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ENV 330

Conservation Plan

Conserving the Yellowstone National Park Ecosystem through Gray Wolves *(Canis lupus)*

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Background

i. Brief History of Canis lupus in Yellowstone National Park

The Gray Wolf (*Canis lupus*) is an essential species to the Yellowstone National Park (YNP) and Northern Rocky Mountain (NRM) ecosystems in the western United States. Following the delisting of gray wolves from the Endangered Species Act (ESA) in 2020, wolves throughout the US were able to be killed, trapped, etc. (U.S. Department of the Interior, 2020). But gray wolves throughout YNP were hunted long before this by colonizers to protect livestock and promote game species, such as deer (National Park Service, 2016). This culling of wolves led to their extirpation in the YNP area by 1940, and a survey conducted in the park in the 70's revealed that no wolf packs inhabited the area (National Park Service, 2016). That was until 1995, when gray wolves were reintroduced to YNP and were successful in not only establishing a population in the park, but they also transformed the ecosystem through facilitating trophic cascades (National Park Service, 2016; Ripple & Beschta, 2012). By conserving the gray wolves of YNP, the entire habitat and ecosystem is in turn, conserved.

ii. Trophic Cascades

Trophic cascade is not clearly defined by scientific literature, but Ripple et al. (2016) suggest that is can be defined as "the effects of predators that propagate downward through food webs across multiple trophic levels." But the authors urge not to compare trophic cascades to a domino effect because of the intricacies of how organisms in an ecosystem interact (Ripple et al., 2016).

YNP has three trophic levels in its ecosystem, comprised of predators, prey, and plants (Strong & Frank, 2010). There are important species in each trophic level in the YNP ecosystem. Wolves are a key predator, elk (*Cervus elaphus*) dominate the prey, and crucial plants such as aspen *(Populus tremuloides)* and willows *(Salix*) in the plant trophic level (Ripple & Beschta, 2012; Grimm, 1939; Barmore, 2003).

Elk had devastating effects throughout the ecosystem without wolves to monitor their populations which affected plants, soils, and smaller mammals (Ripple & Beschta, 2012). Figure 1 shows elk population trends from 1985 to 2010, and the data shows that elk populations were highest before wolf reintroduction.

Aspen and willows were especially affected by the growing elk populations, and their herbivory influenced the long-term decline of these species in the ecosystem (Ripple & Larsen, 2000; Beschta, 2005). Figure 2 shows two graphs detailing the aspen browsing rate of elk (b) and the percentage of young aspen (c). Overall, aspen was not able to recover until wolves were reintroduced because of the increased herbivory of large elk populations. But aspens and willows could not have such a recovery from only decreased elk populations. Wolves changed elk behaviors, particularly in how they browse. Several studies demonstrate that predators can cause their prey to change foraging behavior (Lima & Dill, 1990; Schmitz et al., 1997), and elk may have to sacrifice browsing young aspen stands for dense forests that provide cover from wolves (Creel et al., 2005). A study conducted by Fortin et al. (2005) demonstrated that elk were more likely to avoid aspen browsing during the winter and selected other habitats to avoid predation, while another study found that elk selected more open habitats during the winter and did not try to distance themselves from wolves (Mao et al., 2012).

Like wolves, beavers were reintroduced to YNP after they had been extirpated from the area for 40 years in 1986 (Scrafford et al., 2017). Beavers were extirpated from the area because they were popular game animals, and the elk were eating the willows and aspens that beavers made their dams out of, thus severely limiting their habitat availability (Scrafford et al., 2017; Ripple

& Beschta, 2012). Beaver populations increased after wolf reintroduction, and this is likely because wolf predation changed elk foraging behaviors and decreased the number of individuals browsing on the plants (Creel et al., 2005; Smith & Tyers, 2008). Figure 3 shows wolf populations in relation to elk (a) and the number of beaver colonies (b) from 1994 to 2018. The data suggests that beaver populations began to rise once elk populations declined because of the wolves (Figure 3). While this explanation oversimplifies the complex trophic relationships between wolves, elk, and beavers, there is a stark pattern that demonstrates beaver populations increased when elk populations decreased. Beavers are ecosystem engineers and keystone species, and their presence greatly changes an ecosystem for the benefit of other organisms by creating new habitats (Wright et al., 2002; Naiman et al., 1986).

Through the combined effects of reducing elk populations, modifying their behavior, and creating favorable environments for beavers to live in, the wolves of YNP changed the course of rivers throughout the park (Beschta & Ripple, 2006). This long process was facilitated by the reestablishment of willows along the riverbanks and beavers altering the waterflow through dams (Wolf et al., 2007). While there is a plethora of other factors that influence how the rivers changed, it was no doubt influence by the reintroduction of wolves to the ecosystem. Figure 4 shows a picture of a river at YNP before and after wolf reintroduction, and the changes in vegetation and course are apparent. This vegetation provides habitat for smaller mammals, prevents bank erosion and runoff from entering the water, and thus facilitates a more diverse ecosystem (Hebblewhite & Smith, 2010). Wolves have also had an indirect impact on greater songbird populations and species richness (Baril, 2009), bison populations increased (Ripple & Beschta, 2012), and more.

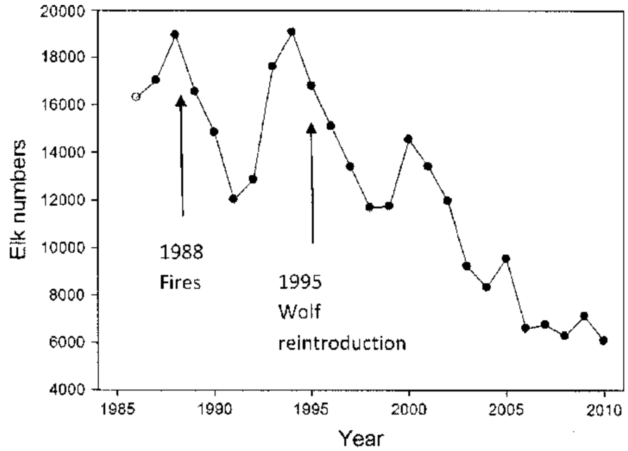

Figure 1: Elk population trends from 1985 to 2010, before and after wolf reintroduction to YNP. Despite elk populations dropping after forest fires in YNP in 1988, they quickly made a recovery before wolves curbed their population ((Romme et al., 2011)

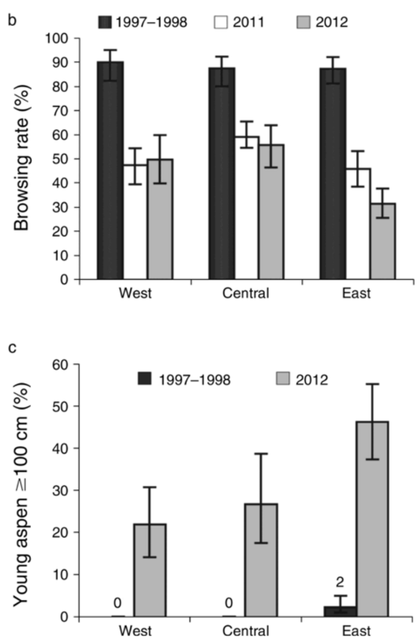

Figure 2: Before and shortly after wolf reintroduction (1997-1998), elk were browsing aspen at a rate of almost 90%, and this rate dropped past 2011 -about a decade after wolf reintroduction - for both central and east areas of YNP to under 50% (b). In the west and central areas of YNP from 1997-1998, there were 0% of young aspen more than 100cm tall, and only 2% in the eastern area (c). Young aspen were able to recover once wolves were reintroduced, as shown in each region in 2012, where each region has at least ~20% of aspens greater than 100cm tall (c) (Painter et al., 2015).

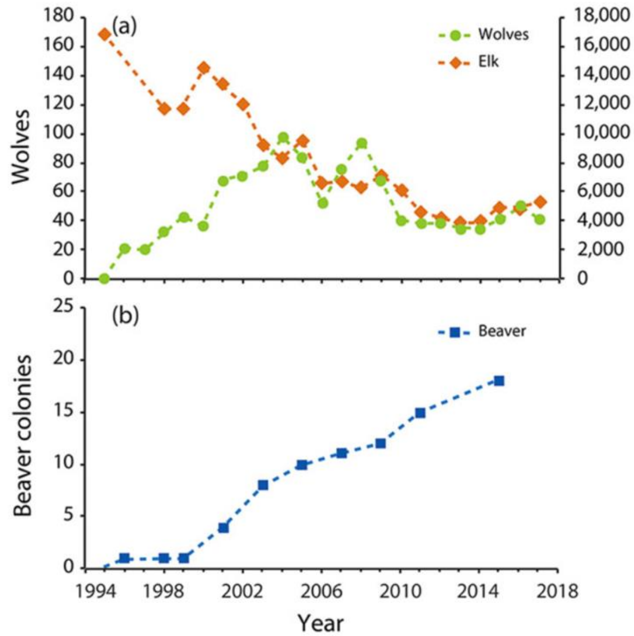

Figure 3: Graphs showing wolf and elk populations (a) and beaver colonies (b) from 1994 to 2018. In graph a, wolves are shown in green and elk in orange, and beavers are shown in blue in graph b. The data suggests that beaver populations increased once elk populations decreased from wolf predation (Beschta & Ripple, 2018).

Figure 4: A river in Yellowstone National Park before and after wolf reintroduction. Note more abundant vegetation along the bank, a more gradual decline to the water, and more sediment on the left of the photo in 2020 (Bescheta & Ripple, 2021).

iii. Greater Yellowstone Ecosystem

All of the complex, trophic-cascading interactions discussed in this paper happen in the Greater Yellowstone Ecosystem (GYE), and it is one of the "largest, nearly intact temperatezone ecosystems on Earth" with half of the world's active geysers and YNP in its center (*"Greater Yellowstone Ecosystem"*, 2016) (Figure 5). Agriculture, logging, and development have put much of the nation's wild lands at risk, making this almost intact ecosystem all the more important to preserve for biodiversity and history (*"Greater Yellowstone Ecosystem"*, 2016). There is a need to protect this ecosystem because it is home to the gray wolf and other landforms, such as the geyser Old Faithful, that make this land unique.

Beyond biodiversity and preserving habitat, Yellowstone National Park has spiritual and cultural significance to many people in the US. The park, like the entire US, was once inhabited by indigenous peoples before colonizers displaced them from their land once the park was declared the first National Park in March 1872 (Grant, 2021). But the park is well-known by many people, and seeing Old Faithful is deemed an accomplishment. In 2021, over 4 million people visited YNP, showing that it is still a popular destination for scientists and tourists alike (Warthin, 2022). The ecosystem of YNP continues to be relevant and must be protected if we are to conserve this vulnerable ecosystem.

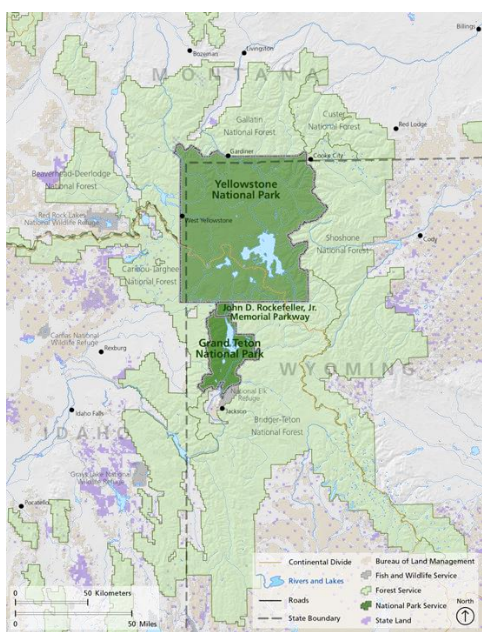

Figure 5: Greater Yellowstone Ecosystem map, with YNP in dark green in the center ("Greater Yellowstone Ecosystem", 2016).

Threats

i. Gray wolf hunting

Gray wolves outside of the NRM area were re-listed on the ESA in February 2022, and no wolf hunting is allowed inside YNP (*"2022 Gray Wolf Questions and Answers",* 2022; National Park Service, 2017). But wolves in Idaho, Montana, and Wyoming are not protected under the ESA since they were delisted from this act in 2011 (*"2022 Gray Wolf Questions and Answers",* 2022) (Figure 6).

When YNP wolves cross state boundaries to areas where wolves are not protected, these formerly protected wolves will often get killed by hunters, which does nothing to aid their reestablishment in the park. From the winter of 2021-2022, 23 YNP wolves were killed in other states as part of a state-authorized hunt of 450 wolves (Associated Press, 2022). But a judge in Montana recently ruled that all wolf hunting near YNP and Glacier National Park is temporarily put on hold and placed stricter limits on the number of wolves people can kill (Associated Press, 2022). National Park Service reported that 25 YNP wolves were killed in 2021-2022, which is about 1/5 of the total population (Partlow, 2022). See Figure 7, which inventories how many YNP wolves were killed by hunters throughout the years. There are only 89 YNP wolves as of February 16, 2022 (National Park Service).

Wolves have proven to be an invaluable, irreplaceable agent of change for the YNP ecosystem, but recreational hunting threatens their long-term success. This hunting, combined with their low population density and breeding only once a year means a very slow recovery for these wolves. YNP will continue to be under threat of extirpation so long as wolf hunting is legal in neighboring states.

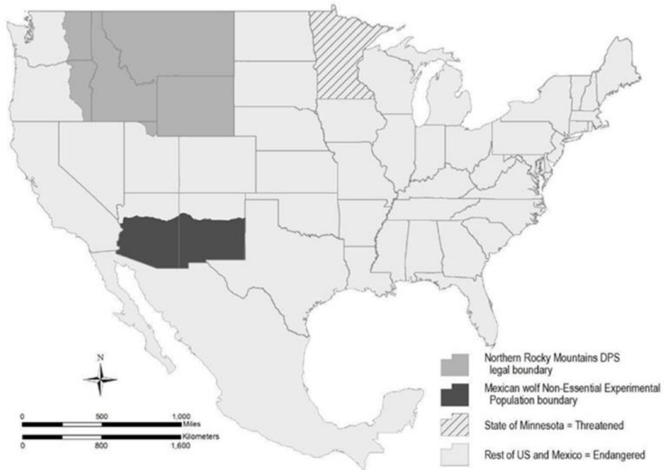

Figure 6: Map of legal boundaries for wolves and their population statuses. Wolves are threatened in Minnesota, endangered throughout the US and Mexico. Notice the unprotected NRM wolves range spans several states ("2022 Gray Wolf Questions and Answers", 2022).

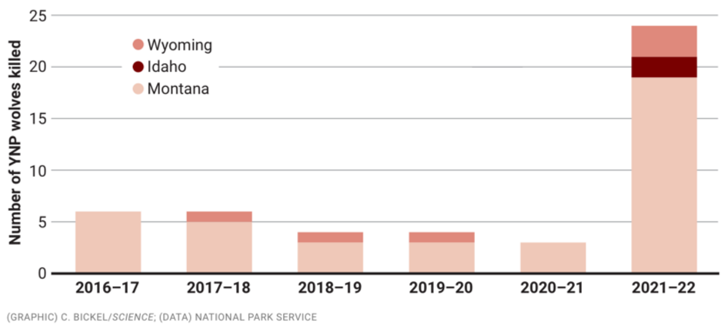

Figure 7: YNP wolves killed by hunting from 2016 to 2022. Colored bars indicate which state each wolf was killed (Morell, 2022).

ii. Genetic diversity

YNP wolf populations have been closely monitored since their reintroduction and maintain a stable population as of 2007 data (Mitchell et al., 2007). However, their population growth at this time was near zero (Mitchell et al., 2007), and this could be due to the Allee Effect, which, in the scope of this paper, means that there is a correlation between population density and the fitness of a population (Hurford et al., 2006). For YNP wolves, this means that a wolf is less likely to find a mate if there is a low population density. While this might seem intuitive, the geospatial separation of potential breeding pairs – such as if they find each other – can influence their chances of reproduction (Hurford et al., 2006). YNP wolves cannot recolonize the area if population density is low, and this is the suspected cause of their slow reproductive success (Hurford et al., 2006). Wolves only breed once a year, and usually only one pair per pack is permitted to reproduce (*"Natural History – Gray Wolf"*). Figure 8 suggests that wolf pack size, population size, and body mass are the most influential on a wolf litter's survival 8 months after birth compared to age, disease, and coat color for YNP wolves. The authors suggest that body size and socialness had the most influence on reproduction (Stahler et al., 2013). Given that body size effects their reproduction, it is essential that individuals consume enough food to be in good health.

In a 2007 study on the genetics of YNP wolves, vonHoldt et al. suggest that these wolves are genetically isolated and that future management decisions should consider the genetic impacts of reintroducing wolves to the area. Genetic isolation can pose dangers to organisms in their long-term survival because this isolation can lead to genetic drift, inbreeding, and the overall loss of diversity in a species, not to mention potential health issues (Frankham et al., 2002). Despite this genetic isolation, the authors observed that YNP wolves strongly avoid inbreeding through various behavioral changes, such as male wolves leaving their pack to breed with non-related wolves (vonHoldt et al., 2007). VonHoldt et al. (2010) went on to analyze DNA from 555 NRM wolves and found that there is a satisfactory amount of genetic dispersal among Greater Yellowstone Area, Montana, and Idaho wolves. Figure 9 shows NRM dispersal corridors across state boundaries, three of which are in YNP. The need for genetic diversity must continue to be at the forefront of YNP wolf conservation if we want to conserve this species for the long-term future.

Figure 10 shows YNP wolf population from 1995 to 2015, and the trends are slightly disheartening since populations have been declining since 2008. Wolf populations increased slightly in 2014 but declined again in 2015. The authors report that an outbreak of Canine Distemper Virus (CDV) caused the declines in 1999, 2005, and 2008, and that sarcoptic mange broke out among the packs in 2009 (Smith et al.). The cause of this population decline could also be that there are fewer vulnerable elk since their populations are below carrying capacity, which suggests that there are more healthy individuals than when the population was above carrying capacity (Smith et al.). This suggests that there is a greater need to monitor health among YNP wolves to ensure they are not extirpated by disease.

Vonholdt et al. (2008) suggest that inbreeding depression will occur in YNP wolves in the future unless current populations exchange DNA with wolves from other areas. But Jankovic et al. (2010) suggest that vonHoldt et al.'s (2008) methods were flawed and that they sampled too many wolves from a small population. Jankovic et al. (2010) also project that there will be no change in the trend of YNP wolf heterozygosity in the future, which could imply that these wolves do not need to be managed for genetic diversity. But the same year, vonHoldt et al. (2010) analyzed DNA samples from 555 NRM wolves and found that there was an acceptable amount of genetic dispersal among these populations. DeCandia et al.'s (2020) suggest in their more recent YNP wolf genetics study that there is a need for more research on these genetic trends before anything conclusive can be said, but that wolf genetics should be considered during management decisions.

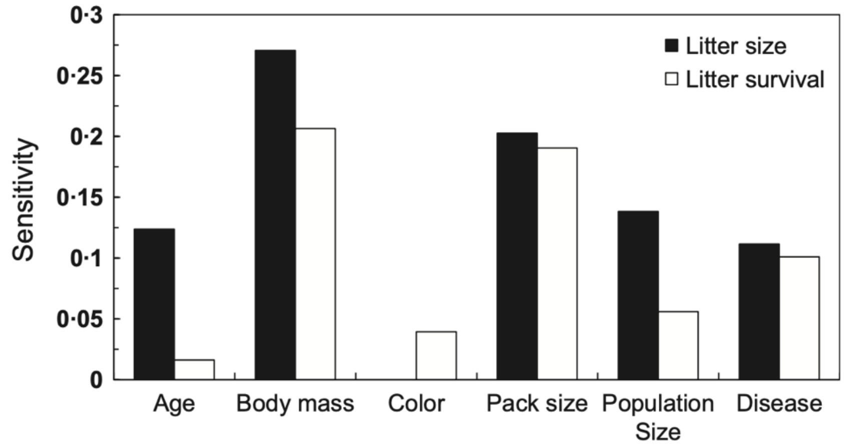

Figure 8: Various individual, group, and population effects on wolf litter size and survival at 8 months old from 1996 to 2009 for YNP wolves. Sensitivity values indicate how influential each characteristic is on litter size and survival. The higher sensitivity rate, the more influence that parameter has on litter size and/or survival (Stahler et al., 2013).

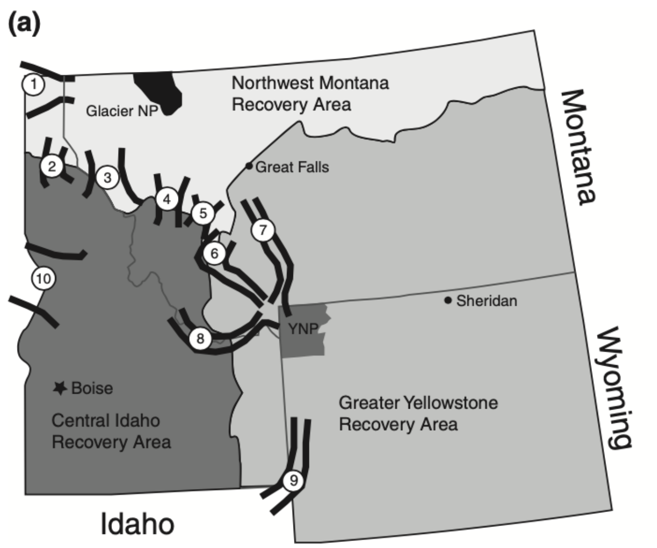

Figure 9: Dispersal corridors of NRM wolves shown by thick, black lines. 10 dispersal corridors are identified throughout Montana, Wyoming, and Idaho. 3 dispersal corridors branch off of YNP (Oakleaf et al., 2006).

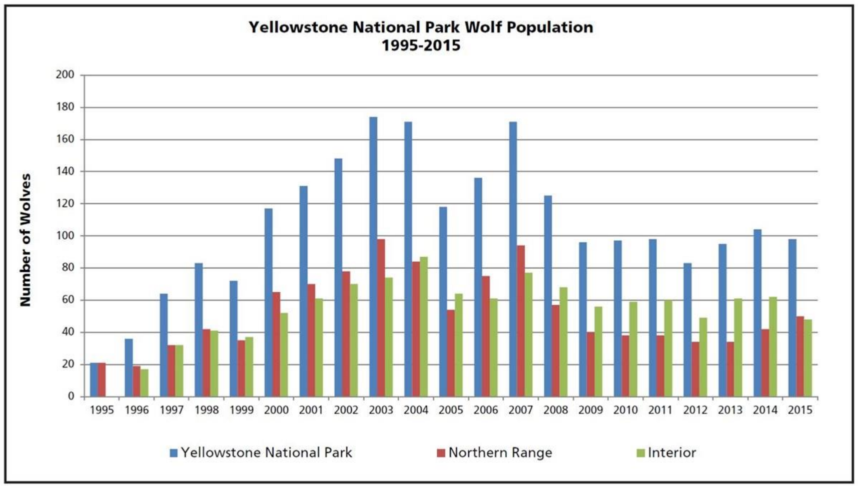

Figure 10: Yellowstone National Park wolf population from 1995-2015. Wolf population has been in decline since 2008 with some variability, but overall decline, since then (Smith et al.).

iii. Disease

As previously discussed, several diseases have broken out among the YNP wolf packs in recent years. Studies have been done on the emergence of diseases in the early 2000's and have found that they have been increasing in prevalence since 2005 (Figures 11 & 12). Common diseases and viruses contracted by YNP wolves include CDV and sarcoptic mange (Smith & Almberg, 2007).

CDV (Canine Distemper Virus) is a "contagious and serious disease caused by a virus that attacks the respiratory, gastrointestinal and nervous systems of puppies and dogs" (*"Canine distemper"*). Survival of CDV produces life-long immunity (Almberg et al., 2012), but this virus is deadly for many individuals. Only 22% of wolf pups survived CDV during an outbreak, in contrast with a typical survival rate of 77% when there are no outbreaks (Almberg et al., 2010). During a CDV outbreak in 2005, YNP lost 30% of its wolf population (Almberg et al., 2009). YNP wolf populations also decline when CDV and mange outbreak at the same time (Almberg et al., 2012) (Figure 11). Almberg et al. (2010) suggests that CDV will likely cause population declines in YNP every 2-5 years, but that there is no recommended management practice yet for this disease.

Sarcoptic mange is caused by the mite *Sarcoptes sacbiei*, is characterized by skin lesions and hair loss, and it first appeared in YNP wolves in 2007 and has been detected every year since then (Almberg et al., 2012). Genetics also influences if these wolves contract diseases, since DeCandia et al. (2020) found that severe mange infections were prevalent in YNP wolf populations that had decreased genomic variation. Figure 13 depicts the shared unique alleles between individual wolves based on mange severity. The graph demonstrates that wolves with similar levels of mange severity share unique alleles. DeCandia et al. (2020) advise that genetic diversity can lower the chances of severe disease outbreaks and that genetics should be incorporated into management decisions.

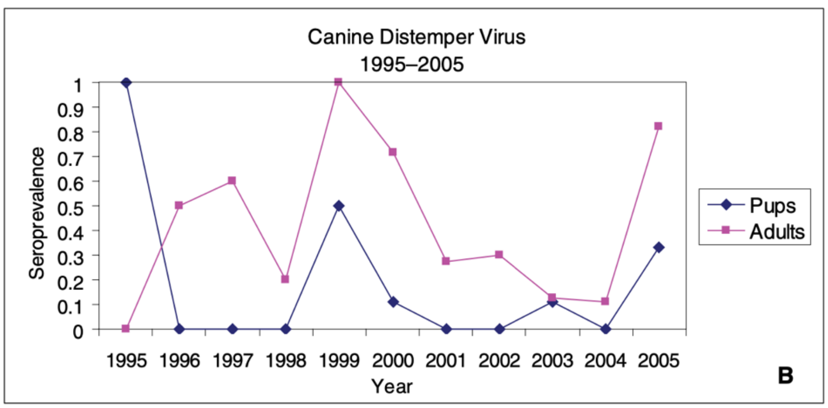

Figure 5: Canine distemper virus seroprevalence (level of pathogen in population) in YNP wolves from 1995 to 2005. Adults seem more likely to contract this virus (Smith & Almberg, 2007).

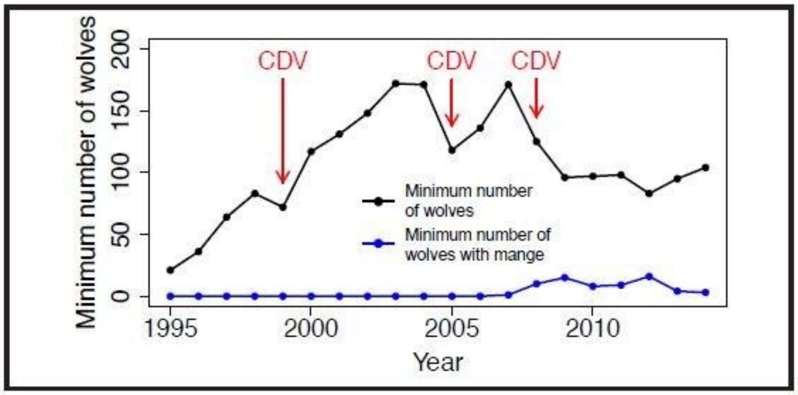

Figure 12: Wolf populations in YNP with and without mange. Wolves without mange shown in black, wolves with mange shown in blue. Outbreaks of CDV indicated by red arrows. Notice how wolf population decreases when more wolves have mange, and how the population increases when less wolves have mange (Almberg et al., 2012).

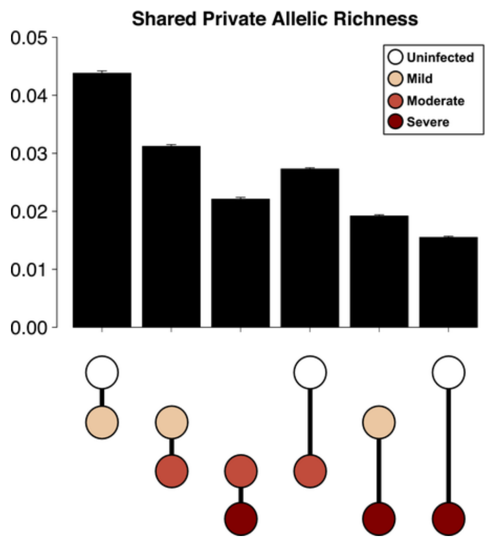

Figure 13: Shared allelic richness among YNP wolves. Higher allelic richness indicates more shared alleles, and a lower score indicates few shared alleles. Mange severity is indicated by various colors, with white being uninfected individuals and dark red severely infected individuals. Wolves that were uninfected or mildly infected shared more unique alleles than uninfected vs. severely infected wolves (DeCandia et al., 2020).

iv. Politics

Perhaps the greatest risk to the survival of YNP wolves is humans and our political disputes. Despite being relisted on the ESA in 2022, gray wolves are still a hot political topic in the western US. There are two vocal sides to this debate: environmentalists, who say that wolf populations are not stable enough to support recreational hunting; and hunters, who say hunting wolves is their lawful right for sport and protecting livestock (Williams, 2022). Animal rights supporters say that wolf trapping is inhumane and cruel, while hunters say that a small trap is nothing compared to the expanse of land that wolves roam and that hunting controls wolf populations (Randall, 2022). But the scientists who lose collared wolves to hunters are outraged since collaring wolves takes a lot of money and time, but more importantly, it negatively impacts their studies and is viewed as slaughter rather than population control (Randall, 2022).

A Wisconsin wolf hunt in February 2021 is an example of how politics can affect wolf management. Wisconsin law holds that if wolves are not on the ESA, wolf hunting is allowed from October 15 to the last day in February. But when wolves were delisted from the ESA by the Fish and Wildlife Service (FWS) in 2021, Wisconsin was not logistically prepared to conduct wolf hunts and instead planned to have the first hunt in November (*"Wolves in Wisconsin*"; Richardson, 2021). But hunters did not like that they could not hunt wolves yet and claimed wolves are a danger to livestock and pets, so a right-wing hunting group known as Hunter Nation sued the state, and the case was ruled in the hunters' favor (Associated Press, 2021; Hunter Nation, 2021). Wisconsin then had no choice but to allow a wolf hunt at the last minute, during wolf breeding season. During this hunt, they killed over 200 wolves (82% over the allowed quota), and Wisconsin was not prepared to respond to this sudden mass-killing of wolves (Richardson, 2021). Wisconsin's Department of Natural Resources requested that the wolf hunts be put on pause, but the Court of Appeals denied this request (Kaedling, 2021). Wolf hunting is currently illegal in Wisconsin in accordance with wolves being on the ESA once again (*"Wolf Hunting and Trapping"*).

Idaho is another state that has allowed for the killing of many of its wolves. A bill was signed into law in Idaho in 2021 that allowed hunters to kill 90% of the wolf population in the state without any limits on the means of killing (Main, 2021). Hunters and republican lawmakers claimed there were too many wolves and that they were killing many cattle (Oppie, 2021). The act allowed for $300,000 to support killing wolves that prey on elk and livestock, and opponents to this new law say that we are returning to the early days of America when wolves were bounty-hunted (Main, 2021). Wolf hunting and trapping is still legal in Idaho (since these wolves are a part of the unprotected NRM populations), and there is no limit to how many wolves a person can kill (*"Idaho Fish and Game",* 2022). The Idaho Department of Fish and Game Director Ed Schriever claims that Idaho wolf populations are "fairly stable" (Francovich, 2022).

In Montana, a judge ruled that their wolf hunts will continue since opposed environmental groups could not support their claim that the state's wolf populations would be forever damaged by hunting (Ehrlick, 2022). Wolf hunts in Montana were temporarily paused previously during a lawsuit brought by another environmental organization, but the case was not ruled in the environmental group's favor and the hunts resumed (Ehrlick, 2022). Wolf hunting is currently legal in Montana, and each person can kill up to 20 wolves each season (*"Hunt by Species: Wolf"*, 2022).

Scientists are calling for more transparent wolf harvesting data from states where wolf hunting is legal (Kareiva et al., 2022). The authors ask for clear data on livestock losses, wolf kills, and how many non-target species are killed by traps set for wolves. They also ask for an economic assessment of wolf hunts, and for these assessments to include a price for the ecosystem services wolves provide. Kareiva et al. (2022) also say that current wolf management is more concerned with livestock protection than anything else, and that reporting methods of livestock kills by wolves is not transparent. This recent publication seeks to hold states accountable for their endorsement of this mass culling of NRM wolves.

Conservation Actions

i. Ensuring genetic diversity

While YNP wolves are facing many threats, one that has a crucial impact on their survival is genetic diversity. Without genetic diversity in a population, these wolves could experience inbreeding depression, which can lead to reduced fitness, decreased resistance to diseases, and even extinction (Nonaka et al., 2019; Smallbone et al., 2016). While there is not enough data on the genetic diversity of YNP wolves to make any conclusions, it would be reasonable to have their genetic diversity accounted for in their management.

One conservation action that could be done to ensure the genetic diversity of YNP wolves would be to introduce wolves of the same species from other geographic areas into the park (Hedrick & Kalinowski, 2000). Gray wolves could possibly be relocated from Alaska, and this would be feasible since these wolves are not protected under the ESA (Alaska Department of Fish and Game). Any wolves chosen for this would need to have a through genetic assessment to ensure they are healthy and able to reproduce. However, while this is a potential way to increase YNP wolves' genetic diversity, the introduced wolves might not be accepted by other packs, and these individuals could die without reproducing. Or these wolves could end up mating with each other and not mingling in the YNP wolves' populations at all. A possible solution to this would be to release these wolves in different areas of YNP so that they might not find and mate with each other. But if the Alaskan wolves did mate with each other, it is likely that their offspring would eventually mate with YNP wolves in the future. If possible, gray wolf individuals could be taken from other countries, such as Europe, but political and financial restrictions could hinder this option.

Another option to increase genetic diversity would be to capture and breed unrelated YNP wolves in captivity and release them once the female became pregnant with the unrelated offspring. While this would be a costly and time-consuming option, this would definitively ensure that these wolves are mating with non-related individuals. Kalinowski et al. (1999) found that captive-bred Mexican and red wolves had higher rates of survival than non-captive bred ones. A key component of this option, however, is to ensure that the captive-bred wolves are released before the offspring get used to living in captivity. If the offspring are not able to be released into the wild, then the captive breeding program would not help YNP wolves' genetic diversity.

ii. Disease Management

The diseases previously discussed in this paper must be managed in YNP wolf populations to prevent periodic population declines. But YNP park policy does not allow for ecosystem intervention unless under specific circumstances (National Park Service, 2016), so changes to this policy must be made to fight the outbreaks among the wolves. Government intervention will be necessary to allow scientists to intervene with YNP wolves. While this could be a time-consuming process, it could benefit the survival of YNP wolves. A key component of saving wild animals from diseases is to prevent the disease from spreading to other individuals (Wobeser, 2002).

Sarcoptic mange can be contracted from direct body contact with an infected individual, or by being bit by the mite itself (Smith & Almberg, 2007). Scientists could capture and rehabilitate YNP wolves that have contracted mange, and this could be done through careful monitoring of the wolves. However, it is not feasible to monitor every individual wolf throughout the park. Wolves that are at a greater risk of contracting mange could be closely monitored, and part of this data has already been collected by DeCandia et al. (2020). But if direct intervention for these wolves is not an option, there might not be much else that can treat these outbreaks. It is not feasible to try to eradicate the mite that causes mange given how small it is and potential unintended impacts on the ecosystem.

CDV is more difficult to treat in wild wolves, since the best way to prevent it is through vaccinations (Vergara-Wilson et al., 2021), and vaccinating pups while still in their dens would be an arduous and potentially dangerous operation. Vaccinating adult wolves who have CDV before they reproduce could be an effective way to prevent its spread and would be much easier than vaccinating individual wolf pups. Unfortunately, there is little work being done on developing CDV vaccines for wild animals and administering the domestic version of this vaccine has shown to have negative effects on wild animals (Vergara-Wilson et al., 2021; Gordon et al., 2015). Further development of a CDV vaccine for wild wolves must first be done before it can be administered to YNP wolves. YNP wolves infected with CDV could be captured and put in isolation until they die of the disease in captivity or recover and can be released. Like many other conservation actions, this would be a time-consuming measure, but it could save other YNP wolves from this disease. Another option for treating CDV outbreaks, though not feasible, would be to kill any YNP wolves that have the disease. Doing so would prevent the spread of CDV to other wolves but could negatively impact wolf populations in the short-term. This option might also be prohibited by the government, since YNP wolves are protected under the ESA.

Before any of these conservation actions could be put into place, adequate funding, qualified scientists, and government support is required for the success of the operation. Humans are critical for this conservation plan, so ensuring that these options are properly planned and executed is essential to its success.

iii. Cooperation and negotiations

The politics around wolf hunting are, as previously discussed, a very heated topic in the western US. Cooperation is essential to negotiations, and each side must be willing to hear the other out if progress is to be made. Given how important hunting is to the people of the US and every state includes hunting in its conservation of species (Arnett & Southwick, 2015), wolf hunting must still be allowed for NRM wolves, but with stricter quotas and means of hunting.

Reading et al. (1993) stress the importance of the people living in the GYE and their opinions on hunting elk, bears, and wolves. The authors conducted a survey of 308 residents of the area in 1988 and asked their opinions on various topics related to hunting large game animals near YNP. Despite their study taking place a few decades ago, their results and methods are still relevant as we make conservation plans today. Assessing the opinions of people in the GYE in the modern day would prove invaluable when making conservation decisions.

Smith et al. (2016) mention that, in the past, wolf hunting has been a part of the general public accepting this species. However, wolf hunts that have no quota limit, such as the hunts in Idaho, can quickly lead to the extirpation of wolves in the state. Game hunting for wolves must first consider their conservation and population stability before allowing the public to use them as a resource. This is where cooperation between environmentalists and hunters must occur, but it is important to note that these two categories are not completely different. Many hunters are environmentalists and vice-versa, and these people could potentially lead the opposing parties to come to an agreement on wolf hunting regulations.

Unfortunately, wolves in the NRM do occasionally hunt livestock and take elk away from human hunters, which can further decrease peoples' opinions of them (Smith et al., 2016). A solution to preventing livestock predation would be to put electric fencing around pastures, or for farmers to have protection dogs for their livestock. If farmers deem it necessary to kill a wolf to protect their livestock, they should be required to report it to the state's relative department. Preventing wolves from killing livestock in the first place is the best way to ensure that wolves will not be killed for livestock protection,

Smith et al. (2016) suggest that no more than 15% of collared YNP wolves and 20% of a pack's population be killed during wolf hunts. Killing breeding pairs should not be permitted, since this could disrupt pack dynamics and prevent reproduction (Smith et al., 2016). Ensuring the reproductive success of gray wolves is crucial to their survival and educating hunters about this is essential to the acceptance of this new rule. Smith et al. (2016) also suggest that conservation of wolves should focus more on sustaining their population than protecting livestock or hunting for sport since wolves do provide beneficial ecosystem services.

No matter what regulations are put in place, it is evident that the public must be educated on the importance of wolves and that lawmakers honor what the citizens want. Humans are responsible for the endangerment of gray wolves, but we can also be responsible for their comeback and reestablishment for years to come.

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