FORAGE SELECTION AND GROUPING PATTERNS OF MALE AND FEMALE SCIMITAR–HORNED ORYX (*ORYX DAMMAH*) ON MASON MOUNTAIN WILDLIFE MANAGEMENT AREA, MASON, TEXAS

THESIS

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by
Sarah E. Robinson, B.S.

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DEDICATION

To my Mom and Dad, Joseph, Ian and Leigh, for being a wonderful, loving and supportive family who have helped me through my years of academic endeavors, whether it be moving me from one apartment to another, feeding my expensive horses, or simply having a bed for me to sleep in anytime I needed to come home for some down time. Thank you and my love to you all. To Zack Robinson, whom I met at the rodeo in Mason, Texas while on a weekend hiatus from intern duties. Since then, he has been faithfully at my side assisting me every weekend of data collection. He continues to give me so much joy as my best friend and now as my husband.

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ABSTRACT

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Sarah E. Robinson, B.S.

Texas State University-San Marcos

May 2008

SUPERVISING PROFESSOR: FLOYD W. WECKERLY

Little is known about resource selection patterns of scimitar-horned oryx (*Oryx dammah*) in Texas, information that is vital for informed management decisions. Scimitar-horned oryx are less dimorphic in body size (males approximately 12% larger than females) than most ruminants (males 20 – 50% larger than females). Ruminants dimorphic in body size display intersexual differences in diet and spatial patterns, presumably because of body size differences. Consequently, scimitar-horned oryx is an ideal species to test for intersexual differences in spatial patterns, diet and food selection. I hypothesized that male and female scimitar-horned oryx associate in mixed-sex groups and do not exhibit intersexual differences in forage selection. My study was initiated in June 2006 at Mason Mountain Wildlife Management Area in central Texas and data collection was completed in April 2007. I measured grouping patterns from systematic vehicle surveys conducted at dawn and evening in six different months. I observed males and femalesthrough binoculars and collected fecal samples from known sex individuals in six different months. I determined food habits by identifying plant fragments in fecal samples. Forage availability was measured seasonally by establishing 100 m transects in areas where fecal samples were collected. Mixed-sex groups were encountered more commonly than other group types and most males and females encountered (≥ 0.69) were in mixed-sex groups. There were no differences between the diet of males and females. Scimitar-horned oryx displayed differences among months in forage selection. In summer and fall, there was an inverse correlation between availability and use of food items. In winter there was a positive correlation and no correlation between availability and use of food items in spring. The majority of the diet was grasses, such as *Sporobolus* sp., *Eragrostis* sp., and forbs. The findings of this study support expectations based on body size, males and females occur in the same groups and consume similar forages. Unlike many ruminants, managers do not have to consider separate habitat requirements of each sex when managing scimitar-horned oryx.

CHAPTER I

INTRODUCTION

Scimitar-horned oryx (*Oryx dammah*, hereafter oryx) are native to sub-Saharan Africa (Mungall and Sheffield 1994, Morrow et al. 1999, Gagnon and Chew 2000). Historically they inhabited the present day countries of Chad, Sudan, Egypt, Tunisia, Morocco, Algeria, Mauritania, Mali, and Niger. Oryx are adapted to an arid climate with grassland habitats. Oryx in their native range are considered gregarious and forage on grasses, however, they will consume browse when grasses are scarce (Mungall and Sheffield 1994). Unfortunately oryx are close to extinction in the native range (Mungall and Sheffield 1994, Morrow et al. 1999) and are listed as endangered. The demise of oryx on native range is a combination of habitat loss, climate change and overexploitation from subsistence hunting.

Oryx were probably first introduced into Texas in the early 1970s and are now common in central Texas (Armstrong and Harmel 1981, Mungall and Sheffield 1994). Landowners stock this exotic species for recreational hunting and conservation efforts. There is a paucity of studies on resource selection by oryx on native and non-native range (Merkord 1987). An understanding of resource selection patterns of oryx is needed to assess possible competition with other exotic and native ungulates and to formulate plans conducive to management objectives (Armstrong and Harmel 1981, Nelle 1992).

Across the spectrum of small to larger ruminant species, resource use is presumably coupled to body size (Demment and Van Soest 1985). Large ruminants have greater gut capacities in relation to metabolic demands. The greater gut capacity in relation to metabolic demands suggests that large animals retain digesta longer so that microorganisms in fermentation chambers have more time to break down structural carbohydrates in plant cell walls. Consequently, small animals may be forced to select forages with more cell soluble nutrients that are readily digested (Barboza and Bowyer 2000).

Most ruminant species are sexually dimorphic in body size with females smaller than males. Extending the model of Demment and Van Soest (1985) to populations within species (the body size hypothesis), females should select a diet that is more digestible than males (Clutton-Brock et al. 1982, Barboza and Bowyer 2000). In accordance with the body size hypothesis are findings that males in some populations consume poorer quality forage than females (Clutton-Brock et al. 1982, Beier 1987, Barboza and Bowyer 2000). Consequently, assessing forage use and selection without accounting for the possibility of the sexes consuming differing diets can result in an incomplete understanding of the resource needs of species that are sexually dimorphic in body size (Weckerly et al. 2003, Bowyer 2004).

Oryx are large and both sexes have horns that are similar in stature (Mungall and Sheffield 1994). Males weigh about 181 kg and females are about 12 % less in weight (Mungall and Sheffield 1994, Morrow 1999, Penfold et al. 2002). In sexually dimorphic ruminants, females are typically 20 to 50 % smaller than males (Weckerly 1998, Loison et al. 1999). Oryx are an ideal species to test the body size hypothesis because, unlike most large ruminants, oryx are less dimorphic in body size (hereafter, sexually monomorphic). Moreover, most tests of the body size hypothesis have been with ruminants that are dimorphic in body size (Main et al. 1996, Mysterud 2000, Bowyer 2004).

The objectives of my research were to measure seasonal resource selection and grouping patterns of male and female oryx at Mason Mountain Wildlife Management Area (MMWMA). I predicted that male and female oryx will not display sexual differences in resource selection and grouping patterns because the species is monomorphic. Differences between the sexes in foraging and grouping patterns were examined because females and males may select different forages but aggregate in the same group (McCullough 1979, Ruckstuhl and Neuhaus 2002).

CHAPTER II

MATERIALS AND METHODS

Study Area

I conducted this study at MMWMA located in Mason County in the Llano Uplift ecological region of Texas (Fig. 1). Elevation ranges from 251 to 686 m. This management area is approximately 2120 ha divided into 5 pastures by 2.4 m high fences. Average annual rainfall is approximately 54 cm with mean temperatures fluctuating from 9° C in January to 27° C in July. During the 2006 data collection year, average annual precipitation was 8.58 cm below average at 44.83 cm. The precipitation total from January 2007 – April 2007 was 11.02 cm above average at 22.68 cm. Weather data were obtained from the National Oceanic and Atmospheric Association website (National Oceanic and Atmospheric Association 2006, 2007).

Exotic species housed on the management area include gemsbok (*Oryx gazella*), greater kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus*), waterbuck (*Kobus ellipsiprymnus*), blackbuck (*Antelope cervicapra*), Thompson's gazelle (*Gazella thopmsoni*), axis deer

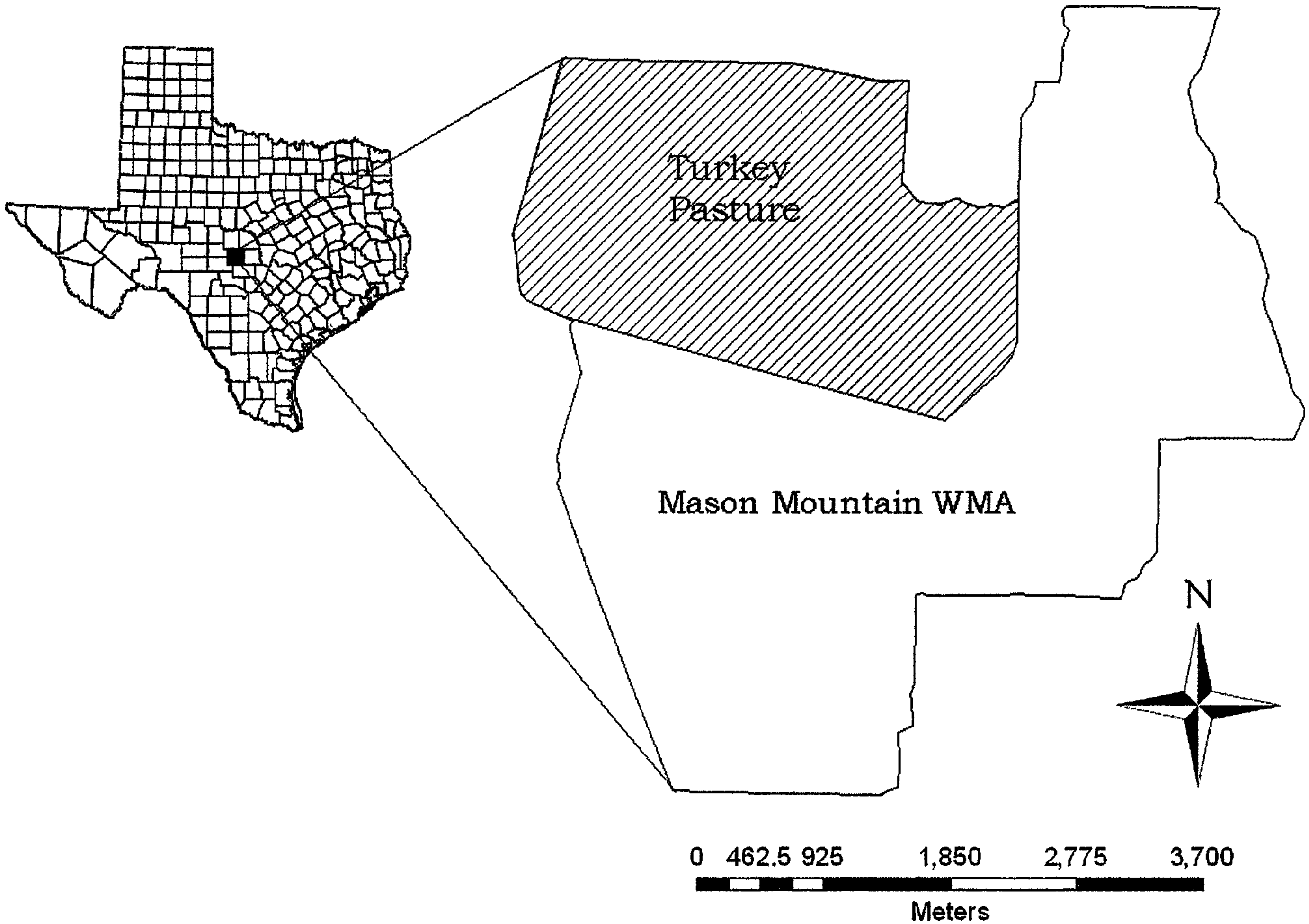

Figure 1. Location of Turkey Pasture on Mason Mountain Wildlife Management Area (WMA). The WMA is located in Mason county in Central Texas.

(*Cervus axis*), sable (*Hippotragus niger*) and scimitar-horned oryx. These species have existed on the property since 1986.

Soil types on MMWMA are primarily loams, sands, or granites (MMWMA soil survey files, 2006). Habitat types on MMWMA include blackjack oak (*Quercus marilandica)* – post oak (*Quercus stellata*) woodlands, live oak (*Quercus fusiformis)* woodlands, mesquite (*Prosopis glandulosa*) – whitebrush (*Aloysia gratissima*) thickets, mixed oak (*Quercus* sp.) woodlands, shin oak (*Quercus sinuata*) mottes, and wooded canyons (*Quercus buckleyi, Sophora segundiflora, Foresteria* sp., *Diospyros texana*). Common grasses in habitats are little bluestem (*Schizachyrium scoparium*), silver bluestem (*Bothriochloa saccharoides*), threeawns (*Aristida* sp.), grama grasses (*Bouteloua* sp.) and love grasses (*Eragrostis* sp.),

Oryx were located in Turkey Pasture which covers 719 ha dominated by about 468 ha of live oak habitat with grasslands, wooded canyons, mesquite – white brush thickets and shin oak mottes. Other native and non-native ruminant species in the pasture were white-tailed deer (*Odocoileus virginianus*), impala, blackbuck and greater kudu.

Grouping Patterns

Grouping patterns were assessed by surveys conducted from a vehicle along a designated route through Turkey Pasture, covering habitat types in Turkey Pasture. Length of the route was approximately 17 km and was driven at a maximum speed of 24 km per hour. Surveys were conducted in June, August, October, and December, 2006, and February and April, 2007. Survey routes were driven morning and evening for five days in each month. Survey directions alternated for each survey so that the same territory was not observed at the same time of day. Locations of solitary animals and groups of oryx were determined using a Garmin® Legend GPS unit. A group was two or more animals that were within 50 m of one another (Clutton-Brock et al. 1982). Numbers of adult males, adult females, juveniles and unclassified animals (oryx that could not be classified into age and sex categories) were recorded during each encounter. Juveniles were distinguished from adults based on shorter horn length and smaller body size. I did not conduct surveys during times of dense fog because of reduced visibility.

Food Habits

Samples of oryx fecal material from known males and females were collected in 2006 during July, August, October, and December. In 2007, samples were collected in February and April. Animals were observed at distances between 20 and 150 m with 10 X 50 binoculars. I distinguished males from females by the prepuce on the abdomen. Some males and females were distinguishable by individual markings, scars, pelage coloration and horn morphology. Fecal samples consisting of a minimum of 5 fecal pellets was collected immediately following defecation and placed into paper sacks. The paper sacks were allowed to air dry for a minimum of 1 month. In each month I collected 5 samples from individual females and 5 samples from individual males.

The microhistological approach was used to identify plant species fragments (Scott and Dahl 1980) in fecal material. Dried fecal material was ground in a Wiley Mill using a 60 mesh (250 μm) screen to obtain plant fragments of similar size (Litvaitis et al. 1996). I soaked the ground fecal material in household bleach for approximately 4 min to clear pigments from plant fragments. I then rinsed the bleached plant fragments through a 120 mesh (125 μm) sieve to remove dirt particles and bleach residue (Sparks and Malecheck 1968). I prepared two slides per fecal sample. Approximately 0.25 ml of fecal material and about 6 drops of Hoyer's Solution was evenly mixed on slides. Cover slips were placed over slides and edges sealed with Permount® mounting medium. I viewed 10 fields per slide with approximately 3 fragments visible per field of view at 100X magnification (Scott and Dahl 1980). Grass fragments were identified to species or genus, and forb fragments using reference slides and reference photographs provided by Green (1985).

Reference slides of known plant species were prepared by soaking plant epidermal tissue in bleach to remove pigments, then removing extraneous material by scraping. These slides were prepared the same way as fecal sample slides.

Vegetation Analysis

To estimate forage availability, I conducted vegetative surveys in areas where fecal samples were collected. During months when fecal samples were collected, I established 10 transects, 1 at each fecal collection site. Each transect was 100 m long. I placed 0.25 m^2 Daubenmire plots (Daumenmire 1968) at 10 m increments along transects. I identified all grass, forb and browse species within plots and assigned Daubenmire coverage classes (Daumenmire 1968). Forage availability was estimated in June and October 2006, and February and April, 2007.

Statistical Analysis

Survey data from morning and evening surveys were pooled because few oryx were encountered during some surveys. Animals were placed into the following group types: solitary males, solitary females, male-only groups, or mixed-sex groups. The total number of animals encountered and the proportion of animals encountered that were not classified to age-sex classes were also calculated. To estimate the extent to which males occurred with females, and vice versa (see Table 1), I calculated the proportion of all males encountered in a month that were in mixed sex groups and I did the same for females. I assessed the possibility of monthly differences in group sizes by conducting an analysis of variance (ANOVA) with month as the factor (Sokal and Rohlf 1995).

I conducted a randomization test (Manley 1997) of the differences in percentages of food items consumed by male and female oryx in each month because the data did not meet the assumption of normality and diet items were not independent of one another. One thousand random reshuffles of the data were performed for each test. The test statistic was the mean difference between male minus female food item percentages. A Pearson's Chi-Squared test was conducted on food habits data to determine whether percentages of food items in diets differed among months (Sokal and Rohlf 1995). Some food items were not detected in every month and sex categories. I added 5 to each cell to meet the Chi-Squared assumption of a minimum of 5 observations per cell.

A Spearman's correlation coefficient was obtained to compare food items to its availability. Summer forage selection is represented by June data, fall by October data, winter by February data and spring by April data. To assess selection of food items, I compared the mean percentage and 95% confidence intervals of each food item that comprised greater than 4% of the diet among months to its availability. I calculated a selection ratio using the following equation:

$$\text{Selection Ratio (SR)} = \frac{\text{Percent use of X diet item}}{\text{Percent availability of X diet item}}$$

An SR >1 indicated selection of that diet item, SR = 1 indicated a diet item was used in relation to availability (no selection), and a SR < 1 indicated that the diet item was not selected (hereafter, avoided). The statistical software R, version 2.6.0 (R Development Core Team 2005), was used to conduct all analyses.

CHAPTER III

RESULTS

I detected no differences in group sizes among the six months (F = 1.51, df = 5, 65, P = 0.196). The mean group size was 10.53 (SE = 1.23, n = 73) and minimum and maximum group sizes were 2 and 52, respectively.

I found, primarily, two types of groups, solitary males and mixed sex groups (Table 1). Mixed-sex groups were most prevalent. Among all six months, the average proportion of groups encountered that were mixed-sex was 0.55 (minimum was 0.32, maximum was 0.77). Most males encountered during surveys were in mixed-sex groups because between 0.72 and 0.95 of all males encountered each month were in mixed-sex groups. Between 0.69 and 1.0 of all females estimated during monthly surveys were also in mixed sex groups.

In each month, the proportion of unclassified oryx encountered during surveys ranged from 0.15 to 0.56. This high proportion did not appear to bias proportions of adult males and females encountered in

Table 1. Summary of number of group types and number of scimitar-horned oryx encountered from vehicle surveys on Mason Mountain Wildlife Management Area, Mason County, Texas, during six different months, 2006 – 2007.

	June	August	October	December	February	April
			Group type*			
Solitary male	5	5	9	2	2	3
Solitary female	0	0	0	2	0	0
Mixed sex	3	6	6	24	11	7
Male only	0	0	0	1	1	0
Female only	0	1	3	2	0	2
Unknown	0	0	1	0	1	0
			Characteristics of animals in all group types			
Number encountered	130	133	125	118	155	91
Proportion unclassified	0.24	0.56	0.30	0.15	0.47	0.26

Table 1 continued.

	All adult males/females encountered					
Proportion in mixed sex group	0.72/1.00	0.86/0.90	0.72/0.69	0.95/0.98	0.88/1.00	0.81/0.80

*Mixed sex groups contained at least one adult male and female, male only groups had adult males, female only groups had adult females, and unknown groups had no animals that could be classified to age and sex catagories.

mixed-sex groups. The correlations between proportion of unclassified oryx and proportion of adult males and adult females in mixed-sex groups were weak (male: r = 0.10, t = 0.19, *df* = 4, *P* = 0.85; female: r = 0.08, t = 0.08, *df* = 4, *P* = 0.94).

I identified 18 different food items in the fecal material (Appendix 1). Nine of these food items comprised over 80% of the diet and each of these food items comprised greater than 4% of the diet for the entire study period. The remaining food items were excluded from further analysis because they were often absent in monthly diets. The nine food items were forb, *Aristida* sp., *Bouteloua curtipendula, Bouteloua hirsuta, Buchloe dactyloides, Eragrostis* sp., *Schizacharium scoparium, Sporobolus* sp., and *Stipa leucotricha.* There were no detectable differences in dietary food items between male and female oryx in any month (Table 2). Therefore, I was able to assess selection among months without regard to sex.

Table 2. Results of randomization tests to assess dietary differences between male and female scimitar-horned oryx from June 2006 – April 2007. The test statistic was the sum of the difference between male and female food items in each month.

Month	Test Statistic	*P*-value
June	-4	0.922
August	4	0.933
October	9	0.788
December	-1	0.999
February	-3	0.943
April	-5	0.888

Oryx diets differed among months (Pearson's X^2 = 287.56, *d.f.* = 40, $P <$ 0.001). Spearman's correlation coefficient indicated high levels of selection during summer and fall because there were inverse correlations between availability and use of food items (Fig. 2). Oryx were not selective in winter but consumed food items in relation to availability because there was a positive correlation between availability and use of food items. In spring, food items were not correlated with food availability. During summer, oryx showed highest selection for *Sporobolus* sp. and *Eragrostis* sp. Selection of food items in fall included these two species as well as *Buchloe dactyloides.* In winter, *Aristida* sp. and *Stipa leucotricha* were a large part of the diet. In spring, *Stipa leucotricha* and *Buchloe dactyloides* comprised much of the diet.

Annually, food items most highly selected among months (selection ratios of greater than 19%) were *Sporobolus* sp., *Eragrostis* sp., and forbs (Fig. 3).

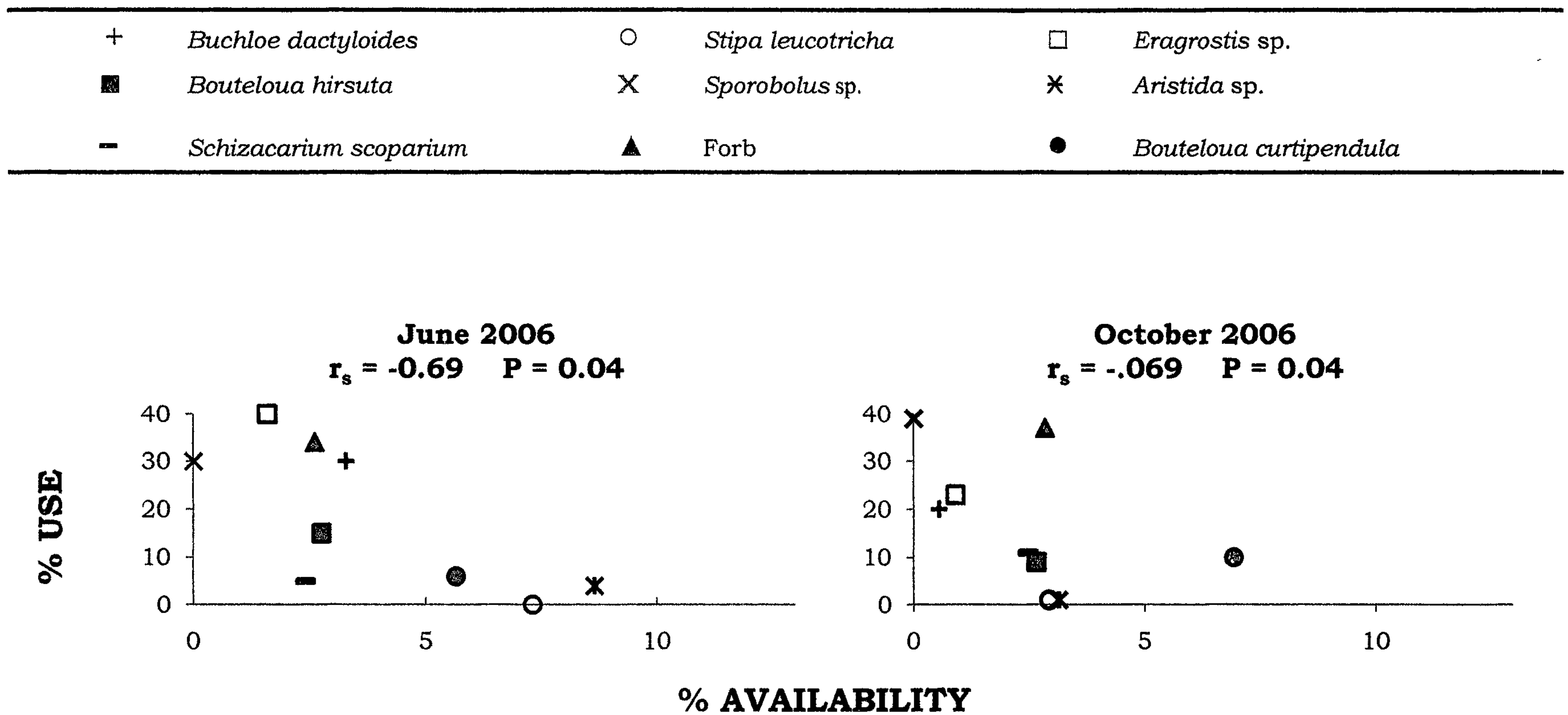

Figure 2. Seasonal forage selection of male and female scimitar-horned oryx on Mason Mountain Wildlife Management Area, Mason County, Texas, June 2006 – April 2007.

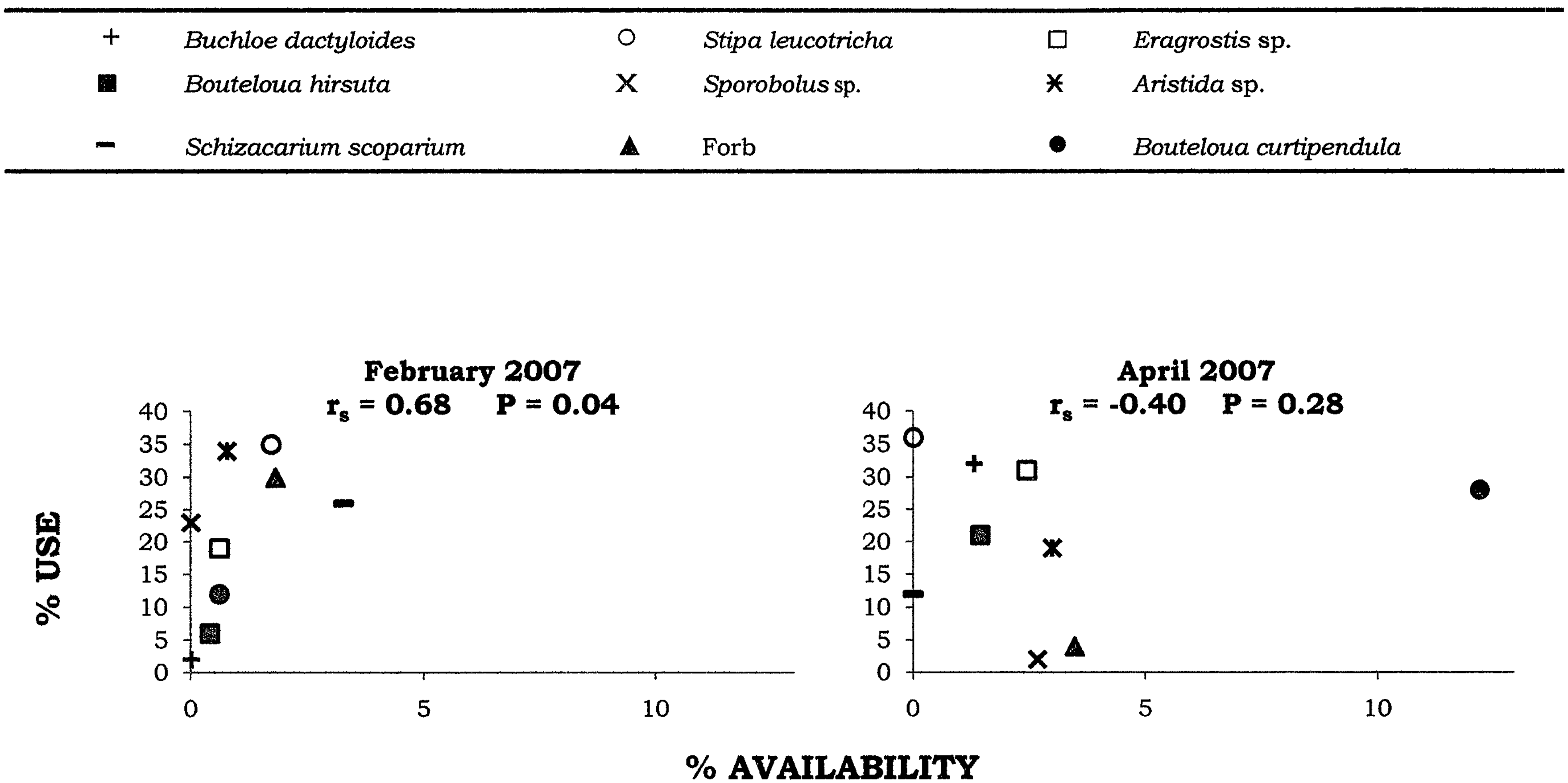

Figure 2 continued

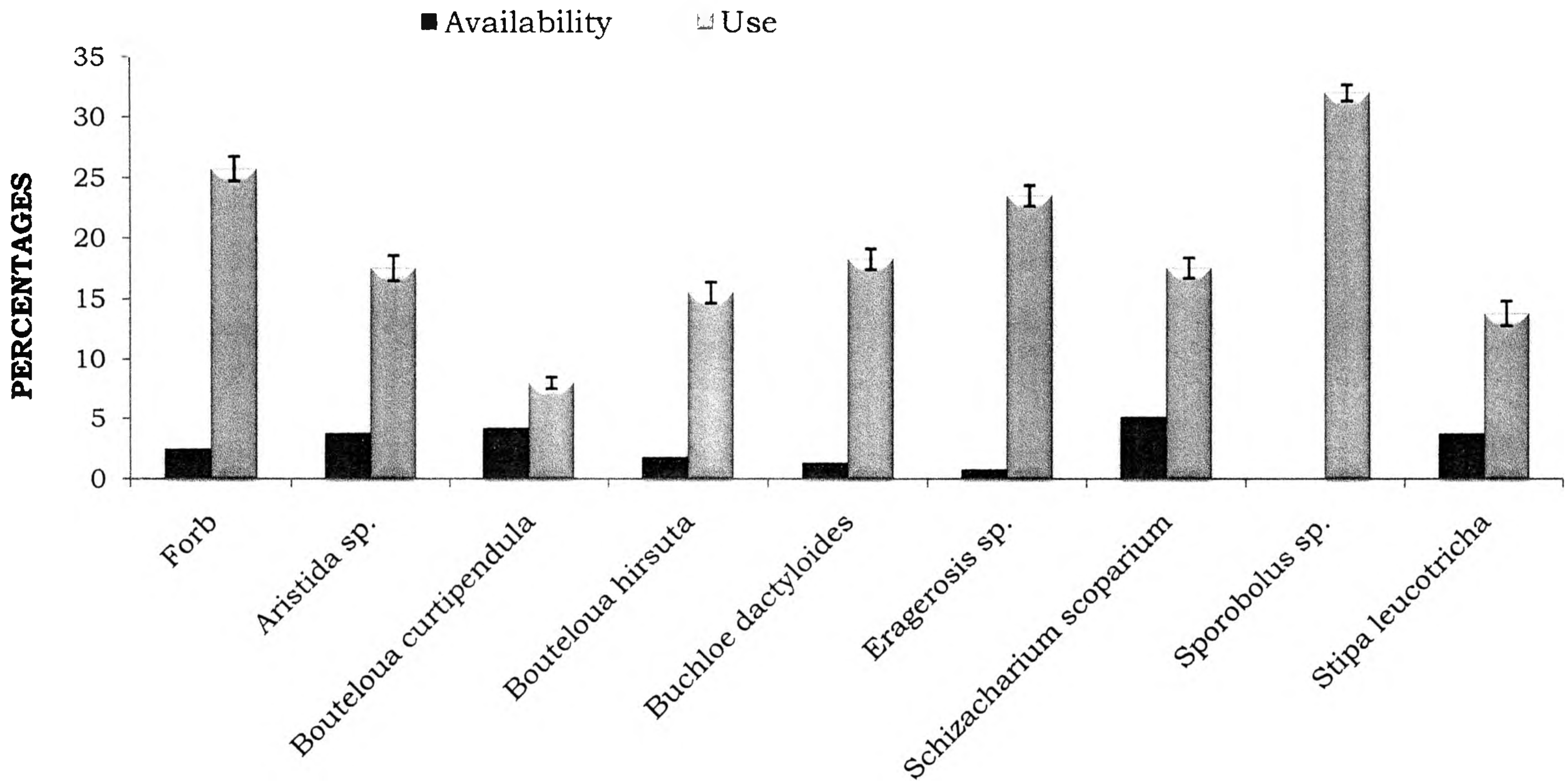

Figure 3. Average annual forage selection of foods that comprised at least 4% of the diet of scimitar-horned oryx on Mason Mountain Wildlife Management Area, Mason, Texas, June 2006 – April 2007. Units on y-axis are log-10 transformed percentages to facilitate presentation. Error bars represent standard errors.

CHAPTER IV

DISCUSSION

My objective with this project was to determine grouping patterns of scimitar–horned oryx and compare these findings with other large ungulates in relation to Demment and Van Soest's (1985) body size hypothesis. I also assessed forage selection of male and female oryx so that land owners and managers may more effectively maintain necessary forage availability on their properties for this exotic species.

I found 72% of males observed in June and October occupied mixed sex groups and 95% of males observed in December occupied mixed sex groups. In addition, proportions of females observed in mixed sex groups were 69% in October and 100% in June and February. Males and females spent greater than 50% of their time in mixed-sex groups; evidence that male and female oryx do not display intersexual resource selection.

However, oryx diets did differ among seasons. As plants mature, the amount of fibrous material increases while crude protein and digestibility decreases (Rayburn 1993, Mousel et al. 2006). Forages are, therefore, consumed at higher rates by herbivores during early stages of growth. Food items that were most highly selected (SR > 19%) from June through February were *Sporobolus* sp. and *Eragrostis* sp.; both are warm season perennials. *Sporobolus* is good winter forage for livestock (Loflin and Loflin 2006, United States Forest Service 2008). *Eragrostis* experiences early growth stages between July and August and is also considered desirable forage for cattle (Loflin and Loflin 2006, United States Forest Service 2008). In fall, *Buchloe dactyloides*, which is also a preferred forage by cattle (Loflin and Loflin 2006), became more prevalent in the diet. Selection was not as prevalent during winter; however, oryx increased their use of *Stipa leucotricha*. This species is a cool season perennial, granting it a higher nutrient content and palatability than other available forages at this time of year (Mousel et al. 2006). This species of grass is also considered a preferred forage for livestock (Loflin and Loflin 2006, Mousel et al. 2006). I observed increased use of *Aristida* during winter as well. *Aristida* sp. are warm season perennial bunch grasses that usually sprout in spring. It is a highly competitive plant during droughts and can maintain relatively normal growth during 1–2 year droughts (United States Forest Service 2008) while other species suffer. It is not usually selected by livestock because of needle-like seed heads, however, once the seed heads drop in late summer-early fall, the vegetative parts are more palatable for winter grazing (United States

Forest Service 2008). This grass can also produce sprouts in fall and winter in warmer climates (United States Forest Service 2008). This phenomenon could be a reason for the increased occurrence of this grass in oryx diets during winter. Forbs occurred with higher frequency in the diet during winter as well. This could be a result of late winter forb emergence due to the mild winter, or a reduced amount of other preferred forages. Finally, oryx did not show selection in spring. Numerous varieties of forages emerge during this time of year, leading to a more diverse diet. However, *Stipa leucotricha* and *Buchloe dactyloides* were used with greater frequency than any other species. These two species experience new growth in spring which provides higher nutrient content (United States Forest Service 2008) possibly indicating greater palatability. *Schizacharium scoparium*, a warm season perennial, was also prominent in spring diets.

During the 2006 data collection months, Mason County was experiencing a severe drought. Oryx appeared to be more selective during this time probably because food items selected were better suited for drier conditions, maintain palatability longer, or experience earlier stages of growth at a time when many other forage species are nearing senescence. *Buchloe dactyloides* is highly drought resistant, maintains palatability throughout the year, and increases upon grazing pressure (Mousel et al. 2006, United Stated Forest Service 2008). During drier times of the year this species can be a valuable forage when other forages are nearing the end of their growth cycle. *Eragrostis* is considered palatable forage for livestock (Loflin and Loflin 2006, United States Forest Service 2008) and maintains nutrient content of 50% – 52% during July and October in Texas (United States Forest Service 2008). The attributes of this grass lead to possibilities for selection during the drier time of year. *Sporobolus* is reported to be a fair source for forage for cattle and is drought resistant (Loflin and Loflin 2006, United States Forest Service 2008). Oryx may have selected this species due to its ability to maintain palatability during drought conditions.

Conversely, the 2007 collection months received a surplus of moisture by 11.08 cm. These early rains possibly stimulated the growth of numerous forage species giving the oryx more variety from which to select. In addition, during the early stages of growth, some forage species, otherwise not desirable by grazers, may be selected for their high nutrient content and palatability, thus resulting in lower selection ratios for that season.

Oryx are sexually monomorphic. Both sexes of oryx occupied the same space at the same time and did not differentially select forages. Since resource use is presumably tied to body size (Demment and Van Soest 1985, Barboza and Bowyer 2000) my findings appear to support the body size hypothesis proposed by Demment and Van Soest (1985).

There have been few studies focusing on intersexual resource selection within a monomorphic species although many have been conducted on sexually dimorphic species. Mysterud (2000) found herbivores with larger differences in body size between the sexes exhibit differential intersexual resource selection with more frequency. The dimorphic desert mule deer (*Odocoileus hemionus crooki),* exhibited differential resource selection by adult males and females during the non-rut season (Bowyer 1984, Scarborough and Krausman 1988).

I concluded that scimitar-horned oryx do not partition spatial or foraging resources. There is ample information regarding sexually dimorphic species and sexual segregation and resource partitioning. However, there continues to be a lack of information on intraspecific resource partitioning in monomorphic ungulate species.

Landowners and managers may manage resources on properties for this species without regard to sex. Oryx can possibly be stocked in lieu of cattle to attain similar results to various grazing regimes. Care should be taken when stocking oryx with other grazers because interspecific competition and overgrazing may become an issue. Furthermore, oryx herds are not easy to handle and move through pastures so using this species as a replacement for cattle may only be beneficial for particular situations. Additional studies may be conducted to further our understanding of the scimitar–horned oryx's foraging habits compared to cattle and other grazers. For example, oryx have smaller muzzles than cattle and may be used as a more selective foraging tool, possibly causing some plant species to be more heavily utilized. Also, they have smaller, sharper hooves that may impact pasture land differently than the hoof-action of cattle.

Landowners and managers may find this information useful when managing resources and stocking a variety of exotic species and livestock on their properties. Further studies on monomorphic species' intraspecific resource use could strengthen the argument for the body size hypothesis. It could also help conservationists better understand how to protect resources most effectively and in the best interest of other endangered species.

APPENDIX 1

Food habits of each fecal sample from male and female scimitar–horned oryx. Numbers refer to the frequency a food item was detected in that animal's fecal content. June 2006.

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	0	0	1	1	0	1	0	1	0	0
Bothriochloa laguroides	0	0	0	0	0	0	0	0	0	0
Bouteloua curtipendula	2	0	0	0	1	0	1	0	0	2
Bouteloua hirsuta	2	0	1	3	3	1	1	2	1	1
Bouteloua rigidiseta	0	0	0	0	0	1	0	0	0	0
Buchloe dactyloides	4	1	2	2	0	3	3	2	12	1
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognate	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	1	7	8	4	6	5	4	3	1	1
Eriochloa sericea	0	0	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	2	0	0	0	0	1	0
Forbs	4	5	3	5	6	1	0	2	2	6
Hilaria belangeri	0	0	2	0	1	0	0	1	0	0
Panicum halii	4	6	1	0	0	1	3	3	0	2
Schizacharium scoparium	0	0	0	0	2	1	0	0	0	2
Sporobolus sp.	2	1	2	0	1	6	7	6	2	3
Stipa leucotricha	0	0	0	0	0	0	0	0	0	0
Unknown Grasses	0	0	0	0	0	0	0	0	1	0
Bothriochloa ischaemum	1	0	0	3	0	0	1	0	0	2

Appendix 1-Continued

July 2006

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	0	0	1	1	0	1	0	1	0	0
Bothriochloa laguroides	0	0	0	0	0	0	0	0	0	0
Bouteloua curtipendula	2	0	0	0	1	0	1	0	0	2
Bouteloua hirsuta	2	0	1	3	3	1	1	2	1	1
Bouteloua rigidiseta	0	0	0	0	0	1	0	0	0	0
Buchloe dactyloides	4	1	2	2	0	3	3	2	12	1
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognata	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	1	7	8	4	6	5	4	3	1	1
Eriochloa sericea	0	0	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	2	0	0	0	0	1	0
Forbs	4	5	3	5	6	1	0	2	2	6
Hilaria belangeri	0	0	2	0	1	0	0	1	0	0
Panicum halii	4	6	1	0	0	1	3	3	0	2
Schizacharium scoparium	0	0	0	0	2	1	0	0	0	2
Sporobolus sp.	2	1	2	0	1	6	7	6	2	3
Stipa leucotricha	0	0	0	0	0	0	0	0	0	0
Unknown Grasses	0	0	0	0	0	0	0	0	1	0
Bothriochloa ischaemum	1	0	0	3	0	0	1	0	0	2

Appendix 1-Continued

August 2006

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	0	0	0	2	0	1	0	0	0	0
Bothriochloa laguroides	0	0	0	0	0	0	0	0	2	1
Bouteloua curtependula	2	2	0	0	0	1	0	0	1	0
Bouteloua hirsuta	2	0	0	0	1	0	4	4	1	4
Bouteloua rigidiseta	0	0	0	0	0	0	0	0	0	0
Buchloe dactyloides	2	2	3	1	1	1	2	3	1	3
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognata	0	0	0	0	0	0	1	0	0	0
Eragrostis sp.	4	3	4	4	4	1	4	6	4	3
Eriochloa sericea	0	0	0	0	0	0	0	0	1	0
Erioneuron pilosum	0	0	0	0	0	1	0	0	0	0
Forbs	1	3	6	4	5	4	4	2	4	3
Hilaria belangeri	0	0	0	1	0	0	0	0	0	1
Panicum halii	0	1	0	3	3	1	1	0	3	0
Schizacharium scoparium	2	0	1	3	0	3	0	0	1	1
Sporobolus sp.	7	9	5	2	5	6	4	5	1	4
Stipa leucotricha	0	0	1	0	1	1	0	0	0	0
Unknown Grasses	0	0	0	0	0	0	0	0	0	0
Bothriochloa ischaemum	0	0	0	0	0	0	0	0	1	0

Appendix 1-Continued

October 2006

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	0	0	0	1	0	0	0	0	0	0
Bothriochloa laguroides	1	1	0	0	0	0	0	0	0	0
Bouteloua curtependula	0	2	3	0	0	2	1	0	2	0
Bouteloua hirsuta	0	0	4	0	0	0	1	1	2	1
Bouteloua rigidiseta	0	0	2	2	0	1	2	0	0	0
Buchloe dactyloides	2	3	2	1	1	1	3	5	1	1
Dichanthelium oliganthes	0	0	0	0	0	0	0	1	0	0
Digitaria cognata	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	2	5	0	2	3	2	3	2	3	1
Eriochloa sericea	3	1	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	0	0	0	0	0	0	0
Forbs	3	4	3	5	5	3	3	3	3	5
Hilaria belangeri	0	0	2	1	1	0	0	0	0	2
Panicum halii	0	0	0	0	3	0	0	0	2	3
Schizacharium scoparium	2	1	1	0	3	3	1	0	0	0
Sporobolus sp.	5	2	2	8	4	2	1	3	7	5
Stipa leucotricha	0	0	1	0	0	0	0	0	0	0
Unknown Grasses	2	0	0	0	0	0	0	1	0	0
Bothriochloa ischaemum	0	1	0	0	0	6	5	4	0	2

Appendix 1-Continued

December 2006

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	1	5	2	4	2	0	0	2	0	0
Bothriochloa laguroides	0	0	0	0	0	0	0	0	0	0
Bouteloua curtependula	1	0	2	2	5	0	0	1	0	0
Bouteloua hirsuta	0	0	0	0	0	0	0	0	0	0
Bouteloua rigidiseta	0	0	0	1	0	0	0	0	1	0
Buchloe dactyloides	0	0	1	0	1	0	1	3	2	4
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognata	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	3	0	7	1	1	5	0	3	1	1
Eriochloa sericea	0	0	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	0	0	0	0	0	0	0
Forbs	5	5	2	2	3	3	7	6	4	5
Hilaria belangeri	1	0	0	0	0	0	1	0	0	0
Panicum halii	0	0	0	1	0	0	0	0	0	0
Schizacharium scoparium	2	1	1	3	0	3	1	1	2	1
Sporobolus sp.	2	4	4	2	4	0	2	0	2	2
Stipa leucotricha	5	5	1	4	4	9	8	4	8	7
Unknown Grasses	0	0	0	0	0	0	0	0	0	0
Bothriochloa ischaemum	0	0	0	0	0	0	0	0	0	0

Appendix 1-Continued

February 2007

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	1	3	5	3	1	2	3	5	7	4
Bothriochloa laguroides	0	0	0	0	0	0	0	0	0	0
Bouteloua curtependula	0	0	0	0	2	2	4	1	1	2
Bouteloua hirsuta	2	1	0	0	1	0	2	0	0	0
Bouteloua rigidiseta	0	1	4	1	1	1	0	2	1	0
Buchloe dactyloides	2	0	0	0	0	0	0	0	0	0
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognata	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	3	2	5	1	1	3	2	1	0	1
Eriochloa sericea	0	0	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	0	0	0	0	0	0	0
Forbs	0	6	1	2	5	5	3	2	4	2
Hilaria belangeri	0	0	0	1	0	0	1	0	0	0
Panicum halii	0	0	0	0	0	0	0	0	0	0
Schizacharium scoparium	2	0	1	3	3	2	4	2	2	7
Sporobolus sp.	7	3	2	5	1	1	1	1	2	1
Stipa leucotricha	3	4	2	4	5	4	1	6	3	3
Unknown Grasses	0	0	0	0	0	0	0	0	0	0
Bothriochloa ischaemum	0	0	0	0	0	0	0	0	0	0

Appendix 1-Continued

April 2007

Food Items	Female 1	Female 2	Female 3	Female 4	Female 5	Male 1	Male 2	Male 3	Male 4	Male 5
Aristida sp.	5	4	7	1	0	3	4	5	1	1
Bothriochloa laguroides	0	0	0	0	0	0	0	0	0	0
Bouteloua curtependula	2	0	1	0	1	0	0	0	0	0
Bouteloua hirsuta	3	5	2	2	4	2	5	4	1	4
Bouteloua rigidiseta	0	1	1	0	3	0	0	0	0	1
Buchloe dactyloides	4	2	2	4	0	4	3	2	0	0
Dichanthelium oliganthes	0	0	0	0	0	0	0	0	0	0
Digitaria cognata	0	0	0	0	0	0	0	0	0	0
Eragrostis sp.	0	0	0	1	4	0	3	0	0	4
Eriochloa sericea	0	0	0	0	0	0	0	0	0	0
Erioneuron pilosum	0	0	0	0	1	0	0	0	0	0
Forbs	0	0	0	0	0	2	0	0	0	0
Hilaria belangeri	0	1	0	1	1	0	1	1	2	0
Panicum halii	0	0	0	0	0	0	0	0	0	0
Schizacharium scoparium	1	2	5	4	1	6	4	3	1	1
Sporobolus sp.	0	4	2	5	2	0	0	5	11	7
Stipa leucotricha	5	0	0	2	3	3	0	0	4	2
Unknown Grasses	0	1	0	0	0	0	0	0	0	0
Bothriochloa ischaemum	0	0	0	0	0	0	0	0	0	0

APPENDIX 2

Seasonal percent availability of food items comprising greater than 4% of scimitar-horned oryx diets on Mason Mountain Wildlife Management Area, Mason Texas. Seasonal availability was recorded as percent cover.

Food Item	Summer 2006	Fall 2006	Winter 2006	Spring 2007
Aristida sp.	8.66	3.14	0.77	2.45
Bouteloua curtipendula	5.66	6.93	0.61	3.48
Bouteloua hirsuta	2.73	2.66	0.41	1.32
Buchloe dactyloides	3.27	0.55	0.02	1.45
Eragrostis sp.	1.57	0.91	0.61	0.00
Forbs	2.59	2.85	1.79	2.86
Schizacharium scoparium	2.39	2.48	3.26	12.23
Sporobolus sp.	0.01	0.01	0.01	0.01
Stipa leucotricha	7.32	2.93	1.70	3.00

LITERATURE CITED

Armstrong, W. E. and D. E. Harmel. 1981. Exotic Mammals Competing With the Natives. Reproduced from PWD LF C2000-0103 (11/81).

Barboza, P. S. and R. T. Bowyer. 2000. Sexual segregation in dimorphic deer: a new gastrocentric hypothesis. Journal of Mammalogy 81:473–489.

Beier, P. 1987. Sex differences in quality of white-tailed deer diets. Journal of Mammalogy 68:323-329.

Bowyer, R. T. 2004. Sexual segregation in ruminants: definitions, hypotheses, and implications for conservation and management. Journal of Mammalogy 85:1039-1052.

Clutton–Brock, T. H., F. E. Guinness, and S. D. Albon. 1982. Red deer: behavior and ecology of two sexes. The University of Chicago Press, Chicago, Illinois, 378 pp.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row Publishers, New York.

Demment, M. W. and P. J. Van Soest. 1985. A nutritional explanation for body-size patterns of ruminant and non-ruminant herbivores. American Naturalist 125:641–672.

Gagnon, M. and A. E. Chew. 2000. Dietary preferences in extant African bovidae. Journal of Mammalogy 81:490-511.

Green, Elizabeth Lauten et al. 1985. "Wildlife Food Plants: a microscopic view". Caesar Kleberg Research Program in Wildlife Ecology. The Texas Agricultural Experimant Station.

Litvaitis, J. A., K. Titus, and E. M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods: research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA. 254-274.

Loflin, B. and S. Loflin. 2006. Grasses of the Texas hill country. Texas A&M University Press, College Station, Texas.

Loison, A., J. M. Gaillard, C. Pelabon, and N. G. Yoccoz. 1999. What factors shape sexual size dimorphism in ungulates? Evolutionary Ecology Research 1:611-633.

Main, M. B., F. W. Weckerly, and V. C. Bleich, 1996. Sexual segregation in ungulates: new directions for research. Journal of Mammalogy 77:449–46.

Manley, B. F. J. 1997. Randomization, Bootstrap and Monte Carlo methods in biology, Second Edition. Chapman & Hall/CRC.

Merkord, P. 1987. Food habits of the Scimitar-horned Oryx. MSc. Thesis, Southwest Texas State University, Dec. 1987. Library call number: (AS36.T46 M46).

McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a k selected species. University of Michigan Press, Ann Arbor.

Morrow, C. J., D. E. Wildt and S. L. Monfort 1999. Reproductive seasonality in the female scimitar-horned oryx (*Oryx dammah*). Animal Conservation 2:261-268.

Mousel, E., R. Gates and C. Maaland. 2006. Grazing Management of Warm–Season Grasses in Eastern South Dakota. FS931e. South Dakota State University Cooperative Extension Service.

Mungall, E. C. and W. J. Sheffield. 1994. Exotics on the range: the Texas example. Texas A&M University Press, College Station, Texas, USA. Pg. 96-102.

Mysterud, A. 2000. The relationship between ecological segregation and sexual body size dimorphism in large herbivores. Oecologia 124:40-54.

Nelle, S. 1992. Exotics: At home on the range in Texas. Rangelands 14:77-80.

National Oceanic and Atmospheric Association. 2006. Annual Climatological Summary. Texas U.S. Department of Commerce, Report No. ISSN 0364-6041. 111:13.

National Oceanic and Atmospheric Association. 2007. Annual Climatological Summary. Texas U.S. Department of Commerce, Report No. ISSN 0364-6041. 112:13.

Penfold, L. M., R. Ball, I. Burden, W. Jöchle, S. B. Citino, S. L. Monfort and N. Wielebnowski. 2002. Case studies in antelope aggression control using a GnRH agonist. Zoo Biology 21:435–448.

Rayburn, E. B. 1993. Plant growth and development as the basis of forage management. West Virginia University Extension Service. http://www.caf.wvu.edu/~forage/growth.htm#Plant (Accessed 29 April 2008).

R Development Core Team. 2005. R: A language and environment for statistical computing. R Foundation for Statistical computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Ruckstuhl, K. E. and P. Neuhaus. 2002. Sexual segregation in ungulates: a comparative test of three hypotheses. Biological Reviews 77:77-96.

Scarbrough, D. L. and P. R. Krausman. 1988. Sexual segregation by desert mule deer. The Southwestern Naturalist. 33:157-165.

Scott, G. and B. E. Dahl. 1980. Key to selected plant species of Texas using plant fragments. Occasional Papers, The Museum of Texas Tech University 64.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research. 3rd edition. W. H. Freeman and Co.: New York. 887 pp. ISBN: 0-7167-2411-1.

Sparks, D. R. and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. Journal of Range Management 21:264-265.

United States Forest Service: Fire Effects Information System. April 21, 2008.http://www.fs.fed.us/database/feis/plants/gramaniods/index.html (Accessed 29 April 2008).

Weckerly, F. W. 1998. Sexual size dimorphism: influence of mass and mating systems in the most dimorphic mammals. Journal of Mammalogy 79:33–52.

Weckerly, F. W., V. C. Bleich, C. B. Chetkiewicz and M. A. Ricca. 2003. Body weight and rumen-reticulum capacity in tule elk and mule deer. Journal of Mammalogy 84:659-664.

Winters, A. 2002. Seasonal diets of gemsbok (*Oryx gazella*) at Mason Mountain Wildlife Management Area, Mason County, Texas. MSc.Thesis, Texas State University, San Marcos.

VITA

Sarah Elizabeth Robinson was the first child born to John and Betsy Stephenson in Dallas, Texas, November 12th, 1980. She has a younger sister, Leigh, and two brothers, Ian and Joseph. She grew up in central Texas; homeschooled through 8th grade, attended Johnson City High School, and graduated with honors in 1999. In 2004, she obtained a Bachelor of Science degree in Animal Science with Wildlife Management emphasis from Tarleton State University, Stephenville, Texas. In the fall of 2005, Sarah enrolled in the Wildlife Ecology graduate program at Texas State University-San Marcos. While attending to her studies, she worked as an instructional assistant teaching freshman Biology and Vertebrate Natural History labs. She completed two summer internships with Texas Parks and Wildlife. The first was at the Kerr WMA in 2005, then at Mason Mountain WMA in 2006, where she conducted her research. In January 2007 Sarah assisted professor Weckerly on an elk research project in Redwood National and State Parks. She was a member of the Student Chapter of The Wildlife Society at Texas State and presented preliminary data of her thesis at the Texas Chapter Meeting of the Wildlife Society in 2007. She received a grant from the Dallas Safari Club in 2006 to help defray costs of her thesis research and was awarded a scholarship from the Houston Safari Club in 2007.

This thesis was typed by Sarah Robinson.