EVALUATION OF A TRANSLOCATED POPULATION OF DESERT MULE DEER IN THE CHIHUAHUAN DESERT OF NORTHERN COAHUILA, MEXICO

A Dissertation

by

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ABSTRACT

Mule deer (*Odocoileus hemionus*) are large (30–150 kg) ungulates that occur from southern Alaska to the desert mountains, grasslands, and coastal regions of northern and western Mexico. In Mexico, conservation efforts have taken place to reestablish mule deer to their original distribution; however, little information exists on these species. I evaluated post-release movements and vegetation type preferences of translocated desert mule deer in northern Coahuila, Mexico comparing soft- and hard-release as methods of liberation. Translocated mule deer presented difference in dispersal distance from the release site of soft- versus hard- release methods ($P = 0.001$); however, no difference existed when comparing post-release range sizes of deer released using these methods ($P = 0.793$). Mule deer habitat was characterized in 3 different classes: creosote flats, lechuguilla hills, and xeroriparian vegetation types. At second order analysis, xeroriparian vegetation type had a higher use/availability ratio ($S_{xeroriparian} = 3.68$). At third order habitat selection, 1 of 15 individuals used xeroriparian vegetation type in lesser proportion than its availability ($S < 1.0$) on the upland study area. Six of 15 individuals used xeroriparian vegetation type randomly ($S = 1.0–1.1$). Eight of 15 individuals used xeroriparian vegetation type in greater proportion than its availability ($S > 1.1$). Translocated mule deer preferred ($P = 0.002$) to use xeroriparian (9.2%) greater than their availability (2.5%); use of Lechuguilla hills (63%) presented no difference ($P = 0.005$) from its availability (64%); and use of creosote flats (25%) was different ($P = 0.004$) when compared to its availability (34%). Considering the results of my research, I conclude the use of soft-release method is a reliable and successful method for reducing post-release movement of desert mule deer. Although their home ranges may not be reduced in size, translocated mule deer that are soft-released tend to establish their ranges closer to their release site. I provide a guide that describes the options for reintroducing mule deer in the Chihuahuan Desert of Mexico.

DEDICATION

To my son Alfonso Eduardo, the greatest inspiration a father can ever have…

To my wife Sandra Victoria, the best companion I could ever ask for…

A mi hijo Alfonso Eduardo, la más grande fuente de inspiración que un padre puede llegar a tener…

A mi esposa Sandra Victoria, la mejor compañera que jamás podré haber tenido…

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CHAPTER I

INTRODUCTION

Mexico plays an important role in wildlife conservation of North America. Ranked among the 3 countries with the most biodiversity in the world, Mexico represents an important corridor for dispersal of plants and fauna (Valdez et. al. 2006). Included in Mexico's wildlife species are 11 ungulates including 5 species of Cervidae (Gallina and Mandujano 2009).

Mule deer (*Odocoileus hemionus*) are large (30–150 kg) ungulates that occur from southern Alaska to desert mountains, grasslands, and coastal regions of northern and western Mexico. The common names bura, buros, or mulos in Mexico are in reference to their long ears. Very few mule deer studies have been conducted in Mexico (Martinez-Munoz et al. 2003, Sanchez-Rojas and Gallina 2003, Mandujano et. al. 2004). Mule deer populations in Mexico have experienced abundance, local extirpation, constant exploitation, and more recently, active conservation and management.

Landowner perspectives have shifted now realizing the value and economic importance of mule deer. This has translated into protection of the species from illegal hunting and in turn, better conservation of the species. Big game hunters' interest in mule deer has contributed to the monetary value (thousands of dollars) of individual trophy animals (e.g., large antlered, large bodied).

The value of mule deer has awakened interest in restoring desert mule deer populations. The corresponding wildlife agencies for Texas, New Mexico, and Arizona significantly aided the restoration efforts in Mexico by providing surplus deer from overpopulated areas. More than 700 mule deer from Texas, New Mexico, and Arizona have been translocated to the states of Coahuila, Nuevo Leon, and Zacatecas (Sanchez-Rojas and Gallina 2000). These translocations have primarily taken place on private ranches.

The historic importance of mule deer has been depicted in aboriginal pictographs (Heffelfinger 2006). Most mule deer herds in Mexico, however, have been victims of overexploitation (Leopold 1959, Baker 1977, Challenger 1998). In Mexico, mule deer are a game species regulated by Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT). Landowners are required to register their properties as Wildlife Conservation, Management, and Sustainable Utilization Units, also known as UMAs (Unidades para la conservacion, manejo y aprovechamiento de la Vida Silvestre) to be allowed to legally harvest mule deer. A problem with this permitting process is the lack of financial resources to enforce game laws (Valdez et. al. 2006). Mule deer have been prioritized by landowners as their economic value has been recognized. In fact, some game ranch operations have removed livestock production entirely in order to benefit wildlife production (Rosas-Rosas et al. 2003, Valdez et al. 2006, Martinez-Garcia 2009).

TAXONOMY

In North America there are 9 to 11 subspecies of mule deer (Cowan 1956, Anderson and Wallmo 1984). In Mexico, 5 subspecies occur, including the desert mule deer (*O. h. crooki*) which have the widest distribution, occurring in Chihuahuan and Sonoran Deserts in northern Mexico and southwestern United States; southern mule deer (*O. h. fuliginatus*), occurring in southwestern California, and northwestern Baja

California Norte; peninsula mule deer (*O. h. peninsulae*) occurring in Baja California Sur and Baja California Norte; Tiburon Island mule deer (*O. h. sheldoni*) inclusive to Tiburon Island; and Cedros Island mule deer (*O. h. cerrosensis*) inclusive to Cedros Island. However, subspecies determination remains unclear and is in constant debate.

DISTRIBUTION

The current distribution of desert mule deer in Mexico is uncertain (Sanchez-Rojas and Gallina 2007). Historical maps for desert mule deer in Mexico generally describe a distribution that includes the states of Coahuila, Chihuahua, Sonora, and Baja California Norte and portions of northeastern Durango, northern Zacatecas, western Nuevo Leon, northern San Luis Potosi, and eastern Baja California Sur.

DESCRIPTION

Mule deer have black noses with white to grey muzzles and a black forehead. The tails of mule deer are described as a white, rope-like tail with a black tip surrounded by a white-rump patch. Mule deer are sexually dimorphic. Females are antlerless and males grow antlers that can attain lengths of 100 cm. Adult males have larger body mass (90–115 kg) than does (60–75 kg). Females attain their maximum weights at 2 years, whereas male continue to increase in weight until 9 years of age (Anderson et al. 1974). Average weight of fawns has been reported at 3 kg at birth and rapid development during their first 6 months is characteristic (Geist 1998). During the first 6–9 months of life, fawns have spotted coats, after this period they change into their adult coats.

Antler development generally will start in late spring (May) and are hardened by fall (September). Antlers are shed annually usually in early spring (March). Antler characteristics vary greatly between individuals. Typical antlers for mule deer include 10 points (5 points x 5 points), or 8 points when no brow tines are developed (4 points x 4 points).

DIET

Mule deer diets have adapted to the large diversity of habitats that occur throughout their distribution (Kufeld et al.1973, Krausman et al. 1997). Many studies have evaluated mule deer diets in the southwestern United States (Krausman et al. 1997); including the northern subdivisions of the Sonoran Desert (Urness et al. 1971, McCulloch 1973, Anthony 1976, Anthony and Smith 1977, Short 1977, Krausman et al. 1989, Marshal et al. 2004) and the Chihuahuan Desert (Anderson et al. 1965, Boeker et al. 1972, Krausman 1978, Leopold and Krausman 1987). Composition of the diets of mule deer varies among areas, seasons, and years (Table 1.1). In the southwestern United States (McCulloch 1973, Krausman et al. 1989, Krausman et al. 1997, Marshal et al. 2004, Alcala-Galvan 2005), browse is the dominant forage consumed by desert mule deer (Fig. 1.1). Browse species comprised 77–88% of mule deer diets in Mexico.

Anderson et al. (1965) reports that forbs may become the most important forage in all seasons during wet years. Desert mule deer consume higher amounts of forbs during spring and summer. account for an average of 5–10% of the diet of mule deer among all areas in central and western Sonora (Alcala-Galvan 2005). This fluctuation is related to geographical and seasonal distribution of rainfall (Peek and Krausman 1996,

Table 1.1. Plant species consumed by mule deer in the Chihuahuan Desert by season.

Class/Species	Spring	Summer	Fall	Winter	Preference
Forbs					
Euphorbias	X	X	X		High
Bladderpods	X			X	High
Gobemallow	X	X	X		Medium
Filaree	X			X	High
Milkwort	X	X			Medium
Plantains	X		X	X	High
Sagewort	X	X			Medium
Goldeneye	X	X	X		Medium
Daleas	X	X			Medium
Bluets	X			X	Medium
Browse					
Apache plume	X		X	X	Medium
Acacias	X		X	X	Medium
Ceonothus	X	X	X	X	Medium
Ephedra	X		X	X	Med-High
Hackberry	X	X	X		High
Oaks	X	X	X	X	Med-High
Mesquite	X	X	X		Low
Redberry Juniper	X			X	Med-Low
Skunkbush sumac	X	X	X		Med-High
Saltbush	X	X		X	Med-High
Littleleaf sumac	X	X	X		Medium
Snowberry	X	X		X	Med-High
Tarbush				X	Low
Mt. mahogany	X	X	X	X	High
Creosotebush				X	Low
Others					
Lechuguilla	X	X	X	X	Medium
Pricklypear		X	X		Med-Low
Sotol	X			X	Med-High
Candelilla	X			X	Med-High
Yucca	X			X	Med-Low
Graminoids	X	X	X	X	Low

Modified from Cantu and Richardson (1997).

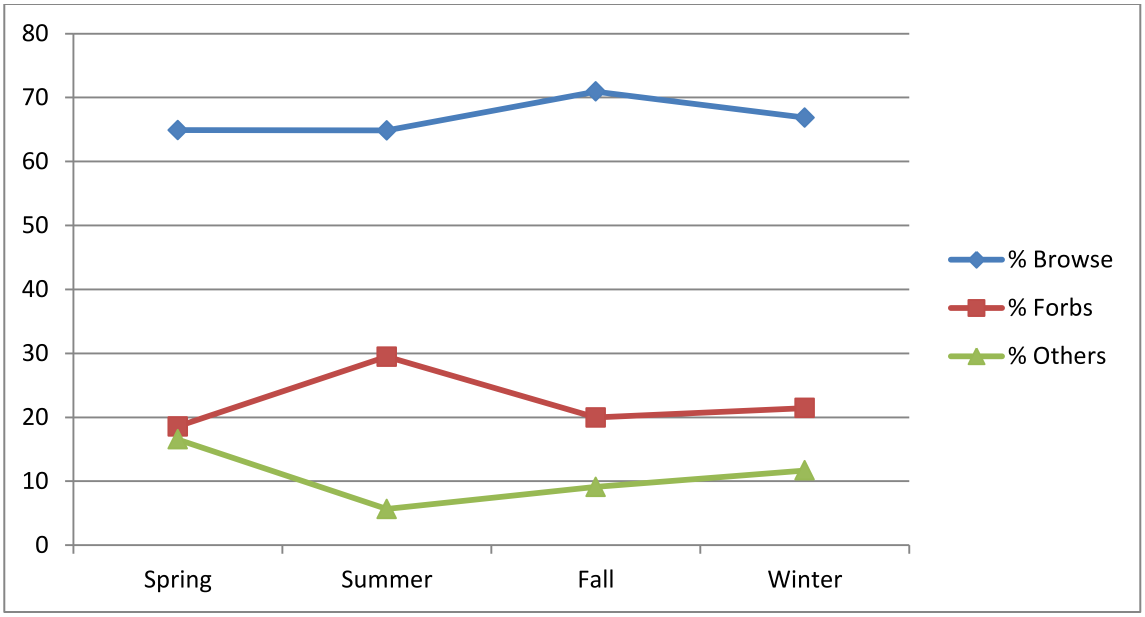


Figure 1.1. Changes in diet composition of mule deer vary seasonally in the Chihuahuan Desert depending on forage availability (Summarized from Anderson et al. 1965, Boeker 1972, Keller 1975, Short et al. 1977, Krausman 1978, Krysl 1979, Ratcliff 1980, Brownlee 1981, and Tafoya 2001).

Krausman et al. 1997). Use of cacti was highly variable among areas, but chainfruit cholla (*Opuntia fulgida*) was consumed consistently in all areas and in most seasons.

Grass species appeared as the lowest forage class in the diet of mule deer throughout central and western Sonora as well as in southwestern United States for most seasons (Krausman et al. 1997); however, higher consumption of native grasses (up to 32% of diet) has been reported in central Sonora (Alcala-Galvan 2005) where only 5 native grass species accounted for more than 65% of the total consumption of grasses throughout the year. Non-native buffelgrass (*Cenchrus ciliaris* L.) comprised <5% of the summer diet of desert mule deer and accounted for <1% of the annual diet. This fluctuation in the diets of mule deer can be attributed to the fact that this study was conducted in areas with a well-established grassland community.

REPRODUCTION

The duration of the mule deer breeding season (rut) varies across their range in Mexico. In southern Baja California, mating occurs between December and late February (Galina-Tessaro et. al.1988, Gallina et al. 2000), whereas in the delta of the Colorado River the rut occurs in February (Stone and Rhoads 1905). Perez-Gil (1981) reported breeding seasons from September to November on Los Cedros Island. For the subspecies *O. h. peninsualae,* Gallina et al. (1992) reported the rut occurred during December to February.

Dominant males begin to overlap home ranges of doe-fawn groups as the breeding season arrives. Males monitor if does are prepared to breed by ritualized courtship behaviors (Geist 1981). Mule deer males are physically ready to reproduce starting in December, although the majority of does do not come into estrus until February. Once a female is bred, bucks may move large distances in search of another doe that is ready to breed (Weber and Galindo-Leal 2001).

Gestation periods of 200–207 days have been reported for mule deer (Robinette et al. 1977). Fawning seasons vary throughout mule deer distribution depending on the beginning of the rut.

Sex ratios are believed to have little effect on fawn recruitment (Horejsi et al. 1988, McCulloch and Smith 1991:39). Mule deer sex ratios approximate 1:1 at birth (Gallina et al. 1992). Adult sex ratios are more variable. Using fecal pellet morphometry to ascertain sex ratios, Gallina (1990) reported a 54:100 buck:doe ratio in adults and Alvarez-Cardenas (1995) calculated a buck to doe ratio of 75:100.

PHYSYSIOLOGY

Development

Mule deer fawns are weaned at 2 months of age (Dixon 1934, Heffelfinger 2006), shortly after their spots disappear (at about 2.5 months [Nichol 1938]). Mule deer fawns weigh 3.2–3.6 kg at birth, doubling in 2 weeks and quadrupling in 30–40 days (Nichol 1938). Adult weights of mule deer vary regionally, by age, and females generally weigh less than males (Heffelfinger 2006). The lowest recorded dressed weight of a male mule deer has been 19.05 kg in at 1.5 years (Anderson 1964), while the highest recorded weight has been 249 kg at 6 years (McCulloch and Smith 1987).

Antler growth usually begins in late spring in the Southwestern United States (Hanson 1955, Truet 1971, Hoffmeister 1986, Heffelfinger 2006). In early fall mule deer present an increase in testosterone levels resulting in mineralization of antlers and shed of the velvet (Clark 1953, Swank 1958, Cantu and Richardson 1997). The opposite occurs at the end of the rut, when testosterone levels decrease and result in the shed of antlers (Truett 1971). In the Chihuahuan Desert region of Texas, antler growth has been reported to maximize at 7.5 years. Body weight also is maximized at 7.5 years. Little difference between 6.5 and 7.5 year old males in both antler growth and body weight was present (Gray and Richardson 2008). Antler development is directly related to nutrition; the proper levels of protein, energy, and calcium are required to reach maximum growth (Ullery 1983). The longest living mule deer reported was 13 years old (Heffelfinger 2006).

Water Requirements

Krausman et al. (2006) reported mule deer are dependent on water, especially in dry periods. In times of high metabolic demand sufficient water intake is especially critical. Varner (2006) recommended a spacing of dependable water sources every 1.6–2.4 km for deer in west Texas. Mule deer in southwestern Arizona frequently visited water catchments; most commonly at 2000 hours or around sunset, with lower visitations throughout the night and individual visits more common than group visits (O’Brien et al. 2006). In the state of Sonora mule deer average travel distances of 1.5–2.0 km, on the Central Plains, and 2.1–3.5 km on the Gulf Coast area (Alcala-Galvan 2005).

Movements relative to known water sources is 0.8–5.0 km and optimum spacing of water developments is <3.2–4.8 km. In the Trans-Pecos Texas, females use sites closer to water sources than males, but this does not appear to be an important factor for home range scale selection for either gender (Lawrence 1995). Water consumption by mule deer varies seasonally and can change depending on the forage consumed (Nichol 1938). Dry forage consumption increases water consumption by 25–65%. In the summer, 2.2 l were consumed per day while winter consumption dropped to 1.1 l/day. Estimates of 3.79–9.46 l of water may be consumed per day when forage does not provide much moisture (Elder 1954, Hervert and Krausman 1986). With higher temperatures and lower humidity (May, June, and July), mule deer visit water more frequently according to Rosenstock et al. (2004). Desert mule deer drank water mostly during the hours of 1900–2200 (Hervert and Krausman 1986). In the summer, Rodgers (1977) recorded water visits mostly during the night and Hazam and Krausman (1988) recorded desert mule deer visited watering sites once a day. Deer concentrate around water sources in dry months (Brownlee 1979, Wood et al. 1970). Pregnant does water up to 4 times per day and remain within a 0.4 km from water sources (Clark 1953). According to Bowyer (1986) the distribution of *O. h. fuliginatus* is strongly affected by the availability of drinking water. Hervert and Krausman (1986) reported that in order to survive periods of water stress deer generally require a source of standing water. In the Chihuahuan Desert in Durango as well as Baja California, studies have reported higher deer concentrations around watering sources (Sanchez-Rojas and Gallina 2000, Gallina et al.

2001). During the dry period of the year, deer concentrated within 0.8–1.6 km from water sources (Ordway and Krausman 1986, Bowyer 1986).

Energy Requirements

Rainfall and the intensity of grazing by domestic livestock are considered the determining nutritional factors of mule deer (Heffelfinger 2006). If rains are delayed, during June or early July mule deer undergo the most nutritional stress. During this period does need to sustain growth for fetus development and lactation once giving birth (Heffelfinger 2006). Energy requirements are influenced by many environmental factors and vary with seasons and age. Mature does require 25 Kcal of digestible energy (DE)/lb of body weight/day (Ullrey et al. 1970). The energy required can increase to 33 Kcal DE/lb/day for females during peak lactation. A fawn's daily energy requirement is of 70 Kcal DE/lb/day (Kirkpatrick et al. 1975). During rut, mature bucks may reduce their energy intake to 50%, none the less 50 Kcal DE/lb/day should allow body stores to replenish and maximum growth to occur.

Thermal Relationships

Desert ungulates thermoregulate through different methods including: behavioral modifications, evaporative cooling, changes in regional blood flow, and morphology (Cain et. al. 2006). Mule deer can adjust timing of activity and become more crepuscular and/or nocturnal during hot and dry periods of the year (Hayes and Krausman 1993, Cain et al. 2006). Desert species present morphological adaptations such as longer and/or thinner appendages and higher surface-area-to-volume that assist with heat dissipation (Cain et al. 2006). Hiding cover and shade of the upper portions of steep slopes in mountains are selected by desert mule deer does for thermoregulation (Fox and Krausman 1994). Truett (1971) reported mule deer used slopes for thermal regulation by using sunny slopes in cooler mornings and shady slopes as the day warmed. Similarly, Tull et al. (2001) reported desert mule deer used shady bedsites on hotter days and sunny bedsites on cooler days. Studies by Leopold and Krausmann (1987) and Hayes and Krausman (1993) reported higher activities of deer during the night and less in the daytime during high summer temperatures.

BEHAVIOR

Social Structure

Mule deer have an aggregated distribution and are social animals (Sanchez Rojas and Gallina 1998). Weber and Galindo-Leal (2001) reported mule deer to be more gregarious when compared to white-tailed deer. They reported doe-fawn-yearling social units of 2–8 individuals. Although mature bucks were solitary, they reported juvenile bucks formed social groups of 4–10 individuals. Mandujano and Gallina (1996) found larger herds were prominent in open habitats. These larger herds can be a result of low availability of water (Gallina et al. 1991). Gallina et al. (1992) and Alvarez-Cardenas et al. (1994) reported similar results showing the smallest aggregations of deer in December and the largest aggregations in March based on fecal pellet groupings.

Movements

In the southwestern United States, mule deer do not migrate, but have been reported to make seasonal and daily movements due to weather, food and water distribution, fawning, segregation of sexes, and disturbances from humans or livestock

(Heffelfinger 2006). Little is known about local movements of mule deer in Baja California (Weber and Galindo-Leal 2001). For most of the year in Baja California, mule deer remain at higher elevations, but after snowfalls deer moved to lower elevations (Leopold 1977, Weber and Galindo-Leal 2001). Gallina et al. (2001) and Velazquez and Reyes (1976) mentioned the possibility of local movements occurring in the Sierra de la Laguna of Baja California. Several studies have reported mule deer moving from their normal home range to access water sources. Rautenstrauch and Krausman (1989) found desert mule deer temporarily moved up to 32.2 km in search of freestanding water.

Bucks make large seasonal movements during the rut (Rodgers et al. 1977, Koerth and Bryant 1982, Relyea and Demarais 1994). Does tend to move to higher elevations that provide more fawning cover (Fox and Krausman 1994, Heffelfinger 2006). Mule deer have been recorded to move from 0.1–1.2 km in one day (Rodgers 1977, Dickinson and Garner 1979). Daily activities reported by Koenen and Krausman (2002), averaged 26% standing, 6% bedded, 29% traveling, and 39% of their daylight hours foraging. Mellink (2005) observed mule deer in the peninsula of Baja California used areas on the tops of mountain ranges for most of the year until winter snowfall would cause a shift to lower elevations.

Spacing

Ordway and Krausman (1986) reported home ranges of 14–45 km^2 for bucks and 2–18 km^2 for does in southern Arizona. Although most studies in the southwestern United States have reported home ranges of 48.3–80.5 km^2, Rautenstrauch and

Krausman (1989) reported home ranges of up to 351 km^2. Geist (1981) reported home ranges of dominant mule deer bucks to overlap those of fawn-doe groups during the rut. Home ranges in the Sonoran Desert are much larger than those of the Chihuahuan Desert (Heffelfinger 2006). Mule deer were discontinuously distributed at the Mapimi Biosphere Reserve in the Chihuahuan Desert (Sanchez-Rojas and Gallina 2000). A study in Northern Coahuila comparing site fidelity of hard (no acclimatization time) versus soft-released desert mule deer showed average movements of hard-released deer to be 4–11 km from release site while those of soft-released deer had averaged 0.9–12 km (Martinez 2009). Of the deer hard-released, 60% remained <5 km of release site and 75% of the soft released individuals exceeded >5km. Average home ranges were 2,880.14 ha and 3,455.18 ha for soft and hard-released deer, respectively (Martinez 2009). Relyea (1992) observed desert mule deer bucks were most active during postrut compared to pre- and peak-rut activity, while movements were high for both pre-rut and post-rut in Trans-Pecos, Texas during the mating season.

POPUATION DYNAMICS

The most influential factor determining mule deer population dynamics in arid environments is rainfall (Alvarez-Cardenas 1994, Heffelfinger 2006, Walser 2006). Seasonality and weather constantly affect the demographics of mule deer habitats and influence population dynamics (McKinney 2003, Mellink 2005, Heffelfinger 2006, Walser 2006). Mule deer populations in the southwestern United States and northern Mexico experience the effects of drought conditions rather than the harsh winters that affect northern mule deer populations (Anthony 1976, Smith and LeCount 1979, Leopold and Krausman 1991, Cantu and Richardson 1997). Walser (2006) reported that population abundance and fawn production are directly affected by the intensity of the drought season. This information becomes useful when observing changes through time and give me a general idea of how populations fluctuate in relation to different factors. It is important for wildlife managers to understand the effects of climatic variation on population dynamics in order to make sound management decisions. For example, late spring and early summer precipitation was most influential on survival of desert mule deer fawns, whereas winter precipitation had the most influence on population abundance (Walser 2006).

Density

Deer densities (number of deer/area) vary. It is important to define density for a specific time due to seasonal fluctuations (Heffelfinger 2006). Despite the difficulties of density estimation, several authors have evaluated different areas across mule deer distribution in Mexico (Gallina 1992, Galindo-Leal 1993, Alvarez-Cardenas 1994, Sanchez-Rojas 1998, Alvarez-Cardenas 1999a, Ahumada Cervantes 2000, Sanchez-Rojas 2000, Lozano-Cavazos 2003). Mule deer densities for Mexico varied from 0.70 deer/km^2 in the Chihuahuan Desert region in Durango, to 42 deer/km^2 in the state of Baja California. Sanchez-Rojas (2000, 2007) suggests lower densities occur in the Chihuahuan Desert due to the limited carrying capacity of this ecosystem.

Population Trends and Current Status

Unlike state wildlife regulatory agencies in the United States, Mexico currently does not monitor long-term trends of mule deer. Little is known about population trends of mule deer in Mexico. Historically, populations of mule deer in Mexico ranged from the Baja California Peninsula through the entire Sonoran and Chihuahuan deserts including parts of the states of Zacatecas, San Luis Potosi, Nuevo Leon, and Tamaulipas (Weber 2001). With increasing ecotourism (Valdez et al. 2006) many ranchers and landowners have initiated activities that promote wildlife populations. Activities range from hunting restriction to species reintroductions. Mule deer have been reintroduced in the states of Nuevo Leon and Coahuila. In the state of Zacatecas there is a limited population.

Productivity and Recruitment

The constant change in deer populations is a result of additions to (reproduction and immigration) and losses from (death and emigration) a population. When mortality exceeds recruitment a natural decline will occur in a population. In contrast, when recruitment exceeds mortality, populations will increase. Recruitment is expressed as a rate or ratio (Heffelfinger 2006). A population can be considered productive when it has a 134:100 fawn to doe ratio, which has been reported for the western-most populations in Mexico (Alvarez-Cardenas 1994, 1999a). In the Chihuahuan Desert Ecoregion in west Texas, fawn to doe ratios varied from 24–48:100 (Gray 2009). This great variability was attributed to the decline of desert mule deer in west Texas that occurred in the late 1970s.

Survival and Mortality Factors

Mountain lion has been reported as the main predator for mule deer (Leopold 1959, Alvarez-Cardenas 1994, Lawrence R. K. 2004, Mellink 2005), however, coyotes

(*Canis latrans*), bobcats (*Lynx rufus*), and golden eagles (*Aquila chrysaetos*) also will prey on mule deer fawns (Mellink 2005). Predation does not necessarily regulate mule deer populations (Heffelfinger 2006). Natural mortality is typically higher in males rather than females. Mortality also can be expressed as a ratio or rate. Mortality generally increases under stressful conditions (such as extended drought) (Mellink 2005, Heffelfinger 2006). Hunting may have a more dramatic impact on mule deer populations in Mexico compared to those in the United States. Although harvest is typically biased towards adult deer and males (Lawrence 2004), harvest pressure in portions of Mexico may be more evenly distributed across gender and ages. Predation usually accounts for mortalities of young deer (Lawrence 2004). The most stressful period for mule deer is the post-rut. The combination of factors (increased activity associated with mate searching, reduced nutrient reserves, and seasonal lows in forage quality) can cause severe nutritional stress, especially for adult males (Lawrence 2004).

Evidence of blue tongue and anaplasmosis were found in a deer population of Baja California (Contreras 2007). This suggests biological continuity of the same biogeographic region and that other diseases not tested (e.g., Lyme disease, bartonelosis) could be present. Further studies need to be conducted to determine if these diseases are affecting deer populations (Contreras 2007).

CHAPTER II

DISPERSAL DISTANCE AND POST-RELEASE MOVEMENTS OF DESERT MULE DEER IN THE CHIHUAHUAN DESERT OF COAHUILA, MEXICO

Mule deer (*Odocoileus hemionus*) are one of the 2 species of native deer that occur in North America (Heffelfinger, 2006). The historic distribution of mule deer in Mexico occupied most of the Chihuahuan Desert (Demarais and Krausman 2000), in the states of Chihuahua, Coahuila, Durango, Nuevo Leon, San Luis Potosi, Sonora and Zacatecas (Schmidt 1979). The current distribution of mule deer in the Chihuahuan Desert has declined mainly due to human related activities including: habitat loss, changes in population age and sex structure, disease, hunting, livestock competition, and combinations of these factors (Valdez et al. 2006; Ballard et al. 2001; Ordway and Krausman 1986; Cannolly and Wallmo 1981; Wallmo 1981). In the state of Coahuila particularly, populations have shown drastic declines over the past several decades to a point that they were considered to be in danger of extirpation; mainly due to illegal exploitation (Baker 1956). Although many restoration efforts have taken place, very few studies have documented their success and little information exists for this species in Mexico (Mandujano 2004). In an effort to better understand the results of mule deer translocations in the Chihuahuan Desert of Northern Coahuila, Mexico, I began a study that would compare 2 different release methods (hard release vs. soft release) and the development of 2 translocated populations.

METHODS

Study Site

This study was conducted from March 2007 to March 2010. I selected 2 study sites (Fig. 2.1) for the development of this project. The first study area was Rancho Pilares which is part of Projecto El Carmen, owned by CEMEX; it is located on the west side of Sierra del Carmen in Northern Coahuila, Mexico. The study area comprised ~50,000 ha. Average annual precipitation was 45 to 58 cm. Elevation on the study site ranged from 1,000–1,800 m. Desert grasslands dominated the foothill rangelands, whereas matorral submontane brushlands dominated the mountain rangeland vegetation type. Native populations of desert mule deer were limited in numbers although previous undocumented reintroductions had taken place (B. P. McKinney, CEMEX, personal communication).

The second study area was Rancho Guadalupe, which was located on the east side of Sierra del Carmen in Northern Coahuila, Mexico. The study area comprised 25,000 ha of hills and valleys between Sierra del Carmen and Serranias del Burro, presenting similar vegetative and climatic characteristics to the first study area (Jimenez-Guzman and Zuñiga-R 1991). However, historical populations of mule deer were believed to be extirpated from this study area for the past 15 years.

Translocation

In spring of 2007 a total of 55 mule deer (7 M, 48 F) was captured using net-guns and a helicopter (Schemnitz 2005) east of Fort Stockton, Texas. From a total of 48 captured females, 40 were selected for monitoring based on their overall appearance and

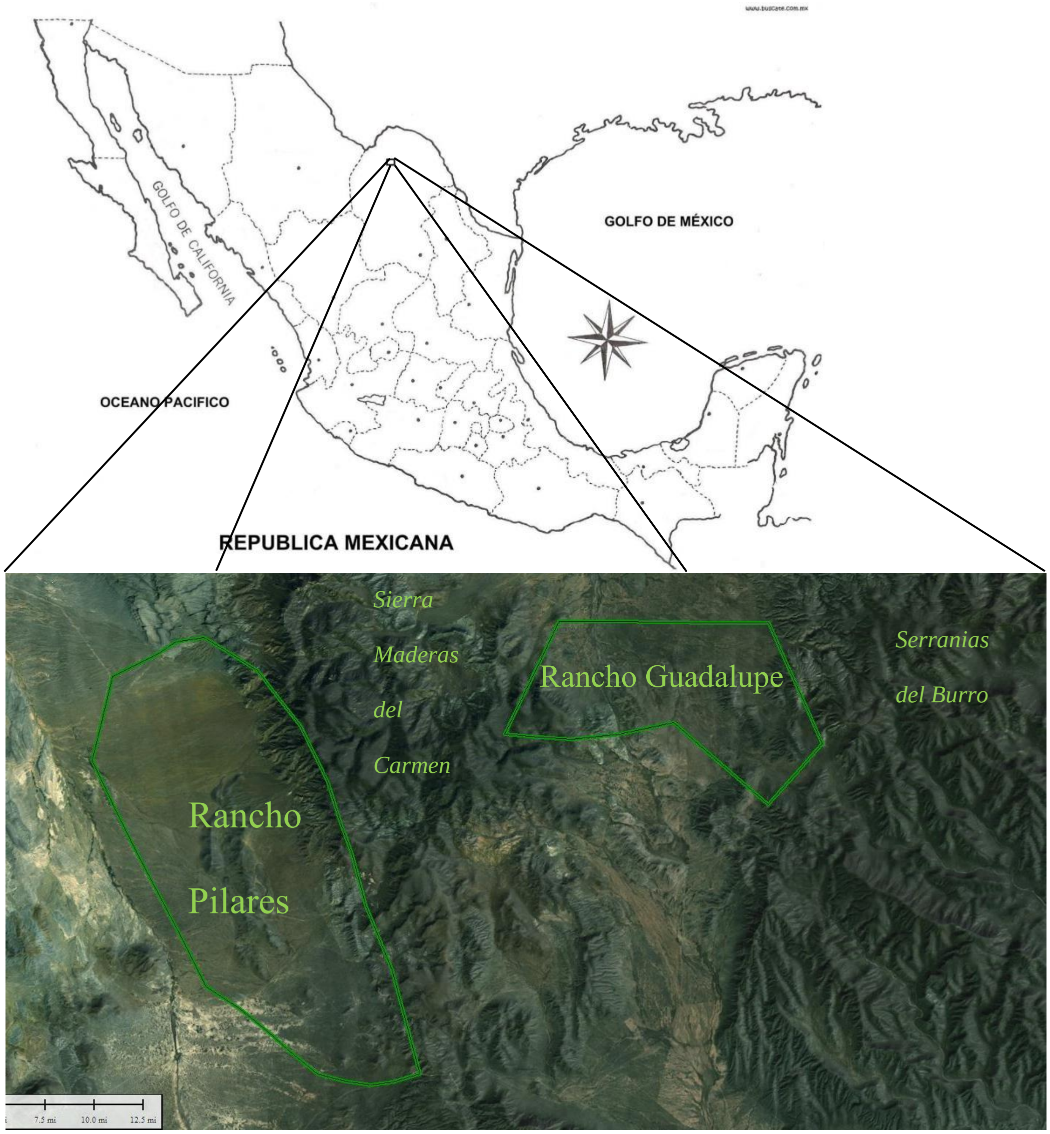


Figure 2.1. Study areas are located east (Rancho Guadalupe) and west (Rancho Pilares) of Sierra Maderas del Carmen in northern Coahuila, Mexico (Buscate 2009).

fitness. Selected deer were affixed with 2-stage VHF radio-transmitters with an 8-hour-delay mortality signal. Deer were transported to Rancho Guadalupe in Coahuila, Mexico in accordance with TTT (trap, transport, and transplant) permits (SGPA/DGVS/00528) provided by Texas Parks and Wildlife Department. After 24 hours of travel time deer were released in a central area of Rancho Guadalupe (UTM coordinates 0762580, 3213215).

In spring of 2008, an additional 73 female mule deer were captured and transported following the same procedures mentioned for 2007, from Brewster County, Texas. Translocated deer were released into a 16-ha temporary holding pen (within 100 m from 2007 release site) during a 12-week acclimation period. On May 2008, 13 radioed mule deer were released. In an effort to decrease dispersal of translocated mule deer from the ranch, 18 (200-l) gravity-feeders with protein feed (Virginiano 18) were strategically distributed throughout the study site.

Additionally, in March 2008, 72 female mule deer were similarly captured and transported to Rancho Pilares on the west side of Sierra del Carmen. A total of 23 radioed deer was hard-released in a strategically located release site (UTM 0734550, 3191251).

Data Collection

Triangulated telemetry locations (Fuller et al. 2005) were collected from the radioed deer 3 times per week. Mortalities were investigated immediately in an attempt to determine causes of death. Increased mortality rate during 2007 reduced the sample size to17 deer for the hard release treatment in Rancho Guadalupe (from the released

40). In 2008, data could only be collected from 13 deer for the soft release treatment. For the hard release treatment in Rancho Pilares, sample size for 10-day locations was 14 Elevated mortality reduced sample size drastically within the first 2 months to <20% of initial sample.

Data Analysis

Site fidelity was expressed as the average linear distance between the release site and individual deer locations. Deer were considered "loyal" if the majority (>50%) of locations were within a 5-km radius from the liberation site. Telemetry triangulation data was evaluated using LOAS 4.0 (Ecological Software Solutions LLC, Florida State) to calculate the estimated location and margin of error of each deer. Location coordinates were then evaluated using ArcGIS (Environmental Systems Research Institute, Redlands, California). I estimated yearly ranges using the Hawth's tools extension in ArcGIS at 95% fixed kernel (Breyer 2004). I also used a 2-tailed t-test to determine statistical differences of home range sizes and dispersal distance between hard- and soft- release. Hard-released deer were monitored from May 2007 to May 2009 and soft-released deer were monitored from May 2007 to March 2008. I used the Kaplan-Meier (Pollock et al. 1988) survival estimate to calculate survival rate from May 2007 to May 2009 for both hard and soft-released deer.

RESULTS

Post-release Movements

Mule deer showed tendencies towards individual dispersion after being hard-released, moving through the area for a period of 2 months before establishing a home range with an average area of 3,565.8 ha ± 882 ha (Fig. 2.2). In contrast, soft-released mule deer showed tendencies to move in small groups (3–6 individuals), and move through the area for a period of 2 months before establishing a home range with an average area of 2,908.5 ha ± 1,124 ha. Even though the average home range for mule deer decreased by 657 ha when soft-released, no significant difference ($P = 0.245$) in home range sizes was found when comparing soft release vs. hard release (Fig. 2.3).

Dispersal Distance

In hard-released deer of 2007 on the Guadalupe ranch, 10 out of 17 deer (60%) remained loyal to the release site, with overall average movements ranging from 4–11 km. In soft-released deer, 9 out of 12 deer (75%) remained loyal to the release site, with overall average movements ranging from 0.9–12 km. In hard-released deer of 2008 on the Pilares Ranch, 6 out of 14 deer (42%) remained loyal to the release site, with overall movements ranging from 1.6–10.7 km. (Fig. 2.4–2.8). Travel distances from the release site of the loyal deer averaged 3.2–6.6 and 1.8–3.7 km for deer that were hard-released and soft-released, respectively. Comparable values for non-loyal deer averaged 7.4–12.8 and 10.7–19.7 km, respectively. Difference ($P = 0.001$) was present in dispersal distance when comparing soft release versus a hard-release 2007. No difference was present when comparing dispersal distance of hard-release deer of 2007 and 2008 ($P = 0.793$).

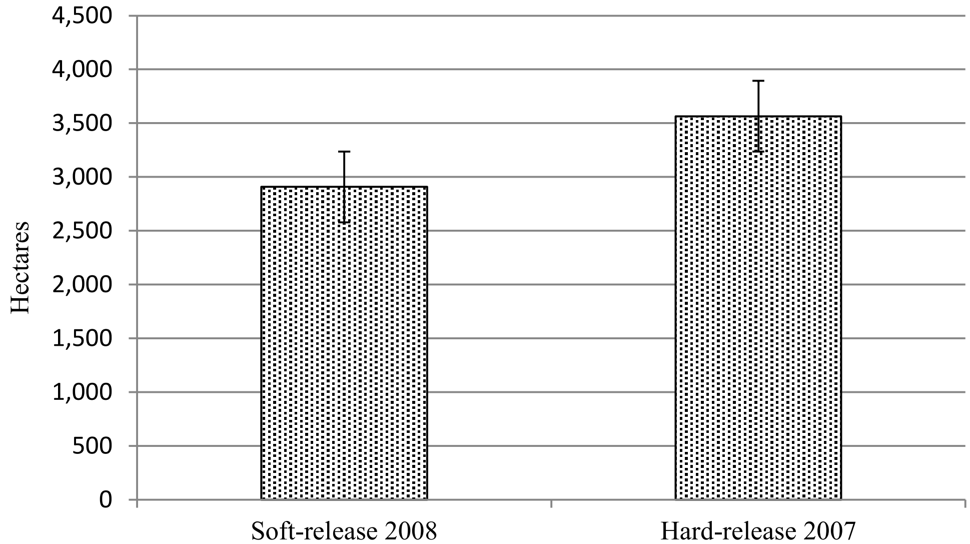


Figure 2.2. Home range size (ha) of hard- and soft-released deer on Rancho Guadalupe, Coahuila, Mexico, 2007–2009 (hard release home range, $\overline{x}$ = 3,565 ha; soft release home range, $\overline{x}$ = 2,908 ha).

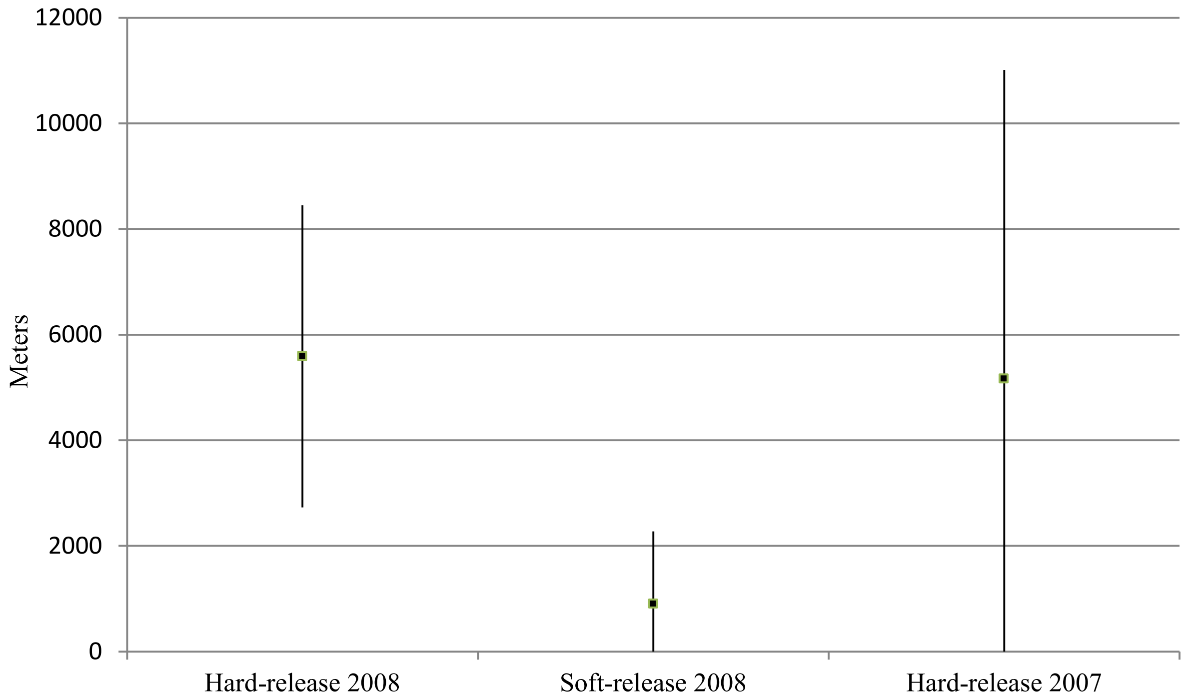
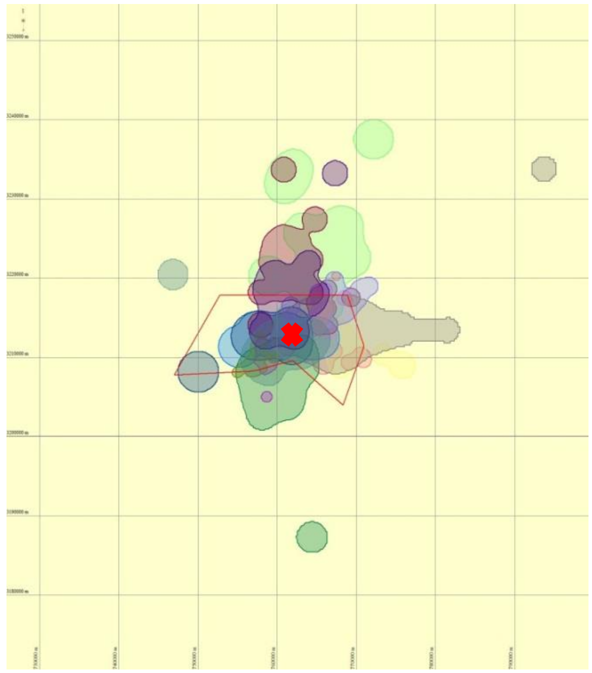


Figure 2.3. Dispersal distance of hard- and soft-released mule deer as a function of average linear distance between release site and subsequent radiotelemetry locations (pooled from both study sites), northern Coahuila, Mexico, 2007–2009.

A



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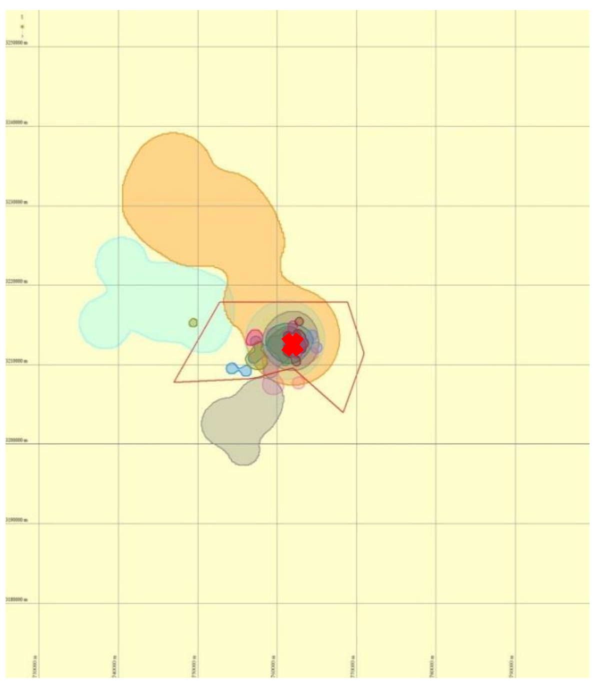
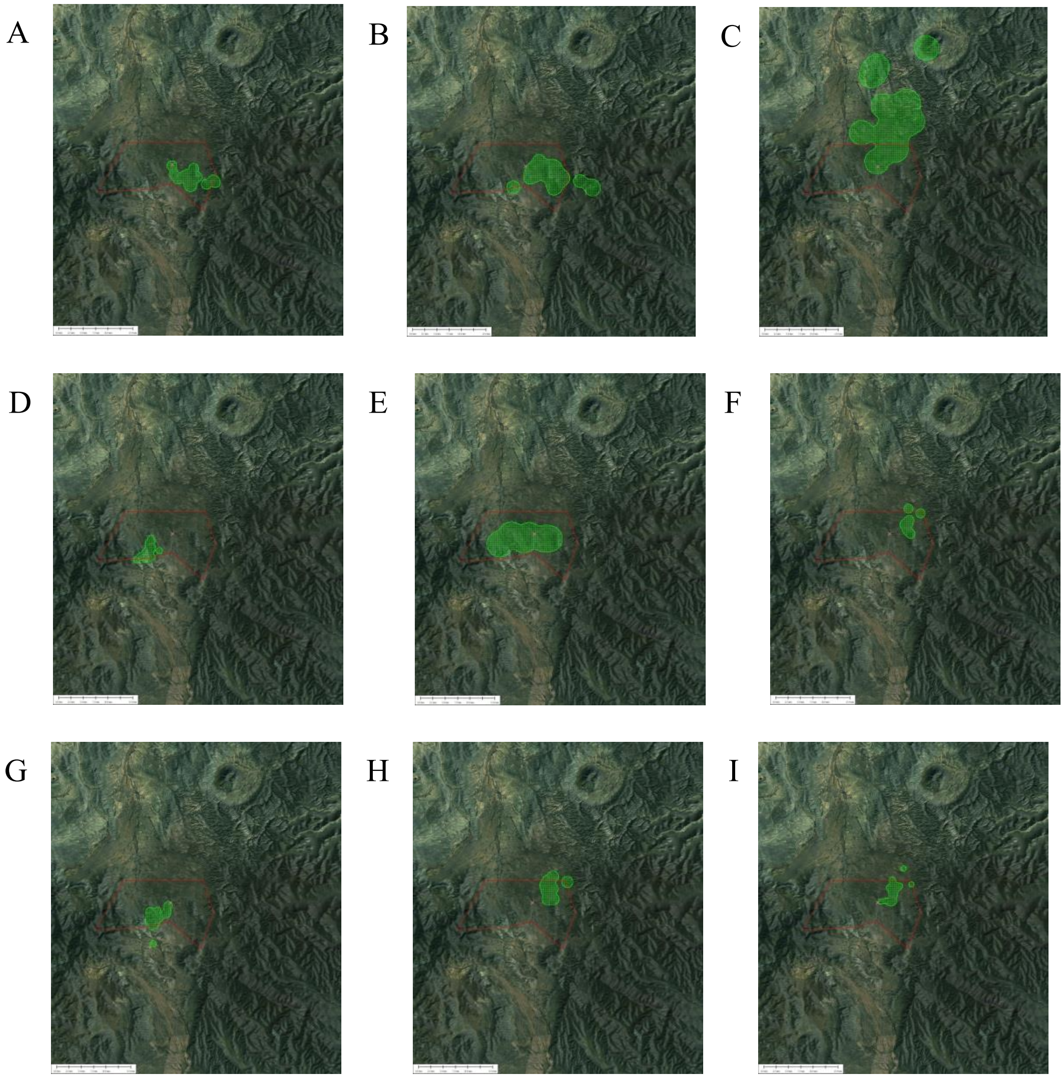


Figure 2.4. A comparison of desert mule deer home range sizes between (A) hard-release and (B) soft-release techniques referenced to the release site (expressed as a red cross) on Rancho Guadalupe, Coahuila, Mexico, 2007–2009.



Deer range

Rancho Guadalupe boundary

Release site for hard released deer

Figure 2.5. Fixed kernel density estimator (95%) of hard-released mule deer (A) 215, (B) 255, (C) 292, (D) 314, (E) 455, (F) 473, (G) 493, (H) 554, and (I) 573 during study conducted on Guadalupe Ranch, Coahuila, Mexico 2007–2009.

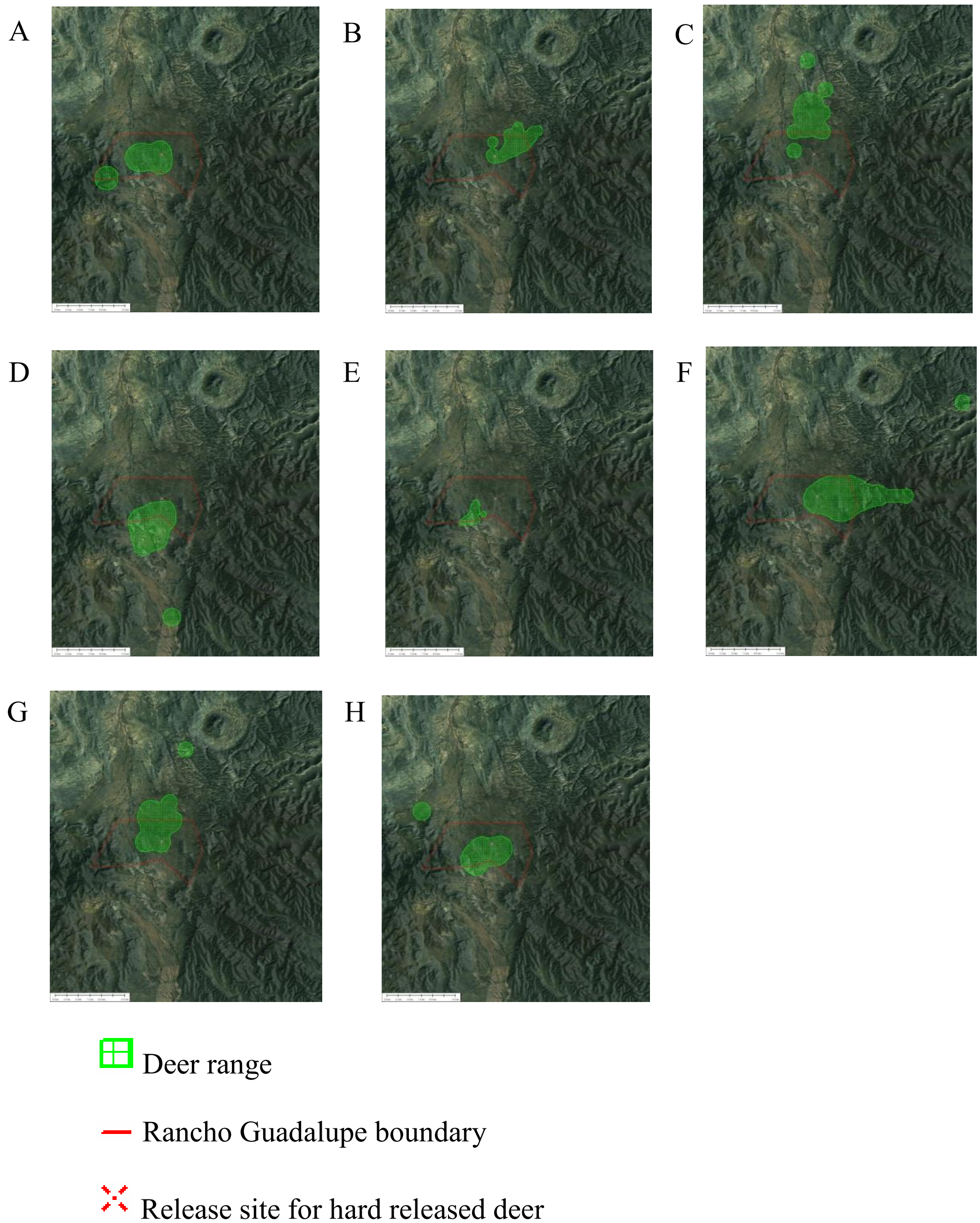


Figure 2.6. Fixed kernel density estimator (95%) of hard-released mule deer (A) 593, (B) 696, (C) 714, (D) 854, (E) 896, (F) 914, (G) 975, and (H) 994 during study conducted on Guadalupe Ranch, Coahuila, Mexico 2007–2009.

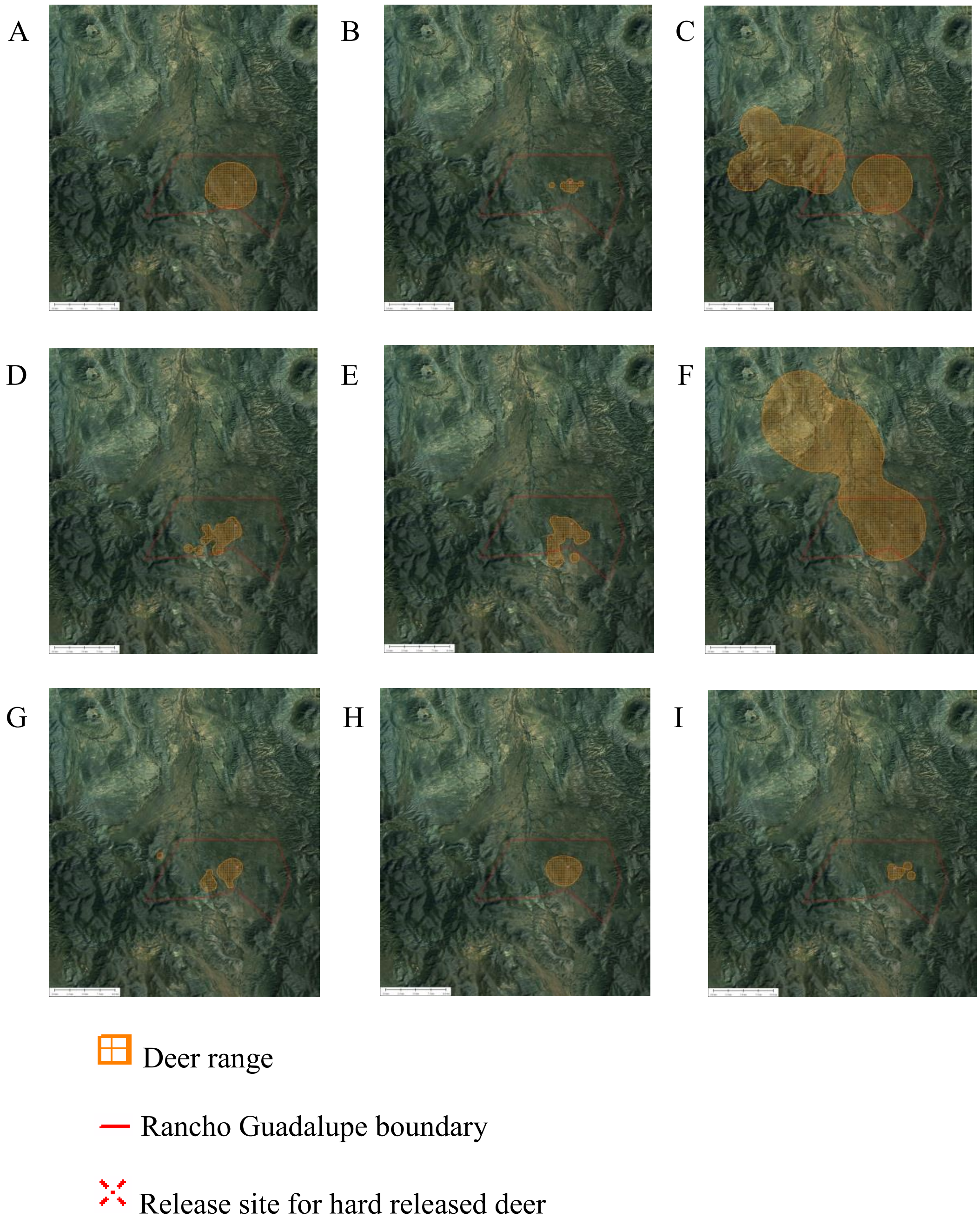


Figure 2.7. Fixed kernel density estimator (95%) of soft-released mule deer (A) 030, (B) 040, (C) 050, (D) 060, (E) 090, (F) 110, (G) 130, (H) 180, and (I) 240 during study conducted on Guadalupe Ranch, Coahuila, Mexico 2007–2009.

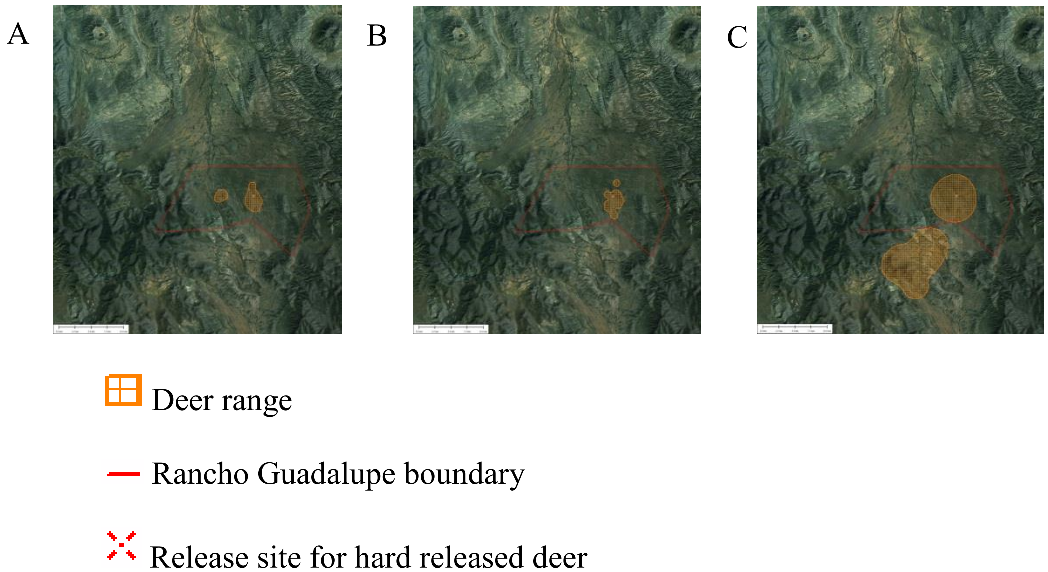


Figure 2.8. Fixed kernel density estimator (95%) of soft-released mule deer (A) 635, (B) 1050, and (I) 1070 during study conducted on Guadalupe Ranch, Coahuila, Mexico 2007–2009.

Annual survival rate also increased in those animals that were soft-released (S = 0.84), compared to those that were hard-released 2007 (S = 0.57) and those that were hard-released 2008 (S = 0.13). Of those individuals that were hard-released in 2007 and survived to January of 2008 (n = 13), there was only 1 mortality in 2008 compared to 20 in 2007. From a total of 130 mule deer that were captured, 76 does were radio-collared in a period of 2 years, 35 of those 76 animals were killed by mountain lions (*Puma concolor*). Ten deaths were capture-related mortalities, 1 doe died in a coyote trap, and 4 others died from unknown causes (Fig. 2.9). On hard releases, translocated mule deer seemed more vulnerable immediately after liberation where 22 of 40 deer died in the first 10 weeks prior to hard-release in 2007 and 15 deer died in the first 10 weeks prior to hard-release in 2008.

DISCUSSION

Soft-release showed to be a useful tool that may decrease dispersal distance of translocated mule deer. Despite it being labor intensive and requiring additional costs (pen construction and materials), the use of the soft release technique decreased average home ranges and decreased dispersal distance compared to hard release. My results concur with Rosatte et al. (2003), who reported reduced dispersal from the release site for soft-released elk ([*Cervus canadensis*] ≤5 km) compared to hard-released elk dispersal (20–50 km). Parker et al. (2008) reported lower dispersal distance and higher survival rate of soft-released translocated Florida key deer (*Odocoileus virginianus clavium*) when comparing them to hard-released Florida key deer. Results for soft- vs.

hard-release comparison allow me to speculate the soft-release method as an effective way to decrease dispersal, as well as ranges of translocated mule deer.

High mortality rate during the first year of the project reduced the initial sample from 40 to only 17 hard-released deer in 2007. In contrast, increased mortality prevented data collection from initial sample to only 14 deer from hard-released in 2008. Predation reduced the sample size of hard release by 58% in 2007 and 65% in 2008, compared to 1 predation event in 2008 for soft-release. On hard releases, translocated mule deer seemed most vulnerable immediately after liberation where 22 of 41 and 15 of 23 deer died in the first 10 weeks prior to release in 2007 and 2008, respectively.

Several authors (Leopold 1959, Heffelfinger 2006) have reported mountain lions as the main predator of mule deer in Mexico. The well-established population of mountain lions in my study areas was reflected by the high mortality caused by them. This abundance may be an additional factor to the elevated dispersal that some of my deer demonstrated.

Translocated deer may go through an exploratory phase as some authors (Beringer et al. 2002, Parker et al. 2008) have suggested. This theory suggests that translocated animals explore the area after translocation to establish a suitable home range, possibly increasing their home range size initially. An acclimation period, as Parker et al. (2008) suggested, results in a reduction of translocated deer home ranges overtime. Predator risk, food, water, cover, reproduction, as well as safe zones may influence the size of home ranges in several species (Edwards 1983, Kie and Czech 2000, Pierce et al. 2004). The Guadalupe Ranch is an intensely managed cattle ranch. I believe that good grazing management provided better habitat for mule deer in the area than the neighboring communal lands. For this reason, it is possible some deer that were loyal to the release site accepted greater risk of predation to meet forage requirements. Mountain lions in my study area were the most significant threat of mortality to mule deer. For this reason, I believe it plausible that levels of predation risk do not play an important role in dispersal distance for mule deer (Pierce et al. 2004). In contrast, Rancho Pilares historically was an overgrazed cattle ranch that has been destocked for more than 10 years. Available habitat was presumed to be in optimal condition, suggests that increased dispersal was directly tied to hard-release method.

Despite different release methods evaluated in this project. Most deer that survived stayed within the boundaries of my study areas. For this particular study dispersal reduction may have not made a difference, but it is important to keep in mind the extension of these properties. In future translocation, smaller landowners may consider collaborating with neighboring ranches and soft-release technique may be a viable practice to consider.

MANAGEMENT IMPLICATIONS

Soft-release technique is recommended if reduction of dispersal distance is an objective. Range evaluation is important before translocations (Martinez-Munoz et al. 2002), being that this could be a factor that increases dispersal. When using soft-release method, mule deer should spend ≥8 weeks in holding pens, after this any time when range conditions are acceptable deer can be released, with increase in time in the holding pens, increases the price of this practice. The proximity of water, cover, supplemental feed and overall good habitat condition close to the release site of soft-released deer are potential factors that affect reduced dispersal in a positive manner.

CHAPTER III

HABITAT USE AND VEGETATION PREFERENCES OF DESERT MULE DEER IN THE CHIHUAHUAN DESERT OF COAHUILA, MEXICO.

Habitat is by definition the place or environment where a plant or animal naturally or normally occurs. In the field of wildlife ecology and management, habitat has further been defined as "the resources and conditions present in an area that produce occupancy (including survival and reproduction) by a given organism" (Hall et al. 1997). By this definition, habitat refers to the necessary resources for organisms to fulfill four basic requirements: (1) food, (2) water, (3) cover, and (4) space (Fulbright and Ortega-S. 2006). Fulfillment of these requirements may not be possible in one particular vegetation association. For this reason, the definition of habitat encompasses more than a particular vegetation type, but rather a combination of such which present the optimal conditions for a species to excel. The manner in which a particular species utilizes or consumes the available resources within the territory it inhabits is known as habitat use (Hall et al. 1997).

Many authors mention habitat loss, combined with other factors, as one of the main reasons for the decline in populations of mule deer (Cannolly and Wallmo 1981, Wallmo 1981, Ordway and Krausman 1986, Ballard et al. 2001, Valdez et al. 2006). In an effort to better understand the habitat use of translocated mule deer in the Chihuahuan Desert of Northern Coahuila, Mexico, I began a study that would compare 2 different release methods (hard release vs soft release) and habitat selection patterns of 2 translocated populations.

METHODS

Study Area

This study was conducted from March 2007–March 2010. My selected study area was Rancho Guadalupe, which was located on the east side of Sierra del Carmen in Northern Coahuila, Mexico. The study area comprised 25,000 ha of hills and valleys between Sierra del Carmen and Serranias del Burro, presenting similar vegetative and climatic characteristics to the first study area (Jimenez-G and Zuñiga-R 1991). However, historical populations of mule deer were believed to be extinct from this study area for the past 15 years. Average annual precipitation is 45–58 cm. Elevation on the study site ranged from 1,000–800 m. Desert grasslands dominated the foothill rangelands, whereas matorral submontane brushlands dominated the mountain rangeland vegetation type.

Translocation

In spring of 2007 a total of 55 mule deer (7 M, 48 F) was captured using net-guns and a helicopter (Schemnitz 2005) east of Fort Stockton, Texas. From a total of 48 captured females, 40 were selected for monitoring based on overall appearance and fitness. Selected deer were affixed with 2-stage VHF radio-transmitters with an 8-hour-delay mortality signal. Deer were transported to Rancho Guadalupe in Coahuila, Mexico in accordance with TTT (trap, transport, and transplant) permits provided by

Texas Parks and Wildlife Department. After 24 hours of travel time deer were released in a central area of Rancho Guadalupe (UTM coordinates 0762580, 3213215).

In spring of 2008, an additional 73 female mule deer were captured and transported following the same procedures mentioned for 2007, from Brewster County, Texas. Translocated deer were released into a 16-ha temporary holding pen (within 100m from 2007 release site) during a 12-week acclimation period. On May 2008, 13 radioed mule deer were released. In an effort to decrease dispersal of translocated mule deer from the ranch, 18 200-l gravity-feeders with protein feed were strategically distributed throughout the study site.

Data Collection and Analysis

Triangulated telemetry locations (Fuller et al. 2005) were collected from the radioed deer 3 times per week. In 2008, data could only be collected from 13 deer for the soft release treatment. Telemetry triangulation data was evaluated using LOAS 4.0 (Ecological Software Solutions LLC, Florida State) to calculate the estimated location and margin of error of each deer. Location coordinates were then evaluated using ArcGIS (Environmental Systems Research Institute, Redlands, California). I classified vegetation types in 3 different classes: (1) lechugilla (*Agave lechuguilla*) hills, (2) creosote (*Larrea tridentate*) flats, and (3) xeroriparian vegetation types. Using ArcGIS 8 (ESRI, Inc., Redland, CA), I delineated arroyos within the study area by hand-digitizing the arroyos visible in study sites from DOQQs (digital orthophoto quarter quadrangles). Xeroriparian habitats were defined by a 100-m buffer of the digitized arroyos. Lechuguilla hills were defined by the thickets visible in the DOQQs. All other vegetation types not contained within the riparian habitats or the lechuguilla hills polygon was defined as creosote flats. I estimated habitat use by mule deer using Bailey's confidence intervals (Bailey 1980) at second- and third-order levels on each study area (Thomas and Taylor 1990) assuming that all habitats, in their respective proportions, were equally available to mule deer (Manly et al. 1993). I then presented ratios (*S*) of habitat use/habitat availability (Lopez et al. 2004) for each study site by population (second order) and by individuals (third order).

I used 100-m line intercept, 100-m x 1-m belt, and 100-m point-step transects (Bonham 1989) to describe habitats of mule deer. Habitats were subdivided by presence or absence of arroyos and visual estimation of arroyo sizes. Channels of riparian vegetation types were >50 m. Transects were placed randomly in areas in the respective vegetation type classifications. Transects were oriented randomly in scrubland habitats and perpendicular to the arroyo channel in riparian habitats. I conducted 2 transects per study area to describe different vegetation type areas. I calculated density, dominance, and frequency of woody vegetation (Smeins and Slack 1982). I calculated vegetation diversity for creosote flats, lechuguilla hills, and riparian habitats using the Shannon-Weaver index (Zar 1999).

RESULTS

I captured 22 female mule deer to conduct this study. Annual ranges of translocated mule deer ranged from 3,565.8 ha ± 882 ha.

Xeroriparian vegetation type occupied 2.6% of 35,264.98 total ha. Mule deer selected for xeroriparian vegetation type at second order analysis ($P < 0.0001$). From

285 telemetry locations among 15 individuals, mule deer used xeroriparian vegetation 9.2% of the time on the study area. At second order analysis, xeroriparian vegetation type had a higher use/availability ratio ($S_{xeroriparian}$ = 3.68). Lechuguilla hills occupied 63% of 35,264.98 total ha. At second order analysis, mule deer used this vegetation type respective to its availability ($S_{lechuguilla}$= 0.98). Creosote flats vegetation type on the study area was 34% of 35,264.98 total ha. At second order analysis creosote flats vegetation type was not selected for presenting much less use in relation to its availability ($S_{creosote}$= 0.73).

For third order habitat selection , 1 of 15 individuals used xeroriparian vegetation type in lesser proportion than its availability (S <1.0). Six of 15 individuals used xeroriparian vegetation type randomly (S = 1.0–1.1). Eight of 15 individuals used xeroriparian vegetation type in greater proportion than its availability (S >1.1).

Xeroriparian vegetation type had a higher vegetation diversity (*J*) than lechuguilla hills and creosote flats areas ($J_{xeroriparian}$ = 0.58, $J_{lechuguilla}$ = 0.20, $J_{creosote}$ = 0.15). Xeroriparian vegetation had greater density, dominance, and frequency values for woody vegetation than lechuguilla hills and creosote flat vegetation types.

Deer use within home range could be distinguished by preference for characteristic vegetation types. Translocated mule deer preferred (*P* = 0.002) to use xeroriparian vegetation (9.2%) greater than their availability (2.5%); use of Lechuguilla hills (63%) presented no difference (*P* = 0.005) from its availability (64%); and use of creosote flats (25%) was different (*P* = 0.004) when compared to its availability (34%).

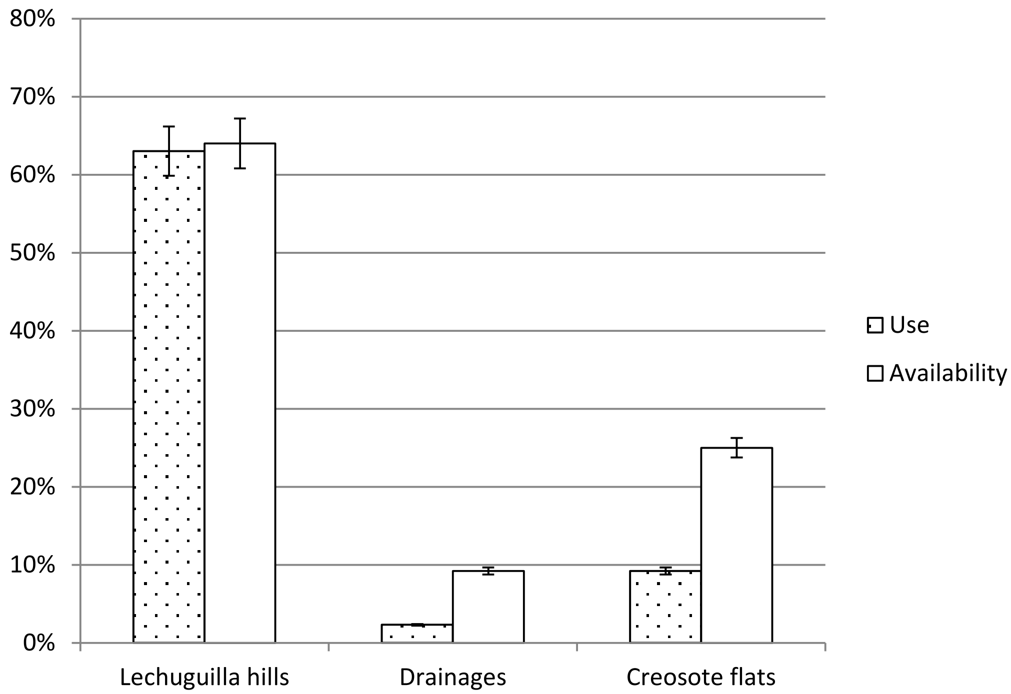


Figure 3.1. Translocated mule deer at second order habitat selection presented difference in habitat use vs. availability for the different vegetation classes in my study area.

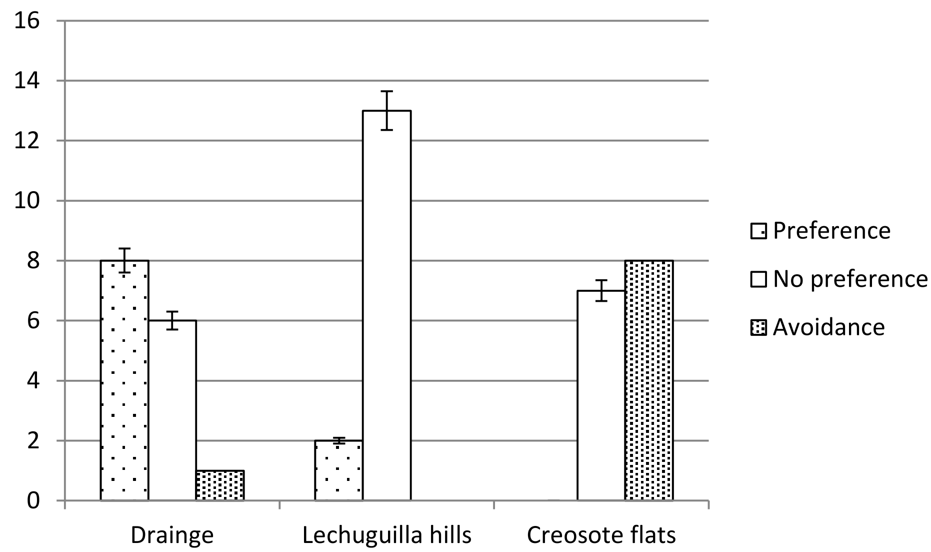


Figure 3.2. Translocated mule deer at third order habitat selection presented variation in habitat use vs. availability for the different vegetation classes in my study area.

Table 3.1 Second order translocated mule deer habitat selection in the Chihuahuan Desert, Coahuila, Mexico.

Vegetation type	Total area (ha)	Proportion of total area	Number of locations	Expected number of locations	Proportion observed	Bailey's 95% confidence intervals		*S*
						Upper	Lower	
Xeroriparian	916.86	0.026	281	148	0.66	0.72	0.59	3.6
Lechuguilla hills	22,216.32	0.643	135	81	0.31	0.38	0.26	0.98
Creosote flats	11,989.76	0.331	10	197	0.03	0.05	0.01	0.76
Total	2,147.47	1	426	426	1			

Table 3.2 Vegetation characteristics of vegetation types on the study area in Northern Coahuila, Mexico, 2009.

Vegetation type	Species	Density Abs. (plants/ha)	Density Rel. (%)	Dominance Abs. (m^2/ha)	Dominance Rel. (%)	Freq.
Creosote flats	*Acacia greggii*	60	1.0	80	1.6	2.5
	Aloysia gratissima	100	1.9	110	2.2	7.5
	Atriplex canescens	550	10.7	280	5.6	15
	Flourensia cernua	200	3.9	130	2.6	5
	Koberlinia spinosa	150	2.9	30	0.6	5
	Larrea tridentata	1,600	31.1	1,925	38.6	62.5
	Parthenium incanum	1,500	29.1	280	5.6	22.5
	Prosopis glandulosa	850	16.5	1,725	34.6	50
	Rhus microphylla	150	2.9	430	8.6	7.5
	Herbaceous spp.			500		
Lechuguilla hills	*Acacia constricta*	100	2.1	80	1.3	5
	Acacia greggii	150	3.2	375	6.1	10
	Agave lechuguilla	950	20.2	1,145	10.8	5
	Atriplex canescens	450	9.6	720	11.7	20
	Dasylirion leiophyllum	400	8.5	1,200	19.4	32.5
	Echinocactus horizonthalonius	50	1.1			
	Flourensia cernua			135	2.2	7.5
	Hymenoclea salsola	600	12.8	320	5.2	12.5
	Yucca faxoniana	400	8.5	785	12.7	25

Table 3.2 Continued.

Vegetation type	Species	Density Abs. (plants/ha)	Density Rel. (%)	Dominance Abs. (m^2/ha)	Dominance Rel. (%)	Freq.
	Lycium spp.	50	1.1	80	1.3	5
	Opuntia leptocaulis	100	2.1			
	Parthenium incanum	750	16.0	215	3.5	15
	Prosopis glandulosa	350	7.4	785	18.5	25
	Rhus microphylla	100	2.1	410	6.6	7.5
	Viguera stenoloba	200	4.3			
	Yucca spp.					
	Herbaceous spp.			1,250		
Xeroriparian	*Acacia greggii*	150	4.7	265	5.1	5
	Atriplex canescens	50	1.6	40	0.8	2.5
	Brickellia spp.	850	26.6	1,320	25.4	37.5
	Chilopsis linearis	550	17.2	2,060	39.7	35
	Hymenoclea salsola	200	6.3	145	2.8	5
	Opuntia leptocaulis	250	7.8	195	3.8	10
	Opuntia spp.	50	1.6	20	0.4	2.5
	Parthenium incanum	100	3.1			
	Prosopis glandulosa	850	26.6	475	9.2	15
	Rhus microphylla	100	3.1	670	12.9	15
	Herbaceous spp.			1,350		

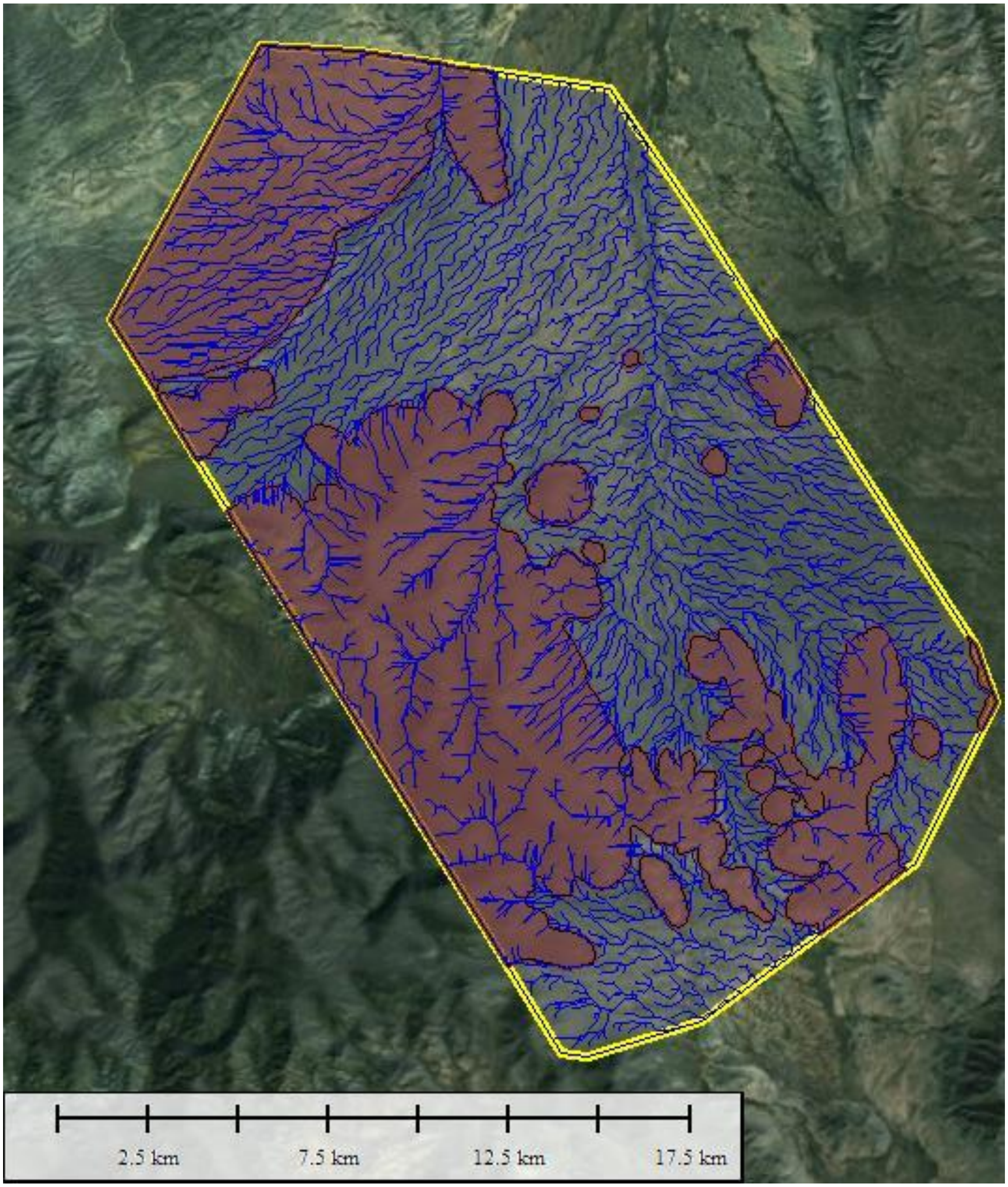


Figure 3.3. Vegetation types for soft released deer were divided in xeroriparian (blue), lechuguilla hills (brown), and creosote flats (grey) in May 2009.

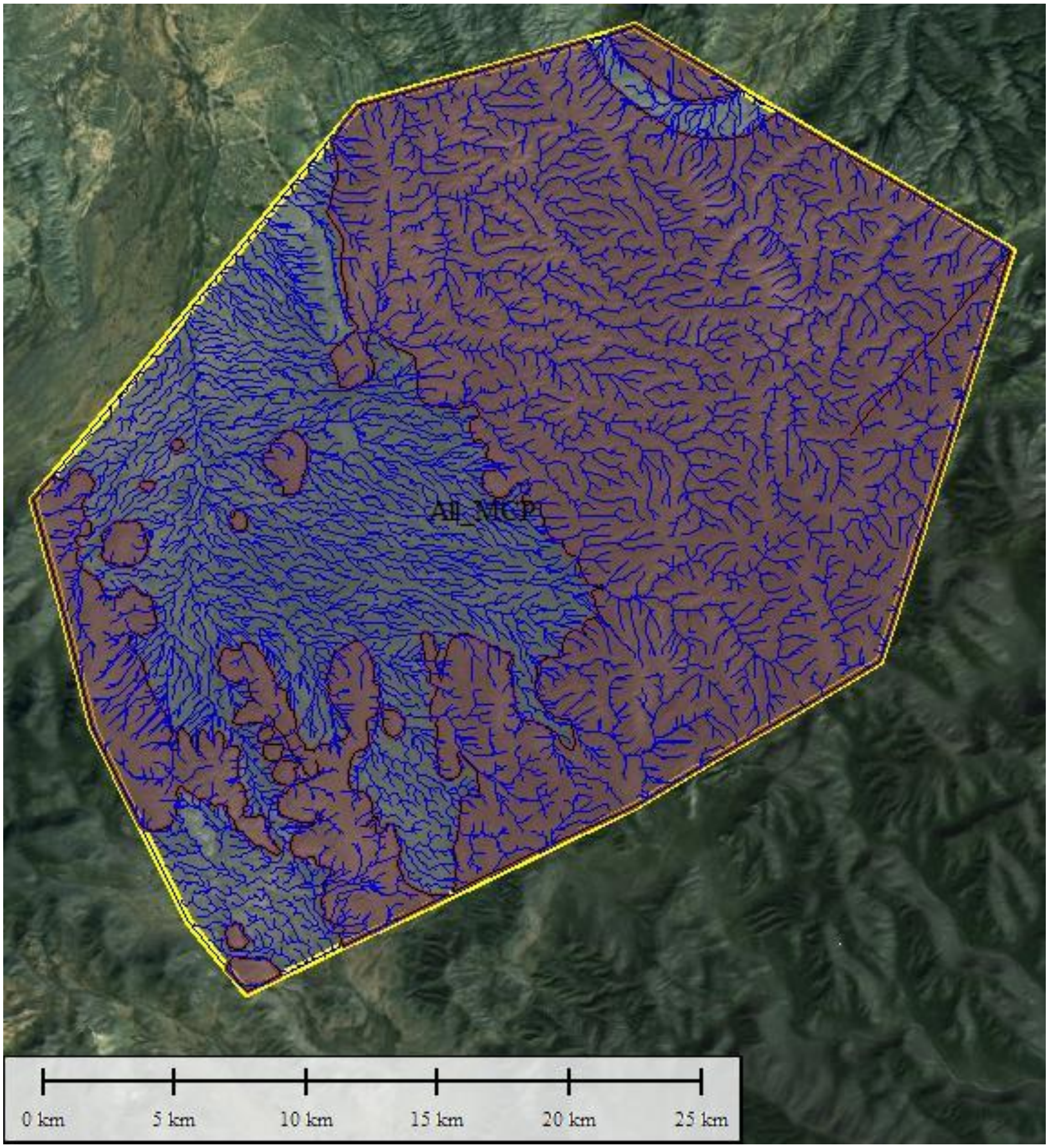


Figure 3.4. Vegetation types for hard released deer were divided in xeroriparian (blue), lechuguilla hills (brown), and creosote flats (grey) in May 2009.

DISCUSSION

Wildlife species present complex interactions with their particular habitats. Understanding the resources and environmental conditions that influence selection of different habitats is important to better understand these interactions. Relationships between forage growth and forage nutritional quality have been demonstrated for different mule deer vegetation types (Marshal et al. 2005). In the majority of cases, mule deer select for the habitat types that readily meet their requirements (i.e. food, water, cover, and space [Heffelfinger 2006]). In desert habitats, xeroriparian vegetation types usually present higher rates of plant growth (Marshal et al. 2005), higher species diversity and , thus, forage of higher quality (Marshal et al. 2005). In many desert systems xeroriparian vegetation types are the only source of food and cover for mule deer (Krausman 1998). The selection of xeroriparian vegetation types may be directly related to forage quality and availability presented in such. Other variables documented to influence the selection of particular vegetation types include slope. In my study, however, the influence slope presents on selection of vegetation types is unclear. Martinez-Garcia (2009) reports that elevation and slope were not important in the within-home-range models for summer ranges in this area. However, other investigators have suggested the dispersal of individual females during birthing season selecting for slopes and steeper terrain (Bergerud and Page 1987, Barten et al. 2001, Heffelfinger 2006, Marshal et al. 2006). Marshal et al. (2006), in particular, reported a higher variation among individuals when referring to selection of steeper terrain. This variation among individuals could be associated with the availability in certain areas of better fawn cover. Better habitat for fawning cover has been associated with slopes by several authors (Riley and Dood 1984, Fox and Krausman 1994), suggesting that steeper slopes are utilized to avoid coyotes (*Canis latrans*) who generally utilize less-steep areas as traveling corridors (Bleich et al. 1997).

There may be reasons for deer to avoid creosote flats. Cattle were present on the study area and there was the potential for competition between cattle and native ungulates (Bleich and Andrew 2000). As a consequence, deer may prefer to avoud this feature and seek forage, cover, or water in other parts of the desert, as most of my radio-collared mule deer appeared to do. Future research using GPS telemetry collars would provide locations with a precision far greater than that of this study, and during times outside of diurnal hours, for example, when deer are more likely to increase activities (Hervert and Krausman 1986).

MANAGEMENT IMPLICATIONS

Utilization of different vegetation types by deer is mainly driven by the availability of food and cover, being these the principal components of wildlife habitats. Many wildlife species that inhabit arid and semi-arid environments have developed the ability to survive for longer periods of time if free-standing water is not available. However, water without any type of vegetation cannot be considered mule deer habitat (Marshal 2006). The importance of xeroriparian areas for mule deer in the Chihuahuan Desert is clear. The abundance and quality of forage that xeroriparian areas present and are utilized by mule deer as food and cover, may reduce the need for seasonal movements. Other advantages of maintaining healthy vegetative conditions of xeroriparian areas are the reduction of competition of forage, as well as avoidance of the risks that long-distance movements entail; which in term could translate to an increased abundance of deer (Nicholson et al. 1997, Krausman and Czech 1998, Bleich and Pierce 2001, Marshal et al. 2006).

CHAPTER IV

SUMMARY AND CONCLUSIONS

Mule deer (*Odocoileus hemionus*) are one of the most popular wildlife species of North America. Not only for their ecological value, but as a game species as well; the importance of mule deer has been recognized from the ancient tribes that initially inhabited their distribution range portraying them in pictographs (Heffelfinger 2006), to most recent times with the development of sport hunting and ecotourism that has been reflected in management of natural resources for the welfare of the species (Valdez et al. 2006). As with most of the wild ungulates of Mexico, the distribution has markedly decreased (Gallina and Mandujano 2009). Many reasons have been suggested by authors; however, the general consensus is that habitat loss and elevated illegal hunting are the main causes for this decrease (Cannolly and Wallmo 1981; Wallmo 1981; Ordway and Krausman 1986; Ballard et al. 2001, Valdez et al. 2006;). The change in perception from ranchers and landowners has shown to be beneficial for the conservation of the species. With mule deer seen as a financial asset, conservation initiatives have taken place to re-establish the species where it has been extirpated, and management has shifted to sustain existing populations (Heffelfinger 2006, Valdez et al. 2006).

DISTRIBUTION

The extent of the Chihuahuan Desert (Fig. 4.1) has been variably delineated by several authors. However, the most conservative estimates report an area of approximately 350,000 km^2 between the United States and Mexico (Schmidt 1979),

Figure 4.1. The Chihuahuan Desert of Mexico is distributed in the states of Sonora, Chihuahua, Durango, Zacatecas, San Luis Potosi, Tamaulipas, Nuevo Leon, Coahuila, and into the United States in Texas, New Mexico and Arizona (Adapted from Schmidt 1979, Buscate 2009).

making it the largest hot desert in North America (Sanchez-Rojas and Gallina, 2007). The Chihuahuan Desert presents an elevation ranging from 500–3195 m. Precipitation varies throughout the landscape, and from year to year between 156–425 mm; receiving 69–90% of total rainfall during the warmer time period of May–October (Henrickson and Johnston 1986).

With such a large extent, this biotic province presents different classes of vegetative communities. The occurrence of these communities varies depending mainly on the topographic features present throughout the landscape. The vegetation types that occur in the Chihuahuan Desert are: (1) desert scrub and woodlands, (2) lechuguilla scrub, (3) grasslands, (4) chaparral, and (5) montane woodlands (Henrickson and Johnston 1986).

Historically, mule deer occupied most of the Chihuahuan Desert in Mexico (Heffelfinger 2006) from the states of Durango, San Luis Potosi, Nuevo Leon, and Tamaulipas, to almost the entire states of Coahuila, Chihuahua, Sonora, Baja California Norte, Baja California Sur and into the United States. However, like with most game species in Mexico, illegal hunting, habitat loss, and human-related activities have reduced their range significantly from the east and the south. The current distribution of mule deer in Mexico is unknown, but some re-introduction efforts in hopes of population restoration have been reported in the states of Coahuila, Nuevo Leon, and Zacatecas (Sanchez-Rojas and Gallina 2007).

DESCRIPTION

Mule deer are popularly referred to as “mulos”, “buras” or “buros” as in burro (donkey in Spanish) or mula (mule in Spanish) for their long ears. Mule deer are characterized for having body lengths of 1,300–2,600 mm total; their characteristic black tails range between 115–190 mm, and males weigh 64–114 kg differing from females who may weigh 45–75 kg. Their weights can vary from year to year depending on habitat condition and forage availability. Mule deer antlers are referred to as bifurcated; meaning that the antlers usually form a back fork and a forward fork. However, mule deer can, and often will, develop a non-branched beam or tine in place of the back fork, resulting in antlers that resemble those of white-tailed deer. It is not recommended that antler conformation alone is used for species identification purposes (Cantu and Richardson 1997, Heffelfinger 2006, Sanchez-Rojas and Gallina 2007).

GENERAL ECOLOGY

Mule deer are generally recognized as gregarious animals, and in the Chihuahuan Desert they are not migratory (Cantu and Richardson 1997, Heffelfinger 2006). During most of the year, males form groups of bachelors, and females form groups with their offspring and other females. Bachelor groups begin to separate as the mating season approaches, and solitary males begin to overlap their ranges with females conducting mating rituals in an attempt to identify those who are ready to breed. The mating period, also known as the rut, varies from year to year, and throughout the ranges of mule deer from November to the end of February (Leopold 1959, Gallina et al. 1992, Alvarez-Cardenas et al. 1994, Cantu and Richardson 1997, Heffelfinger 2006, Sanchez-Rojas and Gallinas 2007).

Once bred, females go through a gestation period of about 200 days (Robinette et al. 1977). Their fawning season spans from June–August, depending on the timing of the rut (Leopold 1959, Stone and Rhoads 1905, Gallina 1989, Galina-Tessaro et al. 1988, Gallina et al. 2000, Perez-Gil Salcido 1981). Mule deer does, typically produce 2 fawns and on rare occasions even 3 fawns per year; however survival of these fawns is highly dependent on habitat conditions, predation, and climatic variables (Cantu and Richardson 1997, Heffelfinger 2006).

Mountain lion (*Puma concolor*) has been identified as the primary predator for adult mule deer (Leopold 1959, Alvarez-Cardenas 1994, Lawrence R.K. 2004, Mellink 2005, Heffelfinger 2006, Martinez-Garcia 2010). However, when habitat conditions present poor fawning cover, coyotes (*Canis latrans*) can predate a substantial amount of fawns (Ballard et al. 2001). Predators with less impact on populations can include bobcats(*Lynx rufus*), and golden eagles (*Aquila chrysaetos*), among others (Mellink 2005).

HABITAT AND NUTRITION

Habitat is defined by 4 different, interrelated requirements: cover, food, space, and water (Fulbright and Ortega-S 2006). In free-ranging populations, providing suitable habitat should be the prioritized objective, considering this has been one of the main causes for the decrease in their distribution. Habitat use and selection varies depending on its availability. Mule deer in the Chihuahuan Desert have shown preference for habitat presenting a higher density and higher diversity of vegetation, characteristics that are naturally present in xeroriparian areas; habitats with lower diversity and density are used to a lesser extent (Sanchez-Rojas and Gallina 2000, 2005, Lozano-Cavazos 2003).

Mule deer are considered selective feeders, as smaller-bodied ruminants they consume forage with concentrated and more digestible nutrients (Cantu and Richardson 1997, Kie and Czech 2000, Heffelfinger 2006). The plant species consumed by mule deer can be classified as browse, forbs, and grasses or others. Mule deer in the Chihuahuan Desert have been identified as primarily browsers in several studies (Anderson et al. 1965, Boeker et al. 1972, Krausman 1978, Leopold and Krausman 1987). However, the use of the different forage types, and species within, will vary among individuals by season, and availability. The Chihuahuan Desert receives most of its annual precipitation during the summer, allowing for the production of nutrient rich forbs. For this reason, the use of forbs will increase during the summer months when enough precipitation is received (Heffelfinger 2006).

In the Chihuahuan Desert, precipitation is one of the most density-independent factors that affect mule deer growth, development, fecundity, demography, and habitat use. (Walser 2006, Esparza-Carlos et al. 2011). When precipitation is sufficient, it allows for forage production and diversity to occur throughout the landscape, facilitating the use of or areas that in years with lesser precipitation do not meet the conditions to satisfy requirements of mule deer (Esparza-Carlos et al. 2011). This is not to be confused with increased movements by mule deer. Movements can decrease in mule deer when resources are more readily available; it is their distribution throughout the landscape that is positively affected with precipitation, allowing for mule deer to select vegetation type not only by forage availability but by predation risk and other factors (Esparza- Carlos et al. 2011). During years with limited precipitation, use of habitat is intensified in areas that present higher production of forages required by mule deer, whereas, areas that may present lower productivity can be avoided (Esparza-Carlos et al. 2011). Distance to water, for example, can be selected for when resources are available at closer distances; however, when food is scarce, mule deer seem to oversee the energy spent in order to fulfill their foraging requirements (Esparza-Carlos et al. 2011). The need of free water is of utmost importance during extended drought periods. In order better distribute the use of habitat by mule deer, water sources are recommended to be no more than 4.8 km apart (Brownlee 1979, Dickinson and Garner 1979), being that deer move 2.4 km to water (Wood et al. 1970).

Management practices should target plant productivity and diversity increase in order to provide optimal habitat conditions. Most rangelands in Mexico are primarily utilized for livestock production. Grazing can be beneficial or detrimental for mule deer habitat (Cantu and Richardson 1997). The most common mistake in livestock management practices is overutilization of available forage. Overutilization or excessive stocking rates often result in direct competition between livestock and wildlife. Moreover, in arid environments, recovery from overgrazing can be timely compared to the short time that it takes for overgrazing to impair forage production.

DENSITY AND MOVEMENTS

Mule deer density can be defined as the number of mule deer, per unit of area at a point in time (Anthony et al. 2006, Heffelfinger 2006). Deer densities constantly fluctuate due to the mobility of animals making density estimates vary throughout the Chihuahuan Desert landscape. Mule deer density has been estimated in several areas of the Chihuahuan Desert (Howard 1966, Wood et al. 1970, Philiips and Hanselka 1975, Brownlee 1979, Hobson 1990, Sanchez Rojas and Gallina 2000*a*,*b*, Bone 2003*a,b*). With the highest density estimate of 34 deer/km^2 (Phillips and Hanselka 1975) and the lowest of <1 deer/km^2 (Sanchez-Rojas and Gallina 2000), the variability is far too great to make any inferences of what a sound population density would be. Densities will vary constantly due to fluctuating populations, differences in vegetative composition, season, and many other factors (Heffelfinger 2006).

Home range is defined as the area included in the daily, seasonal, and annual movements of an individual animal (Bolen and Robison 2003) to meet its need for food, cover, water, and social interactions (Heffelfinger 2006). Mule deer movements are affected by season, sex, age, climatic factors, resource availability, and other factors. Reported home ranges for mule deer in the Chihuahuan Desert vary from 5–13 km^2 (Dickinson and Garner 1979, Wampler 1981, Lawrence et al. 1994, Gallina et al. 1998, Martinez-Garcia 2010).

Males will establish larger home ranges closer to- and during the rut as they separate from their bachelor group in the fall in search of females ready to breed. The success of encountering mates will affect the size of the established home range.

Females on the other hand usually separate from their groups during the summer when the fawning season gets closer and they become ready to drop their fawns (Heffelfinger 2006). The size of their home range or the shift of their home range may vary depending on their ability to find the correct conditions for success of their offspring. For this reason, precipitation is especially important late spring and early summer for fawn survival; whereas, winter rainfall is important for population abundance (Walser 2006).

TRANSLOCATIONS

The change in perspective of landowners viewing mule deer now as an economical asset instead of just as a part of the landscape has increased the desire of landowners to reestablish extirpated populations. This change of view has resulted in reintroduction efforts throughout the historical range of mule deer. Reintroductions in Mexico have been reported in the states of Zacatecas, Nuevo Leon, and Coahuila. Translocation is defined as the transport and release of animals into areas where the species occurred or presently occurs (Nielson 1988). The success of translocations can be easily evaluated by a simple question: did deer release result in the establishment of a local population in the release area? Hard release was defined by Nielson (1988) as the transportation from the capture site to the release areas, and the immediate and unassisted release into the new environment. In many cases, transport and hard release of animals will result in elevated dispersal distances, longer acclimation periods, and low survival of translocated animals.

Mule deer translocations are a significant time and monetary investment for landowners and conservation enterprises. New alternatives have been attempted to increase the success of translocations. Soft-releasing translocated animals has been widely practiced for several species, however, these practices have been rarely documented (Martinez Garcia 2009). Soft release refers to the capture and transport of animals into a holding pen in the release area, and allowing animals voluntary release after an acclimation period (Nielson 1988). Soft release has been reported to increase fidelity to the release site (Parker et al. 2008) as well as their survival by allowing them to acclimate to their new environment.

Hawkins and Montgomery (1969) reported mortality of 68% of translocated white-tailed deer during the first 6 months of their study after hard releasing them into their new environment. Similarly, Martinez Garcia (2009) reported 55% of hard released deer died within the first 2 months of his study. I found (Chapter 1) a mortality of 65% of hard released mule deer in 2008. Moreover, Hawkins and Montgomery (1969) reported deer hard released on the same release site dispersed separately. Martinez Garcia (2009) also reported individualistic dispersal of mule deer in the Chihuahuan Desert following hard release.

Movements and home ranges are not affected by the release method used when translocating ungulates (Hawkins and Montgomery 1969, Parker 2008, Martinez-Garcia 2009, Ortega-Sanchez; Chapter 1), however, dispersal distance from the release site can be significantly reduced when utilizing soft release method. Moreover, soft release shows to have an outstanding impact on survival of translocated animals.

Martinez Garcia (2009) reports 7% mortality of soft released deer (1 event of human-related predation), and none of this percentage is related to natural predators.

The acclimation period can be variable. Parker et al. 2008 suggested a minimum of 30 days in the holding pens for translocation of Florida Key deer. However, knowing the importance that forage availability and quality plays in movements of mule deer; holding deer until good habitat conditions are present may serve the purpose of further reducing dispersal of translocated animals.

Other practices that can aid the fidelity of translocated mule deer to their release site is the placement of supplemental feed. During the acclimation period, mule deer can be encouraged and taught to consume supplemental feed, allowing them to more easily fulfill their nutritional requirements if habitat conditions diminish. It is important to keep in mind that when habitat conditions are optimal, the need for supplemental feed can be null. Feeding when not necessary can become a very expensive and infeasible activity.

Soft release is a useful practice; however, the economic investment of building holding pens and feeding the deer during their acclimation period can seem infeasible for landowners. It is important to consider that if I priced the cost of transportation, capture, permits and additional expenses involved in translocating mule deer. The efficacy of this method on maintaining populations alive and reducing dispersal help prove its feasibility.

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