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THE RISE AND FALL OF PSOROPTIC SCABIES IN BIGHORN SHEEP IN THE SAN ANDRES MOUNTAINS, NEW MEXICO

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ABSTRACT: Between 1978 and 1997, a combination of psoroptic scabies (*Psoroptes* spp.), mountain lion (*Puma concolor*) predation, and periodic drought reduced a population of native desert bighorn sheep (*Ovis canadensis*) in the San Andres Mountains (SAM), New Mexico, from >200 individuals to a single ewe. In 1999, this ewe was captured, ensured to be *Psoroptes*-free, and released back into the SAM. Eleven radiocollared rams were translocated from the Red Rock Wildlife Area (RRWA) in New Mexico into the SAM range and monitored through 2002 to determine whether *Psoroptes* spp. mites were still in the environment. None of these sentinel rams acquired scabies during this period, and no additional native sheep were found to be present in the range. In 2002, 51 desert bighorn sheep were translocated into the SAM from the Kofa National Wildlife Refuge in Arizona (n=20) and the RRWA in New Mexico (n=31). Twenty-one bighorn sheep have died in the SAM since that time, but *Psoroptes* spp. mites have not been detected on any of these animals, nor have they been found on mule deer (*Odocoileus hemionus*) sampled since 2000. We conclude that psoroptic scabies is no longer present in the San Andres bighorn sheep population and that psoroptic scabies poses a minimal to nonexistent threat to the persistence of this population at this time.

Key words: Bighorn sheep, deer, *Ovis canadensis, Psoroptes,* scabies.

INTRODUCTION

The San Andres Mountains (SAM) once supported the largest population of native desert bighorn sheep (*Ovis canadensis*) in New Mexico. An epizootic of psoroptic scabies (*Psoroptes* spp.) that began in 1978 reduced this population from >200 to about 25 individuals by 1989 (Lange et al., 1980; Sandoval, 1980; Hoban, 1990). From 1985 to 1995, 62% (16/26) of the radiocollared bighorn sheep that died in the SAM had clinical scabies, and by 1997, the combined effects of scabies, prolonged drought, and mountain lion (*Puma concolor*) predation had reduced the population to a single ewe (Hoban, 1990; Clark and Jessup, 1992; Logan and Sweanor, 2001).

A fundamental challenge facing managers was how to re-establish a viable bighorn sheep population in the SAM, in the face of ongoing scabies infections. In 1997, it became feasible to eliminate all mites occurring on bighorn sheep in the SAM by capturing the single remaining ewe and then reintroducing mite-free bighorn sheep. However, morphologic, antigenic, and molecular analyses indicated that *Psoroptes* spp. mites might not be host specific (Boyce et al., 1990; Boyce and Brown, 1991; Ramey et al., 2000). Therefore, the possibility existed that *Psoroptes* spp. mites could be reintroduced into the bighorn sheep population from other hosts in the SAM environment. Faced with this uncertainty, managers decided to reintroduce bighorn sheep into the SAM only after they had strong evidence that reintroduced bighorn sheep would not become infected.

This report describes the successful effort to restore a *Psoroptes*-free bighorn sheep population in the SAM. The major components of the project were to 1) identify and treat existing bighorn sheep, 2) conduct a sentinel ram study, 3) survey different host species for the presence of *Psoroptes* spp. mites, and 4) reintroduce and monitor mite-free bighorn sheep.

MATERIALS AND METHODS

Study area and animals

The 2,059-km^2 (205,900 ha) primary study area, located in south-central New Mexico

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(32°40′33″N, 106°32′12″W), encompasses all of the SAM range. The San Andres National Wildlife Refuge (SANWR) comprises 23,154 ha, including the southern third of the SAM, and is surrounded by White Sands Missile Range (WSMR), which is under the jurisdiction of the US Army. The SAM range is long and narrow, measuring more than 129 km (80 mi) from north to south and 9–30 km (6–19 mi) from east to west. The SAM and SANWR have been relatively undisturbed by humans because access is restricted by WSMR. Elevations within the study area range from approximately 1,280 m (4,200 ft) along the east piedmont to 2,730 m (8,957 ft) at Salinas Peak. Fourteen major east–west canyons dissect the range and drain tributary canyons from the north and south. Natural springs with perennial water sources and seeps are scattered throughout the study area.

Three native ungulate species occur on the SAM: desert mule deer (*Odocoileus hemionus*), desert bighorn sheep, and pronghorn (*Antilocapra americana*). Mule deer are the most abundant ungulate and occur throughout the study area. Pronghorn infrequently range into the foothills in the northern portion of the SAM in small bands of <20 animals; however, they are more common in the surrounding flats and likely have little or no contact with bighorn sheep. Gemsbok (*Oryx gazella*), an exotic species, were first introduced to WSMR by the New Mexico Department of Game and Fish (NMDGF) in 1969. Although gemsbok prefer desert basins, the population has increased to >3,000 animals, and they are frequently observed in most areas of the SAM. Barbary sheep (*Ammotragus lervia*), which are native to northern Africa, were released along the Canadian River by the NMDGF beginning in 1950. By 1967, the herd was estimated to be between 175 and 225 animals (Findley et al., 1975). On WSMR, Barbary sheep are occasionally observed, primarily in the precipitous mountainous regions. Carnivores that frequent the study area include mountain lion, coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), and bobcat (*Lynx rufus*). The SAM range has not been grazed by livestock since the mid-1950s, although cattle (*Bos taurus*) occasionally stray into the range from adjoining areas.

Testing and treating extant bighorn sheep

Before sentinel rams could be released into the SAM, it was critical that the known remaining bighorn ewe, SAE-067, was mite-free. She was captured by helicopter net gun on 25 September 1999 for evaluation. Blood was collected for serological screening for *Psoroptes* (Boyce et al., 1991), and her ears were examined for the presence of *Psoroptes* spp. mites. She was given 4.5 cc ivermectin (IVOMEC®, 1% sterile solution, Merck & Co, Inc, Rahway, New Jersey, USA), fitted with a very high frequency (VHF) radiocollar (Telonics Inc, Mesa, Arizona, USA), and quarantined in an enclosure on the SANWR pending test results.

Sentinel ram study

In November 1999, six desert bighorn rams were captured from the RRWA captive breeding facility with a helicopter net gun. Blood and ear swab samples were collected for testing to ensure that each animal was free of mites. Upon capture, the rams were fitted with VHF radiocollars (Telonics Inc.) and transported to the SAM, where they were released individually throughout the range on the basis of historical bighorn habitat locations. Four of the radiocollars had platform transmitter terminals (PTT), as well as VHF beacons. The PTT radiocollars can track animals through ARGOS satellites. The ewe and six rams were intensively monitored by telemetry, air and ground sighting, and satellite tracking over a 2-yr period. Recaptures were scheduled every 4 to 6 mo so that blood could be drawn for *Psoroptes* spp. serology, and ear swab samples were collected to check for the presence of mites. After each capture, the rams were redistributed throughout the SAM to cover as much of the mountain range as possible. Bighorn are gregarious animals and it was expected that the sentinel rams would associate with extant bighorn in the SAM, should any exist. In November 2001, the number of sentinel rams had been reduced to three as a result of three mortalities (one from undetermined natural causes and two lion kills), and to bolster the number of sentinel animals, an additional five rams were captured from the RRWA, screened, radiocollared, and released into the SAM.

Psoroptes spp. survey

From 1988 through 2003, ear swabs and crusts, whole ears, and crusty lesions were opportunistically collected from live or dead mule deer, bighorn sheep, pronghorn, gemsbok, and Barbary sheep and examined for mites. Animals were primarily sampled in the SAM, but other regions were also included to gain an understanding of the distribution of *Psoroptes* spp. mites throughout the state. Samples were examined at the University of California, Davis, for mites with the aid of a dissecting microscope; the bases of whole ears were dissected and spread flat to view all inner surfaces for the

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presence of mites. Many of the mites collected during this period were used in morphometric (Boyce et al., 1990), antigenic (Boyce and Brown, 1991), and molecular (Ramey et al., 2000) analyses of host specificity.

Reintroduced bighorn sheep

In December 2002, 51 bighorn sheep were captured by helicopter net gun and translocated into the SAM from the Kofa National Wildlife Refuge (KNWR) in Arizona (n=20) and the RRWA captive breeding facility in New Mexico (n=31). At the time of capture, each animal was physically examined for mites and scabies lesions, and ear swabs were collected for microscopic evaluation. Each animal was given a SQ injection of 1% ivermectin (KNWR animals received 2–3 cc; RRWA animals received 4–6 cc), and all KNWR bighorn sheep were fitted with a Cutter Gold Insecticide cattle ear tag (10% cyfluthrin, Bayer Healthcare LLC, Shawnee Mission, Kansas, USA) in each ear. A VHF radiocollar (Telonics, Inc.) with mortality sensor was placed on each animal to facilitate monitoring after release into the SAM.

RESULTS

Testing and treating extant sheep

During two previous captures in 1993 and 1997, SAE-067 tested positive for mites, and she was treated with ivermectin each time. In 1999, although both ears were occluded with waxy crusts, there was no evidence of an active *Psoroptes* spp. infection. Serological results were also negative for circulating antibodies against *Psoroptes.* The ewe was released from the enclosure back into the SAM on 5 October 1999.

Sentinel ram study

The ewe and first set of six sentinel rams were intensively monitored from 20 November 1999 to 30 November 2001. During this time, 161 visual observations and 595 satellite telemetry locations were obtained, revealing that the sentinel rams traversed the entire SAM, migrating up and down the range numerous times. The ewe remained within the vicinity of Bennett Mountain and Black Brushy Mountain. Two rams were killed by lions in April 2000 and April 2001, and one ram died of undetermined causes in September 2001. The original goal was to capture each bighorn every 4–6 mo for sampling, but this proved difficult. In 2000, the ewe and five of the rams were each captured at least once during two capture attempts. In 2001, the ewe and all remaining rams were recaptured between one and three times during four capture attempts. In all events, ear swabs, serology, or both were negative for *Psoroptes* spp. mites (Table 1), and no other extant bighorn were observed during the course of the study.

Psoroptes spp. survey

Most of the native bighorn sheep sampled in the SAM from November 1988 through June 1997 were infested with *Psoroptes* spp mites (30/32 samples; Table 1). Mites were not found on any samples from the lone remaining ewe (SAE-067) after June 1997, or any of the sentinel rams in this study. Mites were never found on bighorn sheep at the RRWA breeding facility or in free-ranging populations in New Mexico, other than the SAM (Table 1).

From 1989 to October 1997, mites were found in the ears of mule deer at several locations in and around the SAM, as well as at more distant locations such as the Bosque del Apache National Wildlife Refuge, New Mexico (Table 2). No mites were found in deer ear swabs examined after 1997, but samples were limited because of a substantial statewide decline in mule deer numbers. No mites were found on ear swabs from gemsbok (n=387), pronghorn (n=18), or Barbary sheep (n=1; Table 2).

Reintroduced bighorn sheep

No mites were found on 50 of the 51 bighorn sheep captured and translocated to the SAM in December 2002. However, ear crust and live mites were present on one ewe (SAE-092) from KNWR. The ears of this ewe were thoroughly cleaned to remove crust and mites, and she was given 2 cc of 1% ivermectin and fitted with cyfluthrin-impregnated ear tags before

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TABLE 1. Prevalence of *Psoroptes* in bighorn sheep in New Mexico.[a]

Date	Location	Sample	Prevalence (%)
Nov 1988	San Andres Mountains	Crust	9/10 (90)
Nov 1989	San Andres Mountains	Crust	8/9 (88.8)
Oct 1992	Red Rock Wildlife Area	Swabs	0/22 (0)
Oct 1993	San Andres Mountains	Swabs	11/11 (100)
Oct 1993	Red Rock Wildlife Area	Swabs	0/20 (0)
Jun 1997	San Andres Mountains	Swabs	2/2 (100)
Nov 1997	San Francisco River	Swabs	0/12 (0)
Nov 1997	Turkey Creek	Swabs	0/7 (0)
Aug 1998	Pecos Wilderness	Swabs	0/30 (0)
Jan 1999	Manzano Mountains	Swabs	0/9 (0)
Sept 1999	San Andres Mountains	Swabs	0/1 (0)
Nov 1999	Fra Cristobal	Swabs	0/16 (0)
Nov 1999	Red Rock Wildlife Area	Swabs	0/27 (0)
Nov 1999	Peloncillos	Swabs	0/6 (0)
Nov 1999	Big Hatchets	Swabs	0/3 (0)
Nov 1999	Animas	Swabs	0/2 (0)
Nov 1999	Little Hatchets	Swabs	0/5 (0)
Nov 1999	Ladrones	Swabs	0/1 (0)
Apr 2000	San Andres Mountains	Swabs	0/4 (0)
May 2000	Ladrones	Swabs	0/4 (0)
Sept 2000	San Andres Mountains	Swabs	0/5 (0)
Feb 2001	San Andres Mountains	Swabs	0/3 (0)
Mar 2001	San Andres Mountains	Swabs	0/2 (0)
Jun 2001	San Andres Mountains	Swabs	0/5 (0)
Aug 2001	Pecos Wilderness	Swabs	0/56 (0)
Nov 2001	San Andres Mountains	Swabs	0/4 (0)
Nov 2001	Red Rock Wildlife Area	Swabs	0/15 (0)
Nov 2002	Red Rock Wildlife Area	Swabs	0/30 (0)
Dec 2003	San Andres Mountains	Ears/swabs	0/3 (0)

[a] All San Andres Mountains samples after 1999 are part of the sentinel study.

transport and release into the SAM. This ewe has not died or been captured since translocation, so it is not known whether she still has live mites present in her ears. However, skin lesions suggestive of psoroptic scabies have not been seen during monthly field observations of the reintroduced animals. Likewise, mites have not been found on any bighorn sheep that have died (n=21) in the SAM since December 2002.

DISCUSSION

The epizootic of psoroptic scabies that was first detected in bighorn sheep in the SAM in 1978 persisted until 1997. Despite attempts to treat the herd with insecticidal dust bags and dips, ballistic implants, and injectable ivermectin (Sandoval, 1980; Boyce et al., 1992; Clark and Jessup, 1992), lesions and mites were consistently found in the bighorn sheep population for that 20-yr period (Lange et al., 1980; Sandoval, 1980; Hoban, 1990; Clark and Jessup, 1992; Logan and Sweanor, 2001; Table 1).

In September 1999, the last remaining native ewe was found to be free of mites, and the sentinel ram study from 1999–2001 confirmed that newly introduced bighorn sheep did not become infected with mites. Thus, the near extinction of the native bighorn sheep population finally accomplished what humans could not—the apparent elimination of *Psoroptes* spp. mites from the SAM herd.

The origin of *Psoroptes* spp. mites infecting bighorn sheep in the SAM will likely never be known. The presence of mites on mule deer in and around the

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TABLE 2. Prevalence of *Psoroptes* in mule deer and other ungulates in New Mexico.

Date	Location	Sample	Prevalence (%)
Mule deer			
Nov 1989	Oscura Mountains	Ears	2/2 (100)
Nov 1989	San Andres Mountains	Swabs	2/24 (8.3)
Nov 1989	South of North Oscura Peak	Swabs	11/34 (32.3)
Jan 1990	San Andres NWR	Ears	1/1 (100)
Mar 1990	Bosque del Apache NWR	Ears	2/2 (100)
Mar 1990	Bosque del Apache NWR	Ears	1/1 (100)
Apr 1990	Bosque del Apache NWR	Ears	2/2 (100)
Apr 1990	San Andres Mountains	Swabs	4/28 (14.3)
May 1990	McGregor Range	Swabs	0/31 (0)
Oct 1990	Salinas Peak	Swabs	11/38 (28.9)
Oct 1990	San Andres Mountains	Swabs	6/25 (24)
April 1991	San Andres Mountains	Swabs	1/37 (2.7)
May 1991	McGregor Range	Swabs	0/32 (0)
Oct 1991	Oscura Mountains	Swabs	4/17 (23.5)
Jan 1992	San Augustine Pass	Ears	1/1 (100)
May 1992	San Andres Mountains	Swabs	6/20 (30)
Fall 1992	Carson National Forest	Ears	0/1 (0)
Oct 1993	San Andres Mountains	Swabs	5/15 (33.3)
Jan 1996	Bosque del Apache NWR	Ears	1/1 (100)
Jan 1997	Oscura Mountains	Swabs	12/20 (60)
Sept 1997	Oscura Mountains	Swabs	5/16 (31.2)
Oct 1997	Oscura Mountains	Swabs	6/16 (37.5)
Oct 1997	San Augustine Pass	Swabs	3/3 (100)
Jun 2000	San Augustine Pass	Swabs	0/1 (0)
Oct/Nov 2002	WSMR/Main Range Post	Ears+Swabs	0/6 (0)
Dec 2003	WSMR	Swabs	0/21 (0)
Dec 2003	Organ Mountains	Swabs	0/6 (0)
Dec 2003	WSMR/Wood Ranch	Swabs	0/2 (0)
Dec 2003	San Andres NWR	Swabs	0/1 (0)
Apr 2004	San Andres Mountains	Swabs	0/31 (0)
Barbary sheep			
Apr 2000	San Andres Mountains	Swabs	0/1 (0)
Elk			
Apr 2004	San Andres Mountains	Swabs	0/1 (0)
Oryx			
Jan 1997	Tularosa Basin	Swabs	0/23 (0)
Feb 1997	Tularosa Basin	Swabs	0/18 (0)
Sept 2000	WSMR/Stallion Range Center	Swabs	0/56 (0)
Oct 2000	WSMR/South of 70	Swabs	0/9 (0)
Nov 2000	WSMR/Rhodes Canyon Range Center	Swabs	0/50 (0)
Dec 2000	San Andres NWR	Swabs	0/4 (0)
Dec 2000	WSMR	Swabs	0/73 (0)
Jan 2001	San Andres NWR	Swabs	0/5 (0)
Jan 2001	WSMR	Swabs	0/89 (0)
Feb–Apr 2002	San Andres NWR	Swabs	0/34 (0)
May 2002	WSMR/Stallion Range Center	Swabs	0/26 (0)
Pronghorn			
Sept 2000	WSMR/Stallion Range Center	Swabs	0/18 (0)

[a] WSMR = White Sands Missle Range; NWR = National Wildlife Refuge.

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SAM (Table 2) demonstrated that *Psoroptes* spp. mites were not limited to bighorn sheep. A key question addressed by the sentinel ram study was: do mule deer serve as a reservoir of mites that will infect bighorn sheep? The answer appears to be, "No." One caveat is that our sample size for mule deer was very low after 1997 because mule deer numbers declined markedly during the prolonged drought in the 1990s (Logan and Sweanor, 2001). Additionally, bighorn sheep and deer numbers were both very low during the sentinel study, perhaps reducing the opportunity for mites to be shared between the two host species.

The reason mite infections caused such serious clinical disease in SAM bighorn sheep is not known. Although psoroptic scabies has been linked to historical population declines of bighorn sheep in the western United States (Beuchner, 1960), most current infections seem to be subclinical (primarily confined to the ears) and not associated with any population-level effects (Sandoval, 1980; Mazet et al., 1992). One hypothesis is that mites in the SAM were more virulent than those found in other areas. However, mites from different bighorn sheep populations could not be distinguished from those found on SAM bighorn sheep by morphologic (Boyce et al., 1990), antigenic (Boyce and Brown, 1991), or molecular methods (Ramey et al., 2000). Another hypothesis is that bighorn sheep in the SAM were exceptionally susceptible to scabies. Genetic analysis of bighorn sheep from the SAM and RRWA (which were originally derived from SAM breeding stock) revealed that these populations had far less genetic variability than other bighorn sheep populations (Boyce et al., 1997, Gutierrez-Espeleta et al., 2001). Although no evidence links low genetic variability with enhanced susceptibility to psoroptic scabies, decreased heterozygosity (as was found in the SAM and RRWA bighorn sheep) has been associated with decreased survival in Soay sheep (Coltman et al., 1999).

The results of the sentinel study (no new mite infections), coupled with failure to find mites on mule deer after 1997, provided strong support for the decision to reintroduce bighorn sheep to the SAM in 2002. Animals were obtained from two locations (KNWR and RRWA) because of genetic considerations and the need to introduce a substantial number of animals. Bighorn sheep from the KNWR in Arizona were identified as suitable genetic reintroduction stock because they were highly variable compared with RRWA and SAM animals (Gutierrez-Espeleta et al., 2001). Despite the occasional sighting of *Psoroptes* spp. mites in the ears of KNWR bighorn (Sandoval, 1980), this population had proven to be a productive source of animals for several other bighorn sheep transplants in Arizona and other western states (Cunningham et al., 1993). Because only a limited number of animals were available from KNWR, 31 animals were also translocated from the RRWA. This ensured that at least some descendants of native SAM bighorn sheep were reintroduced, and it increased the starting size of the population.

During the capture and translocation effort in December 2002, one ewe from KNWR was found to have *Psoroptes* spp. mites and crusty material in both ears. After considerable discussion, the decision was made to transport her to the SAM rather than release her back into KNWR. She was treated for mites before transport, but it is possible that live mites were translocated with her into the SAM. It is not known whether this ewe is still infected with mites because she has not died or been re-examined since her release in 2002. However, since the translocation effort, scabies lesions have not been seen on live bighorn sheep during monthly field observations, and mites have not been found on examination of dead sheep.

The decision to relocate the *Psoroptes*-infected ewe from KNWR was controversial. If psoroptic scabies reoccurs in the SAM bighorn sheep population, it will not be possible to determine whether mites

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were reintroduced with the KNWR ewe or originated from some other infected host already present in the SAM. Because KNWR bighorn sheep have evidently coexisted with *Psoroptes* spp. mites for some period of time, it is also possible that any mites introduced by the KNWR ewe are less pathogenic than those responsible for the epizootic that begin in the 1970s.

We conclude that the epizootic of psoroptic scabies in the SAM bighorn sheep population has ended and that psoroptic scabies poses a minimal to nonexistent threat to the persistence of this population at this time. Current management efforts are focused on predator control (lion removal), habitat enhancement (prescribed fire), and herd health monitoring. It remains to be seen whether or not sheep numbers will increase to those seen in the 1970s (>200) before the onset of the scabies epizootic.

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