

FACTORS AFFECTING PRONGHORN FAWN
RECRUITMENT IN CENTRAL ARIZONA

by

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CHAPTER I

INTRODUCTION

Pronghorn (*Antilocapra americana*) are endemic to North America (O'Gara 1978). Historically, they ranged from the southern prairies of Canada throughout the grasslands and shrub steppe plains of the western United States and south to the deserts of northern Mexico (Lee et al. 1998). An estimated 35 million pronghorn inhabited North America before European settlement (O'Gara 1978) with areas of highest densities in the short-grass prairies of the plains (Yoakum 1978). Currently, pronghorn inhabit most of their historic range, however, suitable habitat for pronghorn populations has been restricted by more than 75% (Lee et al. 1998).

By the 1900's, pronghorn numbers had dwindled to less than 20,000 animals (O'Gara 1978). During this period, pronghorn numbers declined more than 99% as a result of habitat loss, fencing, dietary overlap with domestic livestock, and unregulated year-round hunting (Yoakum 1968). By 1924 reestablishment efforts began with a population of 30,500 and by 1983 that number had grown to over a million (Yoakum 1968). Today the pronghorn population fluctuates around 1 million animals throughout their range (Lee et al. 1998).

In Arizona, pronghorn populations exhibited similar trends as those elsewhere in North America. In 1924, surveys found only 700 pronghorn statewide, but by the 1980's that number had increased to more than 10,000, primarily due to transplants from other states (Bright and Van Riper 2000). However, over the past 15 years, Arizona pronghorn populations appear to have declined (Arizona Game and Fish Department 2001). Causes

for this decline are not understood, however, Lee et al. (1998) 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, disease and parasites, and nutritional concerns may play a role in their decline.

In Arizona, fawn recruitment into the population rather than adult mortality tends to be the primary determinant of pronghorn numbers (Ockenfels 1995). Reproductive output of pronghorn appears highly consistent and fawn survival varies greatly from year to year (Vriend and Barrett 1978), causing annual variation in recruitment. Recruitment is commonly defined as the number of young that survive to enter the breeding population (Kohlmann 2004). In Arizona, recruitment is defined as mid-summer surveys that determine fawn: doe ratios (R. Ockenfels, Arizona Game and Fish Department [AZGF] personal communication). Predation, lack of suitable fawn hiding cover, precipitation, and poor maternal condition have all been presumed to affect fawn recruitment in Arizona (Ockenfels et al. 1994; Fagan et al. 2002).

In north-central Arizona, on Fain Ranch, the following pattern has been observed: the pronghorn population has been one of the highest in Arizona, and predator densities were low and fawn recruitment was high (AZGF, unpublished data). Prior to 1999 ranch personnel and Wildlife Services regularly aerial gunned and trapped coyotes (*Canis latrans*) on the ranch, typically removing > 20 coyotes (Jim Miller, Fain Ranch Manager, personal communication). On Fain Ranch fawn: doe ratios typically exceed 50:100 (AZGF, unpublished data). However, its neighboring herd to the north, the Lonesome Valley herd, typically had fawn: doe ratios of 30:100 (AZGF unpublished data). Fain Ranch has long been one of the most productive pronghorn herds in the state (R.

Ockenfels, AZGF, personal communication). It is not known what factors caused the differences in fawn: doe ratios between the ranches but it has been presumed that coyote (*Canis latrans*) control on the Fain Ranch may have been a factor. Survey information from 2002 indicated that a major die-off of more than half the herd on both areas had occurred, possibly due to drought conditions which likely led to starvation (R. Ockenfels, AZGF, pers. comm.). During this period ranch personnel collected > 50 pronghorn carcasses, primarily in drainages near the town of Prescott Valley (Jason Scarborough, Fain Ranch, personal communication).

This study was part of a statewide evaluation of factors affecting pronghorn fawn recruitment, including predator abundance, nutrition, fawn hiding cover, disease, and water availability throughout pronghorn habitat in Arizona. Four study areas were located throughout the state and each had a high and low recruitment site, using paired study sites in an effort to determine factors which may affect fawn recruitment. The purpose of this study was to examine some factors which may affect the differences in pronghorn fawn: doe ratios between the two ranches. Our goal was to monitor diet quality, forage production, and precipitation between the two areas during 4 biologically significant periods for pronghorn does: late gestation (10 April to 25 April), parturition (5 May to 25 May), lactation (20 June to 10 July), and conception (20 August to 10 September).

Chapter II presents results of the diet study, and forage production between the 2 study sites. We tested the following predictions: (1) species composition in pronghorn diets differs between sites, among seasons and between years; (2) nutritive quality of

pronghorn diets differs by site, and season; and (3) pronghorn use available forage species in proportion to their occurrence.

Chapter III presents baseline data for fecal nitrogen (FN) and fecal 2, 6 diaminopimelic acid (DAPA) for pronghorn in Yavapai County, Arizona. We monitored FN and FDAPA at 2 study sites during late gestation, parturition, lactation, and conception from January 2003 through August 2004. Our objectives were to describe seasonal patterns of FN and DAPA and compare those patterns to other ungulate species. Based upon available literature we tested the following predictions: (1) FN and DAPA levels in pronghorn exhibit similar patterns as other ungulate species; (2) highest fecal indices will occur in summer following monsoonal rains; and (3) FN and DAPA levels differ between sites, among seasons and between years.

Chapter IV presents historical data on the relationship of precipitation patterns to pronghorn fawn recruitment in Game Management Unit (GMU) 19A in central Arizona. We analyzed pronghorn survey data and precipitation data from 1960 through 2004 and examined Fain and Lonesome Valley separately from 1993 to 2004. We tested the following predictions: (1) fawn recruitment was correlated to the previous October through March precipitation; and (2) pronghorn abundance was directly related to amount of rainfall.

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CHAPTER II
FORAGE PRODUCTION AND DIETS OF PRONGHORN
IN CENTRAL ARIZONA

Abstract

Over the past 15 years, pronghorn (*Antilocapra americana*) populations appear to have declined in Arizona. Recruitment of fawns into the population rather than adult mortality tends to be the primary determinant of populations in Arizona. The purpose of this study was to examine some factors which may affect differences between pronghorn fawn: doe ratios on the two ranches. Our goal was to determine if nutrition was adequate to support pronghorn and provide favorable conditions for survival and recruitment. This study was part of a statewide evaluation of factors affecting pronghorn fawn recruitment, including predator abundance, nutrition, fawn hiding cover, disease, and water availability throughout pronghorn habitat in Arizona. We studied forage production, and diets of pronghorn during 2003 and 2004 on 2 study sites in central Arizona. Diet composition (microhistological analysis of fecal samples) and selection relative to availability were investigated during gestation and lactation. Forage production during 2003-2004 ranged from 9-304 kg/ha. Forbs made up a major percentage of the biomass in 2003, whereas grasses made up the majority in 2004. Forbs made up 60-69 percent of the diets during gestation and lactation. Grasses were eaten in small quantities during both sampling periods. Browse consumption increased as forbs dried up during lactation. Pronghorn showed selected for forbs and avoided grasses on both study sites. Diet composition was similar on both study sites. Fawn recruitment during our study

increased from year 1 to year 2. It appeared that forage conditions during our study were favorable for fawn recruitment.

Introduction

Pronghorn (*Antilocapra americana*) are opportunistic foragers, selecting the most nutritious and succulent food plants (Yoakum 2004a). Pronghorn will feed on all forage classes, but prefer forbs and shrubs and avoid grasses (Yoakum 2004a). Pronghorn tend to consume many different forage species available to them, however, the degree of utilization varies according to availability, climatic conditions, succulence, palatability, digestibility, and nutritional quality (Yoakum 2004a). Rangelands lacking high quality forage in turn require the animal to forage aimlessly, decreasing the chance that dietary requirements will be met (Heller 1980).

Management of ungulate habitat is based on 2 major assumptions: if provided adequate cover, water, and space 1) the physical well being of the herd is directly related to the quality and quantity of its diet, and 2) a herd maintained on a high nutritional plane is more productive and less influenced by predation, starvation, diseases, and parasites than a herd on a low nutritional plane (Nelson and Leege 1982). Nutritional requirements vary seasonally and the availability and nutritive value of forage species vary by season and place (Nelson and Leege 1982). Further, little is known of the nutritional quality of forage used by pronghorn (Smith and Malechek 1974; Yoakum 2004a).

Diet quality can have significant impacts on the reproductive functions of wild ruminants depending upon the stage of reproduction (Robbins 1983). During late gestation quality of diet is of particular significance to the development of the fawn,

while lactation places the highest nutrient demand on the doe (Robbins 1983).

Consequently, during periods of poor quality diet both fawn and doe may be impacted negatively. Neonatal survival is reduced by low maternal diet quality, and reductions in diet quality for long durations close to parturition and lactation can have significant effects on both fawn and doe (Price and White 1985).

During late gestation and lactation dietary requirements for female ruminants increase dramatically (Nelson and Leege 1982). Energy expenditures of lactating females increase 150 % (Robbins 1983) and protein requirements during pregnancy triple (Nelson and Leege 1982). Therefore, nutrient requirements for female pronghorn increase dramatically during the spring and summer periods. If forage is deficient in either protein or energy during these periods, the fawn may be born weak, or milk provided could lack adequate nutrients for proper growth of the fawn.

One of the reasons postulated for the present low productivity of pronghorn in Arizona is that the vegetation maybe deficient in ≥ 1 critical nutrients (Smith and Malechek 1974). Pronghorn have very high levels of maternal reproductive expenditure and gestation length and prenatal growth rate have been shown to be significantly lower following dry summers (Byers and Hogg 1995). Given the variable nature of precipitation in Arizona and that nutrient content varies in plants by season (Van Soest 1994), inadequate protein or energy content of forage during late gestation and conception could contribute to poor mid-summer fawn: doe ratios (fawn recruitment) in Arizona.

Pronghorn production and survival can be influenced by the quality and quantity of forage consumed (Ellis 1972; Hansen et al. 2001). Pronghorn densities are related

directly to the quality and quantity of vegetation, which is related directly to climate (Yoakum 2004a). Precipitation and climate affect plant growth and abundance, which in turn support varying densities of pronghorn. It is these ecological variables that determine long-term carrying capacity and thus pronghorn population dynamics (Yoakum 2004a).

This study was part of a statewide evaluation of factors affecting pronghorn fawn recruitment, including predator abundance, nutrition, fawn hiding cover, disease, and water availability throughout pronghorn range in Arizona. Four study areas were located throughout the state and each had a high and low recruitment site, using paired study sites in an effort to determine factors which may affect fawn recruitment. Data were collected during biologically significant periods for pronghorn females: late gestation, parturition, lactation, and conception. Here I report on the late gestation and lactation periods for 1 study area (2 paired sites).

We compared pronghorn diets at 2 study sites in central Arizona from April through August 2003. Our objective was to determine the composition of pronghorn diets in Arizona during biologically significant periods. We tested the following predictions: (1) species composition in pronghorn diets differs between sites and among seasons; and (2) pronghorn use available forage species in proportion to their occurrence.

Study Area

We measured pronghorn diet composition, forage availability and forage production at 2 sites in Yavapai County, Arizona. Both study areas were within Game Management Unit (GMU) 19A. The Fain Ranch site encompassed approximately 27,684

ha of short-grass prairie that was bordered on the north by State Route (SR) 89A, on the east by interior chaparral foothills of the Mingus Mountains, on the south by State Highway 69, and on the west by the town of Prescott Valley. The Lonesome Valley (LV) site was a collection of 3 ranches and state land, and was approximately 26,900 ha of short-grass prairie that was bordered on the north by Perkinsville Road, on the east by the vegetated interior chaparral foothills of the Mingus Mountains, on the south by SR 89A, and on the west by the town of Chino Valley and Highway 89.

Potential predators of pronghorn in our study areas included coyote (*Canis latrans*), which primarily prey on fawns, and mountain lion (*Puma concolor*) which were few in these areas but did kill adults on occasion in the rough terrain typical of the eastern edge of the study sites (Ockenfels 1994). A small number of mule deer (*Odocoileus hemionus*) and collared peccari (*Peccari tajacu*) also occurred in these areas.

Climate was mild, with monthly average temperatures above freezing and an average annual rainfall of 30 cm. Precipitation patterns were bimodal, with 45% of annual rainfall falling during monsoonal thunderstorms from mid-July to September and the remainder as irregular winter and spring snow storms from December to February (Western Regional Climate Center, Desert Research Institute; <http://www.wrcc.dri.edu/>). Long-term minimum and maximum daily temperature in January averaged -6 and 11° C, respectively, at Chino Valley (the nearest weather reporting station), whereas July temperatures averaged 15 to 33° C, respectively.

Terrain was mostly flat to rolling hills. Dominant vegetation biomes were grasslands, including short-grass prairies and some interior chaparral. Blue grama (*Bouteloua gracilis*) and ring muhly (*Muhlenbergia torreyi*) dominated the areas. Other

perennial grasses in the area included red three-awn (*Aristida purpurea*), sideoats grama (*B. curtipendula*), tobosa (*Hilaria mutica*), oatgrass (*Danthonia* spp.), and foxtail barley (*Hordeum jubatum*). Annual grasses included red brome (*Bromus rubens*), little barley (*H. pusellum*), sixweeks fescue (*Vulpia octoflora*) and wild oats (*Avena fatua*). Dominant forb species included redstem filaree (*Erodium cicutarium*), western blue flax (*Linum lewisii*), pursh plantain (*Plantago purshii*), and baby aster (*Leucelene erocoides*). Dominant short shrub species were broom snakeweed (*Gutierrezia sarothrae*), winterfat (*Ceratoides lanata*), and threadleaf groundsel (*Senecio douglasii*). Saltbush (*Atriplex canescens*), fendler ceanothus (*Ceanothus fendlerii*), and apache plume (*Fallugia paradoxa*) were prominent in drainages. Chaparral shrubs occurred mainly in drainages and on north-facing slopes. Chaparral species included shrub live oak (*Quercus turbinella*), skunkbrush sumac (*Rhus aromatic*), and beargrass (*Nolina microcarpa*) which dominated the eastern foothills. Scattered throughout the study areas were several succulent species, including cholla (*Opuntia* spp.), and prickly pear (*Opuntia* spp.). Juniper (*Juniperus* spp.) occurred primarily in the eastern most chaparral areas.

Land ownership consisted of a checkerboard of state and private lands. Several 2-track dirt roads dissected both areas. Motorized traffic was restricted in some areas of state land and was restricted to ranch personnel on the Fain Ranch. Cattle grazing occurred at varying intensities on most state and private land.

Methods

Fecal collection

We located and observed a herd or single pronghorn with a spotting scope until the majority of the individuals had defecated. We made every attempt to collect fecal samples from female groups or groups with few bucks in the herd. We used a rangefinder to determine distance to the group. We collected and labeled individual fecal pellet groups by site, date, number of pronghorn in the group, number of each sex in the group, global positioning system (GPS) location, time period, and a unique number for each pellet group, and site. Seven pellet groups from each study site for each time period were pooled to create 1 composite sample for diet analysis. Three composite samples were analyzed per time period per site, so a total of 21 pellet groups were collected from each study area during each of 2 time periods: late gestation, (10 April to 25 April) and lactation (20 June to 10 July). Fecal samples were frozen until laboratory analyses were performed.

Plant collection

We collected samples of all known and suspected forage plant species on each study site to create reference slides for microhistological diet determination. Because pronghorn are selective feeders, we only collected palatable portions of plants (i.e., leaves and terminal buds of shrubs; O' Gara 1978). Once a group of pronghorn had been sighted and feces collected, we collected all plant species from at least 3 areas adjacent to the fecal collection site. We also collected plants from throughout each study area to ensure that all species in fecal samples were represented.

Microhistological analysis

We determined diet composition using microhistological analyses for each composite sample by site by season following procedures described by Holt et al. (1992). Diet composition was based on relative density of each plant species in 300 randomly located fields of a microscope preparation of composite diet samples (Koerth et al. 1984). We were unable to determine differential digestion of forage species, however, we acknowledge that forage species have differential digestion rates and species do not necessarily occur in fecal samples in the same proportions eaten. We feel that the microhistological technique still provides an accurate indication of forage consumed.

Availability and production

We used a double sampling technique to estimate availability and production of forage species (Higgins et al. 1994). Availability and production estimates were taken from 715 (354 Fain, 361 LV) random points throughout each study area, during late gestation (10 April to 25 April), parturition (10 May to 30 May), lactation (20 June to 10 July), and conception (20 August to 10 September). At each random point we made ocular biomass estimates in each of 4 plots for each plant species within a 0.5 m² plot. At a subset of random points, plants were clipped and weighed after the estimates were made. In order to adjust estimated weights to actual weights, regression of the estimated versus actual weights of clipped plants provided an estimator of actual weights for the plants for which only estimates were made.

We determined pronghorn preference ratings of individual plants by dividing the product of the percent of a plant in the diet by the availability of the plant in each study area. Chi-squared tests were used to determine differences between expected utilization

of forage species (based upon their availability) and the observed frequency of their usage (Neu et al. 1974; Krausman 1978; Byers et al. 1984). We used chi-squared tests to determine differences between species utilization at each study site. When significant differences were found we used Bailey confidence intervals to determine which forage species were selected or avoided (Cherry 1996). We used Bonferroni confidence intervals on proportion of Fain pronghorn diets for comparison to Lonesome Valley pronghorn diets. If avoidance or selection was detected, we used Jacobs' D to determine magnitude and direction of forage species selection or avoidance (Jacobs 1974), which gave a rating to forage species consumed independent of relative abundance.

Results

Availability and production

During 2003-2004 total forage production ranged from 9 to 304 kg/ha (Table 2.1). Availability and production data were not collected during conception in 2004 because of time constraints. We found 36 forbs, 13 grasses, 10 shrubs, 3 cacti, and 1 tree species on the Fain Ranch and 41 forbs, 15 grasses, 9 shrubs, 3 cacti, and 1 tree species on Lonesome Valley (Table 2.2). Grasses made up the majority (42.4 %) of the biomass in 2004, whereas forbs made up the major percentage in 2003 (32.1 %; Table 2.3). Although estimates of biomass for individual plant species varied between the two study sites, almost (95 %) all plant species occurred in both areas.

Diets

Analyses of feces with the microhistological technique indicated little variation between diet composition on Fain and LV during gestation and lactation (Table 2.4).

Forbs made up 60 to 69 % of the diet, whereas shrubs made up 19 to 28 % of the diet (Table 2.4). Pursh plantain comprised the highest percentage of any single species (11.1 and 10.8 %) in the diet on Fain and LV, respectively (Table 2.4). Other plants contributing at least 5 % to the diet on Fain included filaree, scarlet gaura (*Gaura coccinea*), baby aster, globemallow (*Sphaeralcea coccinea*), and apache plume (Table 2.4). Other plants contributing at least 5 % to the diet on LV included filaree, scarlet gaura, baby aster, fendler ceanothus, and skunk brush (Table 2.4). The only grass to contribute ≥ 1 % to the diet was blue grama (Table 2.4). Grasses were eaten in small quantities and never made up > 5 % of the diet in any sampling period.

During gestation pronghorn consumed significantly more ($P < 0.05$) filaree, western blue flax, pursh plantain, tobosa, little barley, ring muhly, buckwheat (*Eriogonum wrightii*), and rabbit thorn (*Lycium pallidum*) and consumed significantly less ($P < 0.05$) desert paintbrush (*Castilleja chromosa*), cryptantha (*Cryptantha* spp.), tansy mustard (*Descurainia pinnata*), primrose (*Oenothera caespitosa*), winterfat, and shrub live oak on LV compared to Fain (Table 2.5). During lactation pronghorn consumed significantly more ($P < 0.05$) prairie zinnia (*Zinnia grandiflora*), scarlet gaura, and skunk brush and consumed significantly less ($P < 0.05$) cryptantha, pursh plantain, winterfat, and apache plume on LV compared to Fain (Table 2.6).

Generally, pronghorn used grasses less than available and used forbs and shrubs more than available on both study sites and collection periods (Table 2.7-10). During gestation pronghorn on Fain used all grasses less than available, and forbs and shrubs were used more than available (Table 2.7). Four forbs and 2 shrubs were highly selected (Table 2.7). Pronghorn on Fain during lactation used all grasses less than available and

most forbs and shrubs more than available (Table 2.8). Two of the same forbs and shrubs were highly selected (Table 2.8). A similar pattern was seen during gestation (Table 2.9) and lactation (Table 2.10) on Lonesome Valley. The same 4 forb (*Gaura coccinea*, *Layia glandulosa*, *Oenothera caespitosa*, *Salsola iberica*) species and 2 shrubs (*Ceanothus fendlerii*, *Lycium pallidum*) were highly selected during gestation on Lonesome Valley (Table 2.9 and 2.10, respectively). During lactation 2 forbs and 3 shrubs were highly selected (Table 2.10).

Discussion

Resource availability is among the most important factors affecting abundance of large mammals (Marshall et al. 2002). Forage resources in xeric areas are affected primarily by precipitation and are highly variable from year to year (Marshall et al. 2002). Increased winter rainfall supported higher spring forb production, but grass production was not associated with winter precipitation (Smith and LeCount 1979). Our findings confirm that differences in rainfall between years influence forage production, particularly of forbs. Compared to 2004, higher rainfall in 2003 (McDonald 2005; Figure 4.1) was associated with increased production of forbs, consistent with other studies reporting positive relationships between precipitation and forage production (primarily forbs) in Arizona (Smith and LeCount 1979; Fagan et al. 2004).

Vegetation quality and quantity have been identified as key factors influencing pronghorn production and survival and vegetation characteristics as related to diet selection (Yoakum 2002). The beginning of this study (2003) followed the lowest yearly precipitation ever recorded (Western Regional Climatic Center;

<http://www.wrcc.dri.edu/summary/climsmaz.html>; 21 July 2005), and consequently, the overall productivity of forage species was likely below normal. During the later part of 2003 and April 2004 above normal precipitation was likely the cause for the increase in forage species production in 2004 over 2003. In western Utah little evidence was found to conclude that forage conditions affected pronghorn fawn survival, however, general observations of physical condition and growth of fawns appeared markedly better in years when abundant succulent forbs were available (Beale and Smith 1970). However, forage conditions may indirectly affect fawns if does are in poor condition as a result of poor forage quality.

Vegetation diversity of pronghorn habitat on grasslands numbered 10-20 grasses, 20-60 forbs, and 5-10 shrub species (Lee et al. 1994). Forb-rich plant communities have a significant relationship to pronghorn fawn production (i.e., more forbs equal high fawn recruitment; Hall et al. 2000). However, during our study highest fawn recruitment occurred in 2004 (AZGF, unpublished data) when percent forb composition was lowest. This may have been due to the increase in grass production in 2004. Grasses are not a major component of pronghorn diets (Yoakum 2004a), but they provide critical cover for pronghorn fawns (Yoakum 2004b). Average grass canopy cover during this study increased from 2003 to 2004 (AZGF, unpublished data). In our study, it appeared that species composition provided adequate forage conditions for pronghorn in this region.

When forage was relatively abundant, pronghorn diets were not composed of species in relation to their availability, but rather pronghorn were highly selective for some species. As reported elsewhere, pronghorn are highly selective of forbs followed by shrubs and grasses (Dirschl 1963; Mitchell and Smoliak 1971; Yoakum 1990;

Yoakum 2004a). Our results indicate that there were few differences in diets between the 2 ranches pronghorn diet selection during gestation and lactation. Forage consumption of browse increased from gestation to lactation periods on both areas. The most likely explanation for this trend was the limited availability of forbs due to the dry and hot conditions on our study sites during summer months.

Consumption of skunk brush and apache plume increased greatly from gestation to lactation likely as a result of drying of forb forage. Because of their low-fiber levels, new shrub growth breaks down quickly in the rumen and can permit higher intake levels (Holechek 1984). However, as plants mature, there is usually an increase in the proportion of fiber, a reduction in protein, and a decrease in digestibility results in reduced intake (Arnold 1985). Shrubs may be a critical component of pronghorn diet in this area during dry hot summers. High-fiber diets are poorly digested, reducing rate of passage and thus reducing intake, while highly succulent low fiber diets are highly digestible. Diets during lactation had a higher proportion of shrubs and those diets were likely high in fiber and poorly digestible because plants were mature at this time of year.

Diet quality can have significant impacts on the reproductive functions of wild ruminants, depending upon the stage of reproduction (Robbins 1983). Diet quality during late gestation is of particular significance to development of fawns, while lactation places highest nutrient demands on does (Robbins 1983). Consequently, during periods of poor quality diet both may be negatively impacted. It appears that during late gestation and lactation pronghorn on our study sites received adequate nutrition for production (McDonald 2005). Fawn recruitment increased from year 1 to year 2 of this study

(Figure 2.1) and it appeared that forage conditions were favorable for survival and production of pronghorn on these study sites.

Management Implications

We described forage and diet characteristics of highly productive pronghorn populations in central Arizona which should serve as baseline data for future studies and comparison. Pronghorn were highly selective foragers but changed diets based on plant species availability and palatability. Forage conditions during our study appeared adequate for reproduction and survival. However, during extreme and prolonged periods of drought, decreased forage conditions may inhibit the ability of pronghorn to meet requirements, thus adversely impacting recruitment and survival of fawns. Although pronghorn recruitment in our study did not appear to be influenced by forage availability, these conditions alone do not appear to explain the annual variation in fawn recruitment in this region. With the exception of periods of prolonged and extreme drought, as seen in 2002, nutrition does not appear to influence fawn recruitment. This type of condition was present in 2002 when the area received < 16 cm of annual precipitation (half that of the long-term average), and subsequently >270 pronghorn died and fawn: doe ratios were the lowest on record at these study sites (Arizona Game and Fish Department, unpublished data). Ranch personnel collected > 50 carcasses in drainages near Prescott Valley (Jason Scarborough, Fain Ranch, personal communication). This major die-off was presumably caused by starvation (R. Ockenfels, AZGF, personal communication).

Based on our findings and the literature, if managers want to maintain healthy pronghorn herds in Arizona, several land management actions might be necessary to

encourage or enhance forb growth. Managers may wish to initiate prescribed spring fire to encourage native forb growth and discourage shrub encroachment. Further, Sonoran pronghorn (*Antilocapra americana sonorensis*) were highly selective of areas disturbed by military activity at the Barry M. Goldwater bombing range in southwest Arizona (AZGF, unpublished data). It may be possible for managers to disturb soil by disking to encourage or enhance forb growth. Forage allocation and management should be geared towards maintaining and increasing productivity of preferred pronghorn forage species.

Loss of pronghorn habitat is a major concern for many populations in Arizona (Ockenfels *et al.* 1996). The towns of Prescott Valley and Chino Valley are located adjacent to our study sites. Both of these communities are rapidly expanding. As a result, the surrounding grasslands are being developed at a fast rate and fragmenting existing habitat. Since future development is likely to continue, resource managers need to consult with planning and zoning personnel to maintain vital habitat for these herds. Therefore, to maintain healthy populations in these areas further research is warranted to determine the affects of such development on these pronghorn. Further, the affects of human development, shrub encroachment and habitat loss would be excellent candidates for future, long-term investigation of recruitment rates in Arizona pronghorn populations. It may be possible to analyze aerial photos over time and determine the amount of habitat lost and relationships to fawn recruitment. Geographic Information System (GIS) technologies could be used to determine these variables.

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Table 2.1. Estimated total forage production (kg/ha) on Fain Ranch and Lonesome Valley (LV) during selected biological periods for pronghorn in central Arizona 2003 and 2004.

Biological period	Forage production kg/ha			
	Fain		LV	
	2003	2004	2003	2004
Gestation ^a	125.44	232.41	140.86	210.58
Parturition ^b	142.06	198.99	124.25	233.94
Lactation ^c	303.73	259.28	81.41	315.95
Conception ^d	68.69	NA	105.28	NA
Total	159.98	230.23	105.28	253.49

^a 10 April to 25 April

^b 10 May to 30 May

^c 20 June to 10 July

^d 20 August to 10 September

Table 2.2. Pronghorn forage species availability (%) on Fain Ranch and Lonesome Valley (LV), central Arizona during 2003 and 2004.

Common name	Scientific name	Vegetative composition			
		Fain		LV	
		2003	2004	2003	2004
Grass					
Purple three-awn	<i>Aristida purpurea</i>	1.5	1.9	1.8	2.9
Wild oat	<i>Avena fatua</i>	-	-	0.1	-
Sideoats grama	<i>Bouteloua curtipendula</i>	2.3	3.8	1.6	2.6
Black grama	<i>B. eriopoda</i>	0.3	2.1	2.1	11.6
Blue grama	<i>B. gracilis</i>	5.7	3.9	9.1	15.6
Brome grass species	<i>Bromus</i> spp.	0.1	-	-	0.3
Red brome	<i>B. rubens</i>	0.3	2.5	0.3	0.4
Oatgrass species	<i>Danthonia</i> spp.	1.0	-	0.6	-
Lovegrass species	<i>Eragrostis</i> spp.	-	0.2	-	0.2
Tobosa	<i>Hilaria mutica</i>	4.8	5.6	3.0	1.6
Little barley	<i>Hordeum pusillum</i>	3.2	1.2	0.6	0.2
Creeping muhly	<i>Muhlenbergia repens</i>	1.1	3.1	1.0	2.0
Ring muhly	<i>M. torreyi</i>	5.0	3.0	6.8	3.0
Vinemesquite	<i>Panicum obtusum</i>	tr	0.5	0.3	-
Needleandthread	<i>Sitpa comata</i>	0.1	-	0.1	-
Fluffgrass	<i>Tridens pulchellus</i>	-	0.6	-	0.6
Six-weeks fescue	<i>Vulpia octoflora</i>	0.3	2.2	1.3	1.1
Other grasses		-	3.8	-	9.2
Total		25.7	33.5	43.1	51.3
Forbs					
Corn-kernel milkweed		-	0.1	-	-
Desert paintbrush	<i>Castilleja chromosa</i>	-	-	-	tr
Fairy duster		0.5	0.3	0.5	0.1
Winterfat	<i>Ceratoides lanata</i>	tr	0.4	0.3	0.5
Purple mustard		1.1	-	2.5	-
New Mexican thistle	<i>Cirsium</i>	0.2	1.3	1.5	0.3
Cryptantha species	<i>Cryptantha</i> spp.	1.8	1.0	1.6	0.1
Parry dalea	<i>Dalea parryi</i>	2.0	0.5	0.5	-
Tansymustard	<i>Descurainia pinnata</i>	0.5	0.1	0.7	-
Blue dick	<i>Dichelostemma pulchellum</i>	0.5	0.7	-	0.1
Redstem filaree	<i>Erodium cicutarium</i>	16.8	2.5	12.7	3.2
Rattlesnake weed	<i>Chamaesyce albomarginata</i>	tr	0.6	0.1	-
Scarlet gaura	<i>Gaura coccinea</i>	0.3	0.4	0.7	0.7
Broad-leafed gila	<i>Gilia latifolia</i>	0.1	2.5	0.3	3.0
Tiddy tips	<i>Layia glandulosa</i>	0.1	0.6	0.1	3.0
Baby aster	<i>Leucelene ericoides</i>	1.9	2.4	0.1	2.6
Yellow linathus	<i>Linanthus aureus</i>	0.1	-	0.2	0.1
Western blue flax	<i>Linum lewisii</i>	3.7	2.7	3.0	2.0
Lupine species	<i>Lupinus</i> spp.	tr	0.1	tr	-
Yellow spiny daisy	<i>Machaeranthera gracilis</i>	1.1	0.6	1.9	1.3

tr – represents species with < 0.1 % composition.

Empty cells indicate that species were not detected during random sampling

Table 2.2. (continued) Pronghorn forage species availability (%) on Fain Ranch and Lonesome Valley (LV), central Arizona during 2003 and 2004.

Common name	Scientific name	Vegetative composition			
		Fain		LV	
		2003	2004	2003	2004
Clover species	<i>Medicago</i> spp.	0.1	0.1	-	-
Microseris	<i>Microseris</i>	0.4	0.1	0.2	0.1
Stemless primrose	<i>Oenothera caespitosa</i>	0.1	0.5	0.2	-
Lambert's crazyweed	<i>Oxitropis lambertii</i>	0.3	1.1	0.3	0.1
Bloodroot	<i>Plagiopothryos</i> spp.	1.1	3.2	1.8	3.9
Pursh plantain	<i>Plantago purshii</i>	13.4	2.8	13.2	2.2
Common purselane		0.3	-	0.2	-
Russian thistle	<i>Salsola iberica</i>	0.1	1.4	0.2	1.5
Threadleaf groundsel	<i>Senecio douglasii</i>	tr	-	0.2	0.1
London rocket	<i>Sisymbrium irio</i>	0.2	0.1	1.4	0.1
Silverleaf nightshade	<i>Solanum elaeagnifolium</i>	0.2	0.5	0.1	0.1
Scarlet globemallow	<i>Sphaeralcea coccinea</i>	1.2	1.6	1.8	3.5
Mexican verbain	<i>Verbena ciliate</i>	-	1.6	0.4	-
Vineweed		-	0.1	tr	tr
Prairie zinnia	<i>Zinnia grandiflora</i>	0.2	0.4	0.4	0.6
Other forbs		1.7	0.2	3.1	0.1
Total forbs		49.5	32.3	52.6	31.8
Shrubs					
Serviceberry	<i>Amelanchier alnifolia</i>	-	-	-	0.4
Yerba de pasmo	<i>Baccharis pteronioides</i>	0.2	1.4	0.2	1.0
Fendler's ceanothus	<i>Ceanothus fendlerii</i>	0.4	1.4	0.1	0.1
True mountainmahogany	<i>Cercocarpus montanus</i>	-	0.3	0.1	0.6
Wright's buckwheat	<i>Eriogonum wrightii</i>	3.6	2.2	4.0	3.5
Apache plume	<i>Fallugia paradoxa</i>	0.2	0.5	-	0.1
Broom snakeweed	<i>Gutierrezia sarothrae</i>	2.2	3.9	2.7	4.2
Rabbit thorn	<i>Lycium pallidum</i>	tr	0.6	0.1	0.2
Wait-a-minute bush	<i>Mimosa biuncifera</i>	0.2	1.2	0.1	-
Shrub live oak	<i>Quercus turbinella</i>	8.1	12.8	5.3	3.2
Skunk bush	<i>Rhus aromatica</i>	1.7	3.7	1.8	2.7
Total shrubs		16.7	28.1	14.4	15.8
Trees					
Desert willow	<i>Chilopsis linearis</i>	0.3	-	-	-
Juniper species	<i>Juniperus</i> spp.	-	-	1.0	-
Total trees		0.3	-	1.0	-
Cacti					
Beargrass	<i>Nolina microcarpa</i>	tr	2.2	0.4	0.9
Cholla species	<i>Opuntia</i> spp.	1.3	0.2	1.5	0.3
Prickly pear	<i>Opuntia</i> spp.	6.5	2.2	3.7	-
Yucca species	<i>Yucca</i> spp.	-	0.8	-	-
Cacti total		7.8	5.4	5.8	1.2

tr – represents species with < 0.1 % composition.

Empty cells indicate that species were not detected during random sampling

Table 2.3. Forage species production (kg/ha) on Fain Ranch and Lonesome Valley (LV) in central Arizona during 2003 and 2004.

Common name	Scientific name	Forage production kg/ha dry weight			
		2003		2004	
		Fain	LV	Fain	LV
Grass					
Purple three-awn	<i>Aristida purpurea</i>	4.4	2.6	4.0	7.0
Wild oat	<i>Avena fatua</i>	-	tr	-	-
Sideoats grama	<i>Bouteloua curtipendula</i>	6.1	2.0	8.5	6.2
Black grama	<i>B. eriopoda</i>	0.6	0.1	3.6	53.2
Blue grama	<i>B. gracilis</i>	15.1	12.4	19.3	25.2
Red brome	<i>B. rubens</i>	1.2	0.5	0.9	1.5
Oatgrass species	<i>Danthonia</i> spp.	2.2	0.7	-	-
Lovegrass species	<i>Eragrostis</i> spp.	-	-	0.1	0.4
Tobosa	<i>Hilaria mutica</i>	9.8	4.8	26.5	5.4
Little barley	<i>Hordeum pusillum</i>	8.7	1.2	4.2	0.5
Creeping muhly	<i>Muhlenbergia repens</i>	2.8	1.1	6.1	6.2
Ring muhly	<i>M. torreyi</i>	12.1	8.7	8.4	10.5
Vinemesquite	<i>Panicum obtusum</i>	tr	0.3	0.4	-
Needleandthread	<i>Sitpa comata</i>	0.1	0.1	-	-
Fluffgrass	<i>Tridens pulchellus</i>	-	-	1.0	2.5
Six-weeks fescue	<i>Vulpia octoflora</i>	1.0	1.4	3.7	4.0
Other grasses		0.1	0.2	12.5	30.4
Total		64.1	36.0	99.3	153.4
Forbs					
Desert paintbrush	<i>Castilleja chromosa</i>	-	-	-	tr
Fairy puster		1.1	0.7	0.2	0.1
Winterfat	<i>Ceratoides lanata</i>	tr	0.6	0.4	0.9
Purple mustard		1.5	3.3	-	-
New Mexican thistle	<i>Cirsium</i>	0.4	2.1	0.7	0.3
Cryptantha species	<i>Cryptantha</i> spp.	3.9	4.6	0.4	0.3
Parry dalea	<i>Dalea parryi</i>	3.2	1.3	0.4	-
Tansymustard	<i>Descurainia pinnata</i>	0.7	1.7	0.2	-
Blue dick	<i>Dichelostemma pulchellum</i>	0.4	-	0.3	tr
Redstem filaree	<i>Erodium cicutarium</i>	30.1	21.1	12.4	6.2
Miniature wool-star		-	-	0.7	4.5
Rattlesnake weed	<i>Chamaesyce albomarginata</i>	0.1	0.3	0.1	-
Scarlet gaura	<i>Gaura coccinea</i>	0.4	0.9	0.2	1.1
Broad-leafed gila	<i>Gilia latifolia</i>	0.2	0.4	4.5	5.2
Tiddy tips	<i>Layia glandulosa</i>	0.2	0.4	0.5	5.2
Peavine		1.4	2.6	-	-
Baby aster	<i>Leucelene ericoides</i>	2.8	3.8	4.0	4.3
Yellow linathus	<i>Linanthus aureus</i>	0.3	0.3	-	0.1
Western blue flax	<i>Linum lewisii</i>	5.8	7.1	7.4	2.6

tr – represents < 0.1 kg/ha

Empty cells indicate that species were not detected during random sampling

Table 2.3 (continued) . Forage species production (kg/ha) on Fain Ranch and Lonesome Valley (LV) in central Arizona during 2003 and 2004.

Common name	Scientific name	Forage production kg/ha dry weight			
		2003		2004	
		Fain	LV	Fain	LV
Lupine species	<i>Lupinus</i> spp.	tr	0.2	tr	-
Yellow spiny daisy	<i>Machaeranthera gracilis</i>	1.7	2.5	1.6	1.5
Clover species	<i>Medicago</i> spp.	0.1	-	0.1	-
Yellow menadora	<i>Menadora scabra</i>	-	-	0.7	0.4
Microseris	<i>Microseris</i>	0.7	0.6	0.1	tr
Stemless primrose	<i>Oenothera caespitosa</i>	0.2	0.3	0.1	-
Lambert's crazyweed	<i>Oxitropis lambertii</i>	0.6	0.4	0.1	0.1
Bloodroot	<i>Plagiopothryos</i> spp.	2.1	2.8	3.1	9.0
Pursh plantain	<i>Plantago purshii</i>	23.6	23.7	11.5	2.3
Common purselane		0.3	0.3	-	-
Russian thistle	<i>Salsola iberica</i>	0.1	0.4	0.6	0.8
Threadleaf groundsel	<i>Senecio douglasii</i>	0.1	0.5	-	0.2
London rocket	<i>Sisymbrium irio</i>	0.3	3.5	0.1	0.1
Silverleaf nightshade	<i>Solanum elaeagnifolium</i>	0.2	0.1	0.2	0.1
Scarlet globemallow	<i>Sphaeralcea coccinea</i>	2.0	3.1	2.4	4.2
Mexican verbain	<i>Verbena ciliate</i>	-	0.5	0.7	-
Vineweed		-	0.1	0.1	0.1
Prairie zinnia	<i>Zinnia grandiflora</i>	0.3	0.6	0.3	0.8
Unknown forbs		0.9	5.3	-	0.1
Total forbs		85.9	96.5	54.0	50.6
Shrubs					
Serviceberry	<i>Amelanchier alnifolia</i>	-	-	-	1.1
Yerba de pasmo	<i>Baccharis pteronioides</i>	0.4	1.5	1.5	3.2
Fendler's ceanothus	<i>Ceanothus fendlerii</i>	1.3	0.4	2.4	0.4
True mountainmahogany	<i>Cercocarpus montanus</i>	-	0.4	0.5	1.5
Wright's buckwheat	<i>Eriogonum wrightii</i>	8.2	15.2	12.3	10.3
Apache plume	<i>Fallugia paradoxa</i>	0.7	-	1.2	0.1
Broom snakeweed	<i>Gutierrezia sarothrae</i>	4.9	10.1	18.8	13.5
Rabbit thorn	<i>Lycium pallidum</i>	0.1	0.4	0.6	0.3
Wait-a-minute bush	<i>Mimosa biuncifera</i>	0.6	0.3	1.7	-
Shrub live oak	<i>Quercus turbinella</i>	26.3	23.2	30.6	9.9
Skunk bush	<i>Rhus aromatica</i>	5.3	7.1	7.3	9.2
Total shrubs		47.9	58.6	76.9	49.4

tr – represents < 0.1 kg/ha

Empty cells indicate that species were not detected during random sampling

Table 2.4. Percent composition of forage consumed by pronghorn on Fain Ranch and Lonesome Valley (LV) in central Arizona during gestation and lactation, 2003. Sample sizes in parentheses.

Species	Percent composition					
	Gestation ^a		Lactation ^b		Total	
	Fain	LV	Fain	LV	Fain	LV
Grass						
<i>Bouteloua curtipendula</i>	0.6	0.7	0.8	0.3	0.7	0.5
<i>B. gracilis</i>	1.6	1.4	1.0	1.5	1.3	1.5
<i>Bromus rubens</i>	-	-	0.4	tr	0.2	tr
<i>Hilaria mutica</i>	0.2	0.7	1.0	0.8	0.6	0.8
<i>Hordeum pusillum</i>	0.6	0.8	1.0	0.9	0.8	0.9
<i>Muhlenbergia repens</i>	tr	-	-	-	tr	-
<i>M. torreyi</i>	0.2	0.6	0.5	0.1	0.3	0.4
Other grasses	0.3	-	-	-	0.2	-
Total grasses	3.4	4.1	4.7	3.7	4.1	3.9
Forbs						
<i>Castilla chromosa</i>	6.5	3.0	1.8	1.1	4.2	2.0
<i>Cryptantha</i> spp.	11.4	5.2	0.5	-	6.0	2.6
<i>Dalea parryi</i>	3.5	2.6	-	-	1.8	1.3
<i>Descurainia pinnata</i>	0.9	2.0	-	0.3	0.5	1.1
<i>Erodium cicutarium</i>	7.7	9.7	4.9	5.2	6.3	7.5
Minature wool-star	tr	0.1	-	0.8	tr	0.4
<i>Gaura coccinea</i>	5.2	5.4	8.5	14.4	6.9	9.9
<i>Gilia latifolia</i>	-	0.7	-	0.4	-	0.6
<i>Helianthus annuus</i>	-	-	-	0.1	-	0.1
<i>Layia glandulosa</i>	2.5	1.5	2.2	1.3	2.4	1.4
<i>Lesquerella arizonica</i>	0.1	-	-	-	0.1	-
<i>Lesquerella gordonii</i>	0.1	-	-	tr	tr	tr
<i>Leucelene ericoides</i>	4.4	4.7	8.3	7.3	6.4	6.0
<i>Linanthus aureus</i>	0.3	1.6	0.5	-	0.4	0.8
<i>Linum lewisii</i>	0.7	2.1	1.3	1.4	1.0	1.8
<i>Lotus</i> spp.	0.3	0.2	-	-	0.1	0.1
<i>Lupinus</i> spp.	0.5	0.4	0.9	0.4	0.7	0.4
<i>Machaeranthera gracilis</i>	0.6	0.4	1.0	3.8	0.8	2.1
<i>Medicago</i> spp.	0.4	0.2	1.2	0.2	0.8	0.2
<i>Menadora scabra</i>	3.5	4.4	4.0	3.7	3.7	4.1
<i>Oenothera caespitosa</i>	4.3	2.2	-	-	2.2	1.1
<i>Oxitropis lambertii</i>	-	0.3	-	-	-	0.1
<i>Plantago purshii</i>	6.9	9.8	15.3	11.8	11.1	10.8

tr – represents < 0.1% of diet

^a 04 April to 25 April

^b 06 June to 07 July

Empty cells indicate that plants were not detected in fecal samples

Table 2.4 (continued) Percent composition of forage consumed by pronghorn on Fain Ranch and Lonesome Valley (LV) in central Arizona, during gestation and lactation, 2003. Sample sizes in parentheses.

Species	Percent composition					
	Gestation ^a		Lactation ^b		Total	
	Fain	LV	Fain	LV	Fain	LV
Forbs cont.						
<i>Salsola iberica</i>	2.3	2.2	0.5	-	1.4	1.1
<i>Senecio douglasii</i>	0.3	0.2	1.4	0.3	0.9	0.2
<i>Solanum elaeagnifolium</i>	0.1	-	0.1	-	0.1	-
<i>Sphaeralcea coccinea</i>	4.3	2.2	5.1	5.2	4.7	3.7
<i>Verbena ciliate</i>	1.0	0.3	tr	0.1	0.5	0.2
<i>Zinnia grandiflora</i>	0.3	0.5	2.6	5.7	1.5	3.1
Total forbs	69.1	62.0	60.3	63.3	64.8	62.7
Browse						
<i>Baccharis pteronioides</i>	1.7	2.6	2.7	2.6	2.2	2.6
<i>Ceanothus fendlerii</i>	5.1	4.1	3.7	4.9	4.4	4.5
<i>Ceratoides lanata</i>	1.9	0.9	4.1	1.0	3.0	0.9
<i>Eriogonum wrightii</i>	2.0	3.4	0.7	0.3	1.4	1.9
<i>Fallugia paradoxa</i>	5.0	3.6	8.1	4.3	6.6	3.9
<i>Grindelia aphanactis</i>	-	-	-	0.2	-	0.1
<i>Gutierrezia sarothrae</i>	-	tr	0.2	0.3	0.1	0.1
<i>Juniperus</i> spp.	0.1	0.6	0.6	1.0	0.4	0.8
<i>Lycium pallidum</i>	2.3	4.3	2.6	2.8	2.4	3.6
<i>Mimosa biuncifera</i>	-	-	-	0.3	-	0.1
<i>Quercus turbinella</i>	0.2	-	1.1	0.9	0.7	0.5
<i>Rhus aromatica</i>	0.5	0.8	4.4	8.2	2.4	4.5
<i>Ribes cereum</i>	0.1	0.3	-	-	0.1	0.2
Total browse	19.4	20.5	28.4	26.6	24.9	23.6
Succulents						
<i>Opuntia</i> spp.	0.3	-	0.2	0.1	0.3	0.1
Total succulents	0.3	-	0.2	0.1	0.3	0.1
Unknown	8.1	13.4	6.5	6.3	5.2	9.8

tr - represents < 0.1% of diet

^a 04 April to 25 April

^b 06 June to 07 July

Empty cells indicate that plants were not detected in fecal samples

Table 2.5. Proportions of forage species in pronghorn diets on Fain Ranch and Lonesome Valley (LV) in north-central Arizona and 95% Bonferroni confidence intervals on proportion of Fain diets for comparison to Lonesome Valley, during gestation 04 April to 25 April 2003.

Species	Proportion in diet on LV (P)	Proportion in diet on Fain (P _i)	Bonferroni 95% confidence interval on proportion of P _i
Grass			
<i>Bouteloua curtipendula</i>	0.007	0.006	0.000 ≤ P ≤ 0.011
<i>Bouteloua gracilis</i>	0.014	0.016	0.007 ≤ P ≤ 0.025
<i>Hilaria mutica</i>	0.007 +	0.002	0.001 ≤ P ≤ 0.005
<i>Hordeum pusillum</i>	0.081 +	0.006	0.000 ≤ P ≤ 0.011
<i>Muhlenbergia torreyi</i>	0.006 +	0.002	0.001 ≤ P ≤ 0.005
Forbs			
<i>Castilleja chromosa</i>	0.030 –	0.065	0.048 ≤ P ≤ 0.083
<i>Cryptantha</i> spp.	0.052 –	0.114	0.091 ≤ P ≤ 0.137
<i>Dalea parryi</i>	0.026	0.035	0.022 ≤ P ≤ 0.048
<i>Descurainia pinnata</i>	0.020 +	0.009	0.003 ≤ P ≤ 0.016
<i>Erodium cicutarium</i>	0.097	0.077	0.058 ≤ P ≤ 0.097
<i>Gaura coccinea</i>	0.054	0.052	0.037 ≤ P ≤ 0.068
<i>Layia glandulosa</i>	0.015	0.025	0.014 ≤ P ≤ 0.036
<i>Leucelene ericoides</i>	0.047	0.044	0.029 ≤ P ≤ 0.058
<i>Linum lewisii</i>	0.021 +	0.007	0.001 ≤ P ≤ 0.014
<i>Lotus</i> spp.	0.002	0.003	0.001 ≤ P ≤ 0.006
<i>Lupinus</i> spp.	0.004	0.005	0.000 ≤ P ≤ 0.009
<i>Machaeranthera gracilis</i>	0.004	0.006	0.000 ≤ P ≤ 0.011
<i>Medicago</i> spp.	0.002	0.004	0.001 ≤ P ≤ 0.008
<i>Menadora scabra</i>	0.044	0.035	0.022 ≤ P ≤ 0.048
<i>Oenothera caespitosa</i>	0.022 –	0.043	0.029 ≤ P ≤ 0.057
<i>Plantago purshii</i>	0.098 +	0.069	0.051 ≤ P ≤ 0.087
<i>Salsola iberica</i>	0.022	0.023	0.012 ≤ P ≤ 0.033
<i>Senecio douglasii</i>	0.002	0.003	0.001 ≤ P ≤ 0.008
<i>Sphaeralcea coccinea</i>	0.022 –	0.043	0.029 ≤ P ≤ 0.058
<i>Zinnia grandiflora</i>	0.005	0.003	0.001 ≤ P ≤ 0.007
Shrubs			
<i>Baccharis pteronioides</i>	0.026	0.017	0.008 ≤ P ≤ 0.027
<i>Ceanothus fendlerii</i>	0.041	0.051	0.035 ≤ P ≤ 0.067
<i>Ceratoides lanata</i>	0.009	0.019	0.009 ≤ P ≤ 0.029
<i>Eriogonum wrightii</i>	0.034 +	0.020	0.010 ≤ P ≤ 0.030
<i>Fallugia paradoxa</i>	0.036	0.050	0.035 ≤ P ≤ 0.066
<i>Lycium pallidum</i>	0.043 +	0.023	0.012 ≤ P ≤ 0.033
<i>Quercus turbinella</i>	0.000 –	0.002	0.001 ≤ P ≤ 0.006
<i>Rhus aromatica</i>	0.008	0.005	0.000 ≤ P ≤ 0.000

(+) Represents species selected significantly more on Lonesome Valley than on Fain

(–) Represents species selected significantly less on Lonesome Valley than on Fain

Table 2.6. Proportions of forage species in pronghorn diets on Fain Ranch and Lonesome Valley (LV) in north-central Arizona and 95% Bonferroni confidence intervals on proportion of Fain diets for comparison to Lonesome Valley during lactation, 06 June to 07 July 2003.

Species	Proportion in diet on LV (P)	Proportion in diet on Fain (P _i)	Bonferroni 95% confidence interval on proportion of P _i
Grass			
<i>Bouteloua curtipendula</i>	0.003	0.008	0.001 ≤ P ≤ 0.014
<i>Bouteloua gracilis</i>	0.015	0.010	0.003 ≤ P ≤ 0.018
<i>Hilaria mutica</i>	0.008	0.010	0.003 ≤ P ≤ 0.018
<i>Hordeum pusillum</i>	0.009	0.010	0.003 ≤ P ≤ 0.018
<i>Muhlenbergia torreyi</i>	0.001	0.005	0.000 ≤ P ≤ 0.010
Forbs			
<i>Cryptantha</i> spp.	0.000 –	0.005	0.000 ≤ P ≤ 0.011
<i>Erodium cicutarium</i>	0.052	0.049	0.032 ≤ P ≤ 0.065
<i>Gaura coccinea</i>	0.144 +	0.085	0.064 ≤ P ≤ 0.106
<i>Layia glandulosa</i>	0.013	0.022	0.011 ≤ P ≤ 0.033
<i>Leucelene ericoides</i>	0.073	0.083	0.062 ≤ P ≤ 0.104
<i>Linum lewisii</i>	0.014	0.013	0.004 ≤ P ≤ 0.022
<i>Menadora scabra</i>	0.037	0.040	0.025 ≤ P ≤ 0.055
<i>Plantago purshii</i>	0.118 –	0.153	0.126 ≤ P ≤ 0.181
<i>Sphaeralcea coccinea</i>	0.052	0.051	0.034 ≤ P ≤ 0.068
<i>Zinnia grandiflora</i>	0.057 +	0.026	0.014 ≤ P ≤ 0.038
Shrubs			
<i>Baccharis pteronioides</i>	0.026	0.027	0.015 ≤ P ≤ 0.039
<i>Ceanothus fendlerii</i>	0.049	0.037	0.023 ≤ P ≤ 0.051
<i>Ceratoides lanata</i>	0.010 –	0.041	0.026 ≤ P ≤ 0.056
<i>Eriogonum wrightii</i>	0.003	0.007	0.001 ≤ P ≤ 0.014
<i>Fallugia paradoxa</i>	0.043 –	0.082	0.061 ≤ P ≤ 0.102
<i>Gutierrezia sarothrae</i>	0.003	0.002	0.001 ≤ P ≤ 0.006
<i>Lycium pallidum</i>	0.028	0.026	0.014 ≤ P ≤ 0.038
<i>Quercus turbinella</i>	0.009	0.011	0.003 ≤ P ≤ 0.019
<i>Rhus aromatica</i>	0.082 +	0.044	0.029 ≤ P ≤ 0.060

(+) Represents species selected significantly more on Lonesome Valley than on Fain

(–) Represents species selected significantly less on Lonesome Valley than on Fain

Table 2.7. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on Fain Ranch during gestation in north-central Arizona, 04 April to 25 April, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Grass							
<i>Bouteloua curtipendula</i>	0.031	77	10	0.006	$0.001 \leq p \leq 0.010$	-0.694	Avoidance*
<i>Bouteloua gracilis</i>	0.078	190	51	0.016	$0.012 \leq p \leq 0.033$	-0.682	Avoidance*
<i>Hilaria mutica</i>	0.050	123	7	0.002	$0.000 \leq p \leq 0.008$	-0.925	Avoidance*
<i>Muhlenbergia repens</i>	0.015	36	1	0.000	$0.000 \leq p \leq 0.004$	-0.983	Avoidance*
<i>Muhlenbergia torreyi</i>	0.062	153	17	0.002	$0.002 \leq p \leq 0.015$	-0.948	Avoidance*
Other grasses	0.049	120	11	0.003	$0.001 \leq p \leq 0.011$	-0.877	Avoidance*
Forbs							
<i>Castilleja chromosa</i>	0.0	0	151	0.065	$0.045 \leq p \leq 0.080$	1.0	Preference*
<i>Cryptantha</i> spp.	0.020	49	199	0.114	$0.063 \leq p \leq 0.102$	0.726	Preference*
<i>Dalea parryi</i>	0.017	40	125	0.035	$0.036 \leq p \leq 0.068$	0.368	Preference*
<i>Descurainia pinnata</i>	0.004	9	42	0.009	$0.009 \leq p \leq 0.028$	0.461	Preference*
<i>Erodium cicutarium</i>	0.155	379	192	0.077	$0.060 \leq p \leq 0.099$	-0.372	Avoidance*
<i>Gaura coccinea</i>	0.002	5	139	0.052	$0.041 \leq p \leq 0.075$	0.930	Preference*
<i>Layia glandulosa</i>	0.001	2	64	0.025	$0.016 \leq p \leq 0.039$	0.930	Preference*
<i>Leucelene ericoides</i>	0.015	36	98	0.044	$0.027 \leq p \leq 0.056$	0.514	Preference*
<i>Linum lewisii</i>	0.030	73	24	0.007	$0.004 \leq p \leq 0.018$	-0.608	Avoidance*
<i>Lotus</i> spp.	0.002	6	4	0.003	$0.000 \leq p \leq 0.006$	0.016	
<i>Lupinus</i> spp.	0.0	1	20	0.005	$0.003 \leq p \leq 0.016$	0.923	Preference*
<i>Machaeranthera gracilis</i>	0.009	21	16	0.006	$0.002 \leq p \leq 0.014$	-0.212	
<i>Medicago</i> spp.	0.001	1	15	0.004	$0.002 \leq p \leq 0.013$	0.738	Preference*
<i>Menadora scabra</i>	0.0	0	68	0.035	$0.017 \leq p \leq 0.041$	1.0	Preference*

* indicates a difference at the 0.05 level of significance

tr represents a value < 1

Table 2.7 cont. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on Fain Ranch during gestation in north-central Arizona, 04 April to 25 April, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Forbs cont.							
<i>Oenothera caespitosa</i>	0.001	2	117	0.043	$0.034 \leq p \leq 0.064$	0.957	Preference*
<i>Plantago purshii</i>	0.122	298	185	0.069	$0.058 \leq p \leq 0.096$	-0.304	Avoidance*
<i>Salsola iberica</i>	0.001	1	69	0.023	$0.018 \leq p \leq 0.042$	0.961	Preference*
<i>Senecio douglasi</i>	0.001	1	23	0.003	$0.004 \leq p \leq 0.018$	0.762	Preference*
<i>Solanum elaeagnifolium</i>	0.001	2	1	0.001	$0.000 \leq p \leq 0.004$	-0.110	
<i>Sphaeralcea coccinea</i>	0.011	26	78	0.043	$0.021 \leq p \leq 0.046$	0.621	Preference*
<i>Zinnia grandiflora</i>	0.002	4	11	0.003	$0.001 \leq p \leq 0.011$	0.292	
Other forbs	0.032	79	321	0.104	$0.108 \leq p \leq 0.156$	0.555	Preference*
Shrubs							
<i>Baccharis pteronioides</i>	0.002	5	30	0.017	$0.006 \leq p \leq 0.022$	0.780	Preference*
<i>Ceanothus fendlerii</i>	0.007	16	94	0.051	$0.026 \leq p \leq 0.054$	0.780	Preference*
<i>Ceratoides lanata</i>	0.000	tr	52	0.019	$0.012 \leq p \leq 0.033$	0.988	Preference*
<i>Eriogonum wrightii</i>	0.042	103	54	0.020	$0.013 \leq p \leq 0.034$	-0.366	Avoidance*
<i>Fallugia paradoxa</i>	0.004	9	72	0.050	$0.019 \leq p \leq 0.043$	0.871	Preference*
<i>Lycium pallidum</i>	0.001	2	39	0.023	$0.008 \leq p \leq 0.026$	0.947	Preference*
<i>Quercus turbinella</i>	0.136	332	5	0.002	$0.000 \leq p \leq 0.007$	-0.972	Avoidance*
<i>Rhus aromatica</i>	0.028	67	7	0.005	$0.000 \leq p \leq 0.009$	-0.722	Avoidance*
other shrubs	0.028	70	17	0.008	$0.002 \leq p \leq 0.015$	-0.587	Avoidance*

* indicates a difference at the 0.05 level of significance

tr represents a value < 1 expected/observed in diet

Table 2.8. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on Fain Ranch during lactation in north-central Arizona, 06 June to 07 July, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Grass							
<i>B. curtipendula</i>	0.031	56	18	0.008	$0.004 \leq p \leq 0.019$	-0.617	Avoidance*
<i>Bouteloua gracilis</i>	0.076	137	19	0.010	$0.004 \leq p \leq 0.020$	-0.779	Avoidance*
<i>Hilaria mutica</i>	0.049	89	15	0.010	$0.003 \leq p \leq 0.017$	-0.666	Avoidance*
<i>Hordeum pusillum</i>	0.044	79	16	0.010	$0.003 \leq p \leq 0.018$	-0.639	Avoidance*
<i>Muhlenbergia torreyi</i>	0.061	110	30	0.005	$0.008 \leq p \leq 0.028$	-0.858	Avoidance*
Other grasses	0.062	112	6	0.004	$0.000 \leq p \leq 0.010$	-0.887	Avoidance*
Forbs							
<i>Cryptantha</i> spp.	0.020	35	16	0.005	$0.003 \leq p \leq 0.018$	-0.579	
<i>Erodium cicutarium</i>	0.152	273	151	0.049	$0.064 \leq p \leq 0.106$	-0.556	Avoidance*
<i>Gaura coccinea</i>	0.002	4	139	0.085	$0.058 \leq p \leq 0.099$	0.959	Preference*
<i>Layia glandulosa</i>	0.001	2	39	0.022	$0.012 \leq p \leq 0.034$	0.923	Preference*
<i>Leucelene ericoides</i>	0.014	26	140	0.083	$0.059 \leq p \leq 0.099$	0.726	Preference*
<i>Linum lewisii</i>	0.029	53	15	0.013	$0.003 \leq p \leq 0.017$	-0.395	Avoidance*
<i>Menadora scabra</i>	0	0	68	0.040	$0.023 \leq p \leq 0.054$	1.0	Preference*
<i>Plantago purshii</i>	0.119	215	199	0.153	$0.088 \leq p \leq 0.135$	0.145	
<i>Sphaeralcea coccinea</i>	0.010	19	81	0.051	$0.031 \leq p \leq 0.062$	0.677	Preference*
<i>Zinnia grandiflora</i>	0.002	3	45	0.026	$0.015 \leq p \leq 0.039$	0.887	Preference*
Other forbs	0.085	153	212	0.077	$0.095 \leq p \leq 0.143$	-0.056	
Shrubs							

* indicates a difference at 0.05 level of significance

Table 2.8 cont. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on Fain Ranch during lactation in north-central Arizona, 06 June to 07 July, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Shrubs cont.							
<i>Baccharis pteronioides</i>	0.002	4	23	0.027	$0.006 \leq p \leq 0.023$	0.856	Preference*
<i>Ceanothus fendlerii</i>	0.007	12	65	0.037	$0.024 \leq p \leq 0.052$	0.708	Preference*
<i>Ceratoides lanata</i>	0.000	tr	82	0.041	$0.031 \leq p \leq 0.063$	0.995	Preference*
<i>Eriogonum wrightii</i>	0.041	74	34	0.007	$0.010 \leq p \leq 0.031$	-0.706	Avoidance*
<i>Fallugia paradoxa</i>	0.004	6	94	0.082	$0.037 \leq p \leq 0.070$	0.923	Preference*
<i>Gutierrezia sarothrae</i>	0.025	45	2	0.002	$0.000 \leq p \leq 0.006$	-0.836	Avoidance*
<i>Lycium pallidum</i>	0.001	1	34	0.026	$0.010 \leq p \leq 0.031$	0.955	Preference*
<i>Quercus turbinella</i>	0.133	240	16	0.011	$0.003 \leq p \leq 0.018$	-0.866	Avoidance*
<i>Rhus aromatica</i>	0.027	49	56	0.044	$0.019 \leq p \leq 0.046$	0.250	
other shrubs	0.003	12	6	0.006	$0.002 \leq p \leq 0.015$	0.348	
other/unknown	0.0	0	173	0.065	$0.075 \leq p \leq 0.120$	1.0	

* indicates a difference at 0.05 level of significance

Table 2.9. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on the Upper Lonesome Valley (LV) during gestation in north-central Arizona, 04 April to 25 April, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Grass							
<i>Bouteloua gracilis</i>	0.067	163	47	0.014	$0.011 \leq p \leq 0.029$	-0.664	Avoidance*
<i>Hilaria mutica</i>	0.026	63	13	0.007	$0.002 \leq p \leq 0.011$	-0.586	Avoidance*
<i>Muhlenbergia torreyi</i>	0.047	114	44	0.006	$0.010 \leq p \leq 0.028$	-0.791	Avoidance*
Other grasses	0.054	133	58	0.015	$0.015 \leq p \leq 0.035$	-0.587	Avoidance*
Forbs							
<i>Cryptantha</i> spp.	0.025	61	124	0.052	$0.038 \leq p \leq 0.066$	0.361	Preference*
<i>Dalea parryi</i>	0.007	17	93	0.026	$0.027 \leq p \leq 0.051$	0.586	Preference*
<i>Descurainia pinnata</i>	0.009	22	98	0.020	$0.028 \leq p \leq 0.054$	0.369	Preference*
<i>Erodium cicutarium</i>	0.113	277	220	0.097	$0.072 \leq p \leq 0.109$	-0.085	Avoidance*
<i>Gaura coccinea</i>	0.005	12	135	0.054	$0.041 \leq p \leq 0.071$	0.841	Preference*
<i>Layia glandulosa</i>	0.002	6	42	0.015	$0.010 \leq p \leq 0.027$	0.743	Preference*
<i>Leucelene ericoides</i>	0.021	50	109	0.047	$0.032 \leq p \leq 0.059$	0.401	Preference*
<i>Linum lewisii</i>	0.038	93	51	0.021	$0.013 \leq p \leq 0.031$	-0.299	Avoidance*
<i>Menadora scabra</i>	0	0	86	0.044	$0.024 \leq p \leq 0.048$	1.0	Preference*
<i>Oenothera caespitosa</i>	0.002	4	72	0.022	$0.019 \leq p \leq 0.041$	0.855	Preference*
<i>Plantago purshii</i>	0.127	310	225	0.098	$0.074 \leq p \leq 0.111$	-0.146	Avoidance*
<i>Salsola iberica</i>	0.002	5	59	0.022	$0.015 \leq p \leq 0.035$	0.847	Preference*
<i>Sphaeralcea coccinea</i>	0.017	40	56	0.022	$0.014 \leq p \leq 0.034$	0.140	
Other forbs	0.106	259	243	0.078	$0.081 \leq p \leq 0.119$	-0.168	Avoidance*
Shrubs							

* Indicates a difference at 0.05 level of significance

Table 2.9 cont. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on the Upper Lonesome Valley (LV) during gestation in north-central Arizona, 04 April to 25 April, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Shrubs cont.							
<i>Baccharis pteronioides</i>	0.008	20	33	0.026	$0.007 \leq p \leq 0.022$	0.535	
<i>Ceanothus fendlerii</i>	0.002	5	97	0.041	$0.028 \leq p \leq 0.053$	0.902	Preference*
<i>Ceratoides lanata</i>	0.003	8	22	0.009	$0.004 \leq p \leq 0.016$	0.468	Preference*
<i>Eriogonum wrightii</i>	0.081	199	44	0.034	$0.011 \leq p \leq 0.028$	-0.434	Avoidance*
<i>Fallugia paradoxa</i>	0	0	46	0.036	$0.011 \leq p \leq 0.029$	1.0	Preference*
<i>Gutierrezia sarothrae</i>	0.054	133	2	0.000	$0.000 \leq p \leq 0.004$	-0.989	Avoidance*
<i>Lycium pallidum</i>	0.002	5	65	0.043	$0.017 \leq p \leq 0.038$	0.910	Preference*
<i>Rhus aromatica</i>	0.038	93	17	0.008	$0.003 \leq p \leq 0.014$	-0.675	Avoidance*
other shrubs	0.128	313	18	0.009	$0.003 \leq p \leq 0.014$	-0.889	Avoidance*
other/unknown	0	0	324	0.133	$0.111 \leq p \leq 0.155$	1.0	

* Indicates a difference at 0.05 level of significance

Table 2.10. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on the Upper Lonesome Valley (LV) during lactation in north-central Arizona, 06 June to 07 July, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Grass							
<i>Bouteloua gracilis</i>	0.065	133	37	0.015	$0.010 \leq p \leq 0.029$	-0.641	Avoidance*
<i>Hilaria mutica</i>	0.025	51	19	0.008	$0.004 \leq p \leq 0.018$	-0.517	Avoidance*
<i>Hordeum pusillum</i>	0.007	13	16	0.009	$0.003 \leq p \leq 0.016$	0.165	
<i>Muhlenbergia torreyi</i>	0.046	93	14	0.001	$0.002 \leq p \leq 0.015$	-0.944	Avoidance*
Other grasses	0.047	95	8	0.003	$0.001 \leq p \leq 0.010$	-0.884	Avoidance*
Forbs							
<i>Erodium cicutarium</i>	0.111	225	152	0.052	$0.057 \leq p \leq 0.094$	-0.387	Avoidance*
<i>Gaura coccinea</i>	0.005	10	209	0.144	$0.082 \leq p \leq 0.125$	0.944	Preference*
<i>Leucelene ericoides</i>	0.020	41	155	0.073	$0.059 \leq p \leq 0.096$	0.587	Preference*
<i>Linum lewisii</i>	0.037	76	24	0.014	$0.006 \leq p \leq 0.021$	-0.458	Avoidance*
<i>Machaeranthera gracilis</i>	0.013	27	89	0.038	$0.030 \leq p \leq 0.059$	0.491	Preference*
<i>Menadora scabra</i>	0	0	91	0.037	$0.031 \leq p \leq 0.060$	1.0	Preference*
<i>Plantago purshii</i>	0.124	252	252	0.118	$0.101 \leq p \leq 0.147$	-0.026	
<i>Sphaeralcea coccinea</i>	0.016	33	91	0.052	$0.031 \leq p \leq 0.060$	0.538	Preference*
<i>Zinnia grandiflora</i>	0.003	6	79	0.057	$0.027 \leq p \leq 0.054$	0.908	Preference*
Other forbs	0.174	354	168	0.050	$0.064 \leq p \leq 0.102$	-0.597	Avoidance*
Shrubs							
<i>Baccharis pteronioides</i>	0.008	16	32	0.026	$0.008 \leq p \leq 0.026$	0.540	Preference*
<i>Ceanothus fendlerii</i>	0.002	4	102	0.049	$0.036 \leq p \leq 0.067$	0.919	Preference*
<i>Ceratoides lanata</i>	0.003	6	40	0.010	$0.011 \leq p \leq 0.031$	0.508	Preference*
<i>Eriogonum wrightii</i>	0.079	162	13	0.003	$0.002 \leq p \leq 0.014$	-0.928	Avoidance*

* Indicates a difference at 0.05 level of significance

Table 2.10 cont. Number of observed and expected forage species in pronghorn diets, Bailey's confidence intervals, and Jacobs' D values for proportions of observed species in diets on the Upper Lonesome Valley (LV) during gestation in north-central Arizona, 04 April to 25 April, 2003.

Species	Relative species availability	Number expected in diet	Number observed in diet	Proportion observed in diet	Bailey's 95% confidence interval	Jacobs' D	Preference or avoidance
Shrubs cont.							
<i>Fallugia paradoxa</i>	0	0	77	0.043	$0.026 \leq p \leq 0.052$	1.0	Preference*
<i>Gutierrezia sarothrae</i>	0.053	108	6	0.003	$0.000 \leq p \leq 0.009$	-0.915	Avoidance*
<i>Lycium pallidum</i>	0.002	4	27	0.028	$0.007 \leq p \leq 0.023$	0.866	Preference*
<i>Quercus turbinella</i>	0.121	248	16	0.009	$0.003 \leq p \leq 0.016$	-0.878	Avoidance*
<i>Rhus aromatica</i>	0.037	76	102	0.082	$0.036 \leq p \leq 0.067$	0.397	
other shrubs	0.002	4	18	0.012	$0.004 \leq p \leq 0.017$	0.742	Preference*
other/unknown	0	0	198	0.063	$0.078 \leq p \leq 0.119$	1.0	

* Indicates a difference at 0.05 level of significance

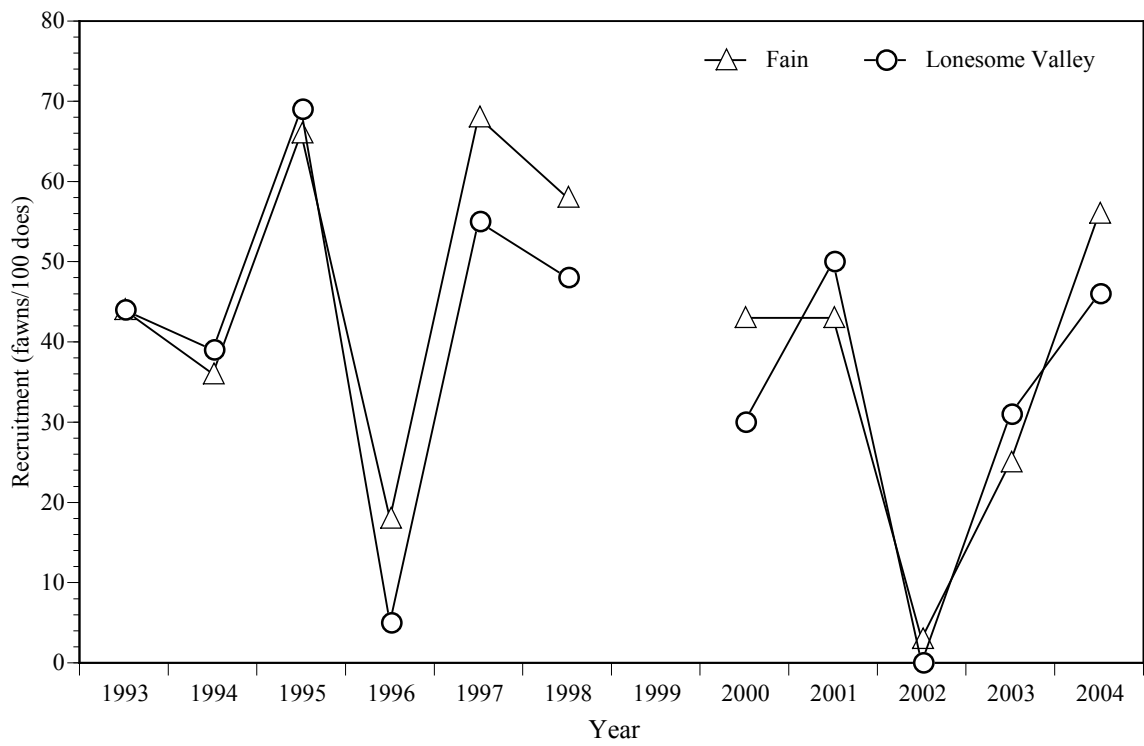


Figure 2.1. Times series of fawn recruitment (fawns/100 does) for the Fain Ranch and Lonesome Valley (LV) study sites in Game Management Unit (GMU) 19A, central Arizona, USA, 1993-2004.

CHAPTER III
FECAL NITROGEN AND 2, 6 DIAMINOPIMELIC ACID
AS INDICES TO DIET QUALITY IN PRONGHORN:
BASELINE DATA

Abstract

Few studies have been conducted to determine fecal nitrogen (FN) and fecal 2,6 diaminopimelic acid (DAPA) as indices to diet quality in pronghorn (*Antilocapra americana*). We determined baseline profiles of FN and DAPA for 2 pronghorn herds in central Arizona during critical periods for females during 2003-2004. This study was part of a statewide evaluation of factors affecting pronghorn fawn recruitment, including predator abundance, nutrition, fawn hiding cover, disease, and water availability throughout pronghorn habitat in Arizona. The purpose of this study was to examine some factors which may affect differences in between 2 ranches at 1 of 4 study sites pronghorn fawn: doe ratios. Our goal was to determine if nutrition was adequate to support pronghorn and provide favorable conditions for survival and recruitment. Fecal DAPA ranged from 0.741 to 1.802 (mg/g) and FN ranged from 1.009 to 1.603 (%). We found a year effect ($P = 0.001$) for DAPA, but no site effect ($P = 0.56$). While for FN there was a site effect ($P = 0.002$) but no year effect ($P = 0.11$). Fecal DAPA reached higher levels than those of other healthy ungulate species, while FN did not. We found a positive correlation between FN and DAPA ($P = 0.02$), while neither index was correlated to precipitation. During our study fawn recruitment increased from year 1 to year 2 and it appeared that diet quality, as indicated by FN and DAPA was adequate for

pronghorn in this region. Our results serve as baseline information for highly productive pronghorn herds in Arizona.

Introduction

Wildlife managers have sought relatively simple indicators of diet quality to assess relationships between habitats and populations. Many methods have been developed to monitor diet quality in free-ranging ungulates. Non-invasive methods of monitoring diet quality, such as fecal indices, are commonly used because samples are easy to collect with minimal disturbance to the animal. Fecal indicators to diet quality are not so constrained by these parameters and may be more useful than other techniques (Osborn and Ginnet 2001). For example, use of urinary analyses is limited to periods of snow and blood analyses require the capture and sometimes death of the animal (Seal et al. 1972; DelGuidice et al. 1991).

Two of the most commonly used fecal indices are fecal nitrogen (FN; Leslie and Starkey 1985; Irwin et al. 1993; Cook et al. 1994; Hodgman et al. 1996; Kucera 1997) and fecal 2,6-diaminopimelic acid (DAPA; Davitt and Nelson 1984; Leslie et al. 1989; Nelson and Davitt 1984; Nelson et al. 1982; Hodgman et al. 1996). Fecal nitrogen and DAPA have been used to assess dietary quality and population performance in elk (*Cervus elaphus*; Cook et al. 1994), bighorn sheep (*Ovis Canadensis*; Irwin et al. 1993), white-tailed deer (*Odocoileus virginianus*; Osborn and Ginnet 2001), mule deer (*O. hemionus*; Kucera 1997), and captive pronghorn (Robinson et al. 2001). To date, limited research has used FN and DAPA as indices to diet quality in non-captive pronghorn (Hansen et al. 2001).

Fecal nitrogen has been used to track changes in dietary nitrogen and DAPA has generally been used to track changes in dietary energy. Fecal nitrogen has been positively correlated with forage intake, dietary protein and digestibility (Leslie and Starkey 1985,1987). Fecal nitrogen and DAPA were poor indicators of physical condition and reproductive performance in mule deer, but FN was related to diet quality seasonally in that it was highest in the summer and lowest in the winter (Kucera 1997). Further, FN was positively correlated with dietary *Purshia*, a forage plant known to be high quality, and negatively correlated with dietary *Artemisia*, a low quality forage (Kucera 1997). Additionally, winter fecal nitrogen concentrations <1.3% may indicate potential for nutritional deficiency by reduced intake in Rocky Mountain bighorn sheep (Irwin et al. 1993).

Fecal nitrogen used as an index of diet quality has received criticism based on the binding of secondary plant metabolites such as tannins to dietary protein, producing elevated FN in diets which would otherwise be low in quality (Holechek et al 1982; Hobbs 1987). Consequently, the utility of FN as an indicator to diet quality has been questioned. However, FN may indicate real changes in diet quality within populations over seasons, within seasons over years, or between populations in similar habitats (Leslie and Starkey 1987). Irwin et al. (1993) supported the findings of Leslie and Starkey (1987) who contended that a significant difference between within-season fecal nitrogen estimates for different populations in similar habitats reflected a real difference in diet quality.

Fecal DAPA is a component of the cell walls of rumen bacteria (Van Soest 1994), which produce a large portion of the digestible energy for ruminants. Because DAPA

passes through the ruminant undigested, its level in feces may reflect intake of digestible energy (Davitt and Nelson 1984). Fecal DAPA exhibits cyclical patterns, high levels when diet quality is high and low levels when diet quality is low and presumably is not affected by factors such as tannins (Davitt and Nelson 1984; Osborn and Ginnitt 2001). Either FN or DAPA might be useful for assessing changes in dietary quality of deer (Leslie et al. 1989).

Diet quality can have significant impacts on the reproductive functions of wild ruminants depending upon the stage of reproduction (Robbins 1983). The diet quality during late gestation is of particular significance to the development of the fawn, while lactation places the highest nutrient demands on the doe (Robbins 1983). Consequently, during periods of poor quality diet both may be impacted negatively. Neonatal survival is reduced by low maternal diet quality, and reductions in diet quality for long durations close to parturition and lactation can have significant effects on fawn and doe survival (Price and White 1985).

This study was part of a statewide evaluation of factors affecting pronghorn fawn recruitment, including predator abundance, nutrition, fawn hiding cover, disease, and water availability throughout pronghorn habitat in Arizona. Four study areas were located throughout the state and each had a high and low recruitment site, using paired study sites in an effort to determine factors which may affect fawn recruitment. Data were collected during biologically significant periods for pronghorn females; (1) late gestation which is of particular significance to the development of the fetus (Ofstedal 1985), (2) parturition terminates the rising energetic costs of pregnancy, but initiates an even more demanding phase, (3) lactation places the highest nutrient demand on the doe

(i.e., nutrient demands for maintenance and milk production for fawn; Oftedal 1985), and (4) conception, at which time the doe must replenish reserves depleted by the preceding periods and have sufficient energy and protein stored to make the risk of pregnancy worthwhile (Price and White 1985).

We monitored FN and DAPA at 2 sites at 1 study area during late gestation, parturition, lactation, and conception from January 2003 through August 2004. We hypothesized that current pronghorn declines and low pronghorn fawn recruitment in Arizona were driven by fluctuations in rainfall and nutritional status, and predator abundance were acting simultaneously to affect these populations.

Our goal was to determine if nutrition was adequate to support pronghorn and provide favorable conditions for survival and recruitment. Our objectives were to describe seasonal patterns of FN and DAPA and compare those indices to other ungulate species to determine if fecal indices from pronghorn on our study sites were comparable to other healthy or unhealthy herds. Based on literature, poor nutrition can negatively impact pronghorn females and lead to low fawn survival (Hansen et al. 2001) and forage quality and quantity are related to precipitation (LeCount and Smith 1979; Fagan et al. 2004). We tested the following predictions: (1) highest fecal indices will occur in summer following monsoonal rains because of increased forage availability; and (2) FN and DAPA levels will differ between sites, among seasons and between years.

Study area

We measured FN and DAPA from pronghorn at 2 sites in Yavapai County, Arizona. Both study areas were within Game Management Unit (GMU) 19A. The Fain

Ranch site encompassed approximately 27,684 ha of short-grass prairie that was bordered on the north by State Route (SR) 89A, on the east by interior chaparral foothills of the Mingus Mountains, on the south by State Highway 69, and on the west by the town of Prescott Valley. The Lonesome Valley (LV) site was a collection of 3 ranches and state land, and was approximately 26,900 ha of short-grass prairie that was bordered on the north by Perkinsville Road, on the east by the vegetated interior chaparral foothills of the Mingus Mountains, on the south by SR 89A, and on the west by the town of Chino Valley and Highway 89.

Potential predators of pronghorn in our study areas included coyote (*Canis latrans*), which primarily prey on fawns, and mountain lion (*Puma concolor*) which were not abundant but did kill adults on occasion in the rough terrain typical of the eastern edge of the study sites (Ockenfels 1994). A small number of mule deer (*Odocoileus hemionus*) and collared peccari (*Peccari tajacu*) also occurred in these areas.

Climate was mild, with monthly average temperatures above freezing and an average annual rainfall of 30 cm. Precipitation patterns were bimodal, with 45% of annual rainfall during monsoonal thunderstorms from mid-July to September and the remainder as irregular winter and spring snow storms from December to February (Western Regional Climate Center, Desert Research Institute; <http://www.wrcc.dri.edu/>). Long-term minimum and maximum daily temperature in January averaged -6 and 11° C, respectively, at Chino Valley (the nearest weather reporting station), whereas July temperatures averaged 15 to 33° C, respectively.

Terrain was mostly flat to rolling hills. Dominant vegetation biomes were grasslands, including short-grass prairies and some interior chaparral. Blue grama

(*Bouteloua gracilis*) and ring muhly (*Muhlenbergia torreyi*) dominated the areas. Other perennial grasses in the area included red three-awn (*Aristida purpurea*), sideoats grama (*B. curtipendula*), tobosa (*Hilaria mutica*), oatgrass (*Danthonia* spp.), and foxtail barley (*Hordeum jubatum*). Annual grasses included red brome (*Bromus rubens*), little barley (*H. pusillum*), sixweeks fescue (*Vulpia octoflora*) and wild oats (*Avena fatua*). Dominant forb species included redstem filaree (*Erodium cicutarium*), western blue flax (*Linum lewisii*), pursh plantain (*Plantago purshii*), and baby aster (*Leucelene erocoides*). Dominant short shrub species were broom snakeweed (*Gutierrezia sarothrae*), winterfat (*Ceratoides lanata*), and threadleaf groundsel (*Senecio douglasii*). Saltbush (*Atriplex canescens*), fendler ceanothus (*Ceanothus fendlerii*), and apache plume (*Fallugia paradoxa*) were prominent in drainages. Chaparral shrubs occurred mainly in drainages and on north-facing slopes. Chaparral species included shrub live oak (*Quercus turbinella*), skunkbrush sumac (*Rhus aromatic*), and beargrass (*Nolina microcarpa*) which dominated the eastern foothills. Scattered throughout the study areas were several succulent species, including cholla (*Opuntia* spp.), and prickly pear (*Opuntia* spp.). Juniper (*Juniperus* spp.) occurred primarily in the eastern most chaparral areas.

Land ownership consisted of a checkerboard of state and private lands. Several 2-track dirt roads dissected both areas. Motorized traffic was restricted in some areas of state land but was restricted to only ranch personnel on the Fain Ranch. Cattle grazing occurred at varying intensities on most state and private land.

Methods

Fecal collection

We located and observed a herd or single pronghorn with a spotting scope until the majority of the individuals had defecated. We made every attempt to collect fecal samples from female groups or groups with few bucks in the herd. We used a rangefinder to determine distance to the group. We collected and labeled individual fecal pellet groups by site, date, number of pronghorn in the group, number of each sex in the group, global positioning system (GPS) location, time period, and a unique number for each pellet group, and site. Seven pellet groups from each study site for each time period were pooled to create 1 composite sample for diet analysis. Three composite samples were analyzed per time period per site, so a total of 21 pellet groups were collected from each study area during each of the 4 time periods (late gestation, 10 April to 25 April; parturition, 5 May to 30 May; lactation, 20 June to 10 July; conception, 20 August to 10 September). Fecal samples were frozen until laboratory analyses were performed.

Chemical analyses

Fecal DAPA concentrations were analyzed according to the methods described by Davitt and Nelson (1984). We used a Kjheltec Auto Nitrogen Analyzer model 1030TM (Tele-Flex Analytical, Cut and Shoot, Texas) to determine fecal nitrogen concentration of composite diets. In order to determine differences in diet quality we used a 3-factor (site, season, year) analysis of variance (ANOVA). These analyses were performed for each fecal index (FN, DAPA) using a one-way ANOVA. When significant differences were detected, we used Tukey's HSD test to separate means (Zar, 1996). We used regression

analyses to determine relationships between FN and DAPA and each fecal index and precipitation.

Results

Fecal DAPA indices during 2003 from Fain generally increased as the year progressed, while DAPA indices from LV generally decreased (Figure 3.1). Fecal DAPA on Fain ranged from 0.741 to 1.802 (mg/g DM) and from 0.915 to 1.726 (mg/g DM) on LV (Table 3.1). Mean fecal nitrogen on Fain and LV ranged from 1.009 to 1.603 % and 0.856 to 1.373 %, respectively (Table 3.2).

Concentrations of DAPA in pellet collections indicated a significant season effect ($F = 3.657$; 3, 32 df, $P = 0.023$), year effect ($F = 12.423$, 1, 32 df, $P = 0.001$), and season-by-site interaction ($F = 3.476$, 3, 32 df, $P = 0.027$), while we found no site effect ($F = 0.344$, 1, 32 df, $P = 0.562$; Table 3.1). Follow-up analysis on the season-by-site interaction indicated only a significant difference during conception ($F = 8.069$, 1, 32 df, $P = 0.008$) with Fain greater than Lonesome Valley in 2003. We found a significant year effect at Fain ($F = 11.426$, 1, 16 df, $P = 0.004$) and a season effect ($F = 5.555$, 3, 16 df, $P = 0.008$) with conception different only from gestation ($P = 0.05$; Table 3.1). On Lonesome Valley we found a significant season by year interaction ($F = 3.753$, 3, 16 df, $P = 0.03$) and found a significant season effect in 2003 ($F = 11.908$, 3, 8 df, $P = 0.003$) with gestation greater than lactation ($P = 0.05$) and parturition greater than lactation ($P = 0.004$) and conception ($P = 0.006$; Table 3.1). We found no significant season effect in 2004 on Lonesome Valley.

Concentration of FN in pellet collections indicated a significant season effect ($F = 6.541, 3, 32 \text{ df}, P = 0.001$) and site effect ($F = 11.016, 1, 32 \text{ df}, P = 0.002$; Table 3.2) with Fain greater than Lonesome Valley. We found a significant season-by-year interaction ($F = 13.456, 3, 32 \text{ df}, P < 0.0001$) and site-by-year interaction ($F = 26.778, 1, 32 \text{ df}, P < 0.0001$), however, these effects were qualified by a season-by-site-by-year interaction ($F = 10.259, 3, 32 \text{ df}, P < 0.0001$; Table 3.2). The 3-way interaction occurred because of the site-by-year interaction during gestation ($F = 8.273, 1, 32 \text{ df}, P = 0.007$) and conception ($F = 46.455, 1, 32 \text{ df}, P < 0.0001$; Table 3.2). We found no significant site-by-year interaction during parturition ($F = 0.0003, 1, 32 \text{ df}, P = 0.871$) or lactation ($F = 0.368, 1, 32 \text{ df}, P = 0.561$; Table 3.2). The interaction during gestation and conception occurred because Fain had higher FN concentrations during gestation 2004 than Lonesome Valley ($F = 16.273, 1, 32 \text{ df}, P < 0.0001$), however, during conception 2003 Lonesome Valley had higher FN concentration ($F = 9.909, 1, 32 \text{ df}, P = 0.004$), while Fain had higher FN concentration during 2004 ($F = 42.182, 1, 32 \text{ df}, P < 0.0001$; Table 3.2).

Our range of DAPA values was greater than those reported for other ungulate species (Table 3.3). Mean DAPA values for other ungulates were also lower than those for pronghorn on our study sites (Table 3.3, Figure 3.1). Conversely, the mean and range of FN values reported for other ungulates was higher than what we observed (Table 3.3, Figure 3.2).

We found no correlation between precipitation and fecal DAPA ($R^2 = 0.0177, P = 0.75$; Figure 3.3) or precipitation and fecal nitrogen ($R^2 = 0.0597, P = 0.56$; Figure 3.3).

We found that pronghorn FN and DAPA were positively correlated ($R^2 = 0.6296$, $P = 0.02$; Figure 3.4).

Discussion

Evaluation of factors potentially affecting trends and population dynamics of pronghorn can provide valuable perspective to wildlife managers addressing questions of management concern (Neff 1986; deVos 1999; Fox et al. 2000; O’Gara and Yoakum 2004). Decline and extirpations of small pronghorn populations present a concern to wildlife management agencies (Cancino et al. 2004; Wakeling 2004), and numerous factors have been suggested to influence these and other pronghorn populations (Lee et al. 1998). Of those factors loss of habitat, severe winters or droughts, low forage availability, and low quality diets were listed by Canadian and U.S. state agencies as threats to pronghorn (O’Gara and Yoakum 2004).

We began our study during the 6th consecutive year of a drought, and consequently, the overall productivity of forage species was likely below normal (W. H. Miller, Arizona State University (ASU), personal communication). During the later part of 2003 and April 2004 above normal precipitation was likely the cause for the increase in forage species production in 2004 over 2003. Vegetation quality and quantity have been identified as key factors influencing pronghorn production and survival, and that vegetation characteristics were related to diet selection (Yoakum 2002). In western Utah little evidence was found to conclude that forage conditions affected pronghorn fawn survival, however, general observations of physical condition and growth of fawns

appeared markedly better in years when abundant succulent forbs were available (Beale and Smith 1970).

Diaminopimelic acid is a well established marker of rumen microbial activity (Davitt and Nelson 1984; Nelson et al. 1982; Nelson and Davitt 1984), and the concentrations of this amino acid have been shown to be related to the quality of the diet consumed by ruminant animals (Irwin et al. 1993; Kucera 1997; Leslie et al. 1989). Concentrations of DAPA in our study revealed seasonal patterns as well as yearly differences. The DAPA values appeared to follow a cycle (i.e., high early in the year corresponding to new vegetation growth) which presumably reflected seasonal changes in forage digestibility and forage quality. We found that Fain DAPA was greater than Lonesome Valley during conception in 2003 and these differences may have been of biological significance. A significant within-season difference between 2 populations that occupy similar habitats reflects a real difference in diet quality (Leslie and Starkey 1987). Higher quality nutrition in 2004 may have lead to greater fawn recruitment on Fain than on Lonesome Valley. It appeared that Fain pronghorn entered winter on a higher nutritional plane than Lonesome Valley and possibly were better able to carry a fawn to term. Based on relatively high DAPA values relative to other ungulates and improvement in pronghorn fawn survival it appears that nutrition was adequate for pronghorn on both study sites during all collection periods.

Diaminopimelic acid measurements exhibited wide variation within each period making it difficult to determine whether differences were significant. Seasonal and yearly patterns of DAPA concentration were also found in pronghorn herds in Oregon (Hansen et al. 2001). Studies on 2 black-tailed deer herds in California found 1 was in

better condition although DAPA concentrations were not different between herds (Kie and Burton 1984). In addition, Kucera (1997) found similar patterns of DAPA concentration and found that while DAPA was related to kidney fat index in late winter, DAPA was a poor predictor of physical condition and reproductive performance. Fecal concentrations of both FN and DAPA reflected both vegetation growth and diet quality. Even though both indices demonstrated significant differences, it was difficult to relate them to fawn recruitment with only 2 years of data. However, these fecal indices provide baseline profiles and the subsequent fawn recruitment for 1 region in central Arizona.

The pattern of fecal nitrogen (Figure 3.1) demonstrated little variation over time, however, there were differences between areas and among seasons. Fecal nitrogen content can be confounded by the binding of secondary plant metabolites to proteins resulting in elevated FN value making it a poor predictor of diet quality (Holechek et al. 1982; Hobbs 1987). In addition, epithelial tissue shed by the gastrointestinal (GI) tract can also elevate FN content. High fiber diets are poorly digested and are highly effective in scouring epithelial tissue from inside the gastro-intestinal tract, while highly succulent low fiber diets are less effective (W. H. Miller, ASU, personal communication). Conversely, Leslie and Starkey (1987) concluded that within-season differences reflected real differences in diet quality on similar habitats.

Diet quality can have significant impacts on the reproductive functions of wild ruminants depending upon the stage of reproduction (Robbins 1983). The diet quality during late gestation is of particular significance to development of the fawns, while lactation places highest nutrient demands on does (Robbins 1983). Consequently, during periods of poor diet quality both may be negatively impacted. Neonatal survival is

reduced by low maternal diet quality, and reductions in diet quality for long durations close to parturition and lactation can have significant effects on fawn and doe (Price and White 1985). It appeared that the pattern of DAPA concentration (Figure 3.1) may be sufficient for pronghorn during all collection periods. Further, DAPA over 1.0 (mg/g) typically reflect very high quality forage, and 0.3 to 0.8 (mg/g) are fair to good (B. Davitt, Washington State University, personal communication). While DAPA values were lower in 2004 compared to 2003 we had higher fawn recruitment in 2004 (Arizona Game and Fish Department, unpublished data), leading us to conclude that diet quality was adequate to support pronghorn and provide favorable conditions for survival and recruitment.

Reductions in maternal diet quality can reduce maternal weight, birth weight of fetuses, and milk production in ungulates (Ofstedal 1985). Fecal nitrogen levels from pronghorn on our study sites during all sampling periods except Lonesome Valley gestation 2004 generally were $\geq 1.1\%$ but were lower than ranges reported for other pronghorn (Hansen et al. 2001). Irwin et al. (1993) suggested concentrations of FN $\leq 1.3\%$ may identify winter diets that were deficient in protein and energy, and at FN levels below 1.7% deficiencies should be suspected in steers (Wofford et al. 1985), suggesting that forage may have been low in nitrogen. While our values were lower than those reported elsewhere (Wofford et al. 1985; Irwin et al. 1993; Hansen et al. 2001), it appears that these FN levels were able to support pronghorn in this region based upon mid-summer fawn: doe ratios.

Correlations between fecal nitrogen and fecal DAPA in pronghorn indicate that FN and DAPA can provide useful indices of ungulate dietary quality (Leslie and Starkey

1985; Leslie et al. 1989; Hodgman et al. 1996; Osborn and Ginnett 2001). Correlations indicate that either index might be useful for assessing changes in diet quality (Kie and Burton 1984; Leslie and Starkey 1987). Seasonal measures of fecal indices may be useful indices of pronghorn nutritional status in areas that have highly variable forage production (Hansen et al. 2001). During our study relationships between FN and DAPA suggested low dietary concentrations of secondary plant metabolites (Leslie et al. 1989; Osborn and Ginnett 2001; Hansen et al. 2001). Further, some shrubs and forbs contain tannins (Van Soest 1994), and relationships between fecal indices and the composition of diets (McDonald 2005) during our study suggest tannins may have had little effect in increasing FN levels.

The high FN values reported for other ungulates may have been the result of tannins in the diet (Holechek et al. 1982; Hobbs 1987; Leslie and Starkey 1987; Hodgman et al. 1996), thus artificially elevating FN concentrations. Browse was the major component of these diets and many browse species have been known to have high levels of tannins (Van Soest 1994). High tannin forages must comprise approximately 25-33% of the ruminant diet before FN values were affected (Hodgman et al. 1996). Compared to average forages available, ruminants also tend to consume diets higher in nutrients and lower in toxins, such as tannins (Robbins 1983).

During our study DAPA values were at or above those reported for other ungulate species. Further, we found fawn recruitment increased from year 1 to year 2 (AZGF, unpublished data). The real value of these data is baseline information for highly productive pronghorn herds in Arizona. While FN values did not reach as high a level as other ungulates we believe that our values were adequate for pronghorn in this region.

When analyzing diet quality using FN it is important to note the effects that secondary plant metabolites may have on nitrogen values. Although convenient, it should be used only qualitatively to illustrate large differences in diet quality and even then it may be biased by confounding effects of protein binding compounds in plants. We were unable to detect small differences likely due to small sample sizes, but these differences could be biologically important. Fecal DAPA is an effective tool for monitoring nutritional status in ungulates and may be a more useful index to diet quality in ungulates than FN since it appears to be unaffected by tannins (Osborn and Ginnett 2001).

Management Implications

This study was designed to examine diet quality of two pronghorn herds in central Arizona. We used fecal indices to represent diet quality. Fecal DAPA follows an annual cycle, reflecting the seasonal changes in diet digestibility (i.e., low when diet quality is low and high when diet quality is high). Pronghorn managers can monitor trends in diet quality and intake by using fecal DAPA and FN. Due to its relative simplicity, the greatest application of fecal analyses may be extensive monitoring programs to determine ungulate nutritional status and its relationship to production and recruitment.

It is important to understand the abilities and the limitations of any method used to estimate diet quality. We suggest that FN and DAPA can be a useful index to diet quality, provided investigators combine estimates of diet quality with a knowledge of diet composition and be aware of the confounding effects tannins may have on results. We reaffirm the cautions of Leslie and Starkey (1987) and emphasize that FN may not be an

accurate index in all situations. Fecal DAPA may be a more useful index to dietary quality, as it does not appear to be influenced by tannins (Osborn and Ginnett 2001). Further research is needed to determine fecal concentration of individual pellets within a pellet group. Fecal values may vary greatly from one pellet to the next increasing the variation in fecal concentration and may increase the likelihood of not identifying differences when they truly exist.

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Table 3.1. Pronghorn mean (\pm SE) fecal 2, 6 diaminopimelic acid concentration (mg/g) from the Fain Ranch and Lonesome Valley (LV) in central Arizona during selected biological periods in 2003 and 2004.

Biological period	Pronghorn herd			
	Fain, n = 24		LV, n = 24	
	2003	2004	2003	2004
Gestation ^a	1.135 (0.174)	0.883 (0.146)	1.423 (0.146)	1.025 (0.116)
Parturition ^b	1.452 (0.263)	0.819 (0.025)	1.726 (0.139)	0.915 (0.070)
Lactation ^c	1.328 (0.134)	0.741 (0.085)	0.917 (0.075)	0.966 (0.031)
Conception ^d	1.802 (0.475)	1.521 (0.217)	0.974 (0.058)	1.307 (0.220)
Total	1.429 (0.145)	0.991 (0.110)	1.260 (0.111)	1.053 (0.072)

^a 10 April to 25 April

^b 10 May to 30 May

^c 20 June to 10 July

^d 20 August to 10 September

Table 3.2. Pronghorn mean (\pm SE) fecal nitrogen (%) from the Fain Ranch and Lonesome Valley (LV) in central-Arizona during selected biological periods in 2003 and 2004.

Biological period	Pronghorn herd			
	Fain, n = 24		LV, n = 24	
	2003	2004	2003	2004
Gestation ^a	1.371 (0.056)	1.202 (0.071)	1.373 (0.021)	0.856 (0.066)
Parturition ^b	1.197 (0.020)	1.175 (0.048)	1.073 (0.058)	1.070 (0.023)
Lactation ^c	1.039 (0.043)	1.053 (0.061)	1.113 (0.093)	1.054 (0.014)
Conception ^d	1.009 (0.030)	1.603 (0.090)	1.279 (0.078)	1.048 (0.086)
Total	1.154 (0.047)	1.259 (0.069)	1.209 (0.047)	1.007 (0.036)

^a 10 April to 25 April

^b 10 May to 30 May

^c 20 June to 10 July

^d 20 August to 10 September

Table 3.3. Fecal nitrogen (FN) and fecal 2, 6 diaminopimelic acid (DAPA) values for pronghorn on Fain Ranch and Lonesome Valley in north-central Arizona and those of other ungulate species in North America, 1984, 1989, 2000, 2005.

Species	Geographic location	Fecal index	
		Nitrogen (%)	DAPA (mg/g)
Arizona Pronghorn	This study	0.86 – 1.60	0.82 – 1.80
Pronghorn ^a	Oregon, Nevada	1.52 – 3.12	0.51 – 0.94
Desert Bighorn ^b	Arizona	1.7 – 3.0	0.22 – 0.63
White-tailed deer ^c	Maine	1.24 – 3.72	0.48 – 1.39
Tule elk ^d	California	NA	0.57 – 1.7
Rocky Mountain elk ^d	Idaho, Washington	NA	0.34 – 1.0
Moose ^c	Maine	0.81 – 3.01	0.51 – 0.78

^a Hansen et al. 2000

^b McKinney et al. 2005

^c Leslie et al. 1989

^d Nelson and Davitt 1984

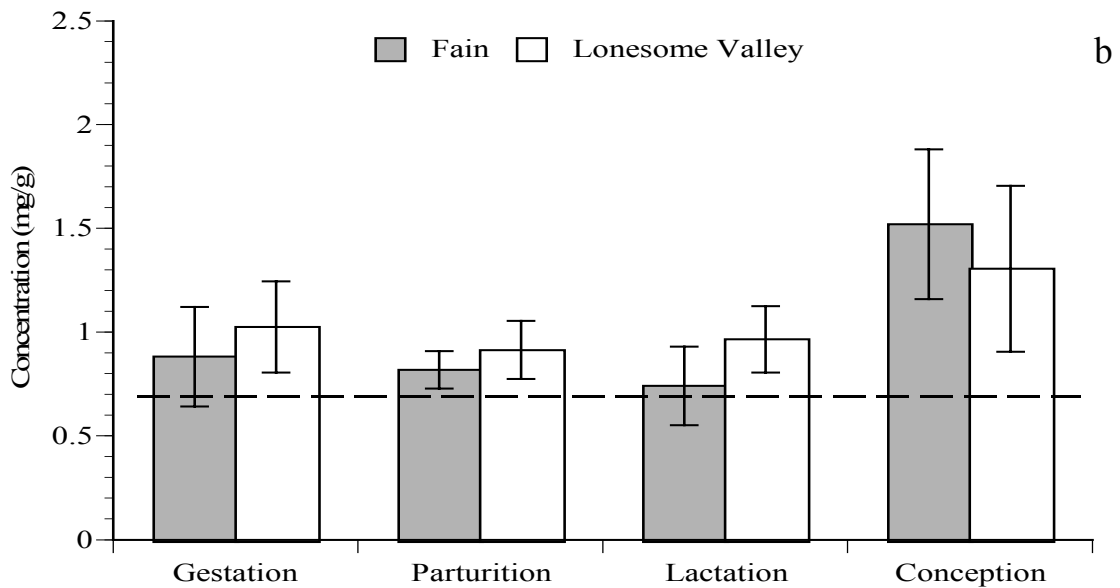
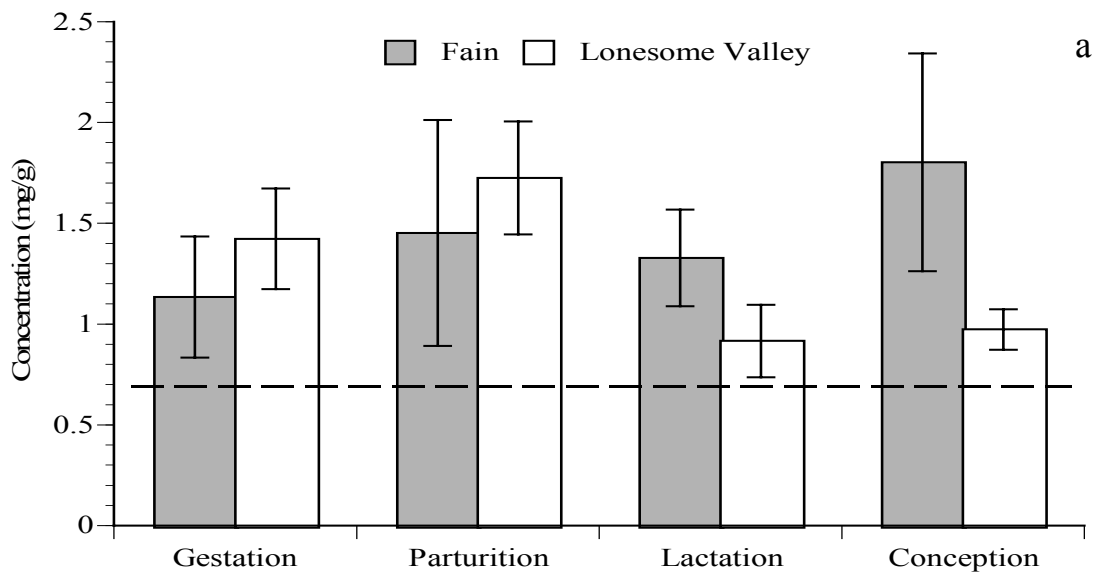


Figure 3.1. Seasonal patterns of fecal 2, 6 diaminopimelic acid (DAPA) (\pm 95% C.I.) concentration in composite samples of pronghorn feces from central-Arizona during 2003 (a) and 2004 (b). Dashed line represents a mean values for other ungulate species (white-tailed deer, mule deer, desert bighorn sheep, pronghorn, Rocky Mountain elk, tule elk). Periods divided into: gestation, 10 April to 25 April; parturition, 10 May to 30 May; lactation, 20 June to 10 July; and conception, 20 August to 10 September

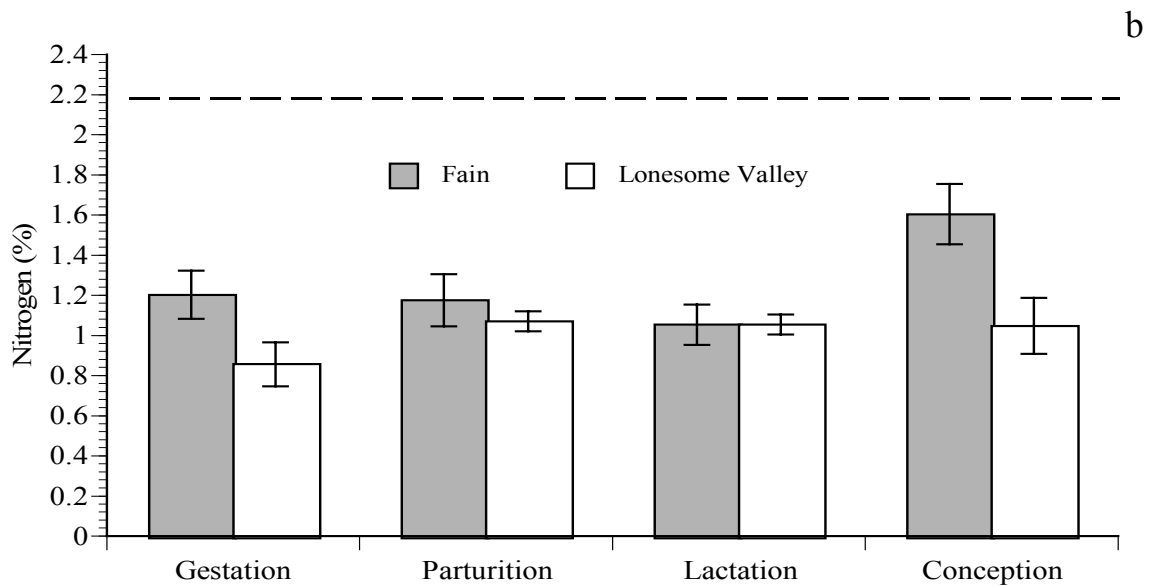
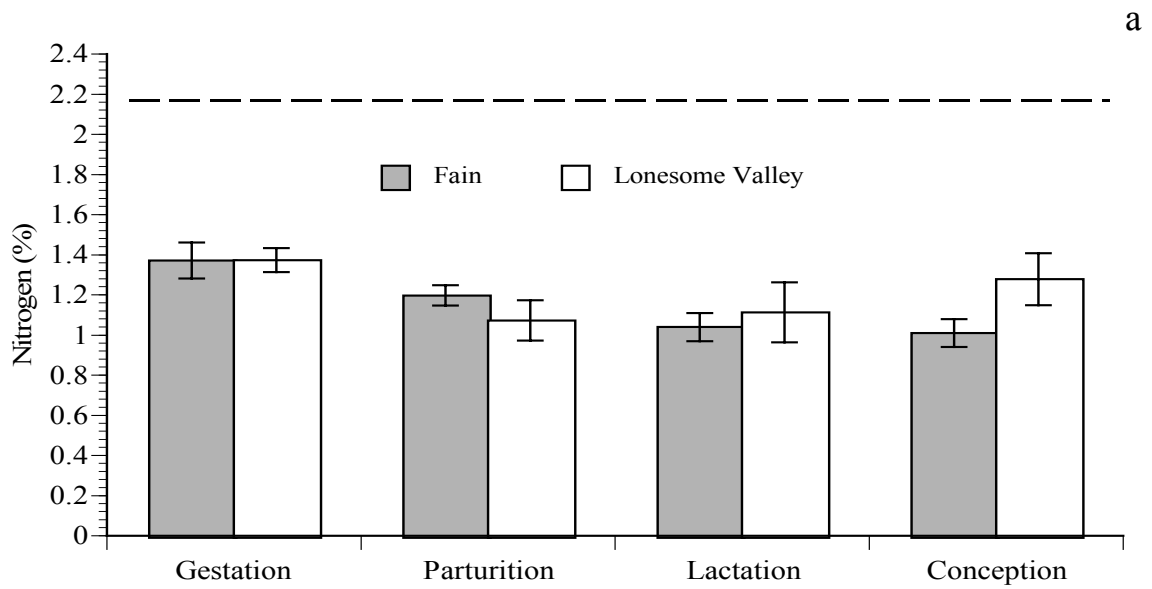


Figure 3.2. Seasonal patterns of fecal nitrogen (FN) percent (\pm 95% C.I.) in composite samples of pronghorn feces from central-Arizona during 2003 (a) and 2004 (b). Dashed line represents a mean values for other ungulate species (white-tailed deer, mule deer, desert bighorn sheep, pronghorn, Rocky Mountain elk, tule elk). Periods divided into: gestation, 10 April to 25 April; parturition, 10 May to 30 May; lactation, 20 June to 10 July; and conception, 20 August to 10 September

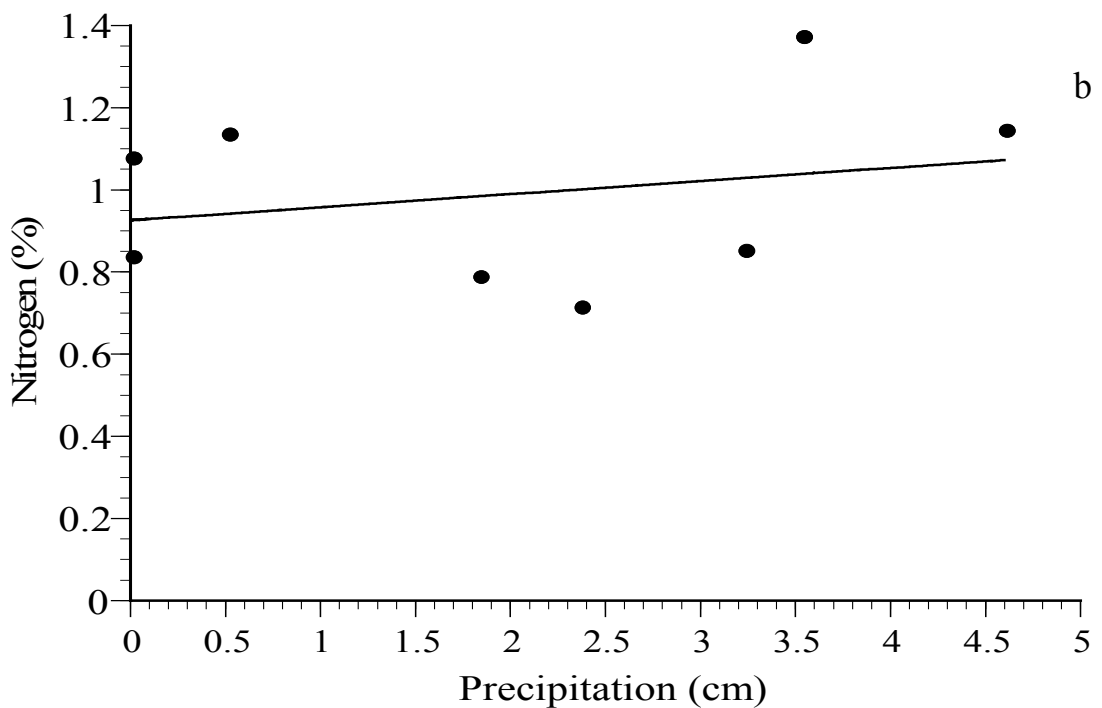
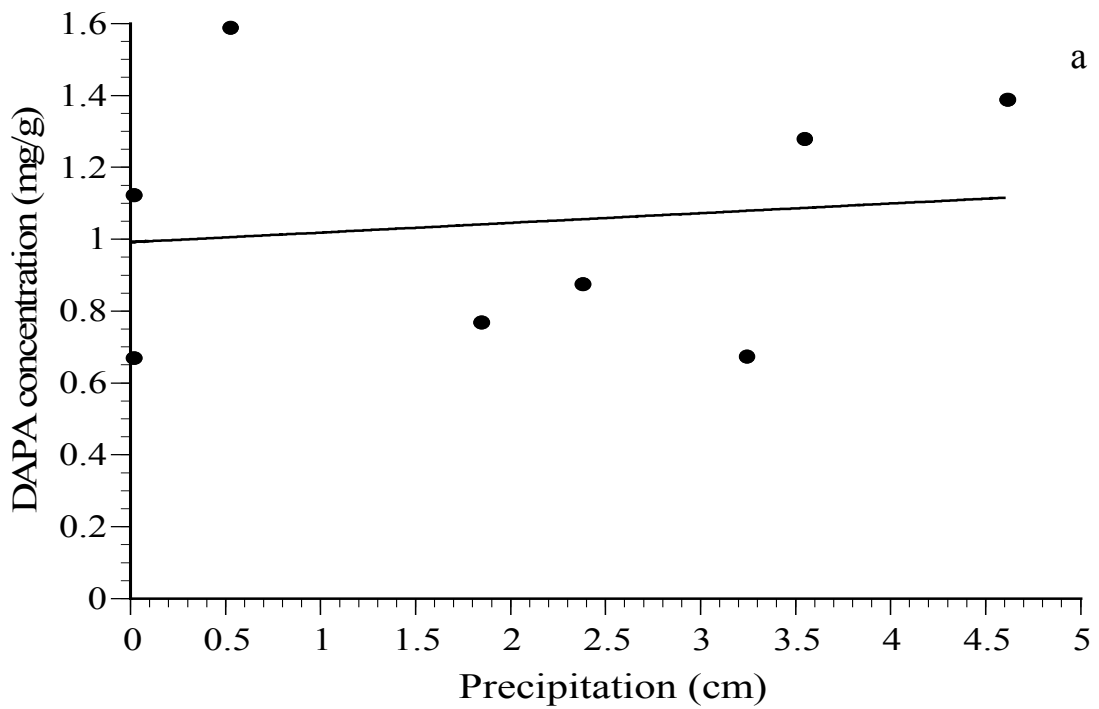


Figure 3.3. Relationships between precipitation and pronghorn fecal 2, 6 diaminopimelic (DAPA; $R^2 = 0.018$, $P = 0.75$) (a) and fecal nitrogen (FN; $R^2 = 0.060$, $P = 0.56$) (b) during 2003-2004, in central-Arizona.

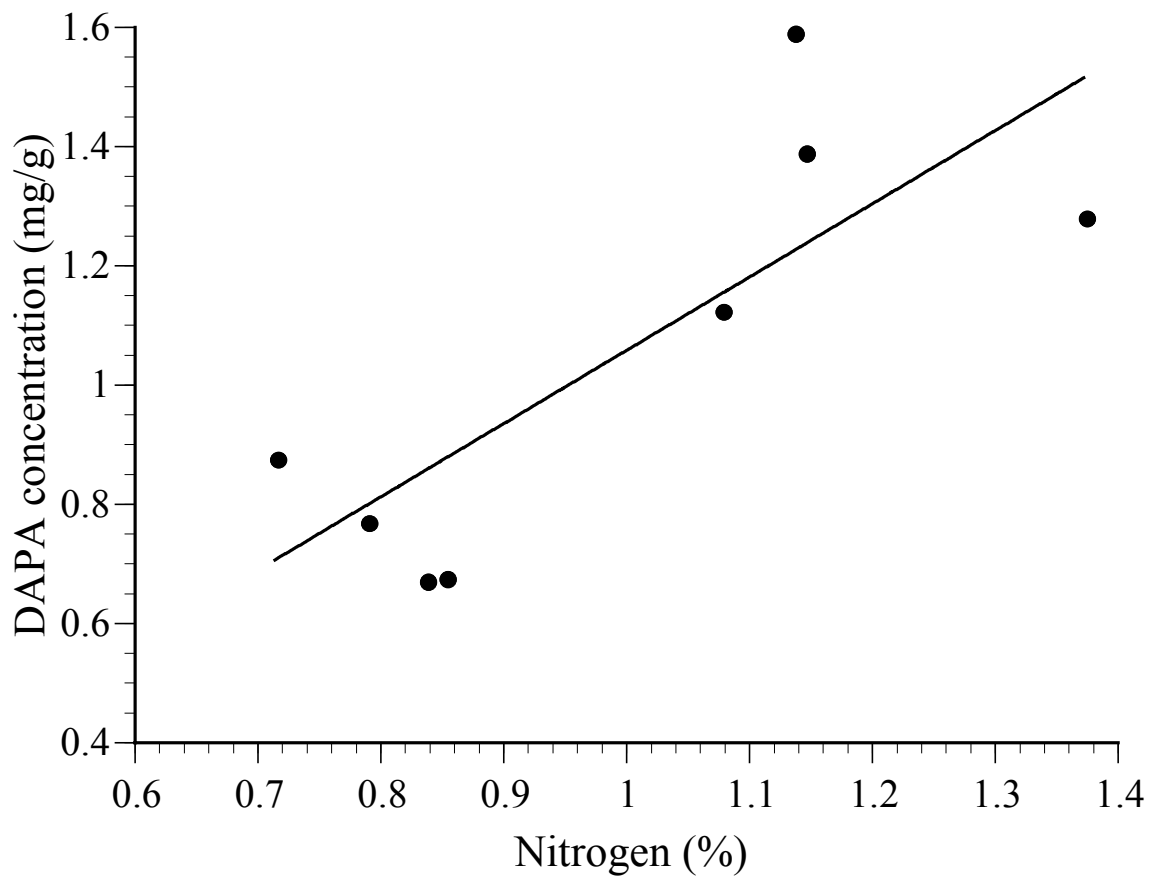


Figure 3.4. Relationship between pronghorn fecal 2, 6 diaminopimelic acid (DAPA) and fecal nitrogen (FN) during 2003-2004, in central-Arizona ($R^2 = 0.6296$, $P = 0.02$).

CHAPTER IV
PRECIPITATION AND PRONGHORN FAWN
RECRUITMENT IN CENTRAL ARIZONA

Abstract

In Arizona over the past 15 years, pronghorn (*Antilocapra americana*) populations appear to have declined. Recruitment into the population rather than adult mortality tends to be the primary determinant of pronghorn populations in Arizona. Causes for this decline are not understood, but we suspected that precipitation affects fawn recruitment. We used long-term rainfall and fawn recruitment records to investigate relationships of precipitation to pronghorn recruitment in central Arizona. We found no correlation between fawn recruitment during winter ($R^2 = 0.12$, $P = 0.27$) or spring ($R^2 = 0.32$, $P = 0.06$). However, we found a positive correlation between annual precipitation and fawn recruitment during 1993-2004 ($R^2 = 0.57$, $P = 0.01$). During 1961-2004 we found a positive correlation between winter precipitation ($R^2 = 0.09$, $P = 0.05$) but no correlation between annual precipitation ($R^2 = 0.03$, $P = 0.25$). We postulated that forb production, as affected by precipitation may be an important variable limiting fawn recruitment in arid areas. Fawn recruitment in central Arizona appeared to be affected by precipitation, however recruitment was variable from year to year and other limiting factors may have greater influence over fawn survival.

Introduction

Precipitation patterns are among the primary factors driving system dynamics in arid regions. In recent years, increasing attention has been given to examining the role of

environmental factors as they affect ungulate populations (Ginnett and Young 2000; Fagan et al. 2002; Marshal et al. 2002; Lawrence et al. 2004). For example, Douglas and Leslie (1986) found that 87% of the variability in desert bighorn sheep (*Ovis canadensis nelsoni*) lamb survival was accounted for by autumn precipitation. In arid west Texas, white-tailed deer (*Odocoileus virginianus*) recruitment was strongly and positively related to March-July precipitation (Ginnett and Young 2000).

When precipitation is variable from year to year, years of abundant precipitation provide abundant forage for ungulates. Consequently, reproduction and survival are high and populations increase. During extreme droughts, large-scale die-offs and population decline of ungulates may occur as a result of decreased reproduction and survival, as occurred in a pronghorn (*Antilocapra americana*) population in the Trans-pecos region of Texas in the 1960's (Hailey et al. 1966). In central Arizona a similar die-off of nearly 50% of the population occurred in 2002, presumably caused by nutritional deficiencies as a result of drought conditions (R. Ockenfels, Arizona Game and Fish Department [AZGF], personal communication).

Recruitment into the population tends to be the primary determinant of pronghorn numbers (Ockenfels 1995). Lee et al. (1998) 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, disease and parasites, and nutritional concerns may play a role in their decline. Causes for this decline are not understood, however, mule deer (*Odocoileus hemionus*) fawn survival, and forb production have been shown to be correlated with October through March precipitation in Arizona (Smith and LeCount 1979). Additionally, Fagan et al. (2002) found a significant positive

relationship between winter precipitation and pronghorn fawn survival in Arizona's Sonoran Desert and southern New Mexico.

We analyzed mid-summer survey and precipitation data from 1960-2004 from central Arizona, Game Management Unit (GMU) 19A. Because recruitment into the population is the primary determinant of pronghorn numbers, we hypothesized that October through March precipitation drives population dynamics and causes fluctuations in pronghorn numbers. We tested the following predictions: (1) fawn recruitment is correlated to October through March precipitation, and (2) pronghorn abundance is directly related to October through March rainfall.

Study area

We investigated relationships between precipitation and pronghorn abundance and recruitment (defined as mid-summer fawn: doe ratios) in GMU 19A and at 2 sites in Yavapai County, Arizona. Both study areas were within Game Management Unit (GMU) 19A. The Fain Ranch site encompassed approximately 27,684 ha of short-grass prairie that was bordered on the north by State Route (SR) 89A, on the east by interior chaparral foothills of the Mingus Mountains, on the south by State Highway 69, and on the west by the town of Prescott Valley. The Lonesome Valley (LV) site was a collection of 3 ranches and state land, and was approximately 26,900 ha of short-grass prairie that was bordered on the north by Perkinsville Road, on the east by the vegetated interior chaparral foothills of the Mingus Mountains, on the south by SR 89A, and on the west by the town of Chino Valley and Highway 89.

Potential predators of pronghorn in our study areas included coyote (*Canis latrans*), which primarily prey on fawns, and mountain lion (*Puma concolor*) which were not plentiful but do kill adults on occasion in the rough terrain typical of the eastern edge of the study sites (Ockenfels 1994). A small number of mule deer (*Odocoileus hemionus*) and collared peccari (*Peccari tajacu*) also occurred in these areas.

Climate was mild, with monthly average temperatures above freezing and an average annual rainfall of 30 cm. Precipitation patterns were bimodal, with 45% of annual rainfall during monsoonal thunderstorms from mid-July to September and the remainder as irregular winter and spring snow storms from December to February respectively (Western Regional Climate Center, Desert Research Institute; <http://www.wrcc.dri.edu/>). Long-term minimum and maximum daily temperature in January averaged -6 and 11° C, respectively, at Chino Valley (the nearest weather reporting station), whereas July temperatures averaged 15 to 33° C,.

Terrain was mostly flat to rolling hills. Dominant vegetation biomes were grasslands and to a lesser extent interior chaparral. Grasslands included short-grass prairies. Blue grama (*Bouteloua gracilis*) and ring muhly (*Muhlenbergia torreyi*) dominated the areas. Other perennial grasses in the area included red three-awn (*Aristida purpurea*), sideoats grama (*B. curtipendula*), tobosa (*Hilaria mutica*), oatgrass (*Danthonia* spp.), and foxtail barley (*Hordeum jubatum*). Annual grasses included red brome (*Bromus rubens*), little barley (*H. pusillum*), sixweeks fescue (*Vulpia octoflora*) and wild oats (*Avena fatua*). Dominate forb species included redstem filaree (*Erodium cicutarium*), western blue flax (*Linum lewisii*), pursh plantain (*Plantago purshii*), and baby aster (*Leucelene erocoides*). Dominant short shrub species were broom snakeweed

(*Gutierrezia sarothrae*), winterfat (*Ceratoides lanata*), and threadleaf groundsel (*Senecio douglasii*). Saltbush (*Atriplex canescens*), fendler ceanothus (*Ceanothus fendlerii*), and apache plume (*Fallugia paradoxa*) were prominent in drainages. Chaparral shrubs occurred mainly in drainages and on north-facing slopes. Chaparral species included shrub live oak (*Quercus turbinella*), skunkbrush sumac (*Rhus aromatic*), and beargrass (*Nolina microcarpa*) which dominated the eastern foothills. Scattered throughout the study areas were several succulent species, including cholla (*Opuntia* spp.), and prickly pear (*Opuntia* spp.). Juniper (*Juniperus* spp.) occurred primarily in the eastern most chaparral areas.

Land ownership consisted of a checkerboard of state and private lands. Several 2-track dirt roads dissected both areas. Motorized traffic was restricted in some areas of state land but was restricted to ranch personnel on the Fain Ranch. Land use of both areas consisted of cattle production. Grazing occurred at varying intensities on most state and private land.

Methods

We obtained rainfall data between 1961-2004 from the nearest weather station at Chino Valley located at the northwest boundary of the study areas (Western Regional Climatic Center; <http://www.wrcc.dri.edu/summary/climsmaz.html>; 21 July 2005). We defined precipitation periods as spring-late gestation (March through May) and winter (October through March). Separate analyses were conducted for March to May, October to March and annual precipitation. In addition, precipitation and recruitment analyses were conducted on the 2 study site herds from 1993-2004, the only years available.

Fawn recruitment was based on mid-summer pronghorn surveys in GMU 19A. Surveys were conducted from 1961-2004 by Arizona Game and Fish Department (AGFD) personnel. Surveys were conducted using aerial fixed-wing transects with 2 observers to identify age and sex of pronghorn. Surveys began at sunrise and lasted approximately 3 hours. We used a subset of the 19A data for Fain Ranch and Lonesome Valley (north of State Route (SR) 89A) from 1993-2004. Regression analyses were used to examine relationships between fawn recruitment (Y) and each precipitation variable (X).

Results

We found for our study site herds (1993-2004) that precipitation, pronghorn populations and fawn recruitment were highly variable from year to year and there was no correlation between annual precipitation and these variables (Figure 4.1; Table 4.1). We found no correlation between mid-summer (18 June) fawn: doe ratios (fawn recruitment) on Fain for winter (October-March; $R^2 = 0.12$, $P = 0.27$; Figure 4.2) or spring-late gestation precipitation (March-May; $R^2 = 0.32$, $P = 0.06$; Figure 4.3), nor winter on LV ($R^2 = 0.27$, $P = 0.09$; Figure 4.4) precipitation. However spring-late gestation precipitation indicated a significant positive correlation ($R^2 = 0.36$, $P = 0.04$; Figure 4.5) on LV. The positive correlation between annual precipitation and fawn recruitment was stronger on Fain ($R^2 = 0.57$, $P = 0.01$; Figure 4.6), and LV ($R^2 = 0.46$, $P = 0.03$; Figure 4.7) than seasonal rains.

The 1961-2004 survey data from GMU 19A indicated a slight reverse trend. We found a significant positive correlation between winter precipitation and fawn recruitment

($R^2 = 0.09$, $P = 0.05$) but no correlation between annual precipitation ($R^2 = 0.03$, $P = 0.25$; Figure 4.8) or spring-late gestation precipitation and fawn recruitment ($R^2 = 0.05$, $P = 0.16$).

Discussion

If populations in arid regions of Arizona 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). Forage resources are affected primarily by precipitation, which is highly variable from year to year in this region. As a result, forage availability and its influence on pronghorn populations is highly variable from year to year. It is possible that pronghorn populations in central Arizona likely are driven by density-independent fluctuations in precipitation that determines forage quality and abundance. Studies throughout the range of pronghorn indicate that the majority of fawn mortalities are due to predation (Neff and Woolsey 1979; Smith et al. 1986; Barrett 1984; Ockenfels et al. 1992). Because production of annual vegetation is positively correlated with rainfall (Smith and LeCount 1979), increased abundance of vegetation may result in increased hiding cover and possibly lower rates of fawn predation. Further, a nutritional explanation for the positive relationships between recruitment and precipitation cannot be ruled out.

Ginnett and Young (2000) found a shift in the nature of the density-independent effects of precipitation on white-tailed deer (*Odocoileus virginianus*) recruitment along a precipitation gradient in Texas. They were the first to report both positive and negative responses of recruitment in an ungulate population to precipitation. Forage quality may

exert a greater influence on deer populations than quantity of forage (Ginnett and Young 2000). Lactating does on poor nutrition may have lower milk production and poorer health (Ginnett and Young 2000). Positive correlations between recruitment and precipitation have been reported for white-tailed deer (Kie and White 1985; Ginnett and Young 2000), mule deer (*Odocoileus hemionus*; Smith and LeCount 1979; Marshal et al. 2002; Lawrence et al. 2004), desert bighorn sheep (*Ovis canadensis nelsoni*; Douglas and Leslie 1986), and mountain bighorn sheep (*Ovis canadensis canadensis*; Wehausen et al. 1987). A similar relationship between recruitment and winter precipitation was found for pronghorn in Arizona (Brown et al. 2002). Arizona's Sonoran pronghorn (*Antilocapra americana sonoriensis*) recruitment revealed significant positive relationships, while in a more mesic area in northern Arizona the relationship was negative (Brown et al. 2002).

Our data consisted of mid-summer survey counts. Because there were no independent estimates of births and mortalities, we were unsure whether precipitation primarily influenced birth rates or survival. Mean parturition dates in central Arizona were mid-May (Scott Poppenberger, AGFD, personal communication). March through May precipitation, therefore, occurred during late gestation, the most critical period for the development of the fetus and early parturition (Price and White 1985). October through March precipitation were related to pronghorn recruitment in southern New Mexico and south-central Arizona (Brown et al. 2002), but summer precipitation was not.

Our analyses indicate that March to May (spring) precipitation may be more important to fawn recruitment in central Arizona than October to March (winter) precipitation. It also appeared that annual precipitation was important to fawn recruitment in this region. Annual precipitation may have more to do with better forage

quality and availability year-round. Because production of annual vegetation is positively correlated with rainfall (LeCount and Smith 1979), increased abundance of vegetation may result in increased hiding cover and diet quality for fawns. Interestingly, Brown et al. (2002) found a significant relationship between October to March (winter) precipitation and fawn recruitment at the K-4 Ranch in central Arizona, no more than 10 km from our study sites. One possible explanation may be that increased rainfall also produces more forage biomass leading to high quality diet which affects milk production, growth rates, and condition of fawns and does (Robbins 1983). Fawn recruitment in this area is variable from year to year, suggesting that other factors likely interact with precipitation to determine pronghorn productivity.

Management Implications

This study was designed to identify factors affecting pronghorn fawn recruitment. The relationships reported here provide an understanding of how precipitation affects pronghorn fawn recruitment in central Arizona. Understanding how ungulate populations respond to environmental variation has important implications for management. Long-term data collection can provide valuable insight into the factors that limit and regulate wildlife populations. Although pronghorn populations in our study had a positive correlation between precipitation and fawn recruitment, precipitation alone does not thoroughly explain the annual variation in fawn recruitment. Further research is needed to determine the mechanisms by which pronghorn and other ungulate populations respond to climatic variables.

Fawn recruitment during this study was considered good by Arizona standards, but would be considered very poor in areas such as Wyoming (R. Ockenfels Arizona Game and Fish Department [AZGF], personal communication). Studies to identify long-term mortality of pronghorn from predation, harvest, and natural stress may be of interest. Radio-marked pronghorn in each sex-age class of interest would be necessary. Managers may then be able to determine what drives these pronghorn populations in central Arizona.

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Table 4.1. Fawn recruitment (fawns/100 does) of pronghorn, and precipitation from Game Management Unit (GMU) 19A, central Arizona, 1993-2004.

Year	Fawns/100 does		Precipitation (cm)		
	Fain	LV	Annual	Oct-Mar	Mar-May
1993	44	44	43.13	37.85	7.98
1994	36	39	29.31	6.96	4.70
1995	66	69	31.06	21.11	5.72
1996	18	4	20.14	3.38	1.07
1997	68	55	37.85	10.19	3.07
1998	58	48	44.65	18.47	8.45
1999	N/A	N/A	32.59	6.05	2.69
2000	43	29	29.97	6.45	3.61
2001	43	50	25.15	21.03	3.84
2002	3	0	15.70	5.77	2.44
2003	25	31	28.47	16.51	4.04
2004	56	46	29.26	8.13	6.28

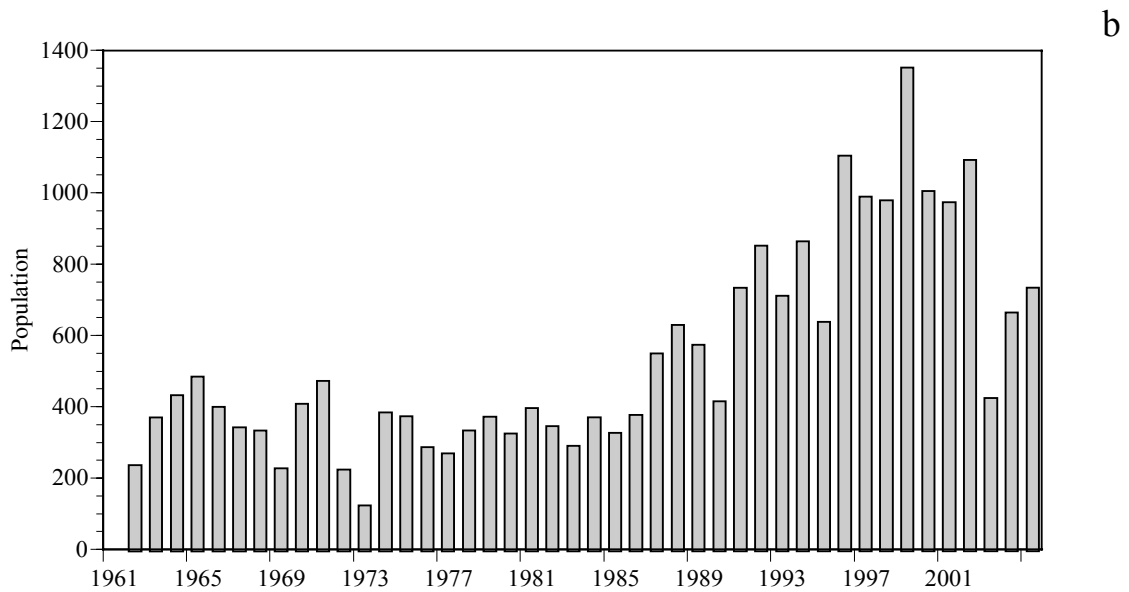
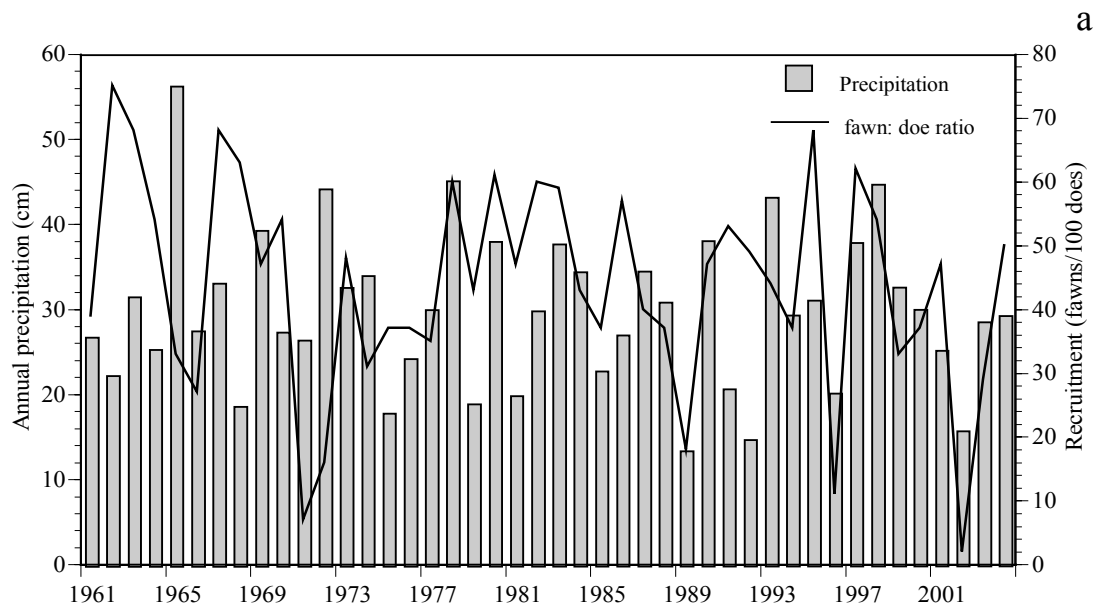


Figure 4.1. Time series of (a) annual precipitation and fawn recruitment (fawn/100 does) for GMU 19A, central Arizona, USA, 1961-2004, and (b) pronghorn population estimates for GMU 19A, central Arizona, USA, 1961-2004.

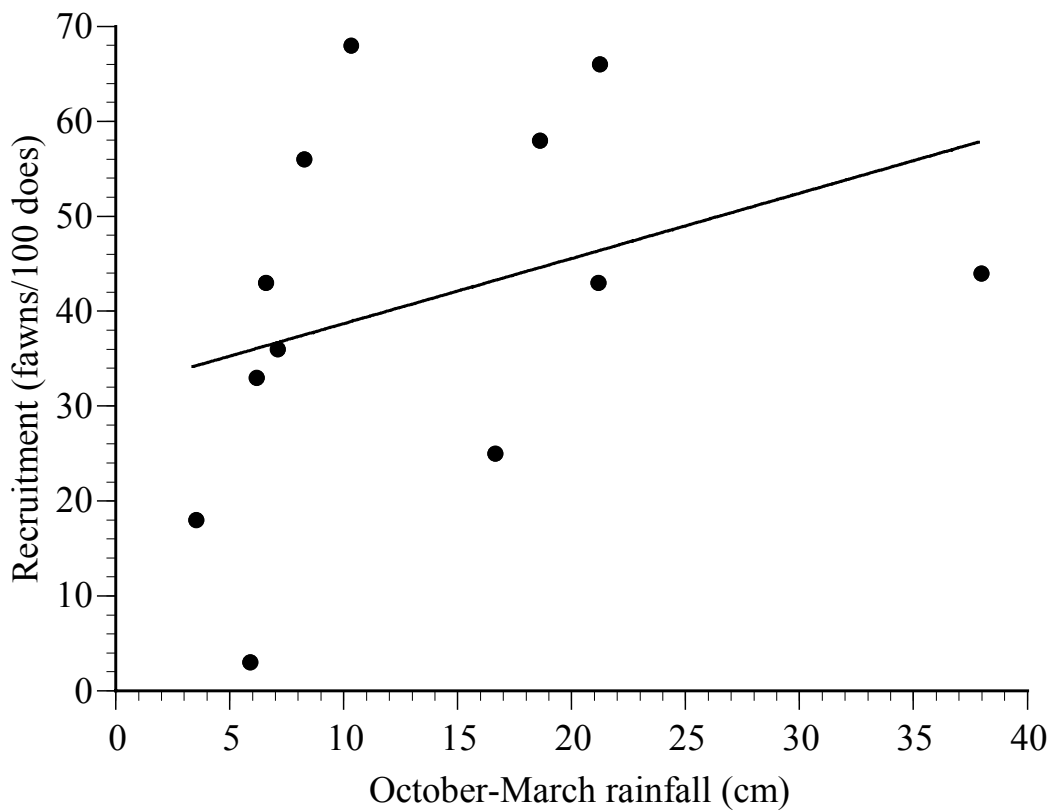


Figure 4.2. Relationship between fawn recruitment (fawns/100 does) and October-March precipitation (cm) on Fain Ranch in central Arizona, Game Management unit (GMU) 19A, 1993-2004 ($R^2 = 0.12$, $P = 0.27$).

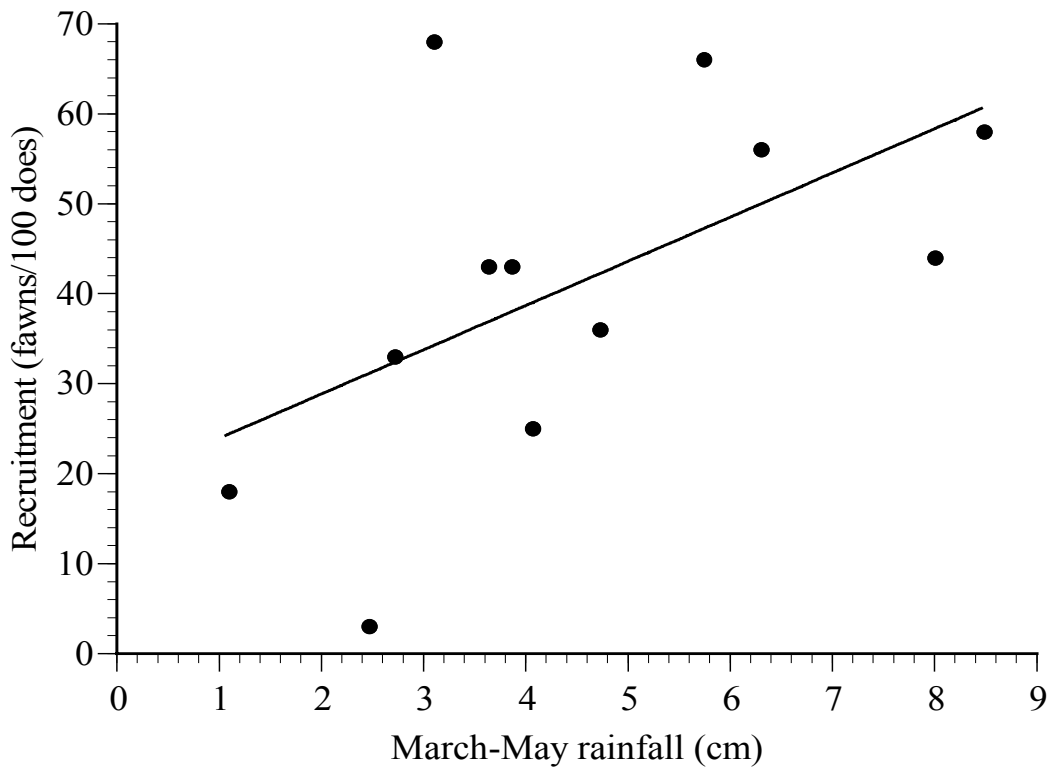


Figure 4.3. Relationship between fawn recruitment (fawns/100 does) and March-May precipitation (cm) on Fain Ranch in central Arizona, Game Management Unit (GMU) 19A, 1993-2004 ($R^2 = 0.32$, $P = 0.06$).

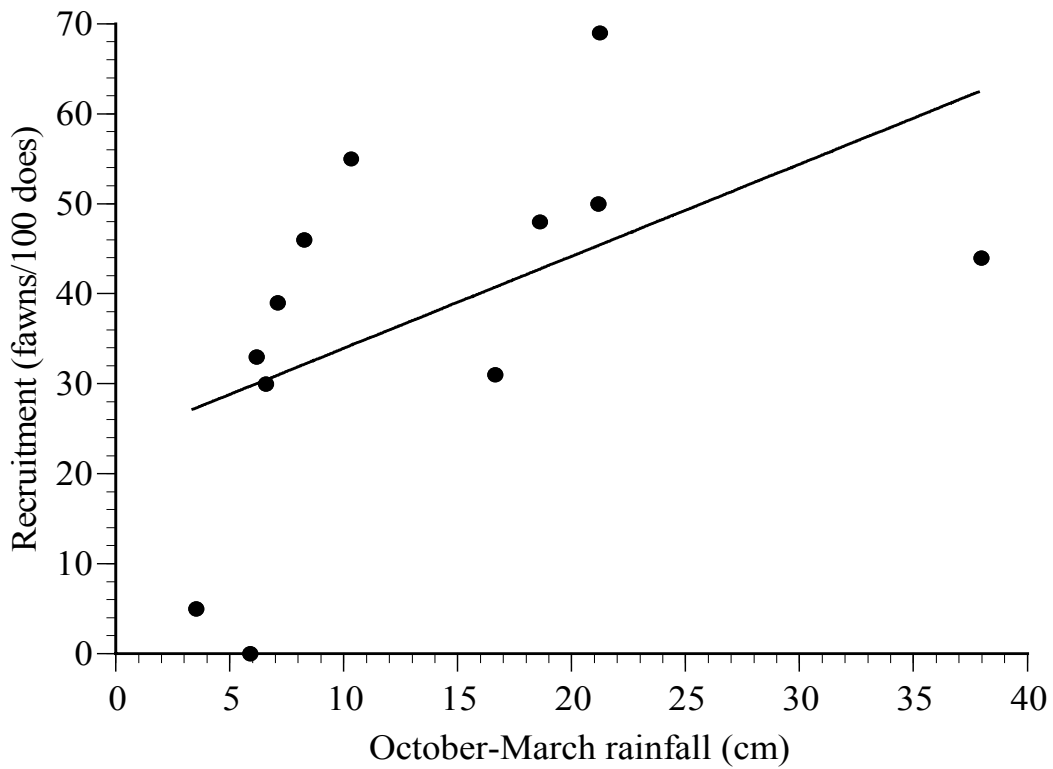


Figure 4.4. Relationship between fawn recruitment (fawns/100 does) and October-March precipitation (cm) on Lonesome Valley in central Arizona, Game Management Unit (GMU) 19A, 1993-2004 ($R^2 = 0.27$, $P = 0.09$).

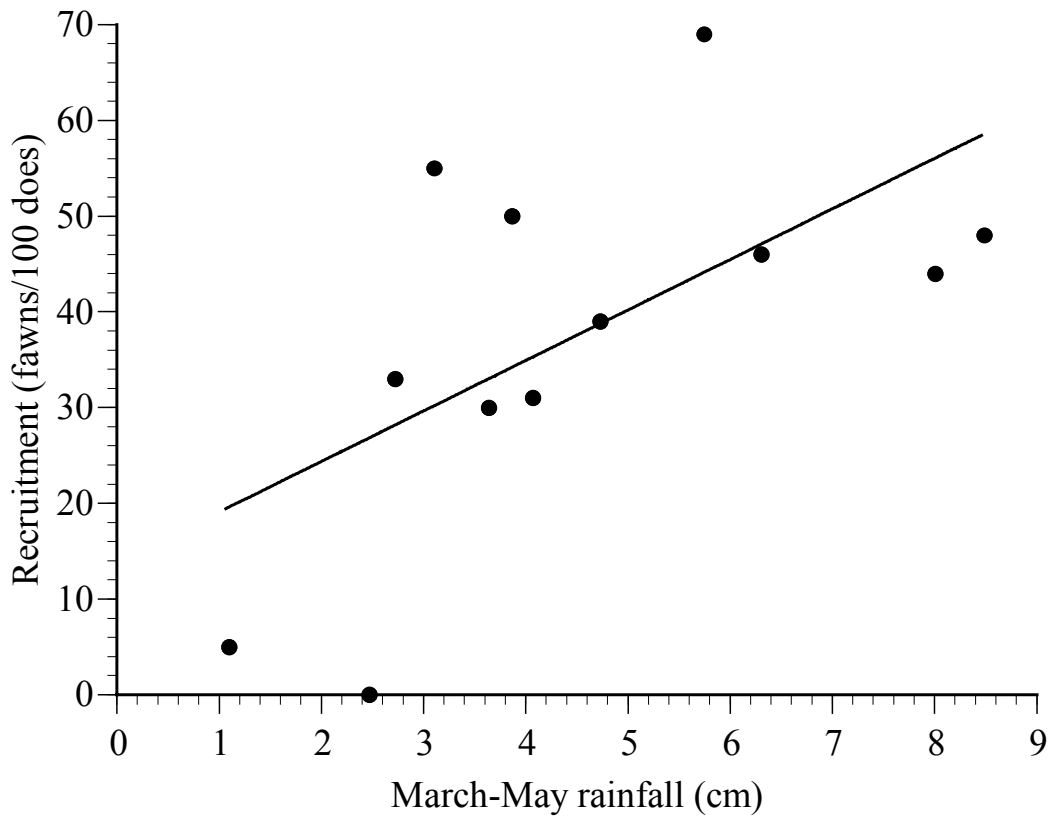


Figure 4.5. Relationship between fawn recruitment (fawns/100 does) and March-May precipitation (cm) on Lonesome Valley in central Arizona, Game Management Unit (GMU) 19A, 1993-2004 ($R^2 = 0.36$, $P = 0.04$).

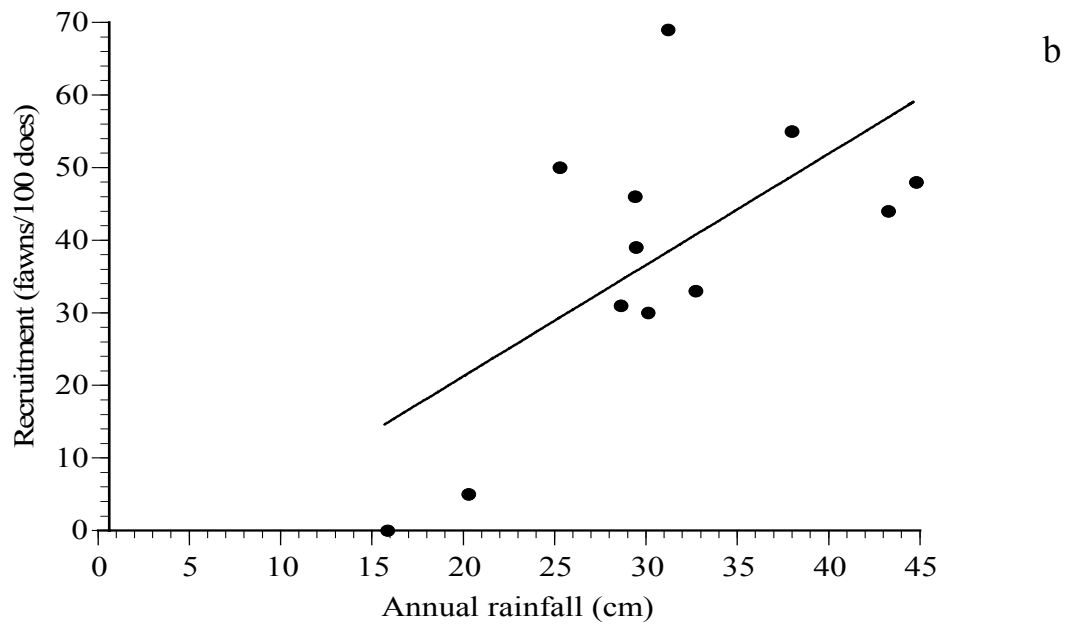
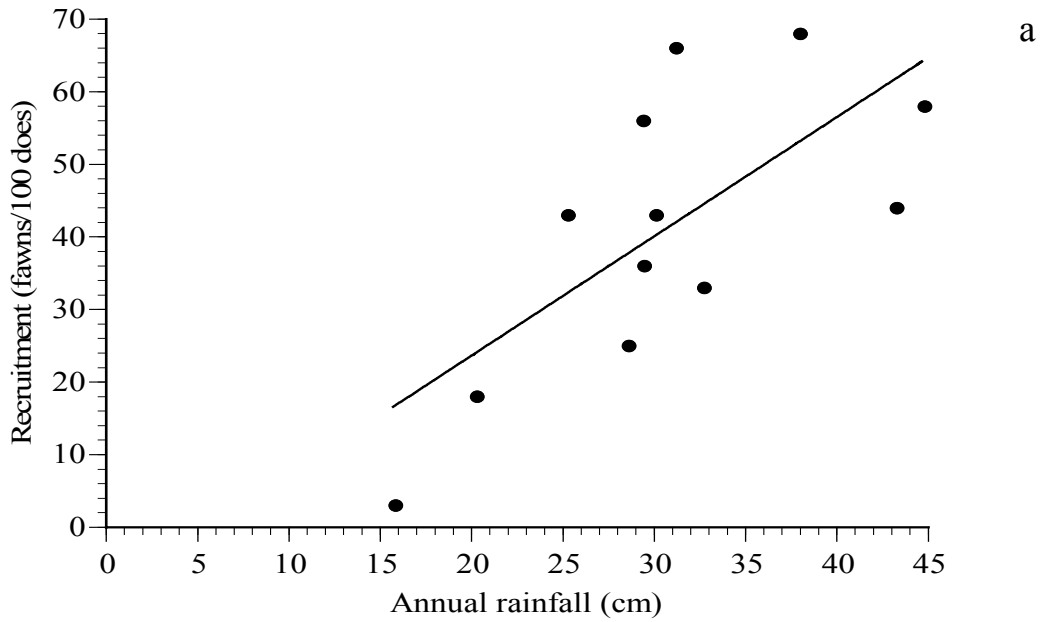


Figure 4.6. Relationship between fawn recruitment (fawns/100 does) and annual precipitation (cm) on (a) Fain ($R^2 = 0.57$, $P = 0.01$) and (b) Lonesome Valley ($R^2 = 0.46$, $P = 0.03$) in central Arizona, Game Management Unit (GMU) 19A, 1993-2004.

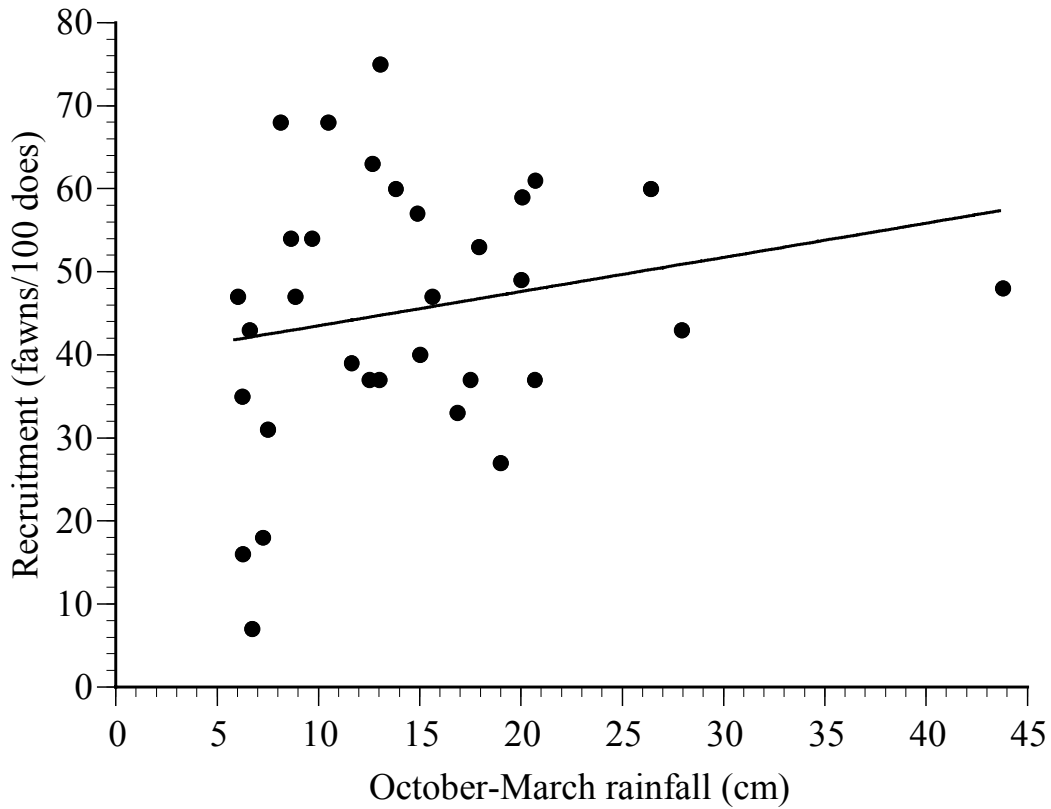


Figure 4.7. Relationship between fawn recruitment (fawns/100 does) and October-March precipitation (cm) in Game Management Unit (GMU) 19A central Arizona, 1961-2004 ($R^2 = 0.03$, $P = 0.25$).

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