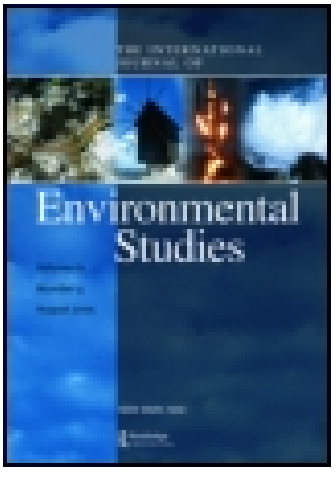

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The role of hunters in conservation, restoration, and management of North American wild sheep

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Wild sheep in North America were abundant and widely distributed prior to European exploration and settlement. By the early twentieth century unregulated hunting, forage competition with domestic livestock, introduced diseases, and human encroachment had dramatically reduced bighorn sheep (*Ovis canadensis*) numbers and distribution in the western US, southern Canada, and mainland and Baja Peninsula Mexico. The restoration of bighorn sheep has been a remarkable conservation success, as a result of efforts by wildlife and land management agencies, conservation organizations, private landowners and other stakeholders. These efforts have been largely underwritten by pro-hunting conservation organizations.

Keywords: Restoration; Hunting; Translocation; Wild Sheep Foundation

Introduction

Occupying the most isolated, rugged, and extreme habitats of North America, bighorn sheep and thinhorn sheep (*Ovis canadensis* and *O. dalli*, collectively referred to as wild sheep) are considered by many to be the iconic wilderness species. Wild sheep have substantial ecological, economic, and cultural value, and are a vital component of the natural heritage of western North America. Historically, distribution of wild sheep extended from portions of Alaska, the Yukon Territory, and the Northwest Territories southward along the Rocky Mountain cordillera to the western portions of the Dakotas, Nebraska, and Texas, and to the tip of the Baja Peninsula and four states in mainland Mexico (i.e. Sonora, Chihuahua, Coahuila, and Nuevo Leon). Native peoples like the Sheepeater Indians (i.e. Tukadika, or Mountain Shoshone) in the northern Rockies to desert-dwelling tribes in the Southwest United States and Mexico opportunistically hunted bighorn sheep, trapping them in rock and/or log catch-pens, or hunting from rock blinds or over water holes in the desert. Rock art panels from throughout western North America bear witness to the importance of mountain sheep to indigenous peoples.

Respected naturalist Ernest Thompson Seton [1] estimated as many as 1.5 to 2.0 million bighorn sheep existed in North America, *c.*1800. While modern-day wild sheep biologists and wildlife/land managers have questioned that estimate, certainly bighorn sheep were formerly much more abundant and widely distributed [2,3] (figure 1) compared to current

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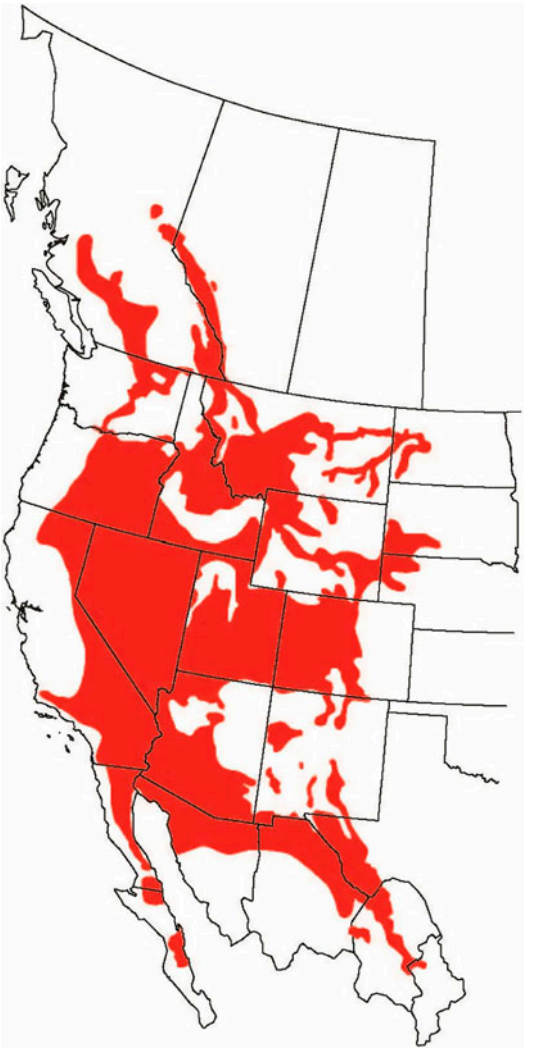

Figure 1. North American bighorn sheep distribution, *c.*1850 (modified by the Wild Sheep Foundation [2,3]).

numbers and distribution. Following western settlement, numbers declined rapidly, and bighorn sheep were extirpated from much of their historic range (figure 2). Unregulated harvest, disease, competition with domestic, feral, and exotic livestock and human encroachment have all been implicated in the decline of bighorn sheep [4,5]. By 1960, when Buechner [2] wrote his monograph *Bighorn Sheep of the United States: Its Past, Present, and Future*, he estimated that bighorn sheep numbers in 13 western states had dwindled to only 15,000–18,200. Combined with estimates from southern British Columbia, and southern Alberta, Canada, and six states in Mexico, bighorn sheep range-wide were estimated at fewer than 25,000 animals [6] by the middle of the twentieth century.

While reliable historic estimates of thinhorn sheep numbers (i.e. Dall's sheep *O. dalli dalli* and Stone's sheep *O. d. stonei*) *c.*1800 are not available, distribution of thinhorn

sheep (figure 3) is not considered to have changed appreciably since historic times [7,8]. Mean population estimates for thinhorn sheep were considered relatively stable from the 1970s to the late 1990s [7], ranging from 91,000 thinhorn sheep in 1975 to 116,350 in 1999 [7], and while recent declines have occurred in portions of some jurisdictions, overall thinhorn sheep populations remain relatively stable, with a 2011 range-wide mean estimate of 102,000 thinhorns [6].

Impacts from exploration/settlement of the West (US, Canada, Mexico)

Settlement of the West led to heavy hunting of bighorn sheep and in many places their numbers were decimated. The animals were pursued for their high quality meat and were most vulnerable on low-elevation winter ranges, at water holes, or where they overlapped

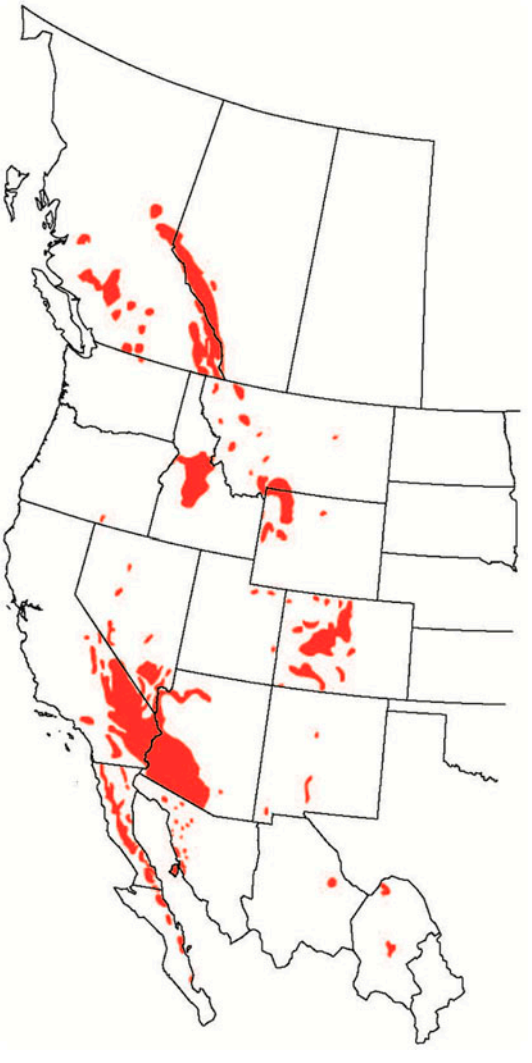

Figure 2. North American bighorn sheep distribution, *c.*1955 (modified by the Wild Sheep Foundation [2,3]).

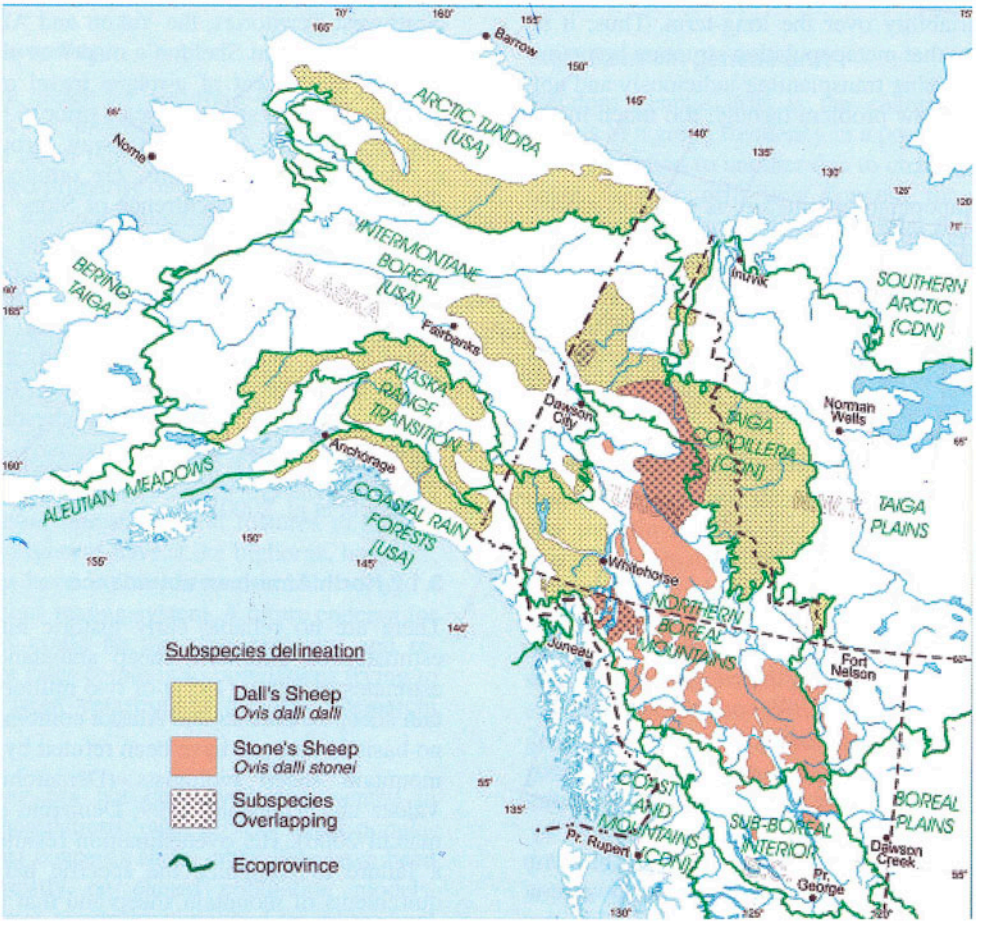

Figure 3. North American thinhorn sheep distribution, *c.*2004 [7], reproduced here with permission.

and competed for forage with domestic livestock [9]. Habitat fragmentation, human encroachment on water sources, and early day market hunting by miners, prospectors, and others all worked to reduce bighorn sheep numbers and range [4].

Almost certainly the greatest impact, however, came from diseases transmitted from domestic sheep [2,9]. As early as 1937, Dr. Shillinger [10] warned of the risk and implications of contact between wild bighorn and domestic sheep. At that time Buechner [2] conjectured scabies, a common disease of domestic sheep caused by *Psoroptes* spp. mites, was responsible for the deaths of thousands of bighorn sheep in Wyoming [11]. This particular infection was certainly unknown to native Americans prior to European settlement [12]. Buechner [2] detailed reports of coincident scabies outbreaks in domestic sheep and deaths of bighorn sheep in several other states as well (e.g. Wyoming, Montana, Colorado, Oregon, California) dating as far back as the late 1800s. The coincidental scabies outbreaks and bighorn sheep deaths made for logical inference concerning the role of disease, and scabies in particular. Given our current knowledge [13–20], it is considered more likely, however, that respiratory pneumonia caused by one or more pathogens (e.g. *Mannheimia haemolytica, Mycoplasma ovipneumoniae, Bibersteinia trehalosi, Pasteurella*

multocida), acting alone or in combination, resulted in far more significant bighorn sheep die-offs, than did *Psoroptes*-induced scabies.

Wild sheep are highly susceptible to respiratory infections [21] and pneumonia spread from domestic sheep typically results in mortality of a large proportion of the population, usually followed by multiple years of depressed lamb survival [22]. These pneumonia-induced demographic effects on bighorn sheep have been documented in more than 70 peer-reviewed scientific publications [21]. While disease research continues, including experimental vaccines to boost bighorn sheep immunity to pneumonia infection, the most direct and effective strategy is to prevent disease transmission by maintaining effective temporal and spatial separation between domestic sheep and goats, and wild sheep [13]. Additional 'Best Management Practices' for domestic sheep and goat grazing in bighorn range have been suggested [23,24], but most of these have not been experimentally tested or validated.

State, provincial and territorial wildlife agency-driven restoration efforts

The frantic wildlife exploitation of the 1800s not only had a significant impact on wild sheep populations throughout the North American West, but, eventually, also on public opinion. By the latter part of the century, the prevailing public attitude had shifted from one of unlimited wildlife harvest to one of concern and protection [25]. Once common, 'mountain sheep' had been eliminated or drastically reduced in numbers and distribution, including the annihilation of an entire subspecies, the Audubon Bighorn Sheep (*O. c. auduboni*) of the Dakotas, Montana, Nebraska and Wyoming [26]. Efforts to restrict wild sheep harvest surfaced as early as the 1870s in the US and Canada, and by the early 1900s, state, provincial and territorial wildlife agencies were being established.

Initial conservation efforts focused on protection of wild sheep and their habitat. Hunting laws in the form of regulated harvest and seasonal restrictions or closures were implemented in most US and Canadian jurisdictions, habitat was acquired and protected (public land), and other programs such as intensive predator control and supplemental feeding of wild sheep were launched. Despite these early efforts jurisdictional coordination was weak or non-existent [27], and many bighorn populations continued to decrease or had declined below recovery levels. The need for more aggressive intervention was clearly recognized by both the newly-founded wildlife agencies and concerned sportsmen, who by now had become a vocal constituency for wildlife conservation.

Scientific mountain sheep censuses began by 1914 [27], and while some jurisdictions were still assessing population declines and designing remedial efforts, others were already initiating more aggressive restoration programs. Use of wild sheep translocations began in 1922 with the capture of 20 bighorns in Alberta, Canada and subsequent release of 12 animals in Montana and eight animals at Custer State Park, South Dakota [28]. Mechanical in nature, primitive early capture techniques included padded steel-leg hold traps, snares, drive-nets, drop-gate panel traps, coral traps, and use of drugs, with animal transportation accomplished using boats, automobiles, and fixed-wing aircraft [29]. By 1935, eight separate relocation operations transplanted nearly 180 animals in six US and Canadian jurisdictions [28]. At the time, wildlife agency resources were severely limited, and the scientific basis for these capture and relocation efforts was in its infancy [26,30]. In addition, these efforts were very expensive, because wild sheep are a large species adapted to rugged and

often isolated habitats. As a result, early success in restoring bighorns to their former numbers and distribution was limited.

Financial support came in 1937 with passage of the Federal Aid in Wildlife Restoration Act (Pittman–Robertson Act), which imposed a federal excise tax on hunting equipment and firearms sold in the United States and apportioned funds to individual states exclusively for the management and restoration of fish and wildlife resources and habitats. At about the same time, strong partnerships began to form between wildlife agencies, sportsmen, landowners and others committed to wild sheep and the lands they occupied, providing a critical coalition of support for efforts at restoration. As a result, by 1960 almost 100 separate projects had translocated nearly 1000 animals within 13 US and Canadian jurisdictions [28]. A decade later, wild sheep translocation efforts had doubled, with over 190 operations conducted and 2100 animals translocated in 15 jurisdictions [28]. Wild sheep restoration and management was now occurring in every state, province and territory where the animals had historically occurred including states such as Nebraska, North Dakota, South Dakota and Texas where bighorns had been extirpated.

In total, from 1920 to 1980, 357 translocation operations (figure 4) moved over 4500 wild sheep within 17 North American jurisdictions [28]. The effectiveness of these translocation efforts in establishing viable wild sheep populations varied considerably [31]. A review of 100 translocations conducted within six western US states between 1923 and 1997 indicated a success rate of only 41%; far from what was needed to return the species to its former range and abundance [32]. It became clear that restoring bighorn sheep to areas from which they had been extirpated was not only difficult, but that success could not be achieved through translocation alone. Improved knowledge of wild sheep biology,

Figure 4. Drop-net bighorn sheep capture, Cadomin Mine, Alberta (photo credit/permission by Andrew Godsalve, Jasper, Alberta).

life history and habitat requirements was also necessary [25]. Eventually wildlife professionals discovered that sheep populations with fewer than 100 individuals were highly vulnerable to disease, predation, inclement weather, declines in habitat quality or quantity, loss of genetic diversity, and unanticipated stochastic events [31]. This basic knowledge of a minimum viable population size was one of the most important insights to emerge from many years of wild sheep research, much of it paid for by North American sportsmen. Advances in capture techniques [29] and population and habitat assessments also assisted in developing and implementing more effective restoration efforts, as well as providing improved management and monitoring strategies for wild sheep populations and their habitats.

Habitat in particular had become an issue; for although great strides had been taken in regulating hunting, the North American landscape had changed significantly through the twentieth century, in many ways detrimental to wild sheep. A history of overgrazing by livestock coupled with decades of fire suppression had significantly degraded wild sheep range. Human encroachment coupled with these vegetation changes both destroyed and fragmented sheep habitat, ultimately limiting both the viability and distribution of bighorn sheep populations [31]. In response, wildlife agencies and their federal partners, landowners and others began to protect critical areas including core habitat, lambing areas, winter and summer ranges, and seasonal movement corridors.

In addition, sheep biologists began to evaluate habitat suitability in potential release sites and to compare the overall health and ecological characteristics of both source and destination areas [31]. They also began to understand better (and thus avoid) the adverse consequences of mixing wild sheep from various source herds. This mixing increased the risk of transferring pathogens between and among bighorn sheep populations as well as between domestic and wild sheep herds. Over time these various efforts did, in fact, improve translocation success and today most wildlife agencies view translocation efforts (figure 5) as necessary for restoring wild sheep to historic ranges, establishing new populations within suitable but unoccupied habitat, and for augmenting existing populations [31]. To date, over 1460 separate projects (table 1) have resulted in the translocation of over 21,470 animals within 17 of the 19 North American wild sheep jurisdictions for an average of 1.3 transplants per month, over the last 92 years [28]. These efforts have resulted in the establishment of self-sustaining sheep populations on many vacant historic ranges, as well as increased sheep numbers, improved genetic diversity of established populations, and expanded ranges for existing populations.

Wild sheep conservation organizations and hunting opportunities

Concern for the status and distribution of wild sheep largely arose from within the hunting community and eventually led to the formation of organized groups dedicated to the cause of recovering wild sheep numbers and managing them within a sustainable use framework. This pattern was to repeat itself many times in North America where similar efforts by hunting enthusiasts drove and supported conservation programs to restore elk, white-tailed deer, wild turkeys, and waterfowl. At a weekend gathering in Mt. Horeb, Wisconsin, in November 1974, 13 wild sheep hunters established the Wild Sheep Foundation (formerly known as the Foundation for North American Wild Sheep) [33]. Incorporated as a non-profit entity in Iowa in September 1977, the Wild Sheep Foundation and its network of almost 30 Chapters and Affiliates across North America has grown into one of the

Figure 5. Bighorn ram being slung below a helicopter, following aerial net-gun capture (photo credit/permission by Mark Gocke, Wyoming Game and Fish Department).

continent's most effective and influential conservation organizations. The purpose of the Wild Sheep Foundation is '*To Put and Keep Sheep on the Mountain*™'. The organization is dedicated to enhancing wild sheep populations, promoting professional wildlife management, educating the public and youth on sustainable use and the conservation benefits of hunting and generally advancing concerns and interests for wild sheep.

Table 1. Records of wild sheep translocations in the United States and Canada, 1922–2015 [28].

Jurisdiction	Number of transplants				Number of animals			
	Imports	Exports	Within	Total	Imports	Exports	Within	Total
Alberta	–	40	7	47	–	708	78	786
Arizona	7	25	108	140	128	306	1756	2190
British Columbia	3	48	90	141	111	693	899	1703
California	5	–	50	55	39	–	491	530
Colorado	18	27	137	182	317	472	2214	3003
Idaho	31	19	33	83	540	291	375	1206
Montana	2	35	133	170	28	694	2263	2985
North Dakota	14	–	43	57	213	–	216	429
Nebraska	8	–	1	9	176	–	26	202
New Mexico	17	5	45	67	169	89	698	956
Nevada	52	43	174	269	804	697	2535	4036
Oregon	28	38	83	149	442	419	1145	2006
South Dakota	10	3	2	15	206	36	25	267
Texas	20	–	30	50	176	–	623	799
Utah	57	3	70	130	1151	30	1021	2202
Washington	32	2	77	111	260	83	664	1007
Wyoming	6	23	65	94	144	398	1528	2070
Others[a]	2	1	–	3	18	6	–	24
Total	312	312	1148	1460[b]	4922	4922	16,557	21,479[b]

[a]Others: (1) Import: OK from MT – 14 total animals. (2) Import: National Zoological Park, Washington, DC from MT – four total animals. (3) Export: Mexico to TX – six total animals.
[b]Total = (Import + Export + Within).

With private funding from members and donors, auction of special Governor's or Minister's hunting licenses for especially sought after hunting areas and an annual fundraising convention known as 'The Sheep Show,' the Wild Sheep Foundation and its Chapters and Affiliates have raised and distributed more than US$100 million over the past 40 years for wild sheep conservation. In addition to contributed funds, Wild Sheep Foundation members annually volunteer vast amounts of time to state, provincial, territorial, tribal, and federal agency wild sheep programs. These volunteer efforts embrace a wide range of activities that include installing and maintaining wildlife water reservoirs and managing vegetation; assisting with population surveys, animal captures and relocations; advocating for legislative and policy changes with political and wildlife agency leaders; and sponsoring and conducting youth outdoor recreation and education programs. Wild sheep conservation volunteers contribute tens of thousands of man hours and donate hundreds of thousands of dollars annually in support of this work.

These volunteers donate their time and effort with little or no expectation of ever being able to hunt a wild sheep. In fact, while bighorn sheep numbers have increased more than threefold over the past six decades, hunting opportunities remain low and offtake rates are strictly managed, ranging from less than 1 to 4% of total estimated bighorn sheep numbers [34]. Montana's 'unlimited' hunt areas provide resident and non-resident hunters annual opportunities to purchase over-the-counter bighorn hunting permits. No other western state offers bighorn sheep hunting licenses except through competitive lottery or drawing systems. Odds of drawing a bighorn license are low, and most western states use various

bonus point or preference point systems for issuing bighorn sheep hunting licenses. Across bighorn range in the western U.S. and Canada, 3300–3700 hunters annually purchase or receive a bighorn ram hunting license, with harvest ranging between 1200 and 1400 rams per year [35]. In thinhorn sheep range (Alaska,Yukon, Northwest Territories, and northern British Columbia), hunting licenses average 10,500/year, with 1500 thinhorn rams harvested annually [35].

Current status of bighorn sheep in North America

Although not yet complete, restoration of bighorn sheep in North America is an extraordinary conservation achievement. Bighorn sheep numbers have rebounded from a range-wide estimate of fewer than 25,000 in the late-1950s [2] to today's estimate of 80,000+ in 15 states, two provinces, and six states in Mexico [35]. A combination of regulated harvest, habitat and predator management, and translocations has proven successful in increasing numbers and expanding the distribution (figure 6) of these animals. Bighorn sheep have been re-introduced to every western state from which they had been extirpated, with populations in some jurisdictions likely reaching historic levels. This has been accomplished through the dedication and cooperative efforts of hunters, wildlife and land management agencies, conservation organizations, private landowners, tribal and First Nations entities, and many other interested parties. Nevertheless, wild sheep still occupy only a part of their former range in North America and current numbers are far less than estimates of their historical abundance [31]. Much further work is required.

Current challenges and future strategies for wild sheep conservation and management

The Western Association of Fish and Wildlife Agencies Wild Sheep Working Group recently identified the most important challenges facing bighorn sheep restoration and conservation efforts [31]. Broad-based management goals and objectives were provided along with suggested strategies for achieving results that will ensure viability of wild sheep throughout their historical distribution. Among the challenges identified are those related to habitat (quality and quantity, human encroachment, and competition), disease, predation, population management (translocations, viability and connectivity, and harvest strategies), organizational roles (funding and personnel resources, management restrictions, and shared management responsibilities), and climate change. In addition, the Wild Sheep Foundation recently helped identify the most significant ecological and human-footprint challenges for Dall's and Stone's sheep in Alaska, northern British Columbia, Yukon, and Northwest Territories [36]. These included unregulated access and off-road travel, predation, potential exposure to domestic sheep and goats, and oil, gas, and mineral exploration in previously-pristine thinhorn sheep range [7,36,37].

The impacts of a rapidly expanding human population are among the greatest challenges facing wildlife agencies everywhere today. Wild sheep managers in North America must constantly strive to ensure adequate quality and quantity of wild sheep habitat by protecting and improving landscapes, while also managing other factors that limit sheep populations, Disease transmission from domestic livestock still remains one of the most important factors affecting wild sheep population viability and protecting and managing the health of wild sheep is essential for continued success in restoration and management of their populations. Minimizing impacts of predation on wild sheep populations while

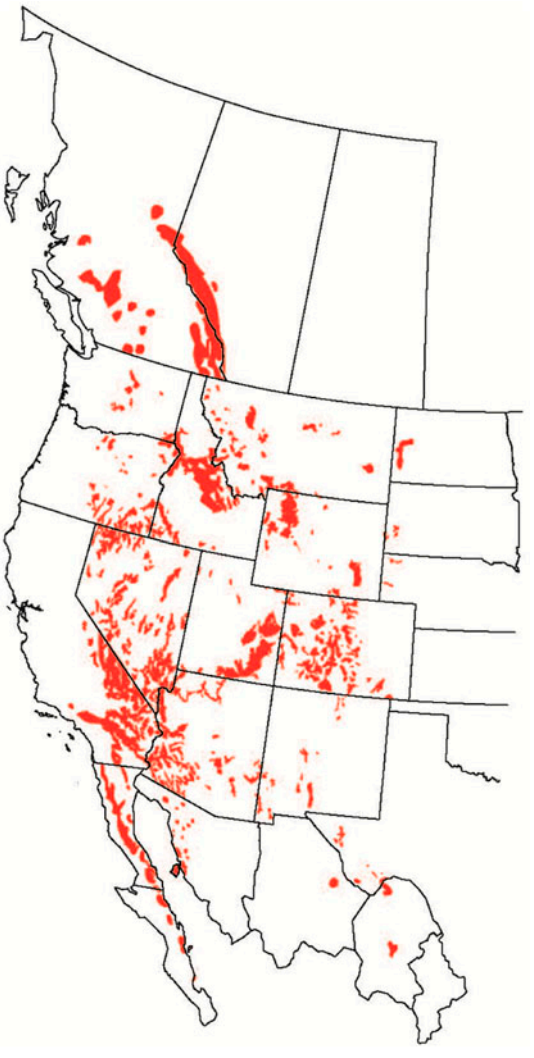

Figure 6. North American bighorn sheep distribution, *c.*2012 (modified by the Wild Sheep Foundation [6]).

preserving ecosystem integrity is also imperative. Managing and restoring wild sheep populations through well-planned and implemented translocations continues to be an important part of wild sheep conservation efforts. Preserving the integrity and connectivity of individual subpopulations to ensure long-term viability of metapopulations is also necessary, and so is implementing appropriate and sustainable harvest strategies that maintain the proper balance between wild sheep numbers and their habitat. Consistent and sufficient sources of funding, plus personnel dedicated specifically to wild sheep management, are essential for meeting current and future challenges. It is also vital to respond well to restrictions that impede restoration and management efforts, and to work collaboratively with multiple jurisdictions, private landowners, non-governmental organizations, and other stakeholders to minimize or eliminate political and social impediments. Assessing sheep

population vulnerability, engaging partners, and implementing adaptive management strategies are essential for ensuring persistence of wild sheep in the face of climate change.

Conclusion

Wild sheep remain a symbolic wildlife species. The importance of these inspiring animals to Native Americans is well documented. Today, they symbolize new beginnings, creativity, endurance, and the last true remnant of wild North America. For over a century, sportsmen and their conservation organizations such as the Wild Sheep Foundation have led the successful efforts to restore wild sheep from the edge of extinction to the population levels equivalent to those of the mid to late nineteenth century. These efforts have resulted in expanded wild sheep numbers and distribution throughout western North America, and have provided the hunting and viewing opportunities of today. Yet, the challenges confronting wild sheep today are larger and more complex than ever before. The continued success of wild sheep conservation is contingent upon learning from mistakes of the past and persisting in efforts to ensure that their habitats and mountain landscapes are protected.

Disclosure statement

No potential conflict of interest was reported by the authors.

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