

BIGHORN SHEEP MANAGEMENT PLAN

August 2019



**NEBRASKA GAME AND PARKS COMMISSION
WILDLIFE DIVISION**



Nebraska Bighorn Sheep Management Plan

August 2019

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BIGHORN SHEEP MANAGEMENT PLAN

I. Executive Summary

Nebraska Game and Parks Commission (Commission) successfully reintroduced Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) to the state starting in the early 1980's. The Commission's continuing goal is to establish a self-sustaining, free-ranging bighorn sheep population in all areas of suitable habitat in the State of Nebraska. However, there are many challenges facing bighorn sheep including disease, predation, and habitat loss or fragmentation. In response, the Commission has developed a comprehensive plan to help manage and mitigate these herds and the issues they face. A number of objectives have been identified in order to assist with management direction. Some tasks related to these objectives have been accomplished while new ones have been created. This plan is not all inclusive and is meant to be dynamic and will be changed and adapted as new information becomes available and sheep populations change over time. This plan should also help facilitate discussions on future management strategies for bighorn sheep.

II. Agency Mission

The mission of the Nebraska Game and Parks Commission is stewardship of the state's fish and wildlife, park, and outdoor recreation resources in the best long-term interests of the people and those resources.

III. Management Goal

The Commission's goal is to establish a self-sustaining, free-ranging bighorn sheep population in all areas of suitable habitat in the State of Nebraska.

IV. History

Bighorn sheep (*Ovis canadensis*) were once an iconic species of western North America. Their historic range stretched continuously from Mexico up into Alaska, and as far-east as the Dakotas, western Nebraska, and west Texas (Buechner 1960). The wild sheep population was estimated to range from 1.5 to 2 million in the early 1900's (Singer et al. 2001). Today there are less than 70,000 wild sheep in North America, and about 31,500-34,500 of which, are Rocky Mountain bighorn sheep (*Ovis c. canadensis*; Wild Sheep of North America). Much of their once contiguous range is gone, resulting in smaller, broken pieces of suitable habitat, further increasing distances between populations (Figure 1). Habitat destruction and fragmentation is only part of the reason for the decline in bighorn sheep. Disease, unregulated hunting, predation, and competition with domestic livestock for resources has also had a major negative impact on bighorn sheep leading to extirpations in many regions (Buechner 1960).

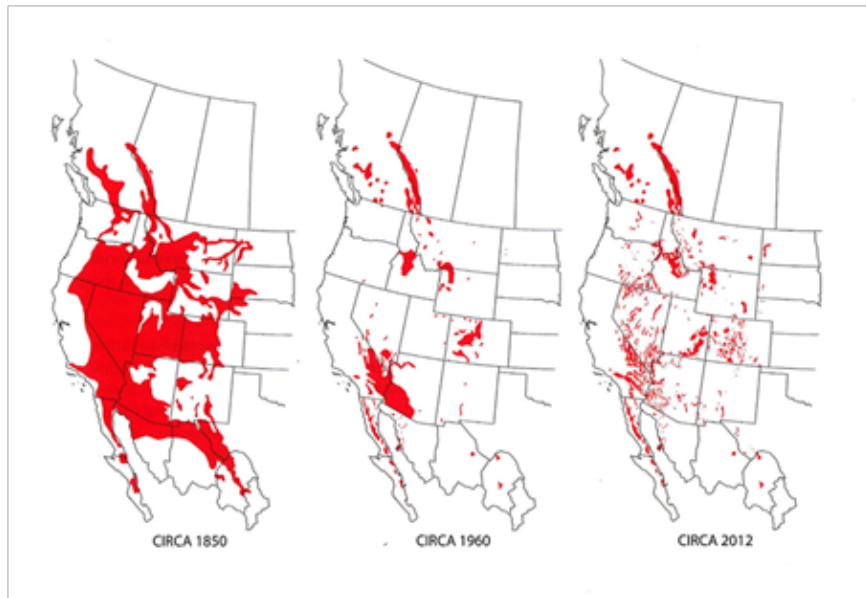


Figure 1. Historic and present-day distribution of Rocky Mountain bighorn sheep in the western United States.

History of Bighorn Sheep in Nebraska

The last confirmed report of bighorn sheep in Nebraska occurred in the Wildcat Hills area in the early 1900's. The Commission became interested in reestablishing free ranging bighorn sheep to all suitable habitat in the state, and in 1981, reintroduced Rocky Mountain bighorn sheep (*O. c. canadensis*) back into the state. This initial group of sheep began with 2 adult male and 4 adult female bighorn sheep from Custer State Park in South Dakota that were moved to a 500 acre, captive enclosure in Fort Robinson State Park. Four additional herds have since been established in Nebraska: Barrel Butte (est. 2005 with the introduction of 49 individuals), and Sowbelly (est. 2012 with 41 individuals) in the Pine Ridge area; and Cedar Canyon (est. 2001 with 22 individuals), and Hubbard's Gap (est. 2007 with 51 individuals) in the Wildcat Hills area.

Sub-Herds: History, Population Trends, and Pneumonia Outbreaks

Unfortunately, while this transplantation effort was successful in bringing bighorn sheep back to Nebraska, disease, particularly pneumonia, has negatively impacted each sub-herd and is inhibiting the program's success. As shown in figure 2, each herd has experienced population fluctuations, and in June 2014 the bighorn population in Nebraska peaked at 459 individuals. Since then, however, each Pine Ridge herd has been in decline mostly due to pneumonia. In 2019, the bighorn population in Nebraska was approximately 249 with about 79.5% of the entire population (or 198 individuals) in the Wildcat Hills (149 of which are in the Hubbard's Gap herd).

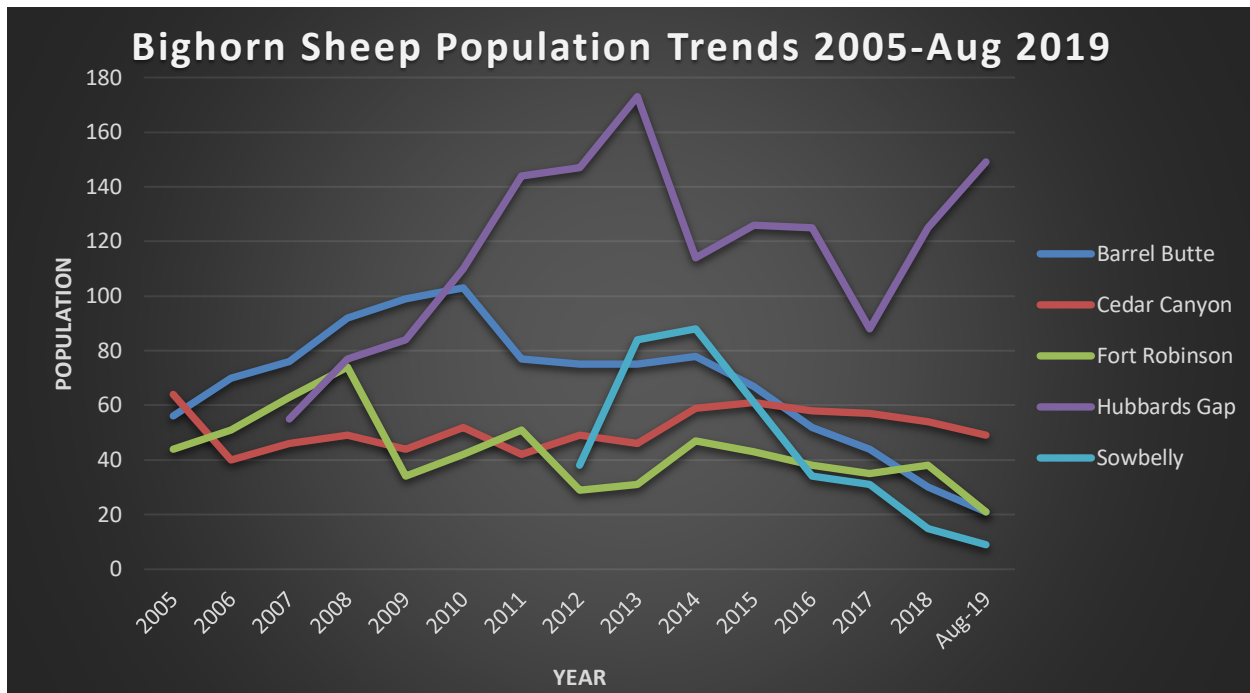


Figure 2. Nebraska bighorn sheep herd population trends since 2005 or initial reintroduction

Fort Robinson Herd: As stated previously, six bighorn sheep (2 males and 4 females) were brought to Nebraska and kept in a captive enclosure. By 1988, there were 44 sheep in the enclosure and the Commission released 21 of the 44 individuals (7 males, 8 females, and 6 lambs) into the park. The remaining 23 sheep (11 males, 8 females, and 4 lambs) were released a few years later in 1993 and the enclosure was removed. The herd in Fort Robinson State Park initially did well after the final release from the enclosure in 1993. The population increased until late 2004 where the herd reached a peak of 130 bighorn sheep. However, in 2005, the herd experienced an all-age-class die-off caused by pneumonia. Their population was reduced by 50% and two years later the herd experienced another all-age-class die-off from pneumonia. In subsequent years lamb recruitment was at an all-time low. To help augment the herd, in 2014, 16 sheep were transplanted from the Hubbard’s Gap herd to the State Park. The herd continues to experience low recruitment and high adult mortality from pneumonia, predators, and other diseases. In August 2019, the herd numbered approximately 21 bighorn sheep in Fort Robinson State Park.

Barrel Butte Herd: In 2005, 49 individuals were transplanted from Montana and released onto the Bighorn Wildlife Management Area near Chadron. While the herd’s range has expanded since its inception to encompass the area between the towns of Chadron and Crawford, the population has experienced fluctuations and poor lamb recruitment due to pneumonia outbreaks. In 2014, ten individuals (2 adult males, 8 adult females) were transplanted from the Hubbard’s Gap herd in order to augment this herd. Twenty-one individuals made up the Barrel Butte herd in August 2019.

Sowbelly Herd: The Sowbelly herd is the youngest herd, only recently established in 2012 with 41 individuals (5 adult males and 36 adult females) transported from the Cadomin Mine region of Alberta, Canada to the Sowbelly Canyon area, northeast of Harrison. In 2014, the herd was hit by a pneumonia outbreak causing an all-age-class die-off losing 40% of the population. Lamb recruitment has been poor to almost non-existent since the die-off and in August 2019, only 9 individuals were still alive in the Sowbelly herd.

Cedar Canyon Herd: The Cedar Canyon herd, located in the Cedar Canyon Wildlife Management Area near Gering, did well originally. Lamb survival was high and adult mortality was low, and from its start in 2001 to 2005 the population rose from 22 individuals to 64 individuals. In early 2006, however, the herd lost 50% of its population to a pneumonia outbreak all-age-class die-off. Lamb recruitment has remained low since the outbreak, and it is only in recent years that the herd has begun to recover. In August 2019, the herd was nearing pre-die-off numbers at 49 individuals.

Hubbard's Gap: Finally, the Hubbard's Gap herd has done well since its start in 2007. The herd was started in the Wildcat Hills just south of McGrew on entirely privately owned land with 51 individuals. The area designated for sheep comprises over 22,000 acres. Following some initial setbacks and population fluctuations, current adult mortality remains low and lamb recruitment has fluctuated but remains high. Twenty-six individuals were relocated from this herd to the Fort Robinson herd and Barrel Butte herd in 2014. In August 2019 the Hubbard's Gap herd numbered 149 bighorn sheep.

Bighorn Sheep Research

- **1985:** W. Sue Fairbanks. Habitat Use and Foraging Behavior of Semi-captive Bighorn Sheep at Fort Robinson State Park, Nebraska.
- **1998:** Kyle M. Forbes and James W. Merchant. Bighorn Sheep Habitat Assessment of the Pine Ridge of Nebraska.
- **1999:** Kyle M. Forbes. Bighorn Sheep Habitat Assessment of Wildcat Hills of Nebraska.
- **2004:** Russel A. Powers. A GIS Based Evaluation of Bighorn Sheep Habitat Pertaining to Reintroduced Low Elevation Herds.
- **2004:** Edward A. Klinksiek. Seasonal, Sex-specific Habitat Selection by a Low Elevation Population of Bighorn Sheep.
- 2006. Todd Nordeen and Chuck Butterfield. Bighorn Sheep Hoof Deformities.
- **2008:** Jennifer Malmberg. The Effects of Disease, Stress, and Distribution on Bighorn Sheep Restoration in Nebraska.
- **2008:** Bruce Trindle. Prepared by: W. Sue Fairbanks and Todd Hanson. Bighorn Sheep Lambing Habitat in the Nebraska Pine Ridge: Development and Evaluation of a GIS Model.
- **2010:** Jeremiah Vardiman. A study of Bighorn Sheep Diet Composition and Home Range on the Pine Ridge Region of Northwest Nebraska.

- **2010:** Rana Tucker, Teresa Zimmerman, and Todd Nordeen. Evaluation of the Use of Escape Terrain and Buffer Model to Depict Northwestern Nebraska's Bighorn Sheep Habitat.
- **2014:** Laura A. McHale, Todd Nordeen, Julie J. Shaffer, and Brian C. Peterson. The Effects of Zuprevo, a Macrolide Antibiotic, on Bighorn Sheep Lamb Survival Following a Bacterial Pneumonia Outbreak.
- **2017:** Thomas A. Morrison, Todd Nordeen, and Karie Decker. Population Trends, Resource Selection, and Area Requirements of Bighorn Sheep in Northwest Nebraska.
- **2017 – 2020:** Emily Moberg, Todd Nordeen, Will Inselman, and Jonathan Jenks. Reproductive Success, Survival, and Cause-Specific Mortality of Bighorn Sheep in Nebraska.
- **2017 – 2020:** Erin Wood, Todd Nordeen, Will Inselman, and John Benson. Quantifying Space Use and Resource Selection of Bighorn Sheep (*Ovis canadensis*) Ewes in Nebraska.
- **2018 – 2020:** Laura McHale, Will Inselman, and Jonathan Jenks. Disease Prevalence in Domestic Sheep in Western Nebraska: Implications for Bighorn Sheep Conservation, Domestic Sheep Fitness and Mutual Benefits.

V. Challenges to Bighorn Sheep in Nebraska

The challenges facing the Nebraska bighorn sheep restoration program are not unique and other wildlife agencies are equally struggling to mitigate the challenges against them. Nebraska may actually be better off than some states due to the limited number of farms with domestic sheep and goats and their lack of grazing on public land. The restoration areas also boast low human densities and there is strong support for bighorn sheep conservation within Nebraska (Bleich 2010). Some of the challenges impacting bighorn sheep in Nebraska and in other herds in the Rocky Mountain west include disease; particularly respiratory diseases, interactions with domestic sheep and goats, predation, and vehicle collisions.

Diseases Impacting Bighorn Sheep

Rocky Mountain bighorn sheep is one of the most susceptible wild animal species to various diseases. Extra precautions must be taken in managing this resource to ensure that a preventable disease outbreak does not decimate populations. Some of the prevalent diseases known to have impacted herds in many states include: contagious ecthyma (CE), epizootic hemorrhagic disease (EHD) or bluetongue virus (BTV), scabies, anaplasmosis, Johne's disease, brucellosis, and pneumonia.

Contagious Ecthyma (CE): also known as sore mouth, is a parapoxvirus infection that causes fluid filled blisters with scabs forming sores and localized swelling on the lips, mouth, nose, eyelids, ears, and teats (IDFG). The infection normally clears on its own within 4 weeks (Thorne et al. 1982), the sores make feeding or nursing painful and can eventually lead to starvation and dehydration.

Epizootic Hemorrhagic Disease (EHD) or Bluetongue Virus (BTV): Transmitted by biting midges of the genus *Culicoides*. Animals infected by EHD or BTV can show signs of weakness, difficulty breathing, swelling of the head or neck, and diarrhea. Animals with chronic EHD can experience abnormal hoof growth, hoof sloughing and can be emaciated (IDFG).

Scabies: A contagious skin infection caused by a parasitic mite, *Sarcoptes scabiei*. Skin becomes irritated, scabby and itchy and loss of hair is common due to persistent scratching and rubbing to gain relief. The loss of hair and damaged skin can compromise the animal's ability to regulate its temperature and protect its skin (Dubay et al. 2002).

Anaplasmosis: Transmitted from ticks and biting flies infected with *Anaplasma ovis* to domestic and wild sheep and goats. Animals infected by this agent develop anemia but usually recover and can be carriers from months to years (Dubay et al. 2002).

Johne's Disease (Paratuberculosis): A bacterial infection caused by *Mycobacterium avium* and causes chronic enteritis. The digestive tract is commonly where the lesions are found and individuals infected by this disease show signs of diarrhea, and emaciation. The bacteria is shed in feces which can contaminate feed or water and expose healthy animals to the disease (Dubay et al. 2002).

Brucellosis: Causes abortions and, if an animal experiences chronic infections, can lead to infertility in both males and females. There are no outward signs or symptoms of brucellosis except males may have swollen testicles or joints (IDFG).

Pneumonia: Multiple strain types have been identified including *Pasteurella multocida*, *Mannheimia haemolytica*, *Bibersteinia trehalosi*, and *Mycoplasma ovipneumoniae*. Pneumonia caused by these particular bacteria will often result in a large die-off (Jorgenson et al. 1997, Grigg et al. 2017) and is typically followed by multiple years of lamb mortality due to pneumonia (Singer et al. 2000, Smith et al. 2014, Grigg et al. 2017). Other viruses are known to cause pneumonia and in conjunction with other infections can be fatal to bighorn sheep including: Parainfluenza 3 Virus (PI3), Respiratory Syncytial Virus (RSV)

- There have been 4 documented strains of *Mycoplasma ovipneumoniae* in Nebraska's bighorn sheep herds. One strain has not been detected since 2014 and was primarily detected in the Sowbelly herd. Another strain has only been detected in our Hubbards Gap herd. The last two identified strains have been detected in our northern herds: Barrel Butte, Fort Robinson, and Sowbelly (Figure 3)

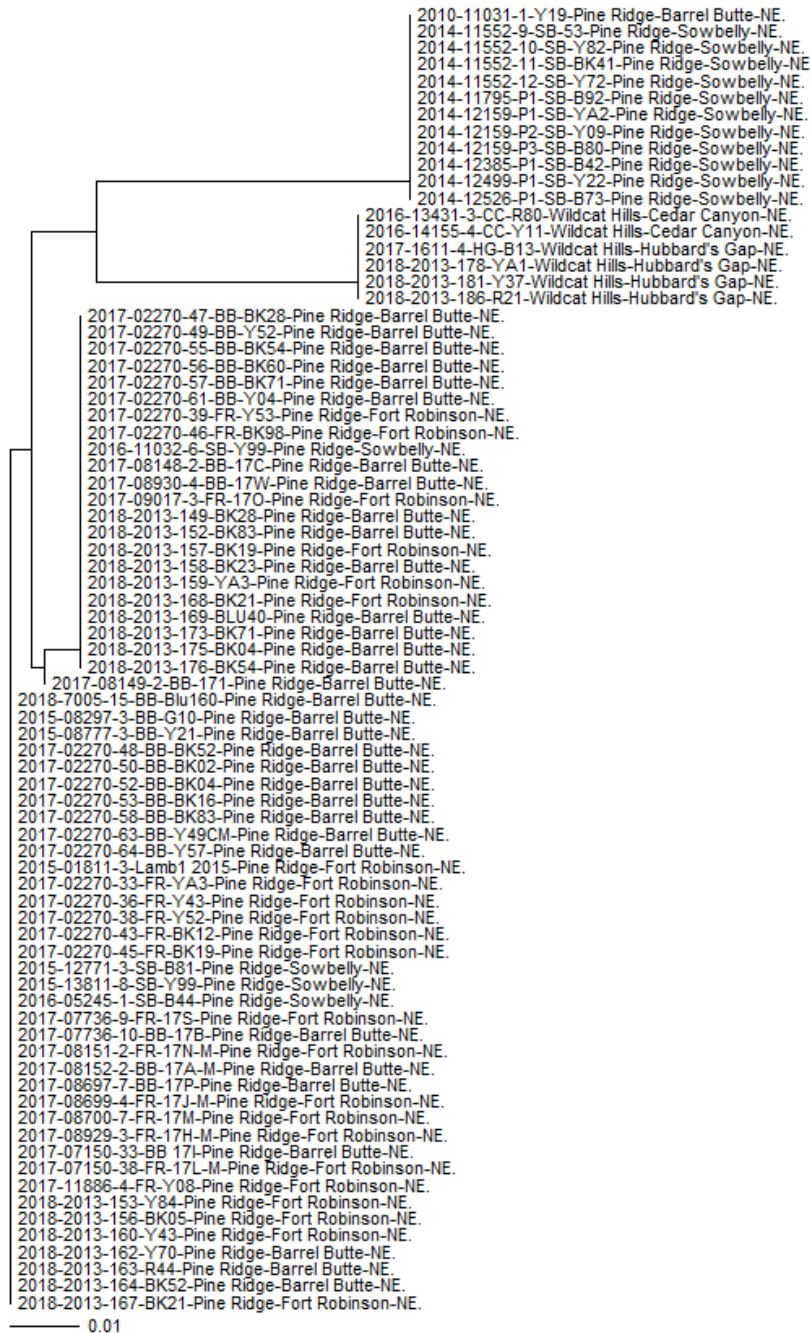


Figure 3. Phylogenetic tree of the different strain types in Nebraska's bighorn sheep herds.

Domestic Livestock Interactions

Current research has not been able to agree on the best management strategies to combat pneumonia in bighorn sheep, however, most researchers conclude that it is crucial to minimize contact between domestic sheep and wild sheep populations. By keeping wild and domestic sheep separate from each other we reduce the risk of inter-species contact and disease transmission.

Guidelines outlined by the Western Association of Fish and Wildlife Agencies (WAFWA) recommend maintaining a 9 mile buffer but in Nebraska, maintaining the recommended buffer is more difficult than in most western states, as open public lands account for only 1.9% of the state's total land area. Meaning most suitable land for bighorn sheep is privately owned and the wild sheep are nearly always located within the recommended buffer zone, (Figs. 3 & 4) although this may vary by season and time of day.

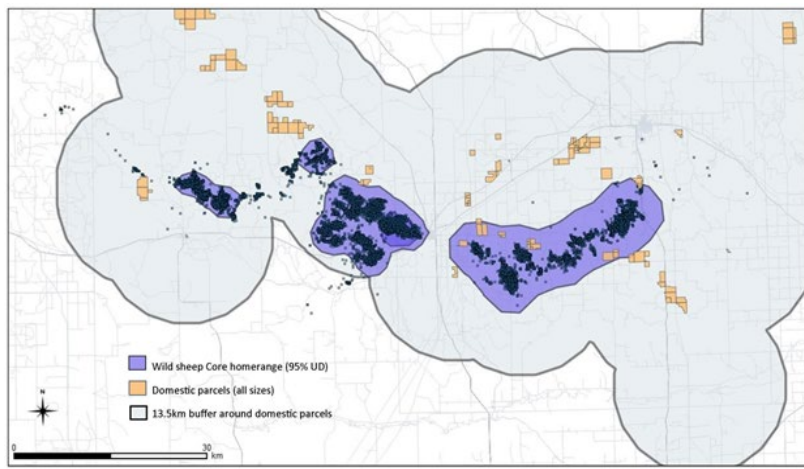


Figure 4. Ram annual home ranges and raw GPS points of wild sheep in the Pine Ridge, NE, illustrating the close proximity of domestic and wild sheep. Private parcels that support domestic sheep/goats outlined in brown (Morrison et al. 2017)

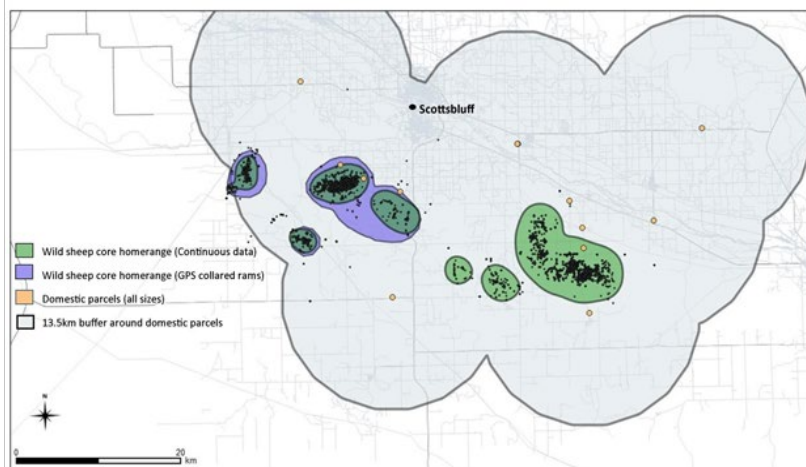


Figure 5. Ram annual home ranges and raw GPS points of wild sheep in the Wildcat Hills, NE. Private parcels with domestic sheep/goats shown in brown (Morrison et al. 2017)

Vehicle Collisions and Predation

Aside from disease, the main documented causes of mortality in Nebraska's adult bighorn sheep have been predation and collisions with vehicles. The main predator threats to Nebraska's bighorn sheep herds are mountain lions and coyotes. Bighorn sheep ranges in Nebraska overlap

with mountain lion distribution, and while not all mountain lions prey on bighorn sheep (Ernest et al. 2002), some individuals can learn to specialize on them. In Nebraska, bighorn sheep primarily exist in small herds and predation by mountain lions can have significant impacts to these populations (Wehausen 1996; Logan and Sweanor 2001). While there are management strategies in place to help alleviate some concerns (See Nebraska's Mountain Lion Management Plan), the story may be more complicated than having higher densities of mountain lions overlapping with small populations of bighorn sheep. For example, there is evidence to support that pneumonia and low alternative prey densities can increase bighorn sheep vulnerability to predation (Wehausen 1996; Rominger 2004; Smith 2014). Coyote predation generally has more impact to bighorn lambs and less with adults but vulnerability does exist with sick or injured adult animals.

The third largest cause of mortality for bighorn sheep is primarily vehicle collisions. In Nebraska vehicle collisions have caused 8 known bighorn sheep deaths as well as additional injuries to other sheep that survived or later succumbed to the injuries. The earliest recorded death by vehicle was in July 2009 when a ram was hit on Highway 71. Three more bighorn sheep (one ram in 2014, two ewes in 2017, two sheep in 2018, and one ram in May 2019) have since been struck and killed by vehicles on Highway 71 south of Gering, NE. Two sheep (one ram in December 2015 and one male lamb in February 2015) were also hit on Highway 20 west of Crawford and one sheep was hit and killed on Highway 2 south of Crawford, in November 2017.

VI. Surveillance and Monitoring

Bighorn Sheep Herd Monitoring Program

Nebraska has among the best monitored wild sheep in the western U.S. in terms of understanding distributions and population dynamics over time. In particular, the consistent monitoring of individually-tagged animals is exceptional in bighorn sheep populations. In many other states, wild sheep inhabit areas that are not easily accessible. Thus, the Nebraska bighorn sheep monitoring program offers a unique opportunity to understand the dynamics of reintroduced sheep over time and provides valuable information aiding research on a national scale.

As of August 2019, the herd surveillance program consisted of population and health monitoring data for all observable individuals in each herd. Sheep were located weekly and counted via visual observation from the ground primarily through triangulation of VHF-collared individuals and locating GPS-collared individuals using satellite points.

Any sign of mortality, respiratory disease, or other health issues are identified, documented, and responded to accordingly. Staff continue to maintain awareness of new discoveries and research related to this topic. When applicable, new individuals can be captured and collared following approved capture protocols (See Bighorn Sheep Protocol Guidebook) and samples are collected and sent to the lab to identify pneumonia positive individuals. Mortality protocols are followed for each death and relevant samples are collected and sent off to the lab for screening. As

needed, the Commission Big Game Capture and Handling Guidelines are updated to create new capture, animal handling, and mortality protocols as well as protocols for addressing any disease occurrence in Nebraska's bighorn sheep herds (See NGPC Bighorn Sheep Protocol Guidebook).

The monitoring effort also includes data recording of interactions with domestic livestock. This data provides important occurrence information as well as potential disease risk. It allows managers to identify individual sheep and consider management actions especially with domestic sheep interactions. Protocols for addressing domestic/wild sheep interactions can be found in the Commission's Bighorn Sheep Protocol Guidebook.

Upon the completion of ongoing research (~2020), a more refined surveillance strategy will be developed based on population parameters for each herd in Nebraska. Population parameters would include population levels that take into account adult survival, lamb survival, recruitment rates, ram:ewe:lamb ratios, age class, disease risk, herd health, and population trends (increasing, decreasing, and stable; Werdel et al. 2018; Parr et al. 2018). Herd assessment surveys will occur annually to consider possible surveillance strategy changes.

VII. Bighorn Sheep Season Setting Guidelines

According to the Commission strategic plan and bighorn sheep management plan, hunting will be utilized to provide recreational opportunities and management of bighorn sheep. Thus far, hunting has occurred in the Fort Robinson, Barrel Butte, and Cedar Canyon herds. However, now that there are additional propagating herds in Nebraska, it is important to develop harvest strategies that will guide season setting and harvestable numbers. Harvest strategies for bighorn sheep can be subjective and vary widely among states. To set harvest recommendations the Commission needs to

- Determine and provide annual classification and population estimates for each established herd.
- Determine harvestable numbers based on annual classification, population estimates, populations trends, as well as herd health and condition.
- Provide an annual, bighorn sheep summary with a harvest recommendation.
- Provide ram age structure and horn size (quality) estimates for each herd

Bighorn Sheep Harvest Information

There are have been a total of 25 mature rams taken by hunters since 1998

Scores:

1998 – Mr. Stride – Auction Permit – Boone & Crocket 185 7/8 – Safari Club 186 7/8

1998 – Ed Morgan – Lottery Permit – Never Scored – Approximately 170

1999 – Tyler Vettles – Lottery Permit – Boone & Crocket 172

2000 – Steve Byers – Auction Permit – Boone & Crocket 174 ½ - Safari Club 176 3/8

2000 – Andrew Summer – Lottery Permit – Never Scored – Approx. 170 – 175

2001 – Leon Kriesel – Lottery Permit – Boone & Crocket 179
 2002 – Burt Kizer – Auction Permit – Unofficial 179 ¾
 2002 – Brad Eriksen – Lottery Permit – Unofficial 180
 2003 – Steve Furley – Lottery Permit – Unofficial 174
 2004 – Brian Newton – Lottery Permit – Taken Archery – Unofficial 179
 2005 – Joe Glover – Auction Permit – Unofficial 180 - 182
 2005 – Jim Milliken – Lottery Permit – Never Scored – Approx. 170 -172
 2008 – David Janssen – Lottery Permit – Never Scored – Approx 170
 2009 – John Marsh – Auction Permit – Official Score – 178 5/8
 2009 – Brett Bollwit – Lottery Permit – Official Score – 170 5/8
 2011 – Thomas Lemmerholz – Auction – Boone & Crockett – 182 2/8
 2011 – Tyson Ritz – Lottery Permit – Unofficial – 177 5/8
 2014 – Johnny Barta – Lottery Permit – Unofficial – 167
 2015 – Barbara Sackman – Auction Permit – Unofficial 174 gross, 173 5/8 net
 2015 – Terry Bogle – Lottery Permit – Official B&C score, 191 1/8 gross, 190 5/8 net
 2016 – Brett Roberg – Lottery Permit – Unofficial net score 165 2/8
 2017 – Jack Nemuth – Lottery Permit – Unofficial score estimation 160s. Never scored
 2017 – Jason Bruce – Auction Permit – Official score 193 1/8 net. 193 5/8 gross
 2018 – Curt Richardson – Auction Permit – Unofficial score 182 net. 183 gross
 2018 – Dave Hunter – Lottery Permit – Unofficial score 160 gross.

Auctions:

1998 – Safari Club International - \$87,500
 2000 – North American Wild Sheep Foundation - \$85,000
 2002 – Safari Club International - \$55,000
 2005 – Grand Slam Club/Ovis - \$83,000
 2009 – North American Wild Sheep Foundation - \$80,000
 2011 – Grand Slam Club/Ovis - \$117,500
 2015 – North American Wild Sheep Foundation - \$130,000
 2016 – North American Wild Sheep Foundation – \$115,000
 2017 – Grand Slam Club Ovis - \$135,000
 2018 – Wild Sheep Foundation- \$115,000

Lottery Applicants from 1998 to 2018 generated:

Year	Applicants	Year	Applicants	Year	Applicants	Year	Applicants
1998	3,443	2004	1,585	2010	NA	2016	2,597
1999	1,996	2005	1,445	2011	1,762	2017	2,756
2000	1,806	2006	NA	2012	NA	2018	2,279
2001	886	2007	NA	2013	NA		
2002	1,838	2008	1,350	2014	1,153		
2003	1,595	2009	1,353	2015	2,307		

Season and Permit Allocation Guidelines

Evaluate Population Indicators

- Conduct surveys to determine
 - Population census
 - Ram classification census (representation of all age classes is desirable)
 -
 - Lamb survival (40-50% lamb survival rate is considered standard for a healthy, growing disease free herd; Parr et al. 2018)
 - Maintain a minimum 1:4 ram/ewe ratio
 - Incidental observations
- Incorporate past, present, and future disease events
- Incorporate natural mortality rate (10-20%; Parr et al. 2018; Singer et al. 2000; Jorgenson et al. 1997) into predicting future population estimates
- Include the possibility of severe weather events (drought, heavy snowfall, etc.) affecting future populations
- Incorporate overall herd health into future harvest decisions

Manage the Pine Ridge and Wildcat Hills as separate units

- A general guideline for permit allocations is a minimum total population of 50 bighorns within in each Pine Ridge and Wildcat Hills management unit with representation of Class I, II, III, & IV rams. (Class I = 1.5 - 2.5 yr old, Class II = 3.5-5.5 yr old, Class III = 6.5 – 7.5 yr old, Class IV = 8.5+)
- After annual surveys, disease evaluations and population assessments, ram permits will be allocated based on the representation of Class I-IV rams (1.5 and older) in the population with emphasis on maintaining some older age rams for harvest, viewing, and genetic diversity.
- Permit allocation and harvest will also consider the number of older rams nearing the end of their life span.
- Any newly introduced herd will not be utilized to determine harvest numbers or seasons for a minimum of 5 years.
- Disease outbreaks that significantly decrease the population may indicate that the season be closed. If permits have been issued it will be the Commissions prerogative to:
 - Close the season and refund all permits
 - Close the season but allow each successful applicant to hunt for a bighorn sheep when harvestable numbers are reached.
- If population objectives and/or cultural tolerances are met or exceeded, harvest and/or translocations of ewes and young rams will be considered.
- All successful permit winners will hunt under the guidance of Commission staff.
- Permit allocation:

- First permit to Nebraska resident via lottery drawing.
- Second permit to conservation organization to be sold via auction.
- Three or more permits to Nebraska resident via lottery drawing or auction for resident or nonresident.

Potential Ewe Harvest Season

When a population's density increases, the risk of disease outbreaks may also increase.

Implementing a ewe harvest in this event could both help stabilize the population and reduce the likelihood of a disease outbreak like pneumonia. Past research looked at the effect ewe removal would have on a population and found that not only did the removal of 12-24% of adult ewes from the herd lead to faster horn growth of younger rams in the herd (attributed to having lowered competition in nursery groups), but also that the removal did not lead to a population decline as was originally feared. Although past research was unable to verify the effect ewe removal would have on potential pneumonia outbreaks (due to the fact that the herd appeared pneumonia free), they suggest that an increase in density could be considered a threat to the population and one management strategy is ewe removal (Jorgenson et al. 1993). In the event that a herd meets plan objectives and is stable, the Commission may implement a ewe harvest. The Commission will evaluate the following population indicators to consider a ewe harvest

Population Indicators

- Conduct surveys to determine
 - Population census
 - 3-year adult ewe population trend (increasing)
 - Adult ewe population <10 (2.5 years of age and older) and consideration to remove all ewes from the herd
 - Lamb survival/lamb/ewe ratio 3-year trend
 - Stable or increasing lamb/ewe ratio with a 40-50% lamb survival rate of lambs >4 months of age (Parr et al. 2018)
 - Maintain a minimum 1:4 ram/ewe ratio
 - Herd reduction is desired to reduce disease risk
 - Herd reduction is desired to improve ram horn growth
 - Herd reduction is desired to improve habitat
 - Herd reduction is desired due to depredation and social tolerance limits
 - Incidental observations
- Incorporate past, present, and future disease events
- Incorporate natural mortality rate (10-20%; Parr et al. 2018; Singer et al. 2000; Jorgenson et al. 1997) into predicting future population estimates
- Include the possibility of severe weather events (drought, heavy snowfall, etc.) affecting future populations
- Incorporate overall herd health into future harvest decisions

VIII. Additional Management Actions and Recommendations

Predation

From Nebraska's 2018 Mountain Lion Management Plan "Due to the ability of an individual mountain lion to cause population declines, it may be necessary for the Commission to remove a mountain lion in order to prevent the extirpation of a bighorn sheep herd or sub-herd. This option will only be considered if a mountain lion has proven to target bighorn sheep, and predation by the individual significantly jeopardizes the existence of a bighorn herd or sub-herd. Mountain lions that prey on bighorn sheep known to be injured, diseased or otherwise debilitated, may or may not be targeted for removal as some predation may be partly compensatory in herds with significant pneumonia (Smith et al. 2014). Any effort to remove a mountain lion for predation on bighorn sheep must be authorized by the Director of the Commission"

Consideration for additional research may be warranted to determine if lower abundance of alternative prey sources could be contributing to increased predation on bighorn sheep (Wehausen 1996; Rominger 2004; Smith 2014). In terms of neonate survival, there have been various cases of suspected predation as well as lowered recruitment due to pneumonia positive adult females. In Nebraska's herds, more concrete data on cause-specific mortality continues to be collected. As of late-2016, a large-scale research project began where GPS, and VHF radio collars were placed on adult females, and expandable breakaway VHF radio collars placed on newborn bighorn sheep. A research project of this nature is unprecedented in Nebraska and will allow for researchers to better assess adult and neonate survival and cause-specific mortality on a large scale.

Vehicle Collisions

In order to assist with mitigating future vehicle collisions, The Commission has been working with the Nebraska Department of Transportation (NDOT) to install warning devices near major roadways where bighorn sheep frequent. Numerous collisions have been confirmed over the years with bighorn sheep as well as the likelihood of many unreported incidents. Future mitigation opportunities with the NDOT and conservation groups are encouraged.

Habitat Protection

Research suggests that current delineated lambing habitat may be only a small portion of habitat that is used for parturition sites and could be biased for habitat that is used when lambs are more mobile (Smith et al. 2015). The Commission, with the aid of the University of Nebraska at Lincoln, is re-identifying suitable habitat that may more precisely encompass preferred parturition sites such as areas with rugged terrain with sufficient flat, shelf-like areas, with minimal human disturbance and preferably on south and west facing slopes (Smith et al. 2015). Also, consider current or new strategies to protect existing habitat which may include acquisition, easements or conservation programs. Habitat modification may also be a

consideration for improvement or protections of bighorn sheep habitat (Bleich 2010, Morrison et.al 2017).

Depredation

The Commission acknowledges that wildlife species periodically cause damage to agricultural crops, stored crops, fences, tree farms, and other property. Wildlife damage cannot always be prevented but in the event that bighorn sheep have caused damage, the Commission will follow normal depredation protocol. A report will be taken and an on-site inspection will determine the extent of the damage and possible responses. Responses may include non-lethal measures, reviews of population levels and ewe harvest season considerations.

IX. Management Objectives

Management Goal

The Commission's goal is to establish a self-sustaining, free-ranging bighorn sheep population in all areas of suitable habitat in the State of Nebraska.

Objectives and Strategies

The following list of recommended objectives and strategies to be considered is not all inclusive and will continue to be updated and adapted as new research and information comes in. Every situation has different variables and special circumstances that must also be taken into account before proceeding on a course of action or combination of actions. Always consider discussing with veterinary professionals and wildlife management officials on the best course of action to take.

Objectives:

1. Attempt to mitigate bighorn sheep loss from disease; including, but not limited to: separation of domestic sheep and goats and wild sheep populations; and targeted culling and translocations.
2. Continue to stay up-to-date on current research and technology as it pertains to bighorn sheep diseases, treatments, and management strategies
3. Continue to conduct research and analyze data on the bighorn sheep herds in Nebraska to help inform future management decisions
4. Create outreach programs to keep the public up-to-date on challenges facing bighorn sheep
5. Follow and update established protocols when responding to diseased animals or mortality events
6. Establish a strategy that will allow for harvest of bighorn sheep within management goals and objectives.
7. Update and modify this management plan as new information on bighorn sheep ecology and management becomes available.

Objective 1. Attempt to mitigate bighorn sheep loss from disease; including, but not limited to: separation of domestic sheep and goats and wild sheep populations; and targeted culling and translocations.

Separation of domestic and wild sheep populations:

Reducing the risk of disease transmission from inter-species contact is vital for the long-term health of bighorn sheep populations. The Commission can do this by monitoring and documenting domestic sheep and goats in land overlapping wild bighorn sheep habitat; offering assistance to owners of domestic sheep and goats to help minimize contact; and educating the public about the potential risks domestic sheep and goats pose to wild sheep.

Other recommendations include:

- Maintaining more permanent movement barriers in areas where domestic properties are in close proximity to wild sheep home ranges.
- Consider funding for double fencing small domestic sheep flocks
- Consider habitat manipulation to enhance sheep avoidance (i.e. by planting dense conifer stands etc)
- Actively scare or herd wild sheep away from domestic parcels
- Consider conservation easements with a domestic/exotic sheep and goat restriction in or near bighorn sheep range
- Remove wild sheep that have directly interacted with domestic sheep or goats
- WAFWA's WSWG recently developed a set of recommendations for consideration.
 - Continue to coordinate with other agencies, landowners, and stakeholders regarding management of domestic sheep and goats on, or near ranges occupied by wild sheep
 - Fully consider the risk of disease transmission when issuing or commenting on permits/regulations associated with private and public lands used for producing of domestic sheep and goats
 - Remove wild sheep that have likely associated with domestic sheep or goats and develop a policy to promptly respond to wild sheep wandering from occupied wild sheep ranges
 - Develop educational materials and outreach programs to interpret the risk of association between wild sheep and domestic sheep or goats
 - Manage wild sheep habitat to promote healthy populations in areas without domestic sheep or goats
 - Provide protocol or system for private landowners with domestic sheep and goats to follow to report interactions of domestic and wild herds
- Consider other mitigating practices as developed

Culling and Translocations:

Some bighorn sheep populations can reach a point of “chronic persistent infections” and will never recover (Wood et al. 2018). If this occurs, there may be no other option but to cull the entire herd and start over with new translocations from healthy herds. Even if the population

is not at the “chronic persistent infections” stage, culling the chronic or super “shedders” (individuals that test positive for *M. ovipneumoniae* for two consecutive years) or symptomatic individuals from the herd could help manage the disease prevalence in the herd (Delfanian 2019). And bringing in new, healthy individuals with new genes could also help a struggling herd after culling the chronic “shedders”. Additional recommended actions:

- Consider culling chronic shedders from the herd
- Consider augmenting herds by relocating animals from other source that are considered disease free
- Continue to monitor each herd and collect samples to determine disease prevalence and cause-specific mortality data to help inform future management actions
- Consider the immediate culling or removal of an individual bighorn sheep that has interacted with a domestic sheep or domestic populations. Attempts should be made before the individual bighorn sheep returns to the bighorn sheep herd.
- Consider new management strategies as research suggests

Bighorn Sheep Population Threshold

As per this response plan, once a sub-herd (Barrel Butte, Fort Robinson, Sowbelly, Hubbard’s Gap, and Cedar Canyon) reaches a ewe population threshold of ≤ 10 and other management strategies have been unsuccessful, consider capture or lethal means to remove the remaining ewes or entire population (Fanning 2014).

- Consider staff culling efforts to remove all animals within a sub-herd
- Consider incorporating a lottery system to distribute bighorn sheep harvest permits to remove the remaining animals within a sub-herd
- Consider auctioning bighorn sheep harvest permits to remove the remaining animals within a sub-herd
- Consider non-lethal capturing of all remaining animals within a sub-herd and moving them to a captive facility for further research.

Re-establishing or Establishing New Herds

- Seek input from WAFWA’s WSWG and Wild Sheep Foundation (WSF) for healthy populations for possible transplant.
- Seek bighorn sheep species type (*Ovis canadensis canadensis*) based on historic, native existence
- Consider transplants from healthy internal populations
- Seek a minimum of 20 ewes and 4 rams for the establishment of a new herd (Nevada Division of Wildlife 2001)
- Consider translocating from a population that has been disease free for at least 5 years
- Consider using a source population of bighorn sheep that would reduce prey-naiveté mortalities

- All transplanted animals will undergo disease testing and be equipped with identifiable collars or tags for recapture or removal if necessary
- Consider antibiotic or vaccination treatments prior to transport
- Consult with United States Department of Agriculture (USDA) and Nebraska Department of Agriculture (NDA) with transplant regulations
- Consider collaring each animal prior to release or transport to monitor movement, health, disease, and mortalities
- Consider exotic/domestic sheep and goat locations and allotments prior to transplant and possible mitigation procedures
- Consider social tolerance of the area prior to reintroductions through public meetings, surveys, direct communication, etc.
- If establishing in a new area, consider modeling habitat suitability and buffering distances from domestic sheep and goat populations

Objective 2: Continue to stay up-to-date on current research and technology as it pertains to bighorn sheep diseases, treatments, and management strategies

Disease Research

In order to manage the interaction of wild and domestic sheep, and thereby the transmission of disease, it is important to identify “hot” zones or areas in which domestic sheep test positive for pneumonia (specifically *M. ovipneumoniae*) (Besser et al. 2012, Besser et al. 2013). By working with landowners to sample their domestic sheep the Commission and researchers can better identify these potential disease-transmission zones. This will also help identify where resources can be funneled in the event a vaccine is available.

Current research regarding vaccines, if considered, suggests to protect wild sheep from fatal pneumonia a vaccine would need to target both lkt+ members of Pasteurellaceae as well as *M. ovipneumoniae* (Besser et al. 2012, Besser et al. 2013, Raghavan et al. 2017). Vaccinating domestic sheep and goats could help protect wild sheep by reducing shedding of *M. ovipneumoniae* from domestic sheep. Vaccinating lambs and/or adults could also improve herd health but may be harder to accomplish due to lack of resources, personnel, inaccessible terrain, and the likelihood that one dose would not be enough to protect the animals (Sirochman et al. 2012, Besser et al. 2013). Additional recommended actions:

- Continue to collect disease samples from wild sheep herds to identify the different strains within the herds.
- Continue to consider new research currently assessing strain types that may suppress fatal strains.
- As research indicates, consider treatment options for bighorn sheep and/or domestic sheep in or near bighorn sheep habitat
- As research indicates, consider treatment options for adults and lambs, which may include antibiotics and vaccines

Objective 3: Continue to conduct research and analyze data on the bighorn sheep herds in Nebraska to help inform future management decisions

Herd Monitoring

Herd dynamics and health are constantly changing. Monitoring programs play a crucial role in developing appropriate management strategies.

- Identify all diseases and parasites that can potentially impact bighorn sheep in Nebraska. Staff continues to maintain awareness of new discoveries and research related to this topic.
- Continue to survey and monitor bighorn sheep herd health, including data collection through observation, disease events, captures, lab tests, and mortality events
- Apply, as needed, the current Commission Big Game Capture and Handling Guidelines to update or create new capture, animal handling, and mortality protocols as well as protocols for addressing any disease occurrence in Nebraska's bighorn sheep herds. (See NGPC Bighorn Sheep Protocol Guidebook for protocols and guides).
- Continue to update electronic databases as per the data management protocol
- Apply and update annually, monitoring and surveillance strategies of each herd for all potential disease and parasite occurrences. Staff continues to maintain awareness of new discoveries and research related to this topic.
- Consider different monitoring strategies once population goals are met

Population Research

Conduct scientifically acceptable research on bighorn sheep populations, disease, behavior, and habitat in Nebraska.

- Conduct follow-up monitoring or research on each release to determine dispersal, and success or failure of transplant, and reasons thereof.
- Conduct monitoring or research into social interactions between bighorn sheep and other wild and domestic species.
- Determine interactions between resident bighorn sheep and additional individuals released into the same area.
- Develop and modify a sound population monitoring strategy for bighorn sheep, and reassess and update the monitoring strategy as needed.
- Consider incorporating a genetics study for the different herds

Objective 4: Create outreach programs to keep the public up-to-date on challenges facing bighorn sheep

Public Outreach

In order to manage bighorn sheep herds successfully, programs need to be in place to keep the public up-to-date on the challenges facing bighorn sheep. While it may not seem intuitive to manage bighorn sheep diseases by using public outreach programs, these programs have a

very crucial part to play. Not only do we need to continue to promote bighorn sheep conservation in general but a large part of the current disease management for bighorn sheep lies in the domestic livestock industry. Keeping domestic sheep and goats from wild populations is crucial in stopping the transmission of diseases, particularly pneumonia. The Commission will also be able to build trust and relationships with landowners through open communication and assistance with certain projects that would have dual benefits for both the bighorn sheep and the private landowners. Ideas for Outreach Programs:

- Develop visual information referencing bighorn sheep ecology and management
 - Provide input into segments of “Outdoor Nebraska” referencing bighorn sheep.
 - Develop watchable wildlife sites for bighorn sheep viewing.
 - Develop materials for use in Project Wild referencing bighorn sheep.
 - Develop interpretive sites with signs at Fort Robinson and elsewhere when appropriate.
- Continue with free bighorn sheep viewing workshops to see wild sheep and learn about their habitat and challenges facing them
- Work with the Commission Communications Division to present current information to the public and interested entities.
- Hold landowner meetings or workshops particularly for domestic sheep or goat owners to educate about disease transmissions and hold discussions on future management proposals
- Provide bighorn sheep best management practices (BMP) for use by private landowners, conservation groups, and other government agencies. The Wild Sheep Working Group (WSWG) from WAFWA has addressed this on a larger scale.
- Coordinate and partner with the NDA, 4-H groups and other entities on education and agreeable management actions considering each species
- As new, pertinent information becomes available, update brochures, and flyers with information about the bighorn sheep in Nebraska

Partnerships and Collaborations: All western states with Rocky Mountain bighorn sheep continue to deal with population fluctuations due to disease events or other factors. Nebraska has remained active with wildlife professionals and conservation partners working towards solutions with the issues the bighorn sheep face. Recommended actions:

- Continue involvement with the WAFWA’s WSWG
- Engage with conservation organizations and interested parties for bighorn sheep funding opportunities and projects

Objective 5: Follow and update established protocols when responding to diseased animals or mortality events

These protocols include immobilization, animal handling and capture, mortality, domestic sheep interactions, targeted culling situations, and data handling. They will be updated as new conditions and procedures arise. They are not to be used exclusively but with good judgement,

veterinary input, trained personnel input, and a certain flexibility. Field situations change constantly and while these protocols will serve as guidelines they cannot account for every variable and should not be used as such. They can be found in the Bighorn Sheep Protocol Guidebook.

Objective 6: Establish a strategy that will allow for harvest of bighorn sheep within management goals and objectives.

- Determine and provide annual classification and population estimates for each established herd.
- Determine harvestable numbers based on annual classification and population estimates as well as herd health and condition.
- Provide an annual, bighorn sheep summary and with a harvest recommendation.

Objective 7: Update and modify this management plan as new information on bighorn sheep ecology and management becomes available.

- Review scientific literature reference bighorn sheep as it becomes available.
- Attend workshops, conferences, symposia, etc. where bighorn sheep ecology and management will be discussed.
- Wildlife Division personnel meet annually to review progress made and changes needed. Other agencies may be invited to participate.
- Inform all interested publics of any changes made to this management plan.

X. Literature Cited

- Besser, T.E., E.F. Cassirer, M.A. Highland, P. Wolff, A. Justice-Allen, K. Mansfield, M.A. Davis, and W. Foreyt. 2013. Bighorn sheep pneumonia: Sorting out the cause of a polymicrobial disease. *Preventive Veterinary Medicine*. 108: 85-93
- Besser, T.E., M.A. Highland, K. Baker, E.F. Cassirer, N.J. Anderson, J.M. Ramsey, K. Mansfield, D.L. Bruning, P. Wolf, J.B. Smith, and J.A. Jenks. 2012. Causes of Pneumonia Epizootics among Bighorn Sheep, Western United States, 2008-2010. *Emerging Infectious Diseases*. 18(3).
- Buechner, H. K. 1960. The bighorn sheep in the United States: its past, present, and future. *Wildlife Monographs*. 4: 3-174.
- Delfanian, C. 2019. Removing ‘Typhoid Marys’ Restores Health of Bighorn Sheep Herd. *South Dakota Game, Fish and Parks Conservation Digest*. Pp. 25-29.
- Dubay, S., H.J.E., Schwant, J. Devos, and T. McKinney. 2002. Bighorn sheep (*Ovis canadensis*) diseases: a brief literature review and risk assessment for translocation. NWSGC proceedings. <<http://media.nwsgc.org/proceedings/NWSGC-2002/2002-Dubay%20et%20al.pdf>>. Accessed 18 January 2019.
- Ernest, H. B., E. S. Rubin, and W. M. Boyce. 2002. Fecal DNA analysis and risk assessment of mountain lion predation of bighorn sheep. *Journal of Wildlife Management* 66:75-85
- Fanning, D. 2014. Counting Sheep (Bighorns, I Mean). *Exploring Wilderness and Beyond*. <<https://rawahranger.com/2014/12/bighorn-sheep/>>. Accessed January 25, 2019.
- Grigg, J.L., L.L. Wolfe, K.A. Fox, H.J. Killion, J. Jennings-Gaines, M.W. Miller, and B.P. Dreher. 2017. Assessing Timing and Causes of Neonatal Lamb Losses in a Bighorn Sheep (*Ovis canadensis canadensis*) Herd via Use of Viaginal Implant Transmitters. *Journal of Wildlife Diseases*. 53(3): 596-601.
- Jorgenson, J.T., M. Festa-Blanchet, and W.D. Wishart. 1993. Harvesting Bighorn Ewes: Consequences for Population Size and Trophy Ram Production. *Journal of Wildlife Management*. 57(3): 429-435.
- Jorgenson, J.T., M. Festa-Blanchet, J. M. Gallard, and W.D. Wishart. 1997. Effects of age, sex, disease, and density on survival of bighorn sheep. *Ecology*. 78: 1019-1032.
- Logan, K. A., and L. L. Swenar. 2001. *Desert puma: evolutionary ecology and conservation of an enduring carnivore*. Island Press, Washington, D.C., USA.
- Morrison T.A., T. Nordeen, K. Decker. 2017. Population Trends, Resource Selection and Area Requirements of Bighorn Sheep in Northwest Nebraska. Final Bighorn Sheep Report, Nebraska Game and Parks Commission, Alliance, Nebraska, USA.

- Nevada Division of Wildlife. 2001. Nevada Division of Wildlife's Bighorn Sheep Management Plan. <http://www.ndow.org/uploadedFiles/ndoworg/Content/public_documents/Wildlife_Education/Publications/bighorn_management_plan.pdf>. Accessed 17 April 2019.
- Parr, B.L., J.B. Smith, and J.A. Jenks. 2018. Population Dynamics of a Bighorn Sheep (*Ovis canadensis*) Herd in the Southern Black Hills of South Dakota and Wyoming. *The American Midland Naturalist*. 179: 1-14.
- Raghavan B., J. Bavananthasivam, A. Kugadas, G.J Haldorson, and S. Srikumaran. 2017. Effect of vaccination against pneumonia on the survival of bighorn sheep (*Ovis Canadensis*) comingled with carrier animals. *Veterinary Microbiology*. 203: 56-61.
- Rominger E.M., H.A. Whitlaw, D.L. Weybright, W.C. Dunn, and W.B. Ballard. 2004. The influence of mountain lion predation on bighorn sheep translocations. *Journal of Wildlife Management*. 68: 993-999.
- Sappington, J.M., K.M. Longshore, and D.B. Thompson. 2007. Quantifying Landscape Ruggedness for Animal Habitat Analysis: A Case Study Using Bighorn Sheep in the Mojave Desert. *Journal of Wildlife Management*. 71(5): 1419-1426.
- Singer, F. J., L.C. Zeigenfuss, and L. Spicer. 2001. Role of patch size, disease, and movement in rapid extinction of bighorn sheep. *Conservation Biology*. 15: 1347-1354.
- Singer, F. J., E.S. Williams, M.W. Miller, and L.C. Zeigenfuss. 2000. Population Growth, fecundity, and survivorship in recovering populations of bighorn sheep. *Restoration Ecology*. 8: 75-84.
- Smith, J.B., T.W. Grovenburg, and J.A. Jenks. 2015. Parturition and Bed Site Selection of Bighorn Sheep at Local and Landscape Scales. *The Journal of Wildlife Management*. 79(3): 393-401.
- Smith, J.B., J.A. Jenks, T.W. Grovenburg, and R.W. Klaver. 2014. Disease and Predation: Sorting out Causes of a Bighorn Sheep (*Ovis Canadensis*) Decline. *PLoSOne*. 9(2)
- Wehausen, J. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. *Wildlife Society Bulletin* 24:471-479.
- Werdel, T.J., J.A. Jenks, T.E. Besser, J.T. Kanta, C.P. Lehman, and T.J. Frink. 2018. Survival of Translocated Bighorn Sheep in the Deadwood Region of the Black Hills, South Dakota. *Northwestern Naturalist*. 99: 222-231.
- Wildlife Health: Diseases affecting Idaho's wildlife. 2018. Idaho Department of Fish and Game. <<https://idfg.idaho.gov/conservation/wildlife-health>>. Accessed January 17, 2019.
- Wood, M.E., K.A. Fox, J. Jennings-Gaines, H.J. Killion, S. Amundson, M.W. Miller, and W.H. Edwards. 2017. How Respiratory Pathogens Contribute to Lamb Mortality in a Poorly Performing Bighorn Sheep (*Ovis Canadensis*) Herd. *Journal of Wildlife Disease*. 53.1: 126-130.