, and radiocollars are scheduled to drop off in December 2013. The 9 Point Mesa study was initiated in December 2012 and will conclude in December 2014. The 2 studies will serve as projects for at least 2 students completing Masters of Science degrees. There are other potential projects that may be used for students pursuing advanced degrees that may be considered for these 2 ongoing studies.

Preliminary results have helped to delineate core-use areas, investigate predation, and identify potential international travel corridors. Future analyses will provide habitat use, home range, and help develop a habitat suitability model specific to Texas.

HABITAT IMPROVEMENTS

Habitat improvement projects in Texas are accomplished through the cooperative efforts of the Texas Bighorn Society (TBS), private landowners, Texas Parks and Wildlife Department (TPWD), and a force of Sul Ross State University-Borderlands Research Institute student volunteers. In March 2011, 3 water catchments were constructed on separate mountains on Big Bend Ranch SP. In March 2012, 3 existing water catchments in the Sierra Diablo Mountains were repaired and new storage tanks put in place to replace old ones. Several hundred gallons of water were long-lined in via helicopter. In March 2012, over 80 kms of fence in the Van Horn Mountains were modified to facilitate wildlife movements. Modifications came in the form of either completely removing the fence or folding up 50–75 m segments of fence every 100–200 m.

HARVEST

Bighorn sheep restoration and management in Texas continues to be funded by hunters through the Federal Aid in Wildlife Restoration Program, Wild Sheep Foundation auction permits, the Texas Grand Slam Hunt Program, TBS, and other Texas wildlife conservation organizations.

Thirty-one permits were issued in 2011–2012. Six of the 31 permits were allocated to state-public land including Elephant Mountain WMA and Sierra Diablo WMA. On occasion, permits are also allocated to BBNP and Black Gap WMA. Because Big Bend Ranch SP is still in the initial restoration phase and no harvestable rams have been observed, it has not received a permit to date. The remaining 25 permits were issued to private landowners in various mountain ranges (Table 2).

PROBLEMS-OPPORTUNITIES

Exotic ungulates, such as aoudad sheep (*Ammotragus lervia*) are frequently observed within bighorn sheep habitat and pose a potential threat to native wildlife species including desert bighorn sheep and mule deer (*Odocoileus hemionus*). Aoudads not only have a higher reproductive potential and seemingly a preference for similar habitat, but also the ability to subsist on lower quality forage. Aoudads are also socially aggressive and have been observed herding female bighorn sheep. Although their potential to transmit disease is unclear, they may be reservoirs of parasites and diseases detrimental to desert bighorn sheep and other native ungulates. Exotic ungulates compete with bighorn sheep for resources as well space. TPWD has the responsibility to manage exotics at lowest possible levels on state land and the authority, with landowner consent, on private land.

The principal predator of bighorn sheep in Texas is the mountain lion (*Puma concolor*). Typically, large free-ranging bighorn sheep populations have the ability to sustain natural levels of predation pressure. However, predation can have significant negative impacts on recently introduced or small populations. TPWD will continue implementing predator management activities in restoration areas, with emphasis on Big Bend Ranch SP. TPWD recommends predator management activities continue on the recently released 9 Point Mesa Mountain herd within private property as well.

Desert bighorn sheep populations in Texas continue to expand in numbers and distribution. Monitoring these populations will require expanded survey efforts which will continue to be a challenge as a result of human resource and budget shortfalls.

The recent establishment of bighorn sheep at Big Bend Ranch SP is a significant achievement for the bighorn sheep program in Texas. Maintaining a viable population will require overcoming many obstacles on both sides of the river including human disturbances, predator issues, free-ranging exotics and pressure from diverse user groups within the park.

Generally, desert bighorn sheep restoration and management in Texas can be viewed as a 3-part equation. Understanding bighorn sheep requirements and potential influences are only one third of the equation. These requirements and influences have been identified through years of research as well as anecdotal field observations. But some of the potential influences must be periodically reviewed and management actions adjusted to stay current with changing times. Ongoing research will help identify current and future management needs and appropriate adjustments.

Another crucial part of that equation includes partnerships. These partnerships may be viewed as the second third of the equation and formed nationally and internationally with state and federal conservation agencies and organizations and interest groups. Solid relations must be well established, as well as clear attainable goals and objectives described to increase the potential for successful reintroductions and restoration.

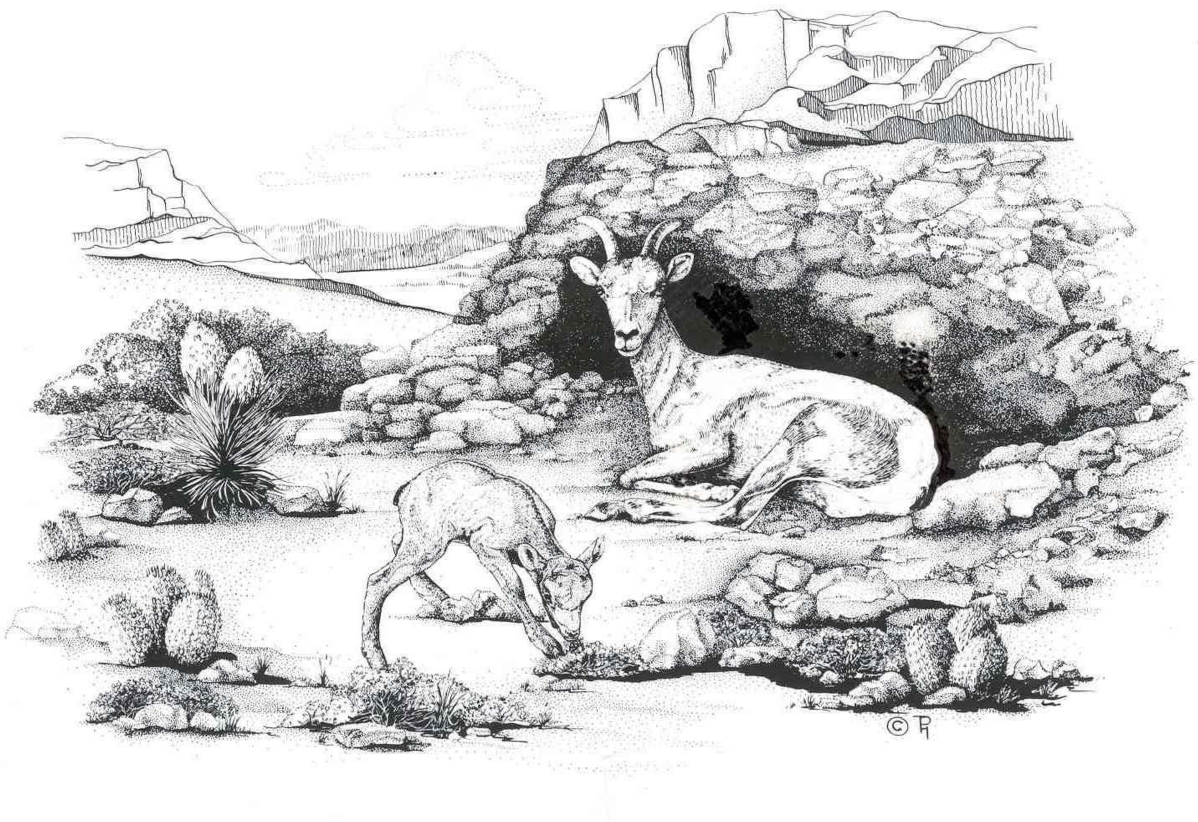
The last third is made up by private landowners. Without landowner cooperation, progress (i.e., captures, transplants, expansion, and public awareness) will be extremely difficult to achieve. This is particularly true for a state such as Texas where over 95% of the land is privately owned.

The three components of the bighorn sheep restoration and management equation should be identical on an international level. However, differences in individual governing styles, economic limitations, and resource or funding availability can complicate or hinder progress.

A consolidation of management resources on an international level to the greatest extent possible can be a consideration to mitigate some of the economic limitations. Implementing a landscape-level ecosystem management approach to promote the conservation of biodiversity can alleviate some of the pressure of different management priorities set by individual governing bodies.

The international restoration effort would benefit greatly from habitat enhancement projects and sound wildlife management practices when conducted simultaneously on both sides. Predator management can be applied to keep predation at a level that does not prevent the establishment of self-sustaining desert bighorn sheep populations. Additionally, the removal of exotic ungulates as needed would increase the potential for bighorn sheep population establishment into reintroduced areas, and subsequent natural expansion. Furthermore, the protection of bighorn sheep coupled with promoting habitat management, including movement corridors, would facilitate natural expansion.

Public awareness and disseminating information to the media, advocacy groups, wildlife organizations, and interest parties will help with public education and perception.



Status of desert bighorn sheep in Sonora, Baja California, and Baja California Sur, Mexico – 2013

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Abstract Free-ranging desert bighorn sheep (*Ovis canadensis*) occur in 7 states in the United States - Arizona, California, Colorado, Nevada, New Mexico, Texas, and Utah. They also occur in 5 states in Mexico - Baja California, Baja California Sur, Chihuahua, Coahuila, and Sonora. The history of land ownership in Mexico, and its effects upon desert bighorn sheep and desert bighorn sheep management, has been discussed in previous Council transactions (Lee 2000; Lee 2009; Lee and Segundo 2011). This paper will address the current status of desert bighorn sheep in Baja California, Baja California Sur, and Sonora.

Desert Bighorn Council Transactions 52:40–43

BAJA CALIFORNIA

Due to a history of producing high-scoring rams, including the World's Record, there has been considerable interest in the desert bighorn sheep of Baja California. Of the top 25 desert bighorn sheep trophies of all time, more than half came from Baja California.

A standardized helicopter survey of Baja California was conducted in December 2010. Reports on the results of this survey were provided by Lee and Segundo (2011) and Lee et al. (2012). During the 2010 survey, 381 desert bighorn sheep were classified in 30.5 hours of helicopter survey time, resulting in an observation rate of 12.5 animals per hour. Data do not indicate that the desert bighorn sheep population in Baja California has decreased in number since the initial helicopter survey in 1992. The present population of bighorn sheep in Baja California is about 2,500 adult animals.

Following the 2011 *First Workshop of Experts on the Conservation and Sustainable Management of the Bighorn Sheep in Baja California,* a plan was developed for the sustainable management of bighorn sheep in Baja California. While the bighorn sheep population in Baja California can certainly support a hunting harvest; the where, when, how many, and who benefits from the revenue must still be determined.

On November 12, 2012, a survey of Sierra Juarez in northern Baja California was conducted with the support of the San Diego Zoo (Table 1). These surveys help demonstrate the fluid nature of this desert bighorn sheep metapopulation in Baja California.

Table 1. Helicopter survey results for desert bighorn sheep in Sierra Juarez, 1992–2012.

Year	Hours	Number classified
1992	10.0	4
1995	2.8	2
1999	*	-- [a]
2010	1.7	16
2012	4.0	67

[a] Due to the low number of observations during the previous surveys, Sierra Juarez was not surveyed during the 1999 statewide survey.

Table 2. Helicopter survey results for desert bighorn sheep in the Ejido Bonfil, 1996–2012.

Year	Hours	Number classified
1996	3.7	99
1997	5.8	103
1999	4.4	131
2003	4.2	137
2012	4.3	43

Table 3. Helicopter survey results for desert bighorn sheep in Sonora, 2006–2012.

Year	Hours	Number classified
2006	59.1	1,114
2009	56.4	972
2012	66.0	1,036

Table 4. Helicopter survey results for desert bighorn sheep on Tiburon Island, 2006–2012.

Year	Hours	Number classified
2006	3.6	366
2009	4.5	265
2012	7.8	163

BAJA CALIFORNIA SUR

On 13–14 November 2012, the Wild Sheep Foundation funded a survey of the principal desert bighorn sheep habitat of the Ejido Bonfil, Baja California Sur. Based on the results of the 1996 survey, it was recommended that 4 permits be issued. With the increasing number of observations, permit numbers also increased, reaching 11 for the 2011–2012 season.

The desert bighorn sheep population in this portion of Baja California Sur increased initially during this period – the 4 consecutive surveys produced increases in the total number surveyed (99, 103, 131, and 137) before declining in 2012 (Table 2).

The total number of rams surveyed showed a similar trend (27, 32, 34, and 34 – declining to 13 in 2012). The number of Class 3 and 4 rams observed during the first 4 surveys was quite consistent at 21, 25, 26, and 23 – before declining to 10 in 2012.

There had been changes in both the bighorn sheep management team personnel and in the political leadership of the Ejido. Recently, many members of the original team and Ejido leadership returned to their former positions. However, due to financial deficits that they inherited, permit levels were kept high (7) for the 2012–2013 season.

Team members have been discouraged by the low numbers of bighorn sheep they have observed during their ground surveys. These low numbers were reflected in the current helicopter survey results. Disturbance may be a factor. These are not large areas. Having 11 hunt teams scouring the mountains for a 6-month period has probably spread bighorn sheep into previously low density habitat to the northwest and to the southeast.

In 1995 and 1996, 26 bighorn sheep were captured in Baja California Sur and relocated to Carmen Island (Jimenez et al. 1997). This 155 km^2 island, located east of Loreto, is privately owned and managed by the Mexican Foundation OVIS. The bighorn sheep population grew quickly, with recent ground surveys estimating over 300 animals. In 2005, 10 bighorn sheep were captured on the island and released on the peninsula near the 1995–1996 capture site. In addition, starting in 2005 special hunting permits for Carmen Island have been auctioned. Carmen Island was authorized to issue 17 permits for 2009–2010. Some of these are used as "management" permits, where lower scoring rams are removed from the population.

There are other populations of bighorn sheep in Baja California Sur. Baja California Sur reopened to desert bighorn sheep hunting in 1998–1999 with 5 permits in 3 specific management units. The following year permits increased to 15 permits in 6 units. In 2009–2010 there were 34 permits issued for 8 units. Hunt success in these units for the past 4 years is 91%.

SONORA

Bighorn sheep management history in Sonora was previously reviewed by Lee (2003). Sonora is currently on a 3-year survey schedule. The most recent survey was conducted 17–30 November 2012, using a Robinson R44 helicopter (Table 3). This survey was conducted by biologists from the Office of Conservation of Commission of Ecology and Sustainable Development of Sonora (CEDES) and from the Office of Forestry and Game Species of Secretariat of Agriculture, Livestock, Water Resources, Fisheries, and Aquaculture (SAGARPHA).

When Sonora reopened for bighorn sheep hunting in 1995–1996 there were 8 permits for 7 management units. These numbers have steadily increased to 123 permits for 40 management units in 2012–2013. Permits are allocated with about an equal number of permits being issued for free-ranging bighorn sheep and for bighorn sheep within fenced enclosures (there are about 20 enclosure facilities). The current population estimate for Sonora is about 2,400 animals.

Tiburon Island is surveyed independently from the mainland; and was also surveyed in November 2012 (Table 4). The preliminary results of that survey show a significant reduction in the number of observations. Hunting permits for Tiburon Island have ranged from 2 in 1998, to 12 in 2011–2012. Nearly 20 rams green scoring greater than 180 points have been harvested on the Island.

The Tiburon Island desert bighorn sheep population has supported numerous translocations (over 500 animals, and over 100 at a time). These animals went to facilities in Chihuahua, Coahuila, and Nuevo Leon, as well as to enclosures in Sonora.

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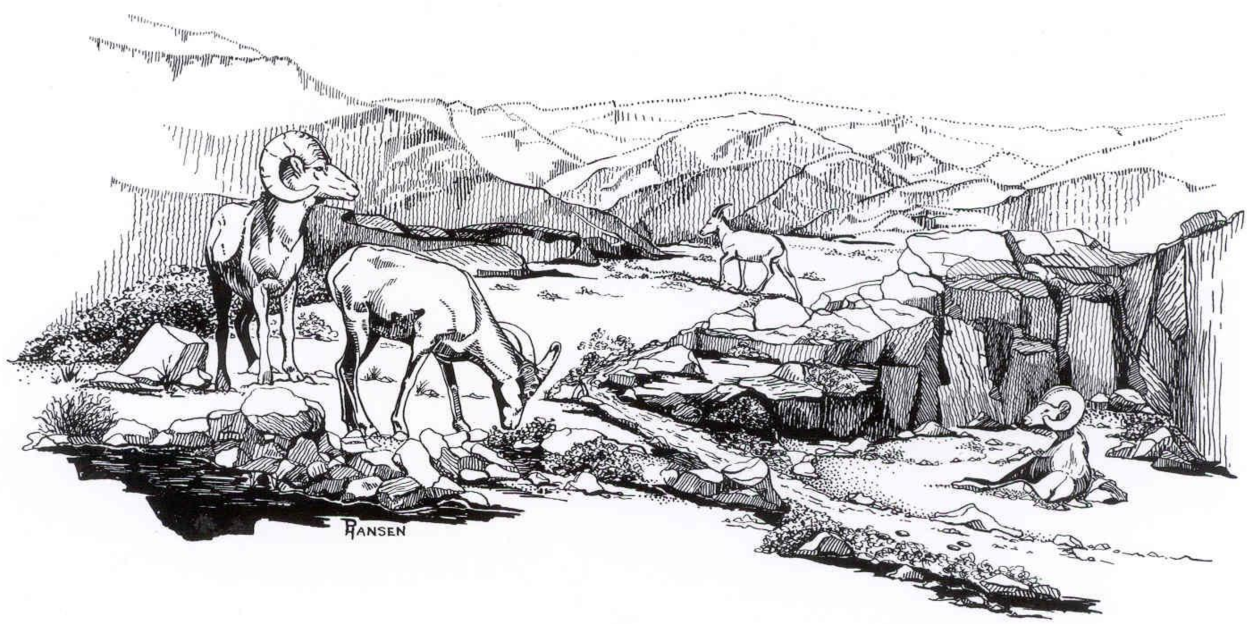

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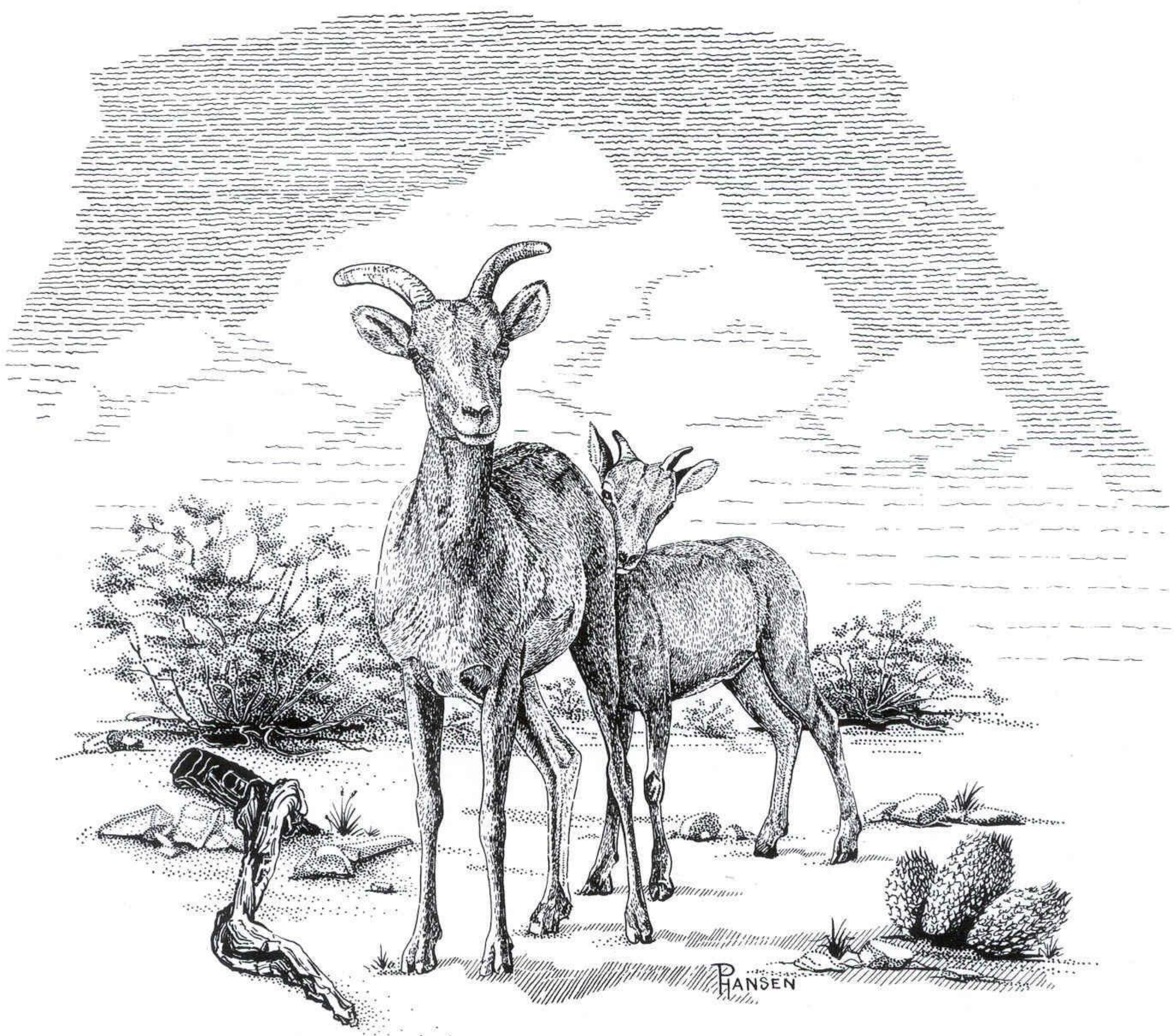
Abstracts of Presented Papers



HABITAT SELECTION BY MOUTAIN SHEEP IN ACTIVE LIMESTONE QUARRIES, SAN BERNARDINO MOUNTAINS, CALIFORNIA, USA

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We investigated how desert bighorn sheep (*Ovis canadensis nelsoni*) select habitat features in an area modified by past and present mining activity. Active and inactive limestone mining operations overlap about 30% of the composite home range for the Cushenbury herd, a group of 12–40 desert bighorn sheep located along the north slope of the San Bernardino Mountains in Southern California. High resolution GPS data were collected for 10 bighorn sheep (8 F, 2 M) from 2006 to 2009. GIS and remotely sensed imagery were used to (1) characterize and quantify mining-related alterations present during the study period and (2) assess selection by male and female bighorn sheep among anthropogenic habitat features in the immediate vicinity of present and historical mining activity. We characterized 5 habitat classes: active mine areas, inactive mine areas, mine reclamation areas, water sources, and a 100-m buffer of undisturbed habitat surrounding the mine operations. Preliminary analysis indicates selection for revegetation areas, water sources, and inactive mine areas, neutral selection for active mine areas, and avoidance of the buffer of undisturbed habitat surrounding the mine footprint.

CLIMATIC VARIABILITY AND NUTRITIONAL CONTENT OF DESERT BIGHORN SHEEP FORAGE IN SOUTHWESTERN ARIZONA

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Forage nutritional quality can have a significant influence on the ecology of herbivores, including desert bighorn sheep (*Ovis canadensis mexicana)*. Physiological condition, reproduction, and survival are all affected by forage nutritional quality. Both seasonal and annual variation in forage quality is strongly influenced by precipitation. Although studies have been conducted on the nutritional quality of desert bighorn sheep forage, most studies have been of limited duration and have therefore not included time periods with the widely varying environmental conditions (i.e., drought, wet periods) characteristic of the Sonoran desert. We assessed nutritional content (i.e., nitrogen, ADF, NDF, ADL, and moisture content) of desert bighorn sheep forage collected from 2002 to 2005 on the Cabeza Prieta National Wildlife Refuge, which included periods of severe drought, abnormally high precipitation, and average precipitation. Nutritional content of forage varied among climatic periods and seasons, with significant differences in nutritional quality metrics associated with plant growth form (i.e., trees, shrubs, forbs, grasses, succulents). In general, nutritional quality and moisture content of trees was relatively high and consistent across seasons and climatic periods, whereas succulents were consistently low in nutritional content, but high in moisture. Grass, forbs, and shrubs were much more variable, but generally increased in nutritional content with increasing precipitation. However, important differences were observed in specific nutritional metrics, particularly across seasons within climatic periods and in comparisons of the plant growth forms across climatic periods.

ALTERNATIVE PREY AND SPATIO-TEMPORAL PATTERNS OF RISK IN THE DESERT NATIONAL WILDLIFE REFUGE: DOES BIGHORN SHEEP USE OF WATER SOURCES INCREASE THE RISK OF COUGAR PREDATION?

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Predation risk from cougars (*Puma concolor*) in desert environments may be enhanced when bighorn sheep (*Ovis canadensis*) increase their use of water sources during summer months. Understanding under what conditions water sources act primarily as ecological traps remains an important issue for wildlife managers. We investigated the spatio-temporal patterns of cougar predation on desert bighorn sheep in relation to water use on the Desert National Wildlife Refuge, NV. The spatial distribution of cougar kills was studied by intensive tracking of 5 GPS-collared cougars, and monitoring of 30 GPS-collared bighorn sheep. Cougar density on the refuge was low (<0.2/100 km^2), and consisted primarily of adult females. Cougar kills comprised ~64.3% mule deer (*Odocoileus hemionus*), 30.3% bighorn sheep, and 5.4% other carnivores, and occurred closer to water sources (3.4 ± 2.4 km, mean ± SD) than random points (9.6 ± 8.0 km). However, only 1 kill occurred within 200 m of a water source. Bighorn sheep occurred closest to water sources during summer months. Extensive use of water sources increased during daylight hours, based on 24-h monitoring with camera-traps. Despite increased use of water sources, few bighorn sheep were killed during summer. Conversely, mule deer were killed across all seasons, with a peak during summer months. While proximity to water sources did not appear to influence the difference in mortality between prey species, more frequent nocturnal visits to water sources and differential use of the landscape by mule deer may explain their increased risk of predation by cougar in this desert environment.

PROTECTING SIERRA NEVADA BIGHORN SHEEP FROM MOUNTAIN LION PREDATION 1999–2011

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In 1999, Sierra Nevada bighorn sheep (SNBS) were listed as endangered under state and federal endangered species acts. Inadequacy of regulatory mechanisms to counter negative effects of mountain lion predation was 1 of 2 reasons for endangered listing. Managing predation figured importantly in the recovery plan for SNBS; however, the plan also cautioned that the management of predation should be carried out in a manner that considered the viability of the local mountain lion population. Wildlife Services was contracted during 1999–2011 to monitor-mitigate predation and to monitor mountain lion population dynamics through development of reliable minimum mountain lion counts. Those counts showed the mountain lion population maintained itself in the face of removals to protect SNBS and other human-caused mortality. Mountain lion predation showed large regional variation, as well as variation over time. Management of predation on SNBS also varied over time, and included an experimental period during which mountain lions known to have killed SNBS were not removed, followed by a period in which those mountain lions were removed. Lack of predation control was correlated with a 5-year cessation in the recovery of 1 SNBS herd; but that recovery resumed after mountain lion removals were reinstated. We found that each geographic area was unique within specific time periods relative to multiple variables that affect predator-prey relationships, and that no generalizations could be made across geographic units relative to predation management needs. Consequently, predation management for SNBS needs to be adaptive and based on continued data input.

BIGHORN SHEEP (*OVIS CANADENSIS*) POPULATION SURVEY IN THE SIERRA SANT ISABEL, BAJA CALIFORNIA, MEXICO: RECOMMENDATIONS FOR SUSTAINABLE USE

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Bighorn sheep are among the most important hunted species in America. In Baja California this species is not hunted, but photographic safaris have been demonstrated to be a "sustainable" activity because they are not extractive and can be conducted yearlong. The objective of this study was to survey the population of bighorn sheep and characterize its habitat during an annual cycle in 2 sites: Los Hemes and El Zamora. The results showed spatial–temporal use variations by bighorn sheep. In Los Hemes during the summer and fall, the female count was highest (n = 44), followed by yearlings (n = 20), while the male count was lowest (n = 36). Observations of adults were consistent in both seasons. In contrast, only 5 females were observed with 3 lambs and a young male during winter. In El Zamora, observations of females and yearlings were very common, especially during fall (n = 79 and 46, respectively). In conclusion, the population study helped to identify sites that are suitable for photographic safari, and the sex and age classes available for photographing. We propose a rule guide for tourists.

STATUS OF THE BIGHORN SHEEEP RESTORATION PROGRAMS IN NORTHEASTERN MEXICO: STATE OF COAHUILA

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CEMEX has made substantial progress towards the restoration of desert bighorn sheep in historical habitat in northeastern Mexico. Major accomplishments include: a) the release of 18 bighorn sheep to Sierra del Carmen Coahuila during 2012; b) 2 successful auctions (1 at Wild Sheep Foundation convention and another at Texas Bighorn Society Round Up in 2012); c) the follow up of cooperative agreements with Texas Parks and Wildlife and Texas Bighorn Society, including the support on the monitoring of the free-ranging bighorn sheep populations in Santa Elena Canyon, Chihuahua; and d) a Master in Science thesis on desert bighorn sheep habitat use on Sierra del Carmen was completed.

INFLUENCE OF LIVESTOCK GRAZING ON FORAGE BIOMASS, ACTIVITY BUDGTS, AND FORAGING EFFICIENCY OF DESERT BIGHORN SHEEP (*OVIS CANADENSIS MEXICANA*) IN SOUTHERN NEW MEXICO

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The desert bighorn sheep (*Ovis canadensis mexicana*) is an iconic species treasured for both aesthetics and sport. Prior to European settlement, desert bighorn sheep numbered in the thousands in New Mexico. By 1980, however, unregulated hunting, disease, and habitat degradation by livestock reduced desert bighorn sheep to just 69 wild animals. In the following 30 years, desert bighorn sheep populations have recovered to about 750 animals statewide. Though trends are promising, desert bighorn sheep recovery remains an ongoing challenge. One profound land use which can affect bighorn sheep populations is cattle grazing. By altering the habitat and foraging behavior of desert bighorn sheep, cattle grazing may influence bighorn sheep population growth. Thus, we have begun research investigating the effects of cattle grazing on desert bighorn sheep in New Mexico. We hypothesize that cattle grazing on desert bighorn sheep habitat reduces the quantity and quality of forage for desert bighorn sheep, thus reducing foraging efficiency. To test this hypothesis we are quantifying forage resources and behavior of desert bighorn sheep in grazed and ungrazed ranges. Specifically, we are measuring the composition and biomass of key forage species at different spatial scales by sampling transects across each habitat and at observed bighorn sheep foraging stations. We are also collecting observational data on desert bighorn sheep activity budgets and foraging bouts to quantify foraging efficiency. Observational data will include time spent feeding, number of steps taken, and time spent in non-feeding activities. We predict that the ungrazed habitat will have higher edible forage biomass, allowing desert bighorn sheep to forage more efficiently than in the grazed habitat.

NUMBER OF FOUNDERS IN THE ARAVAIPA, ARIZONA AND RED ROCK, NEW MEXICO BIGHORN SHEEP POPULATIONS

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Many bighorn sheep populations in western North America have had low numbers and consequently lost genetic variation. Here the possible effects of genetic drift and inbreeding are evaluated in 2 populations of desert bighorn sheep from Aravaipa Canyon, Arizona and Red Rock, New Mexico, both initiated in the 1970s from translocations. From theoretical pedigree analysis, the effective numbers of founders in the Aravaipa population from the 22 sheep released in 1973 was estimated to be only between 5 and 6, depending upon on the reproductive success of the initial ram, Old Granddad. Using these data and estimates of the effective population size in later generations, the current inbreeding coefficient is expected to be between 0.13 and 0.19. From pedigree analysis of the 39 sheep alive in 1976 in the Red Rock population, the effective number of founders was around 17. In this population, about 46% of the ancestry is from Mexican sheep and about 54% from San Andres sheep and the present day estimate of the inbreeding level is 0.10. Estimates of molecular genetic variation in the Red Rock population are low and this analysis suggests that genetic variation in the Aravaipa population is probably even lower. In Aravaipa, the decline in horn size over 30 years and the low survey numbers in 2012 might be related to these high inbreeding levels.

GIS MAPPING OF WILD SHEEP TRANSLOCATIONS IN USA AND CANADA

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Beginning with a round-robin session conducted during the 1996 Northern Wild Sheep and Goat Council biennial symposium in Silverthorne, CO, then completed in 2013 through the efforts of the Western Association of Fish and Wildlife Agencies (WAFWA) Wild Sheep Working Group (WSWG), a "master" EXCEL spreadsheet of every known wild sheep translocation documented in the USA and Canada has been assembled, including capture-site and release-site decimal degree Lat-Long coordinates, reflecting the number of wild sheep translocated within and between jurisdictions. In addition to this EXCEL spreadsheet, GIS maps (in .tiff and/or .jpg formats) displaying wild sheep imports and exports (i.e., "inter-jurisdictional") and translocations within a single state or province (i.e., "intra-jurisdictional") have also been prepared. Anticipated benefits from this spreadsheet and accompanying GIS maps include evaluation of past (and future) wild sheep translocations, with consideration of genetic factors, disease status, population growth rates, proximity to active domestic sheep and goat public-land grazing allotments, and other public- and private-land management scenarios. Plans are to house this spreadsheet and related translocation data on a moderated WAFWA WSWG website, which would allow password- enabled agency access to data, GIS files, and GIS maps; public, NGO, or other interested party access to GIS files, translocation data, and maps will

also be available, on a permission basis. Plans are also in the works for a popular-format glossy publication, to be distributed primarily via the Wild Sheep Foundation and its network of chapters and affiliates. This effort was made in an attempt to discover and document all past wild sheep translocation records before records became lost in agency files and retirement of many current senior-level wild sheep biologists from career positions.

RESEARCH AND MAANGEMENT IMPLICATIONS FOR BIGHORN SHEEP ALONG THE UNITED STATES AND MEXICO BORDER

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Desert bighorn sheep (*Ovis canadensis* ssp.) are among countless species that do not recognize borders, whether private, state, or international. For many of these species and populations to persist and survive, immigration and emigration are crucial. In 2010 and 2011, 141 bighorn sheep were translocated within Texas to the Bofecillos mountain range of the southern Trans Pecos. Though these relocations are just a small stepping stone in working to restore wild bighorn sheep to their native ranges in the Trans Pecos, they have proven that political boundaries are no obstacle to their movements. Numerous challenges within international cooperation, and even within state and private cooperation, add difficulty in restoring, protecting, and managing such an iconic species. Ruggedness and remote environments add to the challenges of obtaining data to further our knowledge and understanding of the restoration and management of the desert bighorn sheep in Texas. International cooperation has been a blessing thus far, but for species such as the desert bighorn sheep to survive and roam freely, more is needed. Implications and obstacles encountered and overcome over the past 2 years will be addressed and discussed.

ANALYSI OF TRANSLOCATED BIGHORN SHEEP MOVEMENTS IN THE BOFECILLOS MOUNTAINS OF THE TRANS PECOS, TEXAS: INITIAL AND SUPPLEMENTAL RELEASES

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Based on historical estimates in the late 1800s, Texas desert bighorn sheep (*Ovis canadensis mexicana)* numbered 1,500 individuals. These sheep roamed across 15 different mountain ranges throughout the Trans Pecos. Despite initial restoration efforts in the 1950s, their numbers continued to decline. It is commonly agreed that unregulated hunting, predation, competition, and disease had major effects and eventually led to the extirpation of the species by the early 1960s. Over time, transplanted sheep from other states and Mexico have helped rebuild a viable bighorn sheep population in Texas. Throughout the past 50 years, over 500 sheep (including over 350 from Texas populations) have been transplanted throughout the Trans Pecos mountain ranges. To date, 8 of the historic 15 ranges now have desert bighorn sheep living within them. December 2010 and 2011 marked historic translocations for bighorn sheep and restoration efforts in Texas. Not only have these been a part of the most recent translocations since 2000, but they have also been the first efforts to transplant desert bighorn sheep into a Texas State Park. Preliminary analysis of their movements, ecology, and survival will be discussed based on information and data gained by the use of radiotelemetry and GPS collars worn by the translocated sheep.

DESERT BIGHORN SHEEP LAMB SURVIVAL AND CAUSE-SPECIFIC MORTALITY IN THE PELONCILLO MOUNTAINS, NEW MEXICO

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Lamb survival is 1 of the most difficult demographic rates to estimate accurately due to the difficulty capturing neonatal lambs and locating lamb carcasses. We are currently studying neonatal lamb survival, recruitment rates, and cause-specific mortality factors in the Peloncillo Mountains, New Mexico. We captured 20 pregnant ewes in November 2011 and 19 pregnant ewes in December 2012 and equipped each with a Vaginal Implant Transmitter to aid locating parturition sites and capturing lambs. Three ewes captured in 2011 died prior to parturition. Of the 17 remaining ewes, all successfully gave birth to live lambs, 12 of which were captured by hand and radiocollared with expandable VHF collars. Lambing began mid-January 2012, with the first lamb captured on 31 January and the last on 22 March. Lambs were monitored daily from capture until 16 weeks of age, every 2–4 days until 6 months of age and weekly thereafter. We documented 3 mortalities of lambs collared in 2012 before their collars started falling off at about 4 months of age. Based on the condition of the carcasses and evidence at the kill sites, we determined the cause of death to be predation by a gray fox (*Urocyon cinereoargenteus*) in 1 case and by mountain lion (*Puma concolor*) in 2 cases. Lamb captures from the 2012 ewe capture are ongoing. The overall goal of this study is to provide much needed data on lamb survival, recruitment, and cause-specific mortality, allowing for more informed management efforts to promote population growth.

DOES FORAGING AT THE WILDLAND-URBAN INTERVACE CAUSE DECOUPLING OF CLIMATE AS A DRIVER OF RECRUITMENT FOR DESERT BIGHORN SHEEP?

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A growing number of ungulate populations are living within or near the wildland-urban interface. When resources (e.g., food, water, refuge from predators) at the wildland-urban interface are of higher quality than that of the adjacent natural habitat, wildlife can be attracted to these developed areas. Under natural conditions, recruitment in desert bighorn sheep populations correlates with variation in the timing and amount of rainfall that initiates and enhances growth of annual plant species. However, for populations that forage in developed areas, this relationship may be decoupled. In the River Mountains of southern Nevada, desert bighorn sheep (*Ovis canadensis nelsoni*) have been feeding in a municipal park at the wildland-urban interface since its establishment in 1985. Nearly 33% of the population uses the park during summer months when nutritional content of natural forage is low. We hypothesized that use of this municipal area, with its abundant vegetation and water resources, may have altered the previous relationship between precipitation and lamb recruitment. We assessed variables known to affect lamb recruitment before and after establishment of the park using linear regression models and AIC for model selection. Our top candidate model for the pre-park period indicated that total November precipitation was the greatest driver of lamb recruitment in this population. After park establishment, this relationship became decoupled; lamb recruitment is no longer driven by weather variables. These results raise management questions about the effects of this decoupling on population growth, and the negative effects of overcrowding in the municipal park, such as disease transmission, increased mortality due to vehicle collisions, and property damage at the wildland-urban interface.

LANDSCAPE GENETICS OF MOUNTAIN LIONS IN THE SONORAN DESERT

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We are investigating the current population genetic status of mountain lions (*Puma concolor*) in the Sonoran Desert with the goal of answering the following questions: 1) what is the probable origin of mountain lions occurring on Kofa National Wildlife Refuge (Kofa NWR) in Arizona; 2) what are the habitat corridors for mountain lion movement in the northern Sonoran Desert; and 3) are there any geographic features (such as interstate highways, Central Arizona Project canal, and the Colorado River) restricting gene flow among mountain lion subpopulations? To answer these questions, we are genotyping ~600 mountain lion DNA samples with 20 well-known *Felis catus* (FCA) microsatellite DNA markers, and with "PumaPlex" – a panel of 26 Single Nucleotide Polymorphism (SNP) markers recently developed for population genetic studies on mountain lions. Using this dataset, we will calculate relatedness between pairs of individual mountain lions and attempt to estimate the likely origin(s) of mountain lions currently occurring on Kofa NWR. We will then test the hypothesis: If population genetic substructure among mountain lions is related to geographic features, then these features are likely specific natural or human-made barriers or isolation-by-distance. To corroborate genetic data on mountain lion population substructure and connectivity, we are also creating a GIS-based habitat suitability model for mountain lions that will provide us with the most potential corridors for mountain lion movement in the northern Sonoran Desert. Data generated from this study will be useful for wildlife managers, stakeholders, and conservation planners in making regional or statewide management decisions for mountain lions, designating wildlife corridor areas, and facilitating collaborative research between individuals, laboratories, and agencies through genetic databases.

ASSESSMENT OF EQUINE POPULATIONS IN A POTENTIAL HABITAT FOR BIGHORN SHEEP IN NORTHWESTERN COAHUILA, MEXICO

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Northwest Coahuila was natural habitat for bighorn sheep populations before they were locally extirpated in the first half of the twentieth century. Recently, reintroduction projects have been developed in the Big Bend and Maderas del Carmen region to recover bighorn sheep populations. Equines (horses and donkeys) are the main potential competitors with bighorn sheep for space and food in Mexico. From spring 2011 to January 2013, a population assessment of domestic and feral equines was performed. A survey was conducted of 106 residents of 5 rural communities in 64,500 hectares of northwestern Coahuila, and by direct animal counting transects. Equine population density was estimated at 1,148 animals (1 equine/56 hectares). Forty-five percent were domestic horses, 30% domestic donkeys, and 25% feral donkeys grazing freely in common land; negative fluctuations in number of equines were because their owners sold them (average 200 animals annually) or death (mainly by predation, and starvation; average 130 animals/year). Equines are an important competitor with bighorn sheep in Coahuila. Reducing equine populations would increase the probability of successful wildlife reintroduction programs.

DETERMINING THE STATUS AND TREND FOR DESERT BIGHORN SHEE IN THE NORTH SAN RAFAEL SWELL

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The North San Rafael (NSR) desert bighorn sheep population has been steadily declining for several years. In 2001, the Utah Division of Wildlife Resources counted 326 animals, but only 150 animals in 2008. On average, annual population growth has been $\lambda = 0.89$ since 2001. In January 2012, 30 ewes and 8 rams were captured, tested for disease and fitted with GPS-VHF collars, which will be worn for 2 years. During that time the sheep will be under constant monitoring. Study objectives are: 1) locate marked females weekly to document survival; 2) locate and necropsy dead bighorn sheep to determine causes of death and limiting factors; 3) quantify production and survival of neonates; and 4) create seasonal range use maps and an associated habitat model. Following the first year of the study, some initial observations can be made. All marked ewes gave birth to lambs. Lambing dates ranged from 4 May to 9 June, with a mean date of 23 May. Lamb to ewe ratios were 45:100 in November 2012. Ten mortalities have been documented. Cougar predation played a role in mortalities. Disease accounted for 1 mortality. There was 1 hunter harvest and 2 mortalities have unknown causes. We estimate the current population to be ~130 animals. Results of disease testing have shown *Mannheimia haemolytica* and *Mycoplasma ovipneumonia* are present in the population.

DENSITY AND POPULATION STRUCTURE OF THE DESERT BIGHORN SHEEP (*OVIS CANADENSIS WEEMSI*, GOLDMAN, 1937) IN THE CARMEN ISLAND, BAJA CALIFORNIA SUR, MEXICO

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El Carmen Island, Baja California Sur, belongs to the National Marine Park of Loreto Bay, decreed published in 1996. Based on geographical location, climatic conditions, shortage of water, vegetation types, and topoforms, it is a site of interest. In particular, studies focused on the desert bighorn sheep conservation (*Ovis canadensis*), which is a species that requires specific habitat conditions regarding water, food, cover, and space. This species belongs to the most popular wildlife group. Their enormous hunting value, as well as its biological and cultural importance, has attracted researchers specializing in wildlife management and conservation. The purpose of this study was to determine the structure and population density of this important hunted species within the island. We used 3 methods for determining the density and population structure. These are: fringe counting method, direct observation of specimen, and fecal monitoring plots. In addition, sightings of individuals in water holes were used to reinforce observations of the species' population structure. We determined a density of 0.1725 bighorn sheep/hectare through the method of counting fringes. The method of fecal monitoring plots yeilded an estimate of 0.68 groups/hectare stool. The method of direct observation was not useful for estimating population density. Finally, a definitive analysis of population structure found an association of male:female:lamb:yearling of 32:40:23:5 (or 0.8:1.0:0.58:0.13).

PUMA:UNGULATE RATIOS IN THE SKY-ISLANDS OF THE CHIHUAHUAN DESERT

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Because minimum puma (*Puma concolor*) kill rates are independent of ungulate prey density, the ultimate effect of predation is linked to the predator:prey ratio. Maximum ungulate (deer-size) densities in the northern hemisphere,

from predator-free enclosures or islands, vary only by a factor of ~3-4 (20-90 ungulates/km^2). Here, I report ungulate densities varying by a factor of 100-185 between adjacent mountain ranges in the Chihuahuan desert. Mule deer (*Odocoileus hemionus*) density in the San Andres Mountains in New Mexico is reported to be 8-10 deer/100 km^2 compared to 900–1,200 deer/100 km^2 in the adjacent Sierra Diablo Mountains in Texas. Desert bighorn sheep (*Ovis canadensis*) density in the occupied portions of the San Andres Mountains is ~40/100 km^2 compared to 200–300/100 km^2 in the Sierra Diablo Mountains. Puma density in the relatively unexploited San Andres Mountains is reported to be ~2 puma/100 km^2. In Texas, where puma are unprotected, the density is unknown but is assumed to be some fraction of that reported for New Mexico. Assuming a 50–75% reduction in puma density, the puma:prey ratio may be as low as 1:1,500 or 1:3,000. In New Mexico mule deer ranges without desert bighorn sheep, this ratio may be as high as 1:4 essentially defying the Kleiber Equation, and 1:67 in habitat with sympatric desert bighorn sheep. The effect of this predator:prey imbalance cascades throughout the trophic structure, often resulting in extirpation or near extirpation of native fauna including desert bighorn sheep, desert mule deer, and porcupines (*Erethrizon dorsatum*). High annual mortality rates associated with the Allee Effect will preclude low-density ungulate populations from increasing, regardless of habitat conditions. In the San Andres Mountains, low mule deer numbers have resulted in the elimination of sport-hunting which is the cornerstone of the North American Model. Low mule deer density in other New Mexico ranges has resulted in hunter dissatisfaction which jeopardizes hunter recruitment and retention.

AN ASSESSMENT OF HIGHWAY CONSTRUCTION DISTURBANCE OF DESERT BIGHORN SHEEP

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We investigated the potential disturbance of construction activities on desert bighorn sheep (*Ovis canadensis nelsoni*) along a 17-mile stretch of U.S. Highway 93, which was realigned and widened during the Hoover Dam Bypass Project. GPS collars collected 33,177 locations from 30 desert bighorn sheep leading up to reconstruction (November 2008–March 2009) and 104,018 locations from 39 desert bighorn sheep during reconstruction (April 2009–November 2010). The change in highway crossing rate from 0.3 crossings/day prior to reconstruction to 0.2 crossings/day during reconstruction was not significant. There was a shift in the distribution of crossings with a 50% increase between milepost 0.0 and 2.2, where construction was completed prior to this phase of the project, and a 96% decline between mile post 5.0 and 9.0. During the project we populated a matrix of construction intensity with values for each day of construction at each 0.1 mile segment of roadway. When considering desert bighorn sheep locations relative to the no, low-moderate, and high disturbance classes of construction activity, we found no evidence of avoidance. The desert bighorn sheep appeared tolerant of heavy equipment and bridge construction activities. They exhibited a dramatic shift away from sections of the highway under very high disturbance (blasting) conditions. The lambing season distribution of female desert bighorn sheep locations during construction showed a significant shift away from the highway relative to lambing distributions prior to construction. There were 68% fewer during-reconstruction locations within 0.31 miles of the highway and 50% fewer locations within 0.62 miles.

POPULATION AND HABITAT USE BY DESERT BIGHORN SHEEP (*OVIS CANADENSIS MEXICANA*) TRANSLOCATED INTO SIERRA MADERAS SEL CARMEN, COAHUILA, MEXICO

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We studied demographic status, seasonal home range and potential habitat distribution of a translocated desert bighorn sheep (*Ovis canadensis mexicana*) population in Sierra Maderas del Carmen, located in the northwest portion of Coahuila State, México. During our study, we monitored 20 radiocollared bighorn sheep (1 ram and 19 ewes released in 2004 and 2009, respectively). We also visually monitored other individuals without radiocollars released during the same periods. We estimated rates of birth, survival, and mortality, as well as the population growth rate. In addition we analyzed the group size in software R. Home range at finding probabilities of 95% ($P = 0.05$), 50% ($P = 0.5$) and 10% ($P = 0.9$) was estimated using the Animal Movement extension of Arcview

3.2 software based on the Kernel method. The potential habitat distribution model was developed by the maximum entropy algorithm (Maxent) using 23 environmental variables (19 climatic and 4 topographic) with 1 km^2 spatial resolution and processed in the ArcGis 9.3 software. Results showed a population with similar demographic rates to bighorn sheep populations in the Southwest USA and a low population growth rate of $r = 0.15$. The average size of mixed groups was statistically different from the other groups ($P = 0.05$). The biggest seasonal home range for all the individuals covered 59 km^2 (home range in summer 2010, $P = 0.05$). This indicates that only 4.7% of the potential habitat (land with values of probability ≥ 0.61) is being used in the Maderas del Carmen Range according to the Maxent habitat distribution model.

RESPONSES OF DESERT BIGHORN SHEEP TO EXPERIMENTAL SIMULATION OF RISK OF PREDATION BY MOUNTAIN LIONS

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Adaptations that reduce vulnerability to predators can be grouped broadly into indirect mechanisms that affect the likelihood of encountering and detecting predators, and direct mechanisms that involve minimizing the success of a predator upon detection, such as by sight, olfaction, or auditory cues. We investigated responses of desert bighorn sheep (*Ovis canadensis nelsoni*) to olfactory cues conferring a direct risk of predation by experimental delivery of feces from mountain lions (*Puma concolor*), their primary predator. We recorded behavior of randomly selected focal animals assigned to one of three treatments; a control with no manipulation ($n = 13$), a control using remote delivery of non-predator feces (horse; *Equus caballus;* $n = 7$), and a treatment incorporating remote delivery of feces from mountain lion ($n = 7$). We evaluated responses with orthogonal contrasts of manipulation vs. non manipulation, and treatment with feces from mountain lion vs. feces from horse. No instances of flight response were observed in trials. Vigilance was significantly greater in treatment vs. unmanipulated trials ($P = 0.004$) and for treatment with mountain lion feces vs. treatment with horse feces ($P = 0.047$). We discuss the adaptive significance of observed responses to risk of predation.

GENETIC POPULATION STRUCTURE AND GENE FLOW PATTERNS IN TWO BIGHORN SHEEP METAPOPULATIONS IN THE LAS VEGAS REGION FROM MICROSATELLITE AND MITOCHONDRIAL DNA ANALYSES

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Recent rapid expansion of human developments around Las Vegas has raised concerns about effects on the bighorn sheep metapopulation to the immediate south, and especially potential isolation of the River Mountains. We investigated this by developing genetic data for 13 populations south and west of Las Vegas Valley. We extracted DNA from fecal samples supplemented with blood and tissue samples where available. We developed and analyzed genetic data for 16 nuclear microsatellite loci for 377 individual bighorn sheep and used those data to estimate gene flow between sampling locations, and to evaluate genetic diversity. We also sequenced a 515 bp segment of the mitochondrial DNA control region for 356 individuals identified from the microsatellite data to identify different haplotypes. For microsatellite data we found consistently high genetic diversity in all populations sampled, which in part reflects the close proximity of populations and high male mediated gene flow that has historically characterized bighorn sheep in this region. MtDNA, however, indicated a lack of genetic diversity in some ranges, including the River Mountains, where the population appears to have been initiated in the 1940s by a small number of ewes from the neighboring Eldorado Range. Of the three potential connections that the River Mountains population has with neighboring ranges, only the connection with the Eldorado Mountains showed gene flow estimates from microsatellite data at a level expected for unhindered migration given close proximity of the ranges. The other connections appear to have been affected by anthropogenic barriers.

PHYSIOLOGICAL FINDINGS WITH DIFFERENT CAPTURE METHODS IN DESERT BIGHORN SHEEP

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Management programs often involve capture of bighorn sheep in Nevada. We compared 3 capture scenarios of desert bighorn sheep including ground darting and helicopter net gun capture with and then without the addition of the sedative drugs midazolam and azaperone. Six ewes were ground darted to evaluate the reversibility of the drug combination butorphanol-azaperone-medetomidine (BAM). A standard dose of 1 ml BAM (27.3 mg B, 9.1 mg A, 10.9 mg M) was used independent of age. Arterial blood samples were collected before and during intranasal oxygen supplementation (6 L/min) and immediately analyzed in the field. For reversal, atipamezole and tolazoline were injected intramuscularly. Recoveries were smooth and calm with sheep walking 2–16 minutes after administration of reversal drugs. All bighorn sheep developed marked hypoxemia (PaO_2 20–54 mmHg) and mild to marked hypercapnia ($PaCO_2$ 46–65 mmHg). Oxygen therapy was efficient in reversing hypoxemia (PaO_2 124-167 mmHg). Compared to ground darting, helicopter net gun captured bighorn sheep showed physiologic changes attributable to physical exertion. The major effect observed was extreme lactic acidosis with concurrent respiratory alkalosis and hemoconcentration.


PHANSEN

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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 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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