

Status, Distribution, and History of Rocky Mountain Bighorn Sheep in Utah

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Abstract: Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) are native to Utah, and were abundant prior to European settlement. Bighorn populations began declining in the late 1800s, and by the 1930s, no self-sustaining populations existed in Utah. In 1966, the Utah Division of Wildlife Resources began reintroducing bighorns into their former ranges. In 1988, Smith et al. reported 242 Rocky Mountain bighorns had been reintroduced in or near Utah resulting in 8 populations. No current information exists, however, regarding the status and distribution of bighorns in Utah. Our objectives were to document reintroductions of Rocky Mountain bighorns since 1988, and provide population estimates, discuss challenges, and offer recommendations for the management of these herds. We interviewed wildlife biologists from state, federal, and tribal agencies to obtain information regarding each bighorn herd in Utah. Over the past 20 years, 607 additional bighorns were reintroduced in or near Utah, 9 new populations were established, and 200 harvest permits were issued. As of winter 2007-2008, approximately 1,909 bighorns resided in or near Utah. Of the 17 herds in Utah, 4 failed, 5 were declining, 1 was stagnant, 3 were growing, and 4 were successful. Disease is the most important limiting factor for bighorns in Utah. Our results chronicle the history of bighorn reintroductions in Utah, and this compilation of updated information will aid in the conservation and management of this unique ungulate.

Key Words: hunting, *Ovis canadensis*, reintroduction, Rocky Mountain bighorn, translocation, Utah.

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Introduction

Rocky Mountain bighorn sheep are native to Utah (Buechner 1960, Rawley 1985). They were historically abundant and

extensively used by Native Americans, early explorers, and settlers (Dalton and Spillett 1971, Rawley 1985). Bighorn populations decreased throughout the state during the late 1800s, and by the 1930s, no stable

populations existed (Smith et al. 1988, Smith et al. 1991). Domesticated livestock, particularly sheep, competed directly with bighorns for range resources. Moreover, domestic sheep were the primary vectors that transmitted diseases to bighorns, which led to catastrophic die-offs (Goodson 1982, Jessup 1985, Bunch et al. 1999, Singer et al. 2000b). Habitat change, human settlement, and indiscriminate hunting also contributed to the decline of bighorn populations in Utah (Irvine 1969, Dalton and Spillett 1971, Smith et al. 1988).

In 1966, the Utah Division of Wildlife Resources (UDWR) began reintroducing Rocky Mountain bighorns to historical ranges. These reintroductions were met with limited success (Smith et al. 1988, Smith et al. 1991). Smith et al. (1988) documented the status and distribution of Rocky Mountain bighorn sheep populations in Utah from 1966 to 1988. At that time, the UDWR, Colorado Division of Wildlife (CDOW), and Ute Tribe Fish and Wildlife Department (UTFWD) had conducted 15 translocations, released 242 bighorns, and established 8 populations in or on the border of Utah. Furthermore, those authors provided a conservative estimate of 239 bighorns in Utah and indicated that no harvest permits were available during that time (Smith et al. 1988).

Since 1988, bighorns in Utah have increased because of translocations, improved management, and high population growth rates in several herds. Our objectives were to update the status and distribution of Rocky Mountain bighorn populations in Utah, discuss challenges and limiting factors influencing each herd, and present the number of harvest permits sold and filled since 1991. This information will assist the UDWR in managing bighorns state wide and inform the interested public of the status and distribution of this unique mountain ungulate in Utah.

Methods

Desert bighorn (*O. c. nelsoni*), California bighorn (*O. c. californiana*), and Rocky Mountain bighorn sheep occupy areas in Utah. We recognize that recent morphometric evidence indicates that Rocky Mountain and California bighorns should not be considered separate subspecies (Wehausen and Ramey 2000); however, the UDWR retains this classification of two subspecies. Here, we refer to Rocky Mountain bighorns, unless otherwise specified.

We defined a reintroduction as moving bighorn sheep into an area without bighorns present and an augmentation as moving bighorn sheep into a location with bighorns already present. We used the term translocation to indicate moving bighorns from one location to a different location. Translocations often refer to reintroductions and augmentations collectively. Also, if multiple translocations occurred in an area within the first year, we considered all these releases as an initial reintroduction (Singer et al. 2000a).

We documented the histories and locations of each bighorn reintroduction by reviewing literature and contacting state, federal, and tribal biologists. We estimated the number of bighorns in each population by reviewing flight data from 2006 and 2007, conducting terrestrial counts by tracking collared animals, and interviewing local biologists. Desolation Canyon, Jack Creek, Bighorn Mountain, and Harper's Corner are rugged and inaccessible areas; therefore, the UDWR adjusted the minimum number of animals observed from aircraft using a 0.6 sighting probability factor to estimate population sizes in those areas (K. Hersey, UDWR, personal communication). Population counts for all other herds were

minimum estimates, mostly obtained from terrestrial counts.

We contacted local biologists to identify potential limiting factors, habitat improvement projects, and the overall status of each bighorn herd. We determined causes of bighorn mortalities for the Mount Nebo, Mount Timpanogos, and Rock Canyon herds by retrieving and assessing carcasses of collared sheep. We sent carcasses that were not consumed by scavengers or bloated because of exposure to high temperatures to the Utah Veterinary Diagnostic Laboratory in Nephi, Utah, for necropsy.

Furthermore, we categorized each bighorn herd as successful, growing, stagnant, declining, or failed. Successful herds reached the minimum viable population number of 125 animals or the management objective number designated by wildlife managers. We considered growing herds to have more animals than released, stagnant herds to have the same number of animals as released, and declining herds to have fewer animals than released. Finally, we considered failed herds as having no bighorns present.

We quantified the number of bighorn harvest permits sold and filled, the amount of money generated from each permit, and the average number of days hunters spent in the field by reviewing harvest records from the UDWR and by conversing with a biologist from the UTFWD. We also contacted members of the Utah Chapter of the Foundation for North American Wild Sheep (UFNAWS) for Boone and Crockett scores of rams harvested in Utah.

Results

Since 1966, 46 bighorn translocations have occurred in or near Utah, 36 of which were conducted by the UDWR (Table 1). The other 10 translocations were

conducted by the Nevada Department of Wildlife (NDOW), CDOW, and UTFWD. In all, 17 bighorn populations have been established in or near Utah. Of those herds, 4 failed, 5 were declining, 1 was stagnant, 3 were growing, and 4 were successful. A total of 849 bighorns were translocated in or near Utah (755 from out of state and 94 within state), and currently an estimated 1,909 bighorns reside in or on the borders of Utah.

Bighorn Herds

Brigham City (1966). – The UDWR selected Brigham City for the first bighorn reintroduction site in Utah (Fig. 1). From 1966-1970, 4 bighorn translocations occurred, resulting in the release of 60 animals (Table 1). Bighorns were held in a fenced enclosure on the mountain prior to being released and would occasionally escape, traveling south to nearby Willard Peak (8 km) and north to the Wellsville Mountain Range (10 km; Dalton and Spillet 1971). In 1973, a mature ram from Brigham City was observed in Weber Canyon, 64 km south of the release site (Stapley 1974). Unfortunately, this herd did not persist due to poaching and diseases contracted from domestic livestock including pneumonia and bronchitis (Smith et al. 1988). Close proximity to areas with domestic sheep and urban encroachment lessen the value of this site for reintroductions in the future. Further information regarding the Brigham City reintroduction is provided by Stapley (1974) and Smith et al. (1988).

Desolation Canyon (1970). – This herd is managed by the UDWR and UTFWD. Between 1970 and 1973, 21 bighorns from Wyoming and Alberta were released in Desolation Canyon (Fig. 1; Table 1). Smith et al. (1988) estimated this herd at 75-100 animals in 1988. Recently, UTFWD and UDWR biologists estimated 733 bighorns in Desolation Canyon (Table 2). Herd growth

was partially due to 2 UTFWD augmentations in 1998 which added 64 sheep (Table 1). Furthermore, high lamb production and recruitment has perpetuated the rapid growth of this herd. Even during recent years of drought, this population recruits 30 lambs/100 ewes (B. Crompton, UDWR, personal communication).

Limiting factors for this herd included mountain lion (*Puma concolor*) predation and pinyon-juniper (*Pinus edulis* and *Juniperus spp.*) encroachment. Biologists have attempted to remove mountain lions that prey on bighorn sheep. Tracking and killing specific mountain lions, however, has been difficult because of the ruggedness of the terrain (B. Crompton, personal communication). Also, in 2008, the UTFWD is planning a prescribed burn on tribal lands in Florence Creek to improve bighorn habitat (K. Courts, UTFWD, personal communication). Additionally, lack of water sources may have limited range use and influenced population persistence in this area. To alleviate this problem, several guzzlers have been installed and five more will be constructed next year potentially allowing bighorns to expand range use (B. Crompton, personal communication).

To minimize interactions with domestic sheep in the area, the UFNAWS spent \$400,000 to convert domestic sheep grazing permits to allotments for cattle (D. Peay, UFNAWS, personal communication). The Bureau of Land Management (BLM) also eliminated a number of domestic sheep allotments in order to reduce the probability of disease related die-offs in this area. In summary, the Desolation Canyon population is the largest herd of bighorn sheep in the state and has served as a source population for 2 bighorn herds in Utah: Mount Timpanogos and Carter Creek (Table 1).

Mount Nebo (1981 and 2004). – In winter 1981, 27 bighorns were captured at Whiskey Basin, Wyoming, and released on Mount Nebo. This herd was augmented with 21 additional sheep from Whiskey Basin the following year (Table 1). Bighorns were held in a fenced enclosure prior to reintroduction, similar to the Brigham City herd. In summer 1983, 55 bighorns were observed. Severe winters in 1983 and 1984, competition with deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*), poaching, and interactions with domestic sheep decimated this herd (Smith et al. 1988). By 1987, only 5 bighorns remained.

In December 2004, the UDWR released 18 bighorns from Augusta, Montana, onto the slopes of Mount Nebo (Table 1). To decrease the probability of contact with domestic sheep, the UFNAWS spent \$50,000 to convert domestic sheep allotments to cattle allotments in this area (D. Peay, personal communication). To reduce mountain lion predation, the UDWR increased mountain lion harvest permits to 20 per year on Mount Nebo. To date, 5 bighorn sheep have died due to mountain lion predation. Additionally, several wildfires have occurred in this area in recent years, thereby increasing the amount of available bighorn habitat by converting conifers and mountain brush to forb-grass habitat.

In December 2006, we observed 37 bighorns on Mount Nebo, and the herd had doubled in 2 years. In January 2007, 25 bighorns from Augusta, Montana were released onto the mountain, increasing the total number of bighorns to 62 (Table 1). Unfortunately in spring 2007, domestic sheep were observed interacting with bighorns and soon thereafter 7 collared ewes died from pneumonia. Of the 37 bighorns observed in 2006, only 11 survived to 2008. Interestingly, only 1 of the 25 bighorns released in 2007 died from disease, possibly

because these animals had little interaction with bighorns from the 2004 reintroduction. Also, bighorns released in 2007 used different areas than bighorns released in 2004. As of winter 2008, we estimated 35 animals occupied Mount Nebo (Table 2).

Domestic sheep continue to threaten the persistence of bighorns on Mount Nebo. In 2007, there were 6 sightings of domestic sheep with bighorns, or in bighorn habitat. No domestic sheep allotments currently exist on Mount Nebo; yet, domestic sheep still frequent this area, raising serious management concerns. Usually, dispersing bighorn rams are the vector for transmitting diseases to bighorn herds (Gross et al. 2000), but in this population, domestic sheep have trespassed into bighorn habitat. It seems unlikely that this herd will succeed unless domestic sheep are eradicated from the area and prevented from returning.

Bear Mountain (1983). – During 1983 and 1984, 38 bighorns were captured at Whiskey Basin, Wyoming, and released on Bear Mountain (also referred to as Bare Top Mountain). From 2000 to 2001, 10 additional bighorns were released to potentially increase genetic diversity (Table 1). This population has been studied extensively and has benefited from many habitat improvement projects over the last 20 years (Greenwood et al. 1998, Smith et al. 1999). In the 1990s, this area was treated with prescribed burns and clear-cut logging. Afterward, Greenwood et al. (1998) found bighorn group size significantly increased in treated areas, and these authors postulated that burned areas would be a key habitat component for bighorns to expand range use in this area. Smith et al. (1999) suggested that bighorns moved into treatment areas possibly because of improved visibility for predator detection. In 1995, UDWR biologists collared 36 bighorns, and mountain lion predation was responsible for

45% of recovered carcasses (C. Greenwood, UDWR, personal communication).

In the 1970s, domestic sheep allotments were purchased or closed in anticipation of restoring bighorns to this area. During 1993 and 1994, however, a slight die-off occurred and decreased the herd to about 50 animals (C. Greenwood, personal communication). Although unconfirmed, disease possibly played a role in the die-off. This population has since recovered, and biologists currently estimate 100 bighorns in the Bear Mountain herd. Additionally, bighorn sheep from Bear Mountain have been captured and translocated to other areas in the state to augment existing herds and to establish new populations. In 1993, 2 bighorns were translocated to the Pilot Mountains, and in 2000, 15 bighorns were released in Jack Creek (Table 1).

Beaver Creek (1983). – In 1983, the CDOW released 21 bighorns from Basalt Ranch, Colorado, into the Beaver Creek Drainage on the border of Utah and Colorado in northeastern Utah (Table 1). Four months later, 3 rams from Beaver Creek were observed with the Bear Mountain herd, 43 km to the west (Smith et al. 1988; Fig. 1). In the early 1990s, a collared ram was observed with a herd of domestic sheep 15 km away near Cold Springs Mountain, Colorado (C. Greenwood, personal communication). Shortly after, a major die-off occurred, reducing the estimated 80-90 bighorn sheep to 10 individuals (C. Heyd, National Park Service, personal communication). Later that year, CDOW and UDWR biologists located and killed all remaining bighorns in an attempt to clear the area of diseased animals, because additional reintroductions were scheduled to occur west of the Beaver Creek Drainage (C. Greenwood, personal communication). This reintroduction was considered a failure

because of fatal interactions with domestic sheep.

Harper's Corner (1984). – This herd is located in Dinosaur National Monument on the border of Utah and Colorado and is managed by the National Parks Service (NPS). In 1952, the CDOW released 32 bighorn sheep near Ladore Canyon, Colorado, just outside Utah (Smith et al. 1988). In 1984, the CDOW released 19 additional bighorns at Harper's Corner, Utah, across the Green River from Ladore Canyon (Smith et al. 1988; Fig. 1). This herd was augmented twice by the CDOW from 1997 to 2000, adding 48 bighorns to this population (C. Heyd, personal communication; Table 1).

In 1999, biologists estimated 150 bighorns resided in the Harper's Corner herd; however, this population has since decreased to 93 animals (Table 2). Biologists attribute the decline of bighorn sheep in this area to disease (C. Heyd, personal communication). The possibility of disease transmission from domestic sheep is high, as grazing allotments for these animals border the Monument. In spring 2006, bighorn lamb production was 45 lambs/100 ewes. Yet, winter lamb-to-ewe ratios were 11 lambs/100 ewes later that year (C. Heyd, personal communication). Another limiting factor is mountain lion predation which occurs in this area, but its impact on the herd is unknown. Additionally, poaching was reportedly a problem in the 1980s and 1990s, although it likely had a minimal impact on the number of bighorns in this area (C. Heyd, personal communication).

Estimating how many bighorns reside in Utah is difficult, as bighorns often swim the Green River and spend time in both states. The NPS initiated a study in 2006 to determine the movements of bighorns within the Monument. Biologists observed 56 sheep during their study and equipped 20 animals with GPS collars, 7 of

which were captured in Utah (C. Heyd, personal communication). Also, the NPS has improved and enhanced bighorn habitat throughout the area by conducting prescribed burns of pinyon-juniper forests.

Deep Creek Mountains (1984). – The Deep Creek Mountains are located in the Great Basin of Utah, and were inhabited by bighorns historically (Dalton and Spillett 1971). In 1984, 16 bighorns were released on the Deep Creek Mountain Range south of Wendover, Utah (Fig. 1). In 1989, this population was augmented with 14 additional bighorns (Table 1). Initially, habitat in this area appeared promising due to the presence of high elevation summer range, extensive winter range, low competition with deer herds, and abundant water sources (UDWR, 1990). However, this herd failed likely because of interactions with wintering domestic sheep near the Trough Springs-Lime Springs area and cougar predation (UDWR, 1990). Indeed, 3 of the 4 confirmed mortalities from 1987 to 1989 were from predation by cougars (UDWR, 1990).

A viable population of bighorns can possibly inhabit the Deep Creek Mountains; however, extensive juniper cover, potential interactions with domestic sheep, and mountain lion predation are problematic. If these potential limiting factors are resolved, the UDWR may transplant 50 California bighorn sheep from Antelope Island State Park, Utah, to the Deep Creek Mountain Range in 2010 (K. Hersey, personal communication).

Pilot Mountain (1987). – Similar to the Deep Creek Mountains, Pilot Mountain is located in the Great Basin and was inhabited by bighorns historically (Dalton and Spillett 1971). This herd is located north of Wendover on the border of Utah and Nevada (Fig. 1), and is managed by the

UDWR and the NDOW. Both states have released animals in the area. The Pilot Mountain herd originated in 1987, with 24 sheep translocated from Basalt Ranch, Colorado. From 1987 to 1998, a total of 58 animals were released on Pilot Mountain (Table 1). These animals have moved extensively and have been observed 13 km south on the Leppy Hills in Nevada and the Silver Island Mountains in Utah. In 1999, the UDWR estimated 100 bighorns occupied the Pilot Mountain Range (UDWR 1999; Table 2); although, this may have been an overestimation (K. Enright, UDWR, personal communication). In July 2006, we observed 25 bighorns on the Silver Island Mountains. The current population estimate for this herd is 40 animals (K. Huebner, NDOW, personal communication; Table 2).

Pilot Mountain receives a mean of 12 cm of precipitation annually. To alleviate water related stress, the NDOW plans to replace an old guzzler in Miners Canyon, which has recently been frequented by bighorns. The NDOW also plans to convert an upland game guzzler to a big game guzzler on Leppy Hills (K. Huebner, personal communication). The major concern for this herd is the close proximity of domestic sheep that seasonally occupy Leppy Hills. At present, there are no plans to augment this herd until the domestic sheep issues are resolved.

Sheep Creek (1989). – This herd originated in 1989 with the release of 21 sheep captured near Whiskey Basin, Wyoming. Between 2000 and 2001, 7 additional sheep were released in the area (Table 1). This herd is monitored by tracking several animals equipped with radio-collars, and this area is aerial surveyed yearly to obtain population estimates (C. Greenwood, personal communication). In the mid 1990s, this herd experienced a lamb die-off. Assuming that lungworm (*protostrongylus*

spp.) infestations were the source of lamb mortality, local biologists responded by medicating bighorns with fenbendazole. This treatment has purportedly increased recruitment (C. Greenwood, personal communication). The management goal is to have 75 bighorns in this area and as of 2007, 55 bighorns were present (Table 2).

Pinyon-juniper encroachment due to fire suppression has occurred in Sheep Creek, resulting in decreased visibility for bighorns which may potentially increase mountain lion predation. Concerned with predation on bighorns, the UDWR increased the number of harvest permits for mountain lions in the Sheep Creek area. At its highest point, 10 mountain lion permits were issued (C. Greenwood, personal communication). The UDWR and United States Forest Service (USFS) have plans to conduct prescribed burns in Sheep Creek and neighboring areas, specifically to increase visibility for bighorns and enhance bighorn habitat.

Hoop Lake (1989). – In 1989, 23 bighorns were released near Hoop Lake on the North Slope of the Uintah Mountains (Table 1). Due to low recruitment and ongoing contact with domestic sheep, the UDWR has been reluctant to augment the Hoop Lake herd. Bighorn sheep and domestic sheep shared a summer range near Burrow Peak, and the range use of these 2 species also overlapped on private land near Gregory Basin (R. Wood, UDWR, personal communication). Biologists were also concerned with high lungworm infestations in this herd and medicated bighorns each winter with fenbendazole.

Contrary to most areas that bighorn populations occupy in Utah, cougar predation has not been observed in the Hoop Lake herd. Few mule deer winter near Hoop Lake, resulting in less overlap of cougars and bighorns on winter range. Coyote

predation, however, has purportedly been a limiting factor, particularly impacting lamb survival (R. Wood, personal communication). Indeed, in other areas, these canids have been efficient predators of young bighorns (Hebert and Harrison 1988, Hass 1989).

Bighorns from the Hoop Lake population have been observed interacting with the nearby Sheep Creek herd in northeastern Utah (Fig. 1). UDWR biologists plan to radio-collar several sheep in winter 2008 to better understand herd movements (R. Wood, personal communication). In 2000, the population estimate was 7 animals. Recently, this population has increased to 26 animals (Table 2).

Bighorn Mountain (1993). – Bighorn sheep on Bighorn Mountain have high growth rates and exceptional survival (B. Crompton, personal communication). From 1993 to 1995, 54 bighorns were released into this area (Table 1). In 2007, there were an estimated 505 sheep on Bighorn Mountain (Table 2). This area has abundant bighorn habitat. It is similar to nearby Desolation Canyon and Jack Creek in that it receives little snowfall in winter and has new-growth forage nearly year round (Fig. 1). Mountain lion predation has been documented, but reportedly has had little effect on the growth of this herd.

Wildlife managers are concerned about water availability and pinyon-juniper encroachment in this area. The UDWR placed several big-game guzzlers on Bighorn Mountain, with plans to install 5 more in 2008. UDWR biologists are also interested in habitat improvement projects that will reduce tree cover in this area (B. Crompton, personal communication). Disease has had little influence on this herd, partially because several domestic sheep allotments were purchased in the early

1990s, and the BLM closed several others during this time. Two years ago, however, a domestic goat was observed interacting with a band of bighorns (B. Crompton, personal communication). Overall, this herd is considered a success.

Jack Creek (2000). – This herd is located 64 km north of Bighorn Mountain along the Green River corridor. In 2000, 15 bighorns from Bear Mountain, Utah, were reintroduced into the area. The following year, 15 more bighorns were augmented to this herd from Montana (Table 1). This herd has experienced substantial growth over the past 8 years. In 2008, biologists estimated 72 bighorns in the area (Table 2). Bighorns from Jack Creek occur as a metapopulation with animals in Desolation Canyon and Bighorn Mountain (B. Bates, UDWR, personal communication; Fig. 1).

When sheep were initially placed in Jack Creek, many were radio-collared, and UDWR biologists documented several bighorn mortalities due to mountain lion predation (B. Crompton, personal communication). Although mountain lion predation has occurred, it has purportedly not inhibited population growth. In 2006, the Trail Canyon Fire improved habitat for bighorns, and possibly encouraged range expansion. The biggest concern for bighorns in Jack Creek is disease. Nine Mile Canyon is north of Jack Creek and has abundant bighorn habitat, but domestic sheep also occur in this area.

Carter Creek (2000). – From 2000 to 2003, 3 bighorn translocations occurred in Carter Creek totaling 24 animals (Table 1). Bighorns in Carter Creek intermixed frequently with animals from Sheep Creek, establishing a metapopulation. The Flaming Gorge Reservoir separates these 2 herds from the Bear Mountain and Goslin Mountain herds (Fig. 1). Regardless, sheep

swim the reservoir and some mixing occurs (Smith 1992). Similar to other herds in northeastern Utah, bighorns in Carter Creek experience persistent mountain lion predation. Pinyon-juniper encroachment has also been a problem in this area. In nearby areas, prescribed burning and logging have proven successful in increasing bighorn habitat and promoting range expansion (Greenwood et al. 1998, Smith et al. 1999). Wildlife managers are planning to implement these habitat improvement projects in Carter Creek in the near future (C. Greenwood, personal communication). Dense tree cover also makes it difficult to get accurate population counts. Therefore, biologists collared several animals and conducted population counts from the ground with greater success. This herd has an estimated 45 animals and is growing (Table 2).

Mount Timpanogos (2000). – Eighty-two bighorn sheep have been released on Mount Timpanogos over the past 8 years (Table 1). The first release occurred in Grove Creek Canyon near Pleasant Grove, which was where one of the last sightings of a bighorn ewe occurred before Rocky Mountain bighorn sheep were extirpated from Utah (Dalton and Spillet 1971). Bighorns on Mount Timpanogos have been monitored continuously since release. In 2007 and 2008, we documented cause-specific mortalities for 10 bighorns: 2 died from disease, 3 were killed by mountain lions, 2 were hit by automobiles, 2 were stranded at high elevations during winter, and 1 cause of death was unknown. Moreover, lambs were seldom recruited into this herd. In spring 2007, we counted 28 lambs born, but only 4 survived to winter. This low survivorship was likely the result of disease. Recently, we estimated 51 bighorns on Mount Timpanogos (Table 2).

In 2007, 20 bighorns from Sula, Montana, and 18 bighorns from Alamosa, Colorado, were released on Mount Timpanogos (Table 1). These newly augmented sheep interacted infrequently with resident sheep (sheep released from 2000 to 2002). Furthermore, newly augmented bighorns resided at higher elevations and used areas outside the home range of resident bighorns. For instance, from 2000 to 2006, only 5 resident bighorns were observed at elevations > 3,000 m. In 2007, however, we observed 30 bighorns at elevations > 3,000 m. These newly augmented bighorns may have used habitats similar to bighorns in their source herd. For example, bighorns from Alamosa, Colorado used winter ranges at 3,000 m and summer ranges up to 4,200 m in their source herd. Overall, this use of dissimilar habitats by these animals is promising for the future of this herd because it may reduce competition among conspecifics for resources thereby increasing carrying capacity.

Rock Canyon (2001). – Twenty two bighorn sheep from Hinton, Alberta, were reintroduced into Rock Canyon in 2001. This herd was recently augmented in January 2007, with 5 ewes from Sula, Montana and 5 ewes from Augusta, Montana (Table 1). Similar to the Mount Timpanogos herd, bighorns released in Rock Canyon in 2007 seldom interacted with resident bighorns released in 2001. Additionally, these augmented bighorns have occupied areas outside the home range of resident bighorns. For instance, we never observed a resident bighorn give birth outside of Rock Canyon; however, 5 of the 10 augmented bighorns gave birth in areas other than Rock Canyon in spring 2007. Again, this range expansion may be beneficial for this herd.

This population has experienced stagnant growth over the past 7 years,

mainly because lamb survival to first winter has been extremely low. In 2007-2008, we documented cause-specific mortalities for 19 bighorns: 14 died from disease, 2 were hit by automobiles, 1 was killed by a mountain lion, and 2 were unknown. Although there are no domestic sheep allotments near Rock Canyon, we often encounter stray domestic animals interacting with bighorns, or in bighorn habitat. In fall 2007, UDWR biologists removed 5 domestic sheep and 6 domestic goats near Rock Canyon. One of these domestic sheep was mingling with a group of 4 bighorns at the time it was removed. Recently, this herd experienced a partial die-off. In January 2008, we counted 41 animals. Since then, at least 12 bighorns have died from pneumonia. We estimated fewer than 29 bighorns now occupy Rock Canyon.

Rock Canyon has exceptional lambing habitat; however, summer and winter ranges are in close proximity to the urban interface, and bighorn were often seen in yards, on roads, and in parks especially during drought years. Only one perennial source of water exists in Rock Canyon, and bighorns have been observed drinking from fountains and swimming pools in residential neighborhoods. Bighorns in Rock Canyon and Mount Timpanogos are considered a metapopulation (Fig. 1), as ewes and rams often cross State highway 189 and interact with neighboring herds.

Goslin Mountain (2005). – The Goslin Mountain herd is the most recent reintroduced population of bighorns in Utah. Over the past 3 years, 76 bighorns from Montana have been released on Goslin Mountain (Table 1). Recruitment has been high for this young herd (C. Greenwood, personal communication). In winter 2007, UDWR biologists estimated 125 bighorn in this population (Table 2). Similar to other herds in northeastern Utah, mountain lion

predation on bighorns occurs on Goslin Mountain, but its impact on population growth appears to be minimal. Pinyon-juniper encroachment was not a limiting factor in this area. In 2002, the Mustang Ridge Fire burned nearly 8,094 hectares (20,000 acres), subsequently expanding and improving available bighorn habitat. The USFS and UDWR combined efforts to reseed much of the area including steep slopes near rock outcroppings and cliffs. This herd has benefited from these habitat improvements and as a result, has possibly the highest potential to succeed of all the bighorn herds in northeastern Utah (C. Greenwood, personal communication).

Hunting Permits

In 1988, no hunting permits were available in Utah for Rocky Mountain bighorn sheep (Smith et al. 1988). In 1991, the first 3 rams were harvested near Rattlesnake Canyon, which is part of the Desolation Canyon herd. Since then, the UDWR has issued 153 Rocky Mountain bighorn ram tags in 5 hunting units, with a success rate of 98% (Fig. 2). The UTFWD sold 12 Rocky Mountain bighorn ram tags to the public, with a harvest rate of 100%. They also issued 35 tags to Ute Indian tribe members with a success rate of roughly 50%. Overall, 200 hunting permits have been issued in Utah since 1991.

Bighorn Sheep hunters spent an average of 8.8 days per hunt. The largest ram harvested in Utah was shot in 2006 on Ute tribal lands and scored 195 4/8 Boone and Crockett (R. Foutz, UFNAWS, personal communication). The most expensive tag purchased in Utah was sold for \$85,000 on the Ute tribal lands (K. Courts, personal communication). Other tags in Utah have sold for as much as \$82,500 (R. Foutz, personal communication). To date, over \$1,155,000 has been raised from bighorn sheep conservation tags (K. Hersey,

personal communication). Similar to other states, conservation tags generate a significant amount of money each year for bighorn research, habitat improvement projects, and translocations (Krausman 2000).

Discussion

Bighorn sheep inhabited nearly every mountain range in Utah prior to European settlement (Dalton and Spillet 1971), but by the 1930s they were virtually extirpated from the state. Since 1966, bighorns have been restored to many of their historical ranges in Utah thanks to the efforts of several state, provincial, tribal, and federal agencies, as well as many conservation groups (Fig. 2). Although the number of bighorns in Utah has grown from 239 animals to over 1,900 animals over the past 2 decades, most populations face an uncertain future. Of the 17 herds reintroduced in Utah, 4 failed, 5 are declining, 1 is experiencing stagnant growth, 3 are growing, and 4 are considered successful. Furthermore, the 4 successful herds contain over 76 % of the bighorns in Utah. Six of the 14 extant herds, however, have been established for less than 8 years, and more time is needed to assess their long-term levels of success (Table 2).

The UDWR has identified several areas they would like to reintroduce Rocky Mountain bighorns, including Lower Desolation Canyon and Nine Mile Canyon in eastern Utah, and Indian Canyon, Diamond Mountain, and Ashley Creek in northeastern Utah. Additionally, Avintaquin Canyon in the Wasatch Mountains is scheduled to receive bighorns in the winter of 2008-2009. To increase the probability of successful reintroductions, the UDWR is identifying potential limiting factors in these areas, with plans to address them prior to reintroducing bighorns.

Management Implications

The number of bighorns initially released into an area can influence the success of a reintroduction. In the western United States, from 1923 to 1997, bighorn reintroductions were deemed unsuccessful if the average ($\pm SD$) number of animals released was 30 ± 3.5 ; whereas, successful translocations averaged 41 ± 4.3 bighorns released (Singer et al. 2000a). In Utah, from 1966 to 2008, the mean number of bighorns initially reintroduced was 22 ± 7.4 (range = 9-48; Table 1). To enhance the success of future reintroductions in Utah, we recommend that wildlife managers increase the number of bighorns initially released to a minimum of 41 animals.

Diseases contracted from domestic sheep are by far the most serious limiting factors for bighorn populations in Utah. Recent recommendations for reintroducing bighorns indicate that a 23 km buffer is needed to reduce the probability of bighorns and domestic sheep from co-mingling (Singer et al. 2001). In Utah, the 4 reintroductions that failed were partially or entirely due to diseases transmitted by domestic sheep. Furthermore, all 6 bighorn herds experiencing declining or stagnant growth either had direct contact, or share seasonal ranges, with domestic sheep. Conversely, the 3 growing and 4 successful herds in Utah have had little to no contact with domestic sheep, in part because the UFNAWS spent nearly \$1,000,000 purchasing or converting domestic sheep allotments to cattle allotments (D. Peay, personal communication). We recommend that wildlife biologists assess bighorn habitat and its proximity to domestic sheep prior to future reintroductions to ensure that these areas are separated by at least 23 km (Singer et al. 2000a).

Finally, bighorn sheep are one of the rarest ungulates in North America (Valdez and Krausman 1999), and small populations of these animals are more susceptible to extinction (Berger 1990). Rocky Mountain bighorn sheep are an integral part of the biodiversity in Utah and are an important game species. The UDWR Statewide Management Plan for Bighorn Sheep (2008) indicates that it is important to establish viable bighorn populations for consumptive and non-consumptive uses. Since the UDWR has plans for several additional reintroductions and translocations of Rocky Mountain bighorns in Utah, we recommend continual monitoring of these herds to identify, mitigate, and remove potential limiting factors, and to determine if populations have been established successfully. Successes and failures of reintroductions are often poorly documented (Short et al. 1992), and much can be learned to enhance the success of translocations (Krausman 2000). Hopefully, this review of the last 4 decades of bighorn management in Utah will help to identify areas of improvement and facilitate the establishment, perpetuation, and conservation of this unique mountain ungulate in Utah.

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Table 1. Area, year, number of animals released, and source herds for all reintroduced populations of Rocky Mountain bighorns in or bordering Utah.

Population	Year Released	# Released	Source Herd
Brigham City	1966	14	Whiskey Basin, WY, USA
Brigham City	1966	20	Waterton, AB, Canada
Brigham City	1969	12	Banf, AB, Canada
Brigham City	1970	14	Banf, AB, Canada
Desolation Canyon	1970	9	Ute Tribe, Whiskey Basin, WY, USA
Desolation Canyon	1973	12	Ute Tribe, AB, Canada
Desolation Canyon	1998	44	Ute Tribe, Kaleden, BC, Canada
Desolation Canyon	1998	20	Ute Tribe, Fowler, CO, USA
Mount Nebo	1981	27	Whiskey Basin, WY, USA
Mount Nebo	1982	21	Whiskey Basin, WY, USA
Mount Nebo	2004	18	Augusta, MT, USA
Mount Nebo	2007	25	Augusta, MT, USA
Bear Mountain	1983	19	Whiskey Basin, WY, USA
Bear Mountain	1984	17	Whiskey Basin, WY, USA
Bear Mountain	2000	7	Almont Triangle, CO, USA
Bear Mountain	2001	3	Basalt Ranch, CO, USA
Beaver Creek	1983	21	CDOW, Basalt Ranch, CO, USA
Harper's Corner	1952	32	CDOW, unknown
Harper's Corner	1984	19	CDOW, Rocky Mtn. Nat. Park, CO, USA
Harper's Corner	1997	21	CDOW, Dome Rock State W. A., CO, USA
Harper's Corner	2000	27	CDOW, Georgetown, CO, USA
Deep Creek Mountains	1984	16	Whiskey Basin, WY, USA
Deep Creek Mountains	1989	14	Whiskey Basin, WY, USA
Pilot Mountain	1987	24	Basalt Ranch, CO, USA
Pilot Mountain	1993	2	Bear Mountain, UT, USA
Pilot Mountain	1998	32	NDOW, unknown
Sheep Creek	1989	21	Whiskey Basin, WY, USA
Sheep Creek	2000	6	Almont Triangle, CO, USA
Sheep Creek	2001	1	Basalt Ranch, CO, USA
Hoop Lake	1989	23	Whiskey Basin, WY, USA
Bighorn Mountain	1993	26	Estes Park, CO, USA
Bighorn Mountain	1995	28	Georgetown, CO, USA
Jack Creek	2000	15	Bear Mountain, UT, USA
Jack Creek	2001	15	Sula, MT, USA
Carter Creek	2000	10	Almont Triangle, CO, USA
Carter Creek	2001	18	Basalt Ranch, CO, USA
Carter Creek	2003	6	Desolation Canyon, UT, USA
Mount Timpanogos	2000	25	Desolation Canyon, UT, USA
Mount Timpanogos	2001	10	Hinton, AB, Canada
Mount Timpanogos	2002	9	Sula, MT, USA
Mount Timpanogos	2007	20	Sula, MT, USA
Mount Timpanogos	2007	18	Alamosa, CO, USA
Rock Canyon	2001	22	Hinton, AB, Canada
Rock Canyon	2007	10	Sula, MT / Augusta, MT, USA
Goslin Mountain	2005	34	Thompson Falls, MT, USA
Goslin Mountain	2007	42	Sula MT / Rock Creek , MT, USA

Table 2. Area, year founded, number of translocations and animals released, past and present population estimates, and status of each bighorn herd in Utah. Four herds failed, 5 populations experienced a decline in bighorns, 1 population is stagnant, 3 populations have experienced growth, and in 4 herds the number of bighorns increased.

Population	Year Founded	Trans-locations	Animals Released	1988 Estimate	1999 Estimate	2007 Estimate	Status
Brigham City	1966	4	60	0	0	0	Failed
Desolation Canyon	1970	4	85	75 - 100	300	733	Success
Mount Nebo	1981	2	48	10 - 15	0	0	Failed
Mount Nebo	2004	2	43	10 - 15	0	35	Declining
Bear Mountain	1983	4	46	70	100	100	Success
Beaver Creek	1983	1	21	30	0	0	Failed
Harpers Corner	1952	4	99	30 - 35	150	93	Declining
Deep Creek Mtns.	1984	2	30	35	?	0	Failed
Pilot Mountain	1987	3	58	24	100	40	Declining
Sheep Creek	1989	3	28	0	50	55	Growing
Hoop Lake	1989	1	23	0	50	26	Stagnate
Bighorn Mountain	1993	2	54	0	140	505	Success
Jack Creek	2000	2	30	0	0	72	Growing
Carter Creek	2000	3	34	0	0	45	Growing
Mount Timpanogos	2000	5	82	0	0	51	Declining
Rock Canyon	2001	2	32	0	0	29	Declining
Goslin Mountain	2005	2	76	0	0	125	Success
Total		46	849	239-309	890	1909	

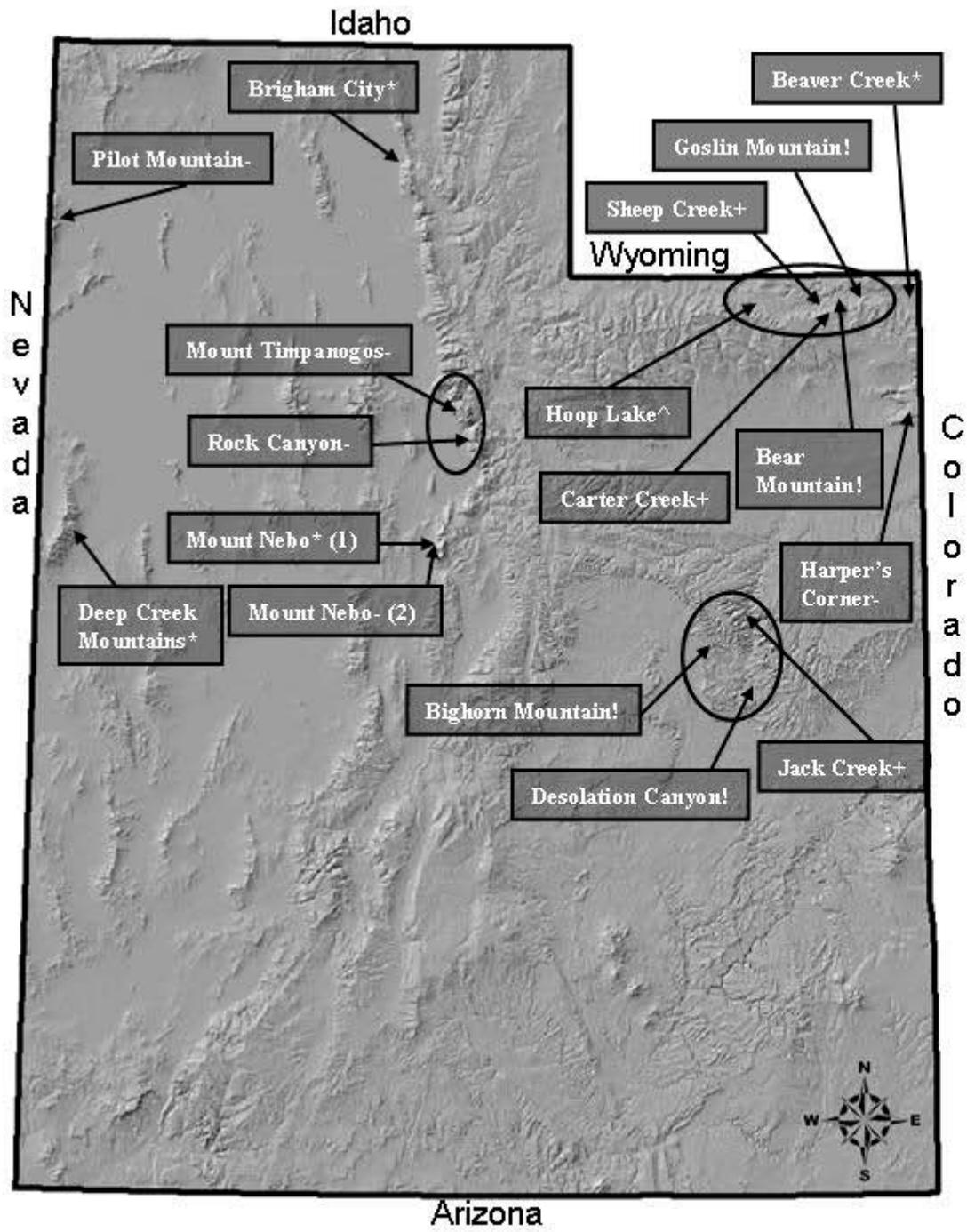


Figure 1. Distribution of 17 reintroduced populations of Rocky Mountain bighorn sheep in Utah. Symbols represent (*) failed herds, (-) declining herds, (^) stagnant herds, (+) growing herds, (!) successful herds. Ovals represent metapopulation structures.

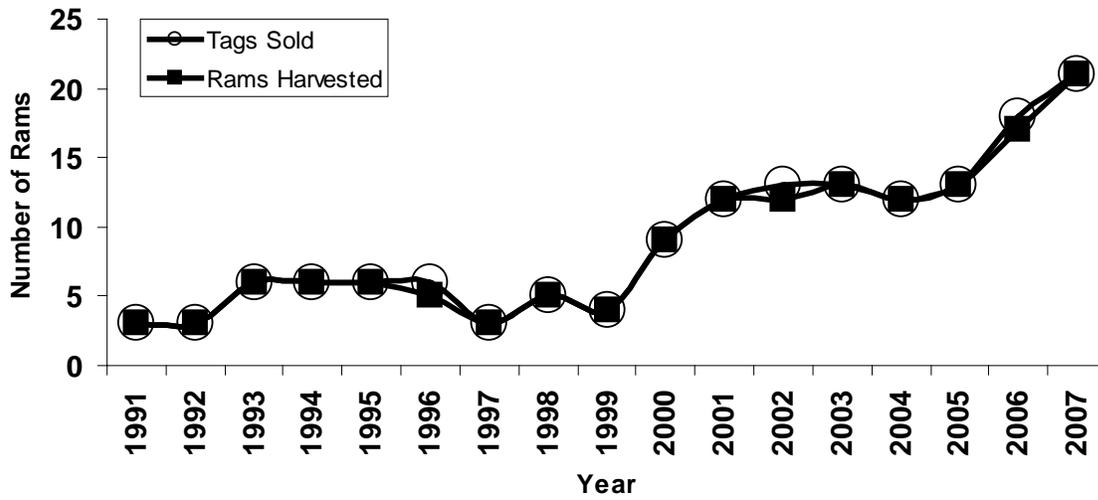


Figure 2. Number of harvest permits sold and filled for reintroduced Rocky Mountain bighorn sheep in Utah. From 1991-2007, the Utah Division of Wildlife sold 153 harvest permits, 150 of which have been filled.