THE ROLE OF PARASITES, DISEASES, MINERAL LEVELS, AND LOW FAWN SURVIVAL IN A DECLINING PRONGHORN POPULATION IN THE TRANS-PECOS REGION OF TEXAS

A Thesis

By

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ABSTRACT

Since the late 1980s, pronghorn populations of west Texas have been in a steady decline. Texas Parks and Wildlife Department's (TPWD) 2012 surveys showed that the population was estimated at 2,751 animals, a 75-year low for the region. In 2009, a study was initiated to determine some of the leading causes for the recent decline in this region, including prevalence of diseases, mineral concentrations, parasites, and fawn survival. I found an average prevalence of titers for blue tongue virus (BTV) to be 97% and 92% for epizootic hemorrhagic disease (EHD) in 2010 and 2011, respectively. Because trace mineral levels (e.g., copper and selenium) have also been tied to productivity in pronghorn, I compared mineral levels between the Trans-Pecos and Panhandle. Copper serum levels were the same between regions ($P = 0.199$), but copper liver levels ($P = 0.002$), and selenium levels were different ($P < 0.001$). I also investigated the roles of parasites and predation as a limiting factor for pronghorn production in the Trans-Pecos. I found a difference when comparing *Haemonchus* worm counts ($P = 0.041$) and fecal egg counts ($P < 0.001$) between regions (Trans-Pecos, Panhandle). In 2011, surveys showed some areas to have fawn crops as low as 0% (0 fawns: 100 does), with a Trans-Pecos average at 10%. In 2012, TPWD surveys indicated that the fawn crops averaged about 16% Trans-Pecos wide. I conducted a pronghorn fawn survival study to determine major causes of mortality. Predation was the major cause of mortality in both 2011 and 2012. Bobcat (*Lynx rufus*) predation accounted for 32%, unknown predation accounted for 28%, and coyote (*Canis latrans*) predation accounted for 24% of all mortalities. Marginal mineral levels, high *Haemonchus* loads, and high predation on pronghorn fawns appear to be having a negative impact on pronghorn populations in the Trans-Pecos.

DEDICATION

To my wife, Kayla Weaver, son, Jaxon Weaver, and parents, Ernie and Vicki Weaver for your amazing love, sacrifice, and support, that allowed me to follow my dreams.

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I: INTRODUCTION

Historic distribution of pronghorn (*Antilocapra americana*) in Texas included most areas west of the 97th meridian (Figure 1.1A) which accounted for approximately two-thirds of the state (Buechner 1950). Presently, pronghorn are now limited to the Panhandle, Trans-Pecos, and portions of the Rolling Plains ecoregions (Figure 1.1B) (Gray 2012). Pronghorn populations have not only been reduced in distribution but also in population size. Aerial surveys conducted by Texas Parks and Wildlife Department in the Trans-Pecos in the summer of 2012, revealed populations numbers had reached an 75-year low with an estimated 2,751 pronghorn (Gray 2012). As recently as 1987, pronghorn populations were estimated to be 17,226 animals in the Trans-Pecos. Precipitation has been tied to productivity in pronghorn for this region, and can explain most of the changes in pronghorn population trends (Simpson et al. 2006). In 2009 and 2010, the Trans-Pecos had favorable conditions due to well-timed precipitation, but populations continued to plummet. Since precipitation was not seen to be the issue regarding the pronghorn decline, research was conducted to determine the role other factors were having on pronghorn populations. Diseases, mineral levels, parasites, and pronghorn fawn survival were deemed to be possible reasons for the decline.

Diseases such as blue tongue virus (BTV) and Epizootic Hemorrhagic Disease (EHD) have been known to cause large die-offs in other western states (Thorne et al. 1988). Pronghorn populations sampled in Arizona showed that 78.5% of pronghorn

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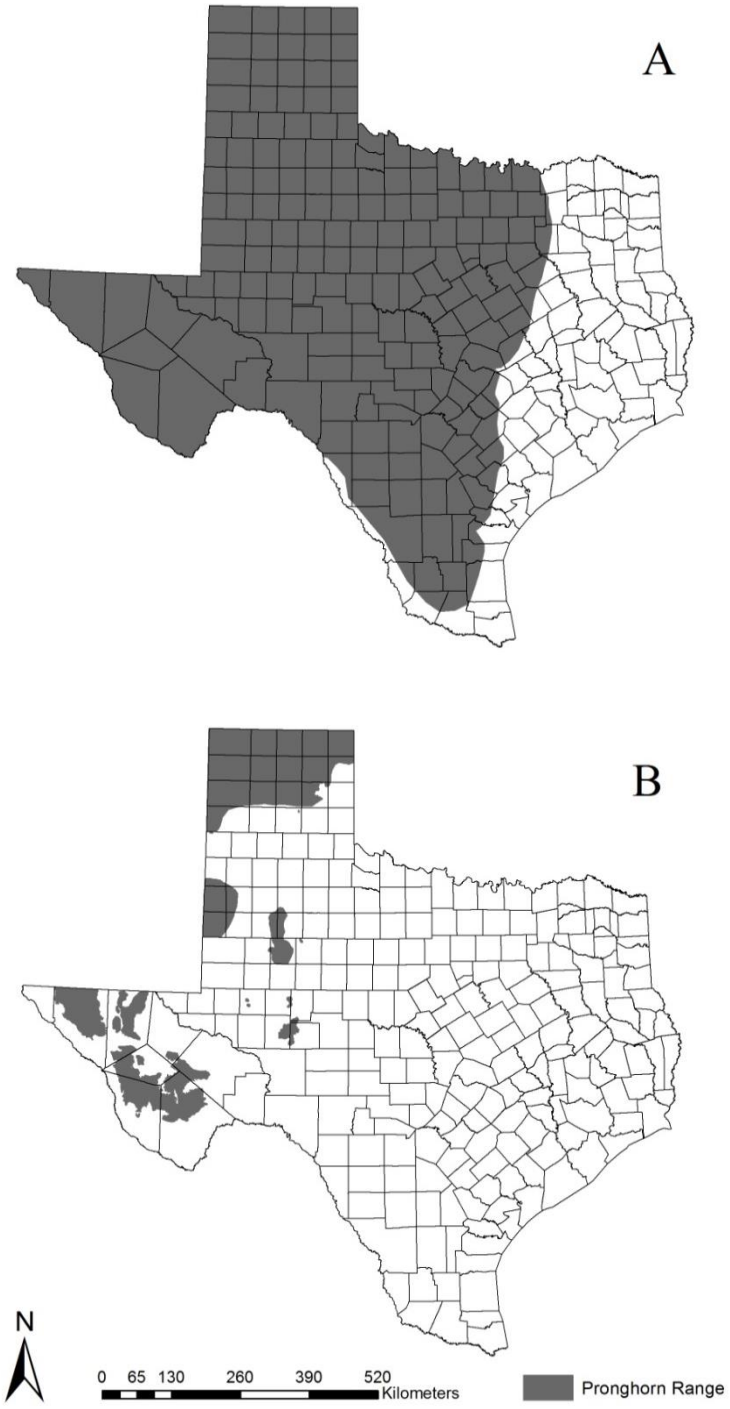

Figure 1.1 Historic (A) and current (B) pronghorn distribution in Texas, USA. (Gray 2012).

tested had been exposed to hemorrhagic disease (Heffelfinger and Olding 1996, Heffelfinger et al. 1999). This is evidence that pronghorn populations in Arizona and possibly other southern populations have a higher tolerance to hemorrhagic disease, which decreases the chance of high mortality rates (O'Gara 2004*c*).

There is also little known about effects of trace minerals in pronghorn and what problems are caused by deficiencies. Pronghorn populations with higher concentrations of copper and selenium have been shown to have higher production (O'Gara 2004*a*). Dunbar et al. (1999) reported marginal levels for copper and selenium in both adults and fawns in a declining pronghorn population in Oregon. Zimmerman et al. (2008) found that copper influenced the production of some free-ranging ruminants. Puls (1994) and Miller et al. (2001) reported copper deficiencies to cause enzootic ataxia, weight loss, infertility, anemia, diarrhea, depressed growth, heart failure, skeletal defects and increased susceptibility to infectious diseases. White muscle disease is one of the major effects of selenium deficiencies, which can lead to death (Flueck and Smith-Flueck 1990). Since pronghorn do not do well in captivity, normal levels of trace minerals are still unclear at this time and most comparisons are done between domestic animals (Dunbar et al. 1999).

Haemonchus was found in pronghorn from the Trans-Pecos region in the late 1960s but this was not seen to be significant (Hailey 1968). Hailey (1968) concluded the dry climate of the Trans-Pecos helped limit the spread of parasites and diseases and were not thought to be of concern. *Haemonchus* is a very productive parasite that can have lethal effects on both domestic and wild ruminants, and can affect animals, populations,

and the industries depending on these animals (McGhee et al. 1981, Newton and Munn 1999). Adult *Haemonchus* worms ingest blood from wounds in the abomasum and lay eggs, which are then carried out of the host by defecation (Zajac 2006). *Haemonchus* can cause many problems to a host including, weakness, weight loss, anemia, and in many cases death (McGhee et al. 1981, Simpson 2000, Zajac 2006).

Fawn survival is critical for populations to thrive (Sievers 2004). Texas Parks and Wildlife Department has documented low fawn crops throughout the Trans-Pecos over the last several years (Gray 2012). Predation is usually the primary cause of pronghorn fawn mortality, which can have a greater impact in small populations (Beale and Smith 1973). Where there is a high nutritional plane, pronghorn populations can be very productive and breeding can begin as early as fawns (O'Gara 2004*b*). Fawn survival may be limiting population recovery for declining Trans-Pecos populations.

The recent decline of pronghorn in the Trans-Pecos is alarming and is not completely understood. In the Texas Panhandle, pronghorn populations are thriving and are used for comparison throughout this thesis. To better understand the recent decline and why these populations are continuing to struggle, I initiated a study in October 2009 to collect disease, parasite, and fawn mortality data on pronghorn populations in the Trans-Pecos. Specifically, I report on mineral levels and disease prevalence in Texas pronghorn (Chapter 2), *Haemonchus*-pronghorn interactions in Texas (Chapter 3), and fawn survival of pronghorn in the Trans-Pecos (Chapter 4).

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CHAPTER II: MINERAL LEVELS AND DISEASE PREVALENCE IN TEXAS PRONGHORN

Since the late 1980s pronghorn (*Antilocapra americana*) populations in the Trans-Pecos region of Texas have been on a steady decline (Gray 2012). In 2012, Texas Parks and Wildlife Department (TPWD) surveys documented a new 75-year low, with the population estimated to be 2,751 animals (Figure 2.1; Gray 2012). To monitor populations, TPWD surveys herd units that have been delineated by the department (Figure 2.2).

In states such as Wyoming, bluetongue virus (BTV) and epizootic hemorrhagic disease (EHD) can cause large die-offs and have a large impact on pronghorn populations (Thorne et al. 1988). In 1976, ≥ 3,200 pronghorn died during a bluetongue epizootic in eastern Wyoming (Thorne et al. 1988). Thorne et al. (1988) reported another BTV epizootic in northeastern Wyoming in 1984 where 300 pronghorn were known to die. Two captive pronghorn in Oregon also died due to EHD and/or BTV (Kistner et al. 1975). Samples tested in Arizona showed 78.5% of pronghorn tested positive for exposure to hemorrhagic disease (Heffelfinger and Olding 1997, Heffelfinger et al. 1999). This indicates that Arizona and possibly other southern populations can be exposed to hemorrhagic disease without experiencing high mortality rates (O'Gara 2004).

Positive titers for BTV and EHD have been reported for a variety of ungulates in west Texas. Pittman (1987) reported prevalence of BTV for mule deer (*Odocoileus hemionus*) at Black Gap WMA at 76.7%. On Sierra Diablo WMA, Waldrup et al. (1989)

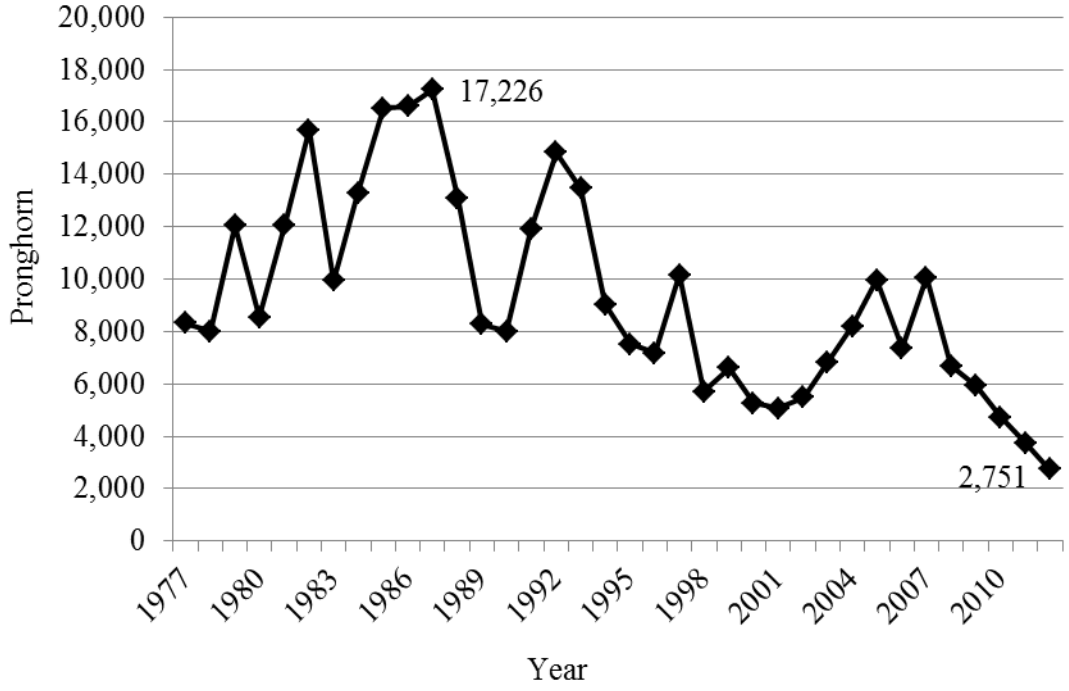

Figure 2.1 Estimated pronghorn population trends in Trans-Pecos, Texas, USA 1977-2012 (Gray 2012).

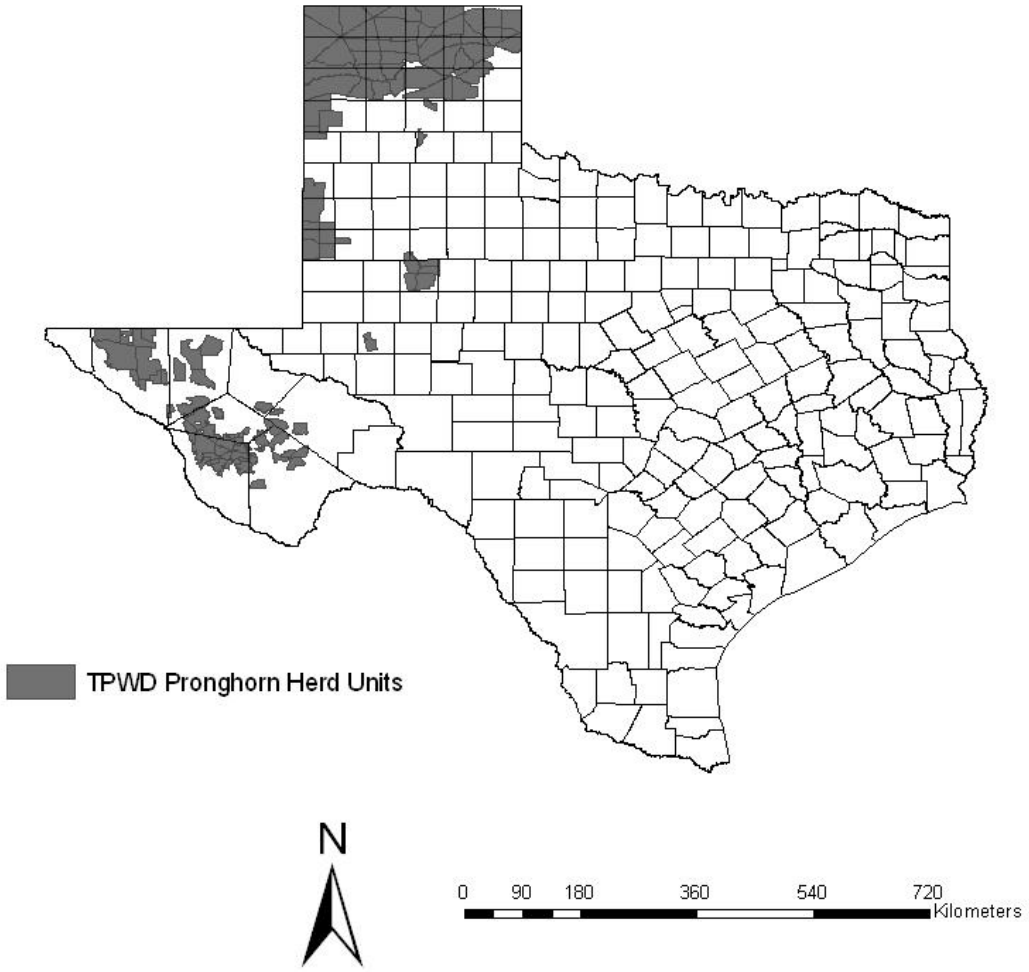

Figure 2.2 Pronghorn herd units, as delineated by Texas Parks and Wildlife Department, Texas, USA (Gray 2012).

reported prevalence of BTV and EHD in mule deer at 25% and 20%, respectively. Prevalence of BT and EHD antibodies for aoudad (*Ammotragus lervia*) on Big Bend Ranch State Park was at 56% and 33%, respectively (TPWD unpublished data). The prevalence of BTV and EHD in pronghorn in the Trans-Pecos region of Texas is unknown, however, in Arizona Heffelfinger and Olding (1997) found 78.5% of 288 hunter-harvested pronghorn tested positive for exposure to BTV.

Deficiencies in certain trace minerals can cause poor recruitment in populations and even cause death in some instances (O'Hara et al. 2001). Copper and selenium are very important in domestic ruminants and deer populations. There is very limited data on the importance and the effects of trace minerals in pronghorn. Normal levels of trace minerals are generally not known for pronghorn; therefore, they are compared to livestock and other pronghorn populations (Stoszek et al. 1978). O'Gara (2004) reviewed several studies on copper and selenium levels in pronghorn and concluded that in general the most productive herds had the highest levels of these trace elements.

Copper levels are tied to productivity in some free-ranging ruminants (Zimmerman et al. 2008). Copper deficiencies in deer cause enzootic ataxia, weight loss, and infertility (Puls 1994). Copper deficiencies can cause many other disorders including anemia, diarrhea, depressed growth, heart failure, skeletal defects, and increased susceptibility to infectious diseases (Miller et al. 2001). Dunbar et al. (1999) evaluated

the health of a declining pronghorn population in Oregon and concluded that both copper and selenium levels were marginal.

Selenium levels have also been tied to infertility in small ruminants. Selenium deficiency in domestic ruminants is largely associated with muscular degeneration, reproductive problems, and illthrift (Flueck and Smith-Flueck 1990). White muscle disease is most common and can cause death, especially in young (Flueck and Smith-Flueck 1990). A selenium deficiency was suspected by Starkley et al. (1982) to be involved in lowered reproductive performance of Roosevelt elk (*Cervus elaphus roosevelti*). Roosevelt elk are found on the coastal Pacific Northwest, which is an area known to be deficient in selenium where domestic livestock require selenium supplementation (Starkley et al. 1982). Selenium deficiency causes lowered fertility of adults and high mortality of young (Church and Pond 1978).

There are many known factors that affect pronghorn populations and other wild ungulates. I initiated a study to determine the prevalence of BTV and EHD, and to document the levels of selenium and copper in pronghorn from the Trans-Pecos region. I predicted (1) that pronghorn in the Trans-Pecos would have a high prevalence of BTV and EHD titers, and (2) would exhibit marginal levels of the trace minerals copper and selenium.

STUDY AREA

The study area consisted of 7 sampling units in the Trans-Pecos region, 1 sampling unit

in the western Edwards Plateau Ecoregion, and also sampling 2 units in the northwest and northeast Texas Panhandle.

Trans-Pecos

The Trans-Pecos is a highly diverse landscape, which contains a wide variety of habitat types and natural resources. The Trans-Pecos region is approximately 7.3 million ha and is located in the Chihuahuan Desert Biotic Province. The Trans-Pecos is made up of 9 counties that are bordered by the Rio Grande, New Mexico, and the Pecos River (Hatch et al. 1990). Elevation ranges from 762 in the low grasslands to 2,667 in the scattered desert islands. Basins usually receive 20-30 cm of annual precipitation, whereas the higher elevations receive 30-46 cm. Soils vary throughout the region with rocky soils on mountains and hills, gravelly soils in the lowlands, and sandy soils in the flats and desert washes (Harveson 2006). Pronghorn habitat is generally described as low-rolling, wide open, expansive grasslands or shrub steppes (O'Gara and Yoakum 1992). Within the Trans-Pecos, pronghorn are directly associated with the Desert Grassland Biotic District (Buechner 1950).

Vegetation types common in the study area included yucca (*Yucca* spp.) savannahs, grama (*Bouteloua* spp.) grasslands, creosote (*Larrea tridentata*) shrublands (Canon and Bryant 1997) and tobosa (*Pleuraphis mutica*) grasslands. Land use practices vary across the region, but most rangelands are used for agricultural purposes (livestock grazing or wildlife enterprises; Harveson 2006). The 7 sampling units pronghorn samples were taken from in the Trans-Pecos consisted of Culberson, Hudspeth, Marathon, Marfa

Northeast, Marfa Northwest, Marfa Southeast, Marfa Southwest and 1 unit from outside the Trans-Pecos: the western Edwards Plateau sampling unit (Figure 2.3).

Panhandle

The northwest Panhandle lies within the High Plains region of Texas and encompasses approximately 8 million ha of the Great Plains eco-region (Keleher 2010). Hatch et al. (1990) reported that about 60% of the area is cropland, half of which is irrigated. The region consists of a relatively high and level plateau of sandy to heavy, dark calcareous clay soils over a layer of caliche known as the Caprock Escarpment (Keleher 2010). The Canadian River runs through the middle of the plateau and has rough riparian topography associated with it. Elevation in the High Plains ranges from 914-1,371 m and receives 38-53cm of precipitation annually (Keleher 2010). The vegetation of the High Plains is described as a mixed-grass plains, short grass high plains, shinnery oak grasslands, and mesquite grasslands (Hatch et al. 1990).

The Northeast Panhandle is part of the Rolling Plains, which compromises 9.7 million ha. This region is very similar to the western Panhandle, largely due to the extent of agriculture in the area. Around two-thirds of the Rolling Plains is used for either cropland or rangeland (Hatch et al. 1990). Topography is flat to rolling with elevations of 243-914 m. Average annual precipitation ranges from 56-76 cm; most rainfall occurs in May and September (Keleher 2010). The Rolling Plains is described with tall and mid-grasses with increasing shrub species by Hatch et al. (1990). The areas I sampled from in the Panhandle were the Northeast and Northwest meta-herd units (Figure 2.3).

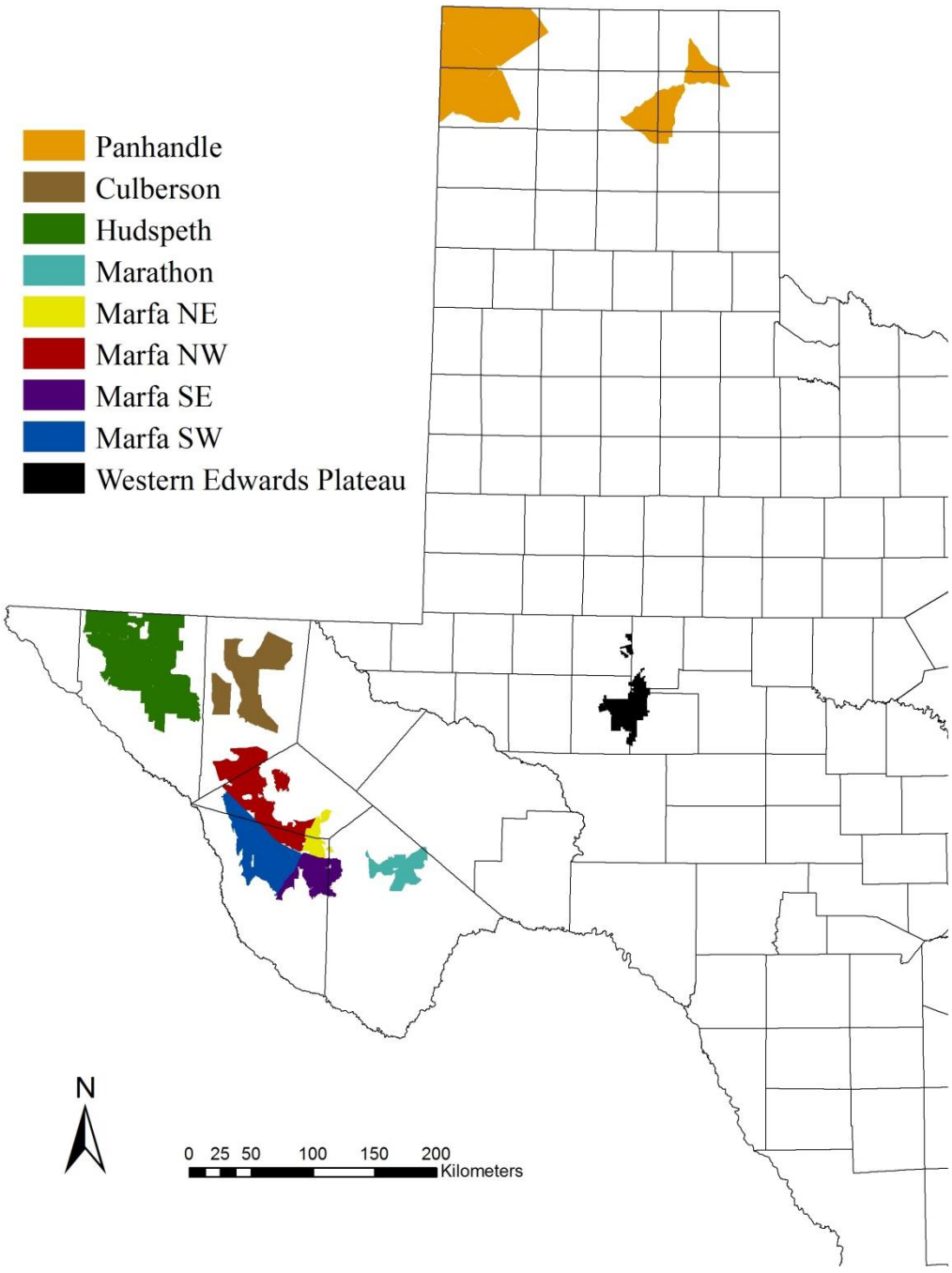

Figure 2.3 Pronghorn meta-herd units in Texas as delineated by Texas Parks and Wildlife Department for disease analysis.

METHODS

Trans-Pecos Sampling

Pronghorn were sampled during the 9-day, buck only, hunting season using hunter harvested animals to evaluate mineral levels (copper and selenium) in blood and liver samples. The blood was also tested for BTV and EHD.

Upon harvest, blood samples were collected from pronghorn via cardiac puncture in non-additive tubes and then transported to Sul Ross State University (SRSU). Within 24 h of collection, blood was centrifuged and serum samples were extracted and frozen. Sera were analyzed by the Texas Veterinary Medical Diagnostic Laboratory (TVMDL) in College Station, Texas. A measurement of copper (Cu), as well as the presence of antibodies against BTV and EHD were analyzed using serum. To test for copper levels in serum, TVMDL used Flame Atomic Absorption Spectrometry (FAAS). Using this method, either an air/acetylene or a nitrous oxide/acetylene flame is used to evaporate the solvent and dissociate the sample into its component atoms. When light passes through the cloud of atoms, the atoms of interest absorb the light from the lamp. This is measured by a detector, and used to calculate the concentration of that element in the original sample (Principle of atomic absorption 2013). To test for BTV and EHD, the lab used 2 different tests known as a Polymerase Chain Reaction (PCR) and an agar gel immunodiffusion (AGID). A PCR focuses on a segment of DNA and makes billions of copies. The method relies on thermal cycling, and short DNA fragments known as primers, which enable selective and repeated amplification (Genetics Home Reference 2013). An AGID is used to detect antibodies against selected bacteria and viruses. An

AGID was used to detect anti-BTV and EHD antibodies. Since 1982, the test has been the standard testing procedure for the international movement of ruminants. AGID is the passive diffusion of soluble antigens or antibodies toward each other leading to their precipitation in a gel matrix (Senne, USDA, APHIS, VS, and NVSL). Whole blood was collected in separate tubes and was used to measure selenium (Se) levels. To identify selenium levels the lab used a Graphite Furnace Atomic Absorption Spectrometry (GFAAS), which is very similar to the FAAS. Here the flame is replaced by a small, electrically heated graphite tube, which is heated to 3,000ºC to generate the cloud of atoms (Principle of atomic absorption 2013).

Tissue samples were taken from carcasses, labeled, and placed in clean plastic bags and stored on ice. Liver samples were sent with sera to TVMDL and tested for copper. The lab also used a FAAS test to detect copper levels in the liver as described above. Horn measurements, age estimates, and kidney indices were also taken in 2010 and 2011 from hunter harvested pronghorn (Appendix A).

Panhandle Sampling

In 2010, samples were taken from 20 harvested does during January. Does were harvested by TPWD for disease monitoring, post hunting season. Sampling and testing protocols were similar to the Trans-Pecos sampling effort, and were used for comparison.

In 2011, blood samples were collected from Panhandle pronghorn that were going to be translocated to the Trans-Pecos. All pronghorn were captured using the helicopter net-gun method as described by Firchow et al. (1986). Once animals were captured and

restrained, blood samples were drawn from the jugular vein. Two tubes were collected for serum testing and 1 tube was collected for whole blood testing. Blood was centrifuged and serum samples were again extracted and frozen. Identical blood tests were conducted to allow for comparison between the 2 populations. In addition to the other blood test, a standard Serum Augglutination Test (SAT) was conducted to test for Brucellosis. SAT is a serological test that is used to detect the presence of brucellosis antibodies.

Statistical Analysis-The program IBM SPSS Statistics 19 was used for all statistical analysis. All data was first tested for normality using Kolmogorov-Smirnov test of normality (Zar 2010). For the Trans-Pecos region, 3 years of data were compared between years, for serum copper, liver copper, and whole blood selenium levels. For the Panhandle region, 2 years of data were compared between years, for serum copper and whole blood selenium levels. The Panhandle region only had 1 year of samples for liver copper levels; therefore, comparisons between years were not possible. All 3 variables (serum copper levels, liver copper levels, whole blood selenium levels) were compared across regions (Trans-Pecos, Panhandle) using a *t*-test. An analysis of variance (ANOVA) was used to compare serum copper levels and whole blood selenium levels across years for the Trans-Pecos. A t-test was used for comparison for the Panhandle since there were only 2 years of data for serum copper and whole blood selenium levels. A Tukey's HSD post hoc test was then used to compare years when a difference was detected. The liver copper levels were non-normal; therefore, nonparametric tests were used for comparisons (Conover and Iman 1980). A Kruskal-Wallis test for independent samples was used to compare between years for all liver copper levels for the Trans-

Pecos region (Zar 2010). A Mann-Whitney U test for independent samples was used to compare liver copper levels across region, only for the year (2010) when both regions were sampled.

RESULTS

Trans-Pecos-I collected 102 samples from hunter-harvested pronghorn in October of 2009, 95 samples in 2010, and 49 samples in 2011 to evaluate the occurrence of BTV, EHD, and copper and selenium levels. All samples collected in the Trans-Pecos were bucks harvested during the 9-day hunting season.

Testing for BTV and EHD was not conducted in 2009. The prevalence of BTV was 96% in 2010, and 100% in 2011. The prevalence of EHD was 92% in 2010, and 93% in 2011 (Table 2.1). Average copper levels from blood sera were 0.68 ppm (*SE* = 0.03) in 2009, 0.72 ppm (*SE* = 0.02) in 2010, 0.84 ppm (*SE* = 0.03) in 2011. Average copper levels from the liver in 2009 were 7.80 ppm (*SE* = 0.37), 8.56 ppm (*SE* = 0.37) in 2010, and 7.91 ppm (*SE* = 0.41) in 2011. Average selenium levels from whole blood averaged 133.80 ppb (*SE* = 9.27) in 2009, 174.06 ppb (*SE* = 8.86) in 2010, and 212.10 ppb (*SE* = 14.88) in 2011 (Table 2.1).

Panhandle-Samples were collected in January 2010 from 20 harvested pronghorn throughout 5 different herd units in the Panhandle. Average copper levels from the liver averaged 10.41 ppm (*SE* = 0.44) and copper levels from blood samples averaged 0.40 ppm (*SE* = 0.03). Average selenium levels from blood samples averaged 164.4 ppb (*SE* = 12.80).

Table 2.1 Average disease and mineral levels from hunter-harvested pronghorn taken from Trans-Pecos, Texas, USA, 2009-2011.

	2009 (n = 102)	2010 (n = 95)	2011 (n = 49)
EHD Prevalence (%)	-	92	93
BTV Prevalence (%)	-	96	100
Cu Liver (ppm)	7.8	8.56	7.91
Cu Serum (ppm)	0.68	0.72	0.84
Se Blood (ppb)	133.80	174.06	212.10

In February 2011, I collected blood samples from 200 captured pronghorn that were to be translocated to the Trans-Pecos. Blood was drawn and results were provided from almost all animals captured in February 2011 (n = 195 for Cu; n = 196 for Se). The prevalence of BTV was 87%, whereas the prevalence of EHD was 50.5% (Table 2.2). Average copper and selenium levels were 0.74 ppm (SE = 0.01) and 208.43 ppb (SE = 3.15), respectively. In addition, 198 samples were tested for brucellosis in 2011 with all resulting in negatives.

Statistical Analysis- When comparing serum copper levels across years (2009, 2010, 2011) for the Trans-Pecos there was a significant difference ($P < 0.001$, $F = 8.227$, $df = 2$). Serum copper levels in 2011 were different than levels in 2009 ($P < 0.001$) and levels in 2010 ($P = 0.006$). There was no difference in serum copper levels between 2009 and 2010 ($P = 0.346$). For the Panhandle, there was also a difference ($P < 0.001$, $t = -11.196$) between 2010 and 2011 serum copper levels. Serum copper levels were also compared between regions (Trans-Pecos, Panhandle), but no difference was documented ($P = 0.199$, $t = 1.287$).

Whole blood selenium levels were compared across years (2009, 2010, 2011) for the Trans-Pecos and there was a difference ($P < 0.001$, $F = 10.19$, $df = 2$). Selenium levels for 2009 were different than levels in 2010 ($P = 0.028$), and levels in 2011 ($P < 0.001$). Selenium levels for 2010 were also different from levels documented in 2011 ($P = 0.035$). The Panhandle also had a difference ($P < 0.001$, $t = -3.588$) between years (2010, 2011). When comparing whole blood selenium levels between regions (Trans-Pecos, Panhandle) there was a difference ($P < 0.001$, $t = -4.767$).

Table 2.2 Average disease prevalence and mineral levels from hunter-harvested and captured pronghorn taken from Panhandle, Texas, USA, 2010-2011.

Averages	2010_a (n = 20)	2011_b (n = 200)
EHD Prevalence (%)	-	50.5
BTV Prevalence (%)	-	87
Cu Liver (ppm)	10.41	-
Cu Serum (ppm)	0.40	0.74
Se Blood (ppb)	164.4	208.43

[a] Harvested
[b] Captured

Liver copper levels were only compared across years for the Trans-Pecos since only 1 year of samples were collected from the Panhandle region. Liver copper levels were the same ($P = 0.433$, $X^2 = 1.675$, $Df = 2$) for all 3 years (2009, 2010, 2011) in the Trans-Pecos. When comparing liver copper levels across regions, levels were only compared for the year (2010) both regions were sampled. There was a difference ($P = 0.001$, $U = 527.5$) between regions when comparing liver copper levels in 2010.

DISCUSSION

BTV and EHD have affected pronghorn populations in other regions of the country and can be very detrimental to a population in some cases. Large die-offs were recorded in Wyoming, which were linked to BTV (Thorne et al. 1988). Kistner et al. (1975) found that BTV or EHD was the cause for 2 captive pronghorn to die in Oregon. Allen (1874) described the largest die-off of pronghorn between the Yellowstone and Missouri rivers during the summer of 1873, which could have been BTV. However, these diseases do not appear to be a major issue in pronghorn in Texas. I collected samples for 3 years in the Trans-Pecos and recorded a very high prevalence for BTV and EHD.

Based on my results, 98% of pronghorn in this region had come in contact with, and showed titers for BTV. I also reported 91% of pronghorn in this region showed titers for EHD. Antibodies for BTV and EHD are normally found at a higher prevalence in southern populations (O'Gara 2004). Stauber et al. (1980) tested 104 adults and 42 fawns in 3 populations in southeastern Idaho and found no reactors to BTV or EHD. Jochim and Chow (1969) performed a serological survey in 1963, he found evidence that 8 (8%) of

96 pronghorn from Wyoming and 34 (35%) of 97 pronghorn from Colorado had come in contact with BTV. Tests conducted in Nebraska, found evidence that 92 and 103 (27% and 30%, respectively) out of 339 pronghorn had positive tests for BTV and EHD (Johnson et al. 1986). In Arizona, 226 (78.5%) of 288 pronghorn tested positive to exposure to BTV (Heffelfinger and Oldin 1997, Heffelfinger et al. 1999). Pronghorn from the Trans-Pecos and other southern populations appear to have a higher prevalence of titers to BTV and EHD than do northern populations. Immunity may be implied by the presence of antibody titers (O'Gara 2004). The year I sampled for diseases in the Panhandle, I saw lower prevalence for EHD, where 50.5% of animals showed titers compared to the Trans-Pecos. The average prevalence for BTV was slightly lower in the Panhandle, where 87% of animals showed titers.

Selenium and copper are both important to pronghorn for overall health and reproduction (Flueck and Smith-Flueck 1990). Dunbar et al. (1999) reported that deficiencies of minerals are responsible for decreased animal condition, fertility, productivity, as well as increased mortality. When comparing mineral levels from pronghorn populations in the Panhandle to those populations in the Trans-Pecos, I concluded that copper levels in the liver and selenium whole blood levels were not the same. The Trans-Pecos region exhibited lower copper levels in the liver and selenium whole blood levels, which may be part of the reason this area is experiencing such low productivity. There is very little data available for normal blood and serum levels of wild ungulates so determining what these levels mean in pronghorn is very difficult (Dunbar et

al. 1999). Therefore, I cannot say that one population has high or low copper and selenium levels or if both populations are normal.

Normal levels of copper in the liver for sheep, cattle, and deer range from 25 to 100 ppm (Dunbar et al. 1999). Though both populations appear to be deficient in copper when compared to these numbers, the Panhandle population was higher than the Trans-Pecos region. Although, I only have 1 year (2010) of liver copper levels for the Panhandle, copper levels in the liver were considerably higher than the same year I collected samples in the Trans-Pecos. A normal level for copper serum for most ruminants is 0.7-1.2 ppm (Dunbar et al. 1999), which shows both regions appear to have marginal levels of copper. There was no difference between the pronghorn populations between regions (Trans-Pecos, Panhandle). Although normal levels of copper and selenium for pronghorn are unknown at this point, I believe that both the Trans-Pecos and the Panhandle regions exhibit marginal mineral levels in pronghorn.

This study was established to determine some of the leading factors causing a pronghorn decline in the Trans-Pecos. Minerals levels and diseases have both been known to cause pronghorn populations to decline. BTV and EHD both have larger impacts in northern populations where titers for these diseases are lower. Since pronghorn in the Trans-Pecos show a very high prevalence for BTV and EHD, I believe that this data places more emphasis on mineral levels and draws less attention to these diseases as major contributors to this population's decline.

Management Implications

Unlike other ungulates, little information is known about normal mineral levels in pronghorn since they do not do well in captivity, which is used to help establish baseline levels of trace minerals. Copper and selenium both play an important role in pronghorn production. Low mineral levels in animals could be a reflection of diet, since minerals levels are diet dependent. Diseases such as the BTV and EHD are both naturally occurring throughout much of pronghorn range. Pronghorn in the Trans-Pecos show very high prevalence for both diseases; therefore, these diseases have little effect on the population. Managers could supplement pronghorn with loose minerals and/or mineral blocks around waters and other areas pronghorn frequently use. Pronghorn have been known to use mineral supplements when they are available. Minerals are tied to productivity in pronghorn so making mineral supplements available for pronghorn could increase their health. Managers should also implement a conservative grazing plan and modify fences, which will allow pronghorn to move freely across the landscape and attain trace minerals from native vegetation. Any pronghorn mortalities found should be reported to state or local wildlife agencies, so proper testing and documentation can be handled and any diseases such as BTV and EHD can be managed.

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CHAPTER III: *HAEMONCHUS*-PRONGHORN INTERACTIONS IN TEXAS

Historically, pronghorn (*Antilocapra americana*) were distributed over approximately two-thirds of Texas including all areas west of the 97th meridian (Buechner 1950). Today pronghorn populations are restricted to the Chihuahuan Deserts (Trans-Pecos), High Plains, Southwestern Tablelands, and Edwards Plateau ecoregions (Gray 2012). Historically, the Trans-Pecos supported approximately 60–70% of the state's pronghorn, with numbers reaching a high of about 17,000 animals during the wetter years of the mid-1980s (Tarrant et al. 2010).

In 2008, following an 8-month drought in the Trans-Pecos, Texas Parks and Wildlife Department documented a significant die-off of adult pronghorn where an estimated 2,000–3,000 pronghorn succumbed in one of the most productive regions of west Texas (e.g., Marfa Plateau; Tarrant et al. 2010). Given the relationship between precipitation and pronghorn demography (Simpson et al. 2006), the 2008 die-off was not surprising. However, in 2009, biologists were not able to attribute the continued decline to precipitation-mediated variables alone. Specifically, the first half of 2009 brought timely and abundant precipitation, which based on population trend data would have been ideal habitat conditions with abundant forage (forbs and browse) and cover (perennial grasses) for population recovery (Tarrant et al. 2010). Unfortunately, pronghorn did not respond to the excellent habitat conditions and population productivity and abundance fell even further. A mean fawn:doe ratio of 13:100 was recorded with a population estimate of 6,000 animals (near record lows) in 2009 (Tarrant et al. 2010).

Haemonchus is one of the most highly prolific parasitic nematodes afflicting both domestic and wild ruminants (McGhee et al. 1981, Newton and Munn 1999). *Haemonchus* is known to cause deleterious effects to the animal, entire populations, and animal wildlife industry (McGhee et al. 1981, Newton and Munn 1999). As a prolific breeder, a single female worm produces about 10,000 eggs per day (Prichard 2001, Zajac 2006). This allows larvae to rapidly accumulate on pastures as the prepatent period (length of time between infection of host and parasite maturity) is between 17 to 21 days (Prichard 2001, Zajac 2006).

The life cycle of *Haemonchus* involves an adult female in the abomasum ingesting a blood meal and laying eggs daily that are subsequently passed in the host's fecal material (Zajac 2006). Fecal material provides the eggs protection from environmental conditions and optimal temperature and moisture for further development (O'Conner et al. 2006). As the first-stage larva forms and hatches from the egg, larvae feed on bacteria and undergo 2 molts before reaching the infective third larvae stage (L3; Zajac 2006). The optimal conditions for development of *Haemonchus* eggs into infective larvae occur at 23°C and 70% fecal moisture content, yet can still occur at a range between 10°C to 36°C (O'Conner et al. 2006, Zajac 2006). However, O'Conner et al. (2006) noted that development can be accelerated if temperatures and moisture content increased or decreased when conditions are less than optimal. Once L3 stage development is complete and in the subsequent presence of rain, larvae make their way out of the fecal material and migrate onto forage to be later ingested (O'Conner et al. 2006, Zajac 2006). L3 stage *Haemonchus* are considerably less susceptible to

unfavorable climatic conditions and this is attributed to their migratory behavior. The population size of *Haemonchus* on a pasture is considered much greater than the number of parasites within a single ruminant (Prichard 2001). As the infective larvae are ingested, *Haemonchus* molts once more into the L4 stage and shed their protective L3 stage larvae sheath in the abomasum.

Severe outbreaks of *Haemonchus* infection are most often reported to occur during warm summer rains, among young, non-immune animals, immunocompromised adult animals, or animals exposed to high levels of parasites (Zajac 2006). Because of the prevalence in many ruminants and reproductive success in tropical and sub-tropical areas, or regions with summer-dominant rainfall, *Haemonchus* encompasses an enormous environmental range of suitable habitat (O'Conner et al. 2006).

Although a majority of all grazing ruminants are infected with stomach worms, only sub-clinical and clinical effects of disease are observed under heavy worm burdens. Clinical signs of disease involve weight loss, diarrhea, "bottle jaw" (e.g., edema, or fluid accumulation under the jaw), protein loss across the gut wall, anemia, weakness, and death (McGhee et al. 1981, Simpson 2000, Zajac 2006). *Haemonchus* has been responsible for numerous infections on a wide variety of ruminants, commonly and most often reported in domestic ruminants such as sheep, goats, and cattle (McGhee et al. 1981, Lichtenfels et al. 1994, Zajac 2006). *Haemonchus* has also been documented in wild ruminants such as white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), and pronghorn (Allen et al. 1959, McGhee et al. 1981, Lichtenfels et al.

1994, Newton and Munn 1999). Bever (1957) described parasitism in pronghorn and field methods to measure the parasitic load. Research conducted during the late 1960s in the Trans-Pecos documented the presence of *Haemonchus* (Hailey 1968), but were not thought to be of concern. Investigators concluded the pronghorn herds were clean of parasites and diseases because of the dry climate, which helps to prevent the spread of diseases (Hailey 1968). Because *Haemonchus* is found in livestock and wildlife there is potential for cross-transmission.

The ability for *Haemonchus* to infect a wide variety of hosts with little geographic impediment allows for great genetic diversity, as well as a high rate of mutation (Prichard 2001). Furthermore, in combination with the use of a broad-spectrum and frequent use of chemical treatment, widespread resistance in *Haemonchus* populations to anthelmintics exists. Chronic problems in the sheep and goat industry have emerged because of the increased resistance of *Haemonchus* to wormers and other treatments. The sheep industry estimates a loss of >$100,000,000/year from the treatment of *Haemonchus* (Newton and Munn 1999).

Therefore, the infection of pronghorn in west Texas with *Haemonchus* poses a series of concerns for the population and future management. However, further research, monitoring, and investigation of host-parasite interaction is imperative to make sound decisions on methods of control or prevention to be utilized. I initiated a study to determine how *Haemonchus* interact with pronghorn and to better understand what effects this parasite has on pronghorn as the host. I wanted to document infection rates for

pronghorn in the Trans-Pecos and compare to other populations. I predicted (1) worm counts in the abomasums will be positively correlated to fecal egg counts, and (2) *Haemonchus* will be negatively correlated with pronghorn fawn recruitment in the Trans-Pecos.

STUDY AREA

In the Chihuahuan Desert (Trans-Pecos) ecoregion, pronghorn principally reside in the Chihuahuan Desert Grassland ecoregion, which ranges in elevation from 1,060–1,680 m and receives 25–46 cm of annual precipitation. Rainfall is from monsoonal events peaking during the months of July–September. The average growing season is about 190–240 days. Dominant plant species include black grama (*Bouteloua eriopoda*), blue grama (*Bouteloua gracilis*), and sideoats grama (*Bouteloua curtipendula*), bush muhly (*Muhlenbergia porteri*), beargrass (*Nolina arenicola*), tobosa grass (*Pleuraphis mutica*), and galleta (*Pleuraphis jamesii*) with scattered creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), acacias (*Acacia* spp.), yucca (*Yucca* spp.), and cacti (*Opuntia* spp.) (Griffith et al. 2007). Land use practices vary across the Trans-Pecos, but most rangelands are used for livestock grazing or wildlife enterprises (Harveson 2006). Seven disease sampling units have been delineated in the Trans-Pecos where I initiated surveillance (Figure 2.3).

Panhandle pronghorn populations are found in the High Plains and Southwestern Tablelands ecoregions with most occurring in the Canadian-Cimarron High Plains, Rolling Sand Plains, and Canadian-Cimarron Breaks ecoregions. These ecoregions are

characterized by short to mid-grass vegetation communities with plant species such as gramas, buffalograss *(Buchloe dactyloides*), bluestems (*Andropogon, Bothriochloa, Schizachyrium* spp.), sand dropseed (*Sporobolus cryptandrus*), Havard shin oak (*Quercus havardii*), sand sagebrush (*Artemisia filifolia*), yucca, mesquite (*Prosopis glandulosa*), skunkbush sumac (*Rhus trilobata*), and Chickasaw plum (*Prunus angustifolia*) being the most common. In addition, large areas of croplands dominate the landscape with a scattering of playa lakes. Elevations vary from 700-1,370 meters. Average rainfall is between 40-58 centimeters and is more bimodal than the Chihuahuan Desert ecoregion with the greatest amount of precipitation falling in the spring and fall months. The average growing season is from 170–200 days (Griffith et al. 2007, Keleher 2010).

METHODS

Trans-Pecos-I coordinated the collection of hunter harvested pronghorn samples with landowners, outfitters, and hunters across the region. Much of the ground work for this was done with the help of the local Texas Parks and Wildlife Department district biologists. In many cases, trained researchers accompanied hunters to ensure samples were taken properly. In 2009, 2010, and 2011 abomasum samples were collected from harvested pronghorn during evisceration. Upon evisceration, a string was used to tie off both ends of the abomasum. After knots were secured, the abomasum was dissected and removed from the body cavity. Abomasums were placed in clean plastic bags, labeled, and transported on ice to the lab. Upon arrival to the lab, abomasums were cut 2laterally and contents were rinsed carefully into a collection vessel. During 2009, abomasums were quantified using a sampling technique, where all the contents of an abomasum were

washed in a container using water. Contents of the wash were gently stirred and 200 ml of fluid content was collected off the surface. All worms were then counted in the 200 ml and that total was then extrapolated to the rest of the solution to estimate a total parasite load for that animal. In 2010 and 2011 a total count was applied to each abomasum to ensure accuracy. All nematodes found in the supernatant and abomasums were counted and stored in alcohol (or formalin) for species identification.

Fecal samples were extracted directly from the rectum of all hunter-harvested pronghorn. Eight to 12 pellets were placed in a plastic bag, stored on ice, and transported to the lab. If samples were stored longer than 24 h, they were vacuumed sealed, to help prevent eggs from hatching. Fecal samples were analyzed using the McMaster's fecal flotation technique as described by Burk and Rossano (2011) to determine the amount of nematode eggs/gram of feces.

To determine if parasite loads were negatively correlated with fawn recruitment as predicted, I compared worm counts to fawn crops, across each meta-herd unit using Spearman's rho correlation test for non-normal data (Zar 2009). Both worm loads and fawn crops were averaged across meta-herd units for comparison. I used worm load data from the fall and compared that to the TPWD fawn crop averages for the following spring (e.g., 2010 worm loads vs. 2011 fawn crops) (Gray 2012). Texas Parks and Wildlife Department flew aerial surveys during the months of June and July annually and this data was used to estimate fawn crops for the different meta-herd units.

Other wildlife species sampled in the Trans-Pecos.—In 2010, I was also able to collect samples from Barbary sheep (*Ammotragus lervia*), mule deer (*Odecoileus hemionus*), and cattle from the Trans-Pecos region. This allowed me to compare parasite loads in pronghorn to other ruminants within the same region.

Panhandle-Samples were collected in January 2010 from 20 harvested pronghorn does throughout 5 different herd units in the northeast and northwest Texas Panhandle. In February 2011, I collected fecal samples from 178 captured pronghorn that were later translocated to the Trans-Pecos.

Species Identification and Drug Resistance-Because a variety of nematodes are common in wild ungulates correct identification of *Haemonchus* may be suspect (O'Gara 2004). Therefore, I preserved samples of the parasitic community in formalin for identification by the USDA's Animal Parasitic Diseases Laboratory in Beltsville, Maryland. I sent samples to the lab where they used DNA and molecular data to compare *Haemonchus* found in Trans-Pecos pronghorn to other known species of *Haemonchus* (personal communication, Hoberg, USDA Animal Parasitic Disease Laboratory, Beltsville, MD).

To better understand the origin and possible host of *Haemonchus* spp., I sent fecal samples off to the University of Georgia's College of Veterinary Medicine to have the DrenchRite® Larval Development Assay (LDA) test performed (personal communication, R. Kaplan, The University of Georgia, College of Veterinarian Medicine, Department of Infectious Diseases, Athens, GA). LDA is an *in vitro* test for

the detection of anthelmintic resistance in the major gastrointestinal nematode parasites infecting small ruminants (sheep, goats, llama, alpaca, etc). LDA evaluates the resistance to benzimidazole (e.g., Valbazen, Panacur, Safeguard), levamisole (e.g., Totalon, Levasol, Prohibit), and avermectin/milbemycin (Ivomec, Cydectin). Nematode resistance to all drug classes listed above is tested for in each assay from a single pooled fecal sample. For LDA, nematode eggs are isolated from feces and placed into the wells of a microtiter plate containing growth media and anthelmintic. The concentration of anthelmintic required to block development of nematode larvae is related to the effectiveness of the drug in the animal.

Statistical Analysis-The program IBM SPSS Statistics 19 was used for all statistical analysis. All data was first tested for normality using Kolmogorov-Smirnov test of normality (Zar 2010). Worm counts and fecal egg count data were non-normal so nonparametric tests were used for analysis. A Spearman's Rho correlation test (Conover and Iman 1980, Zar 2010) was used to evaluate the relationship of worm counts in abomasums and fecal egg counts for 2 years (2010, 2011) in the Trans-Pecos region. A Spearman's Rho test was also used to evaluate the relationship between worm counts in abomasums and fawn crops (fawns/100 does) in the Trans-Pecos for 3 consecutive years (2009, 2010, 2011). An independent samples Kruskal-Wallis test (Zar 2010) was used to compare worm counts and fecal egg counts for the Trans-Pecos region across years. Pairwise comparisons were then used to determine which years differed for both worm counts and fecal egg counts. For the Panhandle region, only 1 year of worm count data was collected, so yearly comparisons were not possible. A Mann-Whitney U test

(Conover and Iman 1980) for independent samples was used to compare pronghorn fecal egg counts by season (Fall/Winter, Summer) for 2011 in the Panhandle region (Zar 2010). For comparisons of worm counts and fecal egg counts between regions (Trans-Pecos, Panhandle) an independent samples Mann-Whitney U test was used. When comparing worm counts and fecal egg counts of other species (Barbary sheep, mule deer) to pronghorn in the Trans-Pecos for 2010, independent samples Kruskal Wallis test was used. Pairwise comparisons were then used to determine which species differed. In the summer of 2011, fecal samples were collected from cattle and pronghorn in the Trans-Pecos and a Mann-Whitney U test for independent samples was used for comparison.

RESULTS

Trans-Pecos-I obtained 102 abomasum samples from pronghorn in 2009, 95 samples in 2010, and 49 samples in 2011. Average prevalence rate of barber pole worm was 94%, that is 201 of the 215 samples that were analyzed had barber pole worms. In 2009, the average number of worms/pronghorn was 551 (*SE* = 70.06) and ranged from 0 to 4,080 worms/animal. The average in 2010 was 268 (*SE* = 44.83) worms, which was 44% less than the average in 2009, but parasite loads still ranged from 0 to 3,145. In 2011, worm loads ranged from 0 to 2,507 and pronghorn averaged 381 (*SE* = 83.67) worms/animal (Table 3.1).

Fecal egg counts for 2010 and 2011 averaged 1,267 (*SE* = 190.33) and 1,053 (*SE* = 194.52) eggs/gram, respectively. Fecal egg counts for the summer of 2011 averaged 1,389 (*SE* = 260.68) eggs/gram and 167 (*SE* = 43.69) eggs/gram in the summer of 2012.

Table 3.1 Comparison of average number of *Haemonchus* worms and fecal egg count averages in Trans-Pecos and Panhandle, Texas, USA, 2009-2012.

Region	Species	*n*	Season-Year	Abomasum Worm Counts	Fecal Egg Counts-Eggs/Gram
Trans-Pecos	Pronghorn	89[c]	Fall-2009[d]	551	-
	Pronghorn	86[a], 91[b]	Fall-2010[d]	268	1,267
	Mule Deer	20[a], 18[b]	Fall-2010[d]	4	15
	Barbary Sheep	14[a], 13[b]	Fall-2010[d]	45	200
	Pronghorn	63[c]	Summer-2011[f]	-	1,389
	Cattle	15[c]	Summer-2011[f]	-	27
	Pronghorn	42[a], 45[b]	Fall-2011[d]	381	1,053
	Pronghorn	27[c]	Summer-2012[f]	-	167
Panhandle	Pronghorn	17[c]	Fall-2009[d]	90	-
	Pronghorn	20[c]	Summer-2011[f]	-	608
	Pronghorn	178[c]	Fall-2011[e]	-	117

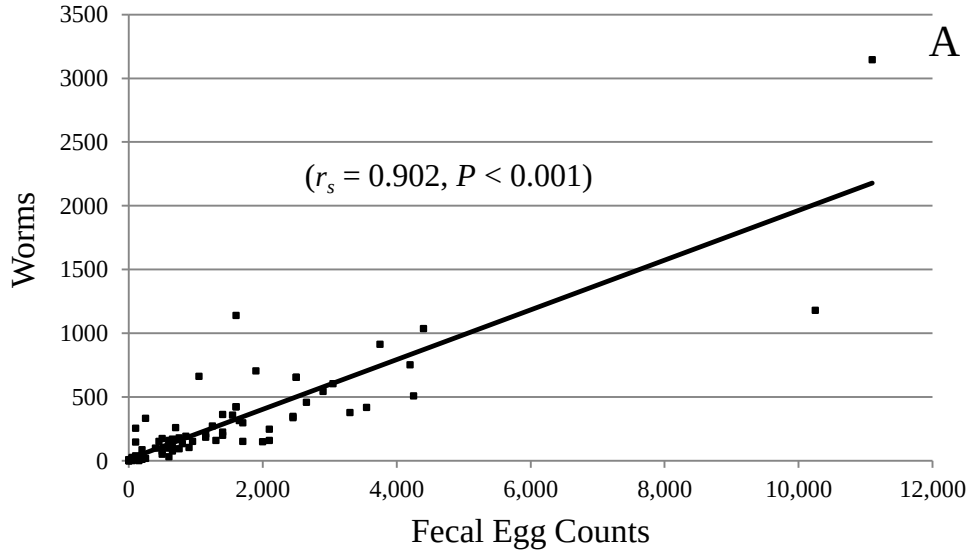
[a] Abomasum worm count sample size
[b] Fecal egg count sample size
[c] Sample size for both counts
[d] Hunter harvested samples
[e] Capture samples
[f] Field samples

Other wildlife species sampled in the Trans-Pecos.—Fifteen samples were collected from Barbary sheep in 2010, which averaged 45 (*SE* = 25.26) worms/abomasum, and the fecal egg counts averaged 200 (*SE* = 106.67) eggs/gram. Twenty-four samples were collected from mule deer, which averaged 4 (*SE* = 2.84) worms/abomasum with fecal egg counts averaging 15 (*SE* = 10.94) eggs/gram. A total of 15 fecal samples was collected from cattle from 3 different ranches and the fecal egg counts averaged 27 (*SE* = 10.76) eggs/gram.

Panhandle- In 2010, the average worm load was 90 (*SE* = 25.99) worms/pronghorn for the 20 does harvested in January. In 2011, fecal egg counts averaged 117 (*SE* = 28.93) eggs/gram for the captured pronghorn. During summer 2011, fecal samples were collected from pronghorn in the northern Panhandle and they averaged 608 (*SE* = 211.46) eggs/gram (Table 3.1).

Statistical Analysis-For the Trans-Pecos region worm counts and fecal egg counts were correlated in 2010 (r_s = 0.902, $P < 0.001$) and in 2011 (r_s = 0.915, $P < 0.001$) (Conover and Iman 1980) (Figure 3.1). Worm loads of fall 2009 were correlated to the fawn crops of spring 2010 (r_s = -0.865, P = 0.012), but were not correlated in subsequent years (Figure 3.2). I found insignificant correlations when comparing worm loads of fall 2010 to the fawn crops of spring 2011 (r_s = -0.143, P = 0.760), and when comparing worm loads of fall 2011 to the fawn crops of spring 2012 (r_s = -0.43, P = 0.397) (Conover and Iman 1980) (Figure 3.2).

In the Trans-Pecos, there was a difference (P = 0.002, X^2 = 12.608, Df = 2) in worm counts in pronghorn when compared across years (2009, 2010, 2011). Worm



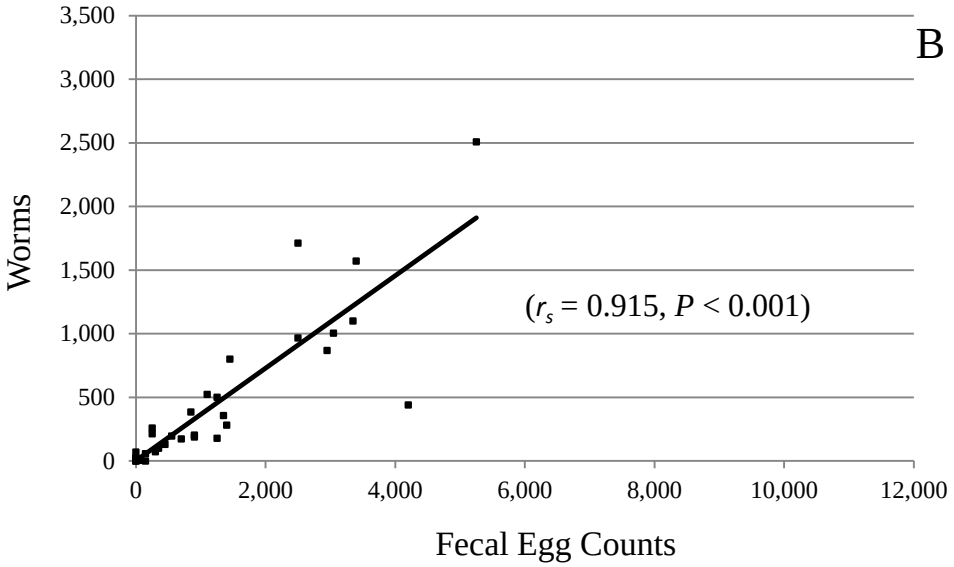


Figure 3.1 Relationship between *Haemonchus* worm counts in abomasums and fecal egg counts for 2010 (A) and 2011 (B) in Trans-Pecos, Texas, USA.

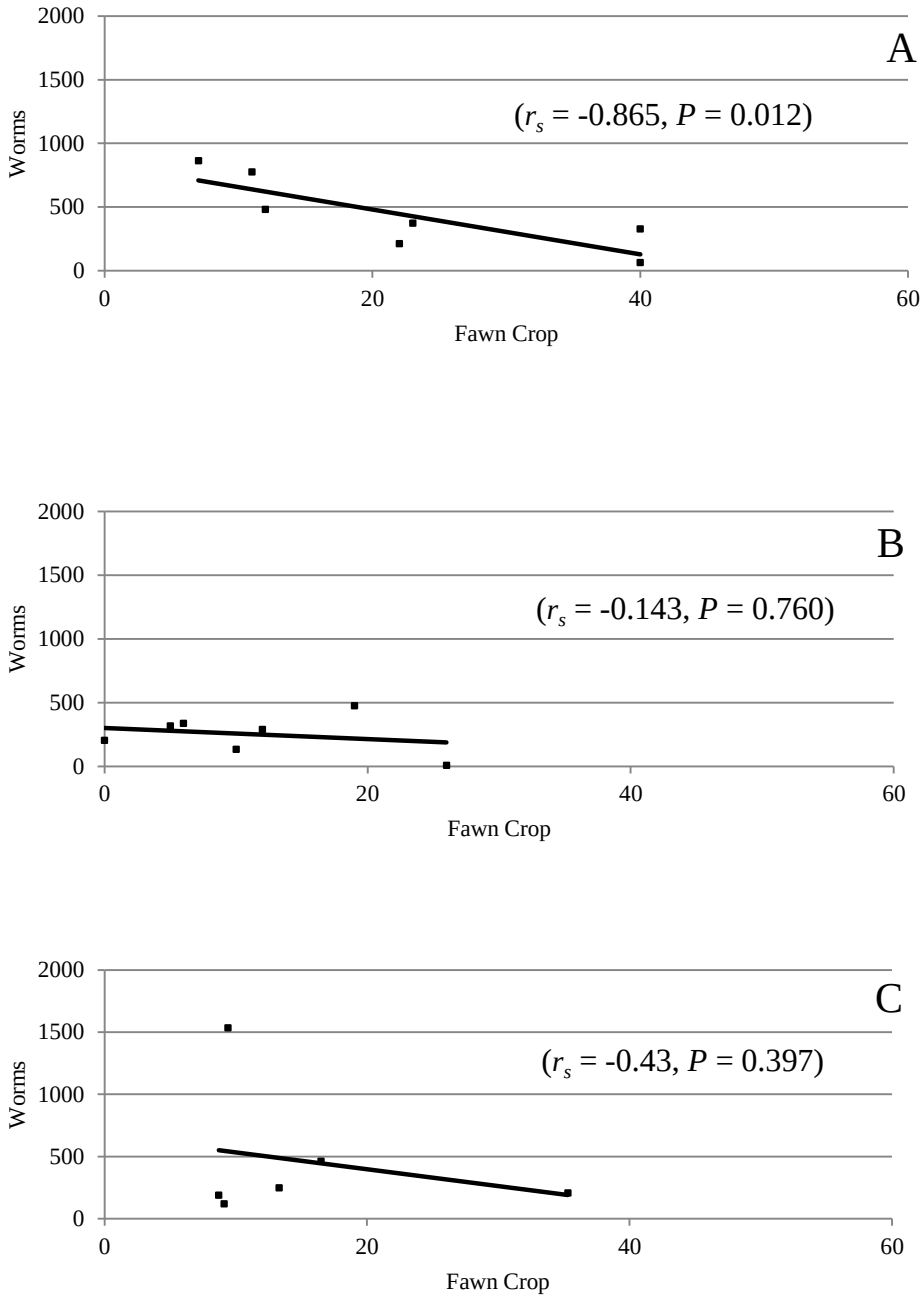


Figure 3.2 Relationship between *Haemonchus* worm loads and subsequent pronghorn fawn crops for 2009 (A), 2010 (B), and 2011 (C) in Trans-Pecos, Texas, USA.

counts in 2009, were different ($P = 0.003$) than worm counts in 2010, but were similar ($P = 0.151$) to worm counts in 2011. Years 2010 and 2011 were also similar ($P = 0.451$) when comparing worm counts in pronghorn. When comparing fecal egg counts in the Trans-Pecos between years (2010, 2011, 2012) there was a difference ($P < 0.001$, $X^2 = 19.339$, $df = 2$). There was no difference ($P = 0.579$) in fecal egg counts between 2010 and 2011. Fecal egg counts in 2012 differed from 2010 ($P < 0.001$) and 2011 ($P = 0.001$).

In the Panhandle region, only 1 year of samples were collected for worm counts so no yearly comparisons were conducted. Fecal egg counts were collected during 2 different time periods (winter, summer) for 2011. When comparing fecal egg counts between seasons, I documented a difference ($P = 0.009$, $U = 1178.5$).

Panhandle worm counts and fecal egg counts were lower than Trans-Pecos estimates. I found a difference when comparing worm counts ($P = 0.041$, $U = 501.5$) and fecal egg counts ($P < 0.001$, $U = 5365.5$) between the Trans-Pecos and the Panhandle regions.

Other species were also sampled in the Trans-Pecos for comparisons to pronghorn. In 2010, pronghorn, Barbary sheep, and mule deer samples were collected and a difference was found when comparing worm counts ($P < 0.001$, $X^2 = 51.254$, $df = 2$) and fecal egg counts ($P < 0.001$, $X^2 = 42.669$, $df = 2$) between the 3 species. Pronghorn worm counts were different from both Barbary sheep ($P = 0.004$), and mule deer ($P < 0.001$). Mule deer and Barbary sheep had similar wrom counts ($P = 0.623$). Pronghorn fecal egg counts also differed from Barbary sheep ($P = 0.003$), and mule deer ($P <$

0.001). Barbary sheep and mule deer fecal egg counts also differed ($P = 0.006$). In the summer of 2011, cattle fecal samples were collected in the Trans-Pecos for fecal egg count comparisons to pronghorn and again I documented a difference ($P < 0.001$, $U = 157.5$).

Species Identification and Drug Resistance-Samples sent to the USDA's Animal Parasitic Diseases Laboratory in Beltsville, Maryland, showed that pronghorn were carrying more than one species of *Haemonchus*. The laboratory reported *H. contortus* and *H. placei* in the pronghorn samples. The lab also reported mixed infections of these species in some hosts, and indicated that there may be evidence for the occurrence of hybrids of these species based on structural characteristics of the adult worms.

As for drug resistance, 4 commercial dewormers (Benzimidazole, Levamisole, Ivermectin, and Moxidectin) were tested and all had very good results. The worms showed very high susceptibility to all the treatments; therefore, showed no resistance. This suggests that *Haemonchus* in the pronghorn were of wildlife origin and did not originate in livestock. It is believed that resistance would have been a result of exposure to chemical dewormers, commonly used in livestock operations.

DISCUSSION

Haemonchus are one of the most highly prolific parasitic nematodes afflicting both domestic and wild ruminants (McGhee et al. 1981, Newton and Munn 1999). Bever (1957) and Boddicker and Hugghins (1969) reported that *Haemonchus contortus* were numerous in sampled pronghorn from South Dakota. In Texas, Hailey (1979) reported

that of 48 pronghorn sampled in the Trans-Pecos ecoregion, 39 (81.3%) contained *Haemonchus contortus* and samples were categorized as lightly infested, moderately infested, and heavily infested. Although his results were subjective, Hailey (1979) concluded that the dry climate aided in preventing the spread of disease or parasites.

When comparing parasite loads from the Trans-Pecos region to the Panhandle region, there was a difference between the 2 populations. Panhandle pronghorn exhibited lower infection rates of *Haemonchus* than did the Trans-Pecos population. Cold winters (Shorb 1943) and desiccation (Besier and Dunsmore 1993) are thought to limit the buildup of free-living larvae on pastures. The Panhandle experiences cold winters and the Trans-Pecos is a desert climate, both of which should limit parasite loads. After an extreme drought in 2011, parasite loads in the Trans-Pecos increased.

By using the McMaster's fecal flotation technique, I documented a correlation between worm loads and fecal egg counts in pronghorn. The McMaster's technique allowed for the monitoring of parasite loads in pronghorn throughout the year, by the collection of fecal samples. The McMaster's technique is a noninvasive approach and does not require harvest or capture of the animal. Although there is some error associated with this method (Burk and Rossano 2011), it can certainly detect to what degree an animal is infected.

When comparing the 2009 worm counts to the 2010 fawn crops, there was a significant negative correlation. There was a slight negative correlation in the following years, but they were not significant. Precipitation and predation are 2 other main factors

that have effects on fawn crops (Brown et al. 2002). In 2009, 2011, and 2012 the Palmer drought severity index (PDSI), showed the Trans-Pecos received well below average precipitation during the crucial time periods of March through August and January through May (NOAA 2012). In 2010, the PDSI values were well above average for the same time periods (NOAA 2012). So the importance of parasite loads to fawn recruitment depends on the year and the habitat conditions for pronghorn.

Very little sign of *Haemonchus* was detected in the other species that were sampled, which implies that this is a more isolated issue for pronghorn in this region. Pronghorn usually inhabit wide open, low rolling, expansive grasslands (Yoakum 1974). Compared to mule deer who prefer mesquite-creosote-dominated (*Prosopis gandulosa*, *Larrea tridentata*) Chihuahuan Desert, dense chaparral, oak woodlands (*Quercus* spp.), pinyon-juniper (*Pinus edulis*, *Juniperus* spp.), and upper desert grasslands (Heffelfinger 2006). Barbary sheep prefer rugged mountain terrain with steep bluffs, mesas, ledges, benches and ridge fingers (Gray and Simpson 1983). Pronghorn are only slightly to moderately sympatric to these species. Pronghorn also have a unique foraging style, where they prefer to eat forbs growing close to the ground (McInnis and Vavra 1987). Browsing and grazing are the main foraging strategies of sympatric ruminants, which could further isolate them from pronghorn. Pronghorn habitat is also used more heavily by livestock, but fecal samples from cattle show a very low infection rate. In some cases livestock grazing could increase the spread and cross cross-transmission of *Haemonchus* in those environments (McGhee et al. 1981). Pronghorn foraging styles and habitat selection may make them more susceptible to *Haemonchus* infection, whereas these other

wildlife species may actually limit their contact with *Haemonchus* by their foraging habits and habitat selection.

The exact *Haemonchus* species affecting Trans-Pecos pronghorn populations is still undetermined for the most part. Hoberg et al. (2004) described the complexity of *Haemonchus* and the importance to document the faunal diversity in both domestic and wild ruminants. *H. contortus* and *H. placei* have both been found in Trans-Pecos pronghorn, which indicates that *Haemonchus* are not host specific. There is also hybrids and possible a new species that is present in Trans-Pecos pronghorn, which might explain how *Haemonchus* is doing so well in a desert environment. There are several factors that are unresolved. First, in some number of hosts there are adult worms that have characters of both species, but cannot immediately be classified as hybrids. Certain male worms have dimensions of spicules that far exceed the mean, and also are larger than the established range for *H. placei*. Second, the cuticular ridges in these specimens are entirely consistent with *H. contortus*. Third, a new species was recently named from Africa that essentially looks like *H. contortus* but has very long spicules and had for many years been called the long-spicule *H. contortus* (Lichtenfels et al. 2001). Currently, there is no molecular data for the long-spicule *H. contortus* species at the USDA's Laboratory in Maryland (Lichtenfels et al. 2001). Based on comparative morphology the long-spicule *H. contortus* species can be excluded as a possibility, but may need to be examined again in greater detail (personal communication, Hoberg, USDA Animal Parasitic Disease Laboratory, Beltsville, MD).

Haemonchus have been known to mutate very rapidly which, may allow them to adapt to this environment. The reason I tested for drug resistance is to determine the origin of *Haemonchus* in the Trans-Pecos pronghorn population. At present, there is no effective alternative to chemical control of parasitic helminths where livestock are grazed intensively. Resistance to anthelmintics has become a major problem in veterinary medicine, and threatens both agricultural income and animal welfare (Wolstenholme et al. 2004). If my samples of *Haemonchus* showed any resistance to anthelmintics, then that would link them to livestock. My samples showed no resistance, so the *Haemonchus* found in Trans-Pecos pronghorn may have come from other wildlife that had not been exposed to chemical dewormers or they originated in pronghorn. This suggests that *Haemonchus* probably evolved with pronghorn and have always been present in this ecosystem. Therefore, parasites must be cycling exclusively in a sylvatic cycle (e.g., exclusive to wild animals).

Management Implications

Pronghorn in the Trans-Pecos and other desert environments tend have very low parasite loads, but little work has been done on the interactions between pronghorn and *Haemonchus*. Parasites can have drastic effects on wildlife in some cases and these populations need to be monitored on a normal basis. By using the McMaster's fecal flotation technique, pronghorn populations in the Trans-Pecos can now be monitored in a noninvasive manner, any time of year. *Haemonchus* appears to be a naturally occurring part of the ecosystem that has adapted to live in this extreme desert environment. Monitoring of parasite loads in pronghorn in the Trans-Pecos and the Panhandle regions

should continue. Future translocations in the Trans-Pecos will be closely monitored both pre and post release, to determine if parasite loads increase or decrease, in hopes of defining what is the cause for the change.

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CHAPTER IV: FAWN SURVIVAL OF PRONGHORN IN THE TRANS-PECOS

The Trans-Pecos has historically held some of the highest densities of pronghorn in the southwestern United States (Southeastern Cooperative Wildlife Disease Study 1982, O'Gara and Yoakum 2004). Historically, Trans-Pecos pronghorn have accounted for approximately 70% of the states pronghorn population (Gray 2012). Pronghorn populations in the Trans-Pecos region have been declining since the late 1980s, with a new 75-yr low recorded in 2012. Due to this recent decline, the Trans-Pecos pronghorn population only compromises about 25% of the state's herd (Gray 2012). Many factors can affect a pronghorn population and cause production and numbers to decrease, such as precipitation (Simpson et al. 2006), predation, habitat loss, diseases and fences and highways, which act as barriers to movement (Gray 2012). The Trans-Pecos region of Texas has been experiencing low fawn crops in their population (Gray 2012; Figure 4.1). In 2011, Texas Parks and Wildlife Department documented a 0% fawn crop in the Marfa Southeast meta-herd unit. The Marfa Southeast meta-herd unit is made up of several herd units and is located in what historically was one of the most productive areas in the Trans-Pecos (Southeastern Cooperative Wildlife Disease Study 1982, O'Gara and Yoakum 2004).

Studies have shown that predation can be the major cause of fawn mortality (Beale and Smith 1973, Tucker and Garner 1980, Barrett 1984, Gregg et al. 2001), and in smaller populations predation may be more significant than normal (Beale and Smith 1973).

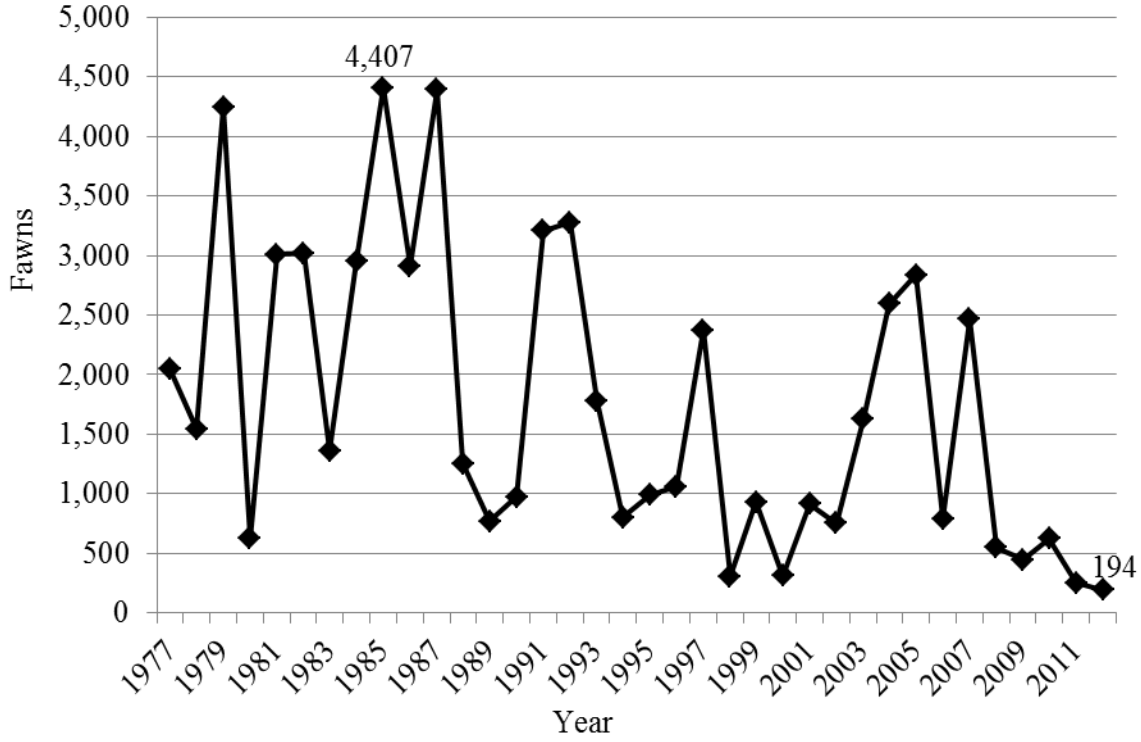

Figure 4.1 Estimated pronghorn fawn trends in the Trans-Pecos, Texas, USA, 1977-2012 (Gray 2012).

Given adequate nutrition, pronghorn have high reproductive potential (O'Gara 2004). Breeding will continue annually until they are ≥ 9 years old (O'Gara 1968). During good range conditions pronghorn have the ability to produce healthy twins. In northern regions, yearlings generally produce twins 90% of the time, and does ≥ 2 years twin 99% of the time (Edwards 1958). In Wyoming, Hepworth and Blunt (1966) found twins to be the rule during first pregnancies and twinning occurred in 98% of the subsequent pregnancies. In fact, pronghorn may begin breeding as early as fawns; however, 16 months is usually the earliest (O'Gara and Yoakum 2004).

Average fawn crops in the Trans-Pecos for 2010, 2011, and 2012 were 22%, 10.5%, and 16.3%, respectively. There are 7 sampling units in the Trans-Pecos and only 1 of those in 2011 had a fawn crop over 20% with only 2 in 2012. Determining the cause of low fawn crops in the Trans-Pecos is critically important in sustaining a viable population. Therefore, I initiated a study looking at pronghorn fawn survival throughout the Trans-Pecos, which was targeted at cause specific mortality of fawns.

STUDY AREA

The study area consisted of 3 major areas within the Trans-Pecos. The Double U Ranch in northern Hudspeth County; Catto-Gage Ranch and Serria La Rana Ranch in Brewster County; and Ryan Ranch, Hughes-Sasser Ranch, Miller Ranch, Nancy Anne Ranch, Antelope Valley Farms, and Mimms Ranch in the Marfa Plateau (Figure 4.2).

The Trans-Pecos is a diverse ecosystem that contains a large amount of contrast throughout the entire region. As part of the Chihuahuan Desert Biotic Province, it

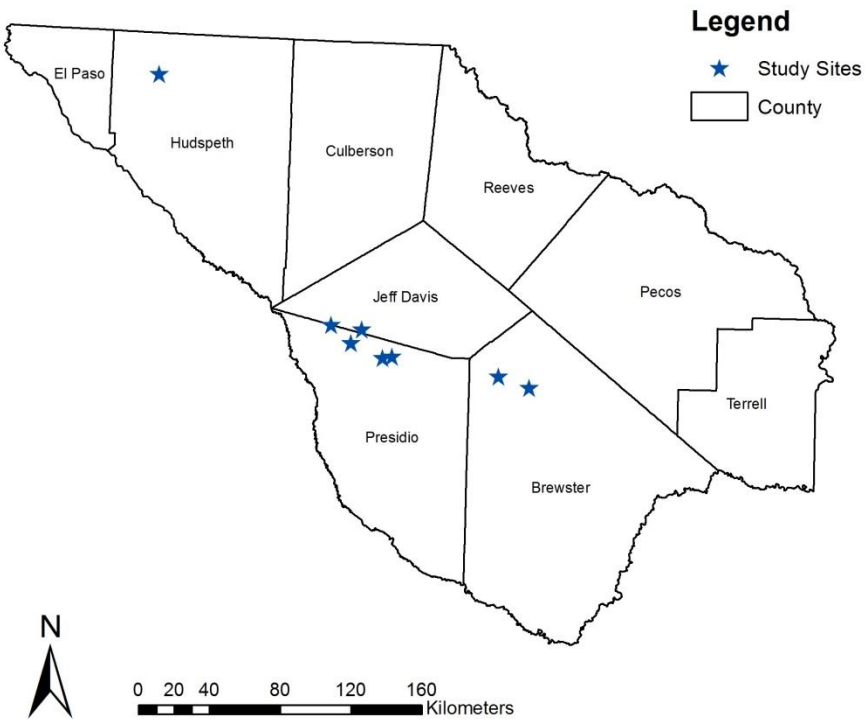

Figure 4.2 Map referencing study sites used in pronghorn fawn survival in Trans-Pecos, Texas, USA, 2011 and 2012.

accounts for about 7.3 million hectares. It is bordered to the west and south by the Rio Grande, to the east by the Pecos River, and to the north by New Mexico (Hatch et al. 1990). Elevation ranges from 762-2,667 meters due to the desert mountain islands scattered throughout the region. Most precipitation is received during the monsoonal season between July and October, and annual averages are between 20-30 cm for lower elevation and 30-46 cm for higher elevations (Simpson et al. 2006).

The study area in Hudspeth County was located in the House and Deep Well Pastures on the Double U Ranch (University of Texas Lands), 72 km east of El Paso in north Hudspeth County, Texas (Cannon and Bryant 1997). Hudspeth County is in the Trans-Pecos mountains and basins ecological area west of the Pecos River. Elevation ranges from 1,465 m to 1,675 m. Topography ranges from steep to gentle hills on the west side bordering the Hueco Mountains, to open flats on the east side of the study area (Cannon and Bryant 1997). This area experiences monsoonal rain, which occurs in late summer through early fall. The temperature for this region ranges from -18°C in the winter to over 38°C in the summer (Cannon and Bryant 1997). The study area has historically been grazed by cattle and still continues today.

The Catto-Gage Ranch in the Marathon Basin is a cattle ranch that is still operational today. This ranch is located about 29 km east of Alpine, Texas and is 704 km^2. The portion of this ranch used for the study was mostly the tobosa (*Hilaria mutica*) grassland south and adjacent to US Highway 90. The study area was bordered to the west by the Del Norte Mountains, to the north by US Highway 90 and a neighboring ranch, to the east by US Highway 385, and to the south by a mesquite (*Prosopis glandulosa*)-

tarbush (*Flourensia cernua*) scrubland. Climate of the Trans-Pecos was characterized as arid with an average rainfall of 35.6 cm per year, typically occurring in mid to late summer (Warnock 1977).

The Marfa Plateau surrounds the town of Marfa, Texas and has historically held some of the highest densities of pronghorn in the southwestern United States (Southeastern Cooperative Wildlife Disease Study 1982, O'Gara and Yoakum 2004). The study area for the Marfa Plateau consisted of 7 ranches scattered across the western portion of the Marfa Plateau. The ranches were mostly characterized as tobosa (*Hilaria mutica*) grasslands, which accounted for as much as 96% of the plant community (Soil Survey 2013). Two ranches contain tobosa grasslands, but also have rolling igneous hills, dominated by grama (*Bouteloua* spp.) and bluestem (*Andropogon* spp.) grasses along with forbs such as buckwheat (*Erigonum* spp.) and crotons (*Croton* spp.). Elevation ranges from 1,064 m in the flats to 1,368 m in the hills (USDA 2013). This area is also characterized by monsoonal rains, where approximately 75% of the precipitation occurs as thunderstorms of short duration and high intensity during the months of June through October (USDA 2013). This area receives 28 to 33 cm of rain annually and has temperatures comparable to those on the Double U Ranch.

METHODS

In order to assess fawn survival and cause of mortality, I captured and radio collared neonates in 3 different areas throughout the Trans-Pecos. I used the nighttime hoop-net capture method as described by Brownlee and Hailey (1970) to capture fawns. Fawns

were captured shortly after parturition using hoop-nets, spotlights, and vehicles. A hoop-net (Tomahawk Live Trap 3350 Mighty Net, Hazelhurst, Wisconsin, USA) was used when catching pronghorn fawns (Brownlee and Hailey 1970).

During the fawning season, field staff traveled to the study sites and glassed for pronghorn fawns from vehicles. Once locations of fawns were documented, teams congregated on the fawning areas using all-terrain vehicles (ATVs) or trucks and spotlights. After fawns were seen at night, researchers approached fawns on foot and with ATVs or trucks. Nets were then placed over fawns. Once captured, fawns were blindfolded to reduce struggling and capture related stress (Byers 1997, Cancino et al. 2005).

An effort was made to minimize capture and handling times to reduce scent transfer and potential for capture myopathy. Rubber gloves were used by handlers to decrease the amount of scent transferred to the fawn. A primary assumption of radio-telemetry studies is that radio-marking does not affect the animals' behavior, survival, or reproductive success (Holt et al. 2009). I selected a lightweight, self-adjusting collar used for young ungulates described by Keister et al. (1988). The study collars weighed 68 grams. Since there is a risk of abandonment, I used cryptic collars (e.g., brown) not noticeable when attached to a fawn. I attached a collar that was self-adjusting, (ATS M4210 Expandable Breakaway Collar) lightweight (68 grams), and programmed with a 4-hour mortality sensor, which allowed for recovery of fawns after death.

Upon capture I recorded weight, neck circumference, total body length, and new hoof growth measurement. Ages were estimated using a regression equation:

$$Y = 0.893549 + 2.3419353\ x_i$$

where x_i is a new hoof growth measurement for an individual fawn, and Y is the estimation for age (Tucker 1979, Sams et al. 1996, Flueck and Smith-Flueck 2005) (Figure 4.3). From these ages, I was able to estimate birthdates for both years (2011, 2012), and I was able to establish length and peak of fawning period in the Trans-Pecos.

Using standard radio-telemetry techniques as described by Barrett (1984) fawns were monitored each day from the ground to document survival or mortality. If a mortality signal was detected, the research team would locate the fawn and perform a thorough and timely investigation to determine cause of death. The immediate area around the carcass was examined for clues, then the carcass was brought back to a laboratory for a necropsy. For necropsies, hide was skinned back to examine canine marks, if present; stomachs were examined to evaluate presence of food; and all other organs were examined if present. All mortalities were classified and cause of mortality was recorded for each year.

Fairbanks (1992) found that most pronghorn fawn mortality occurred before the formation of nursery groups, which was usually around 5-6 weeks after the start of fawning season. Fawns were monitored for approximately 14 weeks after capture to determine survival. For the first 60 days post capture, fawns were checked daily. After 60 days of monitoring, ground surveys were reduced to 2x/week.

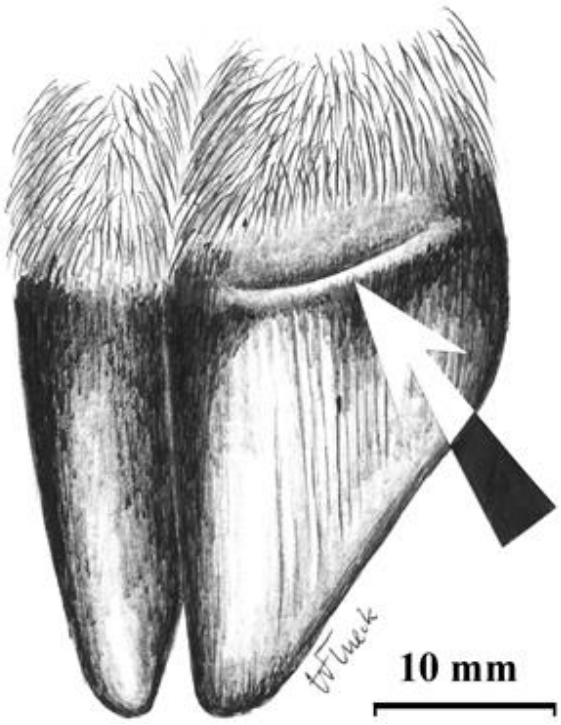

Figure 4.3 New hoof growth was determined by measuring the distance from the hairline to the ridged growth line (arrow) on the abaxial wall of a front hoof. New hoof growth and a corresponding regression equation were used to predict pronghorn fawn age during capture (Tucker 1979, Sams et al 1996, Flueck and Smith-Flueck 2005).

Statistical Analysis- All data was first tested for normality using Kolmogorov-Smirnov test of normality (Zar 2010). The program IBM SPSS Statistics 19 was used for all statistical analysis except for fawn survival estimates. Since fawn ages differed at time of capture, I used linear regression analysis to predict fawn weight by age (days) for 2011 and 2012, separately. This standardized all weight and age measurements, which made comparisons between years possible. The limit for this regression analysis was the maximum age of a fawn at capture for each year. The Kaplan Meier method in Ecological Methodology version 7.2 was used to calculate pronghorn fawn survival estimates for 2011 and 2012 (Krebs 1999). For both years, I calculated survival of radio-marked fawns to 14 weeks using Kaplan-Meier estimator modified for staggered entry (Pollock et al. 1989, White and Garrott 1990, Gregg et al. 2001). To compare survival across years, the weekly survival estimates were compared using 95% confidence intervals (Zar 2010).

RESULTS

In 2011, fawns were captured from 6 different ranches in 4 areas throughout the Trans-Pecos (Figures 4.4, 4.5, and 4.6). A total of 26 fawns captured from 4 May 2011–2 June 2011 were fitted with radio-collars. Average weight for fawns captured was 2.4 kg with a range of 0.95–4.54 kg. Mean neck circumference and total body length was 15.7 cm and 61.5 cm, respectively (Table 4.1).

New hoof growth averaged 4.99 mm. In 2012, fawns were captured from 4 different ranches in 2 different areas in the Marfa Plateau (Figure 4.7). A total of 34

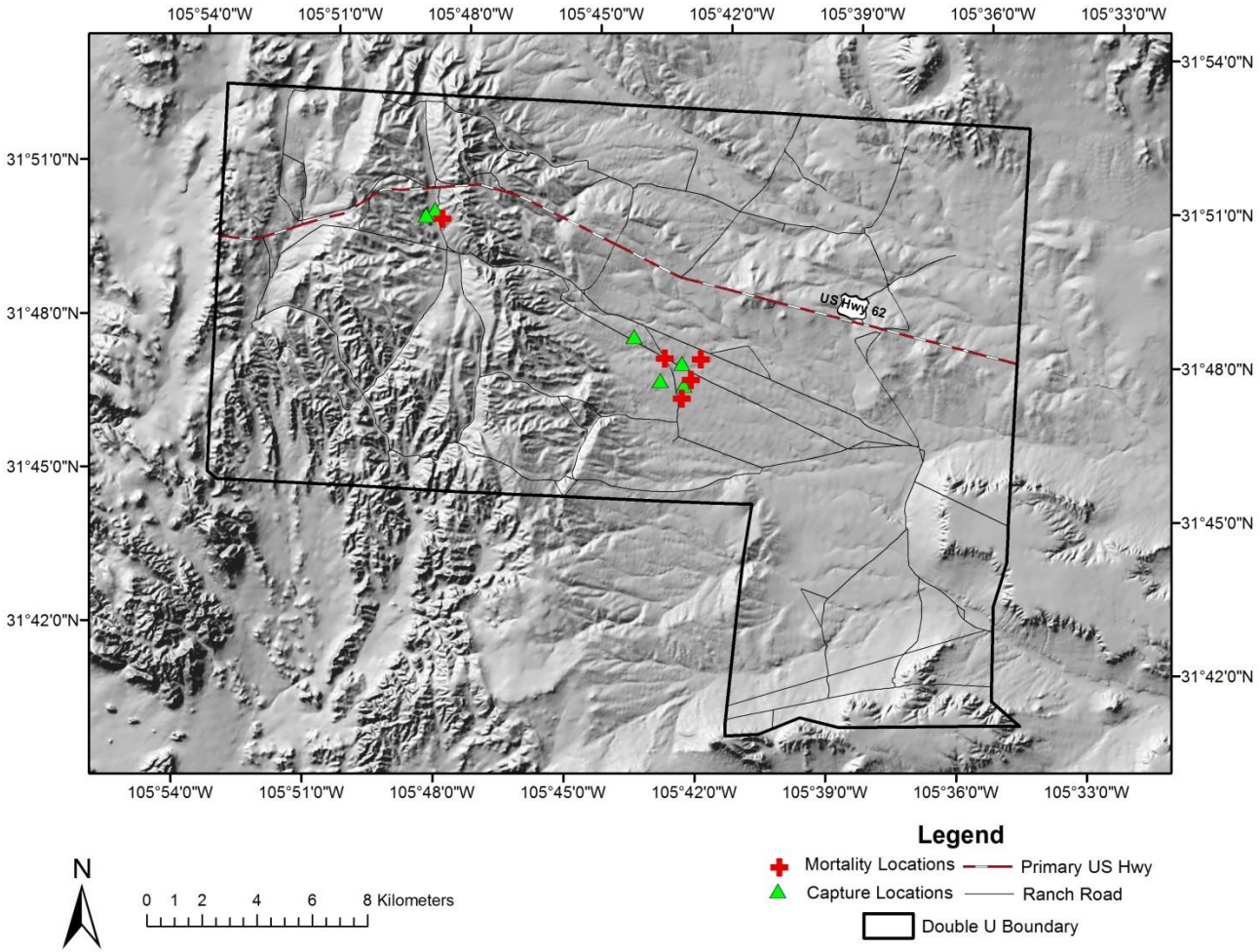

Figure 4.4 Pronghorn fawn capture and mortality locations on the Double U Ranch in Hudspeth County, Texas, USA, 2011.

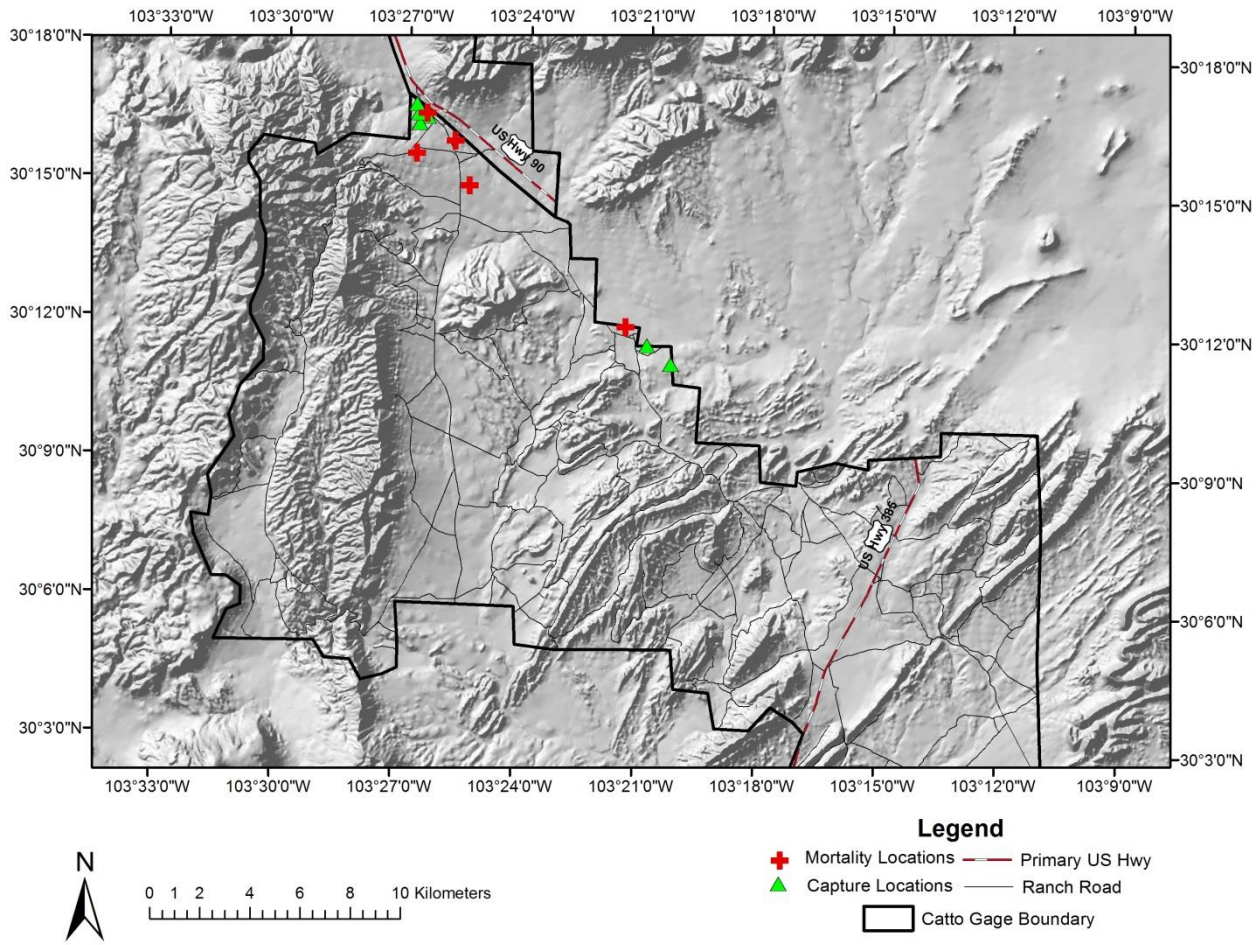

Figure 4.5 Pronghorn fawn capture and mortality locations on the Catto-Cage Ranch in Brewster County, Texas, USA, 2011.

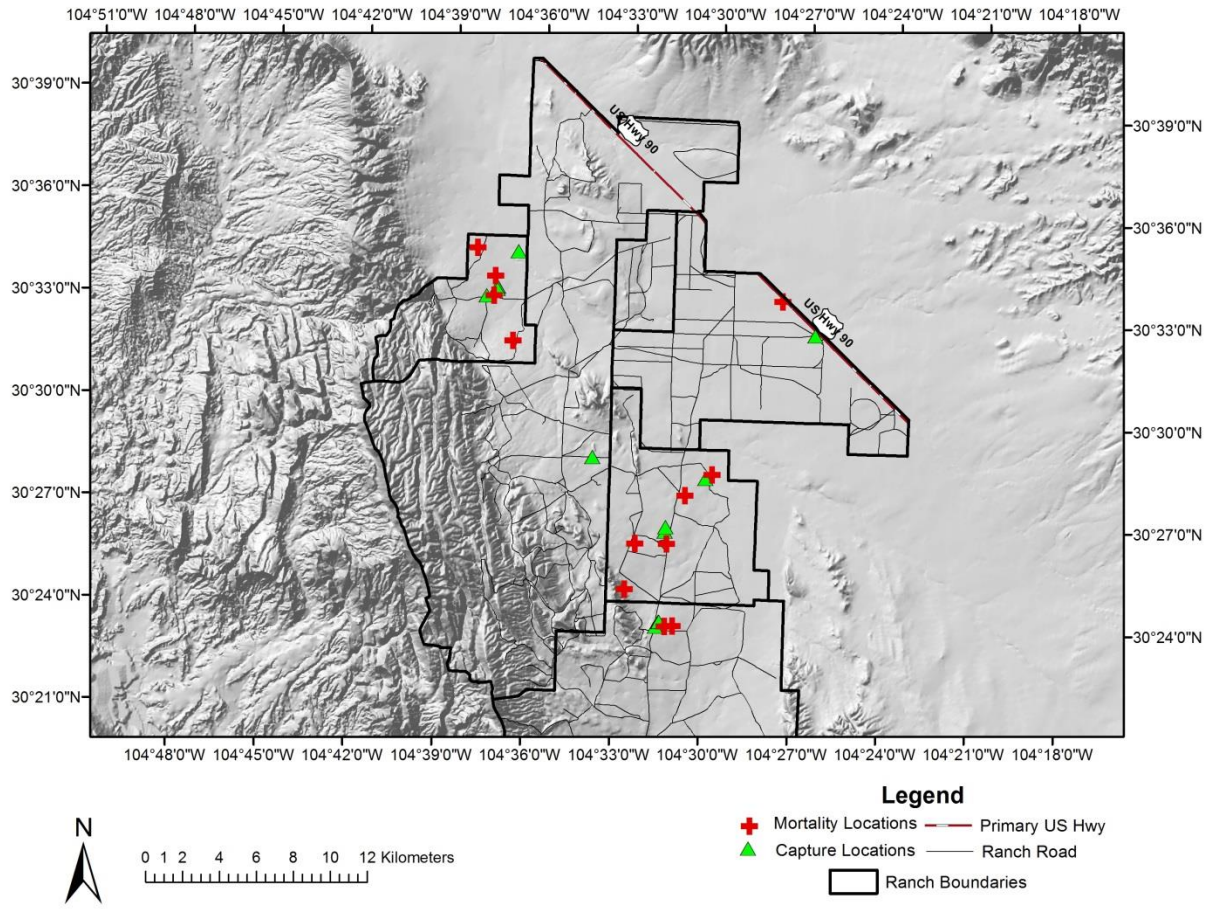

Figure 4.6 Pronghorn fawn capture and mortality locations in the Marfa Plateau in Jeff Davis and Presidio counties, Texas, USA, 2011.

Table 4.1 Characteristics of pronghorn fawns captured in Trans-Pecos, Texas, USA, 2011-2012.

Averages/Percentages	2011 (n = 26)	2012 (n = 34)
Weight (kg)	2.4	3.8
Age (days)	12.6	9.8
Neck circumference (cm)	15.7	16.7
Body length (cm)	61.5	62.2
Handling time (minutes)	5.9	4.0
Percent twins (%)	53.8	56.0
Dam present (%)	84.6	97.0

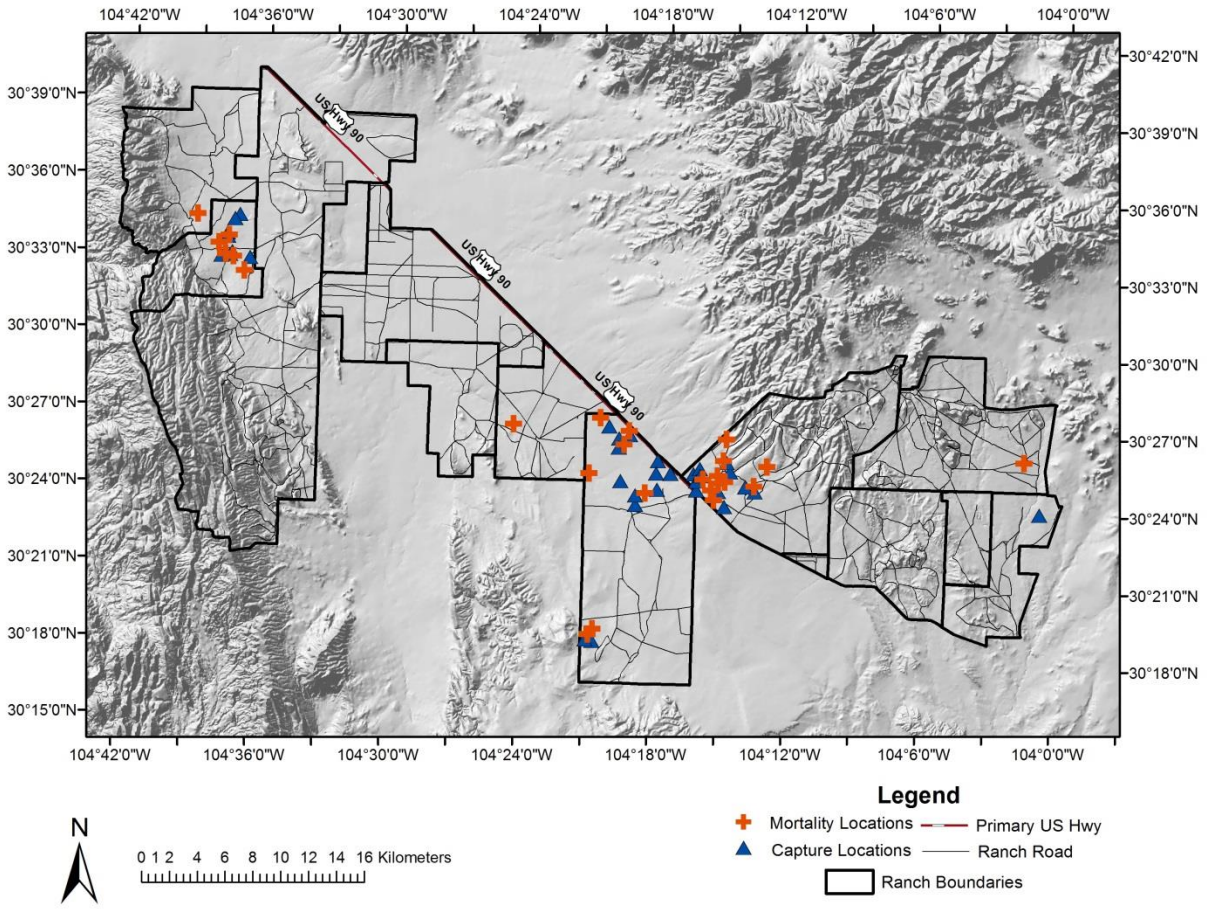

Figure 4.7 Pronghorn fawn capture and mortality locations in the Marfa Plateau in Jeff Davis and Presidio counties, Texas, USA, 2012.

fawns were captured from 3 May 2012–29 June 2012 and fitted with radio-collars. The average weight of fawns caught in 2012 was 3.8 kg and ranged from 2.04–6.2 kg. Mean neck circumference and total body length was 16.6 and 62.2 cm (Table 4.1). New hoof growth averaged 3.79 mm.

In 2011, average age of fawns at capture was 12.6 days old. The youngest fawn caught was 3.24 days old, while the oldest fawn was 23.1 days old. Fawning dates were highly variable resulting in a relatively long fawning period (Figure 4.8). The Hudspeth County study site appeared to fawn first, followed by the other 3 study sites. In 2012, average age of fawns at capture was 9.8 days old. The youngest fawn was 3.2 days old while the oldest fawn was 26.7 days. I documented a fawning period for 2011 and 2012 of 30 and 56 days, respectively (Figure 4.8).

In 2011, of the 26 fawns collared 53.8% were observed as twins at time of capture, and the dam was present during capture 84.6% of the time. Out of the 34 fawns caught in 2012, 56% were twins and the dam was present 97% of the time (Table 4.1).

A total of 23 mortalities and 2 surviving fawns was recorded in 2011. Predation accounted for 96% (n = 22) of the mortalities. One mortality, was unknown (4%), while one fawn was censored (e.g., transmitter malfunction) and was never located after capture. Coyote (*Canis latrans*) and bobcat (*Lynx rufus*) predation each accounted for 26% (n = 6) of all mortalities in 2011. Another 44% (n = 10) was recorded as unknown predation. In these cases, the animal had either been dead too long to determine cause of death or a bloody collar was all that was found. In 2012, 27 mortalities were recorded.

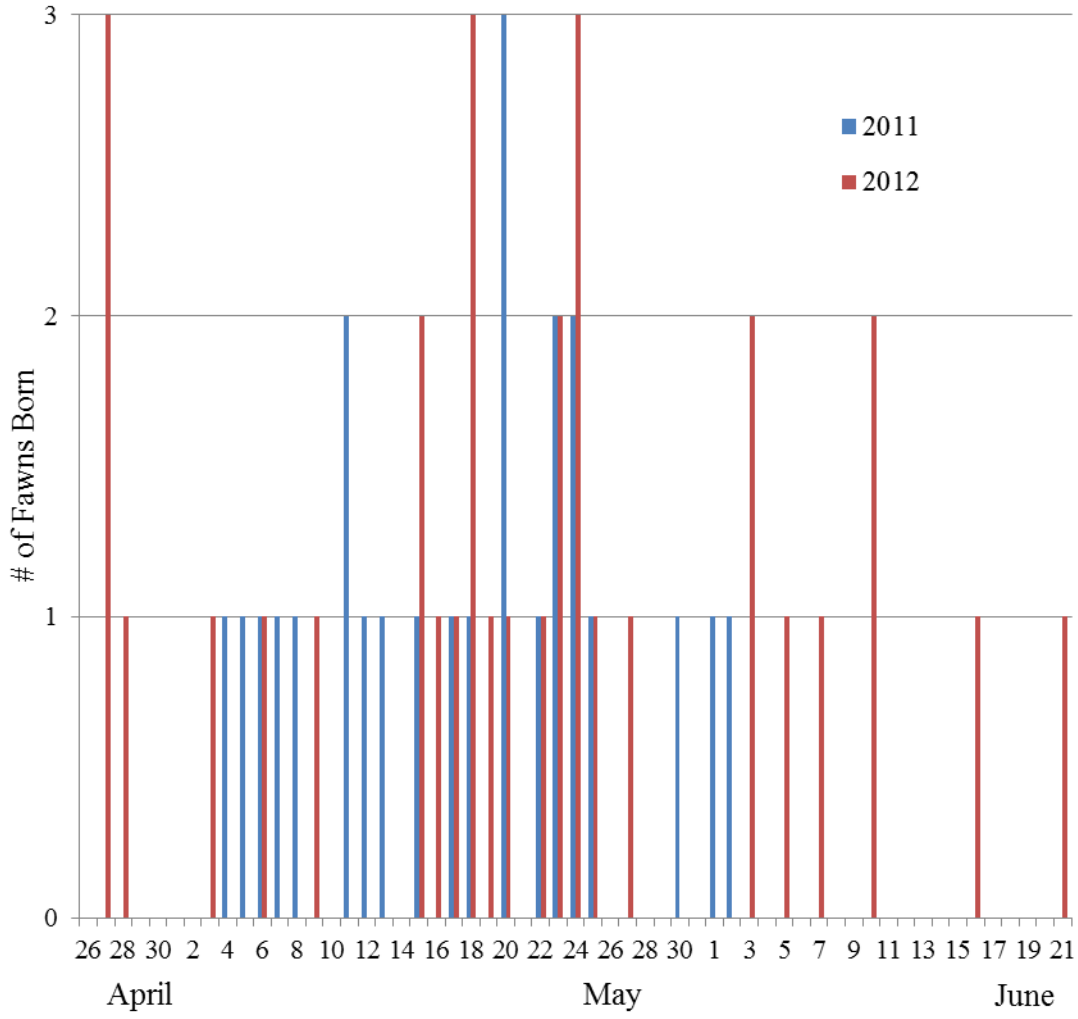

Figure 4.8 Estimated pronghorn fawning dates for neonates captured in 2011 and 2012 in Trans-Pecos, Texas, USA.

Bobcat predation was highest of all predators accounting for 37% (10/27) of the mortalities. Coyote predation was second at 22% (6/27), while unknown predation was 15% (4/27). Other mortality factors totaled 26% (7/27), which included grey fox (*Urocyon cinereoargenreus*) and golden eagle (*Aguila chrysaetos*) predation, abandonment, and unknown causes (Figure 4.9).

Statistical Analysis-For 2011, weights were estimated using the regression equation:

$$Y = 0.95 + 0.142\ x_i$$

where x_i is fawn age in days and Y is the estimation for weight (Zar 2010). For 2012, weights were estimated using the regression equation:

$$Y = 2.347 + 0.15\ x_i$$

where x_i is fawn age in days and Y is the estimation for weight (Zar 2010). Using these regression equations I was able to standardize weights and ages for both 2011 ($R^2 = 0.53$, $P < 0.001$) and 2012 ($R^2 = 0.52$, $P < 0.001$), which allowed for better comparison. At 5 days of age, weight in 2011 was approximately 1.64 kg and up to 3.77 kg in 2012. At 20 days of age, weights were estimated to be approximately 3.77 kg and 5.32 kg for 2011 and 2012, respectively (Figure 4.10).

Kaplan Meier survival estimates for both years were found to be similar using 95% confidence intervals. There was almost complete overlap in survival, where 2011 confidence intervals were $0.051 \leq \bar{X} \leq 0.195$ and 2012 confidence intervals were $0.075 \leq \bar{X} \leq 0.197$. Pronghorn fawn survival in 2011 was 0.027 ($SE = 0.03$) and in 2012 survival was 0.044 ($SE = 0.03$) for a 14 week period (Figure 4.11).

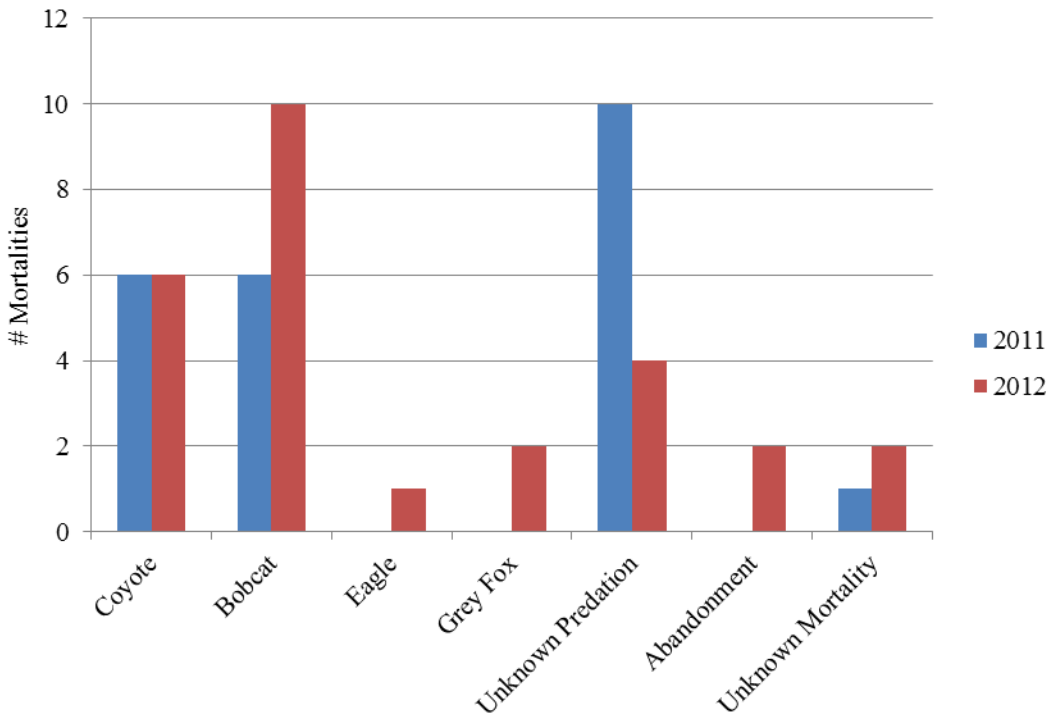

Figure 4.9 Mortality factors for pronghorn fawns captured in 2011 and 2012 in Trans-Pecos, Texas, USA.

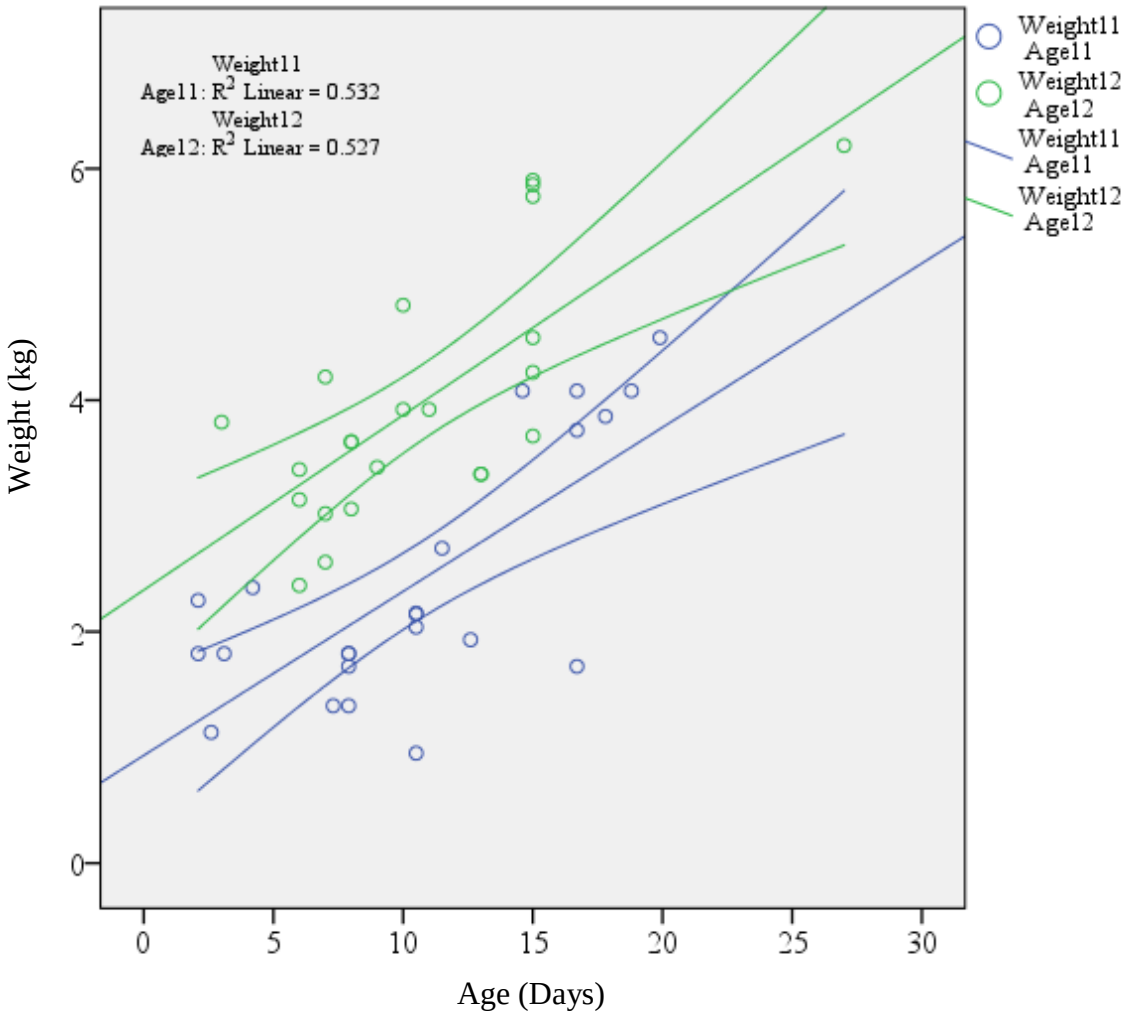

Figure 4.10 Linear regression models for pronghorn fawn age and weight in Trans-Pecos, Texas, USA, 2011 and 2012.

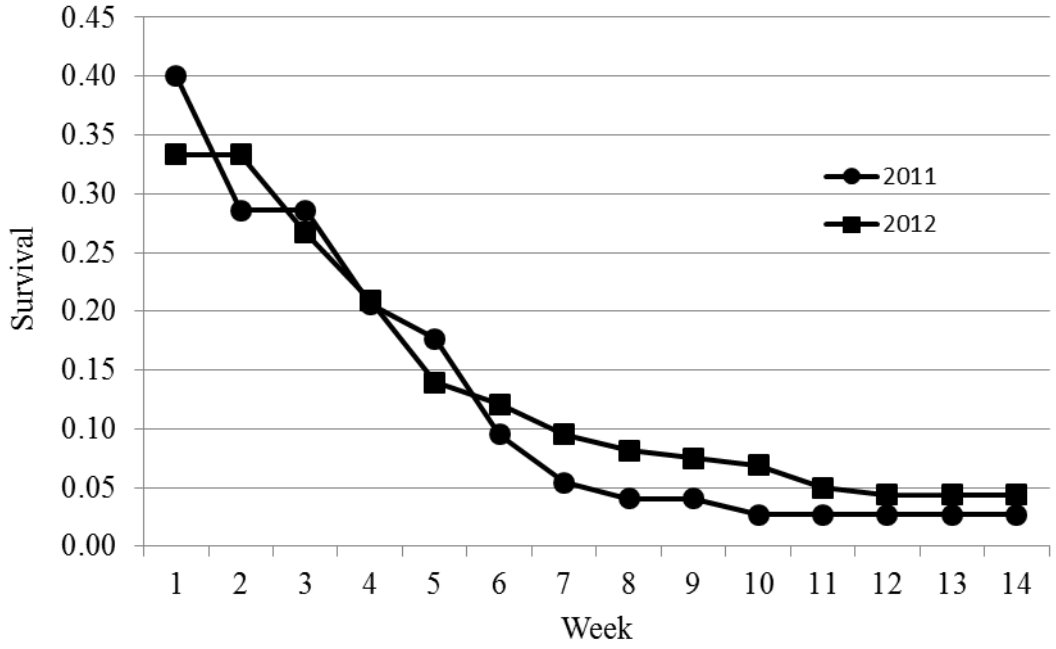

Figure 4.11 Kaplan-Meier survial estimates for captured pronghorn fawns in Trans-Pecos, Texas, USA, 2011 and 2012.

DISCUSSION

Fawn recruitment is essential for pronghorn population growth (Ockenfels 1995). Lee et al. (1989) proposed that dietary overlap with cattle and sheep, fences that prevent movement to more suitable habitat, loss of habitat due to human development, water availability, predators, diseases, and nutritional concerns may play a role in pronghorn population dynamics. The Trans-Pecos region is experiencing many of these problems (Sullins 2002, Simpson et al. 2007), which may have contributed to low fawn recruitment. If populations in arid regions of Texas are limited by forage production, increases due to rainfall should result in better lactation by females and correspondingly better nutritional status of fawns and females (Brown et al. 2002).

In 2011, the Trans-Pecos experienced an extreme drought and very low fawn crops were reported. Twining rates were lower than expected in both 2011 (53.8%) and 2012 (56%). A higher percentage could have been twins, but were not found during capture or had perished before being caught. Studies throughout the range of pronghorn indicate that the majority of fawn mortalities are because of predation (Neff and Woolsey 1979, Tucker and Garner 1980, Barrett 1984, Smith et al. 1986, Ockenfels et al. 1992). During a drought in south Texas, Bradley et al. (2006) recorded that small mammal populations decreased dramatically as resources (e.g., food and cover) began to diminish, which is comparable to severe drought conditions in 2011 experienced in the Trans-Pecos region. It is conceivable that drought may have had an impact on small mammal numbers in the Trans-Pecos resulting in higher predation rates on pronghorn fawns because of the lack of alternative prey.

I documented high predation on pronghorn fawns both years, but other factors could have contributed to this high predation. Lactating does on poor nutrition may have lower milk production and poorer health (Ginnett and Young 2000). In 2011, some fawns appeared to be severely malnourished with low body weights when compared to 2012. Condition of dams in late gestation can have a direct effect on birth weight in ungulates (Thorne et al. 1976). In many cases low birth weight can increase the risk of hypothermia or starvation (Thorne et al. 1976) or increase chances of predation (Clutton-Brock et al. 1982). Birth weights of pronghorn fawns in some years can affect the survival of fawns till weaning (Fairbanks 1993).

Birth synchrony can affect predation rates of young for some ungulates (Gregg et al. 2001). In both 2011 and 2012, I documented very long, extended fawning periods with only a minor peak in fawning for those 2 years. The lack of precipitation throughout the winter and spring may have also been an important factor in later fawning dates in 2011. In 2011 and 2012, the Palmer Drought Severity Index (PDSI) for March through August and January through May was severely below average (NOAA 2012). A short fawning period with a distinct peak allows more pronghorn fawns to avoid predation than does a long fawning period (Gregg et al. 2001). Fawns in the southern part of pronghorn range generally are born later and over a greater span of time (O'Gara 2004). A study conducted by Gregg et al. (2001) in Oregon on the northern part of pronghorn range, documented the birthing pulse to be 12 to 13 days with a peak of 4 to 5 days. Due to this longer birthing pulse, it took 9 to 11 weeks to see a decline in fawn mortality. Fagan et al. (2004) recorded a significant positive relationship between winter precipitation and

pronghorn fawn survival in Arizona's Sonoran Desert and southern New Mexico. In 2011 and 2012, the Trans-Pecos received very little winter precipitation, which might help explain why I documented such high pronghorn fawn mortality.

Throughout the study, pronghorn fawns experienced high predation by bobcats. Beale and Smith (1973) also experienced high bobcat predation in Western Utah, where 61% of pronghorn fawn mortality was attributed to bobcat predation. Most predator control in the Trans-Pecos is targeted at coyotes, which could be one reason I documented a higher percent of bobcat predation. Although Kaplan Meier survival rates for both years are similar, I observed slightly higher survival in 2012 than in 2011. I documented 2 of 26 fawns in 2011 and 7 of 34 fawns in 2012 surviving through the study period. Barrett (1984) found that the majority of predation occurred on fawns between 4-15 days of age, but predation was still of concern to animals 16-57 days old. The pronghorn populations of the Trans-Pecos are facing many challenges and struggles to maintain their population. Since births are the primary mode of growth in a population (O' Gara 2004), fawn survival in the Trans-Pecos is essential. There are many management strategies that can be implemented to aid fawn survival, but abundant and timely precipitation is still the most important (Simpson et al. 2006). Hailey et al. (1964) reported that precipitation received during the late winter and early spring is responsible for the number of fawns produced that year.

Management Implications

When trying to increase fawn survival, many management tools can be implemented to

aid this process. Proper grazing will ensure fawns have the proper cover needed to hide from predators. Grazing properly will also decrease the competition with adult pronghorn, which increases nutrition received by fawns. Also, using predator control measures during certain times have shown to increase pronghorn fawn survival (Cannon 1995, Spencer and Beach 2006, Brown 2009). Coyotes are the most effective predator at killing pronghorn fawns (Barrett 1984, Gregg et al. 2001), and most of that mortality happens before fawns are 1 month old (Barrett 1984). If predators can be reduced from the landscape prior to the fawning season, fawns should have a better chance of surviving (Hailey 1979, Neff et al. 1985, Smith et al. 1986). Hailey (1979) and Neff et al. (1985) found that fawn crops significantly increased when predator control was implemented from November through January. Fences and barriers to movements can be detrimental to pronghorn populations including fawns (Hailey et al. 1966). Removing these barriers will allow pronghorn to move to areas of better nutrition benefitting both adults and their fawns (Gray 2012). Range conditions and pronghorn nutrition are yet to be evaluated in the Trans-Pecos. If adult female pronghorn are not getting adequate nutrition needed to raise fawns then the rest of these factors are secondary. Also, it would be beneficial to study birth synchrony, and how that affects predation on neonatal fawns. Birth synchrony is a very important prey defense mechanism (Dauphine and McClure 1974) that may be affected by drought and other unknown factors.

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Appendix A. Horn measurements, cementum annuli age estimations, and kidney fat indices collected from harvested pronghorn bucks in Trans-Pecos, Texas, 2010-2011.

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
10-001	30.80	11.75	9.84	28.26	7	12.3
10-004	37.78	15.24	11.11	48.26	5	52.3
10-006	30.16	23.81	7.30	21.91	5	7.6
10-007	30.16	13.02	7.94	22.54	7	10.4
10-010	34.93	13.97	8.89	29.85	3	12.5
10-012	24.13	14.61	6.35	24.77	-	-
10-015	41.59	15.88	13.97	23.81	-	7.6
10-017	35.24	14.61	12.70	31.12	5	16.9
10-021	35.88	17.15	12.07	28.89	4	27.7
10-022	41.59	15.24	11.75	37.47	4	9.7
10-027	30.16	13.97	10.16	24.13	4	9.5
10-030	33.97	13.02	10.48	27.31	6	10.7
10-035	33.34	23.18	11.75	38.42	6	5.2
10-037	27.94	12.70	9.53	29.85	3	-
10-038	39.37	14.92	13.34	29.85	5	1.8
10-039	33.34	12.70	6.03	17.78	4	11.1
10-041	33.02	13.65	12.07	26.67	6	11.5
10-042	37.47	15.24	16.51	32.07	6	2.2
10-049	35.24	14.92	8.89	27.94	5	9.6

[a] 10 refers to 2010, 11 refers to 2011

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
10-051	34.29	12.70	10.80	36.20	4	1.8
10-054	36.83	15.24	12.38	28.26	5	10.8
10-058	30.48	14.29	11.11	22.86	3	22.3
10-061	-	-	-	-	4	14.8
10-062	-	-	-	-	4	0.3
10-063	32.70	15.24	11.43	30.48	5	10.6
10-064	33.66	15.56	14.61	25.72	6	11.1
10-066	35.56	15.24	10.16	20.96	5	0.3
10-068	38.74	14.92	10.48	N/A	4	16.5
10-069	39.05	15.56	10.80	30.48	3	1.9
10-070	31.43	17.15	10.16	33.02	7	13.2
10-080	37.47	13.97	12.70	27.94	7	14.7
10-082	35.88	16.51	11.43	22.54	5	18.6
10-083	16.51	7.62	N/A	30.48	-	4.2
10-084	32.70	13.02	12.38	25.40	4	6.2
10-086	36.83	15.24	9.84	19.05	5	21.5
10-089	33.97	16.19	9.21	25.08	5	15.3
10-090	34.61	15.56	15.24	23.50	7	21.6
10-092	-	-	-	-	-	8.5
10-093	31.12	15.88	11.11	25.40	6	7.1
10-095	34.61	15.24	13.34	29.53	4	5.7
10-105	36.83	13.97	12.07	27.94	4	21.3

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
10-106	31.12	14.61	13.97	25.72	5	15
10-107	27.31	13.65	9.84	24.77	6	32.2
10-108	30.16	13.34	11.43	24.77	3	15.2
10-109	34.29	14.92	10.48	27.62	4	1.2
10-111	34.29	13.97	11.43	11.75	3	12
10-112	-	-	-	-	6	9.7
10-114	37.47	13.02	13.02	25.72	4	11.1
10-117	35.24	13.97	10.16	34.61	9	0.4
10-118	31.43	13.65	8.89	24.77	5	3.8
10-119	30.48	13.65	7.30	21.27	5	17.3
10-122	31.43	13.97	12.70	36.83	11	8.5
10-125	34.29	16.51	11.43	26.67	5	1.7
10-127	33.34	14.29	11.43	25.40	5	38.6
10-132	-	-	-	-	8	20.8
10-138	34.29	12.07	10.80	25.40	5	10.8
10-139	30.16	13.34	8.57	22.54	3	78.2
10-146	41.91	14.92	12.70	34.93	6	2.2
10-147	34.61	13.34	10.16	32.39	2	2
10-152	36.20	14.29	9.84	22.86	7	9.9
10-153	37.78	13.97	12.38	19.69	5	20.9
10-157	34.61	13.97	13.02	18.42	5	5.5
10-159	34.29	14.92	10.80	29.21	5	15.2

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
10-160	29.85	13.97	11.11	19.37	5	46.8
10-162	35.56	13.97	8.26	30.48	7	20.9
10-164	35.56	14.61	9.21	27.31	5	9
10-165	31.43	16.83	11.43	29.85	5	27
10-167	34.93	16.19	13.34	31.43	13	19.6
10-170	34.61	14.61	11.75	18.42	11	41.7
10-171	-	-	-	-	6	13.7
10-172	35.56	15.24	10.16	14.29	5	10.6
10-173	35.24	13.65	10.16	17.15	5	41.3
10-174	33.02	14.61	9.84	25.08	6	25
10-176	35.88	16.51	13.02	31.12	5	3.2
10-178	34.61	16.19	10.48	26.35	8	2.6
10-179	35.56	13.97	10.48	26.04	5	9.1
10-183	33.02	13.34	9.53	31.75	5	17.3
10-184	13.34	7.94	15.24	33.66	4	13.23
10-186	31.12	13.97	9.53	28.89	6	10.3
10-187	39.37	15.88	11.11	30.80	5	4.8
10-188	36.51	14.61	11.11	34.61	7	13.4
10-189	32.70	12.70	6.35	25.40	4	0.3
10-195	30.48	10.80	7.62	18.10	4	22.7
10-196	-	-	-	-	-	0.5
10-199	37.47	15.24	12.07	22.23	5	10.9

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
10-201	40.01	15.88	13.34	28.26	3	11.7
10-202	40.01	18.42	15.24	N/A	6	3
10-204	-	-	-	-	5	0.7
11-001	14.75	5.38	2.75	8.38	6	27.3
11-006	13.75	5.63	3.38	11.00	7	0.7
11-007	13.50	5.38	4.75	9.00	-	7.6
11-008	12.63	5.50	4.13	8.50	6	10.8
11-009	12.88	6.13	3.63	16.00	6	12.4
11-010	12.88	6.00	3.75	11.00	4	12
11-011	13.88	5.38	4.38	7.63	6	18.2
11-012	12.50	5.88	5.00	9.13	6	5.7
11-014	13.25	5.63	4.88	11.88	7	19.3
11-017	11.50	5.88	5.50	9.50	6	3.8
11-020	12.00	5.25	4.50	12.50	6	4.3
11-021	13.25	5.75	5.00	11.00	5	5.4
11-029	12.63	5.38	4.50	7.25	6	5.5
11-031	15.88	6.13	6.25	12.00	4	6.8
11-034	13.00	5.50	4.00	9.38	4	16.1
11-036	11.88	5.75	3.50	9.25	7	4.1
11-037	13.25	5.88	4.00	8.13	11	1.8
11-039	16.00	6.13	6.25	10.00	3	-
11-040	15.25	6.00	5.25	10.00	3	2.6

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
11-041	14.25	5.50	4.50	13.00	N/A	5.7
11-044	13.00	5.88	3.50	12.13	3	11.9
11-045	-	-	-	-	2	18.5
11-046	-	-	-	-	-	-
11-049	16.25	6.38	5.50	10.25	5	6.9
11-050	11.00	5.25	2.25	9.63	9	7.6
11-051	14.75	5.88	4.25	10.25	3	16.5
11-052	15.25	6.25	5.25	9.75	4	7.9
11-053	13.25	6.13	5.00	9.00	5	12.5
11-056	15.00	6.25	5.25	10.00	4	0.7
11-058	-	-	-	-	-	5.6
11-059	12.00	4.50	2.50	8.75	5	8
11-060	13.25	4.33	3.50	8.25	-	5
11-061	-	-	-	-	-	12.3
11-068	15.50	6.25	5.38	9.00	4	7.9
11-069	-	-	-	-	3	-
11-070	14.75	4.75	3.00	9.75	6	6.8
11-073	14.00	5.75	4.50	10.00	4	2
11-074	-	-	-	-	4	-
11-079	16.00	6.00	3.75	-	6	1.3
11-081	15.88	6.50	5.00	17.25	2	10.1
11-082	13.13	5.38	4.13	7.25	6	0

[a] Year-Sample ID #	Beam Length (cm)	Base (cm)	Prong Length (cm)	Inside Spread (cm)	Age (Yrs)	Kidney Fat Index (%)
11-090	-	-	-	-	-	10

VITA

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