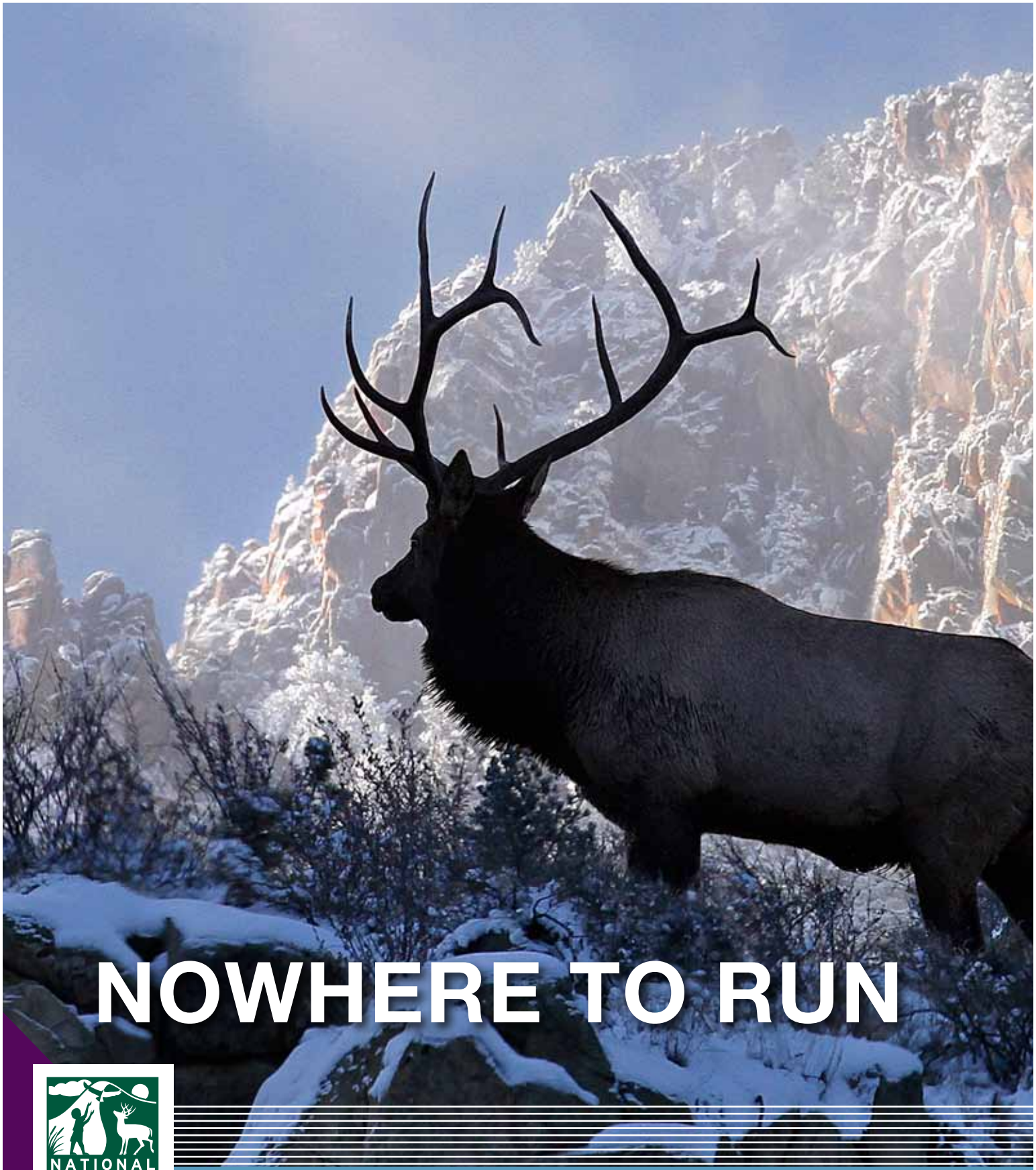


NOWHERE TO RUN

NATIONAL WILDLIFE FEDERATION®

BIG GAME WILDLIFE IN A WARMING WORLD

TABLE OF CONTENTS

Andrew Cattoir

Barbara Wheeler

EXECUTIVE SUMMARY

Kabsik Park

Even the largest species on the landscape—our nation's treasured big game wildlife—are being directly exposed to changing climate, and indirectly through affects on habitat. Populations and habitats have already been affected, and landscapes are changing. Increasingly severe drought, rising temperatures and greater weather extremes will leave no big game species untouched.

Huge investments were made to restore big game in the 20th century and continue today. These investments have come from many sources, especially special excise taxes paid by hunters through the Federal Aid in Wildlife Restoration Act. As a result, many big game habitats and populations have been successfully restored across the Nation. However, restoration of caribou, deer, moose, mule deer, pronghorn and white-tailed deer are expected to be set back by climate change. Bighorn sheep, still at a small fraction of their historical levels, can ill-afford the added challenge of climate change. It appears that bears will be less affected and only elk may fare better, at least for the near future.

Trekking into the outdoors is popular, whether to hunt, watch big game, camp or hike. As climate change progresses, these activities will expose outdoor adventurers to an increased risk of Lyme disease. Its carrier, the deer tick, is expected to survive warming winters in greater numbers and to increase its range by more than half.

Carbon emissions, which drive climate change, can be addressed by implementing the Environmental Protection Agency's authority under the Clean Air Act to reduce carbon pollution from power plants. Development of clean energy sources, such as solar and wind, facilitates reducing fossil fuel use. Restoration of natural carbon sinks has the double benefit of taking carbon out of the atmosphere and providing habitat for big game and other wildlife.

Actions must also be taken to help safeguard big game wildlife from the climate impacts of carbon already polluting our atmosphere. These include promoting the practice of "climate-smart conservation" by explicitly taking climate change into account in our wildlife and natural resource management efforts. Maintaining or restoring connections between winter and summer ranges and reducing other stressors is important. Key habitat areas must be protected where they exist now or could exist in the future. Hunters can support wildlife agencies as they adjust seasons and management plans to account for the effects of climate change.

INTRODUCTION

Climate change is already having significant impacts on big game and their habitats. The past century's conservation achievements of successfully restoring big game wildlife are now at risk from the pervasive effects of climate change. Big game watchers, photographers and hunters, as well as outdoor recreational businesses and wildlife managers, all have a vested interest and a role to play in safeguarding big game and their habitats in the face of climate change. In this report we address the potential effects of climate change on eight of the most common or widespread big game species: white-tailed deer, mule deer, moose, elk, pronghorn, bighorn sheep, black bear and caribou.

Climate Change

Over-whelming scientific evidence shows that human activities are causing the climate to change. Air temperatures in the United States and around the world are rising due primarily to the addition of carbon dioxide and other heat-trapping gases to the atmosphere. Carbon pollution is generated primarily from the burning of coal, oil and gas, with a secondary contribution from deforestation and other changes in land use.[1] In 2012 the lower-48 states had the highest average temperature on record, a full 3.2 degrees Fahrenheit above the 20th century average.[2] Furthermore, seven of the top ten warmest years on record in the lower-48 states have occurred since 1998.[3] Extreme meteorological events, including heat waves, droughts and heavy rainfall, are becoming more frequent and severe, as are associated wildfires and floods.[4]

Observed climatic changes are relatively small compared to projections for the coming decades. Even with significant reductions in carbon dioxide and greenhouse gas emissions in the near-term, the effects of recent and current emissions will continue to manifest for many decades. And while the climate has always exhibited variability, and major climatic shifts have occurred throughout geological history, warming this century is likely to occur ten times faster than during any climatic shift in the past 65 million years.[5]

Ticks, Lyme Disease and Climate Change—A Perfect Storm

Anyone spending significant time outdoors should be concerned about the effects of climate change on ticks. Lyme disease is a bacterial disease carried by western black-legged ticks, as well as black-legged ticks, commonly known as deer ticks, and is most easily transmitted in the spring and summer.[6] Survival of deer ticks is greater in milder winters.[7] Longer summers can lead to proliferation of stronger and more persistent strains of the Lyme disease bacteria with greater severity of infection in humans. As the warm season increases in length there is likely to be an increase in Lyme disease severity, particularly in the upper Midwest, similar to New England where the incidence of Lyme disease is high.[8] As if that isn't enough, climate change could expand the distribution of deer ticks nearly 70 percent by later this century, primarily to the north.[9] This could also lead to an increase in other much less commonly known tick-borne diseases, such as Powassan virus, anaplasmosis and babesiosis.[10]

At Risk—The Successful History of Restoring Big Game Wildlife

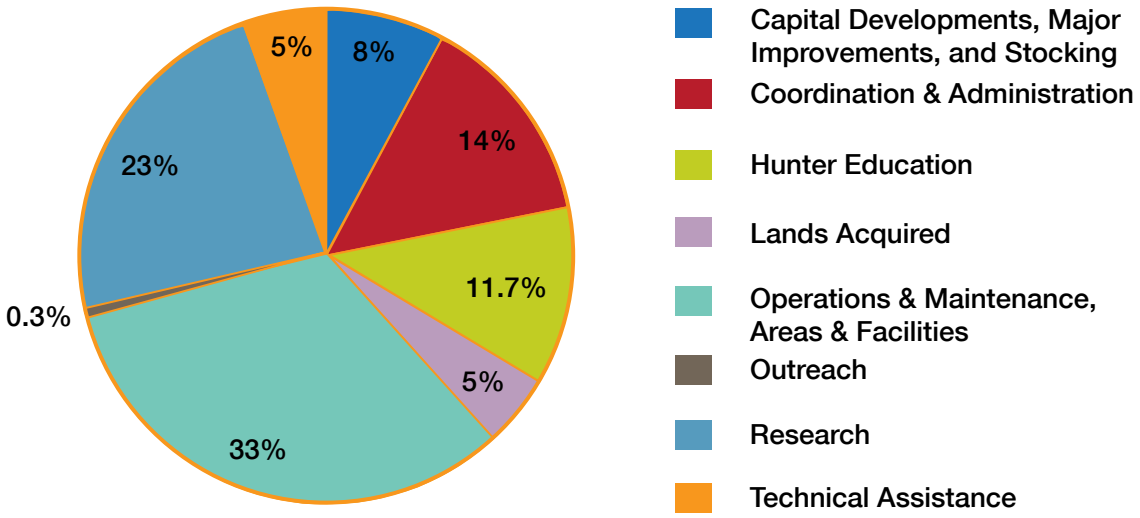
Elk, moose, bear, pronghorn, mule deer and white-tailed deer are all poster children of remarkable conservation efforts. Today these species are common in many areas and are popular game species. They are also extremely popular for viewing, such as in Rocky Mountain National Park where bugling bull elk in rut can be seen shepherding their harems, sometimes with 20 or more cows.[11,12]

Our nation's big game wildlife have not always fared well. By the end of the 19th century and in the early 20th century most of their populations had been devastated by unregulated take and widespread habitat destruction.[13] Even white-tailed deer were rare or gone from much of their historic range.[14]

"We're beginning to see evidence of the impacts of climate change on wildlife species and their habitats. Successful adaptation to changing conditions requires that hunters, wildlife viewers, wildlife agencies and others work together to reduce risks and increase resilience."

Gordon S. Myers, Executive Director, North Carolina Wildlife Resources Commission

Wildlife Restoration Accomplishments



Source: 1986-2011 Federal Aid Information Management System

In the 20th century the dismal status of big game and other wildlife began to improve. Leading the charge was President Theodore Roosevelt, an ardent conservationist. He established the first National Wildlife Refuge in 1903,[15] which was followed by executive orders establishing 50 wildlife refuges, 150 new national forests and five national parks.[16] In 1912 Roosevelt declared that "There can be no greater issue than that of conservation in this country."[17]

In 1933 Aldo Leopold became the first professor of game management in the country and published the book Game Management,[18,19] thereby establishing a foundation for modern wildlife conservation. His conservation philosophy was further developed in "A Sand County Almanac"[20] and he is widely regarded as the "father of wildlife management."[21]

Just a few years after Leopold became a professor, Jay N. "Ding" Darling, an editorial cartoonist and impassioned conservationist, founded the National Wildlife Federation in 1936.[22] He orchestrated adoption of a policy resolution leading to the National Wildlife Federation's first important accomplishment, in collaboration with others, which was passage of the Federal Aid in Wildlife Restoration Act.[23] Strongly supported by hunters, it is also known as the Pittman-Robertson Act or simply P-R for the two congressmen who successfully ushered it through Congress.

Through Pittman-Robertson, the developing wildlife conservation movement now had a critical funding source – an 11 percent manufacturers' excise tax on guns, ammunition and archery equipment. The funds generated from this tax were disbursed to the state wildlife agencies for wildlife conservation and hunter education programs. The law was remarkably innovative. It required that for every three dollars provided, states must provide a matching dollar, thereby expanding the amount of money dedicated to conservation. It also required that to be eligible for Pittman-Robertson Act funds, all other income to state wildlife agencies must be used only for agency conservation purposes. To this day, the Pittman-Robertson Act protects agency funds from diversion to non-conservation purposes. In today's challenging fiscal climate, continuing the dedicated funding from Pittman-Robertson is absolutely critical for facilitating conservation actions by the states.

In 2012 alone more than $290 million was distributed for conservation to the states and U.S. territories. Since its passage 75 years ago nearly $10 billion dollars (inflation adjusted) were distributed to the states and territories. The Pittman-Robertson Act is credited with saving the pronghorn from possible extinction and helping with the recovery of other of big game species across the country.[24]

With the success of the Pittman-Robertson legislation and many other efforts by citizens, state wildlife agencies and federal agencies, hunting and viewing opportunities have grown remarkably. In 2011 there were more than 12 million adult big game hunters, and they spent more than $16 billion for big game hunting purposes. More than 22 million people watched big game around their homes, and 10 million traveled to view big game.[25]

Big Game Hunters and Viewers in 2011, and Wildlife Restoration Funds to States from the Pittman-Robertson Act (1939-2013)

	Big Game Hunters	Wildlife Restoration Funds	Minimum Number of Viewers**
Alabama	477,000	$146,187,403	290,000
Alaska	110,000	$324,027,592	362,000
Arizona	127,000	$181,614,188	394,000
Arkansas	318,000	$136,835,227	316,000
California	154,000	$275,504,950	975,000
Colorado	178,000	$193,296,765	603,000
Connecticut	30,000	$55,841,681	533,000
Delaware	18,000	$45,026,927	62,000
Florida	187,000	$137,495,635	558,000
Georgia	349,000	$165,784,880	924,000
Hawaii	22,000	$44,666,814	14,000
Idaho	177,000	$144,766,093	191,000
Illinois	351,000	$164,850,603	842,000
Indiana	266,000	$139,524,521	627,000
Iowa	199,000	$131,151,393	287,000
Kansas	162,000	$138,060,534	144,000
Kentucky	315,000	$131,655,184	410,000
Louisiana	217,000	$139,470,735	257,000
Maine	143,000	$86,658,861	206,000
Maryland	73,000	$75,074,097	412,000
Massachusetts	41,000	$71,899,248	446,000
Michigan	488,000	$280,578,448	920,000
Minnesota	412,000	$225,849,340	566,000
Mississippi	469,000	$116,759,634	238,000
Missouri	464,000	$204,606,750	539,000

	Big Game Hunters	Wildlife Restoration Funds	Minimum Number of Viewers**
Montana	128,000	$208,371,383	199,000
Nebraska	93,000	$125,787,997	87,000
Nevada	30,000	$135,246,725	90,000
New Hampshire	46,000	$45,165,424	141,000
New Jersey	89,000	$73,629,779	438,000
New Mexico	44,000	$156,917,393	98,000
New York	777,000	$226,376,919	1,633,000
North Carolina	281,000	$174,542,628	760,000
North Dakota*	77,000	$108,479,290	33,000
Ohio	515,000	$176,758,383	708,000
Oklahoma	144,000	$154,604,652	398,000
Oregon	189,000	$180,920,828	372,000
Pennsylvania	755,000	$296,918,459	1,647,000
Rhode Island	9,000	$45,000,605	80,000
South Carolina	224,000	$98,996,866	158,000
South Dakota	122,000	$131,134,378	151,000
Tennessee	337,000	$202,566,384	432,000
Texas	937,000	$357,646,774	1,541,000
Utah	149,000	$125,997,745	261,000
Vermont	84,000	$41,831,874	127,000
Virginia	405,000	$151,128,911	591,000
Washington	189,000	$155,643,365	589,000
West Virginia	244,000	$90,576,988	339,000
Wisconsin	785,000	$236,523,087	1,012,000
Wyoming	130,000	$140,215,920	409,000

Sources:
U.S. Fish & Wildlife Service, DOI. 2013.
U.S. Fish and Wildlife Service. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, 2011.
www.census.gov/prod/www/fishing.html

*North Dakota Big Game Hunter data from the most recent available - 2006
**Larger of number of big game viewers either away from home or at home.

DEER

The most common and widely distributed big game animals in North America are deer, which evoke a range of emotions. For some people, spotting a wild deer moving through the shadows brings a thrill. On the other hand, some urban dwellers despise deer that eat treasured plants; deer populations have exploded due in large part to the absence of both natural predators and hunting in developed areas. Regardless of one's attitude, a fight between two rutting bucks sparring to determine who will prevail and beget the next generation, is one of nature's spectacles to behold.

The United States is home to two native deer species -white-tailed deer and mule deer- each with many subspecies. White-tailed deer inhabit the entire lower-48 states, with the exception of California[26] and some areas in the Southwest. Their range even extends into Central America and South America.[27] Mule deer (including the sub-species Black-tailed deer) range from the western Great Plains to the Pacific Coast and from Canada to Mexico.[28]

One might be skeptical that deer could be in peril from anything, given their widespread distributions, established populations, and diversity of habitats, including wetlands, forests, grasslands, shrub-steppe and developed areas. However, these traits don't provide immunity from climate change; even many common species are expected to lose significant suitable habitat.[29]

White-tailed Deer

The United States population of white-tailed deer is thought to have numbered 24 to 34 million in the year 1500. By the year 1900, however, the population across North America declined to a paltry 300,000 to 500,000.[30] Habitat loss and market hunting were primary factors driving the steep decline. White-tailed deer were extirpated from many areas and were a rare sight where they could still be found. Astonishingly, the nationwide white-tailed deer population rebounded, increasing 30 to 50 fold to about 15 million in 2000.[31,32] The dramatic increase in white-tailed deer populations is exemplified by the fact that, in recent years, Wisconsin's annual harvest approximated the nation's entire white-tailed deer population of just a century ago.[33]

Recovery of white-tailed deer was neither inevitable, nor without a lot of effort. It came during a time when the science of wildlife management was being developed in the early and mid-20th century. Funds from the Pittman-Robertson Act assisted states to research and develop techniques for effective management of white-tailed deer. This facilitated the trapping and actual relocation of white-tailed deer to re-establish them in many areas from which they had long been absent.[34]

Dead and dying white-tailed deer caused by HD.

Extreme weather, disease and changes in habitat are potential climate-driven stressors on white-tailed deer. In northern areas of their range, deer often seek out winter shelter from wind, extreme cold and deep snows in areas known as "deer yards." Deer yards are typically in dense stands of hemlock and white pine with a generally southern aspect.[35] Northeastern states where deer "yard-up" include Maine,[36] Massachusetts,[37] New Hampshire,[38] New York[39] and Vermont.[40] In the Upper-Midwest, deer yards are found in Michigan,[41] Wisconsin[42] and Minnesota.[43] Should climate-driven changes alter the suitability and location of deer yard habitats, deer may have difficulty finding new safe areas to over-winter or be forced into areas difficult to protect.[44]

White-tailed deer are vulnerable to hemorrhagic disease (HD) caused by epizootic hemorrhagic disease and bluetongue viruses. It is most common in the late summer and early fall when viruses are transmitted by insects, specifically biting midges, sometimes called no-see-ums. Because the midges are killed by freezing temperatures, the disease subsides shortly after the first autumn frost. Infected deer can rapidly become ill, losing their appetite and natural fear of humans, and develop a fever and extensive internal bleeding. This is followed by unconsciousness and death.[45,46] In northern states where deer are usually not as frequently exposed to HD, losses can be 25 percent of a local deer population, although it has exceeded 50 percent in some cases.[47]

Hemorrhagic disease occurs most often in southern areas of the United States. Large-scale HD outbreaks frequently occur during hot, dry summers. It is thought that during severe droughts, deer congregate near remaining water sources where midges breed, facilitating the infection of more deer than in wetter years when deer are more widely dispersed.[48, 49]

White-tailed Deer Feeling the Heat

John King, Ph.D.
Professor, Department of Forestry and Environmental Resources, North Carolina State University

Whitetails have a very broad distribution. However, disease, human impacts and the changing climate all have potential to affect wildlife resources. Where I hunt in North Carolina, we have populations of feral dogs that don't appear to suffer much winter mortality due to the increasingly mild climate. Without cold winters to control them, feral dog populations can limit deer populations, making them more difficult to hunt. Human development also poses a major threat to habitat and limits public access. To preserve the quality of deer resources in the South, we really need to identify and manage all of these interacting impacts, including climate change. Otherwise, the future quality of our natural resources remains uncertain.

Hunters Tyler French and Dave Buchner. Tina Shaw/USFWS.

During the drought and heat waves of 2012, an outbreak of HD occurred in at least 15 states,[50] including Kansas,[51] Ohio,[52] South Dakota, Montana, Illinois,[53] Iowa,[54] North Carolina, Virginia, Missouri, Wyoming,[55] Nebraska,[56] and Michigan.[57] For example, Nebraska was hit hard by HD, with nearly 6,000 known mortalities;[58] the total number was certainly far higher considering that many killed deer are never found. The combination of the Nebraska Game and Parks Commission reducing antlerless permits and hunters reluctant to hunt, resulted in about 18,000 fewer deer permits sold. Because most deer permits sell for $30,[59] loss in agency revenue would be more than $500,000. White-tailed deer harvest dropped by about 25,000 compared to previous years. The commission expects it will take four to five years for populations to recover.[60]

Missouri reported more than 10,000 suspected HD cases in 2012's drought; that does not include undiscovered mortalities due to rapid decomposition.[61] In Michigan, there were nearly 15,000 deer reported dead in 2012. Due to these record losses, director of the Michigan Department of Natural Resources signed an emergency order to reduce the number of allowed licenses to hunt antlerless deer.[62]

In 2011 Melissa Clark, a wildlife biologist with Wisconsin's Department of Natural Resources, prophetically stated: "As climate change occurs, the midge is capable of translocation and adaptation to new geographic areas. More frequent outbreaks of HD may occur in Wisconsin as a consequence of climate changes that favor the northward spread of the biting flies that spread the disease."[63] Just a year later, when the severe drought and extreme heat of 2012 plagued much of the country, Wisconsin experienced its second known outbreak ever. The first was in 2002.[64]

There is no effective treatment for HD.[65,66] Researchers are concerned that climate change could have serious impacts on wildlife due to extreme weather and changes in the dynamics of transmission of HD and other wildlife diseases.[67] Because insect-killing frost in the fall typically ends an HD outbreak,[68] longer summers are likely to expose white-tailed deer to disease-carrying midges for longer periods of time.

Mule and Black-tailed Deer

Although scientifically considered one species,[69] the mule deer has a black-tipped tail and the black-tailed deer is appropriately named. Mule deer have large ears, hence their common name, and live throughout the western states. The black-tailed deer occupies habitats along the Pacific coast from Alaska through California.[70] Mule and black-tailed deer on the move are easily distinguished from white-tailed deer. Their stott gait, bounding with all four legs on the ground at once,[71,72] looks odd but is graceful in its own way. They are quite adept at moving quickly to escape predators.

Mule and black-tailed deer may have historically numbered as many as 10 million and 3 million, respectively. But, due primarily to loss of habitat and hunting for food, they were difficult to find by the 1900s. Mule deer began to recover by the 1920s, especially in the Southwest, due to improving habitat conditions. By the early 1960s, when annual harvest reached about 1 million, there may have been more than 7 million mule deer. They again trended downward to fewer than 6 million by the 1980s.[73] Major droughts, projected to be more severe in the future,[74] have contributed to declines of mule deer. Moreover, loss of mule deer habitat to oil and gas development is now a major concern in some areas,[75] especially because of its recent rapid advance on western public lands[76] and plans to further expand drilling.[77]

Some of the long-term decline in mule deer is due to severe drought.[78] On the Colorado Plateau, two decades of severe drought transformed the composition and structure of the plant community, which in-turn was detrimental to mule deer.[79] And, western Colorado's Logan Mountain mule deer population has been in decline, with long-term drought probably the major factor. But other important factors include natural gas and other development, leading to habitat loss and habitat fragmentation.[80] This combination of factors has devastated the Logan Mountain population, reducing the population from about 15,000 mule deer in the 1980s, to 6,000 in the mid-1990s. The population has not recovered.[81]

In Wyoming, extreme drought also has impacted mule deer. Like many other areas in the West, extensive habitat fragmentation from various types of development, as well as competition with elk, have been significant factors. From 2002 through 2012 mule deer have been averaging 15 percent below population objectives. Despite some improvement in moisture, the mule deer population has recently declined about 25 percent, likely due in part to the lag in habitat conditions improving after severe long-term drought stress.[82]

In Colorado's Logan Mountain management area, the antlered harvest dropped by more than two-thirds, from an average of about 1,400 in the mid-1980s to about 400 by year 2000, and has yet to recover. No antlerless harvest has been allowed from 1999 through at least 2010.[83] In Wyoming, mule deer harvest has declined in recent years by about 25 percent. The Wyoming Game and Fish Department has kept harvest levels down to account for severe drought and other factors.[84]

Due to the multiple stressors of oil and gas development, coal mining, impacts on migratory corridors, severe and prolonged drought and other factors, mule deer habitat and populations are under stress in many areas of the West. Failure to address these stressors will increasingly affect hunting and viewing opportunities for mule deer.

Mule Deer and Drought

Dennis Buechler
Director Emeritus, Colorado Wildlife Federation

I have been hunting mule deer ever since I have lived in Colorado (since 1989-24 years). Several years I did not get one. For example, sometimes I had a buck license but only saw does or perhaps the animals were too far away for me to be assured of a good shot. I hate to wound and lose any animal, whether it be big game, pheasants, or ducks. Success for me is not determined solely by whether I took something home for the table, but rather also how much I enjoyed being out in nature and observing all the wildlife and plants.

In Colorado we've been dealing with a lot of drought, which exacerbated the devastation thousands of pine trees by bark beetles. Drought and wildfires have so damaged the undergrowth in many areas that the vegetation is not growing back, and erosion is a major problem. Right now the biggest impacts to wildlife that we're seeing are to fisheries, but we are only just beginning to realize the destruction climate change can wreck on sensitive wildlife and habitat.

Oregon Department of Fish & Wildlife

MOOSE

It is hard for anyone not to be both wary and thrilled to see a 1,300-pound bull moose,[85] with magnificent palmate antlers spreading up to six and a half feet wide.[86] In the United States, sightings are most common in Alaska, where bull moose reach their largest size. Standing up to six feet[87] tall at the shoulder, equipped with long gangly legs, humped shoulders and a "bell" of skin hanging from their throat, they are rather odd looking and unmistakably different from other big game wildlife. In the lower-48, moose populations are found in northern New England, Minnesota and the Rocky Mountain states, from Colorado northward.

Moose are superbly adapted for deep snow and cold climates, enduring extremely cold winter weather[88] in their northern habitats. Their thick winter coats, with guard hair up to 10 inches long and an undercoat of fine hair,[89] keep them warm. Their adaptation to cold weather is also a liability. When winter temperatures rise above freezing, they become heat-stressed. In the summer, when their coats are thinner, they become heat-stressed when temperatures rise above 60 to 70 degrees Fahrenheit.[90] Moose are absent from areas with extended periods above 82 degrees Fahrenheit and little shade or water access.[91] Not surprisingly, as the climate has warmed, moose are already feeling the heat in southern portions of their range, reducing viewing and hunting opportunities.

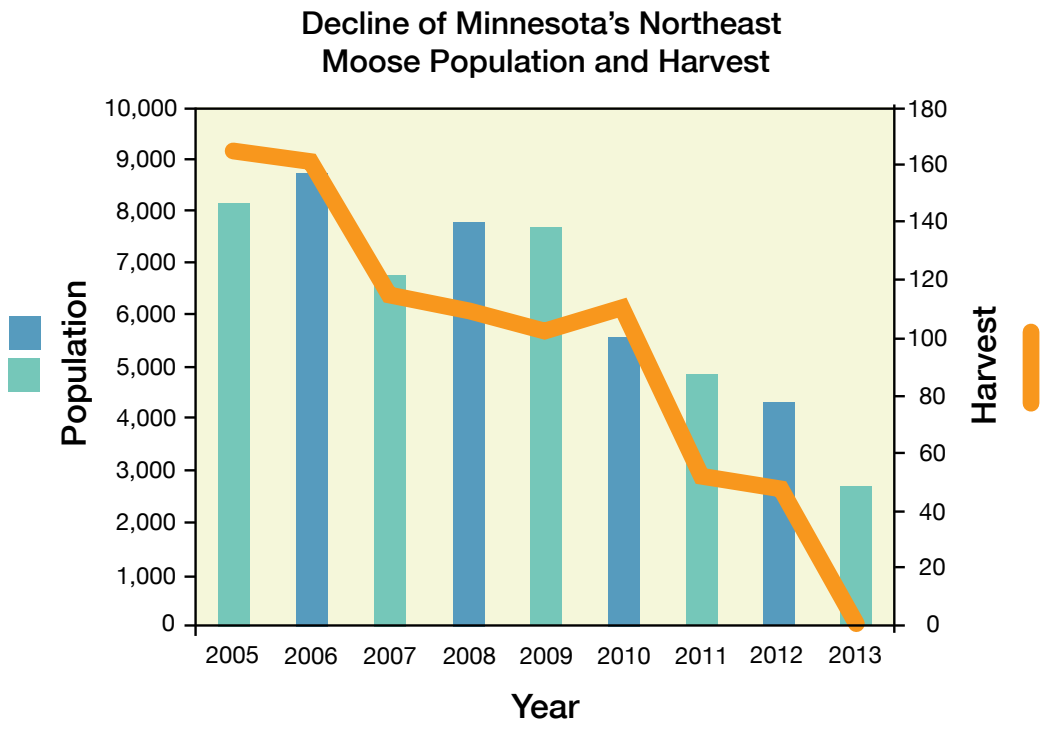
Minnesota's northwest moose population, one of only two populations in the state, was essentially gone by 2008, numbering fewer than 100 animals, down from a population of about 4,000 just 25 years earlier.[92] In the four decades during which the population plummeted, summer temperatures increased 3 to 4 degrees Fahrenheit, and this is considered an important factor in the herd's decline.[93] Harvest of Minnesota's northwest herd was permanently closed in 1997,[94] although hunting was not considered to be an important factor in the population's decline.[95]

A more insidious climate impact on moose is the greater survival of winter ticks facilitated by warmer and shorter winters. In Minnesota, some moose have been found burdened by 50,000 to 70,000 winter ticks—ten to twenty times more than normal.[96] (The winter tick species isn't known to parasitize humans or infect them with disease,[97] unlike the deer tick and blacklegged tick which can transmit Lyme disease to humans.[98]) Heavy winter tick infestations leave moose weakened from blood loss, in poor health, and with greater vulnerability to disease. Winter ticks can cause significant increases in moose mortality.[99]

Another disturbing aspect of heavy winter tick infestations is the effort of moose to rid themselves of the winter ticks by rubbing against trees. This causes their hair to break off at the base, which is white. These resulting "ghost" moose are then without insulating hair, leaving them vulnerable to cold exposure and death.[100]

"Moose are facing a triple threat in our changing climate. Increasing temperatures, changing forest species, and increased mortality due to parasites may make it very hard to maintain a viable moose population in New Hampshire in the future." [106]

- Kristine Rines, Distinguished Moose Biologist,[107] and New Hampshire Fish and Game Department Moose Project Leader



The future of moose, moose watching, and moose hunting in Minnesota appears grim. With Minnesota's northwest herd virtually gone,[101] Minnesota's only remaining viable moose population inhabits the northeastern part of the state and is now itself in precipitous decline. From an estimated population of about 8,000 moose in 2004 through 2009, the population plummeted to only about 3,000 animals by 2013.[102] Now under intense investigation, the stress of warming temperatures associated with climate change is very likely increasing the vulnerability of moose to disease and other natural factors.

Moose hunting ceased altogether in Minnesota when the state's Department of Natural Resources announced a closure of the 2013 hunting season for the northeast population. "The state's moose population has been in decline for years but never at the precipitous rate documented this winter," said Tom Landwehr, DNR commissioner.[103]

New Hampshire's moose are also being harmed by surging winter tick populations, associated with warmer winters. In 2002 winter ticks were blamed for a large number of moose deaths. Heat also affects moose directly, as summer heat stress leads to dropping weights, a fall in pregnancy rates, and increased vulnerability to predators and disease. When it gets too warm, moose typically seek shelter rather than forage for the nutritious foods needed to keep them healthy. Due primarily to these factors, New Hampshire's moose population has declined by 3,100 moose, which is more than 40 percent, since 1997. The New Hampshire Fish and Game Department has reduced the number of moose hunting permits by 60 percent in the last five years.[104, 105]

Moose in some areas of the West are also challenged by climate change. Wyoming's moose herd is currently at just over 50 percent of desired management objectives. A decade of drought fueled by rising temperatures and declining rainfall associated with climate change appear to be reducing the quality of moose habitat.[108] Indeed, western states have experienced extensive climate-induced aspen die-off driven by higher summer temperatures causing drought.[109] Aspen is a preferred forage species for moose and it has declined by about 50 percent in Wyoming.[110]

As populations drop in the warmer southern portions of the moose's range and the climate continues to warm, the future of moose hunting in these areas appears bleak. All moose hunting in Minnesota has been closed,[111, 112] and the likelihood of future moose hunting in Minnesota is highly doubtful. Over the past decade, Wyoming's moose harvest and moose hunter expenditures, a boost to outfitters and local economies, have declined about 60 percent.[113] Since 2007, New Hampshire's moose harvest has also declined by 60 percent.[114]

What's Happening to the Moose?

Bill Rudd, Assistant Wildlife Division Chief at Wyoming Game and Fish (Retired)

I fish, I hunt. I don't "live or die" for hunting, but I do enjoy hunting birds and big game like elk, pronghorn, and moose. Recently we've seen drier, hotter conditions producing less-quality forage, and forage that is drying out quicker than it used to. In some areas, we had millions of acres of forest that just a few years ago were healthy and green. Now we have lost these forests as pine beetles live longer and thrive in this new climate. Since I've been in Wyoming I've noticed a lot fewer of the wetter microhabitats that big game enjoy. Some have just dried up completely. One fall it was so much warmer than normal that moose were very hard to hunt as they stayed in the timber to stay cool. It was very tough to even find them. All these impacts are sort of subtle but lower survival of young has lead to more restrictive seasons and smaller bag limits, and so on. All these point to climate change as the main cause.

Moose are Disappearing

Shawn Perich, Field Editor, Outdoor News

If you came to visit me 10 years ago, we could just drive around and have good odds of seeing a moose. Now I see maybe 2-3 moose all year. Minnesota moose hunting, which was closed indefinitely in 2013, was a very high-quality hunt. I was lucky to participate in two hunts, once in 1989 and again in 2000. Northeastern Minnesota's moose population is in steep decline. I believe the increasing white-tailed deer population within the moose range is partially to blame. Whitetails transmit a fatal brain worm to moose, which can really decimate their population. In the past, occasional harsh winters kept the deer population in check. Now the deer are thriving, thanks to milder winters. Unless we address climate change now, the future prognosis for Minnesota's moose population is grim.

NOAA/Dan Petersen

ELK


Larry Lamsa

The sound of a bugling bull elk, as amazing, loud and piercing as it is, could never be described as pleasantly melodious to most anything other than an elk cow. When in rut, the bull's habit of urinating on itself to make it more attractive to cow elk doesn't seem like a good strategy for mating. Notwithstanding our own perception of these characteristics, elk are large beautiful animals popular with hunters and wildlife viewers. They were native to portions of all states except Florida, Rhode Island, New Hampshire and Maine.[115]

Once abundant and widespread, in an all too familiar story for big game wildlife, the original elk population of an estimated 10 million declined precipitously to about 50,000 or fewer by the early 20th century.[116] The fall bugling of elk in the eastern states was silenced altogether by the early 1800s.[117]

As a result of recovery efforts led by sportsmen, the species now numbers about 1 million.[118] The vast majority of elk are in western North America. They are most common in mountainous areas, although there are also desert elk, the largest herd of which is in the Red Desert of southern Wyoming.[119] One surviving sub-species, the largest of all elk,[120] is the magnificent Roosevelt elk, which inhabits coastal western areas of northern California, Oregon, Washington and small portions of Alaska. In California, the smallest of the elk sub-species, the Tule elk, can be found in grassland/oak woodlands of the Coast Range and in Owens Valley.

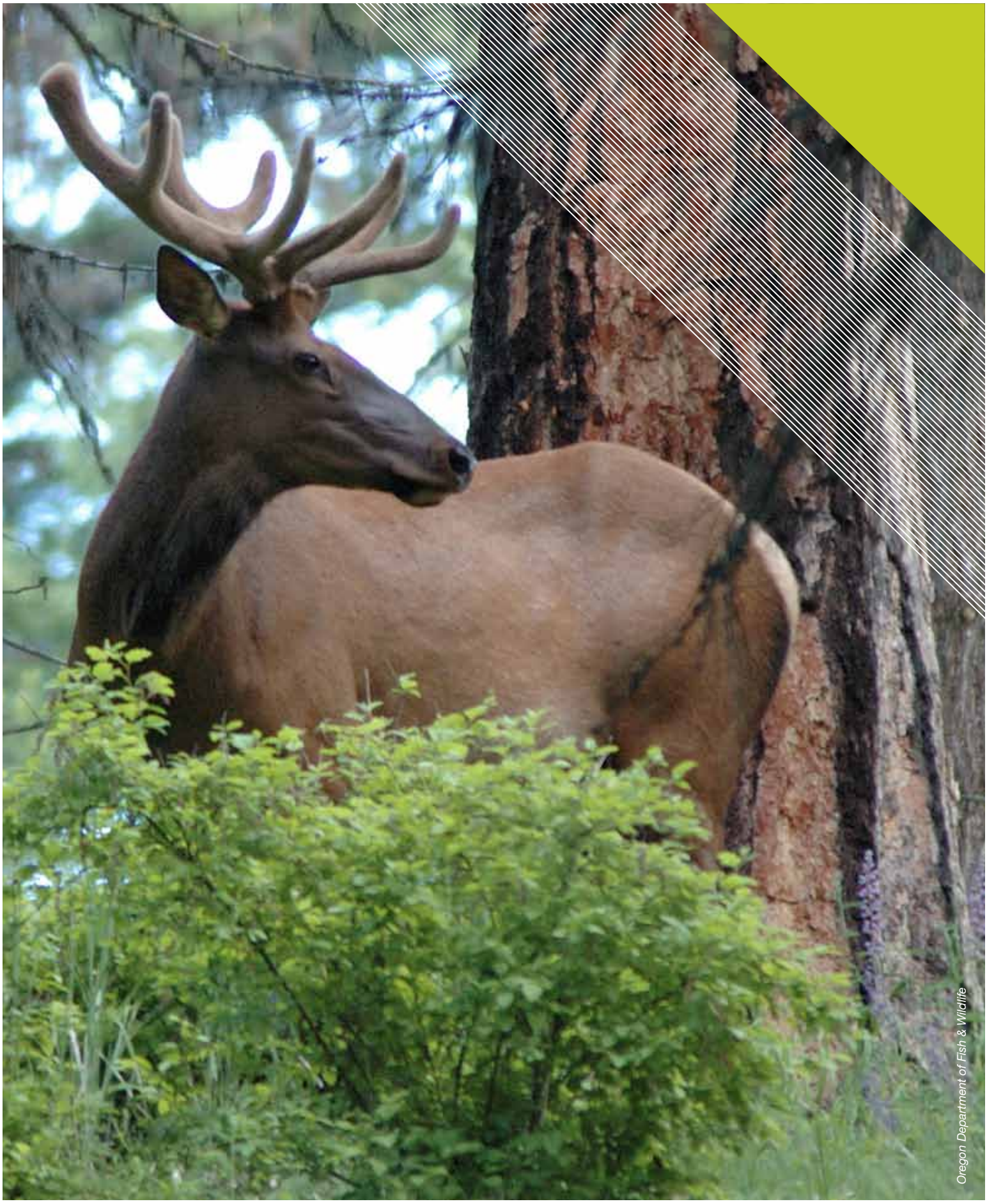
Thanks to successful reintroductions, the bugling of elk can once again be heard through much of the country, including Arkansas,[121] Kentucky,[122] Michigan,[123] Minnesota,[124] Missouri,[125] North Carolina,[126] Pennsylvania,[127] Tennessee,[128] Wisconsin,[129] and Virginia (from the Kentucky herd).[130] The two largest eastern herds are in western Pennsylvania[131] and eastern portions of Michigan's lower-peninsula.[132] Although the eastern herds are only a fragment of their pre-settlement populations, some currently support hunting.

Elk populations are not without continuing challenges, such as extensive development of public lands for oil and gas production, as well as mining. Residential development is having a significant effect near urban areas. Development fragments habitats and encroaches on migratory corridors. Competition with livestock is yet another factor.

It is clear that elk and their habitats will not escape climate change, although there may be both some positive and negative impacts. For example, due to drought western states have experienced extensive die-off of aspen forests, a favored habitat for elk.[133, 134] On the other hand, some think that elk populations could double[135] due to longer periods of mild winter weather and increasing availability and quality of forage if precipitation increases.[136] This may be one factor in Wyoming's elk population increase of about 10 percent in the past decade.[137]

Some elk herds are resident, while others make annual migrations. The longest elk migration in the continental United States is up to 130 miles in the Greater Yellowstone Ecosystem, which affords elk access to luscious mountain habitats in the summer and low-altitude wintering areas with less snow.[138] However, increasingly elk herds are becoming non-migratory; climate change, among other factors, may be one reason for this.[139] The resulting increasing densities of resident elk populations have the potential for increased transmission of disease, while migratory populations are less susceptible.[140]

It seems possible that climate change could benefit elk populations, at least for the near future. Nonetheless, we should be prepared for surprises that will require close monitoring of the status of elk and elk habitat. Hopefully, Rocky Mountain National Park, the Greater Yellowstone Ecosystem and other areas will continue to sustain elk that are popular for viewing. And even with climate change affecting the distribution of elk, they are likely to sustain the hunting opportunities we have now, unless other factors such as oil and gas development and habitat fragmentation have major impacts.



Oregon Department of Fish & Wildlife

PRONGHORN

Pronghorn, although technically in a distinct taxonomic group from the antelope of Africa, are sometimes referred to as pronghorn antelope or simply antelope. They tend to roam the landscape in herds, and can be sighted from long distances across wide-open areas in many western states. Reaching top speeds of as much as 50 miles per hour,[141] pronghorn are truly built for speed and endurance, enabling them to leave race horses, including any Triple Crown winner, far behind.

Native only to central and western North America, pronghorn populations may have numbered as high as 40 million, making them as common as bison. But, by the 1920s the entire population had crashed to a dismal 25,000 pronghorn, or even fewer,[142, 143] less than 1/1000th of what it had been just a few hundred years before.[144] Like the decline of so many other big game species across the continent, it suffered from massive habitat loss due primarily to conversion of the prairies for agriculture, competition with domestic livestock in grazing lands and unregulated hunting.[145] Ranchers feared transmission of disease to cattle and competition for forage, leading to extensive fencing as the West was settled. Pronghorn have difficulty negotiating fences,[146] which inhibited migration to key winter ranges, which also caused decline. The infamous Dust Bowl of the 1930s was yet another blow to pronghorn.[147]

It was the Pittman-Robertson Act, paid for by hunters via dedicated excise taxes on guns and ammunition, that facilitated pronghorn recovery. Research dispelled the fear of disease transmission to livestock, and many areas from which pronghorn had long been absent were restocked through translocation programs.[148] By 1984 the population exceeded 1 million but by 2000 it declined to about 800,000.[149] Two subspecies, the Sonoran and Peninsular pronghorn, were classified as endangered species in 1967[150] and 1975,[151] respectively.

Wyoming harbors nearly 500,000 pronghorn,[152] which is about a third of the total pronghorn population. Nonetheless, in 2012 many areas in Wyoming were stricken by severe drought, necessitating a drop in permits issued.[153] Other states with significant populations include Montana, New Mexico, Texas, Idaho, Oregon, South Dakota, Nevada, Colorado and Arizona.[154] Pronghorn are also found in North Dakota, Nebraska, California, Kansas, Utah, Oklahoma and Idaho. In 2011 they were reintroduced on the Yakama Indian Reservation in the state of Washington.[155]


Gail Collins

Pronghorn inhabit open grasslands, shrublands and deserts as long as there is sufficient water and forage. Their most common shrub habitat is sagebrush,[156] which may comprise nearly 80 percent of their diet in some areas.[157] A well-known factor affecting pronghorn is drought, which can have catastrophic effects on other important pronghorn foods such as mesquite, palo verde and ironwood. Without adequate forage, pronghorn fawns are born underweight[158] and have lower survival rates.[159] Severe drought, which devastated vegetation, wiped out 80 percent of the endangered Sonoran pronghorn population in the Southwest in 2002.[160]

One threat the pronghorn may not be able to outrun is climate change. It is projected to fundamentally alter grasslands and shrublands across the western United States in the coming decades. A combination of impacts is expected to affect these systems, including warmer and drier conditions, altered fire regimes, and invasive species[161] causing conversion of habitats into vegetation consisting primarily of invasive, non-native plants.[162] These changes amount to what could be a “perfect storm” for sagebrush and grassland ecosystems. In some regions, vast areas of sagebrush habitat could be reduced to a fraction of their current size under changing climate conditions.[163] For example, in the Great Basin up to 80 percent of sagebrush ecosystems could be replaced by trees and invasive species such as cheatgrass.[164] There has already been a considerable expansion of pinyon/juniper woodland and ponderosa pine in the Great Basin and other parts of the West, due to fire suppression and grazing practices.[165] This reduces and fragments habitat for pronghorn and other sagebrush-dependent species.

Some pronghorn are highly migratory, moving across long distances in search of favorable habitat and food sources, which can vary from one season to the next.[166] One herd in Wyoming annually migrates 240 miles round-trip through increasingly fragmented habitats. For the pronghorn, enhancing connectivity and establishing wildlife corridors in areas of climatically-suitable habitat,[167] as well as minimizing other factors such as habitat destruction from oil and gas development, are likely to be important strategies to help them cope with changing climate conditions.

Wayne Wormne

Big Game Through the Camera Lens

Vic Schendel, Vic Schendel Photography

As a photographer, I am on the wildlife's clock to do my work. For 300 days out of the year, I follow elk, mule deer, white-tailed deer, moose and bighorn sheep. One drastic change I've noticed is in the timing of the ruts. Over the last four or five years, elk and deer started mating about two weeks later than usual. The mountains are simply staying warmer for longer, putting the breeding season later into the winter. Milder winters are also allowing pine beetles to thrive and kill off larger areas of pine forest. When I take these photos, no one wants to see these dead stands, so that's a challenge. Not to mention the floods that have severely limited public access to some of these areas. I know the wildlife as good as anyone. You don't need scientific surveys to see these changes. It's really not subtle anymore.

Oregon Department of Fish & Wildlife

BIGHORN SHEEP

It takes a keen eye to spot bighorn sheep in their native habitat. "Glassing" a mountainside for rock-climbing bighorn sheep takes both patience and persistence. Whether in the Sierra Nevada or Rocky Mountains, where two subspecies occupy rugged, high-elevation terrain, or in the hot desert systems of the Southwest which is home to desert bighorn, they fit seamlessly into their surroundings,[168] making them very difficult to spot.

Avid hunter Robert Hanneman, in a rather odd choice of words, says that the key to successfully hunting bighorn sheep is to be in "sheep shape." This is because success means packing a nearly 200 pound ram out of rugged terrain,[169] whether hot dry desert or steep mountain slopes. However, whether one is hunting, viewing, or taking pictures, seeing a ram with 40-inch horns and 15-inch bases is well worth the effort.

North America's bighorn sheep population numbered an estimated 2 million centuries ago,[170] but by the middle of the 20th century, their numbers had crashed to an estimated 15-17,000 in the western United States.[171] This was due to a combination of unregulated hunting, competition for forage and water with domestic and escaped livestock, and especially pneumonia and other diseases (e.g. mange and scabies) transmitted from domestic sheep and goats. An estimated 110 separate bighorn sheep populations were lost in California and Nevada by the 1980s.[172] In 1998 the Peninsular bighorn sheep was listed as endangered,[173] followed just a year later by endangered status for Sierra Nevada bighorn sheep.[174]

Making a comeback has been a long and difficult process. In 1939, the Arizona Boy Scouts collaborated with Izaak Walton League, National Audubon Society and

National Wildlife Federation to prevent desert bighorn sheep in Arizona from disappearing altogether. They were successful in protecting habitat and saving this population.[175] The Wild Sheep Foundation, federal and state government agencies, and others continue to work to rebuild bighorn sheep populations.

Over the past approximately nine decades more than 20,000 bighorns have been moved in over 1,400 discrete transplant actions in the western United States and Canada.[176] Today, bighorn sheep exist in 15 western states (Arizona, California, Colorado, Idaho, Montana, Nevada, Nebraska, New Mexico, North Dakota, Oregon, South Dakota, Texas, Utah, Washington and Wyoming), 2 Canadian provinces, and 5 states in Mexico.[177, 178] In 2012 Nevada's bighorn sheep numbers exceeded 10,000 due to long-term recovery efforts.[179] The 2012 population of bighorn sheep in the lower-48 states was about 58,000.[180] Although the bighorn sheep population has nearly quadrupled from its lowest levels in the mid-1900s,[181] it remains far below historic levels.

Bighorn sheep now face the additional challenge of climate change. Winter snowpack in the Rocky Mountains and Sierra Nevada is critical for maintaining important food and water sources for bighorn sheep throughout the year. Across the western United States snowpack accounts for as much as 80 percent of the water supply for people and wildlife alike.[182] Climate change is expected to cause a considerable reduction in average snowpack across the region, as well as earlier and more-rapid spring snowmelt in many locations.[183]

In addition to reducing water availability in summer, another concern about climate change is the earlier onset of spring vegetation. Because the early stages of plant growth provide higher quality forage, this change might seem favorable for bighorn sheep.[184] However, the length of time in which this new growth is available (the period of "green-up") is also expected to shorten, in some areas.[185] As green-up becomes shorter, there could be a significant adverse impact on survival of young. Furthermore, the timing of peak green-up could shift from the usual timing of bighorn reproductive cycles and lambing dates, which could also affect the survival of young bighorns.[186]

Climate change has already been a factor in the decline of desert bighorn sheep in the Southwest in the 20th century, although interaction with domestic sheep and goats was the most important factor. An average temperature increase of nearly 2 degrees Fahrenheit in the region and a 20 percent decrease in precipitation has reduced available forage, particularly in the lower, drier mountain ranges. During this time period 30 of the 80 known populations of desert bighorn sheep in the region died out.[187] It seems likely that more populations will disappear given the projections of rising temperatures and lower precipitation. Re-introduction of bighorn sheep into areas of native habitat has long been, and will continue to be,[188] an important conservation strategy.[189] However, with climate change, managers will need to evaluate potential areas for climatic suitability over the long-term to increase the likelihood that relocation efforts will be successful. Drier, lower elevations are likely less suitable than higher, wetter areas.

Another consideration for bighorns is the decrease in conifers throughout much of the western United States and Canada due to unprecedented bark beetle infestations facilitated by warming winters.[190, 191] Because bighorn sheep do best in open, high-visibility habitats,[192] dramatic decline in tree cover might be a two-edged sword. It could lead to more genetic interchange via pioneering movements by bighorns, but also increasing risk of contact and disease transmission from domestic sheep and/or goats.[193]


Debra Hamilton/CDFW

BLACK BEAR

Most people have never felt the exhilaration of spotting a black bear in the wild. They are fascinating animals to watch as they forage on grasses, berries and seeds, and dig for bulbs and roots. In most of its range, it takes a lot of time outdoors to see a black bear in its natural habitat.

Historically ranging throughout most of North America with the exception of the Great Plains,[194] black bears were maligned and persecuted with a shoot-on-sight mentality driven by bounties. Various bounties existed from at least the 1660s and as late as the 1950s, a period of nearly 300 years. From 1946 through 1957, bounties were paid on more than 10,000 bears in Maine.[195] Changing attitudes have facilitated recovery of bear populations, although the Louisiana subspecies, residing in portions of Texas, Louisiana and Alabama, was listed as a threatened species in 1992.[196] The Pittman-Robertson Act provided the revenue essential for research on the ecology of bears, as well as for acquisition of lands for conservation of black bears and other wildlife.[197]

Bears are omnivores, consuming both plants and animals, but plants provide the majority of their diet and nutrition. In the spring and summer, emerging plants and berries are favored food sources. Grubs are also much sought after.[198]


Joshua Duggan

Acorns, pine nuts, ash seeds and mountain ash fruits are especially important for fattening up to survive the long winter in their dens and bear their young.[199] Fall is a critical time for bears to put on a heavy layer of fat to survive their winter hibernation. If sows (females) are in poor condition, they are less successful at reproducing.[200]

When conditions are unfavorable, bears become desperate to find the food they need to be healthy. They are vulnerable to severe drought, which is expected to increase with climate change.[201] In 2012 from Kentucky[202] to Colorado and California[203] and other areas, bears were on the move far more than normal, as severe drought reduced available food resources. Desperately searching for food, bears wandered into towns, where sightings escalated. One bear stepped up to the counter at a candy store;[204] another cleaned out a pantry;[205] one crashed a local bar;[206] and others helped themselves to farmers' crops.[207] When temperatures exceeded 100 degrees Fahrenheit, two bear cubs seeking a respite from the hot weather cooled down in a swimming pool in Pasadena, California.[208] In Aspen, Colorado, police were inundated in August, 2012 with 292 calls about black bears, compared to 38 the year before when conditions were better.[209] When habitat conditions improved again in the summer of 2013, the number of calls about black bears dropped to a small fraction of the number in 2012.[210]

The movements of hungry bears into developed areas are a risk for humans and bears. Ensuring human safety in these situations is often bad news for bears. Offenders may have to be destroyed. Human/bear conflicts are a growing concern, not only in the summer, but also in winter when bears are normally hibernating. Warmer fall and winter temperatures are resulting in bears being more active than usual during these periods. In the last two decades of the 20th century there were very few complaints about bears during the winter in New Hampshire. Now bear complaints can happen most any time of the year. Especially, when the boars (males) start to look for food in the middle of an unusually mild winter. Bird feeders are being raided even in December and January, when bears should be hibernating.[211]

The black bear's diversity of habitats, wide range across North America, and diverse diet should provide them with some buffer against climate change. However, black bears will not be completely immune due to the potential increase in human--bear conflicts from warm winters, and more frequent and intense severe weather affecting food availability.

USFWS

Black Bear Orphan Cubs on the Rise

Benjamin Kilham, Author: Out on a Limb: What Black Bears Have Taught Me About Intelligence and Intuition

The primary effects on black bears are caused by radical weather patterns. Year 2011 was a very good year for bears due to abundant beechnuts, apples and berries. But, in 2012 we had two weeks of unseasonably warm weather in March with temps in the 70's and 80's, which disrupted the apple and berry crops and caused a lot of hungry mothers looking for food for their cubs. We took in 30 orphaned bear cubs, with the normal being 3-4. Half of the cubs we took in were orphaned when their mothers were shot at chicken coops or bee hives. This was easily preventable as bears can be kept out with simple electric fences baited with smell; food grease or peanut works well. Climate change will lead to more droughts and other weather patterns that can affect the bear's natural food supply and lead to an increase in bear human conflict in which the bears usually suffer.

Western Arctic National Park

CARIBOU

To the surprise of many, woodland caribou were found as far south as portions of northern New England, New York, the Upper Great Lakes states, Montana, Idaho, and Washington until settlement in North America by Europeans.[212] By 1980, only a few dozen animals remained in the Selkirk Mountains of Idaho and Washington,[213] and they were listed as endangered in 1983.[214] In Maine, where the town of Caribou was named for the once common species, a reintroduction effort failed in 1990.[215]

About 750,000 caribou make up Alaska's 32 separate caribou herds or populations, distributed throughout most of the state. The Western Arctic Herd, Porcupine Caribou Herd and Central Arctic Herd number about 325,000, 169,000 and 67,000, respectively.[216] The Western Arctic Herd supports people in 40 northwestern villages[217] while the inland Nunamiut Eskimos rely on the Central Arctic Herd as their single most important food source, as well as much more.[218] Antlers are made into sled parts, fishing jigs, bows, and kayak ribs; skins become clothing, tents, and blankets; bones are crafted into tools and artwork.[219] The Porcupine Caribou Herd supports the Gwich'in Indians in 15 villages in Alaska and northwest Canada. So closely tied are the Gwich'in people to caribou, it is not a surprise that Gwich'in means "people of the caribou."[220]

The Arctic region is the fastest-warming place on Earth, with average temperatures having risen 2-3 times faster than the global average over the last 150 years.[221] As a result, the area of summer Arctic sea ice has rapidly decreased[222] and reached an all-time low in the summer

of 2012.[223] On land, the milder winters are contributing to periods of icing due to thaw-freeze and rain-on-snow events.[224] Ecological systems across the region have been dramatically altered. The ranges of many plants and animals are moving northward and to higher elevations. The timing of important life cycle events such as breeding and annual migrations is shifting, and plant emergence is becoming earlier.[225, 226]

Of particular concern is the fact that plant and animal species respond to changing climate conditions in diverse ways and at different rates, which could lead to so-called ecological "mismatches." In this case, the timing of caribou calving has historically been timed to coincide with the onset of the plant growing season to provide nursing cows with sufficient nutrition to support themselves and their calves, and to provide weaning calves with high quality forage. But while plant emergence is occurring earlier in the spring as temperatures in the Arctic have warmed, the timing of caribou calving has not. The result has been a considerable reduction in production and survival of caribou calves,[227] a likely factor in the major decline of caribou throughout the Arctic.[228]

Another threat for caribou is the possibility of reduced access to forage during winter due to climate change increasing icing events. Caribou survive the long Arctic winter by digging into snow to feed on lichens, a key component of their over-wintering diet. When snow becomes covered with an icy crust, it is much more difficult for the animals to reach food.[229] In the past, such events have been associated with range displacement and catastrophic declines in populations of caribou and other Arctic wildlife.[230, 231, 232]

Is there an upside? Perhaps. An increase in summer temperatures has contributed to an expansion of shrubs and other vegetation into areas of previously open tundra, increasing the amount of green forage available for females nursing their calves, which increases their survival. This has been favorable for herds in northwestern Alaska, which have seen an increase in populations over the past several decades.[233] On the other hand, rising temperatures coincide with an increase in wildfires,[234] which can destroy vast areas of habitat in a short amount of time. Wildfires destroy slow-growing lichens, and it can take decades for the habitat to recover to pre-fire conditions. Wildfires in the northern tundra are projected to become more frequent as climate change continues to unfold.[235]

The dramatic climate changes occurring in the Arctic will continue and certainly affect caribou in various ways. Human communities dependent on caribou may need to consider greater flexibility in seasonal hunting patterns and practices,[236] as well as adjustments to allowable take.

Zak Richter/Alaska National Park Service

A Hunting Tradition

Hopefully, an interesting and clever tradition will be able to continue. In the book ***Kuuvanmiut Subsistence: Traditional Eskimo Life in the Latter Twentieth Century,***[237] the authors describe how hunters approach a herd of caribou without the benefit of cover: "In this case he can take advantage of their response to certain kinds of silhouettes. A low, stalking profile would resemble a wolf or other predator, but the outline of another caribou grazing peacefully causes no alarm. The hunter may extend his arms or two sticks above his head to resemble antlers and then copy a caribou's leisurely, zigzag grazing route as he approaches the herd."[238]

ACTIONS TO HELP BIG GAME

Bighorn sheep reintroduction in Wyoming.

We can no longer wait to take action to address the increasing threats to America's big game and other wildlife. Without significant new steps to reduce carbon pollution, the world is on track for global temperature increases of about 7 degrees Fahrenheit by the end of the century,[239] which would prove devastating to big game wildlife and their habitats. Actions must also be taken now to carry out conservation in ways that better safeguard big game and their habitats from the impacts of climate change.

Get at the Root of the Problem and Tackle Carbon Pollution

The threats to the nation's treasured big game wildlife will increase if carbon pollution continues on the business-as-usual path. Urgent action is needed to change the course we are on. We must move away from the current reliance on fossil fuels and invest in clean energy solutions that do not pollute. Fortunately, we have the tools and know-how to start making this transition today. Priority actions for reducing carbon pollution include:

- **Use and protect the proven, existing laws to tackle carbon pollution.** The Clean Air Act was put in place to protect people and wildlife from pollution. Under this law, the U.S. Environmental Protection Agency (EPA) has the authority and obligation to limit carbon pollution from the largest sources, most notably coal-fired power plants. The president has set a clear path for EPA to issue and finalize the first-ever limits on carbon pollution from new and existing power plants by 2016. This rulemaking is already underway and a key component of a national plan to reduce the carbon that drives climate change.

- **Reduce fossil fuel use and reject expansion of dirty fuels.** Oil, gas, coal, and other fossil fuel development degrade and fragment big game habitat, exacerbating climate stressors for wildlife. We must move towards cleaner, less-polluting forms of energy. This must include stopping the expansion of new dirty energy reserves—such as the massive coal fields in North America and the tar sands oil fields in Canada—that threaten important habitat and would lock in carbon pollution for decades to come. Reducing fossil fuel use and embracing responsible clean energy development are essential for protecting people and wildlife from the dangers of climate change while spurring economic development. Improved energy conservation and efficiency will also reduce fossil fuel use.

- **Invest in clean energy development.** A serious effort to reduce carbon pollution must include investing in clean energy options such as geothermal, wind, solar, sustainable bioenergy, and efficiency measures that will reduce our dependence on carbon-polluting fuels like coal, oil, tar sands and natural gas, which are driving climate change. It is time for the United States to make smarter energy choices that prioritize clean, responsible energy instead of the dirty choices of the past. It is essential that clean energy sources be developed in an environmentally responsible way, to minimize and compensate for potential effects on big game, other wildlife and the habitats they depend upon.

> *"Severe droughts, heat waves and other effects of climate change can devastate wildlife and their habitats. Addressing the climate change issue now is critical to ensure that our children and grandchildren can enjoy the wildlife resources we have today."*
>
> **Bill Geer, Director, Utah Division of Wildlife Resources (retired)**

- **Protect and restore natural carbon sinks.** In addition to transitioning to clean energy, we must also enhance nature's ability to balance the system. Restoring the ability of farms, forests and other natural lands to absorb and store carbon not only provides important habitat and increased benefits for wildlife, but also helps mitigate climate change.

Safeguard Big Game and Their Habitats from the Impacts of Climate Change

The impacts of climate change are already here, and even with aggressive action to reduce carbon pollution these changes will pose a serious threat to big game and other wildlife. Climate change and related extreme weather events increasingly will put our rich conservation and hunting legacy at risk, and require that we commit to helping big game and other wildlife adapt to and cope with these changes as best they can. Climate change will challenge wildlife managers to prepare for and manage for an uncertain and difficult future. The emerging field of climate change adaptation offers guidance on safeguarding our wildlife heritage in a climate-altered future, with priority actions including:

- **Promote the practice of "climate-smart conservation"** by explicitly taking climate change into account in our wildlife and natural resource management efforts. Use science-based approaches to assess the climate-related vulnerabilities of big game species, and carry out conservation actions designed not only to address urgent threats to their survival, but also to reduce the effects of longer-term climate changes on these animals and on their habitats.

- **Provide the room to roam that big game need to survive and to cope with a changing climate.** Especially important is maintaining or restoring unfettered connections between winter and summer range, enhancing corridors connecting protected habitats, and encouraging wildlife-friendly practices on lands and waters used for agriculture, ranching and other human activities.

- **Protect habitat strongholds for big game species.** Protecting and expanding core habitat areas that harbor, or could harbor, robust and healthy wildlife populations will be essential for sustaining big game in an increasingly climate-altered future. Especially important are areas that, due to size, complexity of the landscape, or other factors, may be buffered from the worst effects of warming and serve as climate refuges for these big game species. Consideration needs to be given to managing human access when milder winters increase access to important wintering areas, which could impact big game.

- **Maintain big game populations at sustainable levels.** Managers need to reduce big game populations that may exceed habitat carrying capacity, and may need to adjust desired population targets. Managing populations at sustainable levels will help improve the quality of habitat and allow important forage plants to better endure drought stresses exacerbated by climate change.

- **Engage the big game hunting community** in assisting state wildlife agencies' efforts to address climate change impacts on big game wildlife. This could include publicly supporting wildlife agency climate-adaptation programs, including adjustment in numbers of licenses issued, to reduce pressure on declining populations and drought-stressed habitats. Other actions could include reporting possible climate-related observations such as the spread of diseases and habitat-altering invasive species.

- **Provide sufficient funding** for federal and state wildlife programs, including the National Fish, Wildlife and Plants Climate Adaptation Strategy,[240] Climate Science Centers,[241] Department of the Interior Landscape Conservation Cooperatives,[242] and State and Tribal Wildlife Grants Program,[243] critical to managing big game and other species in a climate-smart way.

CONCLUSION

The knowledge already exists to reduce carbon pollution and safeguard big game and other wildlife from climate change. Now is the time for the President, Congress and all citizens to take actions to address threat of climate change to wildlife.


Michael Scott

Oregon Department of Fish & Wildlife

LEAD AUTHORS & ACKNOWLEDGMENTS

Lead Authors

Doug Inkley, Ph.D., Senior Scientist
National Wildlife Federation

Mary Price, Outreach Assistant
National Wildlife Federation

Patty Glick, Senior Specialist, Global Warming
National Wildlife Federation

Tara Losoff, Manager, National Outreach
National Wildlife Federation

Bruce Stein, Ph.D., Director, Climate Change Adaptation, National Wildlife Federation

Acknowledgments

The report was produced with much assistance from National Wildlife Federation affiliates and staff including:

Brenda Archambo, Steve Bender, Joy Bergey, Alexis Bonogofsky, Gary Botzek, Nic Callero, Lew Carpenter, Jason Dinsmore, David Dittloff, David Ellenberger, Dawn Erlandson, Tom France, John Gale, Miles Grant, Chelsea Harnish, Geralyn Hoey, Don Hooper, Kristin Johnson, Ryan Kingston, Adam Kolton, Grant LaRouche, Julie Lalo, Jay Liles, Samantha Lockhart, Jim Lyon, Avelino Maestas, Claudia Malloy, Todd Martin, Andy McDaniels, Jen Mihills, Richard Mode, Michael Murray, Carol Oldham, Mike O'Leary, Eric Orff, Ed Perry, Bryan Pritchett, Kassie Rohrbach, Tracy Sabetta, Kelly Senser, Corey Shott, Mollie Simon, Marc Smith, Felice Stadler, Amanda Stone, Frank Szollosi, Patricia Tillman, Garrit Voggesser, Eli Walton, Ron Warnken, Aileo Weinmann, Les Welsh, Kate Zimmerman.

We are also sincerely grateful for the time and advice of many partners who provided useful input or reviewed the report, including:

Bill Alldredge, Ph.D. Professor Emeritus, Department of Fishery and Wildlife Biology, Colorado State University and Vice President, Wyoming Wildlife Federation; Robert Brown, Ph.D., Dean, College of Natural Resources, North Carolina University (ret.) and past President of The Wildlife Society; Glen Dickens, Vice President, Arizona Antelope Foundation; John Ellenberger, Big Game Manager, Colorado Division of Wildlife (ret.);Bill Geer, Director, Utah Division of Wildlife Resources (ret.) and Field Representative, Theodore Roosevelt Conservation Partnership (ret.); Kathy Hadley, Western Chair, Board of Directors, National Wildlife Federation; Dick Hamilton, Executive Director, North Carolina Wildlife Resources Commission (ret.); Kevin Hurley, Conservation Director, Wildlife Sheep Foundation and Bighorn Sheep Program Coordinator, Wyoming Game & Fish Department (ret.); Matt Kauffman, Ph.D., Leader, Wyoming Cooperative Fish and Wildlife Research Unit; Tom Mackin, President, Arizona Wildlife Federation; Ken Mayer, Director, Nevada Department of Wildlife (ret.); Steve Merchant, Wildlife Program Manager, Minnesota Department of Natural Resources; Scott Mills, Ph.D., Professor, Department of Forestry and Environmental Resources, North Carolina State University; Dave Moody, Former Regional Wildlife Management Coordinator, Wyoming Game & Fish Department and President, Wyoming Wildlife Federation; Gordon S. Myers, Executive Director, North Carolina Wildlife Resources Commission; John Nunley, President, Idaho Wildlife Federation; Eric Orff, Past Commissioner, New Hampshire Fish and Game Commission and Black Bear Biologist, New Hampshire Fish and Game Department (ret.) and Outreach Consultant, National Wildlife Federation; Jack Prier, Executive Committee, Nevada Wildlife Federation; Reg Rothwell, Supervisor of Biological Services, Wyoming Game and Fish Department (ret.) and NWF Affiliate Representative; Bill Rudd, Assistant Wildlife Division Chief , Wyoming Game & Fish Department (ret); Dave Stallknecht, Ph.D., Professor, Southern Cooperative Wildlife Disease Study, University of Georgia; Amanda Staudt, Ph.D., National Academy of Sciences; Bob Vahle, NWF Representative, Arizona Wildlife Federation; Garrett VeneKlasen, Director, SW Region, Sportsmen's Conservation Project, Trout Unlimited and Vice President, New Mexico Wildlife Federation.

Graphic Design by MajaDesign, Inc.

Photo Credits

Front Cover: Victor Schendel/Vic Schendel Photography, LLC

Back Cover: Alan D. Wilson (bighorn sheep)

For more information, please visit **www.nwf.org/sportsmen**

ENDNOTES

1 National Research Council. 2010. Advancing the Science of Climate Change. Washington, D.C., The National Academies Press: 503.
2 www.ncdc.noaa.gov/news/ncdc-announces-warmest-year-record-contiguous-us
3 www.epa.gov/climatechange/science/indicators/weather-climate/temperature.html
4 Intergovernmental Panel on Climate Change (IPCC). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.). Cambridge, UK, and New York, NY: Cambridge University Press.
5 Diffenbaugh, N.S., and C.B. Field. 2013. Changes in ecologically critical terrestrial climate conditions. Science 341: 486-492.
6 www.cdc.gov/lyme/transmission/
7 Vandyk, J.K., D.M. Bartholomew, W.A. Rowley, and K.B. Platt. 1996. Survival of Ixodes scapularis (Acari: Ixodidae) exposed to cold. Journal of Medical Entomology 33(1): 6-10.
8 Gatewood, A.G., K.A. Liebman, G. Vourc'h, J. Bunikis, S.A. Hamer, R. Cortinas, F. Melton, P. Cislo, U. Kitron, J. Tsao, A.G. Barbour, D. Fish, and M.A. Diuk-Wasser. 2009. Climate and tick seasonality predict Borrelia burgdorferi genotype distribution. Applied and Environmental Microbiology. 75: 2476-2483.
9 Brownstein, J.S., T.R. Holford, and D. Fish. 2003. A climate-based based model predicts the spatial distribution of the Lyme disease vector Ixodes scapularis in the United States. Environmental Health Perspectives 111: 1152-1157.
10 www.cdc.gov/ticks/diseases/
11 www.nps.gov/romo/elk_herd.htm
12 www.rockymountainnationalparkco.com/elk-bugling-elk-ruts-rocky-mountain-national-park
13 Kallman, H. (ed.) 1987. Restoring America's Wildlife 1937-1987. Washington, D.C.: U.S. Fish and Wildlife Service, DOI.
14 Downing, R. 1987. Success Story: White-tailed Deer. In Kallman, H. (ed.) 1987. Restoring America's Wildlife 1937-1987. Washington, D.C.: U.S. Fish and Wildlife Service, DOI.
15 www.fws.gov/pelicanisland/history.html
16 millercenter.org/president/roosevelt/essays/biography/4
17 www.amnh.org/exhibitions/current-exhibitions/theodore-roosevelt-memorial/theodore-roosevelt-memorial-hall
18 www.aldoleopold.org/About/board.shtml
19 Leopold, A. 1933. Game Management. 481 pp.
20 Leopold, A. 1949. A Sand County Almanac: And Sketches Here and There. Oxford, UK and New York, NY: Oxford University Press.
21 dnr.wi.gov/org/caer/ce/eek/nature/aldo.htm
22 Allen, T.B. 1987. Guardian of the Wildlife. The Story of the National Wildlife Federation, 1936-1986. Indiana University Press. 212pp.
23 Downing, R.L. 1987. (See 14)
24 U.S. Fish & Wildlife Service, DOI. 2012. 75 years of Conservation and Partnership Success - Celebrating the Wildlife and Sport Fish Restoration Program (National and State Reports).
25 U.S. Fish and Wildlife Service, DOI, U.S. Department of Commerce, and U.S. Census Bureau. 2011. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. www.census.gov/prod/www/fishing.html
26 Higley, J. 2002. Hunting Deer in California, 2nd Edition. Wildlife Programs Branch, Department of Fish and Game, State of California. www.dfg.ca.gov/wildlife/hunting/deer/docs/deerguide.pdf
27 Halls, L.K. 1978. White-tailed Deer. In Schmidt, J.L., and D.L. Gilbert (eds.). Big Game Animals of North America: Ecology and Management. University of California: Stackpole Books.
28 Wallmo, O.C. 1978. Mule and Black-tailed Deer. In Schmidt, J.L. and D.L. Gilbert (eds.). Big Game Animals of North America: Ecology and Management. University of California: Stackpole Books.
29 Warren, R., J. VanDerWal, J. Price, J.A. Welbergen, I. Atkinson, J. Ramirez-Villegas, T.J. Osborn, A. Jarvis, L.P. Shoo, S.E. Williams, and J. Lowe. 2013. Quantifying the benefit of early climate mitigation in avoiding biodiversity loss. Nature Climate Change 3: 678-682.
30 Downing, R.L. 1987. (See 14)
31 Curtis P.D., and K.L. Sullivan. Date Unknown. Wildlife Damage Management Fact Sheet Series. White-tailed Deer. Wildlife Damage Management Program, Cornell Cooperative Extension.
32 Curtis, P.D. and M.E. Richmond. (See 31)
33 dnr.wi.gov/topic/hunt/popgoal.html
34 Kallman, H. (ed.). 1987. (See 13)
35 www.vtfishandwildlife.com/cwp_elem_spec_dwa.cfm
36 Wiley, J., and C. Hulsey. 2010. Living on the Edge: How Deer Survive Winter. Maine Department of Inland Fisheries and Wildlife. www.maine.gov/ifw/hunting_trapping/pdfs/deer_yards.pdf

37 www.massaudubon.org/Nature_Connection/wildlife/index.php?subject=Mammals&id=28
38 www.wildnh.com/Wildlife/Wildlife_profiles/whitetailed_deer.html
39 Hurst, J.E., and W.F. Porter. 2008. Evaluation of shifts in white-tailed winter yards in the Adirondack region of New York. Journal of Wildlife Management 72(2): 367-375.
40 www.vtfishandwildlife.com/cwp_elem_spec_dwa.cfm
41 deer.fw.msu.edu/management/habitat.php/
42 Dahlberg, B.L., R.C. Guettinger, and J.B. Hale (eds). 1956. The White-tailed Deer in Wisconsin. Wisconsin Department of Natural Resources, Game Management Division, Wisconsin Conservation Department. digicoll.library.wisc.edu/cgi-bin/EcoNatRes/EcoNatRes-idx?type=header;pview=hide;id=EcoNatRes.DNRBull14
43 Axelson, G. 2009. Bounce Back. Minnesota Department of Natural Resources. www.dnr.state.mn.us/volunteer/sepoct09/bounce_back.html
44 Tetra Tech, Inc. 2013. Climate Change Adaptation Framework. Submitted to Vermont Agency of Natural Resources. 144 pp.
45 Pennsylvania Game Commission. Date Unknown. Epizootic Hemorrhagic Disease. Wildlife Disease Reference Library. 4pp. www.portal.state.pa.us/portal/server.pt
46 www.michigan.gov/dnr/0,1607,7-153-10370_12150-26647--,00.html
47 Southeastern Cooperative Wildlife Disease Study. 2012. Hemorrhagic Disease of White-tailed Deer. 6pp. vet.uga.edu/population_health_files/HD-brochure-web.pdf
48 Wildlife Management Institute. 2012. Widespread EHD Outbreaks Anticipated Due to Drought. Outdoor News Bulletin. September 2012.
49 Illinois Department of Natural Resources. 2012. DNR Reports Epizootic Hemorrhagic Disease Outbreak in at Least 51 Illinois Counties. Press Release. September 6, 2012. www.dnr.illinois.gov/news/Pages/IDNRReportsEpizooticHemorrhagicDiseaseOutbreakinatLeast51IllinoisCounties.aspx
50 Lobner, E, and B. Cosh. 2012. EHD confirmed in three additional counties. Weekly News. Wisconsin Department of Natural Resources. dnr.wi.gov/news/Weekly/Article_Lookup.asp?id=2327
51 Huntington Network. 2013. Kansas 2012 EHD Report Puts Outbreak in Perspective. www.bowhunting.com/publisher/hunting-news/2013/4/6/kansas-2012-ehd-report-puts-outbreak-in-perspective
52 Holden, A. 2012. Dry Summer Has Led to EHD Outbreak and Dying Whitetails. www.the-daily-record.com/local%20sports/2012/09/17/dry-summer-has-led-to-ehd-outbreak-and-dying-whitetails
53 Illinois Department of Natural Resources. 2012. (See 49)
54 Lobner, E, and B. Cosh. 2012. (See 50)
55 Peterson, C. 2012. Endemic disease strikes northeast Wyoming white-tailed deer. Star Tribune. trib.com/news/state-and-regional/endemic-disease-strikes-northeast-wyoming-white-tailed-deer/article_2e7dbdde-30dc-56d5-a8ee-f6f54325adb9.html
56 outdoornebraska.ne.gov/hunting/EHD.asp
57 www.michigan.gov/emergingdiseases/0,4579,7-186--283966--,00.html
58 outdoornebraska.ne.gov/hunting/EHD.asp
59 ngpc-permits.ne.gov/NGPC-PS/faces/public/welcome
60 Lincoln Journal Star. 2013. Drought and disease blamed for decline in deer harvest. journalstar.com/sports/local/outdoors/drought-and-disease-blamed-for-decline-in-deer-harvest/article_fac23c0b-11bf-5fae-9ec8-1abbb0db8aee.html
61 mdc.mo.gov/your-property/wildlife-your-property/wildlife-diseases/deer-diseases/hemorrhagic-disease
62 www.michigan.gov/emergingdiseases/0,4579,7-186--283966--,00.html
63 dnr.wi.gov/wnrmag/2011/08/letters.htm
64 Lobner, E, and B. Cosh. 2012. (See 50)
65 Lincoln Journal Star. 2013. (See 60)
66 www.michigan.gov/dnr/0,1607,7-153-10370_12150-26647--,00.html
67 Sleeman, J.M., J.E. Howell, W.M. Knox, and P.J. Stenger. 2009. Incidence of hemorrhagic disease in white-tailed deer is associated with winter and summer climatic conditions. EcoHealth 6: 11-15.
68 Kenefick, K. 2012. Epizootic hemorrhagic disease virus and deer loss: Wishing for a killing frost? Promega Connections. October 2012. promega.wordpress.com/2012/10/05/epizootic-hemorrhagic-disease-virus-and-deer-loss-wishing-for-a-killing-frost/
69 Reid, F.A. 2006. Peterson Field Guide to Mammals of North America, 4th Edition. Houghton Mifflin Harcourt.
70 Wallmo, O.C. 1978. (See 28)
71 nhguide.dbs.umt.edu/index.php?c=mammals&m=desc&id=20
72 americanexpedition.us/mule-deer-information-facts-photos-and-artwork
73 Mackie, R.J. 1987. Trends in History. In Kallman, H. (ed.). Restoring America's Wildlife 1937-1987. Washington, D.C.: U.S Fish and Wildlife Service, DOI.
74 IPCC. 2012. (See 4)
75 Duckett, S. 2011. Draft – Logan Mountain Deer Management Plan Data Analysis Unit D-41 Game Management Units 31 & 32. Colorado Division of Wildlife.
76 Bureau of Land Management, DOI. 2013. Oil and Gas Statistics by Year for Fiscal Years 1988 – 2012. www.blm.gov/wo/st/en/prog/energy/oil_and_gas/statistics.html

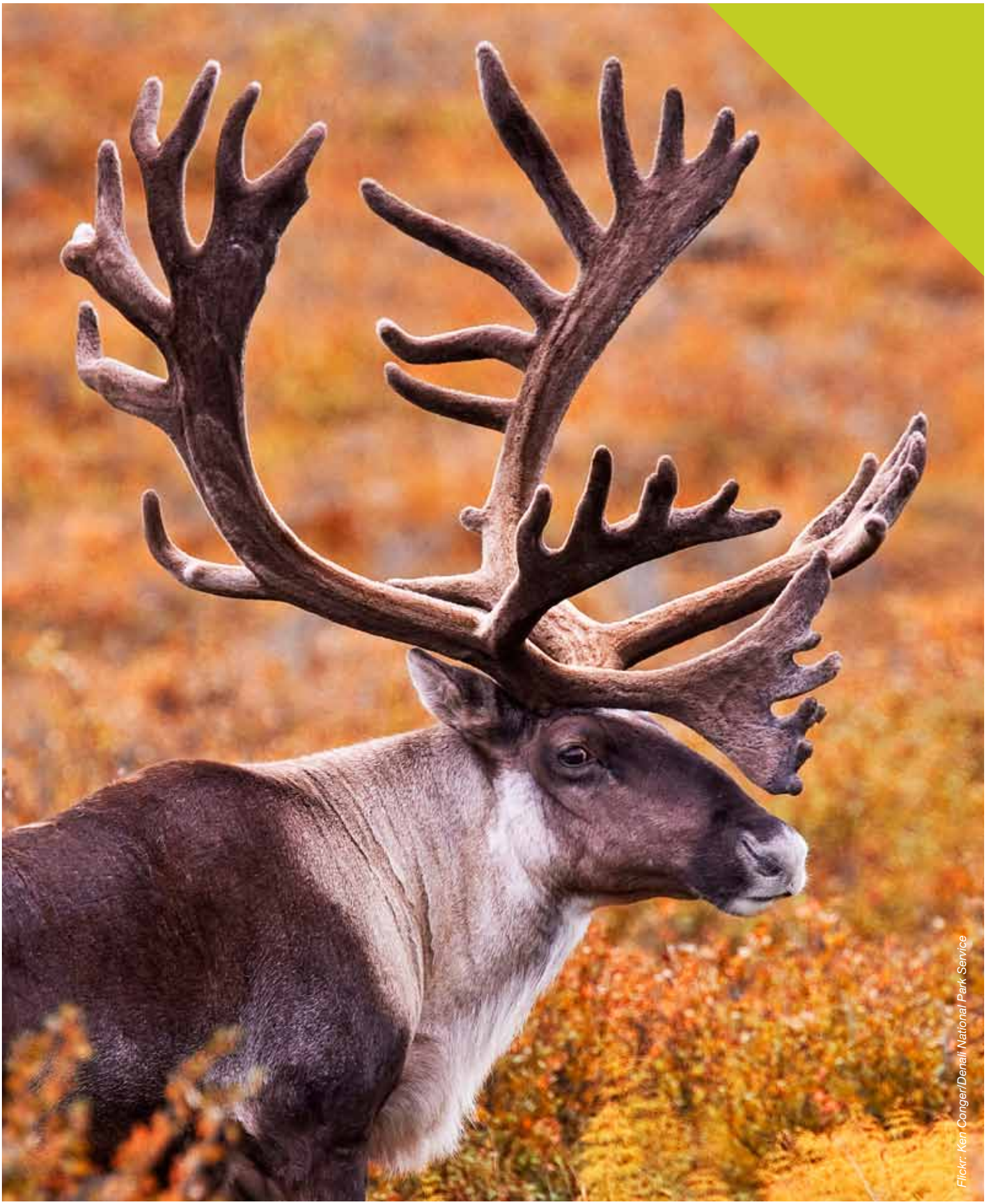
77 www.blm.gov/wo/st/en/info/newsroom/2012/april/nr_04_03_2012.html
78 Cox, M., D.W. Lutz, T. Wasley, M. Fleming, B.B. Compton, T. Keegan, D. Stroud, S. Kilpatrick, K. Gray, J. Carlson, L. Carpenter, K. Urquhart, B. Johnson, and C. McLaughlin. 2009. Habitat Guidelines for Mule Deer: Intermountain West Ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.
79 Watkins, B.E., C.J. Bishop, E.J. Bergman, A. Bronson, B. Hale, B.F. Wakeling, L.H. Carpenter, and D.W. Lutz. 2007. Habitat Guidelines for Mule Deer: Colorado Plateau Shrubland and Forest Ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.
80 Duckett, S. 2011. (See 75)
81 Duckett, S. 2011. (See 75)
82 Wyoming Game and Fish Department. 2003-2011. Annual Reports. wgfd.wyo.gov/web2011/hunting-1000184.aspx
83 Duckett, S. 2011. (See 75)
84 Wyoming Game and Fish Department. 2003-2011. (See 82)
85 www.nps.gov/yell/naturescience/moose.htm
86 Nesbitt, W.H., and J.S. Parker (eds.). 1977. North American Big Game. The Boone and Crockett Club and National Rifle Association of America. Washington, D.C. 367 pp.
87 Franzmann, A.W., R.E. LeResche, R.A. Rausch, and J.L. Oldemeyer. 1978. Alaskan moose measurements and weights and measurement-weight relationships. Canadian Journal of Zoology 56(2): 298-306.
88 Kelsall, J.P., and E.S. Telfer. 1974. Biogeography of moose with particular reference to western North America. Naturaliste Canada 101: 117-130.
89 Schmody, J.L., and D.L. Gilbert. 1979. Big Game of North America: Ecology and Management. The Wildlife Management Institute, Washington D.C., and Stackpole Books, Mechanicsburg, PA.
90 Renecker, L.A. and R.J. Hudson. 1986. Seasonal energy expenditures and thermoregulatory responses of moose. Canadian Journal of Zoology 64: 322-327.
91 Kelsall, J.P., and E.S. Telfer. 1974. (See 88)
92 www.nrri.umn.edu/moose/information/PopulationEstimates.html
93 Murray, D.L., E.W. Cox, W.B. Ballard, H.A. Whitlaw, M.S. Lenarz, T.W. Custer, T. Barnett, and T.K. Fuller. 2006. Pathogens, nutritional deficiency, and climate influences on a declining moose population. Wildlife Monographs 166: 1-30.
94 Minnesota Department of Natural Resources. Minnesota Moose Research and Management Plan Final Plan Approved: December 21, 2011.
95 Murray et al. 2006 (See 93)
96 Cusick, D. and ClimateWire. 2012. Rapid Climate Changes Turn North Woods into Moose Graveyard. Scientific American. Energy & Sustaianbility. May 2012. www.scientificamerican.com/article.cfm?id=rapid-climate-changes-turn-north-woods-into-moose-graveyard
97 www.ccwhc.ca/wildlife_health_topics/winter_tick/wintertick.php
98 www.cdc.gov/lyme/transmission/
99 Samuel, W.M. 2007. Factors affecting epizootics of winter ticks and mortality of moose. Alces 43: 39-48.
100 www.nrri.umn.edu/moose/information/wintertick.html
101 www.dnr.state.mn.us/moose/index.html
102 DelGiudice, G.D. 2013. Aerial Moose Survey. Minnesota Department of Natural Resources. Forest Wildlife Populations and Research Group.
103 news.dnr.state.mn.us/2013/02/06/moose-population-drops-dramatically-hunting-season-will-not-open/
104 Interview with New Hampshire Fish and Game Wildlife Biologist and Moose Project Leader, Kristine Rines, April 30, 2013. In National Wildlife Federation Fact Sheet: New Hampshire: Help Save the Moose from a Changing Climate.
105 New Hampshire Fish and Game Department. 2012. New Hampshire Wildlife Harvest Summary. 36pp. www.wildlife.state.nh.us/Hunting/harvest_summary/Wildlife_Harvest_2012.pdf
106 Morse, S.C. 2012. Ghost Moose: Winter Ticks Take Their Toll. Northern Woodlands. March 13th 2012, spring issue. northernwoodlands.org/articles/article/ghost-moose-winter-ticks-take-their-toll
107 North American Moose Conference and Workshop. 2006. www.wildnh.com/Newsroom/News_2006/News_2006_Q3/Moose_Biologist_Award_072506.htm
108 Kilpatrick, S. 2011. Wildlife Matters - Why are moose populations declining? Wyoming Game and Fish Department. Jackson Hole Conservation Alliance News, summer 2011.
109 Anderegg, W.R.L., J.A. Berry, D.D. Smithc, J.S. Sperryc, L.D. L. Anderegg, and C.B. Field. 2011. The roles of hydraulic and carbon stress in a widespread climate-induced forest die-off. Proceedings of the National Academy of Sciences 109(1): 233-237
110 Kilpatrick, S. 2011. (See 108)
111 Minnesota Department of Natural Resources. (See 94)
112 news.dnr.state.mn.us/2013/02/06/moose-population-drops-dramatically-hunting-season-will-not-open/

113 Wyoming Game and Fish Department. 2003-2011. (See 82)
114 New Hampshire Fish and Game Department. 2013. (See 105)
115 Bryant, L.D., and C. Maser. 1982. Classification and Distribution of Elk in North America – Ecology and Management. In Thomas, J. W., and D. Toweill. (eds.). 1982. pp. 1–60, Stakepole Books, Harrisburg, Pa, USA.
116 Lyon, J., and J.W. Thomas. 1987. Elk Rocky Mountain Majesty. In Kallman, H. (ed.). Restoring America's Wildlife 1937-1987. Washington, D.C.: U.S Fish and Wildlife Service, DOI.
117 Boyd, R.J. American Elk. In Schmidt, J.L., and D.L. Gilbert. 1979. Big Game of North America: Ecology and Management. The Wildlife Management Institute, Washington D.C., and Stackpole Books, Mechanicsburg, PA.
118 www.rmef.org/ElkFacts.aspx
119 www.nwf.org/wildlife/wild-places/red-desert.aspx
120 Robb, B., G. Bethge. 2001. The Ultimate Guide to Elk Hunting. The Lyons Press.
121 www.agfc.com/hunting/pages/huntingelkhistory.aspx
122 www.rmefnky.org/kyelkherd.HTML
123 www.michigan.gov/dnr/0,4570,7-153-10363_10856_10893-28275--,00.html
124 Minnesota Department of Natural Resources Division of Wildlife. Minnesota Elk Past and Present. files.dnr.state.mn.us/recreation/hunting/elk/management.pdf
125 www.rmef.org/ElkFacts.aspx
126 www.nps.gov/grsm/naturescience/elk-progress-report-49.htm
127 www.portal.state.pa.us/portal/server.pt?open=514&objID=622078&mode=2
128 www.tn.gov/twra/elkmain.html re-established 2000
129 dnr.wi.gov/topic/WildlifeHabitat/elk.html
130 www.dgif.virginia.gov/wildlife/elk/management-plan/
131 www.portal.state.pa.us/portal/server.pt?open=514&objID=622078&mode=2
132 www.michigan.gov/dnr/0,4570,7-153-10363_10856_10893-28275--,00.html
133 Eisenberg, C., S.T. Seager, and D.E. Hibbs. 2013. Wolf, elk, and aspen food web relationships: Context and complexity. Forest Ecology and Management 299: 70-80.
134 Anderegg et al. 2011. (See 109)
135 Wang, G., N.T. Hobbs, F.J. Singer, D.S. Ojima, and B.C. Lubow. 2002. Impacts of climate changes on elk population dynamics in Rocky Mountain National Park, Colorado, U.S.A. Climate Change 54: 205-223.
136 Hobbs, N.T., J.S. Baron, D.J. Cooper, M.B. Coughenour, A. Covich, J. Dickens, H. Galbraith, L. Landrum, J. Loomis, M. McDuff, D. Ojima, D.M. Theobald, and W. Stephan. 2003. Final Report: An integrated assessment of the effects of climate change on Rocky Mountain national Park and Its Gateway Community: Interactions of Multiple stressors. Colorado State University.
137 Wyoming Game and Fish Department. 2003-2011. (See 82)
138 Berger, J. 2004. The last mile: How to sustain long-distance migration in mammals. Conservation Biology 18(2): 320-331.
139 Middleton, A.D., M.J. Kauffman, D.E. McWhirter, J.G. Cook, R.C. Cook, A.A. Nelson, M.D. Jimenez, and R.W. Klaver. 2013. Animal migration amid shifting patterns of phenology and predation: Lessons from a Yellowstone elk herd. Ecology 94:1245-1256.
140 Cross, P.C., D.M. Heisey, B.M. Scurlock, W.H. Edwards, M.R. Ebinger, and A. Brennan. 2010. Mapping Brucellosis increases relative to elk density using hierarchical Bayesian models. PLoS ONE 5(4): e10322.
141 U.S. Fish & Wildlife Service, DOI. 2003. Sonoran pronghorn - Antilocapra americana sonoriensis. Fact Sheet. Southwest Region P.O. Box 1306 Albuquerque, NM 87103
142 Hygnstrom, S.E., R.M. Timm, and G.E. Larson. 2005. Internet Center for Wildlife Damage Management – Pronghorn Antelope. icwdm.org/handbook/mammals/PronghornAntelope.asp
143 Hawes, Alex. 2001. Pronghorns - Survivors of the American Savanna. Zoogoer, Nov/Dec 2001. Smithsonian's National Zoo.
144 Cadieux, C.L. 1987. Pronghorn antelope: Great Plains rebound. In Restoring Americas Wildlife 1937-1987. Washington, D.C.: U.S. Fish and Wildlife Service, DOI.
145 Hawes, Alex. 2001. (See 143)
146 icwdm.org/handbook/mammals/PronghornAntelope.asp
147 Cadieux, C.L. 1987. (See 144)
148 Cadieux, C.L. 1987. (See 144)
149 O'Gara, B.W., and J.D. Yoakum. 2004. Pronghorn Ecology and Management. University Press of Colorado, Boulder, Colorado. 903 pp.
150 ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A009
151 ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A04M
152 Wyoming Game and Fish Department. 2013. Harvest Report - 2012 Annual Report of Big and Trophy Game Harvest. wgfd.wyo.gov/web2011/hunting-1001530.aspx
153 Wyoming Game and Fish Department. 2012 Statewide Hunting Season Forecast – Pronghorn. gf.state.wy.us/web2011/Departments/Hunting/pdfs/WGFD_STATEHUNTFORECAST_20120002962.pdf

154 www.nasportsman.com/journal/antelope_about.shtml
155 www.ynwildlife.org/pronghorn.php
156 Yoakum, J.D. Pronghorn. 1978. In Schmidt, J.L., and D.L. Gilbert. 1979. Big Game of North America: Ecology and Management. The Wildlife Management Institute, Washington D.C., and Stackpole Books, Mechanicsburg, PA.
157 Tilley, D.J.,D. Ogle, L. St. John, B. Benson. Date Unknown. Plant Guide. U.S. Department of Agriculture and Natural Resources Conservation Service. plants.usda.gov/plantguide/pdf/pg_artrt.pdf
158 Dickens, G. 2013. Personal Communication. Vice President, Arizona Antelope Foundation.
159 Bright, J.L., and J. J. Hervert. 2005. Adult and fawn mortality of Sonoran pronghorn. Wildlife Society Bulletin 33(1): 43-50.
160 Bright, J. L., and J.J. Hervert. 2003. Sonoran pronghorn 2002 aerial survey summary. Arizona Game and Fish Department Nongame and Endangered Wildlife Program Technical Report 236. Phoenix, USA.
161 Archer, S., D.S. Schimel, and E.A. Holland. 1995. Mechanisms of shrubland expansion: Land use, climate, or CO2? Climatic Change 29: 91-99.
162 Brooks, M.L. 2008. Plant invasions and fire regimes. In: J.K. Brown and J.K. Smith (eds.) Wildland Fire in Ecosystems: Effects of Fire on Flora. U.S. Forest Service, Department of Agriculture, RMRS-GTR-42: 33-45.
163 McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climate change, wildfire, and conservation. Conservation Biology 18: 1-13.
164 Nielson, R.P., J.M. Linihan, D. Bachelet, and R.J. Drapek. 2005. Climate change implications for sagebrush ecosystems. Transactions of the 70th North American Wildlife and Natural Resources Conference 70: 145-159.
165 Chambers, J.C. 2008. Great Basin Sagebrush Ecosystems. U.S. Forest Service, Department of Agriculture, Gen. Tech. Rep. RMRS-GTR-204(53-56).
166 O'Gara, B.W., and J.D. Yoakum. 2004. (See 149)
167 Berger, J. 2004. (See 138)
168 Cowan, I.M. 1940. Distribution and variation in the native sheep of North America. American Midland Naturalist 24: 505-580.
169 Hanneman, R. Sheep Hunting Tips & Tactics. www.rokslide.com/2012-01-09-05-12-00/sheep/189-bighorn-sheep-hunting-tips-a-tactics
170 Seton, E.T. 1928. Lives of Game Animals. Reprint Services Corp. 199 pp.
171 Buechner, H.K. 1960. The Bighorn Sheep in the United States: Its Past, Present, and Future. Wildlife Society Wildlife Monograph (4). 174 pp.
172 Schommer, T.J., and M.M. Woolever. 2008. A review of disease related conflicts between domestic sheep and goats and bighorn sheep. General Technical Report RMRS-GTR-209. Fort Collins, CO: U.S. Forest Service, Department of Agriculture. Rocky Mountain Research Station. 16 pp.
173 U.S. Fish and Wildlife Service, DOI. 2008. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Sierra Bighorn Sheep (Ovis Canadensis sierra) and Taxonomic Revision. Federal Register 73(151). ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A0DR
174 U.S. Fish and Wildlife Service, DOI. 2008. (See 173)
175 Saxton, E.H. 1978. Saving the desert bighorns. Desert Magazine 41. www.scribd.com/doc/2404512/197803-Desert-Magazine-1978-March
176 Hurley, K. 2013. Personal Communication. Conservation Director, Wild Sheep Foundation; Statewide Bighorn Sheep Program Coordinator, Wyoming Game and Fish Department (retired); Past Chair, Wild Sheep Working Group, Western Association of Fish and Wildlife Agencies.
177 Hurley, K. 2013. (See 176)
178 Singer, F.J., M.E. Moses, S. Bellew, and W. Sloan. 2000. Correlates to colonizations of new patches by translocated populations of bighorn sheep. Restoration Ecology 8: 66-74.
179 Mayer, K. 2012. Personal Communication. Director, Nevada Department of Wildlife (retired).
180 Hurley, K. 2013. (See 176)
181 Buechner, H.K. 1960. (see 171)
182 Penderson, G.T., S.T. Gray, C.A. Woodhouse, J.L. Betancourt, D.B. Fagre, J.S. Littell, E. Watson, B.H. Luckman, and L.J. Graumlich. 2011. The unusual nature of recent snowpack declines in the North American cordillera. Science 333: 332-335.
183 Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof (eds.). 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat.
184 Pettorelli, N., J.O. Vik, A. Mysterud, J.-M. Gaillard, C.J. Tucker, and N.C. Stenseth. 2005. Using the satellite-derived normalized difference vegetation index (NDVI) to assess ecological effects of environmental change. Trends in Ecology and Evolution 20: 503-510.
185 Pettorelli, N., F. Pelletier, A. von Hardenberg, M. Festa-Bianchet, and S.D. Côte. 2007. Early onset of vegetation growth vs. rapid green-up: Impacts on juvenile mountain ungulates. Ecology 88: 381-390.
186 Hurley, K. 2013. (See 176)
187 Epps, C.W., D.R. McCullough, J.D. Wehausen, V.C. Bleich, and J.L. Rechel. 2004. Effects of climate change on population persistence of desert-dwelling mountain sheep in California. Conservation Biology 18: 102-113.

188 Singer et al. 2000. (See 188)
189 Singer, F.J., C.M. Papouchis, and K.K. Symonds. 2000. Translocations as a tool to restoring populations of bighorn sheep. Restoration Ecology 8: 6-13.
190 Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Ballice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences 102(42): 15144-15148.
191 Williams, D.W., and A.M. Liebhold. 2002. Climate change and the outbreak ranges of two North American bark beetles. Agricultural and Forest Entomology 4: 87-99.
192 Risenhoover, K.L., and J.A. Bailey. 1985. Foraging ecology of mountain sheep: Implications for habitat management. Journal of Wildlife Management 49(3): 797-804.
193 Hurley, K. 2013. (See 176)
194 Raybourne, J.W. The Black Bear: Home in the Highlands. In Kallman, H. (ed.) 1987. Restoring America's Wildlife 1937-1987. Washington, D.C.: U.S. Fish and Wildlife Service, DOI.
195 Kallman, H. (ed.) 1987. (See 13)
196 ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A08F
197 Kallman, H. (ed.) 1987. (See 13)
198 Washington Department of Fish and Wildlife. Living with Wildlife: Bears. wdfw.wa.gov/living/bears.html
199 Jonkel, C. 1978. Black, brown (grizzly), and polar bears. In Schmody, J.L., and D.L. Gilbert. 1979. Big Game of North America: Ecology and Management. The Wildlife Management Institute, Washington D.C., and Stackpole Books, Mechanicsburg, PA.
200 Inman, R.M. and Pelton, M.R. 2002. Energetic Production by Soft and Hard Mast Foods of American Black Bears in the Smoky Mountains. Ursus 13:57-68. www.bearbiology.com/fileadmin/tpl/Downloads/URSUS/Vol_13/Inman_13.pdf
201 Board on Atmospheric Sciences and Climate Change, Division of Earth and Life Studies, National Research Council of the National Academies. 2010. Advancing the Science of Climate Change – America's Climate Choices.
202 hikinginthesmokys.blogspot.com/2012/07/summer-drought-puts-bears-on-move-in.html
203 CBS News. California bears invading suburbia. 2012. www.cbsnews.com/8301-505263_162-57509293/calif-bears-invading-suburbia
204 Associated Press, Denver. Bear quietly breaks into Colorado candy store, steals cookies. 2012. www.cbsnews.com/8301-201_162-57489513/bear-quietly-breaks-into-colo-candy-store-steals-cookies/
205 Healy, J. 2012. With their food scarce from drought, more animals try dining in town. New York Times. www.nytimes.com/2012/09/07/us/their-food-scarce-from-drought-animals-dine-in-town.html?_r=5&ref=todayspaper&
206 Healy, J. 2012. (See 205)
207 Healy, J. 2012. (See 205)
208 CBS News. 2012. Bear cubs escape heat with dip in backyard pool. www.cbsnews.com/8301-201_162-57488288/bear-cubs-escape-heat-with-dip-in-backyard-pool/
209 Rosenbaum, M., and C. Sandell. 2012. Bear Epidemic Expected to Worsen in the West. abcnews.go.com/blogs/technology/2012/09/bear-epidemic-expected-to-worsen-in-the-west/
210 Herchenroeder, K. 2013. Aspen bears calls down significantly from 2012. www.aspentimes.com/news/7700261-113/bears-aspen-calls-weyer
211 Orff, E. 2013. Personal Communication. Bear Biologist, New Hampshire Fish and Game Department (retired).
212 Zager, P., L. S. Mills, W. Wakkinen, and D. Tallmon. Woodland Caribou: A Conservation Dilemma. University of Michigan. www.umich.edu/~esupdate/library/95.10-11/zager.html
213 Zager et al. (See 212)
214 ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A088
215 Associated Press. 1990. Predators kill Maine's caribou restoration effort. New York Times. www.nytimes.com/1990/11/04/us/predators-kill-maine-s-caribou-restoration-effort.html
216 www.adfg.alaska.gov/index.cfm?adfg=caribou.main
217 McKenzie, L. Caribou: Traditional Knowledge. Wild Explorer: Alaska & the Far North. www.encountersnorth.org/wildexplorer/caribou/traditional-knowledge.html
218 National Park Service. Caribou and People. www.nps.gov/gaar/historyculture/caribou-and-people.htm
219 www.learner.org/jnorth/tm/caribou/UseCaribou.html
220 arcticcircle.uconn.edu/ANWR/anwrgwichin.html
221 IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Quin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge, UK and New York, NY. Cambridge University Press.
222 Comiso, J.C., C.L. Parkinson, R. Gersten, and L. Stock. 2008. Accelerated decline in the Arctic sea ice cover. Geophysical Research Letters 35: doi:10.1029/2007GL031972.
223 www.climate.gov/news-features/understanding-climate/2012-state-climate-arctic-sea-ice

224 Rennart, K.J., G. Roe, J. Putkonen, and C.M. Bitz. 2009. Soil thermal and ecological impacts of rain on snow events in the circumpolar Arctic. Journal of Climate 22: 2302-2315.
225 Post, E., M.C. Forchhammer, S. Bret-Harte, T.V. Callaghan, T.R. Christensen, B. Elberling, A.D. Fox, O. Gilg, D.S. Hik, T.T. Høye, R.A. Ims, E. Jeppesen, D.R. Klein, J. Madsen, A.D. McGuire, S. Rysgaard, D.E. Schindler, I. Stirling, M.P. Tamstorf, N.J.C. Tyler, R. van der Wal, J. Welker, P.A. Wookey, N.M. Schmidt, and P. Aastrup. 2009. Ecological dynamics across the Arctic associated with recent climate change. Science 325: 1355-1358.
226 Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J.M. Welker, K.S. Winker, and K. Yoshikawa. 2005. Evidence and implications of recent climate change in northern Alaska and other Arctic regions. Climatic Change 72: 251-298 .
227 Post, E., and M.C. Forchhammer. 2008. Climate change reduces reproductive success of an Arctic herbivore through trophic mismatches. Philosophical Transactions of the Royal Society B 363: 2369-2375.
228 Vors, L.S., and M.S. Boyce. 2009. Global declines of caribou and reindeer. Global Change Biology 15: 2626-2633.
229 Kohler, J., and R. Aanes. 2004. Effect of winter snow and ground-icing on a Svalbard reindeer population: Results of a simple snowpack model. Arctic, Antarctic, and Alpine Research 36: 333-341.
230 Kohler, J., and R. Aanes. 2004. (See 229)
231 Hansen, B.B., R. Aanes, I. Herfindal, J. Kohler, and B.-E. Sæther. 2011. Climate, icing, and wild arctic reindeer: Past relationships and future prospects. Ecology 92: 1917-1923.
232 Stien, A., L.E. Loe, A. Mysterud, T. Severinsen, J. Kohler, and R. Langvatn. 2010. Icing events trigger range displacement in a high-arctic ungulate. Ecology 91: 915-920.
233 Griffith, B., D.C. Douglas, N.E. Walsh, D.D. Young, T.R. McCabe, D.E. Russell, R.G. White, R.D. Cameron, and K.R. Whitten. 2002. The Porcupine caribou herd. In Douglas, D.C., P.E. Reynolds, and E.B. Rhode (eds.). 2002. Arctic Refuge Coastal Plain Terrestrial Research Summaries. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD BSR-2002-0001: 8-37.
234 Joly, K., T.S. Rupp, R.R. Jandt, and F.S. Chapin III. 2009. Fire in the range of the Western Arctic caribou herd. Alaska Park Science 8: 68-73.
235 Hinzman et al. 2005. (See 226)
236 Berkes, F., and D. Jolly. 2001. Adapting to climate change: Social-ecological resilience in a Canadian western Arctic community. Conservation Ecology 5: 18.
237 Anderson, D.B., W.W. Anderson, R. Bane, R.K. Nelson, and N.S. Towarak. 1998. Kuuvanmiut Subsistence: Traditional Eskimo Life in the Latter Twentieth Century. Washington, D.C.: U.S. Department of the Interior, National Park Service.
238 Anderson et al. 1998. (See 237)
239 Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. United States Global Change Research Program. New York, NY: Cambridge University Press.
240 National Fish, Wildlife and Plants Climate Adaptation Partnership. 2012. National Fish, Wildlife, and Plants Climate Adaptation Strategy. Washington, DC: U.S. Fish and Wildlife Service, DOI; and National Oceanic and Atmospheric Administration, Department of Commerce. **www.wildlifeadaptationstrategy.gov/**
241 **www.doi.gov/csc/index.cfm**
242 **www.doi.gov/lcc/index.cfm**
243 Association of Fish and Wildlife Agencies. 2011. State & Tribal Wildlife Grants (SWG) Program - 10 Years of Success. **209.15.226.145/~fishwild/corecode/uploads/document/uploaded_pdfs/corecode_fishwild/StateWildlifeGrants_10YearSuccess-Report_11.pdf**



Flickr: Ken Conger/Denali National Park Service