

Nevada's Mule Deer

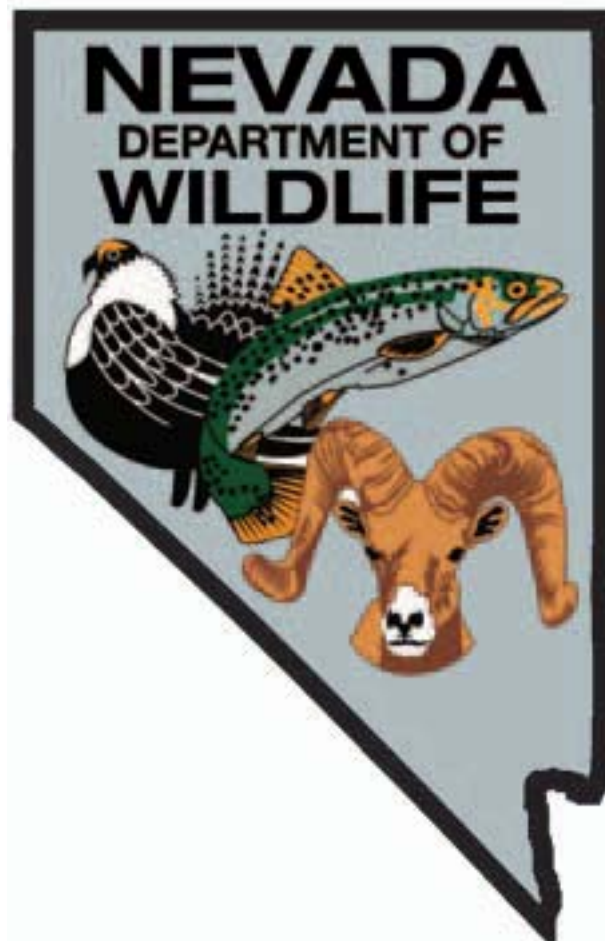


**Population Dynamics:
*Issues and Influences***

Mule Deer

Population Dynamics: *Issues and Influences*

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Nevada's Mule Deer
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Cover Photo: Buck and doe mule deer standing on weed-infested winter range, a site once occupied by sagebrush and other native vegetation.

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Introduction

Mule deer are the primary big game species in Nevada. Mule deer are the most numerous, most widespread (appendix 1), and most recognizable of Nevada's wild ungulates. Mule deer populations in Nevada have fluctuated greatly over the past 150 years. After reaching what was arguably an all-time population high in the late 1980s, mule deer have spent the last 15 years struggling to maintain numbers roughly half of what existed 15 years ago. The suspected causes and culprits contributing to mule deer losses are abundant. This biological bulletin endeavors to address not only the biological factors surrounding the recent decline of mule deer in Nevada, but the biology of mule deer population dynamics in Nevada by thoroughly examining, the evolution and natural history of mule deer; the history of mule deer in Nevada, and the risks, threats, and issues facing mule deer. Additionally, the history and philosophies of harvest strategies will be explored.

Evolution and Natural History

The mule deer is a native of North America. The species originated on this continent from a primitive deer that came from Asia probably well over a million years ago. Mule deer most likely evolved in the rugged mountains of the West where it developed numerous adaptations to the frequently inhospitable environment. The mule deer is an animal of broken forests and mountain brush zones, dependent on Mother Nature and other environmental forces to provide the disturbances that stimulate the production of favorable forage and cover species.

The mule deer was first described by Lewis and Clark in 1804. They gave it the name "mule deer" on account of the length of its ears. The scientific name *Odocoileus hemionus* (*Odocoileus* means hollow tooth and *hemionus* means half-mule) came several years later when Constantine Samuel Rafinesque (1783-1840) supplied the name based on descriptions of the animal he

had read about in the journals of a Canadian trader named Charles Le Raye. Le Raye had been held captive by the Sioux for nearly 14 years. In his journals, Le Raye referenced "mule deer" and provided a physical description. Based on the physical descriptions supplied by Le Raye, Rafinesque derived the scientific name.

History of Nevada's Mule Deer

Most people consider current mule deer populations as "low" or "down". As with any population, the highs and lows are only high or low relative to some historical reference point. In order to determine whether the current status of mule deer is "up" or "down," it is necessary to evaluate the complete history of mule deer population dynamics in Nevada.

Accurate historical data on mule deer populations is sparse. Although trappers and pioneers traveled to and through Nevada as early as 1824, true mule deer population census data have only been collected since the early 1950s and intensively only since 1976. Despite the lack of early census efforts, there are still some useful indicators of early mule deer numbers.

Although there are numerous sources of mule deer population data, there are only four main sources of data. Each of the four sources covers four different time intervals. Mule deer presence and absence data from roughly 1825 - 1850 were recorded quite well by the early pioneers. Many of the early trappers and pioneers kept detailed journals and diaries of their daily activities, which included observations of wildlife and wildlife sign (i.e. tracks around water sources). These diaries and journals have been evaluated thoroughly by multiple individuals and any and all references to wildlife have been recorded and evaluated.

Mule deer data from approximately 1850 - 1900 are recorded quite thoroughly in the numerous newspapers that began as a result of the mining booms. Due to widespread interest in wildlife as potential table fare, the early newspapers did an



excellent job of documenting mule deer dynamics. These historical newspapers have also been evaluated thoroughly by multiple individuals and all references to wildlife have been recorded and evaluated.

Deer data collection between 1900 and 1950, although still primarily derived from newspaper accounts, was assisted by the development of the first natural resource agency in Nevada, the United States Forest Reserves. Now known as the Forest Service, the agency was formed in 1906. Annual reports from the various “forests” in Nevada provide some of the earliest mule deer population estimates recorded.

For most of the last 50 years, 1950 - present, the Nevada Department of Wildlife has conducted mule deer census activities in association with mule deer management.

Despite the varied sources, the compilation and evaluation of these data create a historical perspective of mule deer population dynamics that generally correlates with similar evaluations in most of the western states. Although absolute numbers for historical mule deer populations are impossible to create with any degree of certainty, there is general consensus

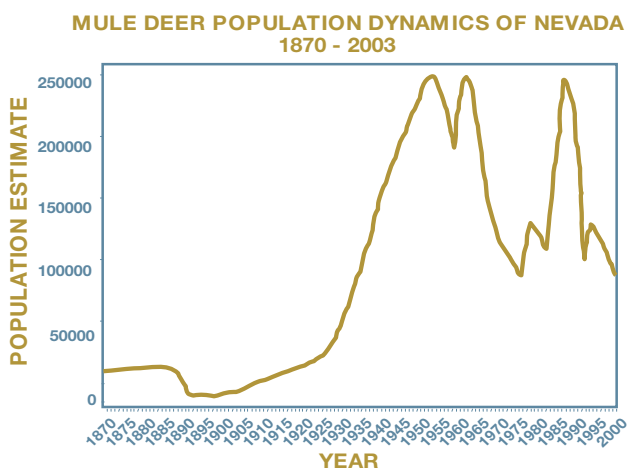


Figure 1. An approximation of Nevada’s mule deer population dynamics from the late 1800s to 2003. Although early data are sparse the United States Forest Reserves began reporting mule deer estimates in the early 1900s.

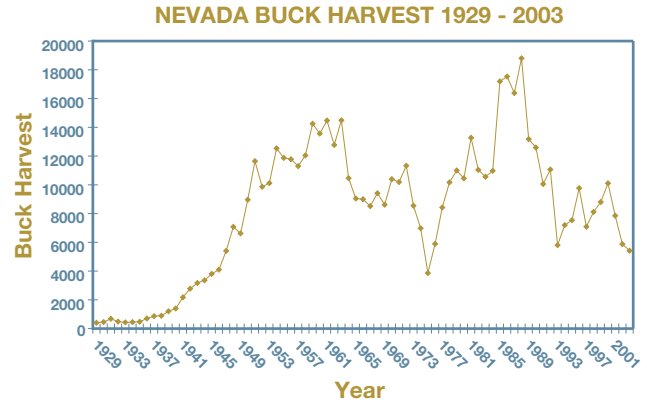


Figure 2. Total reported buck harvest for Nevada. Early data were based on expanded 10% questionnaire data while data from 1975 is from mandatory questionnaire. Data accuracy generally increases through time and provides strong insight to population trends.

among experts that although widely distributed, mule deer in Nevada existed only in very low densities.

Figure 1 displays an approximation of the complete history of mule deer population dynamics in Nevada from the early 1800s through 2003. It is important to recognize that population levels for many of the early years in this figure are mere approximations. However, the general trend that is depicted reflects expert opinion.

Perhaps an even more representative depiction of the mule deer population fluctuations can be found in Figure 2. Figure 2 shows buck harvest over a slightly shorter timeline(1929-2003). Although year-to-year variation in buck harvest can be attributed to a number of factors including weather, season length, and season timing, long-term dynamics of buck harvest are probably the most accurate index of mule deer population dynamics that exist for Nevada.

In an effort to display the most representative long-term trend in mule deer populations in Nevada, 10-year averages of buck harvest were calculated and are represented by the dark line in Figure 3. Averaging long-term buck harvest data creates a smoother picture of mule deer population dynamics through time.

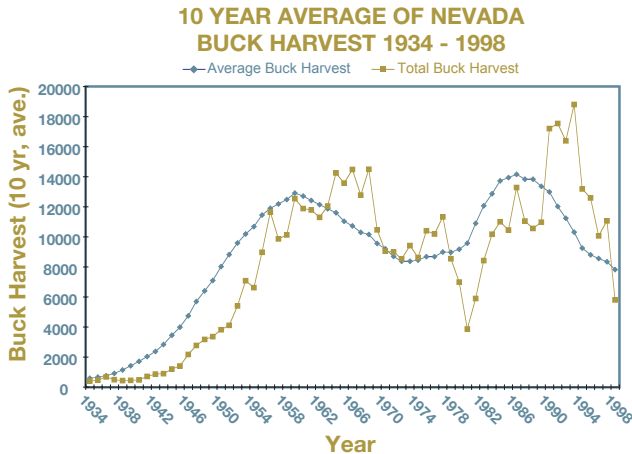


Figure 3. Ten year average of Nevada's buck harvest from 1934 - 1998. The 10 year average smooths the line and portrays the long-term trend in a more discernable manner.

Mule deer population dynamics are discussed throughout this document. For the purpose of discussing the “hows” and “whys” of mule deer population dynamics, it is helpful to break the data with consistent trends into specific time blocks or phases. The mule deer population increase phases have been classified as “initial increase” and “secondary increase.” (figure 4). Similarly, the decrease phases have been termed, “initial decrease” and “secondary decrease.” As we continue to explore the specific causes of these increases and decreases, we will refer specifically to these phases of increase and decrease.

Mule Deer Status

Nevada has higher population levels of mule deer today than during any time during the 125 years following Nevada's exploration by Peter Skene Ogden and Jedediah Smith in 1825 and 1826 respectively (figures 1-4). Despite having significantly more mule deer today than during Nevada's early history, Nevada has been experiencing a mule deer population decline since 1988. As demand for trophy quality mule deer hunting opportunity increases, the quantity of mule deer continue to decrease, heightening the concern for mule deer populations.

The primary concerns over mule deer population declines in Nevada can be attributed to what Nevada residents have experienced largely over the last 25 years. Many of Nevada's hunters have a fond and vivid recollection of mule deer hunting experiences from the late 1970s through the late 1980s. Mule deer populations were increasing rapidly during this time and by the late 1980s, tag quotas were at all time highs. Not only were hunters more likely to draw a tag from the limited draw system implemented in 1975, but hunters also had a great chance of harvesting a mature buck. As mule deer populations began to decline in 1989, hunters hardly took notice. However, mule deer populations continued to slide and were significantly impacted by the severe winter event that occurred in 1992 - 1993 at which point, sportsmen began to feel the effects of decreased quotas.

When mule deer populations failed to respond positively even 4 and 5 years after the winter of 1992 - 1993, many people began to question the then Division of Wildlife's management of mule deer. In an effort to “save” mule deer and return to the “quality” hunts of the 1980s, conservative quotas were implemented, with post-hunt buck ratio objectives of 30 and higher. More than 6 years have passed since the implementation of the first state-wide post-hunt

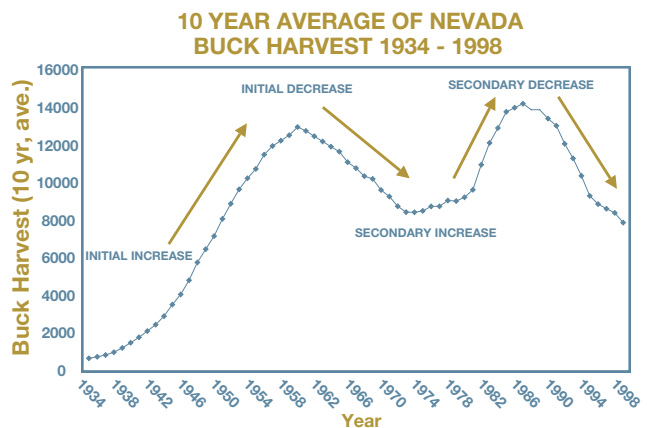


Figure 4. Identification of the mule deer population increase and decrease phases.



buck ratio objective of 30, and some hunters continue to have concerns about the absence of large bucks, leading one to conclude that this conservative strategy may not be providing the desired result.

In 2004, Nevada grapples with the notion that while current mule deer populations are considerably higher than historical populations, they are still less than 50% of what they were 15 years ago. And despite significantly curtailing hunting opportunities, conservative harvest strategies have not resulted in the expected or desired outcome of increased trophy quality, and the supply of mule deer in Nevada is far less than what's required to meet current demands. Although it can be substantiated that Nevada has more mule deer now than it did historically, over the short term, mule deer have declined significantly.

Mule Deer Decline

In 2004 Nevada has more mule deer than it did 100 years ago, but Nevada's mule deer populations are currently in the midst of a 15-year downturn. Mule deer declines are not unique to Nevada; in fact, mule deer populations are depressed throughout much of their range.

Simply put, populations of animals decline when mortality (death) exceeds natality (births). Therefore, we can conclude that either survivorship or fecundity (or both) of mule deer has somehow decreased. Decreased survivorship equates to increased mortality. In the case of mule deer, the increase in mortality could be caused by any number of factors, most of which will be discussed within this document. Fecundity is a term that applies to the number of offspring an individual can contribute to a population throughout their lifetime. Therefore, decreased fecundity means fewer animals are being conceived, carried to full term, and/or living long

enough to become part of the population. If the age to sexual maturity, or breeding age, was delayed or if the age of sexual senescence (the age at which reproductive potential decreases) was reduced, a decrease in fecundity would be the result. To demonstrate, consider a scenario in which a normal healthy doe mule deer could conceive at 2 years old and continue producing fawns until she was 10 years old. If, due to poor body condition, a particular doe was unable to conceive until 3 years of age and could no longer conceive after 8 years of age, the population to which she belonged would be experiencing a decrease in fecundity. A decrease in the incidence of twinning is another example of decreased fecundity.

Knowing that decreased survivorship and decreased fecundity are the causes of population declines and what is meant by the two terms, it is now possible to examine the data as it relates to each. Measures of reduced survivorship are virtually nonexistent, though we can sometimes index survival from fawn ratios and buck ratios. Mortality can discriminate by age class or gender or it can affect all segments of a population. Vehicle collisions, and a whole host of other sources of mortality seldom target specific segments of the population. Predation and starvation can differentially affect fawns but are difficult to measure. Sport harvest targets specific gender and age segments of the population, and consequently can be carefully monitored and regulated by monitoring buck ratios.

Contrary to what many people believe, wildlife biologists do not count deer to derive population estimates. Wildlife biologists classify deer according to gender and age. It is the gender and age data that are monitored for changes from year-to-year, to determine the status of the population. If a source of mortality was affecting all gender and age segments



of the population proportionally, ratios in and of themselves, would be insufficient to demonstrate reduced survivorship. However, at some point, if the mortality was significant enough, survey sample size would reflect the population decrease. Further complicating the measures of decreased survivorship is the concept that different sources of mortality could be simultaneously affecting different segments of the population in the same way, resulting in no measurable change in the proportion of animals in the population, thus diminishing the biologist's ability to detect decreased survivorship.

Fortunately, decreased fecundity is somewhat easier to discern. Fawn ratio data is the most direct measure of fecundity currently available for Nevada. Fawn ratios are nothing more than the ratio of the number of fawns expressed as a ratio to the number of does or total adults. If survey data are collected at a time of year when bucks still have antlers, allowing differentiation of bucks and does, fawn ratios are typically expressed as fawns per 100 does; whereas when survey data are collected during a time of year in which bucks have shed their antlers, fawn ratios are expressed as fawns per 100 adults.

The term fecundity really refers to much more than a simple fawn ratio. Fecundity, as alluded to above, pertains to an animal's ability to conceive, carry full term, deliver, nurse and nurture its offspring. Fawn ratios are only a small metric of changes in fecundity. However, Nevada possesses an extensive data set with observed fall and spring fawn ratios for over 40 years. These data strongly suggest that during the current mule deer decline, Nevada's mule deer have experienced a decrease in their fecundity. Observed spring fawn ratios varied greatly during two distinct 16-year periods of mule deer history in Nevada, the "secondary increase phase (1973 - 1988)" and the "secondary decrease phase (1989 - 2004)" (figure 5).

Figure 5 illustrates a 16-year period of the "secondary increase phase," in which, for every 100 does in the state's mule deer population there was an annual average of 47 fawns recruited into the population statewide. It also demonstrates that during a different 16-year period, the "secondary decrease phase," for every 100 does in the state's mule deer population there was an annual average of 41 fawns recruited into the population. Although a difference of 6 fawns per 100 does may not sound like a large difference, it is important to realize that the magnitude of this difference can be significant when it occurs over a 16-year period, as this has. As an example, if a population contained 100,000 does, a difference of 6,000 deer, or roughly 3,000 females in the first year alone could result. As we carry that out over the 16-year period represented, all things being equal, we end up with conservatively 120,000 more fawns or over 60,000 potentially productive does. Although this oversimplification fails to recognize many factors, it accurately illustrates a point that an annual difference of 6 fawns per 100 does can manifest itself as a huge difference in a population even over a relatively short period of time if the habitat conditions are right.

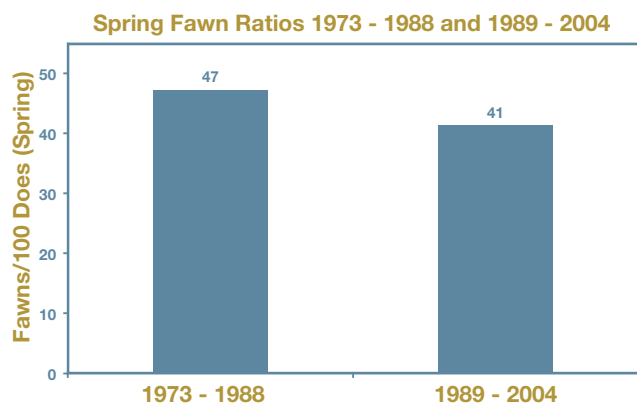


Figure 5. Spring fawn ratios 1973 - 1988 and 1989 - 2004. Spring fawn ratios are the number of fawns per 100 does or 100 adults. These values are fawns per 100 does surveyed via helicopter during spring deer surveys over two different 16 year periods. Although a seemingly small difference, mule deer populations can be hugely impacted by a difference as small as this.

Poor Body Condition

What causes underlie the fawn ratio differences? The primary culprit in both decreased survivorship and decreased fecundity is poor body condition. Poor body condition principally refers to insufficient energy levels and fat stores to meet the basic metabolic demands of life (i.e. thermoregulation, rutting activity, predator avoidance, conception, gestation, lactation, etc.). There are certainly instances of reduced survivorship that occur independent of poor body condition. For example, mortality caused by vehicle collisions is typically independent of body condition. However, most instances of reduced survivorship and virtually all cases of reduced fecundity are somehow the result of poor body condition. Research has consistently shown that deer on good quality ranges have higher rates of ovulation, conception, and pregnancy than deer on poor ranges. Research has shown that fawn losses are associated with the nutritional condition of the does: whereas (1) well-nourished does lost only about 5 % of their fawns; (2) does fed deficient diets during the winter lost about 33 % ; and (3) does underfed throughout their pregnancy lost 90 % of their fawns (Verme 1962). Studies have also demonstrated that poor body condition in mule deer has led to: prolonged sexual maturity (Morton and Cheatum 1946), delayed estrus (Severinghaus and Tanck 1964), decreased rates of ovulation and fetus' per doe (Julander et al. 1961), increased rates of fetal absorption, increased rates of spontaneous abortion, increased incidence of still-borns (Dasmann and Blaisdell 1954), reduced birth weights, increased fawn abandonment (Verme 1962), reduced lactation (Short 1981), and increased overwinter losses (Verme 1962). Although much more difficult to demonstrate empirically, it is likely that poor body condition also predisposes the affected individuals to a higher incidence of disease, a greater suscepti-

bility to predation, and greater likelihood of starvation. The impacts of poor body condition are numerous and well documented. However, determining the causes of poor body condition is the first step to rectifying Nevada's reduced fawn production.

Mule Deer Digestive Physiology and Diet

Mule deer are ruminants. Ruminants are animals that possess a four-chambered stomach. Their stomach contains a complex digestive tract with a rumen that is used as a fermentation vat, which enables deer to digest highly fibrous roughage (plants). The rumen contains a compliment of digestion aiding bacteria and protozoa, otherwise called microbes. The microbes in the rumen are essential in the digestive process. Mule deer eat vegetation that contains cellulose, which is virtually resistant to digestive enzymes and acids typically found in the stomachs of most omnivores, like humans. The fibrous roughage, or vegetation, contains potentially available energy in the form of cellulose and hemicellulose (long-chain molecules that exist in the cell walls of plants). However, in the absence of the microbes to break down these complex molecules and convert them into usable energy, mule deer would derive very little metabolic benefit from eating vegetation, their only dietary item. Therefore, mule deer are critically dependent on the microbes in their rumen to create the energy necessary for life from the digestion of the highly fibrous roughage they consume.

With respect to mule deer digestive physiology, the digestibility, palatability, crude protein, and chemical contents of plants vary greatly. Therefore, not surprisingly, mule deer are selective foragers. Mule deer exhibit a high degree of selectivity not only for the plant species they choose to eat, but also for the specific parts of the plant and the time of year



that a particular plant may be eaten. When deer are feeding on browse, they prefer the most tender parts, the new shoots and tips or “leaders.” Leaders are the most nutritious, most easily bitten off, most flavorful, and most easily digested part of the browse.

The selective foraging behavior of mule deer translates to very specific habitat requirements. Mule deer are a secondary successional species, taking advantage of plant species that are often the result of some type of disturbance. Succession is a natural change in the species composition of a community over time. Secondary succession is the replacement of species already in a given area by new species, usually triggered by some change or disturbance in the

local conditions. The plant species replace one another in a definite sequence, leading to a shift in the dominant plant species of an area. In the absence of the disturbance that facilitated the original shift in plant species composition, a slow but gradual return to successional climax plant species may occur. Habitats in Nevada have experienced numerous disturbance events that have resulted in drastic changes in the vegetation. As will be discussed more completely below, some of the vegetation changes in Nevada have been hugely beneficial to mule deer, while other changes in vegetation may negatively affect mule deer populations over time.



Habitat Factors

Degraded Habitat

The term “degraded,” when referring to mule deer habitat, means a reduction in potential for the habitat to produce and support mule deer. Currently, a number of factors are negatively affecting the ability of Nevada’s mule deer habitat to produce and support mule deer. They include range related factors such as plant senescence (loss of vigor resulting from age), pinyon juniper encroachment, overgrazing, exotic invasive species, fire, and type conversions; cyclic phenomenon such as drought; and human population factors such as housing, roads, mining and deer migration impediments.

Although mule deer habitat today may still be more suitable and more productive than mule deer habitats of 100 - 150 years ago, over the last 30 to 40 years mule deer habitat has been on the decline with respect to its productive potential. To better understand the specifics of these assertions, we need to examine the history of Nevada’s mule deer habitats.

Some disagreement still exists as to the exact appearance of Nevada’s mule deer habitats prior to European man’s arrival and subsequent disturbance. Some people are inclined to believe that Nevada was a huge expanse of grasslands while others hold to the view of a sea of sagebrush 8 feet high and taller. Some believe Nevada seldom experienced fires and this contributed to the expanses of decadent sagebrush, while others believe the frequent fires started by Native Americans and lightning maintained Nevada’s grasslands. Although it is likely that each belief holds some validity, neither scenario portrays an abundance of habitat that would be very beneficial for mule deer. Thus, it is assumed very few mule deer existed in Nevada historically. However, as European man began expanding and exploring the Great Basin, habitat for mule deer was rapidly being created.

The 1849 gold rush in California resulted in the creation of several trails, routes, and paths across Nevada. With established routes, Nevada became less intimidating and more navigable. The Comstock Lode was discovered in 1859. The Central Pacific Railroad was completed in 1869 and not only opened the door even further for ambitious adventurers but also greatly facilitated both the importation and exportation of livestock. More than 100,000 people had rushed to Nevada’s mining camps by 1870 and over 35,000 lived in Virginia City and surrounding areas. Livestock grazing and mining were well under way and acting as the main, albeit unintended, catalysts in the creation of mule deer habitat in Nevada.

Mining processes required a great deal of timber products. Timber was required to construct the supports through the hundreds of miles of below ground shafts. Timber was used to support rails within the mines and extensively required for the production of charcoal to be used in the smelting process of the mineral ore. However, the greatest use of timber was fuel wood. The populations associated with the mining camps were huge. With no such thing as natural gas heaters, propane fired furnaces, and being too far from coal, fuel wood was essential in home heating and cooking. Before 1900 alone, more than 16 million cords of wood and 3.5 billion board feet of lumber were harvested for wood consumption, bullion production, and ore processing (Hess 1990). For perspective, that’s enough wood to build a wall 12 feet wide and 22 feet high around the entire state of Nevada (Hess 1990). Further evidence of the extent of tree removal, exists in the fact that in some areas of the state, up to 90% of the modern pinyon-juniper woodland is less than 150 years old.



The removal of trees and associated disturbances, resulted in an immediate increase in sagebrush habitat. "Sagebrush habitat" includes sagebrush and other browse species such as bitterbrush, serviceberry, snowbrush, and snowberry. It also includes a host of grasses and forbs that exist in the interspaces between the browse. Mule deer are browsers and benefit when shrub species are productive components of their range (Dietz and Nagy 1976). The habitats that resulted from tree removal were ideal for mule deer.

Simultaneous with the widespread vegetation impacts from mining, large numbers of sheep and cattle were trampling Nevada's landscape at an unprecedented rate. Livestock populations irrupted during the 1870s and 1880s reaching estimated levels of 700,000 cattle and 400,000 sheep. Domestic livestock operations were developed to serve the new markets the mines and mills provided. Livestock numbers peaked between 1910 and 1930 with 3 to 4 million sheep grazing Nevada ranges immediately following World War I.

As a result of the early mining and grazing activities, wide-spread, landscape scale vegetation disturbance resulted in a seral plant community with a vastly expanded feeding niche for mule deer. Mule deer benefited from this increased feeding niche and peaked in the late 1950s. Since that peak, several different range related factors have resulted in degraded mule deer habitats.

Plant Age and Senescence

Mule deer are a highly selective browser very dependent on rumen microbes to derive energy from plant matter. For browse species plants, mule deer consume primarily plant "leaders". "Leaders" are the long thin twig like extensions from most browse

plants, that are the current year's growth. Deer prefer leaders to the other parts of the plant, as they are much more tender and thus more easily digested. As forage plants mature, their cell walls thicken. The parts contained within the cell are up to 98% digestible (Short and Reagor 1977). However, the cell wall contains such components as cellulose, hemicellulose, lignin, cutin, pectin, and tannin. The rough feel and appearance of leaves on deer browse is the result of high amounts of cell wall materials. Some of the cell wall constituents can be broken down by the microbes in the stomach, while others cannot. Lignin, a non-carbohydrate polymer that binds the cell together, is indigestible. The older a plant becomes, the more cell wall material it contains, hence, the older a plant, typically, the less digestible.

Additionally, older age plants typically possess greater amounts of secondary compounds. Secondary compounds are chemical constituents in the plant that make the plant taste bad or smell bad in order to protect the plant from herbivory (being eaten). As sagebrush ages, it produces increasing amounts of volatile oils as an anti-herbivory mechanism that decreases its palatability to animals that might feed on it. Sagebrush is a key browse species for deer. The high levels of volatile oils don't appear to deter mule deer from eating sagebrush. However, the volatile oils in sagebrush can have a bactericidal effect on the microbes in the rumen (Nagy et al. 1964). Consequently, mule deer trying to meet metabolic demands by eating old age sagebrush are quite possibly getting less nutrients and energy from their diet due to the fact that they are killing the very microbes they are dependent on for digestion.

Further complicating the issue of old age plants is the observation that many of the preferred browse species lose vigor with age. Bitterbrush, in

many places the most important browse species for mule deer (Hormay 1943, Nord 1965), ceases its production of leaders and seeds as it ages. At 60 years old, seed production and leader growth begin to decline (McConnell and Smith 1977). In grazed areas seed production and leader growth of bitterbrush may begin declining at a much younger age (Clements and Young 2001). Not only does the lack of leaders present obvious problems for foraging mule deer, but the lack of seed production significantly reduces a plant's ability to replace itself or recruit new plants.

Old age vegetation presents a number of problems to mule deer. As a result of reduced leader production, mule deer have less forage available to them. The limited forage is less palatable, is less digestible, and may kill microbes in the rumen that are so essential in digestion. Additionally, as a result of their old age, many browse species are experiencing reduced seed production and reduced ability to replace themselves or recruit new plants over time.

Pinyon Juniper Encroachment

Pinyon pine and juniper, collectively referred to as pinyon-juniper or more simply PJ, are an integral part of mule deer habitat. Studies examining winter mortality in Nevada mule deer have concluded that mule deer wintering on range that contains a PJ component, experience less winter mortality than similar areas without PJ (pers. Comm. Mike Hess, Nevada Department of Wildlife Game Biologists ret.). During severe winter conditions, PJ offers mule deer a more favorable microclimate in which to seek shelter from the elements and thermoregulate. For that reason, a term often applied to PJ extant in mule deer habitat is "thermal cover". However, when it comes to PJ cover, there can be too much of a good thing.

Every year, thousands of acres of mule deer habitat are impacted by PJ encroachment. Among the most pronounced vegetation changes in the past 130 years has been the increase in both distribution and density of juniper and pinyon (Miller and Tausch 2001). Prior to about 150 years ago PJ woodlands were more open. The most important factor contributing to this openness appears to be a much higher fire frequency during this period (Gruell 1999, Tausch 1999). The expansion of PJ has more than tripled the area dominated by PJ woodlands over the last 150 years (Tausch 1999). PJ woodlands now cover nearly 18 million acres in the Great Basin (Tueller et al. 1979), cover greater than it was before European settlement (Tausch et al. 1981). Both species are extremely aggressive and, once established, reduce understory productivity (West 1984, Vaitkus and Eddleman 1987), cover (Driscoll 1964), diversity (Burkhardt and Tisdale 1969), increase site aridity (Angell and Miller 1994), and accelerate soil erosion (Buckhouse and Mattison 1980). Losses of the understory productivity and diversity are particularly detrimental to mule deer.

The understory being lost to PJ encroachment contains grasses, forbs, and most importantly mule deer browse species such as sagebrush and bitterbrush. Nearly 25 years ago Tausch et al. (1981)



reported that substantial reductions in the forage for both game and livestock had apparently occurred in the previous 50 to 70 years. This loss in forage is a direct effect of increased tree density and dominance resulting in exclusion of the understory. The loss of understory has further reduced the fuel and consequently fire frequency. Decreases in fire frequency increase the rate of tree encroachment even more. Tausch et al. (1981) concluded that barring some major environmental change, this forage reduction will probably continue until trees dominate most of the sites favorable to their survival.

The rate of mule deer habitat loss is difficult to observe. Without photo plots, the magnitude of tree dominance might go understated. Fortunately, during the middle stages of development when woodlands contain understories of native shrubs and forbs, they can be successfully treated, especially with fire. However, once sites become tree dominated woodlands, treatment options become more difficult and more expensive.

Overgrazing by Livestock

Although livestock grazing and the disturbance associated with it, was instrumental in creating and maintaining historical mule deer habitat in Nevada (Gruell 1986), the impacts from long-term grazing have reduced the quality and capacity of mule deer habitats (Cottam and Evans 1945, Robertson and Kennedy 1954). Selective feeding is one such way livestock grazing has impacted mule deer habitat (Bowyer and Blich 1984). Most herbivores exhibit preferences with respect to not only the species they consume but also the parts of the plant they consume. Livestock exhibit grazing preferences for both certain plant species and for particular plant parts. Depending on the ecosystem and the time of year that the grazing occurs, the effects of grazing can dif-

fer. However, mule deer habitats appear to have been negatively affected by both types of selective grazing.

Early season grazing by livestock tends to focus grazing pressure on grasses and forbs. Early season typically refers to spring and early summer.

“Forbs” are herbaceous plants other than grasses. Livestock prefer grasses and forbs in the spring because following normal levels of winter moisture, grasses and forbs emerge in the spring, tender and green, palatable, highly digestible, and provide a good source of nutrients. Mule deer benefit from the consumption of forbs throughout the year and are especially assisted by consumption of grasses and forbs in the spring and summer (Austin and Urness 1985). However, heavy livestock use can result in significant reductions in species richness primarily by decreases in the amount of grasses and forbs in an area (Austin et al. 1986, Cottam and Evans 1945, Robertson and Kennedy 1954). The reduction in plants is due to their removal via consumption by livestock and also by other more complicated means. Many grasses and forbs are annuals that rely on seed production to persist from year-to-year. As annual grasses and forbs dry out and die, they set seeds that lie dormant until the following spring. If grasses and forbs are consumed by livestock prior to seed development, reductions in seed production may result.

Perennial grasses and forbs, although able to persist longer in the absence of annual seed production, also suffer from continued selection by livestock. As perennial grasses and forbs experience a high incidence of grazing, their seed production may also be limited. Although not as immediate as the result of limited seed production in annuals, the long-term effects of limited seed production in perennials can be equally detrimental to the persistence of these species. Not only can seed production be limited by selective early season grazing, but direct mortality



as a result of excessive utilization and/or complete plant removal by consumption or hoof action can also occur. Selective foraging by livestock on winter allotments has resulted in the severe reduction of grasses and forbs on many of Nevada's rangelands. Perennial bunchgrasses are particularly susceptible to winter utilization by livestock, and their abundance is frequently diminished as a result.

From a mule deer habitat perspective, one of the more significant results of selective foraging by livestock is the change in species composition and proportional abundance of plant species inhabiting an area. Consequences of selective foraging by livestock that have been documented include; decreased species richness, decrease in palatable species, increase in unpalatable species, and a decrease in plant productivity (Cottam and Evans 1945, Pickford 1932, Reynolds and Trost 1980, Robertson and Kennedy 1954). Each of these effects of livestock grazing can decrease the suitability of a habitat for mule deer.

Late season or hot season livestock grazing presents another, perhaps more significant, problem for mule deer. Mule deer also forage selectively. Mule deer prefer the leaders of browse species such as; bitterbrush, serviceberry, snowberry, and sagebrush. As mentioned above with regard to plant senescence, leader growth is more digestible, more palatable, provides more nutrition, and has fewer secondary (anti-herbivory) compounds than other parts of the plant. Livestock also turn to leader growth for food, for all the same reasons as mule deer and coupled with the fact that by late season, most grasses and forbs have "cured" and are no longer suitable as high quality forage.

Consequently, in an environment which has already

been recognized as limited in quantity and quality browse, livestock are reducing the already limited supply even further. The ramifications of reduced forage availability are obvious. Heavy utilization of bitterbrush leader growth can be especially harmful to mule deer when it occurs on "transitional range" (habitat used by mule deer when in route from summer range to winter range), or when it occurs on winter range. Dasmann and Blaisdell (1954) found steep declines in fawn survival when bitterbrush utilization exceeded 34 % .

The loss of fawn hiding cover due to overgrazing has also been documented (Bowyer and Bleich 1984). The strategy employed by mule deer, white-tailed deer, antelope, and elk to ensure the survival of their offspring is called "hiding." However, the hiding strategy evolved in the absence of domestic grazers. The over-utilization of some habitats (aspen stands or riparian areas) by livestock may subject fawns to heightened levels of danger. The heightened danger may come in the form of increased risk to predation or may simply be an increased metabolic cost of thermoregulation as the result of the loss of shade cover. In either event, losses of hiding cover can result in increased mortality whether direct, as in the case of predation, or indirect, as in the case of starvation.



Wildfire and Invasive Species

Wildfire plays an important role in many ecosystems. However, the timing, intensity, and frequency of fire tend to vary greatly between ecosystems. The vegetational composition in an ecosystem can reveal significant information as to the specific role of fire in an area. For example, very productive sites with a high number of fire tolerant species suggests a relatively high frequency of fire. Conversely, unproductive sites with few fire tolerant species suggests a low fire frequency and likely a reduced role of fire in that system when compared with the former. While the historical role of fire in Nevada can be debated most would agree that fire frequencies in Nevada were largely determined by fuel loads. The more productive sites burned perhaps once every 20 years or less and the least productive sites going perhaps as long as 300 years between fires. However, as new land-uses changed the vegetation, changes in the fire timing, intensity, and frequency also occurred.

Prior to European-American settlement, fire influenced vegetation by suppressing shrubs and trees, and promoting the production of forbs (Cooper 1961, Daubenmire 1968, Vogl 1979, Arno 1985). However, as studies of fire history have shown, with the arrival European man, a pronounced reduction in the size and frequency of fires occurred. The primary factor attributed with the reduction in size and frequency of fires, was livestock grazing (Julander 1962, Urness 1976, Gruell 1985). Livestock removed the fine fuels that were instrumental in fire ignition and travel. The development of man-made fuel breaks such as roads and irrigated land, combined with the advent of fire fighting agencies to reduce the role of fire even further.

The reduction in fire coupled with continued livestock grazing has resulted in major shifts in the vegetational composition in much of Nevada (Miller

and Rose 1999, Gruell 1999). The loss of fire as a disturbance mechanism to reset succession and restore native grasses and forbs plus the continual removal of grasses and forbs by livestock, resulted in a shrub dominated landscape. The absence of a native understory coupled with grazing related disturbances opened many of the sites to invasion by non-native cheatgrass. Cheatgrass is among the most invasive introduced species in the Intermountain West. Cheatgrass, named for its ability to “cheat” other plants of water and nutrients, increases fire frequency (Whisenant 1990) and out-competes native perennial grasses (Reichenberger and Pyke 1990). Consequently, cheatgrass which thrives in the presence of fire, has affected the conversion of millions of acres of sage-brush steppe to annual communities. Nevada’s long-term buildup of woody vegetation when combined with drought and fire-prone invasive species, has resulted in significant changes to the vegetative composition due to catastrophic wildfires. As a result of these fires, woody shrub species such as sagebrush and bitterbrush are being completely lost from sites as they become replaced by virtual monocultures of fire prone weeds like cheatgrass and tansy mustard.



Cheatgrass and other fire prone weeds out-compete native species (Reichenberger and Pyke 1990) and dominate a site. Site domination by cheatgrass not only spells trouble for native plants excluded by the cheatgrass but it also negatively affects all the animal and insect species dependent on those native plant species. As mentioned above, the presence of cheatgrass also greatly increases the fire ignition potential of a site. Cheatgrass, native to Asia, has an entirely different phenology than most native plant species. Phenology refers to the timing of growth, reproduction, and curing of a plant species. Cheatgrass has a much earlier phenology than native grass species. Cheatgrass turns green earlier thus “cheating” its competitors of resources, and consequently matures and cures earlier. The earlier curing date is especially problematic with respect to fire. The cured cheatgrass is a prime ignition source and excellent fuel source for wildfire.

Once a site with cheatgrass and tansy mustard has burned, virtually all native plant species are excluded as a thick mat of highly flammable low value wildlife habitat dominates. Further complicating the issue is the fact that once these sites burn, they pose an even greater threat for future ignition sources, they burn more readily, and the fires destroy even more native habitat by creating larger and larger fires. The cheatgrass fire cycle in Nevada presents an ever-increasing, self-perpetuating cycle of permanent habitat loss, more fire, and more permanent habitat loss. Portions of Area 6 of critical deer winter range in western Elko County that burned 40 years ago are still dominated by cheatgrass today.

Since the 1960s, Nevada has experienced wildfires unprecedented in size and intensity. For example, Area 6 has had over 660,000 acres burned between 1999 - 2001. The crucial winter ranges for the deer in the southern portion of Area 6 has

reduced in size from 184,320 acres in the early 1960s to a mere 22,400 acres in 2004. Commensurate with the habitat loss, mule deer numbers have declined. Although during the late 1980s most management areas in Nevada experienced all time population highs in mule deer, Area 6 did not. The Area 6 mule deer population was already realizing the effects of reduced carrying capacity that resulted from fire-caused habitat losses. Population estimates today suggest that Area 6 contains only about 1/3 of the mule deer it once did and data suggests fire related habitat loss is the main reason.

Type Conversions

“Type conversion” is a term that applies to the conversion of a vegetation type in an area from one “type” to another. The most common type conversion that Nevada has experienced is from mechanical and herbicide (2,4,D) assisted conversion from a native upland type consisting of native browse, forbs, and grasses, to a nonnative monotypic stand of crested wheatgrass. Although seldom performed today, during the 1960s millions of acres of mule deer transitional range and winter range were sprayed with herbicide and reseeded with crested wheatgrass. Additionally, crested wheatgrass was often used as the primary seed component in post fire revegetation efforts. Although the crested wheatgrass seedings provided a needed forage base for livestock, the seedings resulted in the conversion, and degradation, of millions of acres of mule deer habitat. Many of the areas sprayed with herbicide were formerly dominated by sagebrush and bitterbrush; two key mule deer browse species. Although many of these “type converted” rangelands have regained many of their previously existing native plant species, many crested wheatgrass seedings have yet to experience the return of more preferable mule deer forage.



Interrelated Range Factors

Each of the six aforementioned range related factors, independently present mule deer with significant challenges that reduce carrying capacity. However, many relationships exist between these factors that make their collective influences even greater. For example, the effect of pinyon juniper encroachment exacerbates the effects of plant senescence (old age). As pinyon and juniper invade or reinvade areas, they further inhibit mule deer browse species from becoming established. Pinyon and juniper outcompete most plant species in the understory by robbing them of sunlight, moisture, and nutrients. As this continues, significant mortality of browse species occurs, the recruitment of new browse is restricted, establishment of forbs and grasses is limited, and the overall site diversity is radically decreased, leaving less forage for mule deer. Furthermore, the mule deer forage that remains is not only reduced in quantity but also is of reduced quality.

Another interaction between factors is found between overgrazing and pinyon juniper encroachment. Overgrazing is believed to facilitate pinyon juniper encroachment via several mechanisms. Livestock commonly remove the grasses that exist in the spaces between the trees. The grasses, when present, act as a fine fuel source that carries fire from tree to tree. In the absence of the fine fuel source that grasses provide, fire cannot occur as frequently in the pinyon juniper cover type (Campbell 1954, Ellison 1960, Burkhardt and Tisdale 1976) and when fire does occur, in the absence of fine fuels, it doesn't travel well. Additionally, with livestock removing the grasses and forbs that exist in these interspaces, the pinyon and juniper realize a competitive advantage (Cottam and Stewart 1940, Madany and West 1983). Therefore, the reduction of plant materials by livestock between pinyon and juniper facilitates further tree encroach-

ment by reducing fire frequencies and decreasing the competition from other plants.

Overgrazing also facilitates invasive species (Pickford 1932, Robertson and Kennedy 1954). In the absence of disturbance native systems are very resilient to invasion by exotic weeds. However, when native systems are disturbed, they become highly susceptible to invasive species. Although seeds from invasive species are plentiful, in the absence of disturbance, establishment can be difficult. Livestock generated disturbances greatly enhance a site's susceptibility to invasion by unfavorable species. High use areas like feeding and watering areas are commonly inhabited by invasive plants. Not only does the disturbance generated by livestock increase the opportunities for establishment of invasives, but livestock themselves provide effective dispersal of seeds from invasive species. Livestock disperse seeds from invasive species on their legs, underside, and tails. There are the obvious negative impacts associated with invasive species such as; loss of native habitats, loss of species diversity, and loss of the animal species associated with the native flora. However, in the case of cheatgrass, the potential for fire and further habitat loss greatly exceeds the typical rate of habitat losses that result from invasive species alone.

The effect of livestock grazing on vegetation succession and senescence is probably the strongest and most detrimental of the interrelated factors. As livestock continually remove the more palatable species from a site, they are effectively increasing the abundance and proportion of the unpalatable species (Cottam and Evans 1945, Robertson and Kennedy 1954). Within a given grazing season, the effects of selective herbivory can be relatively minor. However, after years (100+) of selective foraging in a given area, many of the highly nutritious and highly palatable



species have been grazed so frequently for so many years, that they have been effectively eliminated from the habitat (Cottam and Evans 1945, Reynolds and Trost 1980). Many studies have demonstrated this phenomenon and many of Nevada's ranges exhibit it. The selective foraging also allows the old age vegetation to grow even older. Since the old age vegetation is lignified (tough) and bad tasting anyway, livestock avoid it and it continues to age and as other species are lost, old age browse effectively increases its proportional abundance.

Although volatile oils found in old age sagebrush possess bactericidal properties fatal to rumen microbes that are necessary for proper digestion in mule deer, the bactericidal effects appear to be dampened when mule deer have a complex diet comprised of a variety of species (Dietz et al. 1962). However, when plant diversity is low and grasses and forbs are lacking in the understory and interspaces of the sagebrush, due to the low species diversity the bactericidal effects may be enhanced. This further complicates the task for mule deer to get more energy and nutrients from less vegetation of poorer quality.

Cyclic Phenomena

Although wildlife populations demonstrate a number of cyclical patterns as the result of several different phenomena, no cyclic phenomenon exerts a greater influence on mule deer populations than weather. Droughts are especially difficult on mule deer and their associated habitats. In Colorado mule deer became lean when 3 successive years of drought reduced browse (Anderson et al. 1972a). Nevada, the most arid state in the Union, has experienced numerous well-documented dry periods and the impacts of drought on Nevada's mule deer have been significant.

The mechanisms by which climate affects mule deer are numerous. Some of the effects are direct, such as ambient temperature and the costs associated with thermoregulation. Other effects are more indirect, such as the effects of weather on the quantity and quality of forage.

Because Nevada is so dry, it is logical to consider precipitation first when looking at climatic influences on mule deer. However, in Nevada, there is no apparent relationship between mule deer population trends and total annual precipitation (figure 6). In effort to better understand the specific effects of precipitation on mule deer, it is necessary to evaluate the amount and timing of precipitation. Although winter snowfall and the accumulated snow-packs are critical to stream flows and reservoir levels in Nevada, spring and summer precipitation are equally critical for the creation and maintenance of high quality mule deer forage.

In most of the last 52 years, the precipitation falling in Elko, Nevada has exhibited an inverse proportionality between spring precipitation (February, March, and April) and summer precipitation (July, August, and September)(figure 7). Years receiving

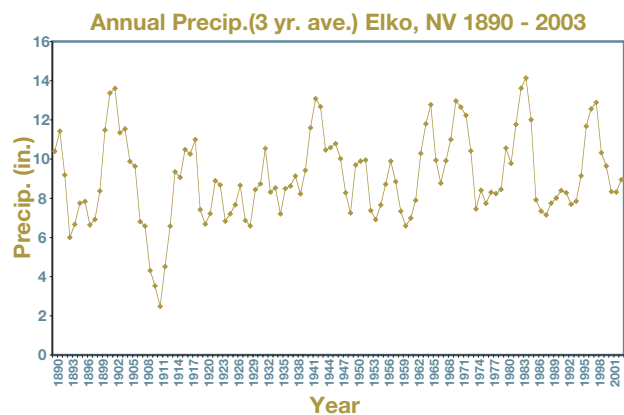


Figure 6. Three year average of total precipitation in Elko, NV 1890 - 2003. Note the absence of any particular correlation with mule deer population trends.



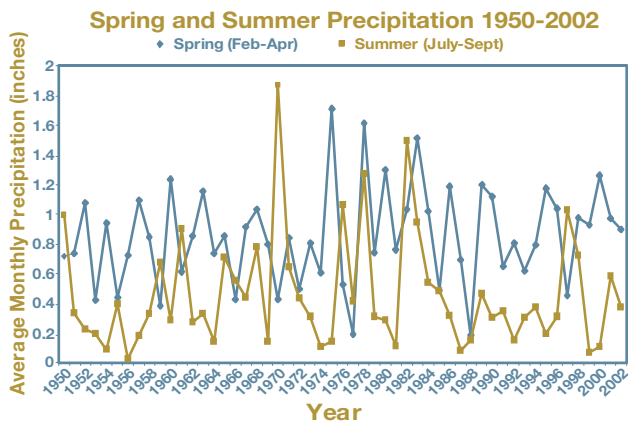


Figure 7. The relationship between spring and summer precipitation is typically inversely related, as spring precipitation increases, summer precipitation declines and so forth. However, for several years in the late 1970s and early 1980s spring precipitation and summer increased simultaneously, uncharacteristic of long-term precipitation trends in Nevada.

high amounts of spring precipitation receive very little summer precipitation and years receiving low amounts of spring precipitation typically receive high amounts of summer precipitation. However, several years through the late 1970s and early 1980s reveal a direct proportionality between spring and summer precipitation, with high amounts of precipitation in both the spring and summer. This particular period coincides with Nevada's last significant mule deer increase.

Two periods discussed above, the “secondary increase (1980s)” and the “secondary decrease (1990s),” lend themselves well to analysis of precipitation data. These periods, one of which represents a rapid increase phase while the other represents a rapid decrease phase, have available, excellent data on weather, fawn ratios, deer harvests, and population estimates, therefore, allowing any climatic influences to be readily discernable.

The biggest climatic difference that occurred between the “secondary increase” phase and the “secondary decrease” phase, is the amount of summer precipitation received (figure 7). More specific evaluation of two 6-year periods from two different weather

stations in Elko County further demonstrate these findings (figures 8 and 9). In the six years prior to the mule deer population peak, denoted as the “secondary increase,” summer precipitation appeared to be well above normal. However, during a similar 6-year period denoted as the “secondary decrease,” summer precipitation was conspicuously absent. The 6-year time intervals used to analyze summer precipitation (figures 8 and 9) are relatively short compared to the overall history of precipitation data for Nevada.

Therefore, in an effort to determine whether either or both of these 6-year time intervals were anomalous with respect to summer precipitation data, long-term summer precipitation history was examined.

Interestingly, 3-year averages of summer precipitation in Elko, revealed that 6 of the wettest summers in the last 114 years occurred between 1970 and 1984 (figure 10). The analyses of weather influences are specific to Elko County because Elko County contains the majority of Nevada's mule deer. Large mule deer sample sizes are obtained in Elko County and changes in mule deer

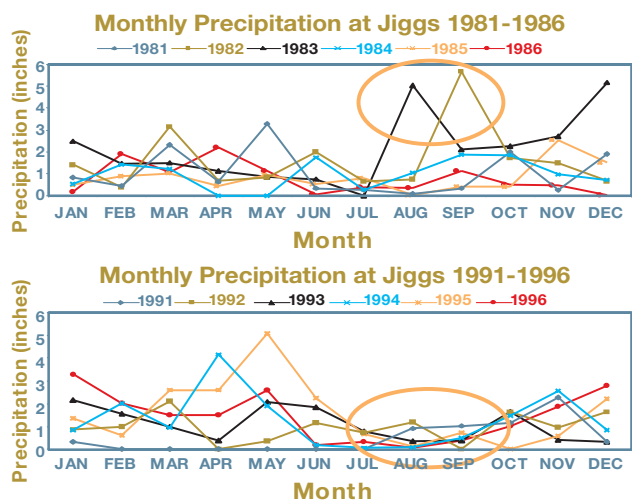


Figure 8. Monthly precipitation totals for two different six year periods (1981-1986 & 1991-1996) at Jiggs, NV. Summer precipitation is strikingly high in the early 1980s and conspicuously absent from the 1990s.

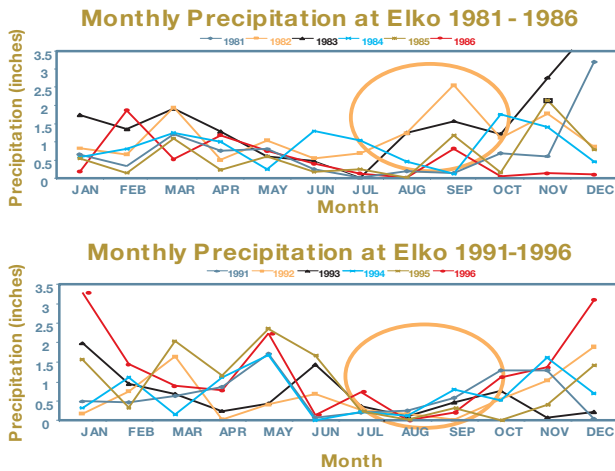


Figure 9. Monthly precipitation totals for two different six year periods (1981-1986 & 1991-1996) at Elko, NV. Summer precipitation is strikingly high in the early 1980s and conspicuously absent from the 1990s.

populations in Elko County strongly influence statewide population estimates. However, the pattern of precipitation received in Elko, was not restricted to Elko during these time intervals. The same precipitation patterns were also being observed in Austin (Lander Co.)(figure 11) and Orovada (Humboldt Co.)(figure 12).

Precipitation appears to have a major influence on Nevada's mule deer populations. The effect of precipitation on mule deer forage quality is probably the most important weather related influence. Mule deer diet and digestive physiology, as previously discussed, are unique. Throughout the year mule deer diets change radically in response to forage quality. Forage quality, although a somewhat abstract term, is best described as a cost benefit based activity. In other words, mule deer forage quality is largely determined by the relative cost, or energy expenditure, associated with procurement of the food item, compared to the benefit, nutrients and energy, provided by the food. The ideal scenario is one in which high energy yielding, highly nutritious food is widely distrib-

uted, for which mule deer are required to expend very little energy to locate and consume. On the other end of that continuum is a scenario in which mule deer expend more energy foraging than they receive back from the forage they consume, in which case, if prolonged, starvation results.

Both spring precipitation and summer precipitation play a role in forage quality. Spring precipitation combined with winter snowfall and the associated runoff are the key components of soil moisture. Spring soil moisture determines forage abundance and forage growth. Leader growth of browse is strongly correlated with spring soil moisture. Herbaceous forage production, grasses and forbs, are also dependent on soil moisture. Most all forage is of relatively high quality as it emerges in the spring. However, subtle differences in spring forage quality may exist as the result of temperature or moisture. For example, cool spring temperatures can slow plant growth and increase the leaf to stem ratio of many forbs (Cook et al. 1956). The increase in leaf matter to stem matter translates to increased digestibility and available nutrition.

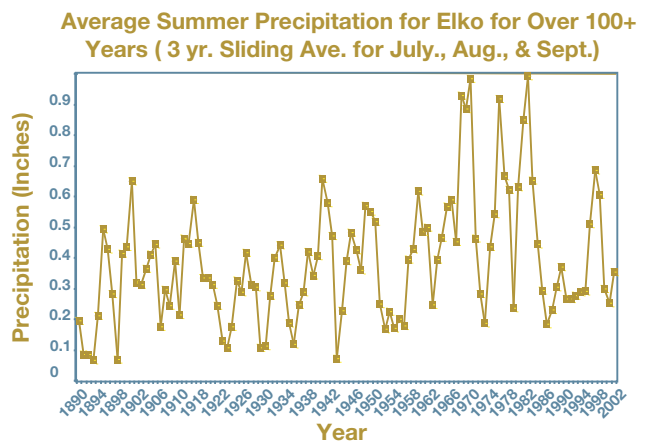


Figure 10. Average monthly summer precipitation for Elko, NV 1890 - 2003. The period of the late 1970s and early 1980s with high summer precipitation were truly anomalous in Nevada's recent precipitation history.

**Average Monthly Summer Precip (July - Sept.) Orovada, NV
1976 - 1985 and 1994 - 2003**

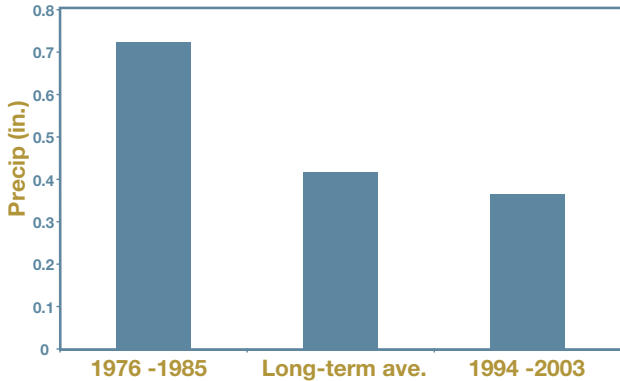


Figure 11. Average monthly summer precipitation at Orovada (Humboldt Co.), NV 1976 - 1985 and 1994 - 2003. A similar trend of increased summer precipitation was observed throughout the state during the late 1970s

**Average Monthly Summer Precip (July - Sept.)
Austin, NV 1976 - 1985 and 1994 - 2003**

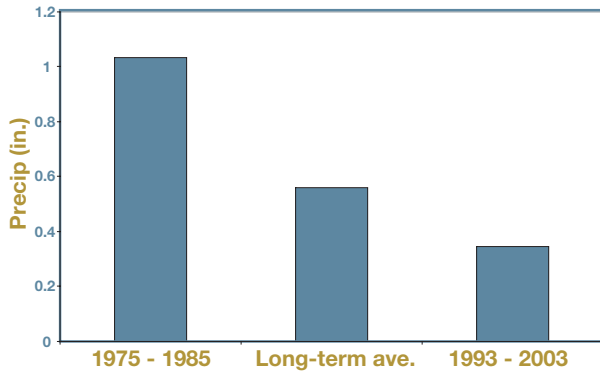


Figure 12. Average monthly summer precipitation at Austin (Lander Co.), NV 1976 - 1985 and 1994 - 2003. A similar trend of increased summer precipitation was observed throughout the state during the late 1970s and early 1980s.

Although spring precipitation and soil moisture are vital for the creation of high quality mule deer forage, summer precipitation is critical in maintaining it. Huge differences in forage quality can result from the presence or absence of summer precipitation. Digestibility and crude protein are the most commonly used indices of mule deer forage quality and both are affected by timing and amount of precipitation. In the absence of precipitation, both are decreased, resulting in lower quality forage. Drought conditions exacerbate the already challenging task of digestion by increasing the rate of lignification. Lignification is the

process of cell stiffening as the result of cell walls dying and creating an impermeable layer that likely provides further protection from desiccation (drying out). The lignin, cellulose and hemicellulose exist in greater proportions and occur earlier, in the absence of precipitation. Summer rains can prolong the onset of lignification, maintaining high digestibility and consequently high forage quality longer through the year.

In 1984, satellites that could provide certain measures of forage quality were launched. These satellites are capable of determining photosynthetic activity in plants from space. Photosynthetic activity simply means that a plant is in a growth mode and has not yet become lignified. Therefore, photosynthetically active plants possess higher forage quality, primarily via greater digestibility, than photosynthetically inactive plants of the same species.

In an effort to better understand the specific effects of summer rains on the quality of mule deer forage in Nevada, two starkly different summer precipitation years (1985 and 2000 (figure 13)) in Management Area 7, which lies in the extreme northeast corner of Nevada, were analyzed. One satellite image acquired October 1, 1985 was compared with a satellite image acquired October 1, 2000 to determine

**Average Summer Precipitation in Elko for 100+Years
(3 yr.sliding ave. for July, Aug., & Sept.)**

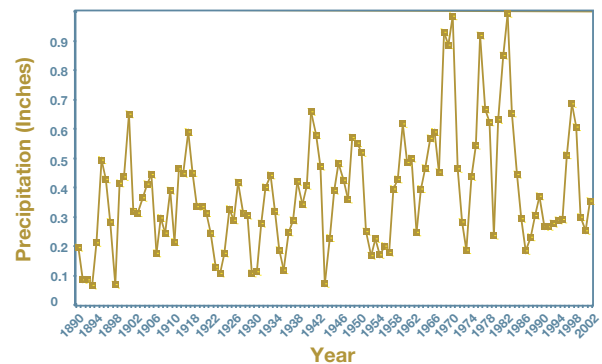


Figure 13. Total summer precipitation (3 yr. ave.) at the Gibbs Ranch (northern Elko Co.), NV. The years 1983, 1984 and 1985 had much greater summer precipitation totals than any years since.



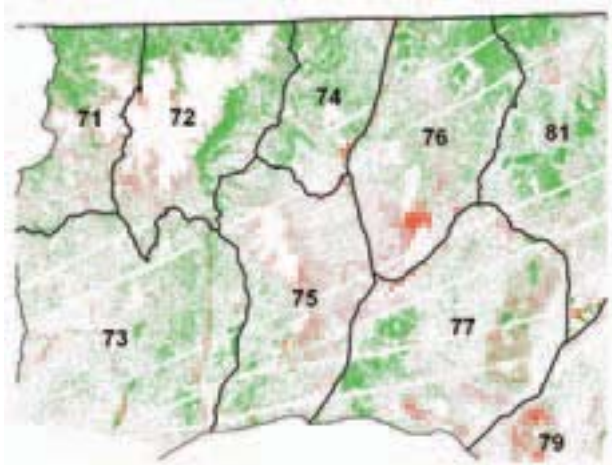


Figure 14. Management Area 7 satellite image analysis results in which differences in forage quality are indicated by photosynthetic activity. Only areas below 7000' elevation were analyzed and all areas in green possessed higher forage quality in 1985 than in 2000. Conversely, areas in red were of higher forage quality in 2000 than in 1985. The image analysis indicated that in Area 7 in 1985, there were over 250,000 acres of higher quality forage available than in the same area in 2000. The three pairs of parallel lines represent jet contrails and their associated shadows.

the difference in photosynthetic activity of vegetation. October 1 was chosen for several reasons. Late August to early October is the time of year during which mule deer accumulate key fat stores that are so essential in determining their over-winter survival and spring body condition. This late summer period is also the period in which forage quality is most affected by summer drought and differences in forage quality should be most discernable. And finally, October 1 was the only day that high quality images of this area could be obtained for both of the respective years. Although plant species were not differentiated in this analysis, due to the time of year, location of key species, and the probable distribution of mule deer, only those areas below 7,000 feet in elevation were used in the analysis. The results (figure 14) express the importance of summer precipitation in maintaining high quality mule deer forage. In the portion of Management Area 7 that was analyzed, which excluded some of the periphery and all areas above 7,000 feet in elevation, there existed approximately 250,000

acres of vegetation with greater photosynthetic activity on October 1, 1985 than on October 1, 2000. If quantity of high quality summer forage is limiting mule deer populations and given the magnitude of difference revealed by this analysis, a correlation should exist between mule deer population estimates and summer precipitation. Analysis of Nevada's mule deer populations and summer precipitation data reveals that over 80% of the variation in mule deer population estimates from 1978 through 2002 can be explained by a 6-year average of monthly precipitation received in July, August, and September (figures 15 and 16).

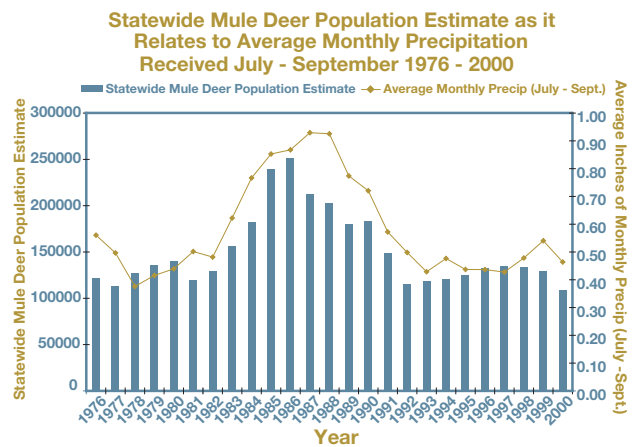


Figure 15. The relationship between statewide mule deer population estimate and summer precipitation. Summer precipitation is a six year average lagged 2 years.

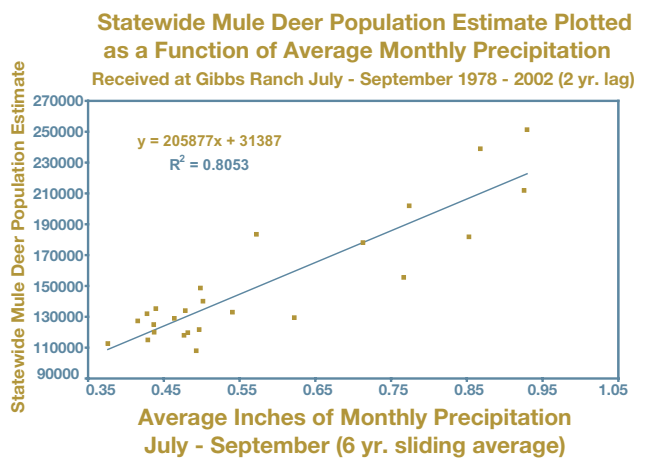


Figure 16. Regression of mule deer population estimate and summer precipitation.

Further support for the role of precipitation in producing high quality mule deer forage is provided by the West-wide synchronization of mule deer population dynamics. Although mule deer irruptions occurred throughout the West, initial mule deer irruptions were not synchronized, rather a function of the time from the initial disturbance. Even within Nevada initial irruptions were not synchronized but varied with time of initial disturbance. The first irruptions in Nevada occurred in the western part of the state where the first disturbances, as a result of the Comstock Lode, occurred. The second irruptions occurred in the central part of the state in association with the mining districts of Eureka, Austin, and Tonopah. Irruptions in Elko County occurred even later.

Although the initial increases were not synchronized, more recent population dynamics across the West have been. It appears that once vegetation attains a certain age, forage value ceases to decline. That is to say, that browse at 70 years old is equally bad at 80, 90, or 100 years old. Therefore, 30 years difference in timing of initial disturbances can result in 30 years difference in initial irruption, but at 100 years post disturbance all vegetation is of the same poor quality and that poor quality is only overcome by a far-reaching west-wide type of phenomenon like climate or more specifically, precipitation.

Human Population Factors

Mule deer habitats are degraded by numerous factors. The effects can be intermittent, occurring only occasionally, or take place on a cyclical basis. Some impacts are reversible or can be adequately mitigated. However, human population growth is likely to exert a consistent, irreversible, and ever-increasing negative influence on most mule deer habitats in Nevada. Keeping in

mind that human population growth should be credited as the cause for the creation of most of Nevada's historical mule deer habitats, current growth and its accompanying effects on mule deer habitat present an entirely different set of issues. For example, the need for housing today far exceeds historical demands for housing and demand continues to increase. We continue to construct homes and businesses on critical mule deer habitats (figure 17).

Another increasing and consistent negative influence on Nevada's mule deer habitats, pertains to migratory impediments. Occurring throughout the state, some mule deer migrations exceed 100 miles in length. Railroads, fences, highways, guardrails, canals, housing, and mining related activities can all impede migration routes and can all occur multiple times in a single migration route. These impediments can result in degraded mule deer habitat in more than one way. Initially, each of these impediments creates habitat destruction or habitat loss associated with its development. Subsequent to the initial habitat disturbance, is the potential to impede migration. Mule deer have exhibited very little adaptability with respect to altering migration routes to avoid impediments. Therefore, the ever-present and ever-increasing migratory impediments, continue to impose additional hardships on migrating mule deer.



Figure 17. Mule deer winter range occupied by houses and mule deer. Gradual replacement of native browse by houses and ornamental shrubs is a significant challenge mule deer currently face throughout the west.



In addition to the migratory impediments discussed above, other factors such as habitat fragmentation, poor habitat quality, and rural development are affecting mule deer distribution. For example, when native uplands become less suitable for mule deer (i.e. drought, fire, etc...) we find more deer residing in and around agricultural areas. Similarly, as we develop homes and businesses on mule deer habitat we find more deer in our yards, on our streets, and around our homes. Deer seldom thrive in these environments. However, due to the protection afforded them from such factors as private property and firearm restrictions common in urban areas, combined with high water availability and typically low predator numbers, valley bottom deer and urban deer continue to increase. Despite the relatively low statewide mule deer population levels, both valley bottom deer and urban deer have increased significantly and often show signs of poor body condition resulting from a diet comprised largely of ineffectual nonnative forage.

Factors Reducing Animal Condition and Survivorship

Human Induced Factors

The previous section discussed how Human Population Factors resulted in degraded mule deer habitat. This section deals more specifically with the mechanisms by which Human Induced Factors reduce animal condition and/or survivorship. Although many of the factors are the same, more specific examples of mule deer mortality and reduced animal condition will be examined.

With respect to migration disruptors, probably the two greatest sources of mortality and reduced body condition are fences and roads, which kill hundreds or more deer each year in Nevada. As we

observe the ease and grace with which most mule deer navigate a fence, the notion that this object could somehow be an imposition seems impossible. However, several factors acting alone or in concert can radically change the impression from a seemingly harmless fence, to a very real and significant threat to mule deer.

Most highway right-of-way fences and public land fences are constructed to meet a specification intended to minimize fence related impacts. However, fence specifications do not apply to private land fences, do not include fence density limitations, and do not stipulate a maximum slope limitation on which fences should be constructed. Consequently, fences quietly kill hundreds or more deer a year. Fences kill deer in both direct and indirect ways. Direct mortality occurs when deer become entangled in fences (figure 18) or are otherwise injured when crossing

Reduced body condition and associated mortality as the result of fencing is much more difficult to observe or document but occurs in several ways. Disruption of time budgets and energy budgets by fences may be significant, especially fencing on migration routes. Mule deer undertaking a 100-mile migratory trek can



Figure 18. Mule deer have more obstacles to overcome than at any other time in their history. Fences continue to increase throughout the west and while increased fence encounters cause some deer to succumb immediately, others suffer in less apparent fashion via increased energy expenditures and modified time budgets.



easily encounter 50, 60, or more fences traveling to or from winter range. When encountering a fence they often walk up or down the fence contemplating the best place to cross. As they continue on their migration, they encounter many more fences and undertake this same pattern of behavior at each fence they encounter along the 100-mile trail. Many times during the migration, the deer may stop and backtrack for a short distance, requiring some deer to cross certain sections of fence 3 times while migrating in just one direction. Since the deer do not migrate solely on public lands, they will be required to cross or circumnavigate wildlife unfriendly fences. As mule deer spend more time and energy navigating these new and ever-increasing obstructions, they are not only exerting more energy and traveling more miles to end up on the same winter range, but they also have less time and less energy to forage.

Exacerbating the complications of fencing even further is the slope of the ground upon which the fence is constructed. A four-foot fence constructed on a slope can easily become functionally an eight-foot fence to a deer on the downhill side. In this case, deer are left with no choice but to expend time and energy looking for a place to cross. In the event of deep snow, the energy expended to cross fences and look for ways around fences, can be significant. However, the resulting starvation or poor body condition that ensues from the added energy expended may not manifest itself until the deer are on winter range or are somewhere else. Therefore, since people are not finding dead deer piled up around the fences, other than those that die when becoming entangled, most people are unaware of the cumulative impacts the fences can have on mule deer.

An increased impact occurs when fences are constructed near or close to road right-of-ways. This creates a gauntlet scenario where deer experience increased mortality from the combined effects of the fences, guardrails, and the road, especially when constructed on steep roadside slopes, when the mortalities increase even more. Roads, much like fences, can also cause mule deer to expend additional energy looking for locations to cross. Blaxter (1962) suggests that standing mule deer might require 10-15 % more energy than reclining mule deer. Mule deer negotiating fences are likely expending even more energy.

Another human induced factor resulting in reduced body condition or reduced survivorship is railways. For the same reasons discussed for fences and roads, railways can negatively affect mule deer. Especially in periods of deep snow when train tracks are often the only clear or open area, mule deer mortality as a result of train collisions can be quite high.

All the examples provided above are consistent, ever-increasing, logistically or politically irreversible negative influences on Nevada's mule deer resource. Road traffic and railroad traffic are not only affected by increases in the population of Nevada, but also by neighboring states as residents from neighboring states travel through Nevada. Population growth within the state results in increased traffic on all the state's roadways and the need for more roads. Property development and housing is adding to the number of fences already in place. With increased concerns over livestock management, additional fences on Nevada's public rangelands are being constructed daily.



Climatic Extremes

All species experience significant mortality events as the result of climatic extremes. Mule deer are no exception. Because the greatest amount of mule deer mortality is documented during winter, traditional wildlife managers often concluded that winter severity and winter range quality were the primary determinants of mule deer mortality. Some believe that while high mortality can be documented on winter ranges, it is partly because the high concentration of animals results in concentrated mortalities and makes them easier to find and easier to document. Because mule deer are so widely distributed in other times of the year and the persistence of a corpse is so limited, mortalities are more difficult to discover and document in high numbers. Although extreme winter conditions can result in significant mule deer mortality, recent research has suggested that winter mortality may, in large part, be a function of summer climate.

In 1992 - 1993, Nevada experienced an extreme winter event, resulting in the loss of a significant numbers of mule deer (figure 19). However, the likely result of an ongoing drought, mule deer numbers in Nevada had been declining in the 4 years prior to the catastrophic winter of 1992 - 1993. Some studies claim that thermoregulation in the summer can be more metabolically expensive for mule deer than thermoregulation in the winter. In other words, it takes more energy for a mule deer to remain cool in hot times than it does to stay warm in cool times. Part of the reason for the high cost of staying cool in the summer may be due to the limited number of sweat glands possessed by mule deer. At any rate, drought and the associated extreme summer temperatures can affect mule deer foraging activity and mule deer forage quality (as discussed above) resulting in winter losses or, more difficultly detected, summer mortality. At a minimum, there exists a strong likeli-

hood that as a result of poor body condition, climatic extremes in the summer contribute to winter mortality and climatic extremes in the winter contribute to summer mortality.

Disease

The role of disease and parasites in Nevada's mule deer population is difficult to assess. Typically, diseased animals seek seclusion likely in an effort to avoid contact with other animals and predators. When diseased animals die, this behavior results in mortalities that are concealed and dispersed, making detection and collection very difficult. Consequently, mule deer disease related literature is largely restricted to large scale die-offs.

For the reasons mentioned above, disease events in Nevada's mule deer have not been well documented. Although Nevada is certainly not immune to the potential for an epizootic event, there are some characteristics of Nevada's deer herds that reduce the likelihood of such an event. Nevada's mule deer, although widespread in distribution, maintain an insular pattern of distribution. The island-like pattern of distribution combined with the relatively low densities in which they occur, both reduce the likelihood of a far-reaching epizootic event.

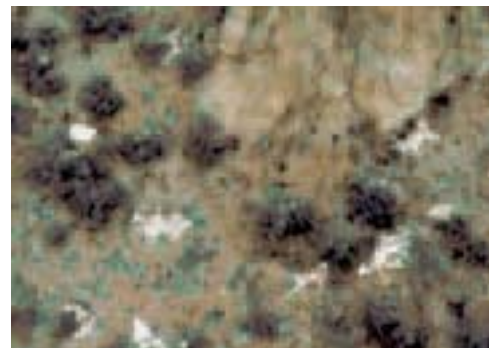


Figure 19. Winter killed deer in Area 6 after the winter of 1992 - 1993. The approximately ten deer carcasses in this photo resulted from severe winter conditions but were likely exacerbated by drought conditions and compromised habitat quality.



Isolated cases of disease have been observed in Nevada and have often been found in close association with agricultural fields. The probable link between disease and agricultural fields is based on nutrition. Mule deer exhibit a preference for irrigated alfalfa but in most cases lack the necessary microbes for proper digestion of this form of fibrous roughage. Consequently, although deer go through the motions of feeding, ingesting, ruminating, cud chewing, etc., they are not receiving proper nor sufficient energy or nutrients from the forage. The weakened condition that results from improper nutrition predisposes mule deer to disease pathogens, many of which may be present without symptoms in domestic livestock commonly found in these same agricultural areas.

As of 2004, Chronic Wasting Disease (CWD), a type of spongiform encephalopathy which is the cervid equivalent of mad cow disease in bovines, scrapie in sheep, and Creutzfeldt-Jakob Disease in humans, has not been identified in Nevada. Some experts feel that CWD presents a “slow motion epidemic” that will eventually affect all deer populations. Should CWD ever be detected in Nevada, mule deer management and mule deer harvest management may become significantly more challenging.

Predation

As the current mule deer decline has continued, hunting and predation, two readily discernable sources of mortality, have received a disproportionate amount of attention as factors affecting mule deer populations. The two main reasons people focus on the mortality caused by hunting and predation is due to the tangibility of the mortality and the optimism to affect positive change. Mortality that results from degraded habitat, i.e. abortion, fawn abandonment, starvation, etc., are seldom witnessed and therefore

somewhat abstract as sources of mortality. When a source of mortality can be witnessed as in, hunting or predation, it compels the concerned observer to “save” mule deer by minimizing the mortality, especially in times of population decline.

As mule deer have declined, some people have placed heavy blame on predators. Several hypotheses specific to Nevada have been offered as to how or why predators may be controlling mule deer. One hypothesis is based on the idea that the “initial increase” of mule deer occurred during a time of high predator control activities. Since that time, many of the more effective means of predator control have been outlawed and predator control efforts have decreased while predator numbers have soared and mule deer numbers have continued to decline, implying a cause and effect relationship. Although there may be some validity to this concept, data do not necessarily support it. In the 1960s, Nevada’s deer populations crashed despite the simultaneous occurrence of what was arguably the most aggressive predator control program ever implemented in Nevada. Surprisingly, Nevadans harvested more mule deer bucks in 1996 and 2000 than were harvested in any of the last 5 years of the 1960s when tags were not limited by quotas and predator control activities were at an all time high.

Another prevalent hypothesis relating to the impacts of predators stems from fluctuations in fur prices and trapping efforts. The most recent mule deer peak, “secondary increase,” coincided with all time high fur prices and trapping activity. Therefore, many people have concluded that since the removal of large numbers of coyotes, bobcats, and perhaps an occasional lion occurred just prior to and during the last mule deer boom, there must be a cause and effect relationship. Although certainly plausible, the data



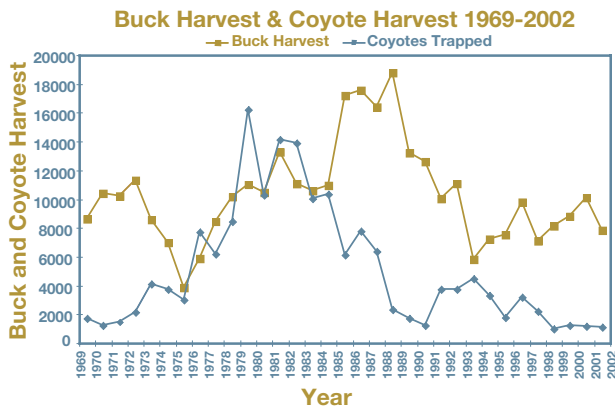


Figure 20. Coyote take and mule deer buck harvest 1969 - 2002. Coyote take includes sport harvest and Wildlife Services activities. High buck harvests followed high coyote harvests and suggests a possible cause and effect relationship exists.

do not necessarily support this hypothesis either. At first glance the data do suggest a cause and effect relationship between coyote take and buck harvest (figure 20). However, when summer precipitation data is added to the analysis, a tighter and more compelling relationship of buck harvest and summer precipitation emerges (figure 21). It is very likely, however, that despite the strong relationship exhibited between buck harvest and summer precipitation, that the high predator harvest associated with the high fur prices facilitated the mule deer population growth. The predator take may have allowed mule deer to take advantage of favorable habitat conditions more quickly than might have occurred in the absence of predator removal.

Another commonly stated predator related hypothesis is that coyotes are having a significant impact on fawns. There is no question that coyotes eat fawns. However, if coyote predation of fawns were limiting mule deer populations, fawn ratio data and coyote harvest data should display some type of cause and effect relationship. Although a general trend consistent with this hypothesis exists for a period, data fail to substantiate the hypothesis, especially over the last 10 years (figure 22).

While some are inclined to blame predators for mule deer declines, others contend the real issue affecting mule deer is habitat quality. Although the scientific literature lacks consistent findings with respect to the effects of predators on mule deer, many studies indicate a strong relationship between predation and habitat (Ballard et al. 2001). Predation and habitat are inextricably linked and rather than discuss the two as independent issues in an “either or” type discussion, they should be regarded as integrally associated, covarying phenomenon.

Poor habitat quality can result in increased rates of predation or increased effects of predation. For example, as discussed above, fawn production is a function of habitat quality. In the event of reduced fawn production, the impacts of predation can increase even if predator numbers or pressures remain unchanged.

Studies have also demonstrated that as poor habitat quality leads to poor body condition, age to sexual maturity may be delayed (Severinghaus and Tanck 1964). Not only can poor quality habitat decrease fawn production through increased rates of fetal absorption, stillbirths, fawn abandonment, insufficient lactation, starvation, low birth weights, etc.,

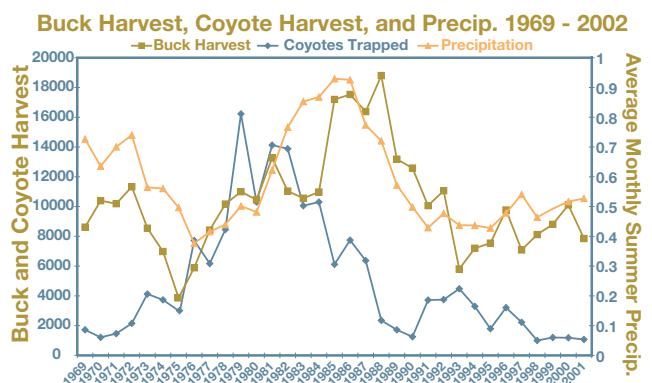


Figure 21. Coyote take, mule deer buck harvest, and summer precipitation 1969 - 2002. Although a cause and effect relationship between coyote harvest and buck harvest seems to exist, the pattern is strengthened even further by the addition of summer precipitation data.



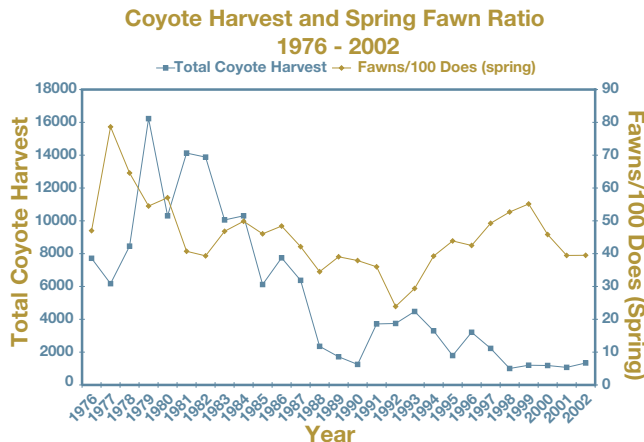


Figure 22. Coyote harvest and mule deer spring fawn ratios 1976 - 2002. Although a cause and effect relationship seems apparent for several years in the graph, the pattern reverses in more recent years.

it can also decrease fawn production via delaying sexual maturity. Delayed sexual maturity results in a reduction in the percentage of reproductive females in the population, again resulting in fewer fawns being produced which increases the potential significance of fawn predation.

Poor quality habitat can also prolong the estrus period in does. By prolonging the period over which does are receptive, a commensurate increase in parturition (the act of giving birth) occurs. Synchronized parturition creates a birth pulse of fawns in a population that results in a “swamping” effect on the predators. Predators become “swamped” by the sheer number of prey items and are simply unable to consume significant numbers of animals. However, if estrus is prolonged, parturition becomes prolonged, and the outcome is fawns being born at a more metered rate over a longer period of time, thus increasing the fawns’ susceptibility to predation and the period over which predators can have an impact.

“Swamping” predators is one method ungulate populations employ to try to overcome the effects of predation on their young. Another strategy commonly employed by mule deer, antelope, and elk, is called “hiding.” This strategy requires sufficient cover to exist

that enables the adult to secure their virtually scentless fawn in such a way to conceal them from the predator’s sight. The thick vegetative cover also conveys significant thermoregulatory benefits to the fawns. However, in vegetation suffering from a drought or overgrazed by livestock or feral horses, hiding cover may be sparse or altogether lacking, resulting in increased predation.

Poor habitat quality is often the effect of a drought or some significant human related disturbance. If water distribution patterns change or water availability decreases, as it would in conjunction with a drought, mule deer may be required to meet their water intake requirements with fewer available options. In the event mule deer lose water sources, they become more concentrated on fewer waters, once again increasing their susceptibility to predation, particularly by mountain lions which are known to frequent water sources for hunting.

Poor habitat quality has significant ramifications on time budgets too. Mule deer foraging activity in high quality habitat as compared to poor quality habitat is vastly different. As selective foragers, and not bulk feeders, mule deer are required to canvas an area seeking the best plants and best parts of plants. When the quantity and quality of their forage has been decreased, they are required to spend a greater amount of time locating food. The additional time spent foraging increases susceptibility to detection by predators and hunters and also takes away from time that could otherwise be spent conserving energy via resting, thermoregulating, or ruminating. Again, Blaxter (1962) suggests that standing mule deer might require 10-15 % more energy than reclining mule deer. .

The poor body condition that results from poor habitat quality means that mule deer in a



weakened state will have less energy to evade predators. The energy expended in evasion of predators becomes more critical to survival, and the number of evasion events may be limited by available energy. If mule deer in a weakened condition survive the evasion events and the winter period, they are predisposed for disease. In the event they contract a disease, either they survive in a weakened condition ready to continue the cycle discussed above or they succumb and their flesh goes to support some of the very scavengers posing the threat.

Other Issues

Harvest and Antler Development

European man has hunted mule deer in Nevada for more than 150 years. Native Americans have hunted wild game in Nevada for thousands of years. However, over the last 50 years, hunting attitudes and methods have changed a great deal. Attitudes have evolved from primarily sustenance based hunting to “trophy” hunting. As hunters became less dependent on their bounty for table fare, they became more interested in other measures of success, like antler size. As the importance of antler size surpassed the importance of deer as a food source for some, the hunting methods also changed. Hunters in pursuit of bigger deer began using 4-wheel drive vehicles to get to locations that were less accessible. Technological advancements including 2-way radios, Global Positioning Systems, high-powered optics, All Terrain Vehicles, weapon advancements, combined with increased knowledge of mule deer biology and behavior, provide a significant advantage to trophy hunters, essentially spring-boarding mule deer trophy hunting to the popular status that it enjoys today.

In addition to increased “trophy” hunting, another area of mule deer hunting in which attitudes have changed dramatically over the last 50 years is antlerless hunts. Hunters in Nevada harvested more does than bucks for a couple of years in the early 1960s (figure 23). Mule deer populations had increased to a point that the state legislature mandated the Nevada Department of Fish and Game to attempt to have doe harvest meet or exceed the buck harvest. However, as mule deer experienced their “initial decrease,” doe hunts were discontinued. As mule deer recovered during the “secondary increase” phase, limited doe hunts were reinstated to provide opportunity and maintain a balance between herd size and habitat carrying capacity. The recent mule deer declines, have once again resulted in a very limited number of doe hunts (figure 23). In some instances doe hunts are a very necessary and critical management tool to protect habitat, minimize private land conflicts, and minimize or control disease potential. For example, in 1999, after in excess of 2 million acres of Nevada were charred in range fires, state and federal agencies, along with sportsmen’s organizations, spent more than a million dollars in contributed time, money, and other resources to help restore the lost wildlife habitat. In Area 6, the fires consumed more mule deer winter range than summer range. Although Area 6 summer ranges could continue to produce nearly the same number of deer as before the fires, the carrying capacity of winter ranges had been drastically reduced as a result of the fires. Consequently, the disproportionate loss of winter to summer range, resulted in a winter range that was overstocked, seriously jeopardizing the rehabilitation efforts. The best solution was to remove does via harvest to a level that would not negatively affect the newly established vegetation, until such time that



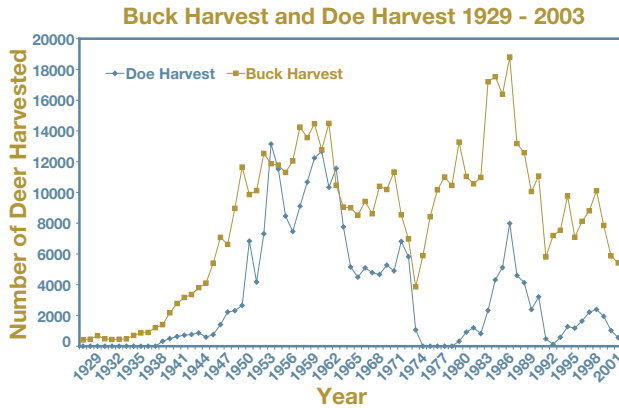


Figure 23. Nevada's buck and doe harvests 1951 - 2003. Under state mandate Nevadans killed more does than bucks a couple of years in the early 1960s. Recent doe harvests have been extremely conservative relative to historic doe harvests.

the vegetation was established and more resilient to disturbance and herbivory.

Many sportsmen currently focus on two primary objectives with respect to mule deer management in Nevada. One objective is to produce more deer, an obvious need and commendable goal, and the other objective is to generate bigger bucks. Hunting is inaccurately regarded as a primary source of mule deer mortality and thus wrongly targeted by some well-meaning sportsmen, as a way to reverse mule deer declines. Mule deer mortality associated with hunting is the most managed of all sources of mortality. Restrictions on gender of harvested animals, weapons used, season timing, season length, and tag quotas all act in concert to manage hunting related mortality. However, many people still perceive hunting to be the primary threat to mule deer survival. For example, after devastating fires in 1999, some sportsmen suggested closing Area 6 to hunting in an effort to "save" the mule deer. This strategy would only work if hunting was the primary source of mortality, which it is not. Nevada has always maintained a very conservative mule deer harvest program, with the possible exception of the early 1960s. Since the implementation of the quota system in 1975, Nevada

has never had an annual harvest greater than 10% of the statewide population estimate. Over the last 5 years, the percentage of the state's deer that have been harvested has steadily decreased from 10% 5 years ago, to just 5% in 2003. Harvesting 5% of the statewide mule deer population in the form of a virtual bucks only hunt, although an identifiable source of mortality, possess no significant biological threat to Nevada's mule deer.

In addition to creating more deer via conservative quotas, many of Nevada's sportsmen also want to produce bigger bucks. Since for the first few years of a buck's life, antler size is highly correlated with age, many people assume that age is the primary determinant of antler size. Therefore, it is believed that reduced mortality, through more conservative quotas, will enable bucks to attain higher ages, resulting in an increase in older deer, and consequently increasing the number of deer with large antlers. This may be the result in more heavily hunted states with extremely aggressive buck harvests, or in areas with very low buck ratios (single digit), or also in areas in which the mature bucks suffer much higher mortality than the younger age classes. However, conservative quotas have not resulted in more large bucks in Nevada. Ironically, the data and literature suggest that Nevada may actually be limiting antler growth by maintaining such high buck ratios and such conservative harvests.

Antler size is determined by several factors. Age (Steinhoff 1967), genetics (Taber and Dasman 1958), body size (Robinette et al. 1977), and forage quality (French et al. 1956, Long et al. 1959, Wallmo 1960) are the factors most often cited. Antler length, diameter, and spread have all been shown to peak at 6 years of age (Steinhoff 1967, Robinette et al. 1977). Nevada currently harvests approximately 15% of the



state's estimated buck population in any given year. Even if 100% of that buck harvest occurred in bucks 6 years old and older, which harvest data shows isn't true, we would still have a high number of old age bucks. Therefore, due to the conservative harvest in Nevada, buck age and consequently age-related antler size is not limited by harvest.

The role of genetics in mule deer antler development is typically beyond the control of biologists and wildlife managers. Mule deer either possess the appropriate genetic makeup to grow big antlers or they do not. Many studies dismiss genetics as a significant contributor of antler size. Body size and forage quality, not necessarily independent of one another, are factors that we have some control over as wildlife managers. Body size in mule deer, just as with humans, is partly determined by genetics but heavily influenced by forage quality. Numerous studies have demonstrated correlations of antler length and antler volume with body fat or kidney fat. Therefore, most actions that increases body size should result in increased antler size and conversely, most factors reducing body size will result in a commensurate decrease in antler size. For example, an Arizona study on antler growth showed that the percentage of yearling bucks that were spikes dropped from 52 % of the yearling bucks during a drought-impacted summer to 12 % of the yearling bucks during a less severe summer (Swank 1958). Similarly, Snyder (1959) recorded that, among yearling bucks in the Guadalupe Mountains in New Mexico, spikes decreased from 64.4 % of the yearling bucks to 25.7 % of the yearling bucks when total annual precipitation increased 2-fold. There are many examples of increased forage quantity and quality increasing body size and consequently antler size. By increasing the number of bucks in the population on drought-impacted habi-

tats, we may be increasing the level of competition between the bucks (intraspecific competition) and an increase in intraspecific competition in the buck segment of the population, could quite possibly be contributing to reduced body weights and consequently reduced antler size.

In Nevada, bucks initiate antler development in April. Although antler growth is relatively slow for the first month, incredible growth occurs through May, June, and July. Antler growth is affected by both post-winter body condition and forage quality. Winter body condition of mule deer has been shown to affect antler shedding dates and antlerogenesis (new antler growth). Animals in better body condition (more fat) will shed antlers earlier and, all else being equal, produce larger antlers due to their healthier body condition. The forage that is typically plentiful in the spring due to winter snowfall and spring precipitation can begin to lose quality by late June. Long et al. (1959) commented that nutritional levels during the late summer stage of antler growth were most crucial to final antler development. Additionally, reduced forage quality can further compromise antler growth for the animals already suffering from poor body condition because body growth in bucks takes precedence over antler development (French et al. 1955).

During the period of antler production, bucks are grouped together in "bachelor" groups, sharing buck pastures. Increases in buck ratios could possibly be resulting in increased competition amongst bucks for high quality forage and leading to reduced body weights. Antlers apparently have a lower priority for growth than most other body tissues and are therefore more directly affected by limitations in forage quality than body size (Cowan and Long 1962). If increased in competition is occurring, smaller antlers



may be the outcome given that a 5% reduction in body weight due to food limitation translates to a 50% reduction in antler volume (Park and Day 1942). Nevada is currently experiencing an extended drought that has reduced the quantity and quality of mule deer habitat. Buck ratios have been maintained at high levels (~30 and above) for several years and despite the lost hunting opportunity that results, Nevada's hunters have not realized an increase in the antler size of their quarry.

Data from The Nevada Record Book is consistent with the hypothesis that intraspecific competition may be limiting antler growth. The number of annual entrants in the Nevada Record Book is very small when expressed as a percentage of the total harvest. For the years 1977 through 2002 the percentage of harvested typical mule deer that made the Nevada Record Book varied from a high of just over 0.7 % to a low of just over 0.1 % . The two highest years were 1997 and 1995 followed by 1984 and 1983. The two highest years were years that followed extremely high buck harvest years. Partly due to the false expectation that deer herds were rebounding well from the catastrophic winter of 1992 - 1993, quotas in 1994 and 1996 were fairly liberal, resulting in high buck harvests. Interestingly, the years following these high buck harvests had the highest percentage of the buck harvest entered in the record book.

Another example consistent with the hypothesis that intraspecific competition may be limiting antler growth are the years with the third and fourth highest record book entrants, 1984 and 1983. Both of these years followed significant winter events and buck harvests that were a greater percentage of the population (8%) than we harvested in 2003 (5%). As discussed above, Nevada also had much better precipitation conditions in 1983 and 1984.

Although counterintuitive, these data suggest that in order to increase antler size, especially in the event of poor habitat conditions, buck ratios may need to be maintained at levels lower than 30 bucks per 100 does in populations at or near carrying capacity.

Competition

Intraspecific competition, as discussed above, may not be the only type of competition limiting antler growth. Interspecific competition may also be decreasing body condition and consequently negatively affecting fawn production and antler development. Species most commonly considered as mule deer competitors include but are not limited to; domestic sheep, cattle, feral horses, and elk. Numerous studies have been conducted to examine the competitive interactions between cattle and mule deer. Studies have not been consistent with respect to their conclusions. Cattle are broad-mouthed bulk feeders while mule deer are narrow-mouthed specialist browsers. However, significant dietary overlap between cattle and mule deer has been reported, and some of the long-term effects of cattle grazing that have been substantiated include; decreased productivity (Cottam and Evans 1945, Robertson and Kennedy 1954), decreased species richness (Reynolds and Trost 1980), decreased fawn hiding cover (bowyer and Blich 1984), increased invasive species (Pickford 1932, Robertson and Kennedy 1954), and consequently decreased quantity and quality of mule deer habitat.

Very little work has been conducted to examine the potential for competition between feral horses and mule deer. Horses have been observed to aggressively defend water sources in water-limited habitats, at the expense of mule deer. Horses could possibly be in direct competition with mule deer in many areas of the state, especially the more water-limited



portions of their range. The greatest potential for competition likely exists on transitional ranges and winter ranges. Although competition is certainly possible on mule deer summer range, the elevation and terrain of most mule deer summer range, may decrease the potential. Despite recent concerns over wildlife habitat lost to feral horse use, horse numbers are still only a fraction of cattle numbers and, excluding localized incidences, likely provide only a fraction of the competition of cattle.

Despite population numbers well below both cattle and horses, elk have also received blame for the mule deer decline. On December 1, 1997 the Wyoming Cooperative Fisheries and Wildlife Research Unit at Laramie, Wyoming published a document entitled "Potential for Competitive Interactions Between Mule Deer and Elk in the Western United States and Canada: A Review" (Lindzey et al. 1997). This study examined over 480 references including many peer reviewed journal articles, Master's theses, and Ph.D. dissertations. Additionally, biologists from 11 western states and provinces were questioned, all in an effort to determine if elk and mule deer competed for resources. With the exception of the Nevada specific cases, most of what's provided below on competition was taken directly from Lindzey et al. (1997).

Defining competition can be difficult. Most people, when considering elk and mule deer competition, feel simply that if the two animals are occupying the same area during the same time of year, presumably, they are competing for some resource, be it space, shelter, or food. Classic competition theory predicts that if individuals of one species survive longer and/or produce more young than those of the competitors, that species will eventually replace or exclude the other. In competing species, one species' benefit is at some cost to the other

species. In order for competition to be occurring, first there must be a shared resource, food, shelter or space, that when used by one species, precludes its use by the other and consequently benefits the user at the cost of the excluded. However, if potentially competing species are found to coexist over time, as elk and mule deer have for centuries, then many ecologists would surmise that there has been some shift by one or both competitors in their ecological niche (Schoener 1982, 1983). Elk and mule deer are co-evolved sympatric species. This simply means that these two animals have lived together for a very long time in the very same areas and under historical habitat conditions, one has yet to exclude the other. Ecological overlap, or use of the same habitat, by elk and mule deer may be an expression of interspecific tolerance (Colwell and Futuyma 1971, Vandermeer 1972). Most sympatric species that use common resources during some period of time are least likely to overlap or use that common resource during periods when conditions are most severe, such as during winter or drought (Schoener 1982, 1983). The hypothesis here is that past evolutionary forces have selected for species' divergent adaptations to harsh conditions, that each species would utilize the set of resources to which it is best adapted and thus reduce competition when survival is already tenuous. Conversely, there may be substantial spatial and dietary overlap when resources are plentiful. For example, in the spring when high quality forage is not limiting, elk and deer can have significant spatial and dietary overlap with no apparent detriment to either species due to abundance of the shared resource. It is only when a shared resource, space, shelter, or food, is limited, that one species can be negatively affected by the consumption of the forage or the occupancy of the space, by the other species and during times of



severe conditions, niche separation is the greatest, thus minimizing the potential for competition between sympatric species.

Competition in natural systems is generally acknowledged to be difficult to determine (Holt 1977, Pianka 1981, Schoener 1983), stemming from the ambiguous significance of overlap or separation of resource use exhibited by two or more species (Putnam 1996). Significant overlap may indicate competition if the shared resource is scarce, but alternatively may signal the absence of competition if resources are abundant.

Few studies claiming competition between elk and mule deer exist. In the Rocky Mountain states and provinces, winter is generally the period of most limited food and greatest physiological stress from low temperatures, snow cover, and low nutritional value of forage. Studies that appear to support Schoener's (1982) hypothesis regarding niche separation were conducted in Wyoming (Compton 1975), Montana (Mackie 1970, Baty 1995), South Dakota (Wydeven 1979), Alberta (Morgantini 1979), Oregon (Sheehy 1987), Idaho (Ackerman et al. 1984), and provided evidence that there was little spatial and/or dietary overlap between mule deer and elk during winter when food is limited. Compton (1975) reported a very high level of dietary overlap between wintering deer and elk but that they inhabited spatially separated winter ranges. Additionally, in Tule elk and black-tailed deer, niche separation occurred (lower dietary overlap) when high quality forage was limited in winter (Gogan and Barrett 1995). In other parts of their range, sympatric deer and elk face greater environmental stresses during hot, dry summer months. In New Mexico (Sivinski 1979) and Utah (Julander and Jeffery 1964), both found that deer and elk were spatially separated during these severe conditions.

The majority of studies reviewed in the report by Lindzey et al., indicated that sympatric populations of mule deer and elk tend to partition resources during periods when resources are probably most scarce.

Several physical, physiological, and ecological differences are present between elk and mule deer.

Thermoregulation - Thermally critical environments for mule deer during winter occurred at temperatures $< -20^{\circ}\text{C}$ and $> +5^{\circ}\text{C}$ and for elk at temperatures $< -20^{\circ}\text{C}$ and $> +20^{\circ}\text{C}$. In summer, thermoregulatory costs increased in deer at temperatures $> 25^{\circ}\text{C}$ and in elk when temperatures exceeded $25-30^{\circ}\text{C}$ (Parker and Robbins 1984). Energy cost of foraging for both species depends on forage type and abundance (Wickstrom et al. 1984). Elk tend to select sites more on a basis of solar and thermal radiation rather than ambient temperature and seek what Beall (1976) refers to as a "comfort zone." Merrill (1991) concluded that elk do not require cover in summer to maintain body temperatures, but McCorquodale et al. (1986) found cow elk preferred to bed in gullies and ravines with cooler conditions than flat land and low vegetation in the shrub-steppe of Washington. Although both elk and mule deer possess numerous sweat glands, mule deer apparently sweat minimally while elk have extensive sweating capabilities (Parker and Robbins 1984). Deer pant and elk sweat to dissipate heat in hot environments. Elk appear to have a greater latitude than deer in habitat selection during summer because of their ability to dissipate heat more effectively than deer.

Locomotion - Cost of locomotion is proportionately similar in the absence of snow (Parker et al. 1984) but snow generally exerts a greater energy demand on deer than elk (Wickstrom et al. 1984). Cost of locomotion in light, powdery snow is more



costly for deer than elk, but proportionately less costly for deer in dense snow because of their reduced sinking depth (Parker et al. 1984). Hobbs' (1989) model predicted that winter mule deer survival was more sensitive to snow depth than temperature. Greater leg length also seems to benefit elk as it relates to the energy cost of locomotion in the snow. Because they are less influenced by snow depths and higher ambient temperatures than deer, elk will likely have a greater area available to them in the winter as well as summer. Parker (1983) predicted that snow depth, because of the increased costs of locomotion to animals would influence winter habitat use by both deer and elk with deer being the most sensitive to snow depths. Snow depths of 25 cm (10 in.) were sufficient to discourage use and stimulate elevational movements in mule deer (Wallmo and Gill 1971); elk distribution and resource use patterns are generally affected by snow 46 cm (18 in.) deep (Beall 1976). Although elk may be able to move through snow up to 70 cm (28 in.) deep, they apparently prefer to feed in areas covered by snow depths less than 40 cm (16 in. Sweeny and Sweeny 1984).

Diet choices of deer and elk should reflect each species' unique anatomical and physiological adaptations (Baker and Hobbs 1987). Elk and mule deer diet selection and digestive morphology indicate that they utilize foods differently (Hobbs et al. 1983, Baker and Hansen 1985). Hobbs et al. (1983) documented that plant parts eaten by deer were more digestible and had twice the crude protein levels of plant parts eaten by elk. Hobbs et al. (1983) and Collins and Urness (1983) noted that mule deer ate more browse than elk and elk more grass than deer. Estimated energetic costs of foraging for the two species support general dietary differences. Wickstrom et al. (1984) concluded that deer were

well adapted to exploit low-biomass, shrub habitats while elk were better suited to forage in high biomass, herbaceous or mixed communities.

Elk and deer have anatomical and physiological traits that would seemingly facilitate their ecological separation. Each is best suited to eat and digest specific food types. Elk are capable of thriving on predominantly grass diets while deer require higher quality forages to meet metabolic needs. Body size and herd-forming behavior of elk generally mean they will choose to feed in areas of higher food biomass and move more while feeding than deer. Hansen and Clark (1977) have concluded that dietary overlap has not caused the apparent decline in mule deer numbers. Studies that have examined diets of sympatric deer and elk have not demonstrated resource competition. Additionally, Kvale and Kuck (1984) and Oedekoven and Lindzey (1987) found that on winter ranges used in common by deer and elk, the species tended to spatially separate by elevation and plant community.

Coincident with increasing elk ranges, mule deer populations had declined but often in areas where elk did not occur. Eight of 11 states reported deer had declined where elk were not present. Eight of 11 states reported that habitat changes have



avored elk. Habitat changes are more often cited than competition with elk when attempting to explain decreases in the west's mule deer numbers. Mule deer population declines have been attributed to many factors including hunting, range deterioration or changes due to overbrowsing, vegetation succession, livestock grazing and competition, predation, destruction or loss of habitat, and climate/weather changes (Mackie et al. 1982). These same factors were reported by the biologists from the 11 western states and provinces. Also reported to have made habitats less favorable for mule deer were; timber harvest, mechanical treatments, fires, chemical control, and livestock grazing. Although widely variable, successional changes in vegetation communities undoubtedly impact the habitats of both mule deer and elk and may allow one or the other to increase in numbers. Successional changes that favor elk populations may be particularly significant as mule deer habitats become increasingly restricted.

Because the two species often overlap in distribution and use of habitats, it is appropriate to question whether the growth of elk populations has contributed to the apparent decline of mule deer. However, competition is difficult to isolate from other factors that influence population dynamics in natural systems. Observations from states and provinces provided no consistent trends in populations of the two species, when sympatric, that would suggest a cause-and-effect relationship. Mule deer populations had apparently declined, grown or remained the same in the presence of elk while showing similar trends where elk were absent or present only in small numbers. Research studies aimed at examining the relationship between deer and elk provided similarly equivocal results. Most commonly, studies failed to demonstrate competition between the species.

Elk and deer differ anatomically and physiologically, presumably providing ample opportunity for separation in resource use patterns even if they overlap spatially. Even if the diets of the two overlap during one or more seasons, it may be of little consequence to their potential to compete because the two species segregate spatially. Even where deer and elk share the same range during periods of food scarcity, amount of dietary overlap has varied. Dietary preferences, digestive capabilities, and spatial segregation apparently allow deer and elk to co-exist without competing.

Obviously, much is different since pre-settlement times. The character of the habitats has changed through natural vegetation successional patterns. Changes in land uses and historical fire frequencies coupled with vegetation treatments aimed at increasing domestic livestock forage have also altered the landscape. Changes in the habitats necessitate realignment in the proportional abundances of these two species. Deer and elk may simply be independently responding to general changes in the availability and suitability of habitats.



Summary- The Whole Story

This document has revealed and discussed a number of factors that impact mule deer (appendix 2). Each of these factors is a piece of a complex puzzle, with effects varying through time and space. The challenge that remains is to combine the findings of science with data from Nevada to synthesize and clarify a comprehensive account of Nevada's mule deer population dynamics.

Historically, although widespread, mule deer were sparse, probably only experiencing localized episodes of abundance resulting from various disturbance events. Prior to European Americans arrival in Nevada, the vegetation was not conducive to large numbers of mule deer. Depending on the location, some sites were dominated by decadent, old-aged browse, while others had an abundance of grass. Neither offered mule deer much forage value. As the gold rush, Comstock Lode, railroad, livestock industry, and their associated infrastructures changed Nevada's landscape, mule deer were poised to capitalize.

In 1906, approximately 50 years after the widespread landscape scale disturbances, the predecessor to today's United States Forest Service (USFS) the United State Forest Reserves was founded, resulting in increased production and protection of mule deer summer range. Old, poor quality forage was replaced by new, high quality forage. Even more mule deer habitat was created as grazing of grasses and forbs caused an increase in shrubs. As a result of removal of fine fuels by livestock, fire frequencies decreased and further assisted the dominance by mule deer favored shrub species.

In 1934 the predecessor of today's Bureau of Land Management (the United States Grazing Service) implemented the Taylor Grazing Act which resulted in improved management of critical mule deer transition

range and winter range. In addition to federal protection of prime, fawn producing summer ranges by the USFS and critical transition and winter ranges by the BLM, the federal government was also aggressively removing predators at unfathomable rates. The stage had been set for the mule deer irruptions that constituted the "initial increase" phase. Mule deer responded favorably and their populations and harvest levels both increased to levels never before seen, peaking in the mid to late 1950s.

Mule deer populations began their first significant decline around 1958. Drought conditions existed throughout the state prompting the governor to declare "a state of drought" in 1961. Despite this period representing the most active years of predator control in Nevada's history, and despite having ideal vegetational composition for mule deer, mule deer populations simply could not withstand the severe drought conditions that persisted. Further complicating the effects of the drought was the conversion of millions of acres of winter range to crested wheatgrass seedings. The drought prevailed as the population experienced its "initial decrease." Also potentially contributing to the rate of the decline were the aggressive doe harvests. For two years during the early 1960s, doe harvests exceeded buck harvests, as was mandated by the state legislature, to help quell fears of potential resource damage by the huge mule deer populations.

Mule deer continued to decline until the mid 1970s. By the time Nevada's mule deer populations had reached their low point, all doe hunts had been closed and a restrictive quota system had been implemented. This period marked the beginning of the "secondary increase" phase. High fawn ratios, ideal weather conditions, and high predator take likely combined to create the second mule deer population peak of the century. Although things looked pretty



rosy for mule deer in the late 1980s, the high times wouldn't last as the culmination of numerous negative factors were about to take effect.

The vegetation that was so instrumental in the "initial increase" of mule deer was getting old and beginning to lose its vigor. The century-long grazing practices were reducing diversity and productivity on many of Nevada's rangelands. Invasive weeds, assisted by fire were taking over ever more of the deers habitat. Pinyon and juniper were also encroaching into mule deer habitats at unprecedented rates. Nevada's human population was rapidly expanding, and roads, mines, houses, and the resulting traffic were imposing an ever-increasing burden on mule deer populations. As drought conditions began to negatively affect the quantity and quality of forage, mortality from all sources increased. The weakened condition of Nevada's mule deer became readily apparent as it resulted in a catastrophic die-off in the winter of 1992 - 1993.

Still stuck in a drought cycle, we strive to meet mule deer glory from the past. Not realizing that all-time population peaks are unrealistic goals as population objectives, we limit the harvest of does, restrict harvest of bucks, remove predators and still do not see a response in mule deer populations as they remain low. Meanwhile, Nevada continues to experience incredible human population growth, develop houses and businesses on crucial deer winter range, and experience the conversion of millions of acres of mule deer habitat to fire prone weeds and pinyon-juniper. However, there is hope—hope for favorable climatic conditions, such as summer rain to help mule deer overcome the difficulty of deriving nutrients and energy from ineffectual browse and hope for habitat treatments that will restore young vigorous browse accompanied by an intact native

understory. We must actively protect existing mule deer habitat while we create and restore new mule deer habitat because the reality remains that as mule deer habitat goes, so goes the mule deer.



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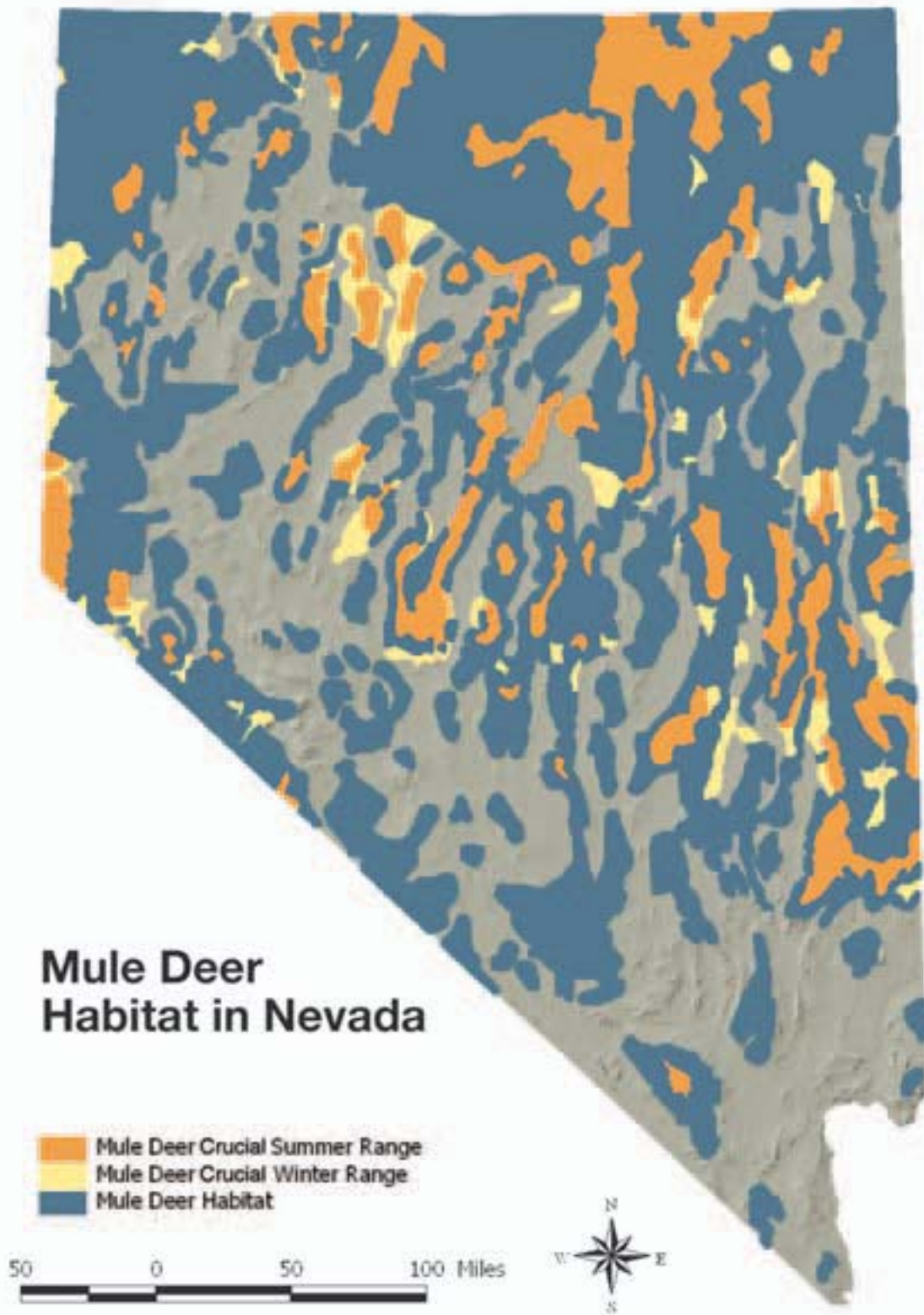


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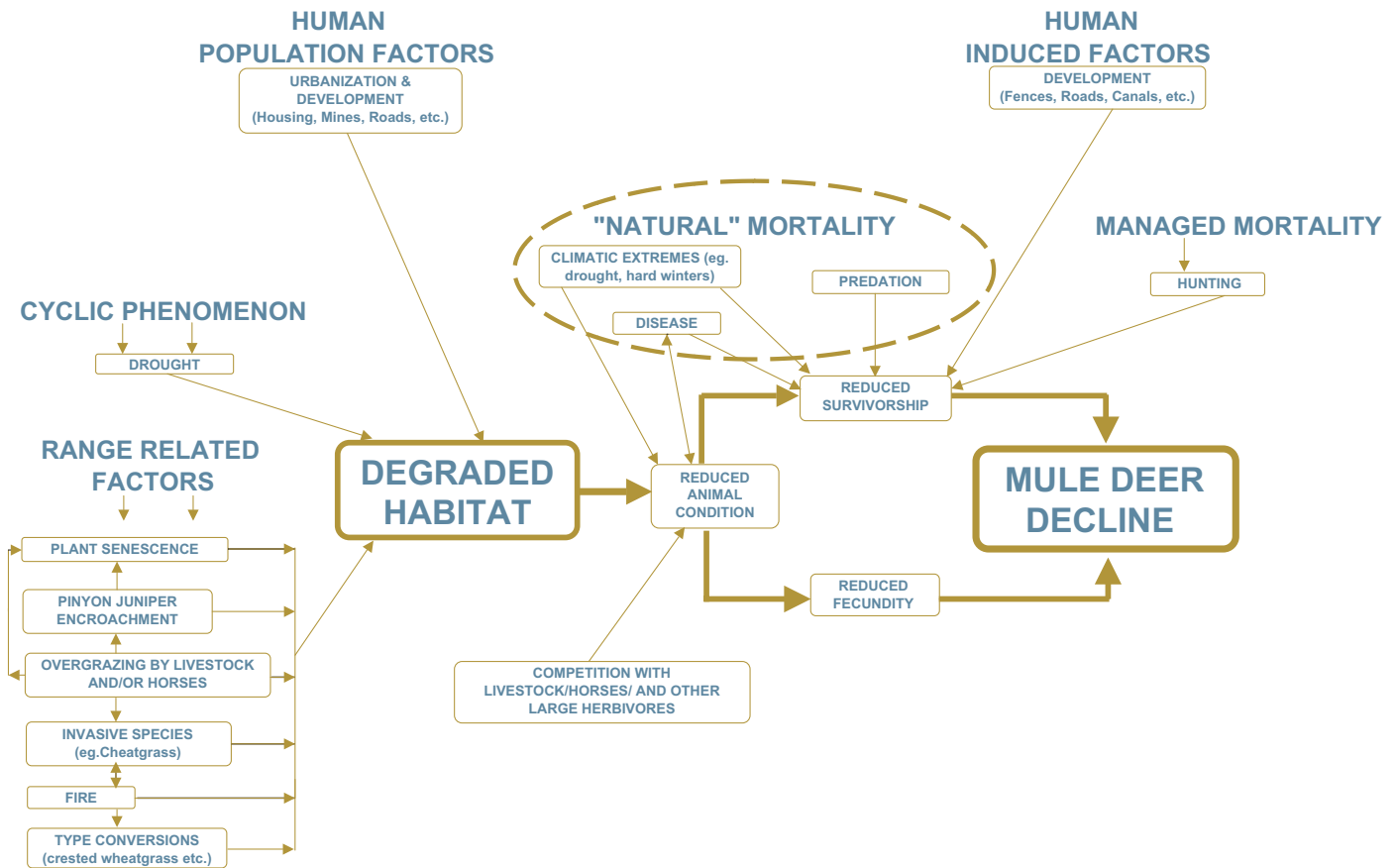
APPENDIX I

Appendix I. Statewide map of mule deer distribution and associated habitats.



APPENDIX II

Appendix 2. Flowchart depicting issues and influences affecting mule deer population dynamics.



Mule Deer References and Additional Readings

Appendix 3. Additional mule deer readings.

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Nevada's Mule Deer

**Population Dynamics:
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